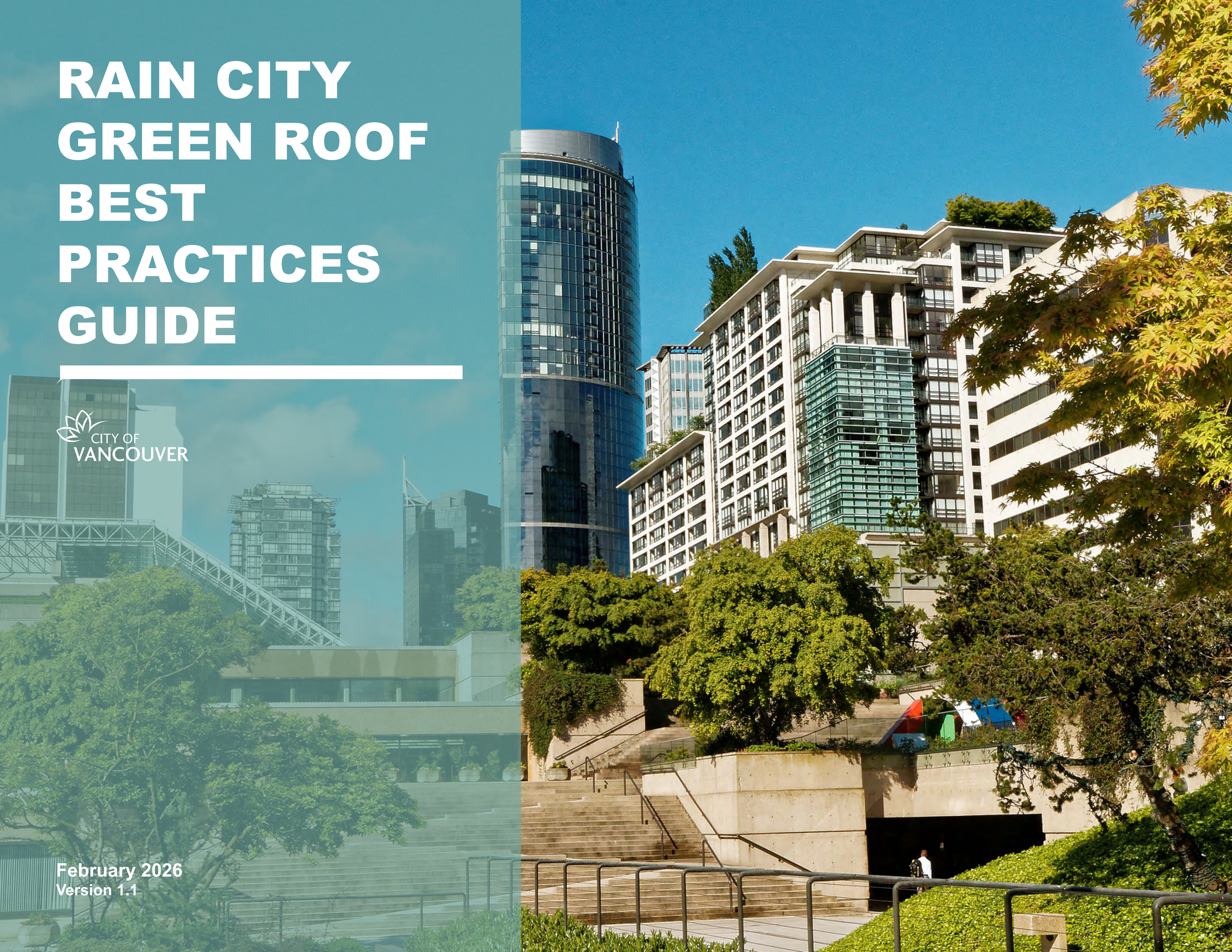
RAIN CITY GREEN ROOF BEST PRACTICES GUIDE

CITY OF VANCOUVER



February 2026
Version 1.1

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CITY OF
VANCOUVER

* VanDusen Botanical Garden Green Roof (Vancouver) - Image courtesy of Connect Landscape Architecture

ACKNOWLEDGMENTS

We acknowledge with respect and gratitude that this document was produced on the traditional, unceded territories of the xwməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish) and səlilwətaɬ (Tsleil-Waututh) Nations. The Nations have called this place home since time immemorial and have stewarded these lands and waterways to help ensure prosperity for future generations.

This document was initiated and advanced by the Climate Adaptation and Equity Group as part of Rain City Strategy implementation on private property. Staff from various City departments were involved in this work though participation in the Green Roof Group, including Engineering Services (ENG), Planning, Urban Design, and Sustainability (PDS), Development, Buildings and Licensing (DBL), Arts, Culture, and Community Services (ACCS), and Real Estate and Facilities Management (REFM). A special thank you to Reece Rehm.

Consulting services were provided by PFS Studio and their team of sub-consultants, including Kerr Wood Leidel Associated Ltd, Read Jones Christoffersen Ltd, and Christine Thuring. Additional advisors included Introba, LMDG Building Code Consultants and Arcadis. Sub-consultants provided expertise in areas such as rainwater management, building envelope engineering, building code, architecture, and ecology.

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BACKGROUND

1.1 ABOUT THIS DOCUMENT

1.1.1 Introduction and Context

The City of Vancouver is facing a number of challenges with respect to rainwater management, water and air quality impacts, urban heat increases, biodiversity losses, and other related land development and climate adaptation issues.

The city is responding to these challenges by adopting a more holistic approach that uses green rainwater infrastructure (GRI) such as green roofs and rain gardens to help manage rainwater where it lands, improve air quality, reduce heat impacts, and enhance biodiversity and habitat.

Green roofs can also provide many other benefits such as complementing amenity, childcare, and urban agricultural spaces, increasing access to nature, and expanding educational opportunities. Green roofs and other GRI are useful for addressing these needs because they mimic certain natural processes and are multifunctional.

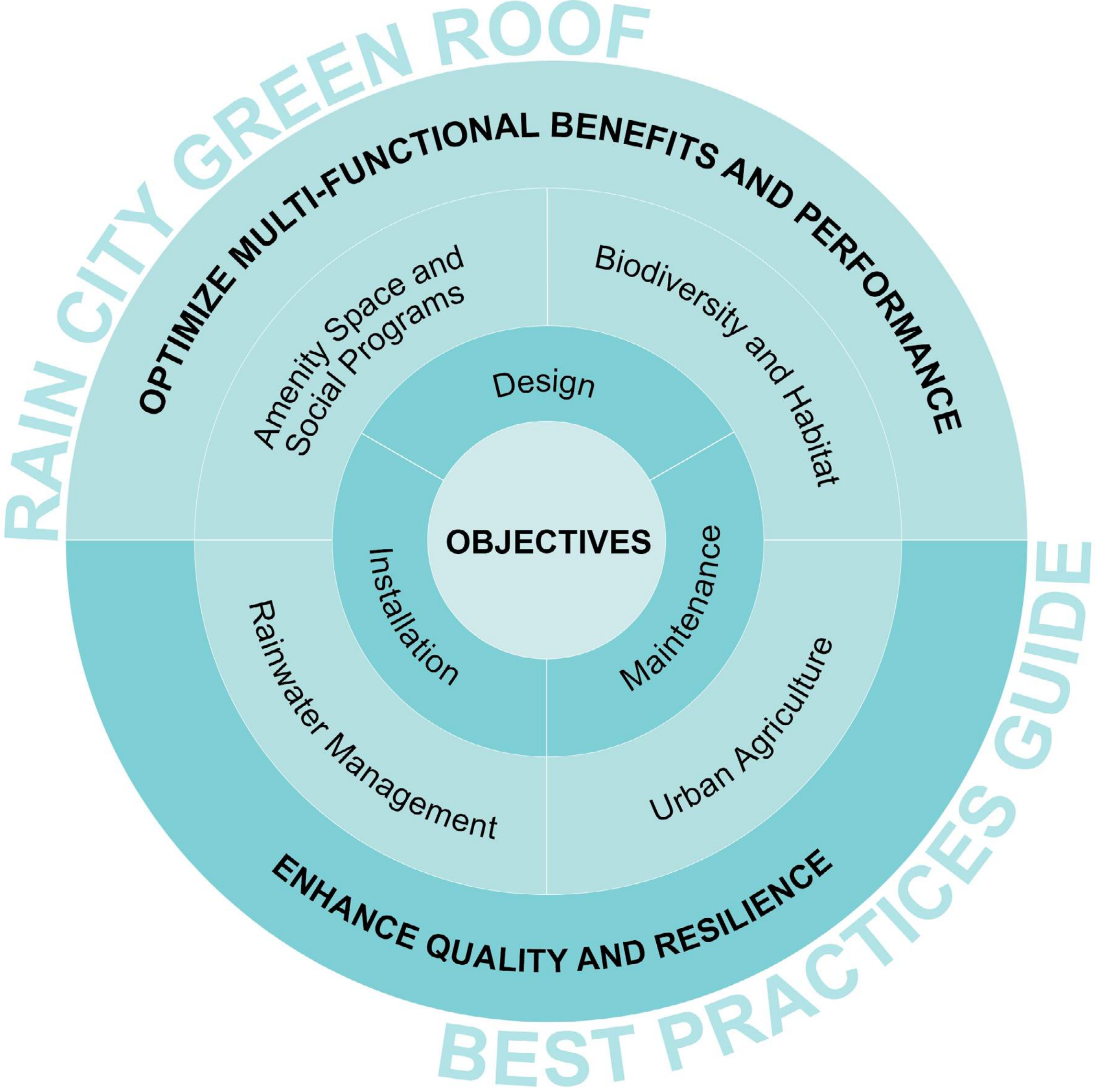
When undertaking a green roof project, it is important to consider both **quality** and **function**. Green roof quality and resilience can be enhanced by carefully considering all **major lifecycle stages of design, installation, and ongoing maintenance**. Green roof function and performance can vary greatly depending on design choices such as plant types and soil depths, which can emphasize particular benefits such as rainwater management, biodiversity enhancement, amenity provision, and urban agriculture.

1.1.2 Purpose and Objectives

The **Rain City Green Roof Best Practices Guide** is a resource for people interested in undertaking a green roof project. Green roofs have been successfully constructed in Vancouver for many years. The objectives of this document are to build on that success and:

- Promote **education**
- Help address common implementation **barriers** to green roof uptake
- Encourage designs that optimize the **multi-functional benefits and performance** of green roofs
- Help enhance the **quality and resilience** of green roofs through the major life cycle stages of design, installation, and maintenance

It is envisioned that this information will **help lead to even more resilient and multifunctional green roofs on suitable building projects** in the City of Vancouver.



1.1.3 Audience

This document serves as a resource for a range of teams and individuals, including:

- Development Permit applicants who are considering including green roofs in their projects
- Members of the General Public
- City of Vancouver staff

1.1.4 What is Included

This document includes information that helps address the topics stated under ***1.1.2 Purpose and Objectives*** and was **developed in collaboration with city staff and industry professionals** such as landscape architects, building envelope consultants, ecologists, and rainwater management specialists. Content is informed by a bibliography of relevant literature and by practical experience from professionals who have been designing, constructing, and maintaining green roofs in Vancouver for many years.

Chapter 1 provides an overview of the **benefits and types** of green roofs, examples of relevant city **bylaws and strategies** advanced by green roofs, and **case study** information on select green roof projects in the city.

Chapter 2, 3 and 4 discuss best practices pertaining to the three major life cycle phases of Design, Installation, and Operations & Maintenance. **Design** includes content on a range of considerations, including site programming, team selection, site context, structural loading, waterproofing, drainage, growing medium, irrigation, vegetation, lighting, and safety/ access. **Installation** discusses the typical order of laydown but also addresses issues such as trades coordination and materials delivery. **Operations & Maintenance** includes topics such as plant and fertilizer management, irrigation systems, and human access.

Chapter 5 discusses various warranties and **managing liability**. **Chapter 6** combines these best practices learnings and applies them to **design scenarios** that emphasize particular performance co-benefits such as rainwater management, biodiversity enhancement, social programming, and urban agriculture.

Appendix A is a **Recommended Green Roof Plant List** for Vancouver. The list highlights approximately 95 plants suitable for use on green roofs in the Vancouver climate. Plants are predominantly native, are categorized by growing medium depth, and include information such as habit (size/ shape), height, seasons of bloom, drought tolerance, host plant status, and pollinator type.

Appendix B is a **Habitat Enhancement Guide** that includes content on the importance of biodiversity, designing for biodiversity, and how to support specific species such as native bees on green roofs in Vancouver. The Habitat Enhancement Guide focuses on growing media, vegetation, habitat structures, and niche spaces. Both the Plant List and Habitat Enhancement Guide are intended to be used together.

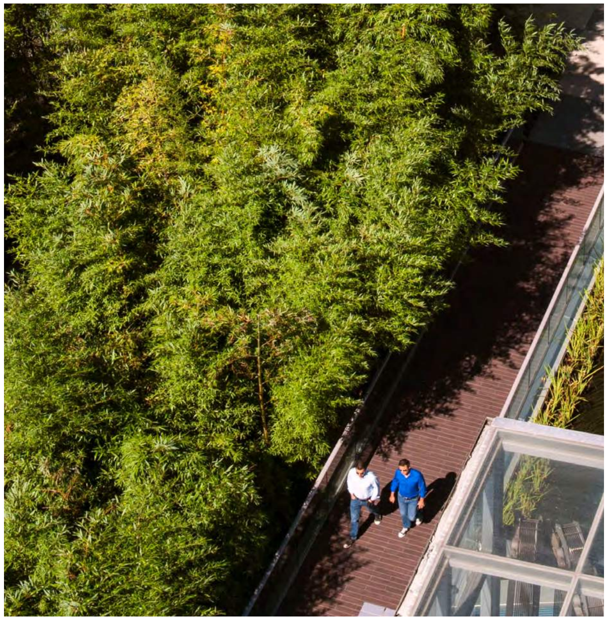
Appendix C provides a **Glossary** of common terms. **Appendix D** includes a **Bibliography** categorized by chapter that sources document content and serves as additional reference information.

1.1.5 Disclaimer

This document is intended for general information purposes only and should not be relied upon as a substitute for design, construction, installation, maintenance, engineering, or policy advice.

This document is not intended to displace any applicable laws, statutes, regulations, bylaws, and policies. Adherence to all applicable laws, statutes, regulations, bylaws, and policies, including (without limitation) City of Vancouver bylaws, is required.

The City of Vancouver does not assume responsibility for errors or oversights resulting from the information contained in this document. While care has been taken to ensure accuracy, readers must refer to the actual wording of City of Vancouver bylaws and policies and the other documents referenced in these guidelines.



1.2 WHAT IS A GREEN ROOF?

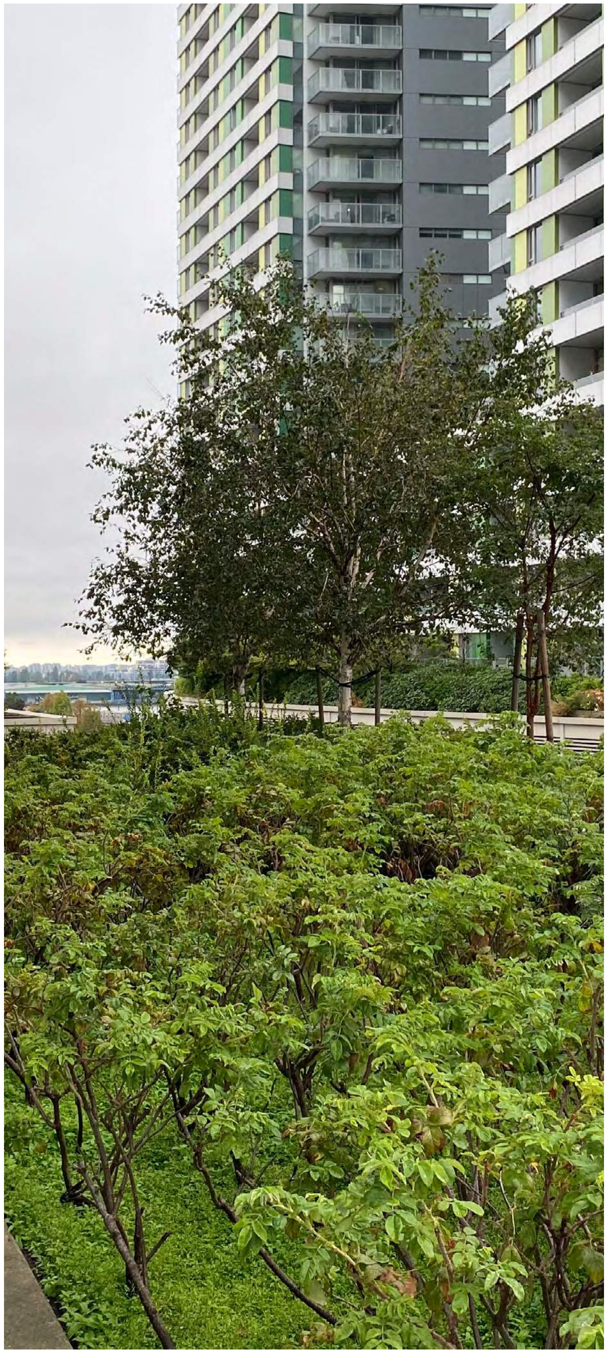
A green roof, also known as a vegetated roof, living roof, blue-green roof, or eco-roof is a **vegetated roofing system that can help advance many livability and environmental objectives.** Green roofs are generally classified by their growing media ('soil') depth as extensive, intensive, or semi-intensive (which includes aspects of both types).

Green roofs can also be modified with **additional technologies such as solar panels or shallow water reservoirs (blue-green roof)**, which can help irrigate the plants. Many green roofs are located on rooftops, but they can also be found on top of structures at or close to ground-level.

When properly designed, installed, and maintained, a green roof is a **valuable tool that can be used by developers, designers, builders, and the public** to improve the quality of the environment and our spaces for living, working, and playing.

MORE THAN JUST VEGETATION

Plants are the heart of a green roof. However, a green roof system also relies on many other components to support plant health, enhance the longevity of a building, and contribute to social and environmental goals. For more information on the various components that make up a green roof, see ***Chapter 2: Design***.



1.3 ROOFS AND IMPERVIOUS AREA ON PRIVATE PROPERTY

The City of Vancouver is comprised of approximately 112 square kilometres of land, which is used for various purposes such as residential and commercial buildings, schools, cultural and recreation centres, hospitals, libraries, firehalls, roads, parks, golf courses, and other green spaces.[1]

The development of the city has created **two fundamental types of surfaces: impervious (51%) and pervious (49%)**. (*see **Figure 1.0** for the proportion of these surface types by land use and **Figure 1.1** for how these surfaces are distributed throughout the city*).[1]

Impervious surfaces do not allow water to be absorbed into the underlying soil. Examples include asphalt roads, concrete sidewalks, and rooftops. Rainwater picks up pollutants from these surfaces before entering our sewer system and discharging to our rivers and inlets (*see **1.4.2 Reducing Overflow Events** for more information*). Pervious surfaces include parks, grass boulevards, golf courses, and other green spaces.

Roofs on buildings comprise over 18% of total city area and a large portion (36%) of the total city impervious area. If road rights-of-way (streets) are subtracted from the city impervious area, roofs represent the majority (57%) of remaining impervious area. **Roofs represent an even higher portion (60%) of private property impervious area**.[1]

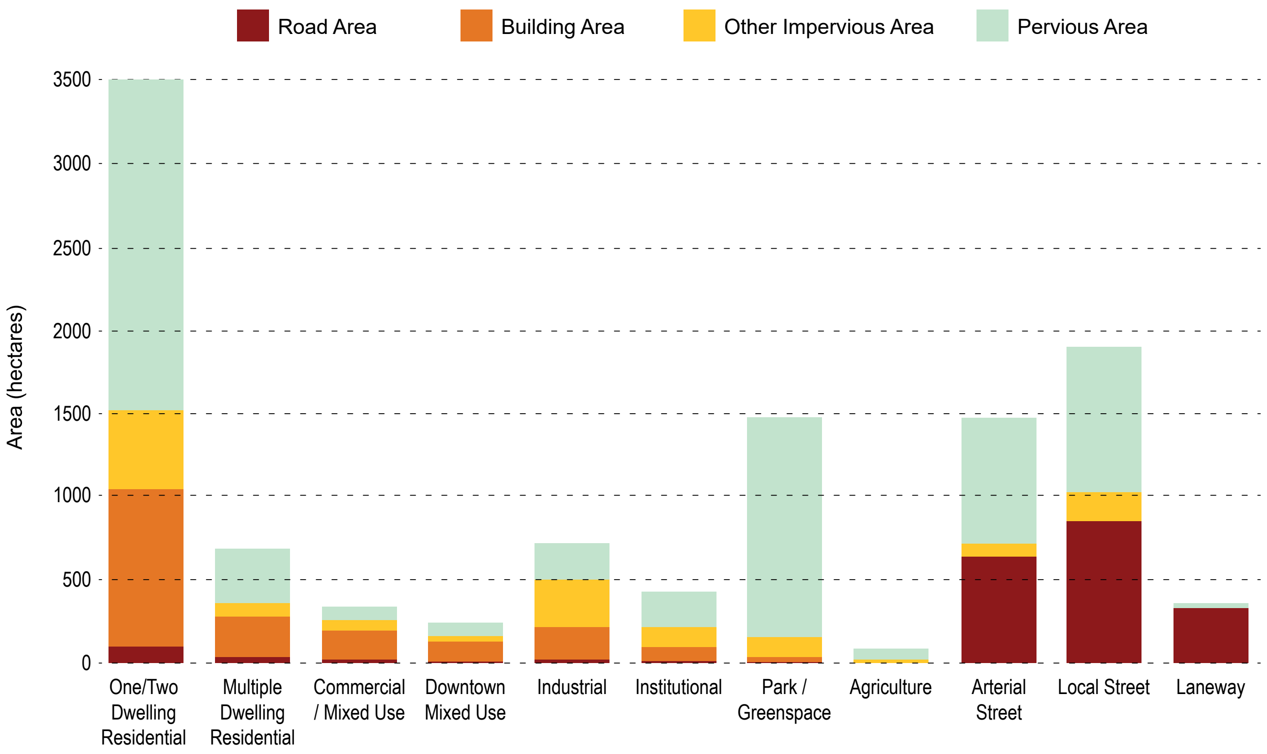


Figure 1.0 - Proportion of impervious area occupied by buildings in Vancouver.[1]

1.4 BENEFITS OF GREEN ROOFS

Depending on the growing medium depth, choice of plants, and other features, green roofs can be designed to help provide a range of environmental, social, agricultural, and economic benefits. Green roofs can help manage rainwater on-site, reduce urban heat island effects by creating cooler rooftop surfaces, and enhance biodiversity and habitat.

Green roofs can also be designed to complement amenity, childcare, and urban agricultural spaces, increase access to nature, and expand educational opportunities. By transforming rooftops into attractive and accessible green spaces, green roofs can help promote social interaction and increase health and well-being. Green roofs are so useful because they mimic nature.

Environmental Benefits

- Improves water quality
- Improves air quality
- Reduces runoff and flooding
- Enhances resilience to climate change (rainwater, carbon, urban heat)
- Enhances biodiversity and habitat

Social and Agricultural Benefits

- Supports urban agriculture
- Increases access to nature and improves education, health, and well-being
- Provides recreational, play, and amenity space

Economic Benefits

- Reduces sewer infrastructure costs
- Improves roof longevity and lowers heating and cooling costs for buildings
- Complements generating energy (integrated photo-voltaic green roof)
- Increases property value
- Improves aesthetic appeal
- Creates jobs

Descriptions of some of these 'co-benefits' are provided for additional information.

1.4.1 Reducing Runoff with On-Site Rainwater Management

Green roofs and other GRI such as permeable pavements and rain gardens can help achieve the City of Vancouver's on-site rainwater management requirements by capturing rainwater at the source and holding a portion of rainwater in the growing medium, which plants can then absorb and use.

Some of the water held in the growing medium layer will evaporate, while some will eventually transpire through the leaves of the plants. These processes reduce the volume and rate of rainwater leaving a site and entering the sewer system (*see **1.5.4 Modifications and Additions** for more information on Blue and Blue-Green Roofs*).[2]

GRI can therefore help offset a building site's **Detention Volume Requirements** (refer to the **Vancouver Building By-Law**).

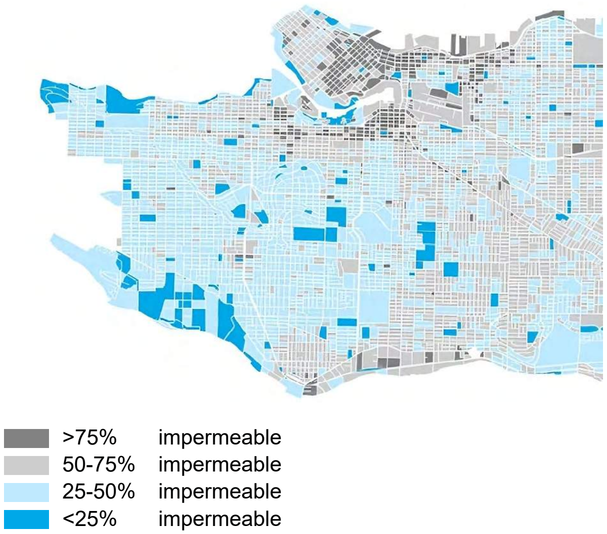


Figure 1.1 - Analysis of Impermeable Surfaces in Vancouver. (2018)[1]

1.4.2 Reducing Overflow Events

Vancouver’s sewer system was originally designed to carry both wastewater and rainwater in a single pipe, known as a “combined system.” Heavy rainfall can overwhelm the system, leading to Combined Sewer Overflows (CSOs), where untreated water is discharged into our surrounding rivers and inlets.

The city has been gradually replacing these combined pipes with separate storm and sanitary sewer pipes and, as of 2022, approximately 56% of the mainline sewers and 60% of service connections have been separated.[3]

Green roofs can contribute to managing CSOs by reducing the volume and rate of rainwater entering the combined sewer system, thereby reducing the discharge of pollutants into our rivers and inlets (*see **2.3.2 Managing Rainwater** to learn more about* **Detention** *and* **Retention**).

TRACKING COMBINED SEWER OVERFLOWS

The City of Vancouver’s CSO outfalls are located along the shoreline. A map of these locations can be found on the City’s website. Metro Vancouver also actively monitors CSO events through a live feed map that provides real-time updates across the region. This tool enables residents and stakeholders to stay informed about water quality issues and helps drive efforts toward reducing the frequency and impact of CSO events in Vancouver.

The map can be viewed by searching for Metro Vancouver’s GIS Map of the Regional Wastewater System at metrovancouver.org.

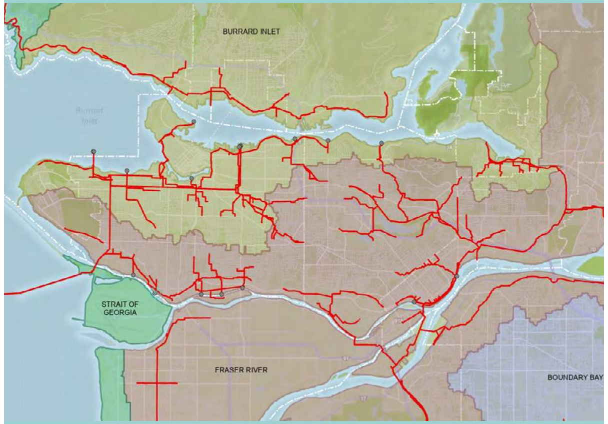


Figure 1.2 - Map of Combined Sewer Overflow locations across Vancouver (2024)[4]

1.4.3 Enhancing Resilience to Climate Change by Reducing Urban Heat Island Effects

When solar energy hits a roof surface, some of the energy is absorbed by the roof material and some is reflected back to the sky. The absorbed energy slowly radiates heat both inside and outside the building. Materials vary in how much energy they absorb and heat they emit.[5]

The **urban heat island (UHI)** effect occurs when trees and other natural landscapes are replaced by buildings and surfaces that absorb, retain, and emit relatively more energy from the sun, **causing ambient temperatures to rise by 1-3°C beyond typical values** in surrounding areas.[6,7]

These temperature increases can result in **thermal discomfort, increased building energy demands for cooling, and conditions that can affect the survivability of plants, insects, and animal species**. Climate-related challenges such as droughts and extreme heat are anticipated to magnify this issue.[6,7,8]

Green roofs can help increase our city's resilience to the UHI effect and climate temperature challenges by reducing solar heat gain and emissions in three ways:

- Using surficial vegetation to shade material on or around the green roof surface.
- Using **the entire vegetated roof assembly to cover the darker, underlying roofing materials**.[5,7]
- Using evapotranspiration, which involves the conversion of water to vapour (evaporation) and the release of water vapour by plants through tiny pores in their leaves (transpiration). These processes takes heat from the plant leaves and surrounding air and reduce the ambient air temperature.[5,7]

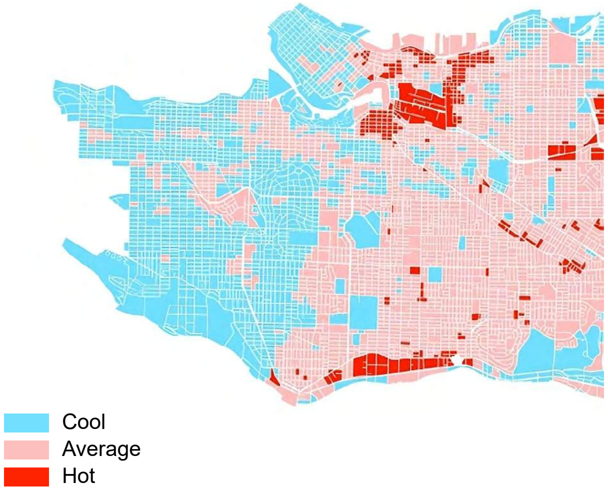


Figure 1.3 - Analysis of Heat Island Effects in Vancouver. (2018)[1]

1.4.4 Enhancing Biodiversity and Habitat

Habitat size and connectivity influence the health of animal and plant populations. The streets and buildings associated with the growth of our city have created barriers to connectivity by fragmenting our natural habitat into patches such as parks, back yards, boulevards, and other green spaces.[9]

Green roofs can enhance biodiversity by creating habitat and micro-climates that help support bees, birds, and a range of invertebrates, including spiders and beetles. At a larger scale of implementation, green roofs have additional potential to enhance biodiversity by acting as ‘stepping stones’ for species movement between patches of greenery.[10]

1.4.5 Supporting Urban Agriculture and Gardening Opportunities

Roofs are premium locations for growing food, offering opportunities for both larger-scale community farming and smaller-scale gardening plots. Both activities make use of traditionally underutilized space and produce food closer to home, thereby helping to shorten food supply chains and reduce carbon emissions.

Providing physical **access to gardening spaces** also allows tenants and community members to grow their own fresh produce, learn about agriculture, contribute to food security, participate in community interaction, and create a connection to nature.[11]

Green roofs that are designed to complement or enhance food production can contribute to community well-being by **supporting pollinators** (*see* ***Appendix B: Habitat Enhancement Guide***), increasing nutritional health, improving educational and social opportunities, and improving the local economy (see ***1.5.4 Modifications and Additions*** for more information on Urban Agriculture).

1.4.6 Increasing Access to Nature and Health Benefits

The various activities in the urban environment create environmental health issues such as vehicle noise, higher temperatures from the UHI effect, and poor air quality. **The inclusion of natural elements such as trees and other vegetation provide relief** by creating acoustic buffers from nearby noise pollution[7], providing shade from the sun, and intercepting particulate matter from the air.[12] Studies have shown that visual and physical contact with nature can also **improve mental health**.[13,14,15,16]

1.4.7 Improving Educational Opportunities

As with other green spaces, green roofs may be designed to enhance or create **enriching sensory environments and educational opportunities for adults and children**. Access to these green spaces can promote curiosity by providing hands-on learning experiences about ecology, plant growth cycles, seasonality, weather impacts, and insect interactions.[17]

Green roofs can help foster a deeper understanding of nature in early learning programs and, if designed accordingly, can **complement childcare centres** that co-occupy rooftop spaces.

1.4.8 Reducing Sewer Infrastructure Costs

Green roofs and other GRI return water to the ground, atmosphere, and landscape near its source. This process reduces the volume and rate of water entering our sewer system, which helps postpone the need for costly upgrades to existing sewer infrastructure. The use of traditional sewer systems with both onsite GRI and off-site GRI in streets and public spaces represents a more holistic and integrated approach to rainwater management, potentially **reducing overall infrastructure costs**.[18]

1.4.9 Improving Roof Longevity and Lowering Heating and Cooling Costs for Buildings

Many traditional roofs are built so that the waterproofing membrane is relatively more exposed to the sun, rain, and other types of weather. Solar radiation and fluctuating temperatures, which repeatedly expand and contract the membrane, can accelerate the material's degradation. This can lead to increased repairs, maintenance costs, and accelerate the need for membrane replacement.[19]

Green roofs provide extra layers of material that buffer the roof membrane from solar radiation and temperature fluctuations. This buffering may lead to fewer maintenance repairs, prolonged service life[16], and less waste material in the municipal landfill. By providing better insulation than traditional roofs, green roofs can also reduce heating costs in the winter and cooling costs in the summer.[20]

1.4.10 Energy Generation

Energy demand in Canada is anticipated to double between 2024 and 2050.[21] Roofs can be suitable locations for photo-voltaic (PV) panels, which have the potential to play a large role in meeting this energy demand. If properly designed, **green roofs and PV panels can occupy the same rooftop areas** and improve efficiency of electrical energy generation.[22] (see ***1.5.4 Modifications and Additions*** for more information on Integrated Photo-voltaic Green Roof).

1.4.11 Job Creation

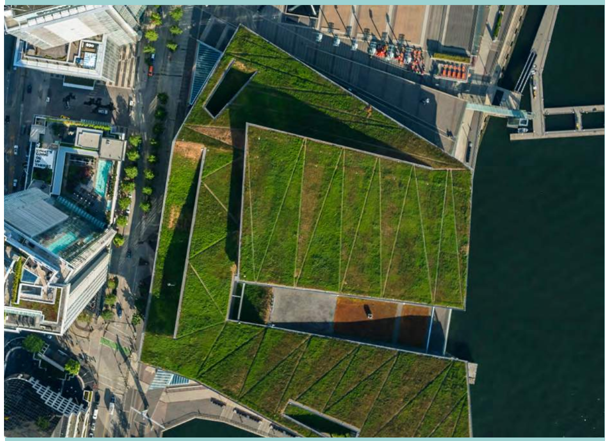
Green roofs must be cared for after their design and installation, as plants are living organisms that need seasonal pruning, irrigation, and weeding. While these commitments are low-cost relative to a building's overall maintenance and operation budget, such tasks can lead to **job creation for horticulturalists and landscape contractors** who specialize in designing, installing, and maintaining green roofs.[23]

1.4.12 Improving Aesthetic Appeal

Introducing vegetation on buildings and in open areas can create interesting visual enhancements and other sensory experiences that help reduce anxiety and stress. Green roofs can help apply these enhancements and experiences to developments by softening harsh edges, creating natural aesthetics that **make spaces more inviting**, and **encouraging social and cultural activities that further benefit health and well being**.[13]

PROJECT EXAMPLE:
VANCOUVER CONVENTION CENTER

The Vancouver Convention Center is a large scale example of rainwater management practices. The rooftop of the building captures and reuses rainwater for various non-potable uses while filtering overflow before it enters the city sewer system and receiving waters.



1.5 TYPES OF GREEN ROOFS

Since the original construction of Robson Square between 1979 and 1983, the integration of green roofs and related green systems into building architecture has led to much design experimentation in Vancouver.

There are several kinds of green roofs, each with their own characteristics, uses, and suitability to specific applications. This guide introduces the **green roof categories of Extensive, Semi-Intensive, and Intensive** based on growing medium depth, which influences suitable plant types, relative benefits, costs, and maintenance requirements. Note that the growing medium depths for semi-intensive green roofs can include both extensive and intensive sections with associated ranges of plant diversity and other characteristics.

Three **additional modification categories of Blue-green, Integrated Photo-voltaic, and Urban Agriculture** are also introduced.

FIGURE 1.4 - COMPARATIVE CHART OF GREEN ROOF TYPES

	Extensive	**Semi-Intensive**	**Intensive**
Depth of Growing Medium*	60 - 150mm (2.4 - 6 inches)	60 - 1000mm (2.4 - 40 inches)	300 - 1000mm (12 - 40 inches)
Plant and Biodiversity	Lower	Varies	Higher
Suitable Plant Types	Sedum, Perennials, and Wild Flowers	Sedum, Perennials, Wild Flowers, Groundcovers, Shrubs, and Trees	Groundcovers, Shrubs, and Trees
Water Retention	Lower	Varies	Higher
Urban Heat Reduction	Lower	Varies	Higher
Accessibility	Inaccessible or limited access to private or public users	Varies	Usually accessible to private or public users
Compatibility with Other Uses	Less suitable	Varies	Highly suitable
Irrigation System	Optional	Likely Required	Likely Required
Saturated Weight	Lower	Varies	Higher
Cost per Square Meter	Lower	Varies	Higher
Installation Method	Can be modular or built-in-place	Likely built-in-place but can be modular	Built-in-place
Maintenance	Lower	Varies	Higher
Retrofits**	May be more suitable for retrofits with limited structural capacity	May be suitable for retrofits with limited structural capacity	May be less suitable for retrofits with limited structural capacity

*Growing medium depth varies according to the selected plant requirements and other design needs.
**Studies required on suitability of existing structure

1.5.1 Extensive Green Roofs

Extensive green roofs are characterized by their relatively **shallow growing medium** (soil) depth, which typically ranges between 60 mm (2.4 inches) and 150 mm (6 inches).

This depth supports a plant diversity that usually consists of sedums, perennials and wildflowers. Extensive roofs are typically **not designed with human access in mind** and water retention and urban heat reduction may be relatively lower compared with intensive green roofs.

Despite the shallow growing medium depth, extensive green roofs offer advantages. The lower saturated soil weight does not usually require significant structural support enhancements, which makes them **suitable for most new buildings and particularly suitable when retrofitting existing buildings**. Maintenance requirements are typically lower than intensive green roofs and irrigation can be optional.

Extensive roofs offer a **cost-effective solution** for advancing sustainability initiatives such as rainwater management, urban heat reduction, and biodiversity enhancement without significant structural reinforcement.

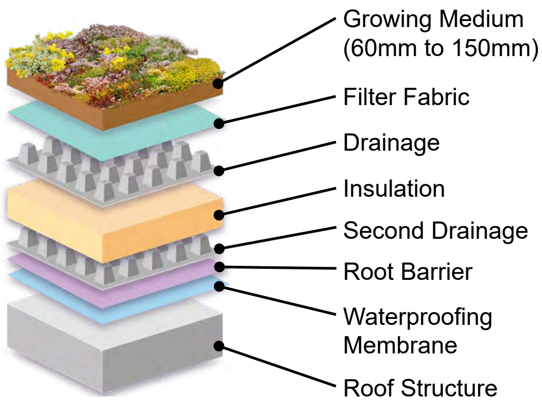


Figure 1.5 - Comparison of extensive green roof build-up on a protected roof assembly. Order of assembly layers can vary.

1.5.2 Intensive Green Roofs

Intensive green roofs are characterized by their relatively **deep growing medium** (soil) depth, which typically ranges between 300 mm (12 inches) and 900 mm (36 inches).

This depth supports a **greater plant diversity** that usually consists of shallow vegetation, bushes, shrubs, and even small trees. Intensive roofs are typically **designed with human access in mind** and water retention and urban heat reduction may be relatively higher compared with extensive green roofs.

Due to the deeper growing medium depth and greater diversity of plantings, intensive green roofs offer other advantages. Although the higher saturated soil weight usually requires structural support enhancements, the green spaces are more **conducive to providing or complementing amenity space** and to supporting human accessibility and interaction with nature. In contrast, maintenance requirements are typically higher than extensive green roofs and irrigation is likely required.

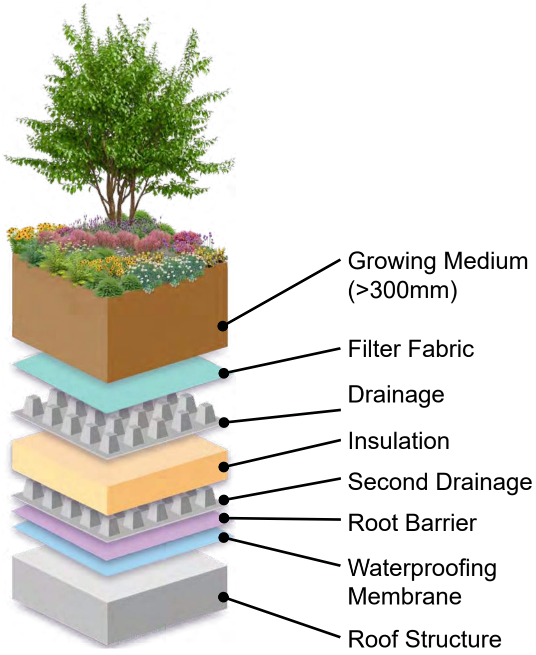


Figure 1.6 - Comparison of intensive green roof build-up on a protected roof assembly. Order of assembly layers can vary.

Intensive green roofs offer an enhanced solution for advancing sustainability initiatives such as rainwater management, urban heat reduction, biodiversity enhancement, social opportunities, and interactions with nature. **Structural reinforcement is a consideration to be assessed against enhanced social and ecological benefits.**

1.5.3 Semi-Intensive Green Roofs

Semi-intensive green roofs use a **hybrid approach that can include both extensive sections and intensive sections** with associated ranges of growing medium depth, plant diversity, and other characteristics. **Growing medium** (soil) depth typically ranges between 60 mm (2.4 inches) to 900 mm (36 inches).

This depth supports a **broad plant diversity** that usually consists of sedums, perennials, wildflowers, shallow vegetation, bushes, shrubs, and even small trees. Semi-Intensive roofs may or may not be designed with **human access** in mind and **water retention** and **urban heat reduction** may be relatively higher compared with extensive green roofs.

Although the higher saturated soil weight associated with the intensive sections usually requires enhanced **structural support**, the green spaces are more conducive to providing or complementing **amenity space** and to supporting human accessibility and interaction with nature. In contrast, **maintenance** requirements are typically higher than extensive green roofs and **irrigation** is likely required.

Semi-intensive green roofs offer an enhanced hybrid solution for advancing sustainability initiatives such as rainwater management, urban heat reduction, social opportunities, interactions with nature, and especially biodiversity enhancement (see ***Appendix B: Habitat Enhancement Guide***). As with intensive green roofs, **structural reinforcement is a consideration to be assessed against enhanced social and ecological benefits**.

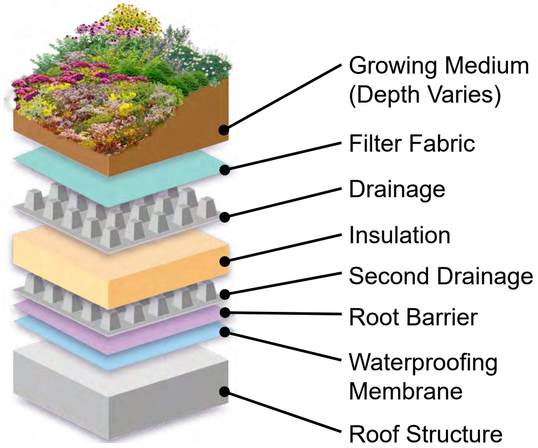


Figure 1.7 - Example of semi-intensive green roof build-up on a protected roof assembly. Order of assembly layers can vary.

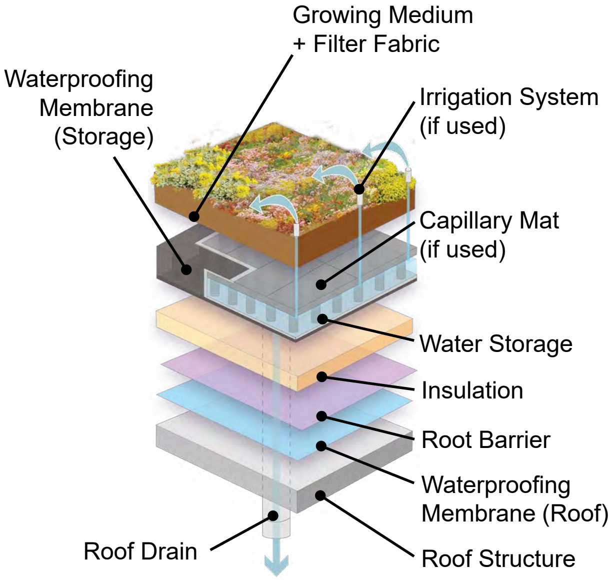


Figure 1.8 - Example of blue-green roof build-up on a protected roof assembly. Order of assembly layers can vary.

1.5.4 Modifications and Additions

In addition to the three general categories of extensive, intensive, and semi-intensive, there are other modifications and additions that can be used to enhance or create green roof benefits relating to rainwater management, energy generation, and food production.

Blue and Blue-Green Roofs

Blue roofs use a shallow water reservoir to detain rainwater on rooftops before releasing it to a drainage system.

Green roofs use their growing medium to detain rainwater, which will either be released into the air though evapotranspiration or will slowly migrate downward through the growing medium to a drainage layer and drainage pipe system (see ***1.4.1 Reducing Runoff with On-Site Rainwater Management*** to learn more).

Blue-Green roofs are a hybrid design that use a shallow water reservoir located below the green roof growing medium to provide enhanced detention capacity. This helps further reduce the volume and rate of rainwater leaving the site, thereby contributing to the city's on-site rainwater management requirements (see ***2.3 Design to Support Programming*** to learn more about rainwater detention and retention).

If combined with a wick or capillary mat, the reservoir can also help offset plant irrigation requirements (see ***2.10 Irrigation*** to learn more).

Water storage on a blue, green, or blue-green roof should be designed to comply with the structural load limitations of the building and according to all City of Vancouver drainage and other requirements.

Integrated Photo-Voltaic Green Roof

Energy demand in Canada is anticipated to double between 2024 and 2050. Depending on considerations such as orientation, roof slope (tilt), sunlight exposure (including shading), and structural adequacy, roofs can be suitable locations for photo-voltaic (PV) solar panels.[21]

Natural Resources Canada approximates that if photo-voltaics were installed on all technically available rooftop space, then 100% of residential and 49% of commercial and institutional building's electrical needs could be satisfied. With a potential to generate up to twice Canada's current electrical power capacity, photo-voltaics can play a significant role in our energy transition.[24]

Integrated photo-voltaic green roofs, also called "biosolar" green roofs, combine vegetated roof assemblies with PV solar panels on a shared roof space. Roofs that are not covered with vegetation absorb and radiate relatively more heat than roofs covered with vegetation, even on cool sunny days (see ***1.4.3 Enhances Resilience to Climate Change by Reducing Urban Heat Island Effects*** to learn more). This issue is compounded when sunlight is reflected onto the roof surface from nearby window glazing.[22]

PV solar panels are most efficient when operating within specific temperature ranges. **If panels become too hot, they become less efficient. Green roofs can also help increase renewable energy production by cooling the ambient temperature of rooftops and providing a more suitable operating climate for the panels.**[22]

Urban Agriculture

There is a growing recognition of the importance of our local food system, which includes community gardens and orchards, urban farms, farmers markets, processing and composting facilities, and neighbourhood food networks.[11,25]

Roofs are premium locations for growing food, offering opportunities for both larger-scale community farming and smaller-scale gardening plots. Both activities make use of traditionally underutilized space and produce food closer to home, thereby helping to shorten food supply chains and reduce carbon emissions.[11, 26]

Providing physical **access to gardening spaces** also allows tenants and community members to grow their own fresh produce, learn about agriculture, contribute to food security, and create a connection to nature. Gardening also creates social spaces that encourage community interaction and well-being.[11]

Green roofs can complement or be designed to deliver activities that promote community gardens, urban farming, and edible landscapes.

Above - Photo-Voltaic Solar Panels on a Green Roof

Green roofs can also be planted to support pollination (*see **Appendix B: Habitat Enhancement Guide***). **Did you know that roughly one-third of our food depends on pollinators?**

A roof used for urban agriculture will usually require a greater depth of growing medium (450 mm – 900 mm) for plants and trees used for food production. The design of these spaces should consider precautionary measures to allow for the safe use of sharp gardening tools and related food-growing activities, which could potentially damage a roof's waterproof membrane.

While rooftop agricultural systems can be open-air and seasonal, they can also take the form of greenhouses that provide a controlled climate for plants to grow year-round. Greenhouses require both the construction of adequate shelters and well-designed heating, ventilation, and air conditioning (HVAC) systems.

Above - Urban Agriculture on a Green Roof

1.6 CITY STRATEGIES AND POLICIES ADVANCED BY GREEN ROOFS

The City of Vancouver is responding to environmental and livability challenges by adopting a more holistic and nature-based approach in our strategies and related objectives.

Green roofs can be designed to provide many benefits such as managing rainwater, improving air quality, reducing urban heat, enhancing biodiversity and habitat, and providing or complementing amenity, childcare, and urban agricultural spaces.

Green roofs can also deliver additional benefits such as increasing access to nature, expanding educational opportunities, and improving aesthetics, health, and well-being. **By providing these benefits, green roofs can help advance many city strategies and other policies**.

Descriptions of some of these strategies (marked with an asterisk in the following list), and how they are advanced by green roofs, are provided in this section of the guide. The Vancouver Building By-law is also included as it provides information relevant to the design of green roofs and their potential role in on-site rainwater management.

EXAMPLES OF CITY STRATEGIES AND POLICIES ADVANCED BY GREEN ROOFS

Plans and Strategies

Biodiversity Strategy*
City of Vancouver UNDRIP Strategy*
Citywide Integrated Rainwater Management Plan*
Climate Change Adaptation Strategy*
Climate Emergency Action Plan*
Healthy City Strategy*
Rain City Strategy*
Resilient Vancouver Strategy*
Rewilding Vancouver Action Plan
Urban Forest Strategy*
Vancouver Bird Strategy
Vancouver Food Strategy*
Vancouver Plan*
VanPlay Parks and Recreation Services Master Plan

Bylaws

Sewer and Watercourse Bylaw
Vancouver Building Bylaw*
Zoning and Development Bylaw

Policies

Rezoning Policy for Sustainable Large Developments
Guidelines
Bird Friendly Design Guidelines*
Childcare Design Guidelines (and toxic plants list)
High Density Housing for Families with Children Guidelines
Urban Agriculture Guidelines for the Private Realm (Appendix A plant list)
Urban Farm Guidelines
Various city-owned or leased-facility guidelines
Water Wise Landscape Guidelines (Appendix C green roof plant list)*

Bulletins

Roof-mounted Energy Technologies and Green Roofs
Urban Honey Beekeeping

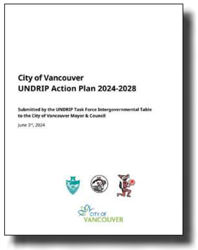
1.6.1 Biodiversity Strategy

Biodiversity is the variety and abundance of living organisms in a particular habitat or ecosystem, including plants, animals, fungi, and microorganisms. Biodiversity contributes to ecosystem stability and resilience.

The Biodiversity Strategy presents goals and actions for protecting and restoring natural areas, species, and ecological processes, and for improving access to nature in neighbourhoods. The Strategy complements the Urban Forest Strategy, Rewilding Action Plan, and Vancouver Bird Strategy.

Green roofs help advance eight of the ten principles of biodiversity management. Two of the principles (manage at city-wide scale, focus on habitat) explicitly recognize that green roofs can be essential for extending the city's ecological network, providing access to nature, and enhancing biodiversity.

Green roofs also help advance other objectives of this strategy, including reducing impacts to biodiversity (for example, using designs that minimize pesticides, light pollution, and bird collisions), contributing to rainwater management, advancing education, and enhancing habitat for birds and pollinators (see ***Appendix B: Habitat Enhancement Guide***).



City of Vancouver
UNDRIP Action Plan 2024-2028

Submitted by the UNDRIP Task Force Intergovernmental Table
to the City of Vancouver Mayor & Council

June 3rd, 2024

1.6.2 City of Vancouver UNDRIP Strategy

The United Nations Declaration on the Rights of Indigenous Peoples' (UNDRIP) Strategy is a Reconciliation framework for upholding and protecting Indigenous Peoples' rights and their enjoyment of those rights. As part of the UNDRIP Strategy, the City's task force identified specific calls-to-action under the four themes outlined in the BC Declaration on the Rights of Indigenous Peoples Act (Declaration Act).

Green roofs can help advance or complement the UNDRIP Strategy objectives by contributing to various subjects of interest, including healthy lands and waters, environmental initiatives, reducing rainwater infrastructure impacts on receiving waters, and generally reducing contaminants in air and water.

1.6.3 Citywide Integrated Rainwater Management Plan

The Citywide Integrated Rainwater Management Plan (IRMP) demonstrates how the municipality will meet the requirements of the Metro Vancouver Integrated Liquid Waste and Resource Management Plan (ILWRMP), which helps protect human health and the environment, while using wastewater (sewage and rainwater) as a resource.

The IRMP's vision is to maintain clean water from watershed to receiving environment, reduce potable water demand, and connect people to nature. A key desired result is improving water quality by reducing Combined Sewer Overflows (CSOs) into our receiving waters.

Green roofs are listed as a rainwater management tool with benefits that include reducing rainwater peak flows, providing building insulation, reducing the urban heat island effect, and providing urban habitat.

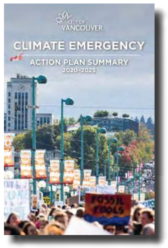
1.6.4 Climate Change Adaptation Strategy

Climate change has implications for health and well-being, nature and biodiversity, infrastructure, and the economy. **Adaptation refers to actions taken to prepare for and respond to these impacts by both reducing risk and enhancing resilience**.

The Climate Change Adaptation Strategy (CCAS) uses updated climate projections to inform actions to help reduce risk to people and infrastructure from extreme heat, drought, poor air quality, extreme rain, and sea level rise.

Green roofs can help advance the CCAS objectives by helping reduce impacts from extreme heat, extreme rainfall, and poor air quality, thereby helping reduce detrimental impacts to:

- Health and well-being (less heat-related illness, mental health impacts, flooding)
- Nature and biodiversity (less stress, pollutant runoff)
- Infrastructure (lower energy costs for cooling, lower stormwater impact)
- Economy (fewer business and childcare closures, flood cleanup)

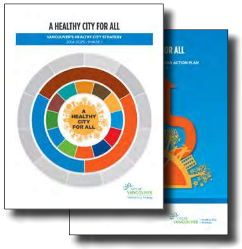


1.6.5 Climate Emergency Action Plan

Climate change has implications for health and well-being, nature and biodiversity, infrastructure, and the economy. **Mitigation refers to limiting climate change through the reduction of greenhouse gas emissions in the atmosphere**.

The Climate Emergency Action Plan (CEAP) is a mitigation framework that focuses on reducing the city’s largest emission sources: buildings (57%) and transportation (36%). The Plan sets bold targets to cut carbon pollution in half (relative to 2007) by 2030 and be carbon neutral by 2050.

Green roofs can help advance or complement the CEAP carbon reduction objectives by contributing to Big Move 5 (materials with relatively lower embodied carbon) and Big Move 6 (helping to sequester carbon from the atmosphere).



1.6.6 Healthy City Strategy

The Healthy City Strategy seeks to increase health and well-being for vulnerable populations and enhance liveable environments now and in the future. This plan includes goals for creating complete, compact, and connected communities by constructing a wide range of affordable homes for everyone (including supportive, social, and secured rental housing), increasing neighbourhood food assets, and increasing access to nature (environments to thrive in).

Green roofs can help advance or complement the Healthy City Strategy objectives and goals by providing places that cultivate social connections, support food assets, enable access to and interaction with nature, and contribute to a healthier environment (cleaner air, greater biodiversity).

1.6.7 Rain City Strategy

The Rain City Strategy (RCS) treats rainwater as a valuable resource and calls for a shift in approach to achieving the goals of improved water quality, increased resilience, and enhanced livability. The RCS advocates for holistic solutions that mimic the natural hydrological cycle by capturing and treating rainwater where it lands using trees and other GRI such as green roofs and ground infiltration systems like rain gardens and permeable pavement.

Green roofs are also recognized as a means to address issues such urban heat extremes and habitat loss. The RCS 2050 vision includes a ‘meadow‘ of green and blue-green roofs across the city accompanied by other green spaces, water storage, food gardens, rooftop patios, solar panels, restored creeks (where feasible), public art, and park and boulevard spaces that act as ‘sponges’.

1.6.8 Resilient Vancouver Strategy

The Resilient Vancouver Strategy provides a framework to transform Vancouver into a city that can survive, adapt, recover, and thrive in the face of challenges and changes. This Strategy calls for many actions to enhance resilience, including seismic risk reduction and hazard mitigation, a focus on building community connectivity, the inclusion of equity, and a ‘build back better’ approach.

Green roofs can help advance or complement the Strategy objectives by enhancing public rooftop amenity spaces and encouraging social connections. Green roofs could further advance resilience as part of a suite of resilient building components (along with solar panels, water reuse systems, cool roofs, and trees) and can be included in post-disaster development (build back better).

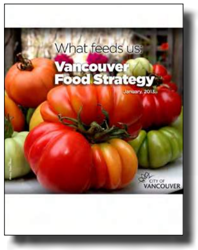
1.6.9 Urban Forest Strategy

Vancouver was heavily forested prior to the 1860s but logging, burning, and land development have significantly reduced the original native forest to approximately 18% of land area (2013).

Urban forests are increasingly recognized as a critical part of a sustainable city. Trees mark changes in seasons, enhance physical and mental health of residents, provide food and, as a part of Vancouver’s green infrastructure, help manage rainwater, filter pollutants, shade streets and buildings, and support birds and other forms of biodiversity.

The Urban Forest Strategy outlines goals and targets to protect, plant, and manage trees to create a diverse, resilient, and beautiful urban forest on public and private lands across the city.

If properly designed, green roofs can support trees and increase the city’s tree canopy. Planting trees on rooftops is commonly practiced in the city as it can add aesthetic and other value. However, even vegetated roofs with no trees can still complement the Strategy objectives by providing similar social and ecological benefits and by strengthening the urban ecological network.



1.6.10 Vancouver Food Strategy

The Vancouver Food Strategy promotes a sustainable food system that fosters healthy, vibrant, and inclusive communities and local, participatory food production. Action areas include supporting all forms of urban agriculture (community gardens, orchards, and urban farms in backyards, rooftops, and other private and institutional settings), improving access to healthy, local, affordable food, and reducing food waste.

Green roofs can help advance the Vancouver Food Strategy by facilitating actions that promote community gardens, urban farming, and edible landscapes. Green roofs can also be planted to support pollination (see ***Appendix B: Habitat Enhancement Guide***). **Did you know that roughly one-third of our food depends on pollinators?**

1.6.11 The Vancouver Plan

The Vancouver Plan is a visionary, long-range land-use plan to help Vancouver become more livable, affordable, and sustainable. The Plan guides growth and change of various types of buildings, structures, public facilities, parks, open spaces, and ecological networks over the next 30 years.

The Plan encourages new private developments to protect and create natural assets, use ecological landscaping, retain and manage rainwater, reduce carbon, use materials, energy, and drinking water efficiently, and help mitigate air pollution, extreme heat, and flooding,

Other polices include providing access to nature and related educational opportunities, supporting healthy child development, enhancing groundwater recharge, increasing local food production, and integrating with the ecological network.

Green roofs can help advance the Vancouver Plan by contributing to most if not all of these policy objectives.

1.6.12 Vancouver Building By-Law

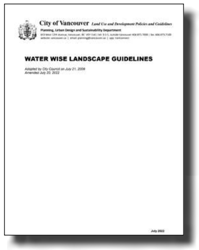
The Vancouver Building By-law (VBBL) regulates the design and construction of buildings, as well as the administrative provisions relating to permitting, inspections, and enforcement of these requirements. Vancouver's ability to adopt its own Building By-law is unique in BC.

Book I (General) and Book II (Plumbing Systems) address the minimum standards for buildings in Vancouver and include the same broad objectives as the Provincial regulations, with additional provisions in certain areas.

Rainwater management requirements on private property are regulated under The VBBL (Book II, Div B). **Other information relevant to green roofs (vegetated roof assemblies)** may be found on topics such as:

- Vegetated Roof Assemblies (Book I)
- Structural Loads and Procedures (Book I)
- Determination of Wind Load (Book I)
- Installation of Protective Materials (Book I)
- Drainage Systems (Book II)

The VBBL should be thoroughly consulted early in the design process to understand city expectations relating to green roof projects.



City of Vancouver *Land Use and Development Policies and Guidelines*
Planning, Urban Design and Sustainability Department

WATER WISE LANDSCAPE GUIDELINES

Adopted by City Council on July 21, 2009
Amended July 20, 2022

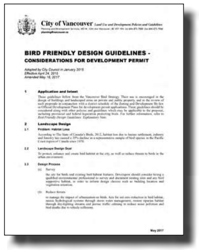
July 2022

1.6.13 Water Wise Landscape Guidelines

The Water Wise Landscape Guidelines were created for applicants considering or undertaking development on private property whose projects have a landscape component.

The Guidelines encourage applicant designs that maximize the ratio of planted to non-planted surfaces, reduce the consumption of potable water for irrigation while maintaining the quality of the urban landscape, enhance livability and urban ecology, and increase long term viability of the landscape plantings and materials. **The appendix includes a drought tolerant plant list for both ground-based landscapes and green roofs**.

Green roofs can help advance many of these objectives, including potable water considerations when selecting drought-tolerant plant species, where appropriate.



City of Vancouver *Land Use and Development Policies and Guidelines*

BIRD FRIENDLY DESIGN GUIDELINES -
CONSIDERATIONS FOR DEVELOPMENT PERMIT

Adopted by City Council in January 2015
Effective April 24, 2015
Amended May 16, 2017

May 2017

1.6.14 Bird Friendly Design Guidelines

The Bird Friendly Design Guidelines support the Vancouver Bird Strategy, whose goal is to create the conditions for native birds to thrive in Vancouver and across the region. Strategy action areas include: bird friendly landscape design guidelines; bird friendly building design guidelines; research and monitoring; arts, awareness, and education; and economic development and tourism. **The use of the Bird Friendly Design Guidelines is encouraged in the design of buildings and landscaped areas on private and public property**.

Green roofs can help advance these objectives when designed to align with two focus areas:

- Protecting, enhancing, and creating bird habitat (by reducing light pollution, minimizing lawn area, incorporating snags, providing water, etc.).
- Reducing threats to birds (by increasing visibility of glass, reducing dangers of attractants, etc.). Habitats that benefit birds also benefit other species.

The Bird Friendly Design Guidelines should be used with this document (also see ***Appendix B: Habitat Enhancement Guide***).

FIGURE 1.9 - SUMMARY OF HOW GREEN ROOFS CAN ADVANCE CITY STRATEGIES

GREEN ROOF BENEFITS	IMPROVING AIR QUALITY	INTEGRATING RAINWATER MANAGEMENT	REDUCING URBAN HEAT ISLAND EFFECTS	ENHANCING BIODIVERSITY AND HABITAT	INCREASING ACCESS TO NATURE	SUPPORTS SOCIAL CONNECTIONS	LOWERS BUILDING ENERGY CONSUMPTION
CITY OF VANCOUVER PLANS AND POLICIES							
BIODIVERSITY STRATEGY	I	I	●	●	●	●	I
CITY-WIDE INTEGRATED RAINWATER MANAGEMENT PLAN	●	●	●	●	●	●	I
CLIMATE CHANGE ADAPTATION STRATEGY	●	●	●	●	●	●	●
RAIN CITY STRATEGY	●	●	●	●	●	●	I
URBAN FOREST STRATEGY	●	●	●	●	●	●	I
VANCOUVER FOOD STRATEGY	I	I	I	●	●	●	I
VANCOUVER PLAN	●	●	●	●	●	●	●
WATER WISE LANDSCAPE GUIDELINES	I	●	I	●	I	I	I

● - The green roof benefit is also a direct strategy objective.
I - The green roof benefit may not be a direct strategy objective, but will likely be realized from strategy implementation.

VANDUSEN BOTANICAL GARDEN VISITOR CENTRE, VANCOUVER

1

The roof of the visitor center at the VanDusen Botanical Garden was carefully planned to reflect the Pacific Northwest Coastal grassland ecology and includes over twenty species of plants, bulbs, and grasses.

The complex roof geometry, mimicking the shape of an orchid leaf and flower, presented a unique set of challenges for planting on slopes and opportunities for leveraging captured rainwater. The unique undulating roof planes simulate rolls and hummocks with gentle slopes ranging from 5% to more than 50%.

The various roof solar orientations create multiple opportunities for grassland and bulb plant communities to thrive. A vegetated ramp connects the green roof to the ground plane, encouraging use by local fauna and promoting biodiversity.

The design was intended to use 100% of captured precipitation as reused water. The roof and site plantings are designed to thrive without an irrigation system.

Completion Year	2011
Green Roof Type	Semi-Intensive
Green Roof Size	1,486 m^2
User Accessible	No
Roof Features	• Blue roof • Planting on slope • LEED-NC® Platinum • Living Building Challenge 2.1
Project Team	• Perkins & Will • Zinco • Architek • Cornelia Hahn Oberlander • Connect (formerly Sharp & Diamond) Landscape Architecture

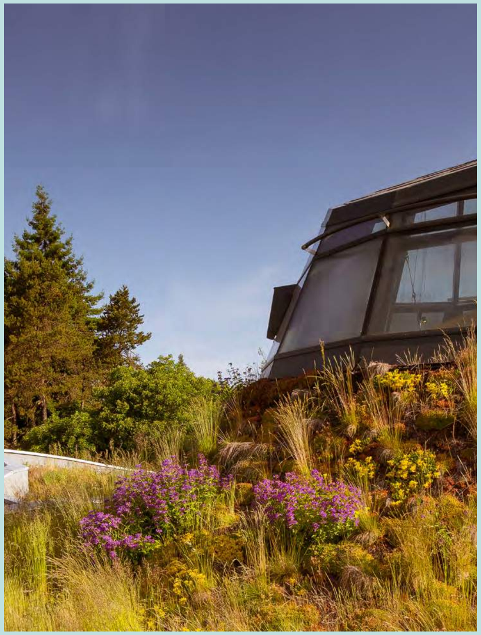


Photo credits: (above) © Connect Landscape Architecture, (below) © Connect Landscape Architecture

VANDUSEN BOTANICAL GARDEN VISITOR CENTRE, VANCOUVER

2

Project Goals and Objectives

- Connect the public to contemporary environmental issues
- Manage rainwater
- Enhance ecology and habitat
- Meet Living Building Challenge standards, including no irrigation system on the site
- Meet net-zero building certification requirement

Photo credits: (above) © Connect Landscape Architecture, (left) © Connect Landscape Architecture

ROBSON SQUARE AND BC LAW COURTS, VANCOUVER

1

Completion Year	1978 (Original), 2009 (Reconstruction)
Green Roof Type	Intensive
Green Roof Size	~12,500 m^2
User Accessible	Yes
Roof Features	• At-Grade Access • Automatic Dripline Irrigation
Project Team	• Cornelia Hahn Oberlander • Arthur Erickson • PFS Studio (Reconstruction)

Robson Square, completed between 1978 and 1983, is a landmark example of green roof technology and civic design in downtown Vancouver. Spanning three blocks, this continuous roof garden—designed by Cornelia Hahn Oberlander and Arthur Erickson—blends architecture and landscape to create a public oasis atop interconnected civic buildings, including the Law Courts and Vancouver Art Gallery.

The entirety of Robson Square's multi-level plaza is sited on rooftops, showcasing innovative approaches to integrating green roofs within an urban context. Oberlander's planting design emphasizes sensory variety, featuring massed rhododendrons, pines, and ivy alongside cascading waterfalls and reflecting pools. Elevated planters and densely vegetated terraces provide a park-like atmosphere, while the roof gardens incorporate soil and water systems to support 50,000 trees and shrubs, demonstrating the feasibility of large-scale green roof applications.

As both a public gathering space and a technical achievement, Robson Square illustrates how urban landscapes can enhance livability while reimagining the potential of green roofs. The project highlights the role of landscape architecture in transforming city centres and has provided many lessons learned regarding green roof design since then.

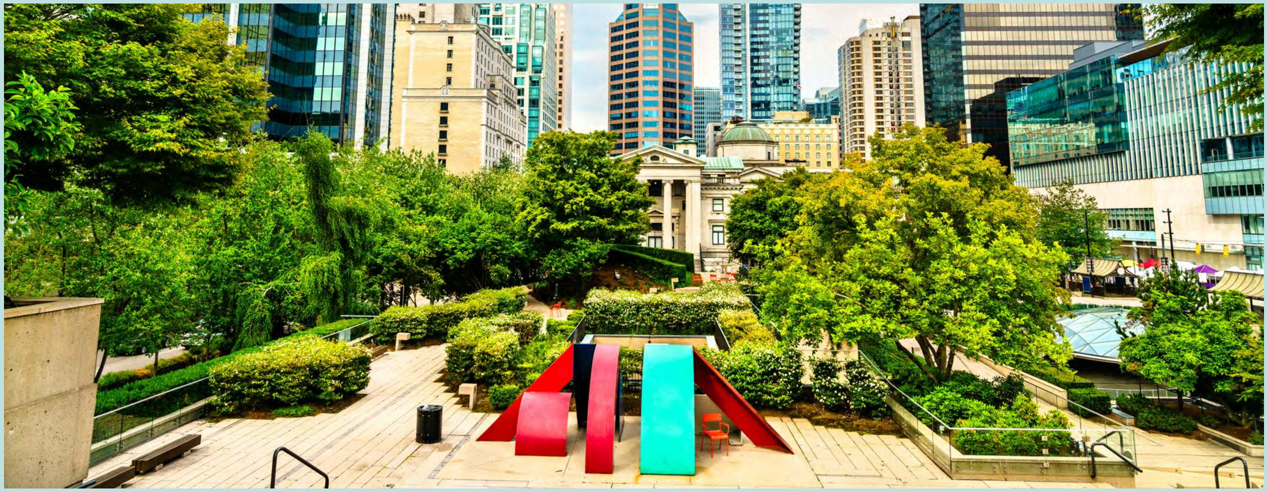
Photo credits: ©jovannig / Adobe Stock

ROBSON SQUARE AND BC LAW COURTS, VANCOUVER

2

Project Goals and Objectives

- Provide accessible green space in a dense urban area, create connections to nature and enhance public well-being
- Implement effective rainwater management through green roof technology to reduce runoff and support sustainable water use
- Enhance urban ecology by integrating native plant species that support local biodiversity and habitat
- Minimize reliance on external water sources by designing the green roof to thrive with minimal irrigation
- Support Vancouver's sustainability initiatives by promoting the use of green roofs as a model for integrating nature into urban environments



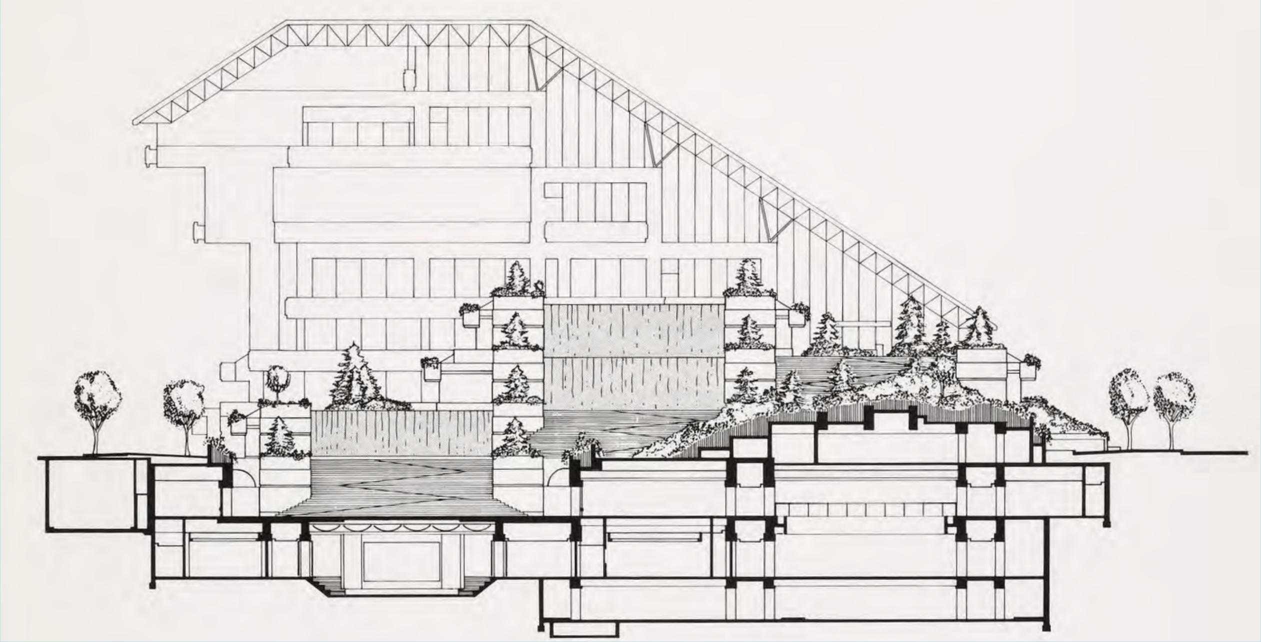


Photo credits: (above) © Leonid Andronov / Adobe Stock (below) © Canadian Centre for Architecture

MARINE GATEWAY, VANCOUVER

1

Completion Year	2016
Green Roof Type	Extensive, Intensive
Green Roof Size	10,000 m^2
User Accessible	Yes
Roof Features	• LEED-CS (Core and Shell certified) • Automatic Irrigation
Project Team	• Perkins & Will • PWL Partnership • PCI Developments

Marine Gateway, completed in 2016, is a LEED-CS certified, mixed-use development that incorporates 10,000 m^2 of green roofs as a cornerstone of its sustainable design. The green roofs enhance urban biodiversity, reduce urban heat island effect, and provide critical habitat for birds and insects within a dense urban environment.

Thoughtfully designed with natural elements, including logs repurposed from the construction site, the green roofs also play a role in rainwater management by mitigating runoff and improving water quality. These features integrate seamlessly into the project's broader sustainability goals, which include transit-oriented development and energy-efficient systems.

Marine Gateway's green roofs not only support ecological function but also exemplify how urban developments can contribute to environmental resilience in densely populated areas.

Photo credits: (above) © Reece Rehm (below) © Reece Rehm

MARINE GATEWAY, VANCOUVER

2

Project Goals and Objectives

- Enhance urban biodiversity and foster micro-ecosystems by creating habitats for insects and birds within the green roofs
- Improve energy efficiency by utilizing green roofs for natural insulation, reducing heating and cooling demands
- Implement effective rainwater management that reduces runoff and alleviates pressure on the City's stormwater infrastructure
- Enhance urban livability by creating aesthetically pleasing and functional green spaces
- Provide educational opportunities and access to urban gardening for office users through the use of urban agriculture plots

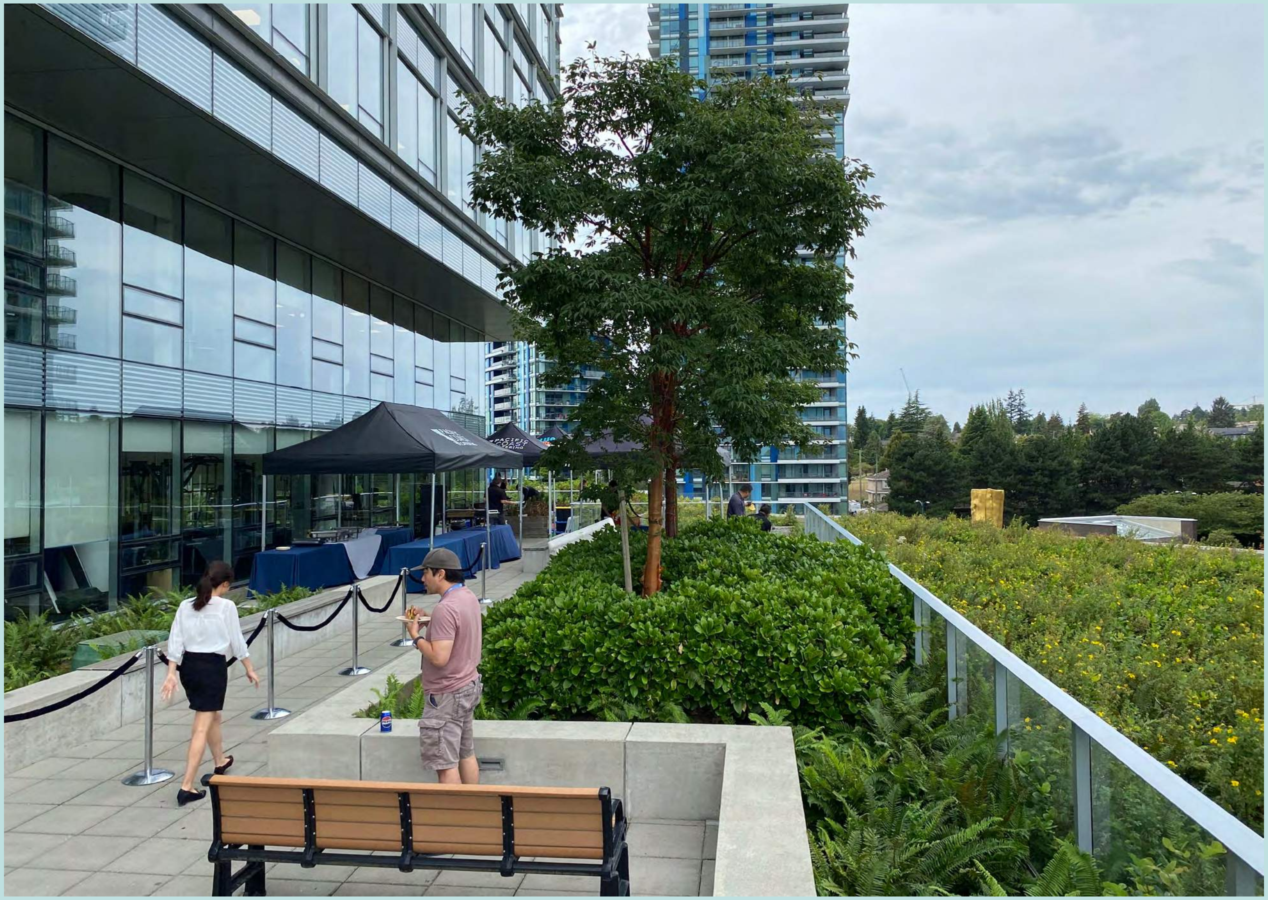
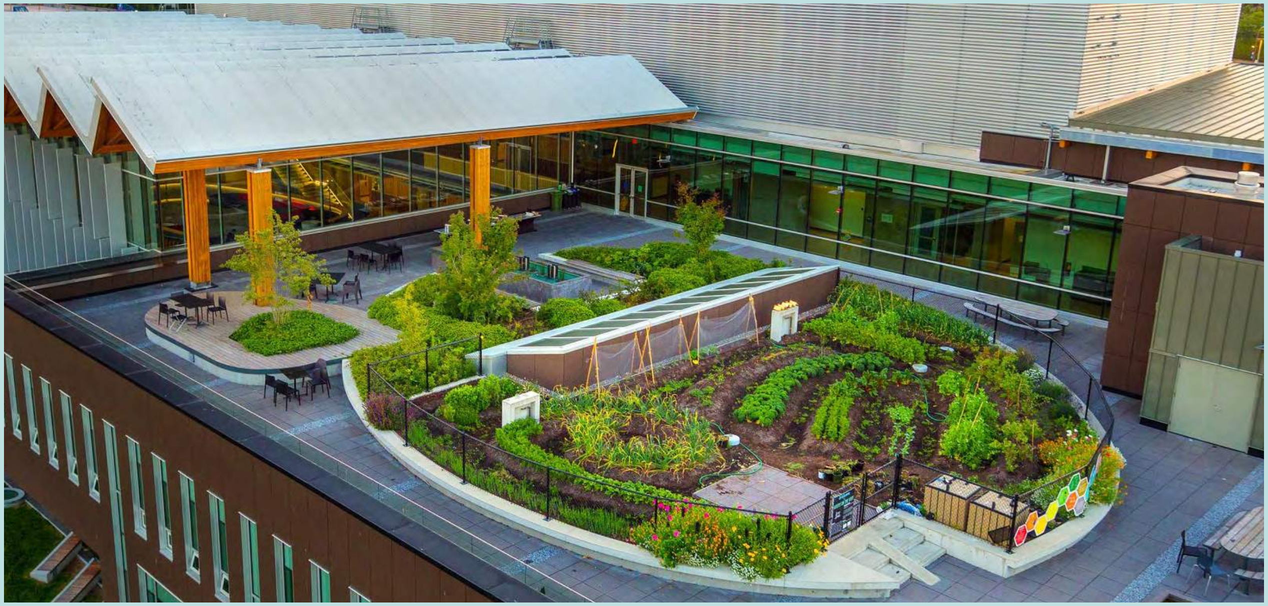


Photo credits: (above) © Reece Rehm (left) © Reece Rehm

THE NEST, UBC STUDENT UNION BUILDING, VANCOUVER

1



The Nest features a green roof that supports environmental goals and also serves as a community resource. A standout feature of this green roof is the community garden, which provides students and staff with access to gardening spaces, fostering a sense of community and connection to the natural environment.

The community garden is an integral part of the Nest's design, offering a hands-on educational space where members of the UBC community can learn about sustainable agriculture and urban gardening. The garden is maintained by Roots on the Roof, a community initiative that supports UBC's sustainability goals and also provides fresh produce and educational opportunities for those involved.

Completion Year	2015
Green Roof Type	Intensive
Green Roof Size	192 m^2
User Accessible	Yes
Roof Features	• LEED® Platinum Certified • Living Building Challenge • Manually irrigated
Project Team	• B+H Associated Architects • DIALOG • PWL Partnership • RJC Engineers • Applied Engineering Solutions

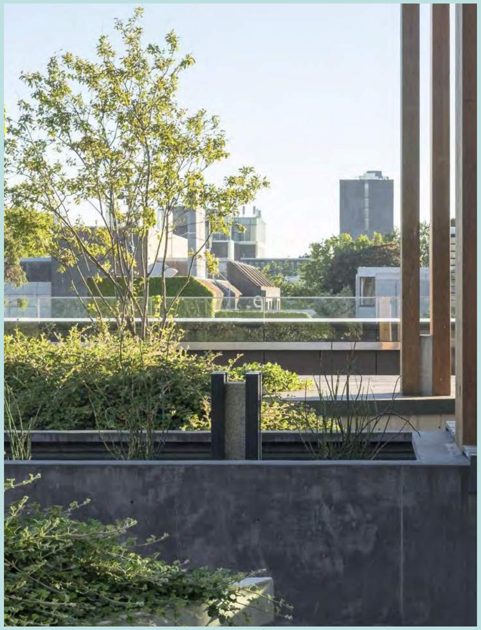


Photo credits: © (above) UBC Properties Trust (Below) © PWL Partnership Landscape Architects Inc.

THE NEST, UBC STUDENT UNION BUILDING, VANCOUVER

2

Project Goals and Objectives

- Provide educational opportunities for the UBC community to engage with sustainable practices, learn about urban gardening, and participate in the cultivation of fresh produce
- Integrate green infrastructure and reduce the building's environmental footprint
- Supplement rooftop plant irrigation with a rainwater collection system

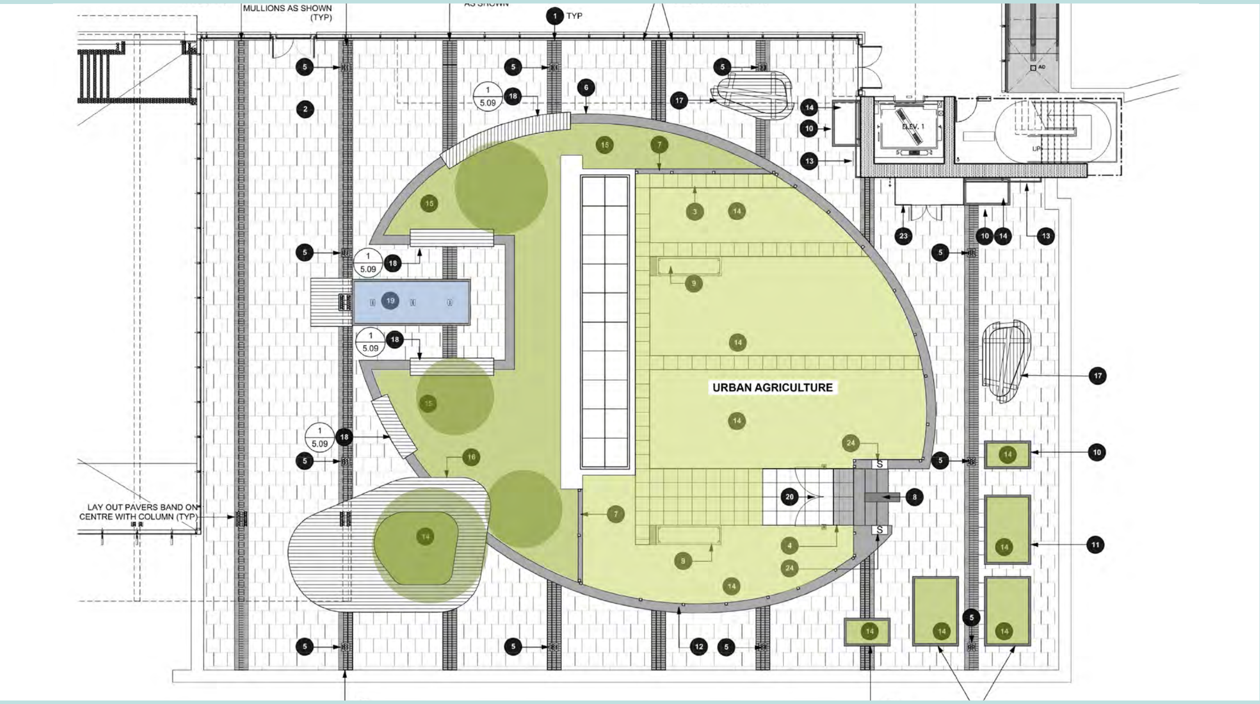


Photo credits: (above) © AMS Design Office (below) © PWL Partnership Landscape Architects Inc.

CHAPTER 2
DESIGN

2.1 ABOUT THIS CHAPTER

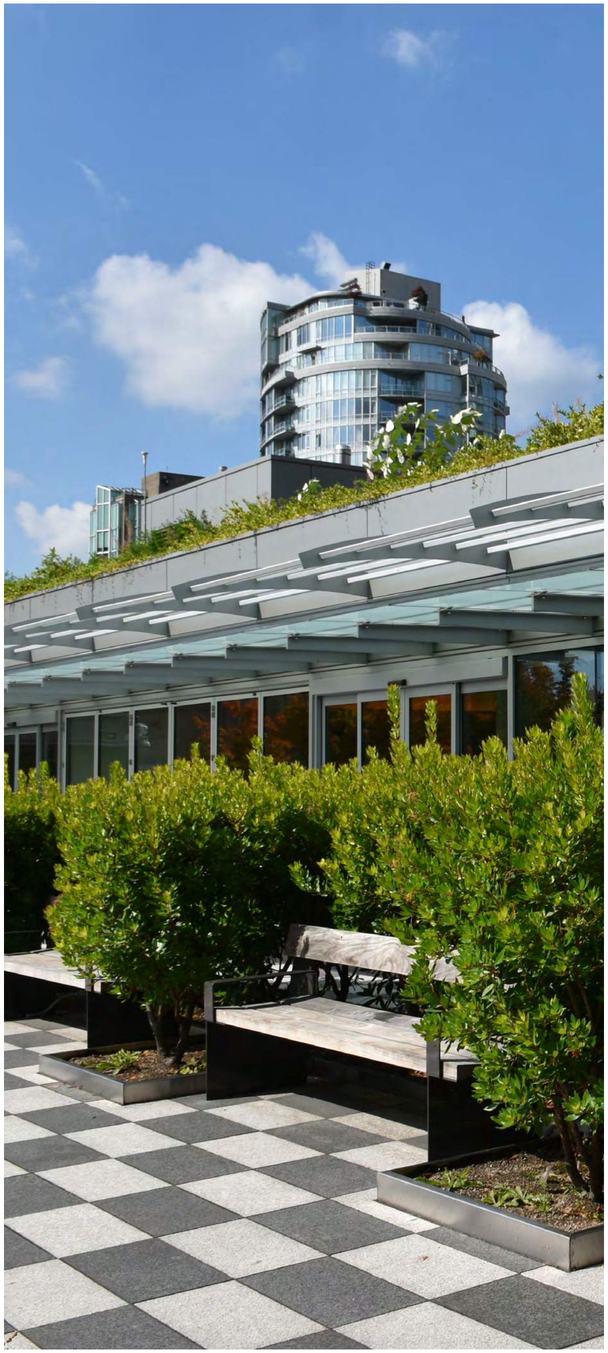
2.1.1 Introduction

Design represents the first of the three major green roof life cycle phases of Design, Installation, and Operations & Maintenance. Green roof design is influenced by various factors including **site variations** and the desired **site program**.

Site variations typically include the surrounding natural and built environment, local climate, and rooftop structural considerations. A site program may be defined as a list of **desired experiences, activities, and other functions** to be provided or supported by that space. Examples include rainwater management, habitat and biodiversity enhancement, amenity (and social) space provision, and urban agriculture. Design responses involve issues such as drainage, soil depth, plant and irrigation selection, and lighting and access needs.

By incorporating site context, social and environmental programming objectives, the structural capacities of the supporting building, and other important considerations, effective design can help create and enhance desired green roof experiences, activities, and functions.

Creating a thriving, long-lasting green roof that satisfies specific technical, aesthetic, social, ecological, and other programming objectives also requires the expertise and coordination of a **qualified team of professionals** that are knowledgeable in all stages of the green roof life cycle.



2.1.2 What is Included

This chapter discusses best practices for initiating, planning, and designing an effective and successful green roof project. The chapter begins by introducing the **major project life cycle stages** and the **issues to consider when designing to support programming** that includes rainwater management, habitat and biodiversity enhancement, amenity and social space provision, and urban agriculture. The various members that typically comprise a **multidisciplinary green roof project team** are then described.

The remaining content discusses other important design influences. **Site variations and considerations** includes topics such as the surrounding natural and built environment, local climate, building types, and roof slope. **Structural considerations**, which includes reference to dead and live loads, building construction materials, and retrofits, is then followed by **roofing and waterproofing**, which supports water integrity and long-term performance of the building.

The chapter also includes content on **drainage and rainwater management systems**, with reference to factors influencing rainfall capture such as plant selection and catchment area. **Growing medium selection** provides an overview of medium composition and its influence on weight, water storage and drainage, habitat, and maintenance. **Irrigation design** includes an overview of different approaches such as spray heads, drip lines, and capillary mats.

Plant selection is addressed in relation to site characteristics, the influence of plant installation methods, programming goals (with a closer look at aesthetics and biodiversity), growing medium depth, fire, irrigation, and maintenance.

Lighting Design includes ways to minimize glare and other forms of light pollution. Finally, the chapter provides information on **safety and access design**, including exits, maintenance access, guardrails, and fall protection systems.

CODE COMPLIANCE

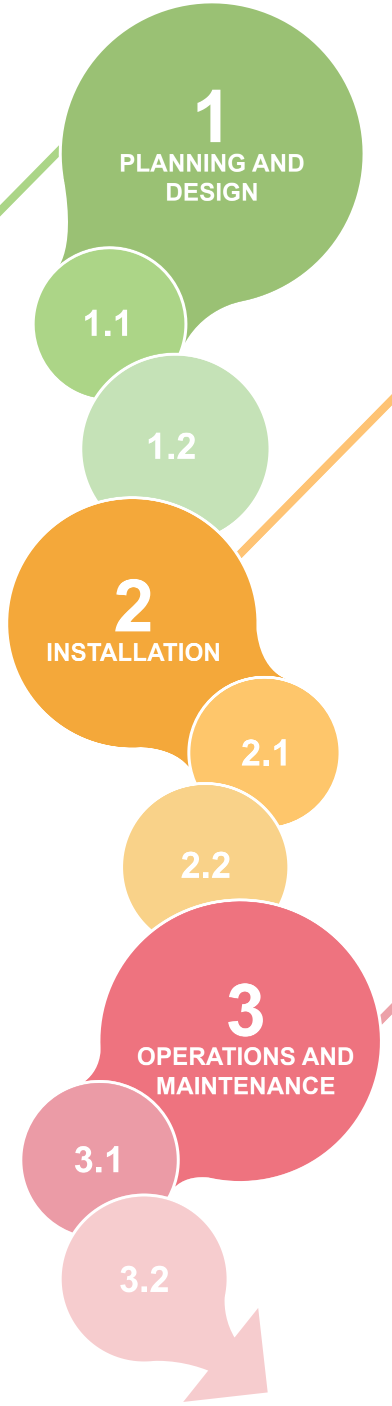
Consult the City of Vancouver Building By-law when planning and designing a green roof to help ensure understanding and application of the required minimum standards for building materials, products, and assemblies, which advance code objectives of safety, health, accessibility, fire and structural protection, and environment. Adherence to the Building By-law is critical for helping prevent structural and building envelope issues.

Consult other relevant By-laws, strategies, policies, guidelines, and bulletins to help ensure other regulations and community social and environmental objectives are being addressed. Key By-laws to consult include (not exhaustive):

- ***City of Vancouver Building By-law (Book I & II)***
- ***City of Vancouver Drinking Water Conservation By-law***
- ***City of Vancouver Fire By-law***
- ***City of Vancouver Standards of Maintenance By-law***
- ***City of Vancouver Zoning and Development By-law***

2.2 MAJOR PROJECT LIFE-CYCLE STAGES

Green roof quality, resilience, functionality, and performance can be enhanced by considering and coordinating between all major lifecycle stages, including design, installation, and ongoing maintenance. The accompanying diagram outlines typical steps undertaken at each stage; it is intended as a general reference and is not an exhaustive checklist.



1.1 Project Planning

- Determine the project's budget, goals, and desired social and environmental programming (experiences, activities, functions).
- Assemble a multidisciplinary team of consultants and coordinate throughout the project.
- Evaluate the site context (variations and considerations), structural requirements, and other performance needs that will support the proposed green roof programming (or modify accordingly).
- Identify long-term maintenance needs early to inform planning and design.

1.2 Roof Design

- Incorporate design strategies that support programming and long-term maintenance requirements.
- Develop the schematic design, refine the design, and prepare construction documents.
- Address jurisdictional requirements, such as development and building permit applications.

2.1 Construction

- Prepare the site and ensure proper sequencing of green roof component installations.
- Undertake quality control measures throughout the construction process.

2.2 Project Delivery

- Conduct a final inspection of the green roof installation.
- Hand over maintenance manuals to the project owner.

3.1 Maintenance and Warranty Period

- During the contractor warranty period, monitor the establishment of plants and performance of materials.
- Address any issues that could affect the longevity of the green roof.

3.2 Ongoing Life-cycle Maintenance

- Review the status of plant health, irrigation, and drainage seasonally and after major weather events.
- Monitor the roof structure and membrane integrity.

2.3 DESIGN TO SUPPORT PROGRAMMING

2.3.1 About this Section

Depending on the growing medium depth, choice of plants, and other features, **green roofs can be designed to help provide a range of ecological, social, agricultural, and economic benefits**. Green roofs can help manage rainwater onsite, reduce urban heat island effects by creating cooler rooftop surfaces, and enhance biodiversity and habitat.

Green roofs can also be designed to complement amenity, childcare, and urban agricultural spaces, increase access to nature, and expand educational opportunities. By transforming rooftops into attractive and accessible green spaces, green roofs can help promote social interaction and increase health and well-being. Green roofs are so useful because they mimic nature and are multifunctional (see ***Chapter 1: Background*** for more information).

The design of a green roof or other physical space is typically guided by a **site program**, which may be defined as a list of **desired experiences, activities, and other functions** to be provided or supported by that space. The Site Program, in addition to reflecting the proposed project scale and associated costs, should also reflect the environmental (e.g. sun, wind, rain), ecological, and social opportunities and constraints provided by the supporting building and its adjacent areas.

What is included: This section provides an overview of **four site program scenarios**. Each scenario emphasizes one of the following co-benefits:

- **Managing Rainwater**
- **Enhancing Habitat and Biodiversity**
- **Providing Amenity and Other Social Spaces**
- **Supporting Urban Agriculture**

Each scenario includes a general description and some design considerations relevant to their program. Note that because green roofs are multifunctional, each program scenario has the potential to provide other co-benefits beyond its primary performance purpose.

Examples of **conceptual design scenarios** based on each of these four programs are also included in this guide (see ***Chapter 6: Design Scenarios*** for more information).

2.3.2 Managing Rainwater

Managing rainwater refers to ways to capture, store, use, slow down, treat, and release rainwater, which can be achieved with various tools such as green roofs, detention tanks, and ground infiltration systems like raingardens.

Using green roofs to manage rainwater is particularly useful in dense urban locations where most of a site may be occupied by a building's footprint and opportunities for infiltrating rainwater into the ground are limited.

Green roofs manage rainwater by using both **detention and retention practices**. **Non-potable water systems** can also be designed to capture rainwater for reuse. Detailed descriptions of these three processes are as follows.

Note: These practices are presented to illustrate general approaches and functional differences between detention, retention, and non-potable water reuse systems. They are not exhaustive, nor are they intended to replace project-specific analysis. Actual requirements, performance targets, and design solutions will vary by site conditions.

Rainwater Detention

Rainwater detention is **the temporary storage and controlled release of excess rainwater on-site** to prevent flooding and reduce associated impacts on downstream areas. **Detention practices slow down but do not reduce the volume of water leaving a site and entering a sewer system**.

Detention may be achieved with at-grade landscapes, green roof growing medium, shallow water reservoirs in a blue-green roof, detention basins, or tanks. In the illustrated example (see ***Rainwater Management Practices - Example Scenario Diagram***), the roof surface collects and directs rainwater into a pipe system, which is connected to an on-site storage tank. The water is then released at a slower rate into the public sewer system, helping to reduce peak flows.

Any detention requirements, including volume and release rate, are typically outlined in local regulations, which may vary by municipality. Designers should consult applicable regulations for specific requirements early in the site programming and design process *(see the* **City of Vancouver's Building By-law Section 2.4.2.5. Rainwater Management** *for more information)*.

Rainwater Retention

Rainwater retention involves the **temporary storage and use of rainwater on-site**. **Retention practices use various means to reduce the volume of water leaving a site and entering a sewer system**.

Retention may be achieved with trees, plants, and other GRI such as green roofs (using water evaporation and plant transpiration, a process also known as evapotranspiration), retention ponds (using water evaporation, ground infiltration), and cisterns (using water reuse), In the illustrated example (see ***Rainwater Management Practices - Example Scenario Diagram***), retention of rainwater is represented by evaporation from roof surfaces, transpiration from vegetation, and infiltration into the ground.

Any retention requirements are typically outlined in local regulations, which may vary by municipality. By using both retention and detention practices, projects can achieve combined benefits such as reduced peak flow rates, increased groundwater recharge, improved water and air quality, increased biodiversity, enhanced site aesthetics, and greater access to green space and amenities.

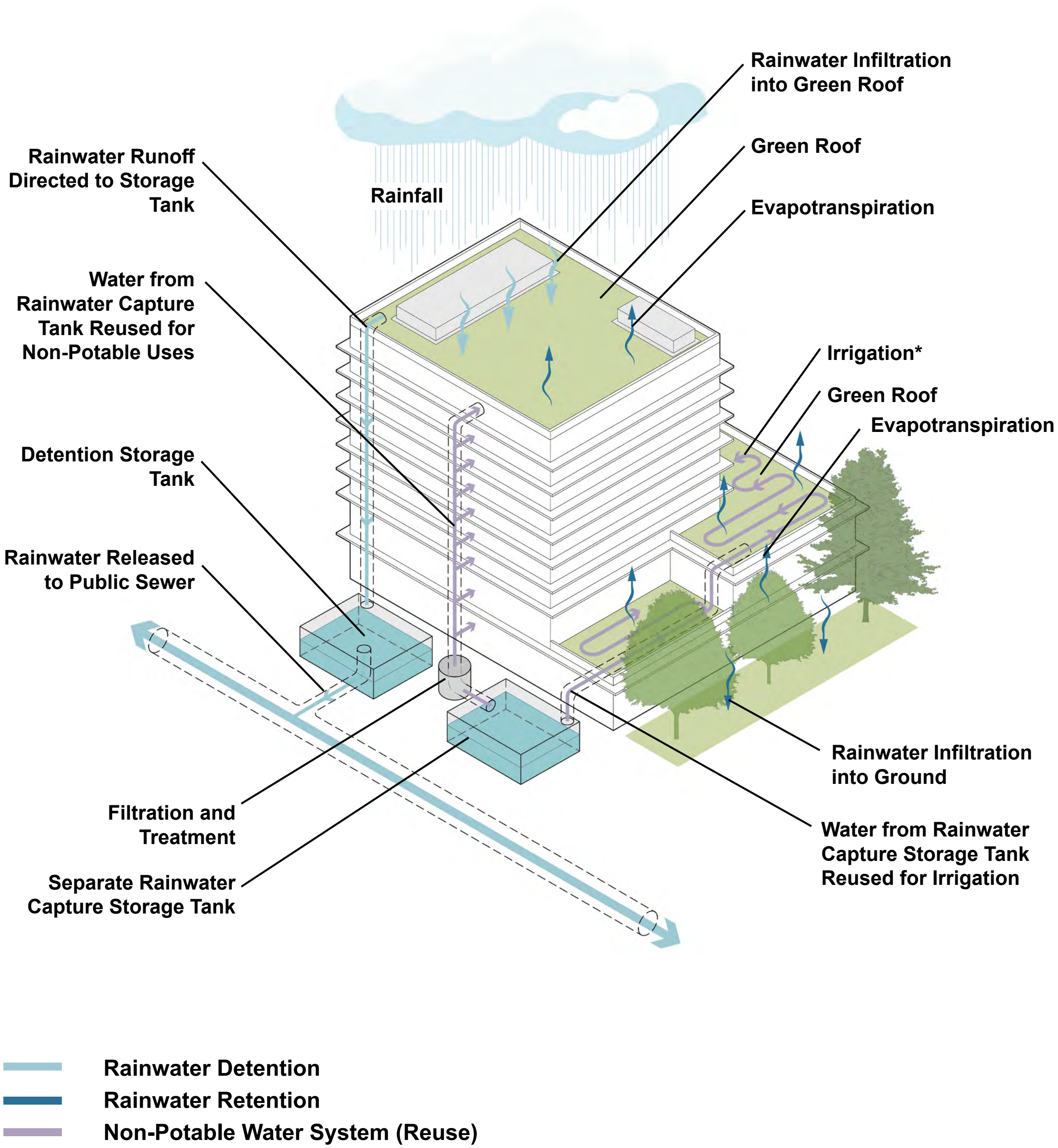
Non-Potable Water Systems

A non-potable water system is a related water management tool whose main purpose is to offset potable water demand. Potable water is water that meets standards prescribed by relevant regulations and is safe for human consumption.

Non-potable water is not suitable for human consumption but may be used for other purposes. Non-potable water (reuse) systems **capture and treat non-potable water sources for use in non-potable water applications**.

As with detention and retention practices, non-potable water requirements, including **allowable sources and applications, are typically outlined in local regulations**, which many vary by municipality. For example, the City of Vancouver currently allows rainwater to be used for some applications such as the irrigation of non-food purpose plants. Designers should consult applicable regulations for specific requirements *(see the* **City of Vancouver's Building By-law Section 2.7 Non-Potable Water Systems** *for more information)*.

Rainwater Management Practices - Example Scenario Diagram



DESIGN CONSIDERATIONS FOR MANAGING RAINWATER

As described in this chapter, some site-wide design considerations for managing rainwater include:

- Holistic, on-site systems approach that may combine green roofs with other retention-based and detention-based tools

Some green roof design considerations for managing rainwater include:

- Site variations and considerations (local climate, building types, roof slope)
- Structural considerations
- Roofing, waterproofing, and drainage conditions
- Growing medium selection and depth
- Plant selection
- Access and safety
- Maintenance implications of design choices

* When considering water reuse systems, consult the VBBL for allowable water sources and applications (end uses).

2.3.3 Enhancing Habitat And Biodiversity

Biodiversity is the variety and abundance of living organisms, including plants, animals, fungi, and microorganisms, which contributes to ecosystem stability and resilience.

A more biodiverse ecosystem is better able to generate various ecosystem services that provide human societies with, as example, a habitable environment, food, construction materials, medicinal plants, and other items. A more diverse environment also contributes to enhanced spiritual and aesthetic experiences.

The streets and buildings associated with the growth of our city have reduced and fragmented our natural habitat into patches such as parks, back yards, and boulevards. **Green roofs can enhance biodiversity by creating habitat and micro-climates that help support bees, birds, and a range of invertebrates, including spiders and beetles**. Green roofs can also act as 'stepping stones' for species movement between patches of greenery.

Green roof projects that include biodiversity enhancement should complete a **biological assessment** prior to the design phase to evaluate various factors onsite and in the surrounding area, including the connectivity and threats to natural habitat, species diversity and abundance, site potential to support habitat, and anticipated ecological outcomes based on preliminary choices that include, as example, plant species, substrate (type and depth), and use of features such as nesting boxes and insect hotels *(see **Appendix A: Recommended Green Roof Plant List** and **Appendix B: Habitat Enhancement Guide** for more information)*.

DESIGN CONSIDERATIONS FOR ENHANCING HABITAT AND BIODIVERSITY

As described in this chapter and in the appendices, some design considerations for habitat and biodiversity enhancement include:

- Site variations and considerations (natural and built environment, local climate, building types, roof slope)
- Including a biological assessment to evaluate green roof performance
- Structural considerations
- Roofing, waterproofing, and drainage conditions
- Growing medium selection and depth (biodiversity considerations)
- Irrigation design
- Plant selection (biodiversity considerations)
- Lighting design (biodiversity considerations)
- Access and safety (including who will have access and use of the space)
- Maintenance implications of design choices

PROJECT EXAMPLE:
ARBUTUS RESIDENCES IN VANCOUVER

The Arbutus Residences in Vancouver features an extensive green roof design that integrates amenity space provision with biodiversity enhancement. Spanning multiple levels, this green roof provides residents with accessible outdoor space, enhances the building's energy efficiency, and includes diverse native plants and drought-resistant species, which helps manage rainwater and reduce the urban heat island effect.

The Arbutus Residences exemplifies how programming and design choices can create green roofs that provide multiple benefits and help advance Vancouver's broader social and environmental goals.

2.3.4 Providing Amenity and Other Social Spaces

Many Vancouver residents live in multi-family buildings that may include open green spaces that can support activities such as engaging with neighbours, exercising, relaxing, dining outdoors, gardening, hosting other social events, or connecting with nature.

Although public parks can serve as communal ‘backyards’, residents also benefit from a **multifunctional green space within their own building** that includes features such as seating, terraces, recreation areas, cooking facilities, childcare areas, community gardens, and event spaces.

When programmed accordingly, green roofs can enhance rooftop amenity spaces, encourage social connections, and enable access and interaction with nature. Structural and related safety issues must also be addressed when designing green roofs to accommodate human access *(see **Section 2.13 Access and Safety Design** for more information)*.

Designers should consult applicable regulations for specific requirements. Be aware that regulatory requirements can vary depending on the type of building, size and purpose of the roof space, and other related issues *(see, as example, the* **Vancouver Building By-Law, including Section 9.8. Stairs, Ramps, Handrails and Guards** *for more information)*.

DESIGN CONSIDERATIONS FOR PROVIDING AMENITY AND OTHER SOCIAL SPACE PROGRAMS

As described in this chapter, some design considerations for amenity space and social programs include:

- Site variations and considerations (natural and built environment, local climate, building types, roof slope)
- Structural considerations
- Roofing, waterproofing, and drainage conditions
- Growing medium selection and depth
- Irrigation design
- Plant selection (and avoiding species not suitable for human interaction)
- Lighting design (social program considerations)
- Access and safety (including who will have access and use of the space)
- Maintenance implications of design choices

2.3.5 Supporting Urban Agriculture

Urban agriculture involves growing food in a variety of urban locations, including community gardens, orchards, backyards, and rooftops. Enabling locals with the opportunity to engage in food production can shorten supply chains and reduce carbon emissions, contribute to food security, job opportunities, economic growth, and help foster healthy, vibrant, and inclusive communities.

Roofs are premium locations for growing food as part of either larger-scale community farms or smaller-scale-gardening plots. Both activities make use of traditionally underutilized space. Green roofs can also be planted to support pollination. Did you know that roughly one-third of our food depends on pollinators? *(see* ***Appendix B: Habitat Enhancement Guide*** *for more information)*.

Intensive green roof systems are typically selected to support rooftop urban agricultural activities because deeper growing medium may be required for certain plantings such as fruit-bearing trees and shrubs. When proposing rooftop programming that includes urban agriculture, it is important to determine the structural capacity of the supporting building, given that growing medium contributes a significant portion of a green roof's weight.

Rooftop food production also requires other considerations, including the need for ongoing care and harvesting of plantings, suitable irrigation methods, access considerations, tool use, and other supporting systems.

DESIGN CONSIDERATIONS FOR SUPPORTING URBAN AGRICULTURE PROGRAMS

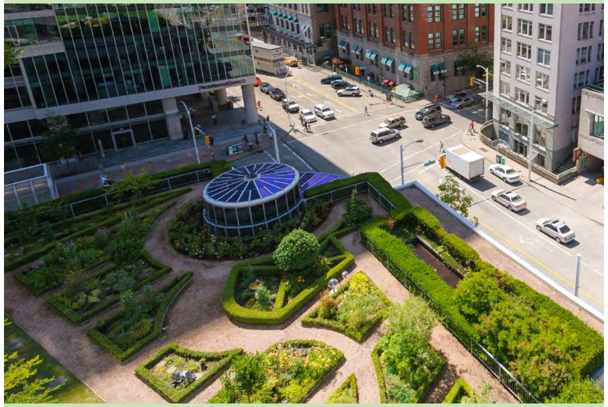
As described in this chapter, some design considerations for urban agriculture programs include:

- Site variations and considerations (local climate, building types, roof slope)
- Structural considerations (especially growing medium)
- Roofing, waterproofing, and drainage conditions
- Growing medium selection and depth (agriculture considerations)
- Irrigation design (agriculture considerations)
- Plant selection (agriculture considerations)
- Access and safety
- Maintenance implications of design choices

PROJECT EXAMPLE:
FAIRMONT, VANCOUVER

The Fairmont Waterfront Rooftop Garden is a pioneering example of urban agriculture and pollinator conservation, featuring one of Vancouver's first green roofs established in the 1990s. Located on the third-floor terrace of the iconic waterfront hotel in downtown Vancouver, British Columbia, the 2,100-square-foot organic garden grows a variety of herbs, vegetables, fruits, and edible flowers, while hosting thriving honeybee hives and native pollinator habitats that produce hundreds of pounds of honey annually.

The rooftop integrates sustainable agriculture with urban infrastructure, providing fresh, locally sourced ingredients to the hotel's restaurant and setting a precedent for eco-friendly rooftop projects in dense urban environments.

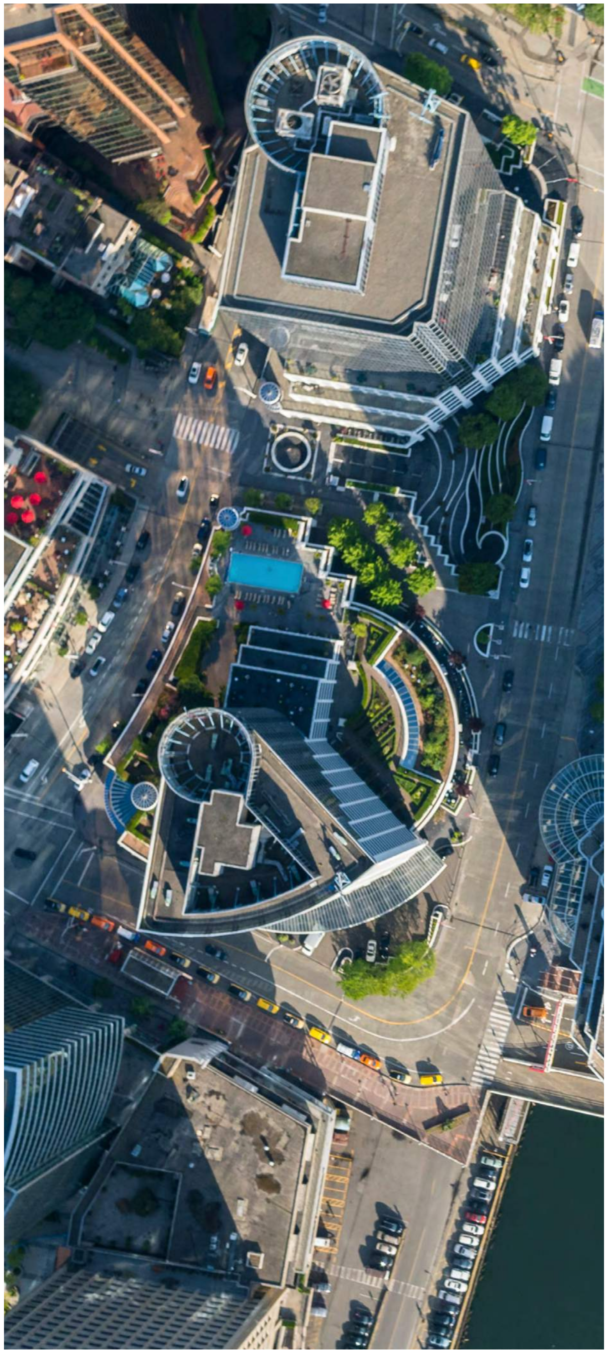


2.4 GREEN ROOF TEAM

2.4.1 About this Section

A green roof is a system of components that work together to perform multiple functions in sometimes challenging environments. Creating a thriving, long-lasting green roof that satisfies specific technical, aesthetic, social, ecological, and other desired programming objectives requires the expertise and coordination of a qualified team of professionals that are knowledgeable in the design, installation, and maintenance stages of the green roof life cycle.

What is Included: This section discusses the team members, and their associated areas of expertise, that are recommended to be involved in the design, installation, and maintenance stages of the green roof life cycle.



2.4.2 General Expertise

Building Systems Expertise

Designing a green roof requires careful integration of structural, waterproofing, and drainage systems to ensure functionality and longevity. For example, the roof structure must be engineered to support the additional weight of the green roof. Additionally, coordination with mechanical consultants is necessary to accommodate any rooftop equipment.

Social and Ecological Systems Expertise

The social and ecological potential of green roofs warrants the participation of dedicated specialists in these fields. Selecting appropriate plant species, for example, requires expertise in horticulture and ecology to ensure that plants will thrive in the specific microclimatic conditions of the roof, resist drought, and support biodiversity.

Obtaining input from designers with expertise in multifunctional social programming helps to ensure that rooftop spaces enhance social interaction. Similarly, the input from designers with knowledge of universal access and safety can help ensure that a green roof's accessibility standards are suited to its intended users.

Navigating the Regulatory Landscape

A coordinated and qualified team of professionals can streamline much of the work necessary for designing a green roof, better navigate the various regulations and policies relating to green roofs, and potentially secure permits and approvals in a quicker manner.

2.4.3 Team List

The following list describes the professionals, and their associated areas of expertise, that are recommended to be part of a green roof team.

Generally, these professionals would already be part of a typical building project team, regardless of the inclusion of a green roof.

Others listed in this section are typically involved only at the installation stage or the operations and maintenance stage, but can be involved earlier during the planning and design stage to help identify knowledge gaps and ensure that green roof–specific best practices are appropriately integrated into the project.

🟩 Professionals typically included in the planning and design stage of a building project

🟧 Professionals typically involved at later project stages, but who may be included during planning and design to support green roof–specific best practices

Developer/Owner

Developers/owners play a fundamental role in conceptualizing and advancing building projects. Developers/owners typically oversee the first two lifecycle phases (design, installation) of any associated green roof project, from conceptualization to completion, ensuring that it aligns with the financial goals and market demands pertaining to the larger building project. Their role involves securing overall project financing, managing the project's budget, and working with architects, engineers, and contractors to help coordinate project team members.

Developers/owners can also play a key role in driving the adoption of green roofs as part of broader development strategies aimed at enhancing property value, community well-being, and environmental performance.

Landscape Architect

Landscape architects play a central role in transforming rooftops into flourishing green spaces that provide aesthetic appeal, ecological benefits, and other desired functions. Their expertise can help to ensure that green roofs are visually captivating and contribute to biodiversity, habitat creation, and overall sustainability within urban environments.

Landscape architects also coordinate between various actors and team members to ensure successful delivery of a green roof project.

Architect

Architects play a fundamental role in designing, planning, and integrating green roofs into building projects. Their expertise in building design and sustainable architecture is central to the implementation of green roofs. Architects consider the building's overall aesthetics and functionality, ensuring that the green roof aligns with the project's architectural vision and goals.

Given that they often take on the role of building project manager, architects are well suited to coordinate the integration of green roofs with the rest of the building's systems.

Structural Engineer

The primary responsibility of a structural engineer is to assess the building's capacity to support the additional weight of the green roof, including the growing medium (soil), vegetation, water retention system, occupancy loads, and other relevant loads.

Structural engineers evaluate the distribution of loads from the rooftop down through a building's framework to its foundation. They determine the appropriate load-bearing capacity of the roof support structure and design any necessary reinforcements or modifications to ensure the support structure can accommodate the green roof without compromising the building's stability.

Building Envelope Engineer

Building envelope engineers help to ensure proper design and functioning of the interface (building envelope) that separates the building's interior and exterior environment.

They play an important role in collaborating with architects and other design professionals to seamlessly integrate any green infrastructure elements, such as green roofs, green walls, and rainwater harvesting systems, into the building's envelope. This process involves coordinating the placement and design of these features to ensure they function effectively while maintaining the building's structural integrity and weather resistance.

Building Code Consultant

Building codes and by-laws are essential for establishing minimum standards for building materials, products, and assemblies, and for helping to ensure safe and compliant building operations. The Vancouver Building By-law establishes requirements to address the five objectives of safety, health, accessibility, fire and structural protection of buildings, and environment.

The Vancouver Building By-law and Fire Safety By-law contain important information relating to green roofs. Provincial codes and municipal by-laws can often be complex and continue to evolve. To help ensure that all aspects of a green roof project remain compliant, it is important to have a dedicated expert who is up to date on these changes and able to effectively interpret and apply these regulations.

Civil Engineer

Proper water management on a green roof is essential for preventing water accumulation, potential leaks, and structural damage. Civil engineers help ensure proper water management by designing an efficient drainage system that meets local government expectations for on-site rainwater management.

Civil engineers may also coordinate the design of a green roof with detention tanks, water reuse systems, and other on-site GRI such as ground infiltration systems (e.g. rain gardens).

Irrigation Consultant

Depending on considerations such as seasonal rainfall, solar exposure, plant selection, and growing medium depths, green roofs may require irrigation to support plant growth.

An irrigation consultant can assist landscape architects and civil engineers in designing and installing irrigation systems that help achieve the project's water conservation targets by providing the right amount of water to the plants through consideration of factors such as plant species, seasonality, watering schedules, and required water pressure.

Ecologist

Ecologists can help ensure that the urban ecosystems created on a green roof will provide the intended ecological benefits desired from the green roof design objectives. They may work closely with landscape architects to select plants that are suited to the local climate and that address any desired biodiversity targets.

Ecologists can also support maintenance teams by applying adaptive management approaches that utilize monitoring and knowledge of plant community dynamics to generate feedback on wildlife responses to design and maintenance.

Roofing Contractor

Roofing contractors can assist with the successful implementation of green roofs by applying their knowledge of traditional roofing systems to the specific requirements associated with green roofs. For retrofit projects, roofing contractors can evaluate the existing roof membrane, insulation, and other roof assembly components to determine their condition and suitability for accommodating a green roof.

Roofing contractors who also possess appropriate vegetated roof system certification (such as those associated with RCABC's RoofStar Vegetated Roof Guarantee Program) can additionally provide green roof installation and maintenance services.

Contractors/Builders

Builders are responsible for the physical construction of green roofs at the installation stage of a project, ensuring that all elements are properly assembled according to the design specifications provided by architects, engineers, and other consultants.

The role of builders also involves coordinating the various trades, managing on-site activities, and adhering to construction schedules and budgets.

Warranty and Insurance Providers

Warranty and insurance providers can offer coverage that addresses the specific risks associated with general building construction, such as potential leaks, defective building materials, or mishandled installation processes. They provide warranties that help ensure the performance of buildings over a set period of time and offer insurance policies tailored to the unique aspects of these projects.

Their involvement can also help manage risk and protect the investment in the green roof, ensuring that any issues can be addressed in accordance with the terms of the coverage.

Green Roof Professional

Green Roof Professionals (GRPs) are accredited through the Green Roof Professional (GRP) Training & Accreditation program, which was created by the industry association Green Roofs for Healthy Cities (GRHC).

GRPs possess knowledge of best practices in green roof design and installation, waterproofing and drainage, and plants and growing media. They are trained to help ensure that green roof projects are optimized for long-term performance.

Material and Plant Suppliers

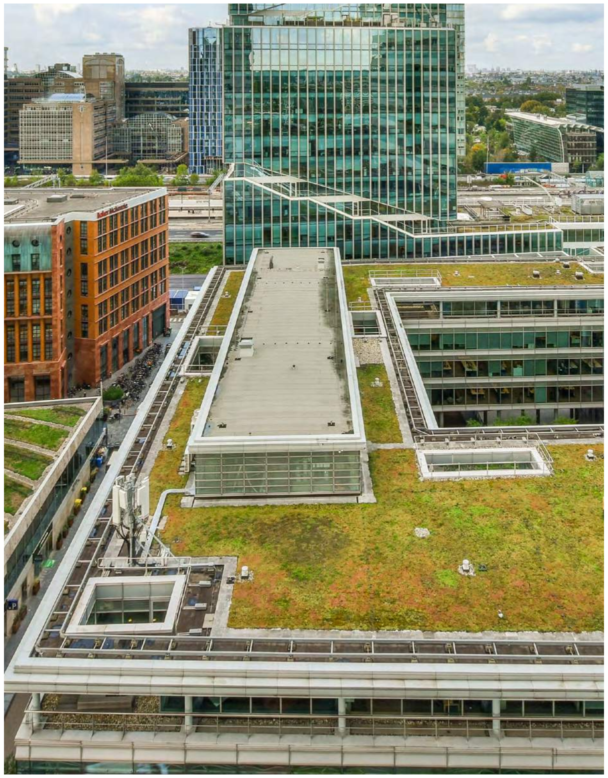
Material and plant suppliers provide the specialized products essential for the construction of green roofs. Their role involves sourcing and delivering materials like growing media, root barriers, and drainage layers, as well as supplying plant species suited to the specific environmental conditions of the rooftop.

Suppliers work closely with project teams to help ensure that all materials meet the required specifications necessary for supporting the green roof's performance and longevity objectives.

Maintenance Contractor

Building operations and maintenance teams are responsible for providing the ongoing care and maintenance of a green roof after the project is designed and constructed.

Their role involves routine inspections, maintenance of plant health, upkeep of irrigation systems, and monitoring of the roof's functionality and performance over time. These teams play a crucial part in ensuring the green roof remains a valuable asset to the building.



2.5 SITE VARIATIONS AND CONSIDERATIONS

2.5.1 About this Section

Green roofs can be exposed to a range of conditions and be designed to help provide a range of environmental, social, agricultural, and ecological benefits. To help ensure successful performance of a green roof, the design process must reflect both contextual and site-specific factors such as adjacent buildings, surrounding landscape and natural environment, local climate, height above the ground, building type, and roof slope.

What is Included: This section discusses some of these important contextual and site-specific factors that influence green roof design and performance, including surrounding built and natural environment, local climate (precipitation, solar, and wind), building type and function, and roof slope.

2.5.2 Surrounding Natural and Built Environment

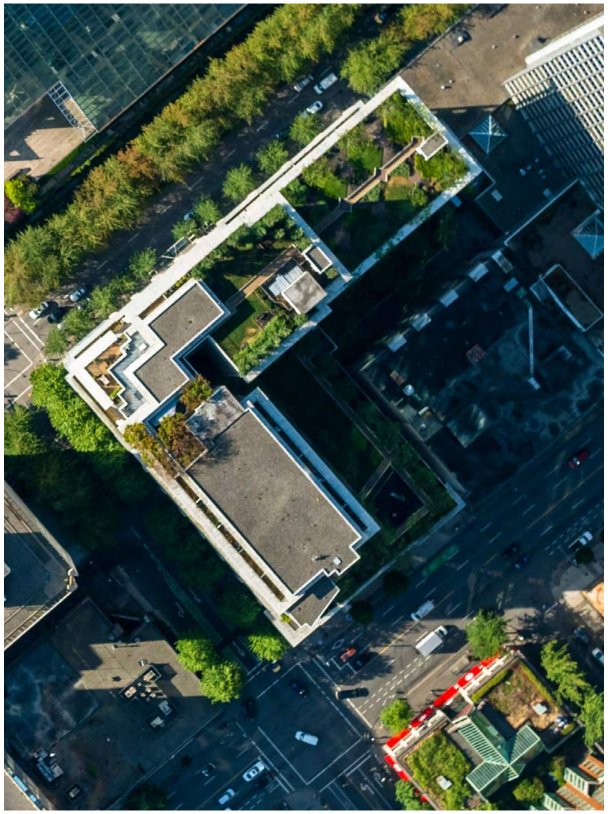
The green roof design process should consider **factors from the surrounding natural environment** such as proximity to natural ecosystems and habitat corridors. Urban areas are typically comprised of various kinds of green spaces, including nature reserves, wetlands, parks, ground vegetation, street tree canopy, back yards, community gardens, streams, and foreshore areas. These spaces provide valuable habitat and, collectively, can also form a habitat network used by a range of species, including birds and insects.

Green roofs can become an important part of this network by enabling buildings to also provide habitat and connectivity to other adjacent green spaces, both natural and engineered. Consequently, regardless as to whether a green roof program intends to enhance habitat, biodiversity, and connectivity, the design should consider both the surrounding natural environment and the site itself *(see **Appendix B: Habitat Enhancement Guide** for more information)*.

The design process should also consider **factors from the surrounding built environment**. For example, the proposed green roof site may be partially or completely surrounded by taller buildings or other structures, which can potentially block sunlight and funnel wind.

Conversely, the glazing and mullions on these nearby adjacent buildings can also reflect and focus sunlight onto the space occupied by the proposed green roof, resulting in periods of intensive glare and excessive heat. Potential impacts from adjacent future developments should also be anticipated, where possible.

Finally, green roofs offer a meaningful opportunity to **enhance views from surrounding buildings**, contributing to visual interest, seasonal change, and a stronger relationship between built form and landscape. When thoughtfully designed, these visual connections can reinforce the environmental, social, and aesthetic benefits of green roofs within dense urban contexts.



2.5.3 Local Climate

Climate considerations involve understanding how precipitation, solar and shade exposure, temperature, wind, and related factors vary on a site. These variations are affected by the surrounding built environment and influence a green roof's programming, design, functionality, ongoing maintenance requirements, and overall resilience.

For example, the wind patterns and velocities experienced by a green roof are influenced by factors such as the green roof's wind exposure, height above the ground, and proximity to other structures that may block or funnel wind. Wind patterns and excessive velocities may move or erode growing medium (soil), impact plant selection (as some species are better suited to withstand strong winds), influence the distribution of water and nutrients, and create an upward lifting 'suction' on the green roof surface.

Windbreaks, wind-resistant plantings, and other design solutions may be necessary in windy locations to create more hospitable growing conditions.

Green roofs should therefore be designed to leverage and respond effectively to site-specific climatic challenges and opportunities by undertaking a **climatic considerations assessment**, which helps to ensure the suitability of programming choices and informs strategies relating to, for example, plant selection, irrigation, energy efficiency, and rainwater management.

2.5.4 Building Types

Different building-site typologies, such as residential, commercial, industrial, and institutional, vary in terms of allowable onsite and internal building uses, densities, and heights. These typology variations typically impact other factors relating to the rooftop space, including available rooftop area, rooftop load-bearing capacity, rooftop accessibility, and the suitability of public versus private use in the space.

Different building-site typologies therefore have varying opportunities and constraints, which influence green roof programming choices. For example, industrial buildings may choose to prioritize rainwater management whereas residential buildings may additionally focus on incorporating complementary community gardens and amenity space.

The design team should consider and leverage the opportunities and constraints associated with particular building-site typologies when developing green roof programs and associated designs.

2.5.5 Roof Slope

The roof slope or pitch is an important factor in green roof design as it **can impact wind resistance, maintenance accessibility, drainage patterns, and growing medium rainwater retention**, which influence rainwater management.

Steeper slopes require specialized engineering to prevent soil erosion and provide adequate support for vegetation. Extensive green roofs are usually a more suitable choice for steeper-sloped roof conditions as they minimize the need to stabilize deeper growing medium layers that are typically associated with intensive green roofs.

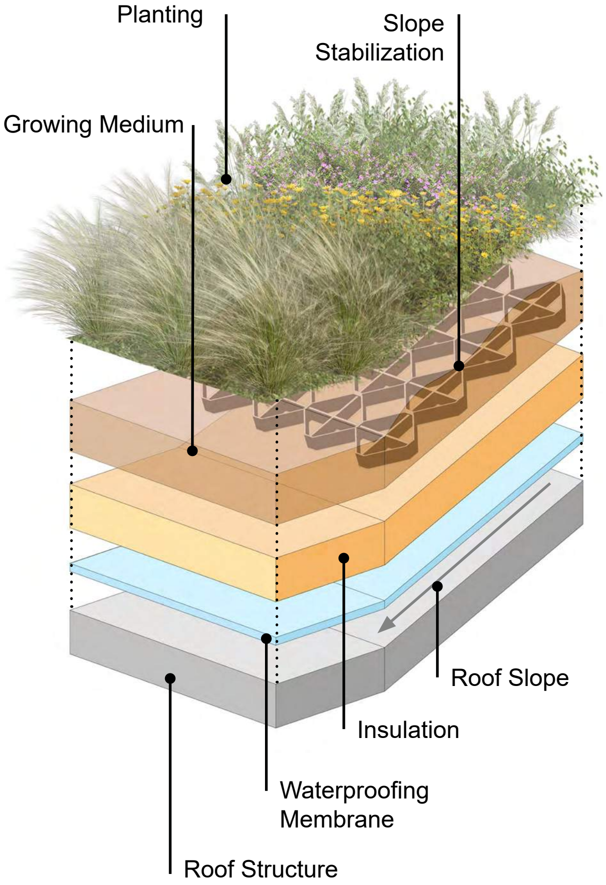


Figure 2.1 - Example of Green Roof Assembly on Slope

2.6 STRUCTURAL CONSIDERATIONS

2.6.1 About this Section

Maintaining the structural integrity of the supporting building is a critical requirement when assessing green roof project feasibility. Various structural design factors must be considered to help ensure that **the weight of the green roof system, including vegetation, growing medium, retained water, and intended uses, does not exceed the structural capacity of the building**. It is important to work with structural engineers to help ensure that structural and related issued associated with a green roof project are properly addressed.

What is Included: The following section outlines some important structural considerations when designing a green roof, including dead loads, live loads, and seismic loads. Common **material variations** in the supporting roof structure and considerations relating to green roof **retrofit projects** are also briefly discussed.

2.6.2 Dead Load, Live Load, and Environmental Load

Loads are defined as imposed deformations, forces, and pressures applied on a structure.

Dead loads refer to the permanent, static (unchanging) deformations, forces, and pressures exerted on a structure. Dead loads are primarily due to the self-weight of the structure's own components and permanent fixtures. Examples include the weight of a roof exerting a load onto supporting walls, which exert loads onto supporting floors and foundations. On a green roof, the dead loads include the weight of all system components, including the vegetation and growing medium.

Live loads refer to the temporary, dynamic (changing) deformations, forces, and pressures exerted on a structure by movable objects. Examples include the weight of occupants, furniture, equipment, and storage. On a green roof, the live loads come from similar objects, such as the weight of visitors, workers on the roof, and maintenance equipment.

Environmental loads refer to the temporary, dynamic (changing) deformations, forces, and pressures exerted on a structure by environmental events. Examples include rainfall or irrigation water, snow accumulation, and wind pressure. On a green roof, the environmental loads come from similar events.

Loads create bending, shear, tension (stretching), and compression (squeezing) stresses and forces in the components that make up the supporting structure. These considerations must be carefully addressed to ensure the green roof system and underlying structure can safely support varying loads.

2.6.3 Dead Load: A Closer Look

Growing Medium – The weight of growing medium contributes a significant additional load onto the supporting roof structure, especially when the growing medium is wet or saturated, as water is a relatively heavy material. The standard saturated density (mass/volume) of growing medium typically used on rooftops ranges between 1,100 and 1,900 kilograms per cubic meter (kg/m3). Other lightweight growing medium solutions are available to help reduce the overall weight of the green roof *(see **Section 2.9: Growing Medium Selection** for more information)*.

Figure 2.1 summarizes the approximate dead load of the growing medium for each type of green roof. Note that the loads are given as pressures in kiloPascals (1 kPa = 1 kiloNewton/m2 = 101.97 kg/m2):

Plant Types and Densities - **The weight of selected plant types** and **overall density of plantings** on a green roof contributes a load onto the supporting roof structure. For example, gardens containing trees and shrubs result in greater loads than those that only contain grasses and other herbaceous species.

The weight of vegetation on a green roof will also increase as plants mature. Saplings, for example, will grow into fully mature trees. **The anticipated mature weight of vegetation should be used when determining the loads** that the green roof system will transmit onto the supporting rooftop structure.

Plant Changes - A roof's program may also change over time and plants may be replaced with other species not originally specified in the roof design. Potential changes to existing green roofs will need to consider the impact on the supporting roof structure. **Structural drawings should be consulted as the green roof ages and changes**.

FIGURE 2.1 - GROWING MEDIUM DEAD LOAD ACCORDING TO DEPTH

	Depth of Growing Medium	**Approximate Load**
Extensive	<150mm	<2.9 kPa
Semi-Intensive	150-300mm	2.9 to 5.7 kPa
Intensive	300-450mm	5.7 to 8.5 kPa
	450-900mm	8.5 to 17.0 kPa
	>900mm	>17.0 kPa

* Loads may vary depending on the product and composition of the growing medium. Product information should be consulted with the help of a structural engineer to accurately determine a green roof's load. The FLL Green Roof Guidelines (2018) can provide additional information on growing medium loads and density.[27]

2.6.4 Live and Environmental Load: A Closer Look

Use and Occupancy of Accessible Areas - Green roofs have specific programming, accessibility (including public versus private considerations), and maintenance requirements that must be **carefully coordinated with a structural engineer** to ensure that all associated live loads are included in the analysis. An accessible rooftop should comply with all applicable By-laws, including the **Vancouver Building By-Law (VBBL)** requirements for assembly areas that are accessible to pedestrian traffic. In the case of existing buildings with new green roofs, the intended use and occupancy loads may be impacted by the addition of the green roof, and this must also be reviewed by a structural engineer.

Snow Load - Green roofs may be exposed to varying snow loads during winter months and must be designed to resist this additional loading. While Vancouver's snow loads are relatively less frequent and shorter in duration than some other parts of Canada, **significant snow loads can still accumulate in a short amount of time**. Structural engineers must be consulted to carefully assess and determine the appropriate design specifications, including roof pitch and the selection of materials that can withstand the potential snow accumulation. In the case of existing buildings with new green roofs, the snow loads may be impacted by the addition of the green roof, and this must also be reviewed by a structural engineer.

Transient Water - A green roof typically includes a growing medium layer, drainage layer, and, if a blue-green roof, a water storage layer. Whereas the water in a growing medium is considered a dead load, **the water in drainage and storage layers is considered a live load** because it is relatively more 'transient'.

Refer to ***Section 2.8 On-Site Drainage And Rainwater Management*** for further details on green roof design considerations for waterproofing and drainage.

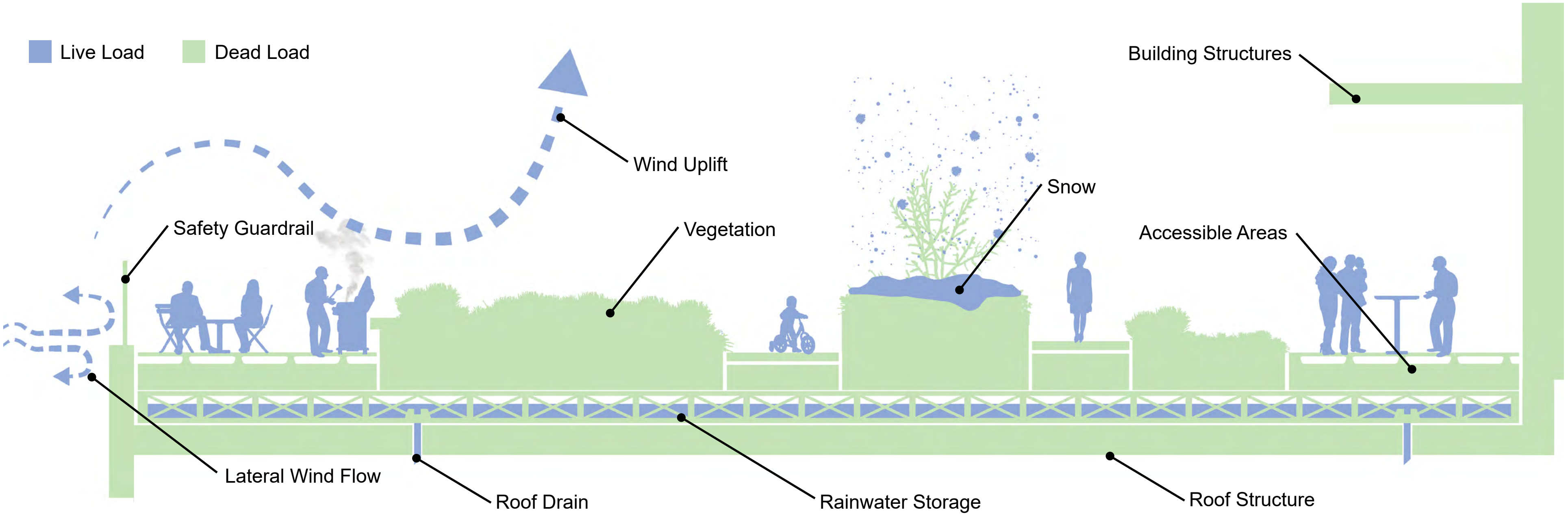


Figure 2.2 - Illustration of dead and live loads on a roof structure

Wind Load - Green roofs **may be exposed to varying wind patterns and velocities**, and must be designed to resist both wind uplift (suction) and lateral wind pressure. Uplift loads occur when wind flows over the roof, potentially lifting materials, while lateral wind loads exert pressure against the sides of a structure (see ***Figure 2.2***).

Design for wind uplift on green roofs should follow the same principles as other ballasted roof systems (see ***2.7.3 Protected Roofs: A Closer Look*** for more information on roof assemblies that require with ballast layers).

Applicable design standards for wind uplift include guidance from organizations such as ANSI/SPRI and the National Research Council Canada (NRCC), which provide methods for calculating wind loads and specifying appropriate anchoring or ballast to ensure roof stability.

Seismic (lateral) Load - Earthquakes create both horizontal (lateral) and vertical ground motion. When horizontal ground motion moves the base of the building, the upper portions of the building resist this movement, causing sway, deformation, and the generation of stresses and forces in the building's structural components.

These seismic forces are directly proportional to the 'seismic weight' of a building, which is calculated according to procedures in the National Building Code of Canada. When adding a green roof onto a building, the **self-weight of the green roof assembly** must be included when determining the seismic weight of the building.

For a low-rise wood frame building, which has a relatively low self-weight, the addition of growing medium could significantly increase the seismic weight. Conversely, for a multi-storey concrete building, which has a relatively high self-weight, the addition of growing medium would likely minimally increase the seismic weight, and thus the seismic forces.

For green roof retrofits, structural upgrades for the lateral load system typically involve **strengthening existing components or adding new components**, such as braces or shear walls and their foundations.

2.6.5 Building Structural Capacity and Retrofits

New buildings can be proactively designed to address the additional weight, accessibility needs, and other necessary or desired features associated with a green roof project. **Existing buildings can also be retroactively designed and potentially modified to accommodate a green roof**.

Determining the overall technical feasibility and cost of a green roof retrofit project will require a **structural analysis** to understand whether the structural capacity of the existing building is sufficient to support the additional loadings (including seismic) created by the green roof. A related analysis should also assess other necessary or desired components or features, such as the waterproof membrane, roof access, and water access.

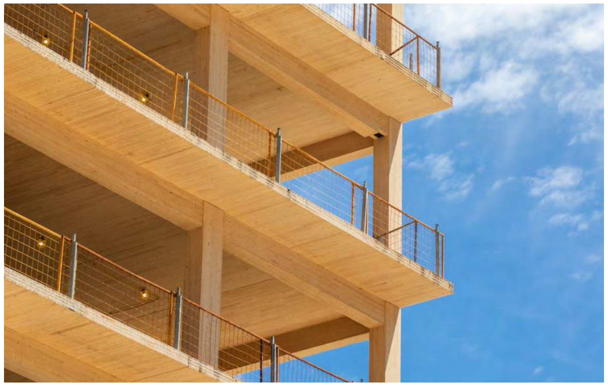
Should **structural seismic retrofits** be necessary to accommodate seismic (lateral) loading, they typically involve strengthening existing components or adding new components, such as braces or shear walls.

Should **structural retrofits** be necessary to accommodate vertical (gravity) loading, they typically involve strengthening existing components or adding, as example, additional framing to decking, joists, beams, column walls, and foundations.

A **structural engineer** should be consulted to understand the structural capacity of the building and the best approach for upgrading the building to support a green roof.

2.6.6 Building Construction Materials

The materials used in the construction of a building will have a **significant impact on the load-bearing capacity of the building and associated roof structure**. Three types of materials are commonly used for building construction in Vancouver: **wood, concrete, and steel**. Each material has advantages and disadvantages to consider when assessing suitability for accommodating the additional loading of a green roof system.



Wood Structure - Wood is an organic material used in building construction. Wood is relatively lightweight, has a high strength/weight ratio, is strong in tension (stretching) and compression (squeezing), is durable when adequately protected from moisture, provides sound absorption, resists electrical current, can be locally sourced, and is biodegradable. The design of a wood structure should consider shrinking and swelling of the material.

Two framing forms are common: stick-frame and mass timber. **Stick-frame** utilizes light framing methods with dimensional lumber and is typically used in **low-rise residential construction**. **Mass timber** utilizes an engineered wood product such as cross-laminated timber (CLT), parallel strand lumber (PSL) or glue-laminated timber (glulam). Mass timber is typically used in **larger structures**, such as high-rise residential buildings and community centers.

Reinforced Concrete Structure - Concrete is a mixture of water, cement, and aggregate. Concrete is strong in compression, can help regulate interior temperatures by acting as a thermal mass, is durable, and can withstand higher temperatures, particularly when using special heat resistant mixes.

Cement production contributes to greenhouse gas emissions. These structures will also include steel reinforcement (rebar) to help compensate for concrete being weaker in tension. Most **tall residential or office buildings** in Vancouver are constructed with reinforced concrete.

Steel Structure - Steel is an alloy consisting mainly of iron and carbon. Steel has a very high strength/weight ratio, is strong in tension and compression, is ductile, and suitable for prefabrication and mass production. Steel is susceptible to corrosion and is more energy-intensive and expensive to produce.

Various structural elements are common, such as open-web steel joists, beams, girders, and columns. Steel is typically used in **large retail establishments and industrial spaces**.

2.7 ROOFING AND WATERPROOFING

2.7.1 About this Section

A well-integrated roofing and waterproofing system is essential for the success of green roof installations. Ensuring that these components are properly designed can help make the green roof both functional and sustainable, offering long-term benefits to the building and its environment.

What is Included: This section provides an overview of the two types of roof assemblies most relevant to green roofs, the specific layers that comprise green roof systems, techniques for managing penetrations into the membrane, and drainage considerations for retrofit projects.

2.7.2 Green Roof Assemblies

Green roof assemblies are comprised of various layers, including, from top to bottom:

- **Green roof system**
  - Vegetation
  - Growing medium
  - Filter fabric
  - Drainage layer (or system)
  - Root barrier*
- **Waterproofing membrane***
- **Supporting roof assembly**
  - Protection board and attachment accessories
  - Insulation
  - Vapour barrier and roof sheathing (if applicable)
  - Roof structural deck

(see ***Section 2.7.6 Roof Assembly: A Closer Look at Green Roof Layers*** *for more information)*

There are **two general types of roofing assemblies** most relevant to green roofs and each differs based on the position of the insulation layer.

Conventional (or conventionally insulated) Roof Assemblies place the insulation below the waterproofing membrane.

Protected Membrane Roof (PMR) assemblies, sometimes referred to as Inverted Roof Assemblies, place the insulation above the waterproofing membrane.

The choice between these assemblies should be based on project-specific design considerations, including long-term durability, exposure, maintenance requirements, and budget.

ROOT BARRIER PLACEMENT

Regardless of the chosen roof assembly, **the root barrier should always be placed immediately above the waterproofing membrane**. If it is located anywhere higher up in the green roof system, it will act as a drainage plane and trap moisture below it.

ROOF ASSEMBLY SLOPE DESIGN

Regardless of the roof assembly type, all green roof systems require a slope to facilitate adequate drainage. **A minimum slope of 2% is generally recommended**.

2.7.3 Protected Roofs: A Closer Look

In a protected membrane roof (PMR) assembly, **the waterproofing membrane is applied directly to the roof structure or roof sheathing**, with the insulation layer installed above it. This configuration keeps the membrane at stable temperatures and protects it from UV exposure and foot traffic, helping extend its service life.

Protected roofs require a ballast layer such as stone or paving over top to weigh down the insulation and counteract wind uplift forces. **Green roofs can be conveniently designed to function as this ballast layer**.

2.7.4 Conventional Roofs: A Closer Look

In a conventional roof assembly, **the waterproofing membrane is installed above the insulation layer**, exposing the membrane to greater temperature variations. Nevertheless, these assemblies also provide **easier access to the membrane**, which can better accommodate inspections and repairs. but also increase vulnerability to accidental damage. To mitigate risks, the roof design should use protective measures such as pre-finished metal flashings.

Figure 2.3 on the right compares the typical layer configurations of protected and conventional roof assemblies.

2.7.5 Modified Protected Roof Assembly

In a modified protected roof assembly, **insulation layers are placed both above and below the waterproofing membrane**. This hybrid configuration can enhance thermal performance.

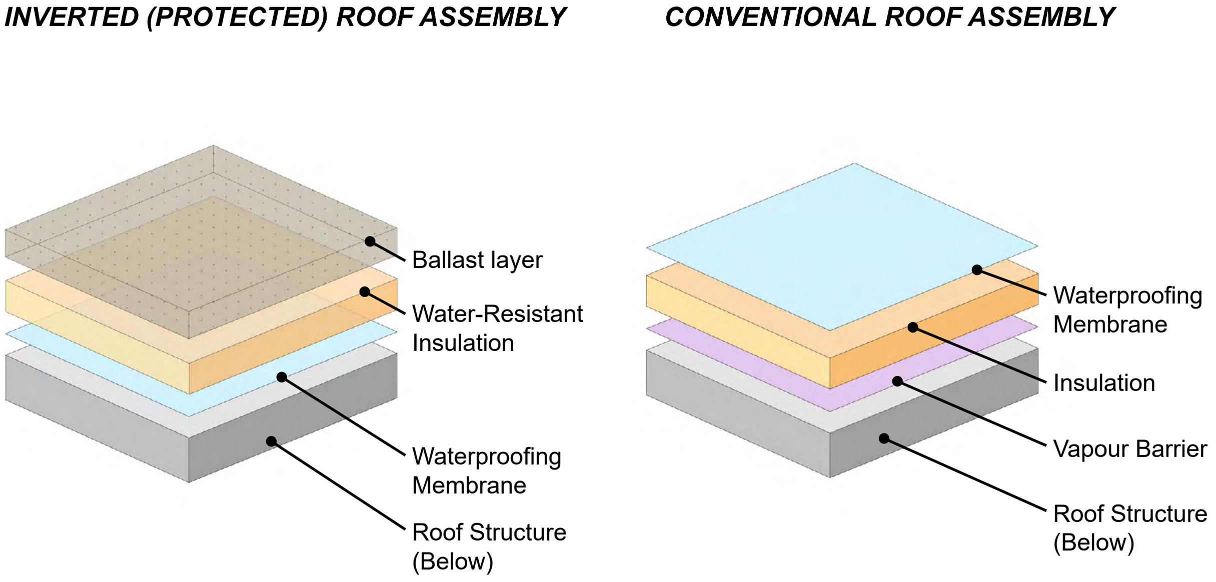


**Diagram simplified for legibility.*

Figure 2.3 - Comparison of roof assembly types

2.7.6 Roof Assembly: A Closer Look at Green Roof Layers

This section provides a closer look at the various layers that comprise a green roof assembly. The illustration shows the typical layer arrangement for a Protected Membrane Roof Assembly.

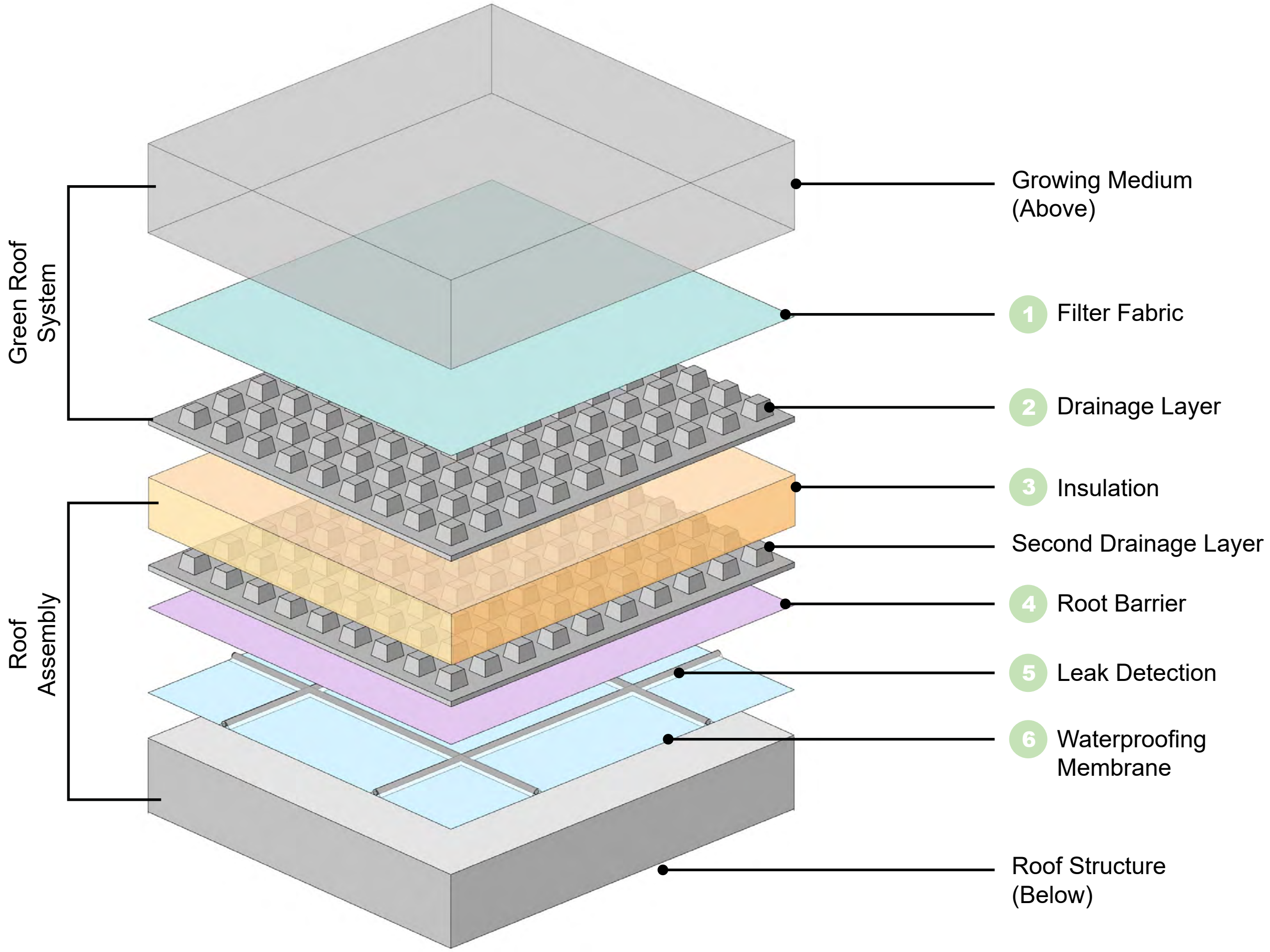


Figure 2.4 - Example of green roof build-up supported by a protected roof assembly

1 **Filter fabric** – Filter fabric separates the growing medium from the drainage layer (mat). **It is designed to retain the growing medium while also permitting water flow**. When selecting a filter fabric product, some considerations include:

- **Types of synthetic filter fabrics**: Synthetic filter fabrics can either be woven or non-woven. Woven filter fabrics have a high tensile strength, while non-woven filter fabrics provide superior filtering properties. Non-woven synthetic filter fabrics generally have the desired characteristics for most green roof designs.
- **Key characteristics**: When selecting a filter fabric or geotextile, consider tensile strength, puncture resistance, UV resistance, permeability (or flow rate of water), toxicity, fire resistance, and moisture retention.
- **Sediment buildup protection**: Locating growing medium above a filter fabric layer helps prevent sediment buildup in the roof drains. Note that some drain mat products come with an integrated filter fabric.

② **Drainage Layer** – An aggregate layer, drain mat or drainage board **facilitates drainage of rainwater within the green roof assembly**. Drainage boards can be located above, below, or above and below the insulation, depending on the project's design parameters. Some drain mat products include a filter fabric. When selecting a drain mat product, some considerations include:

- **Compressive strength**: This refers to the material's ability to withstand pressure without being crushed, measured in pounds per square inch (psi) or kilopascals (kPa). The drain mat chosen must be able to resist the design load from the overburden, including the weight of the growing medium, vegetation, and maintenance activities.
- **Water absorption rate**: This refers to how quickly water can pass through the drainage layer. The product should allow sufficient water movement to prevent pooling or waterlogging, especially during heavy rainfall.

③ **Thermal Insulation** – Closed cell insulation **offers thermal resistance for the roof assembly** and can **protect the membrane** in a PMR or inverted roof system. Additionally, the insulation layer can facilitate drainage if the product is grooved on the underside.

Extruded polystyrene (XPS) is typically used for insulation in PMR systems due to its effective thermal performance. XPS is a closed cell insulation material, giving it a high resistance to water absorption in comparison to other types of insulation commonly used in construction. When selecting an XPS product, some considerations include:

- **Compressive strength**: XPS comes in a wide range of compressive strengths depending on the project's requirements. Specifying the correct compressive strength is essential to help ensure that the insulation can support the applied loads (i.e., soil, vegetation, snow loads, any expected foot traffic, and others) of the green roof system above.
- **Insulation performance**: This is a measure of thermal resistance per unit thickness (RSI per mm). The selected product should have adequate RSI to meet the building's energy efficiency and thermal protection requirements.
- **Water absorption rate**: This is required to maintain insulation performance and prevent degradation in wet conditions. Lower absorption rates can help maintain insulation performance and prevent degradation in wet conditions.

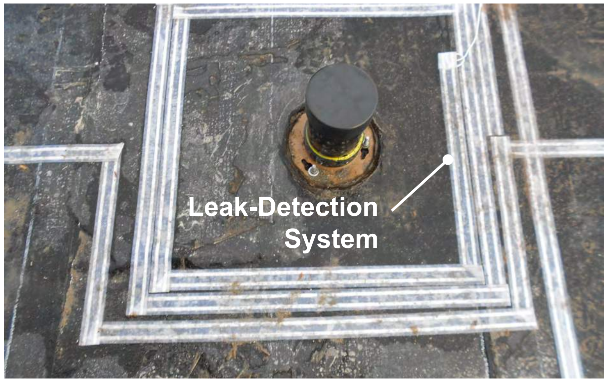
4 **Root barrier** – Root barriers are designed to **prevent plant roots from accessing materials or areas where they could cause damage**. When selecting a root barrier product, some considerations include:

- **Durability**: The ability of a material to resist tearing, puncturing, and degradation over time. A durable barrier helps ensure long-term protection against aggressive root systems and physical damage to other layers.
- **UV resistance**: The ability of the material to withstand exposure to UV light without degrading. UV resistant barriers should be considered if the material will be regularly exposed to sunlight.
- **Thickness**: The physical depth of the barrier material, which contributes to its strength and resistance to penetration. Thicker barriers generally offer better protection against root intrusion.

5 **Leak Detection System** – An electronic leak detection (ELD) system is a permanent installation that can be used to **detect the exact location of a failure or breach in a waterproofing membrane**. A traditional ELD system consists of a grid of copper tape with sensors or technologies that use high or low voltage to detect leaks or breaches in the roof membrane.

Waterproof membrane issues are typically identified by observing water ingress within the building itself. If ELD systems are not installed, it may be necessary to remove significant sections of the green roof before the problem is uncovered.

By helping to determine the location of the leak, ELD systems minimize the amount of removal (and cost) necessary to confirm and resolve the issue. **It is recommended that all green roofs include an ELD system**.



When selecting a leak detection system, some considerations include:

- **Compatibility**: ELD systems will not be effective on conventionally insulated roofs and EPDM membranes due to electrical conductivity issues.
- **Response time**: The effectiveness of the system depends on the monitoring method and speed of repairs once a leak is detected.
- **Location in the roof assembly:** Exactly where the ELD system fits within the roof assembly—above or below the membrane—can vary according to the manufacturer and the technology used.

⑥ **Membrane** – The waterproofing membrane makes up an important element in the roof assembly as it **protects the building's structure from moisture ingress**, which could result in structural damage, or mold growth. Membranes can be categorized into three general groups:

- **Single ply;**
- **Two ply; and**
- **Hot rubberized asphalt**

The single ply membrane option can be more budget-friendly but lacks layer redundancy and is therefore at higher risk of being damaged by construction-related activities. Two ply membranes and hot rubberized asphalt are typically the most durable choices for green roofs.

Nevertheless, single ply membranes may still be a good solution for blue roof systems that use an additional waterproofing liner separate from the roof assembly membrane. The choice of membrane for a roof assembly and green roof system should be based on the specific project needs and determined by a specialist.

CHARACTERISTICS OF A MEMBRANE

There are numerous membranes available, but the choice of product suitable for a specific green roof system will depend on the following factors:

- **Thickness of the membrane**
- **Type of reinforcement used**
- **Tensile strength**
- **Puncture resistance**
- **Dimensional stability**
- **Expected service life**

MEMBRANES ON BLUE ROOFS

When the design involves a blue or blue-green roof, it is strongly recommended to not just rely on the primary membrane of the building envelope for water containment. Best practice includes **providing redundancy by incorporating a secondary containment layer** for water retention.

INTEGRITY SCANS

When using a protected membrane system, it is recommended that, prior to installing the green roof components, an integrity scan be conducted on the waterproofing membrane to ensure integrity. These scans use an electrical current to detect breaches that need to be repaired prior to concealing the membrane. Note that integrity scans are not effective on conventionally insulated assemblies and EPDM membranes.

2.7.7 Penetrations into the Membrane

A roof penetration is any object that passes through a roof's surface. Penetrations are typically required for plumbing, heating, ventilation, and other services that require rooftop access. Examples include chimneys, skylights, plumbing pipes, air conditioning units, and exhaust vents.

Penetrations through the waterproofing membrane create edges that act as potential weak points and are more susceptible to leakage. Penetrations therefore require careful detailing and execution to ensure longevity. Where penetrations are unavoidable, a roofing design specialist should be consulted to develop site-specific solutions that can be reliably waterproofed.

When planning for roof penetrations, some considerations include:

- **Minimize penetrations**: **The roofing design should ensure that penetrations are minimized, adequately spaced, and properly flashed or sealed into the waterproofing layer**.
- **Access to penetrations**: it is important to **install buffers that inhibit vegetation and enable access for inspecting and servicing penetrations, especially drains.** Examples include paving or river rock strips placed between the green roof growing medium and the penetrations.
- **Planter walls and mechanical supports**: Design "pre-curbs" or "starter curbs" that can be completely encapsulated by the roofing membrane.
- **Accessible rooftops**: Guardrails or safety barriers should be anchored to perimeter walls, ideally on the vertical plane and above the waterproofing membrane to help avoid penetrations. If a barrier is proposed on the inside of a roof perimeter, it should be secured using non-structural methods or anchored to a raised structural element, such as a starter curb.

EXAMPLES OF ROOF MEMBRANE PENETRATIONS

The following list describes examples of roof design components that may require penetrations into the roof membrane. These examples are illustrated in ***Figure 2.5***.

1. Gravel maintenance layer
2. Roof drain access/enclosure
3. Roof drain
4. Edger for containing green roof system
5. Growing medium
6. Drainage layer (with filter fabric above)
7. Insulation (with root barrier below)
8. Roof structure and membrane
9. Starter curb
10. Raised bed planter
11. Accessible paving
12. Building parapet wall
13. Pre-finished metal flashing
14. Guardrail
15. Permanent rooftop equipment (e.g. lighting mast)

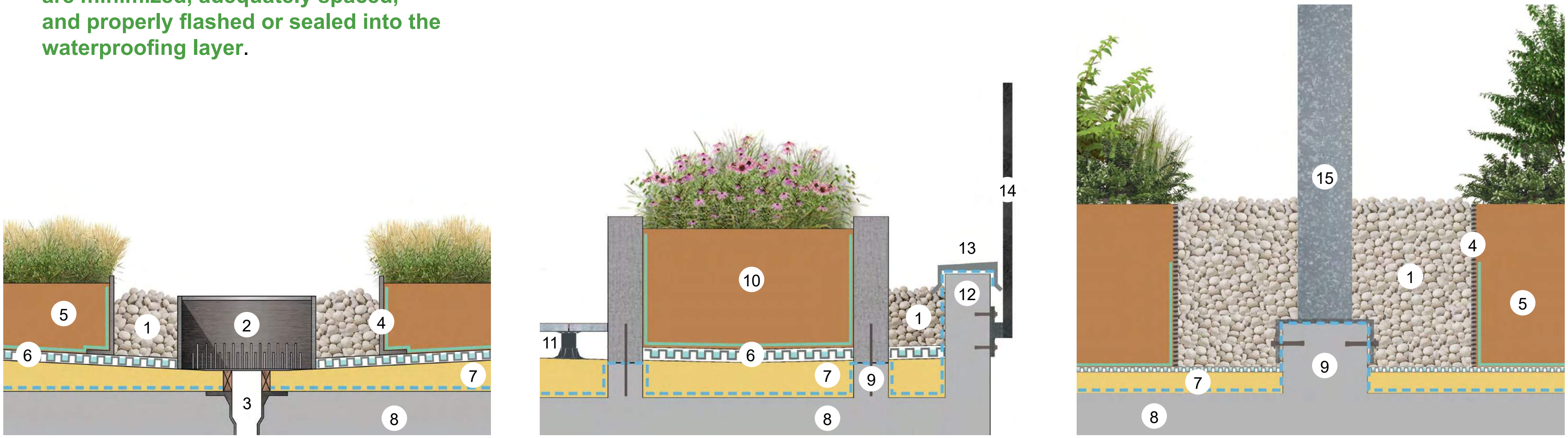


Figure 2.5 - Example details of roof membrane penetrations

2.7.8 Roof Assembly Considerations for Retrofits

Green roof retrofits involve the installation of a green roof on an existing building or structure. When undertaking a retrofit project, some considerations include:

- **Compatibility of existing roof**: The original roof structure and other related design aspects may not include many of the requirements for accommodating a green roof.
- **Roof assembly service life**: Service life is the period during which a product or system is expected to be functional. Green roof assemblies are typically designed for a relatively longer service life to allow vegetation to mature. To optimize service life alignment, green roof retrofitting should ideally be undertaken at the end of the existing roof assembly's service life. Therefore, a green roof is best installed as part of the scheduled replacement of the existing roof system.
- **Membrane evaluation**: **A thorough evaluation of the roof membrane, including age and condition, should be conducted** to determine its suitability for green roof installation.
- **Guarantors of the roofing**: Either a third-party insurer or the manufacturer warranty should be consulted to understand how these coverages may be impacted by the installation of a green roof on the existing building. Specific qualifications of a green roof product or design may be required to comply with warranty or guarantee requirements specific to green roof systems (see ***Chapter 5: Warranty and Managing Liability***).

2.8 ON-SITE DRAINAGE AND RAINWATER MANAGEMENT

2.8.1 About this Section

Strategies for managing rainwater on a property will vary depending on the requirements of the local jurisdiction. If a green roof is used to help satisfy these requirements, two issues should be addressed: **green roof drainage** and green roof **contributions to onsite rainwater management**.

All green roof systems must be designed to safely drain the rainwater that falls on their surface to avoid prolonged periods of saturation in the growing medium and the potential for standing water, which exerts a load on the waterproof membrane and supporting structure *(see* ***Section 2.6 Structural Considerations*** *for more information)*.

Standing water can also increase the potential for water ingress issues unless accounted for in the design. Consequently, the **growing medium in a green roof system must be well-draining** to prevent saturation during extended periods of rain and avoid ponding or storage of water above the base of the growing medium (see ***Section 2.9 Growing Medium Selection*** for more information).

A green roof can also be designed to contribute to the property's **rainwater management plan**, which may include objectives such as **recharging local aquifers** by infiltrating more rainwater into the ground, or releasing the same or smaller volume of rainwater at a slower rate into the downstream sewer system, thereby **helping to extend sewer capacity and postpone costly pipe upgrades**.

Generally, a green roof project can help address both potential objectives by **retaining** and **detaining** rainwater by itself or in conjunction with other rainwater tools such as detention tanks and ground infiltration systems like raingardens.

What is Included: This section discusses some design considerations when using a green roof to meet a hypothetical onsite rainwater management detention volume target. Topics include understanding key factors that affect rainwater management, determining the catchment area, calculating the required green roof size and growing medium depth, and selecting the appropriate hydraulic components to achieve the desired benefits.

RAINWATER MANAGEMENT REQUIREMENTS

On-site rainwater management requirements for private property in the City of Vancouver are described in The **City of Vancouver Building Bylaw (VBBL), Book II (Plumbing Systems), Division B, Section 2.4.2.5**. The design example in this section demonstrates the potential of a green roof to contribute to onsite rainwater management. **It should not be assumed to satisfy requirements in VBBL Section 2.4.2.5.**

2.8.2 Factors that Affect Rainwater Management

A green roof's ability to manage rainwater is accomplished through the two processes of detention and retention.

- **Detention**: the temporary storage and controlled release of excess rainwater onsite to prevent flooding and reduce the associated impact on downstream areas. Detention may be achieved with green roof drainage layers including mats, aggregates, and crate-type structures, blue-green roof shallow water reservoirs, detention basins, or tanks. While the growing medium layer can slow the discharge of rainfall from a roof, it should not be designed to store water. **Detention practices slow down but do not reduce the volume of water leaving a site and entering a sewer system**.
- **Retention**: The temporary storage and use of rainwater on-site. Retention may be achieved with trees, plants, and other GRI such as green roofs (evaporation, transpiration), retention ponds (evaporation, ground infiltration) and cisterns (reuse). **Retention practices reduce the volume of water leaving a site and entering a sewer system**.

Detention and retention processes in a green roof are largely influenced by three factors:

1. Water interception and uptake by plants
2. Composition and depth of growing medium and drainage layers
3. Seasonal precipitation levels

1. Water Interception and Uptake by Plants

Different species of plants selected for a green roof will have **different watering needs, evapotranspiration levels** (which is the combined process of evaporation and transpiration), and rainwater runoff reduction potential.

- **Evaporation**: The process that changes water from a liquid to a gas (vapour). It typically occurs from water accumulated on plant surfaces and growing medium surfaces.
- **Transpiration**: The process where plants take up liquid water from the growing medium and release water vapour from their leaves.

Plants with higher water needs, such as sword ferns (*Polystichum munitum*), will absorb more water from the growing medium and reduce more annual rainfall runoff. This benefit must be balanced with the need for more irrigation during the dry months of the year. Conversely, plants with lower water needs, such as Sedum species, will absorb less water from the growing medium and reduce less annual rainfall runoff. Relatively less irrigation is needed during the dry months of the year.[28]

One study estimates that a green roof in Vancouver that uses plants with ‘low water’ requirements and a growing medium depth of 150 mm could potentially reduce annual rooftop rainwater runoff by approximately 29%. A green roof using plants with ‘high water’ needs and a growing medium depth of 150 mm could potentially reduce annual rainwater runoff by 58%.[28] Again, note that the larger annual runoff benefit obtained from plants with high water needs also typically requires more irrigation in the summer months.

2. Composition and Depth of Growing Medium and Drainage Layers

A deeper growing medium will provide **greater water storage capacity** and therefore a greater potential to detain and retain rainwater.

The **coarseness of the growing medium** and the ratio and **composition of organic matter and mineral materials** will also affect the amount of rainwater runoff detained and retained by a green roof (see ***Section 2.9.4 Water Storage Capacity and Drainage*** for more information).

The drainage and storage layer below the growing medium can be composed of matting material, aggregate such as clean pea gravel, or a storage structure usually composed of a series of interlocking plastic crate structures. The drainage and storage layer functions both to drain excess water out of the growing medium above it, so that the growing medium will not remain saturated, and to provide storage for detention of rainwater so that the rate of flow from the roof may be controlled to a lower rate.

3. Seasonal Precipitation Levels

In 2024, Vancouver received a total annual precipitation of approximately 1,359 mm, with approximately 64% of this volume occurring in the fall and winter months of October, November, December, and January.[29]

During these wetter and cooler months, the water storage capacity of the growing medium will be periodically exceeded and the plants will undertake less evapotranspiration and, therefore, absorb less water. Both circumstances will reduce green roof retention contributions. During the warmer and drier summer months, there will be greater plant demand for water and higher rates of evapotranspiration. However, the storage in the drainage layer will be as functional as during the drier season. Therefore, the detention capacity of the roof will function through the wet winter season if the green roof is designed to provide detention.

Although there are seasonal design considerations, the **overall annual performance of green roofs can still make a meaningful contribution to onsite rainwater management objectives.**[28]

2.8.3 Green Roof Catchment Area

A green roof typically captures and manages rainwater that falls directly onto its surface. **A green roof can also be designed to receive rainwater runoff from other adjacent or non-adjacent areas of the roof or site**. The green roof rainwater catchment area therefore includes **both the green roof area and other contributing areas** that may be collecting and directing rainwater to the green roof. If other contributing areas are involved, some considerations include:

- The directed runoff should pass through a settling sump, which will help settle and remove particles, prior to discharge onto the green roof.
- To help ensure a desired level of performance (capture and detention), additional growing medium or drainage and storage layer depths may be required to accommodate runoff from the other contributing areas.
- Although the design requirements of a green roof will be determined by qualified professionals, the additional catchment areas draining onto the green roof should typically be no more than the area of the receiving green roof. In other words, the green roof can manage water that falls on a total area of up to twice its area.

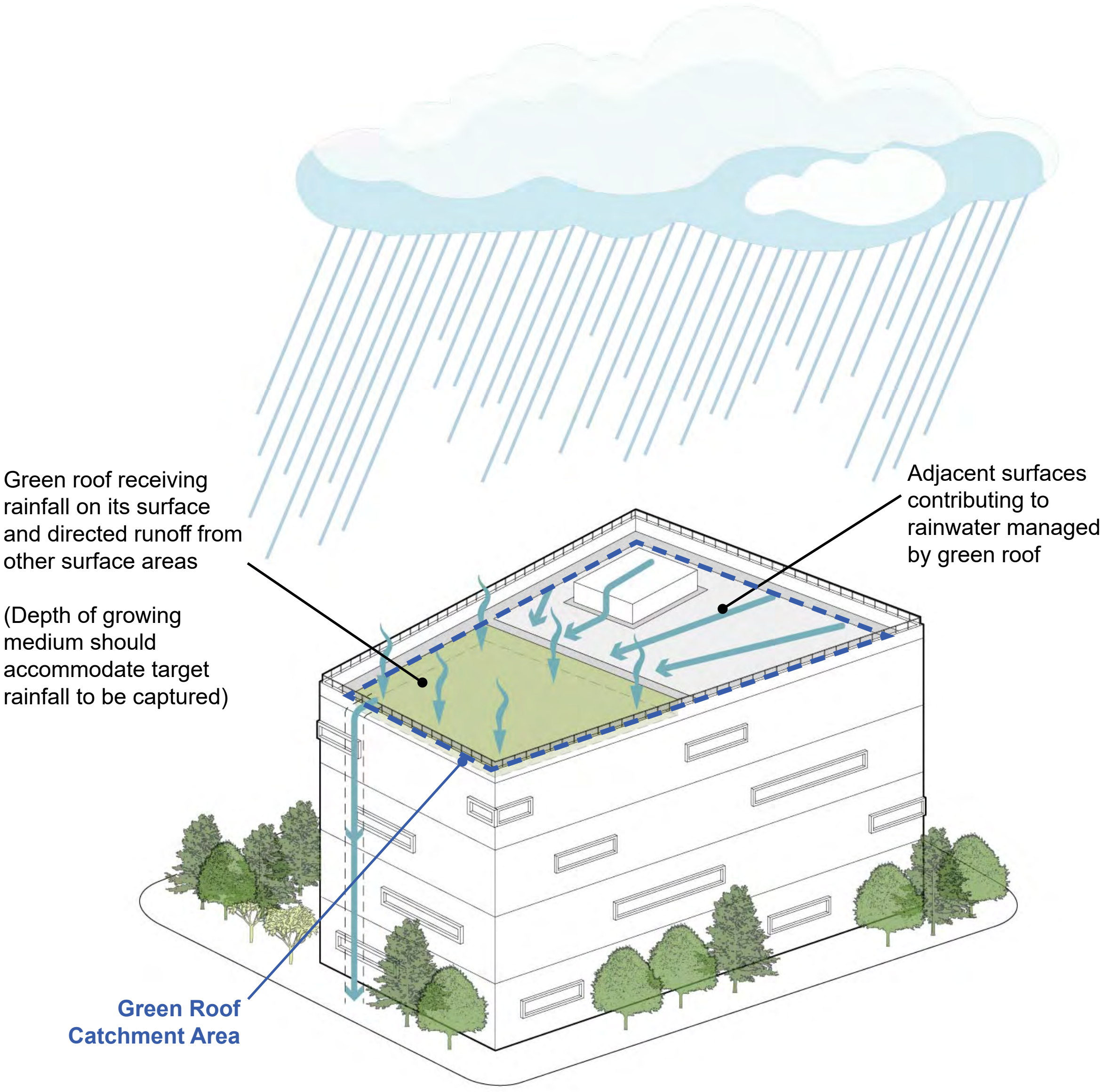


Figure 2.6 - Example of a green roof catchment area

2.8.4 Calculating Growing Medium Depth for Rainwater Capture

Rainwater falls directly onto the entire surface area of a green roof. A portion of this rainwater is retained by the growing medium and vegetation, which perform evaporation and transpiration. The green roof growing medium depth can then be calculated based on the properties of the growing medium and on the desired rainfall depth to be managed.

Rainwater management systems for a site can also be comprised of multiple tools (i.e. rainwater source controls) such as detention tanks and ground infiltration systems like raingardens. Given that green roofs are one part of a rainwater management system for a site, **the multiple source controls used in a project should be modeled together** to determine the overall system performance.

The following formula calculates the required growing medium depth necessary to manage a specified amount of rainfall.

$$Ds = \frac{R}{WHC}$$

Where:
Ds = Depth (thickness) of growing medium (mm)
R = Rainfall capture depth (mm)
WHC = Water holding capacity of the growing medium (unitless)

**Values should be calculated by engineering consultant*

More detailed steps breaking down the components of the formula are provided in the information box to the right.

STEPS FOR CALCULATING GROWING MEDIUM DEPTH FOR RAINWATER CAPTURE

1. State the targeted (desired) amount of Rainfall (R), in mm, to be captured and managed by the green roof. For example, “manage the first 24 mm of rain to fall in a 24-hour period”.
2. Lookup or calculate the Water Holding Capacity (WHC) of the growing medium.
    - Water Holding Capacity (WHC) is the moisture content that a growing medium can hold between Field Capacity and Permanent Wilting Point.
    - WHC = FC – PWP, where:
    - Field capacity (FC) is the growing medium moisture content that remains after free water has drained away; and
    - Permanent Wilting Point (PWP) is the growing medium moisture content, below which a plant can no longer extract water.
    - The WHC of the growing medium may also be obtained from a product manufacturer or supplier if using a proprietary growing medium product.
3. Calculate the growing medium depth (Ds), in mm, required to manage the targeted amount of rainfall.
    - If Ds is less than 150 mm, default to a minimum of 150 mm to reflect values required to accommodate typical root depths. This default may potentially be waived if the planting plan only includes shallow-rooted plants (e.g. Sedums) that are anticipated to survive in such conditions.
    - If Ds is greater than 600 mm, verify that these larger (and heavier) growing medium and water depths can be accommodated by the roof structure and are still consistent with the objectives of the planting plan, overall project, and budget.
4. If Ds exceeds structural or other design constraints of the supporting rooftop, then either the constraints should be addressed, or Ds be limited accordingly. In this latter case, any rainwater that cannot be managed by the green roof should be managed by other means, such as directing overflow to another source control such as an infiltration rock trench in the ground.
5. Larger rainwater volumes can also be captured using an additional water storage layer under the growing medium and filter fabric, provided the additional layer can be accommodated by the supporting roof structure.

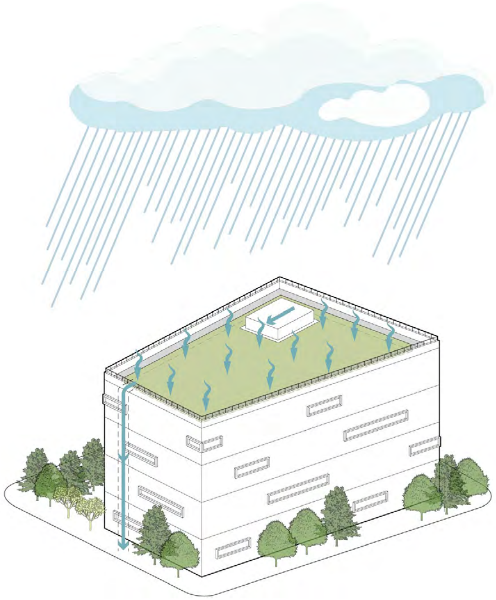
2.8.5 Varying Green Roof Area and Growing Medium Depth

The volume of rainwater managed by a green roof is a function of the growing medium depth, the area of the roof that will be covered by vegetation, and whether or not rainwater from adjacent surfaces is directed to the green roof. The following page provides a series of scenarios that illustrate how the relationship between these three aspects of a green roof impact the volume of rainwater managed.

Assumptions: The water holding capacity (WHC) of the growing medium is constant for all scenarios and enables 150 mm of growing medium depth to retain 24 mm of rainfall.

Each scenario calculates the necessary growing medium depth for three different green roof areas, measured as percentage of rooftop: 100%, 50%, and 0% (i.e. no green roof).

Scenario 1 - Full Green Roof Coverage

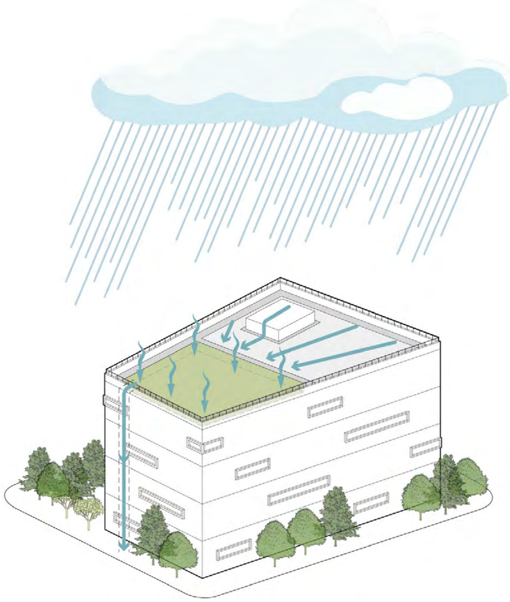


The green roof covers 100% of a building's rooftop with 150 mm of growing medium depth. The green roof could capture 100% of the first 24 mm of rain falling on itself, which also equates to 100% of the first 24 mm falling on the building rooftop.

Note that, in a real-world application, a green roof will never cover 100% of the rooftop because space must be provided for other functions, including rooftop mechanical equipment, maintenance strips, and other necessary non-vegetated surfaces.

Unless the rainwater captured on these non-vegetated areas is directed, as run-on, toward a green roof water storage or growing medium layer, these areas will not be managed by the green roof.

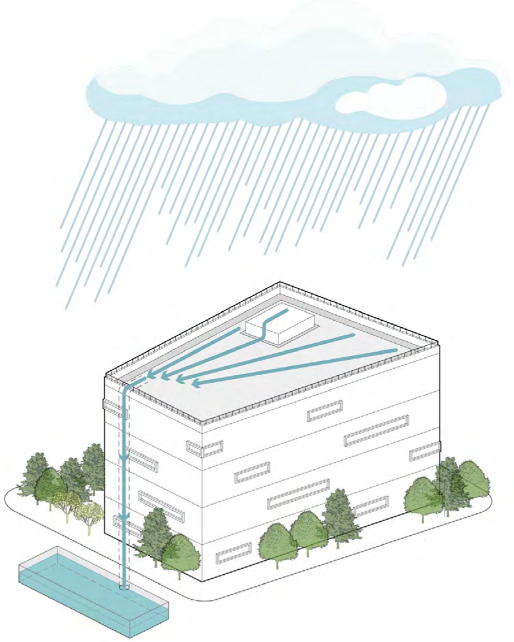
Scenario 2 - 50% Green Roof Coverage



The green roof covers 50% of a building's rooftop with 150 mm of growing medium depth. Given the assumed WHC value, the green roof could capture 100% of the first 24 mm of rain falling on itself, which equates to 50% of the first 24 mm of rain falling on the entire building rooftop.

If the rainwater from the non-vegetated, impermeable areas (e.g. the remaining 50% of the building rooftop) is also directed to the green roof (doubling the rainwater to be managed), then the growing medium depth could be similarly doubled to 300 mm, or paired with an additional water storage layer, to accommodate the additional volume, thereby achieving the same outcome as 'Scenario 1'.

Scenario 3 - No Green Roof



In a scenario with no green roof, 100% of the first 24 mm of rain falling on the building rooftop will need to be managed by other rainwater management systems (i.e. source controls), such as on-roof detention (blue roof), in-ground detention tanks and in-ground infiltration systems like raingardens.

2.8.6 Green Roof Hydraulic Components

A green roof uses various components to help ensure effective drainage and manage rainwater. The common components of a drainage system are listed below.

1. Underdrain or Drainage Layer

An underdrain or drainage layer is a drainage component installed under the growing medium layer to collect, store and transport water that drains through the growing medium. An underdrain is standard practice for green roofs to help prevent the growing medium from **becoming saturated and negatively impacting the plant roots**.

Water percolates down through the growing medium and retention layer. The drainage layer functions by collecting, storing and then conveying this water to the rooftop discharge points (drains).

When designed to provide adequate flow conveyance, this layer also relieves water pressure on the roof membrane, thereby **helping to reduce the likelihood of roof membrane leakage**.

2. Bi-Level Drain

A bi-level drain is a drainage component that collects water at two different elevations, generally at and below the surface. During extreme rainfall, the infiltration capacity of the growing medium may be overwhelmed, causing water to pond on the surface and then overflow off the green roof. A bi-level drain can be designed to help avoid any **excess water accumulating on the surface** of the green roof. The lower drain level is set to the bottom of the drainage layer if no storage in that layer is intended.

For a blue-green roof intending to detain a specified volume of water, the lower bi-level drain elevation should be set at the maximum ponding depth (e.g. overflow elevation), which is typically the top of the drainage and storage layer.

3. Roof Drain or Discharge Point

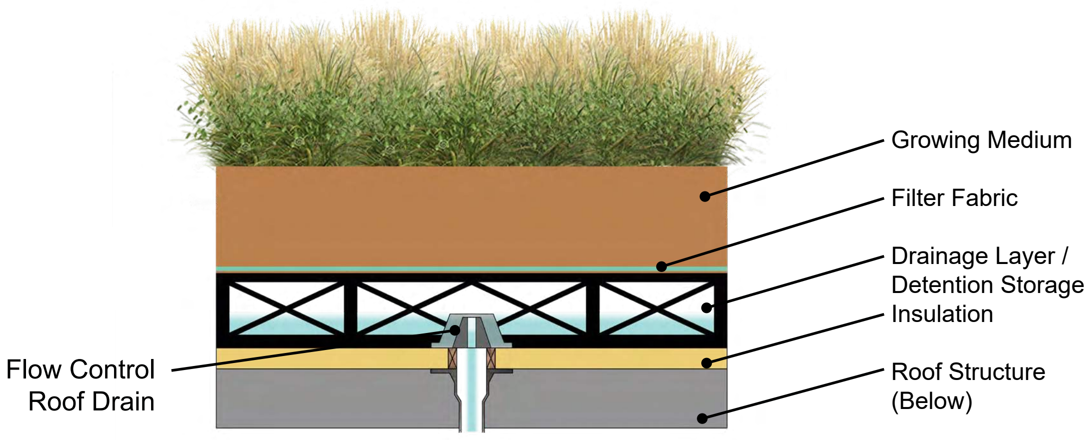
A discharge point, such as a roof drain or downspout, is a drainage component that receives water from other drainage systems on rooftops, such as underdrains and bi-level drains, and then **conveys that water off the rooftop to a detention tank or municipal storm sewer.**

Multiple discharge points are likely required to provide drainage across the roof because they provide redundancy in case of clogging. Additionally, roof drains must be accessible for periodic inspection and cleaning, ensuring compliance with **all relevant VBBL and other applicable requirements**.

FLOW-CONTROL DRAINS AND SMART DRAINS IN A DETENTION SYSTEM

On a green roof that includes a rainwater detention storage layer such as a reservoir, it is necessary to use a flow-control drain to manage the rate of flow out of the detention storage layer. This drain should be located at the bottom of the storage layer.

To optimize rainwater as a resource, **drains can be equipped and controlled with "smart" sensors** that will retain or release water based on weather patterns and rainwater management requirements. For example, water from a previous rain event that is being kept in the storage layer for plant irrigation purposes can be drained to accommodate rainwater volumes from a pending large storm event.



2.9 GROWING MEDIUM SELECTION

2.9.1 About this Section

The growing medium is an essential component of a green roof system because it **performs various functions** such as anchoring vegetative root structures, capturing and filtering rainwater, enabling drainage, providing nutrients, and holding water and oxygen in the spaces between soil particles. Unlike conventional topsoil, **growing medium is an engineered mix** typically composed of lightweight volcanic aggregates, organic matter, and sometimes sand.[27]

Growing medium should be selected to enhance overall longevity, maintain its compositional integrity over time, remain uncompacted, avoid becoming saturated ('water-logged'), be suitable for use on a roof assembly, and support the vegetation and other habitat features necessary to help sustain a desired level of social programming and biodiversity.[30]

Several characteristics should be reviewed when selecting the appropriate growing medium, including:

- **Weight** of the growing medium and **structural capacity** of the building.
- **Water storage capacity** and **permeability** of the growing medium.
- **Other characteristics**, such as organic content, acidity (pH), air content, salt content, granulometric (particle size) distribution, compaction, stratification, and fire characteristics.[27]

Consultation with a soil scientist or industry expert is recommended to help determine the most suitable growing medium mix (see ***Figure 2.7***).

What is Included: This section discusses design considerations for selecting an appropriate green roof growing medium, including mineral and organic content, sourcing local materials, weight and the building's structural capacity, balancing water storage capacity and permeability, biodiversity and habitat objectives, and maintenance considerations.

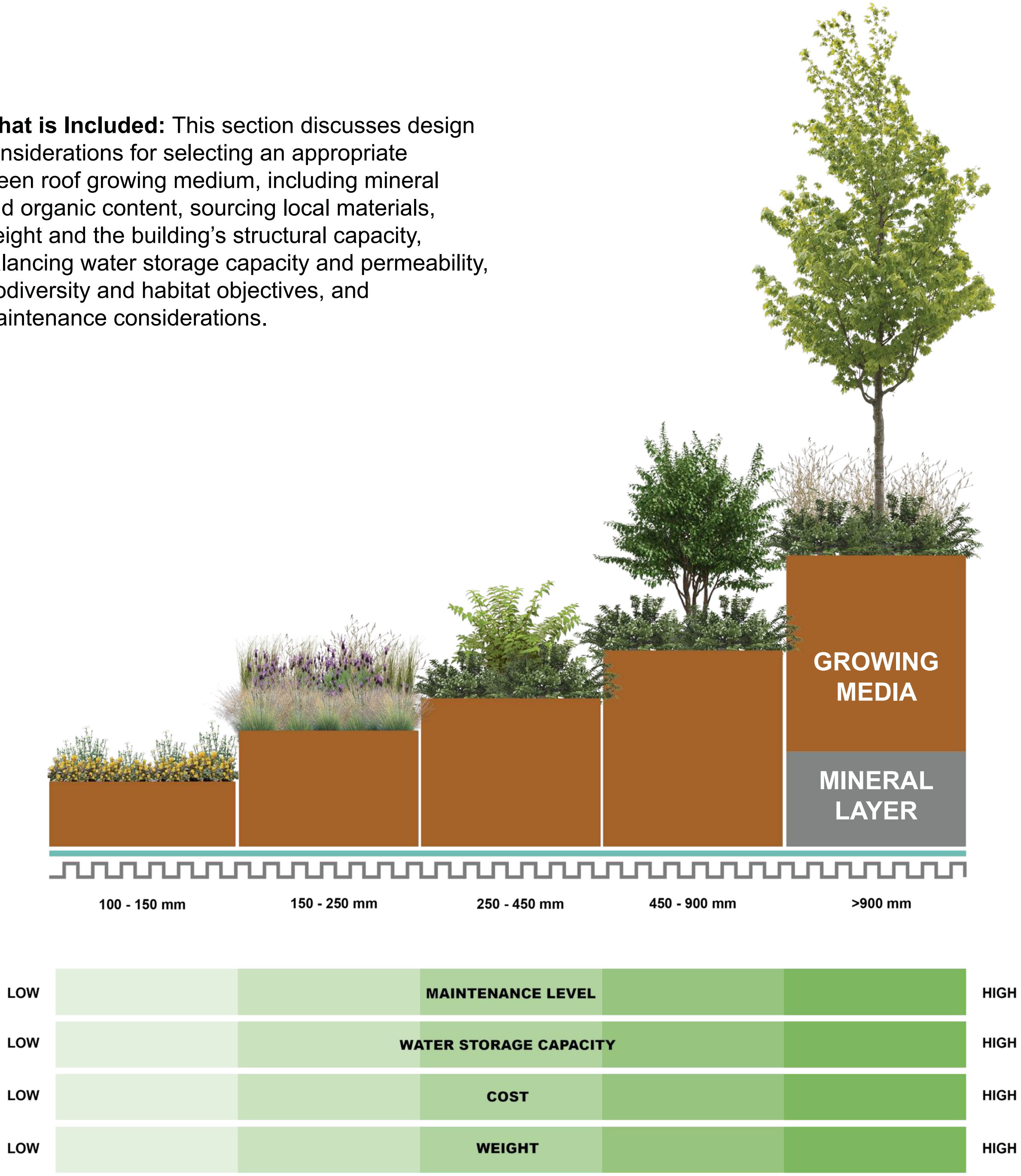


Figure 2.7 - Characteristics of various growing medium depths per Canadian Landscape Standards[31]

2.9.2 Growing Medium Composition

A green roof growing medium is composed of a **blend of inorganic (mineral) matter and organic matter**.

Inorganic (Mineral) Matter – Mineral matter is the **main component in a green roof growing medium**. Mineral matter can range in size from 0.5 mm (finer growing medium) up to 10 mm (coarser growing medium), with corresponding implications for infiltration, water storage capacity, and maintenance (see ***Figure 2.8***).

The percentage and size of these particles determines the **permeability** of the growing medium. Many minerals have a porous structure that improves drainage while also retaining water, thereby **supporting plant hydration**.

Some minerals also have structures that help **prevent compaction over time** and **maintain air content in the root zone**. This is crucial for plant health, as compaction can reduce aeration and hinder root development. It is recommended to have a variety of mineral sizes in a green roof.

Minerals come from a **variety of sources**, including volcanic rock, clay, and shale.

Organic Matter - Plants grow and maintain their structures by converting sunlight, atmospheric carbon dioxide, and nutrients from organic (carbon-based) and inorganic matter into other organic compounds. When the plant roots, stems, and leaves die, soil organisms such as bacteria and fungi decompose these and other dead organisms back into organic matter that can, once again, be used by plants. Organic matter is therefore used and created in a continuous cycle.

The growing medium design and specification should compensate for potential **longer-term organic matter depletion** by including reference to the initial recommended percent of organic matter and any need for ongoing fertilization.

Organic matter in the growing medium provides multiple important roles, including **supporting plant life** and contributing to **moisture retention and water storage capacity**.

Organic matter used in green roof growing medium may come from a **variety of sources**, including worm compost, aged pine bark, green waste, ripe produce, mushroom manure, biochar (i.e. carbon-rich charcoal), and coir (i.e., fiber from coconut husks). These ‘soil additives’ are decomposed, screened, blended, and tested to determine their **nutrient content**.

2.9.3 Weight and Structural Capacity

Growing medium varies in content, depth, weight, and the resulting load imposed upon a building. Given that a growing medium is typically the heaviest component of a green roof, especially when saturated with water, it is critical to ensure the growing medium weight is suited to the building’s structural capacity.

Although growing medium used in at-grade plantings is typically heavier than that used in green roofs, this type of medium can be used on all green roof types so long as adequate structural capacity is available and other design requirements are satisfied. This circumstance occurs primarily with intensive green roofs, which have relatively deeper growing medium depths. For semi-extensive and extensive green roofs, which have relatively shallow growing medium depths, a **lightweight growing medium is typically used** to further reduce the structural load and minimize the need for more robust structural design requirements.

A growing medium product can be specified, or a customized growing medium mix can be designed, for particular green roof conditions in collaboration with a qualified soil scientist and in coordination with structural and civil engineers.

2.9.4 Water Storage Capacity and Drainage

A green roof growing medium should be designed to **store and maintain adequate moisture levels** for vegetation, satisfy other desired design requirements such as reducing (retaining) and delaying (detaining) rainwater runoff, and also have **adequate permeability and drainage capability** to help avoid prolonged waterlogging, which can harm certain plants and increase the structural load on a building's roof.

A balance of these considerations is achieved by varying the organic matter content, which affects the water storage capacity, and the **mineral content**, which affects the permeability.

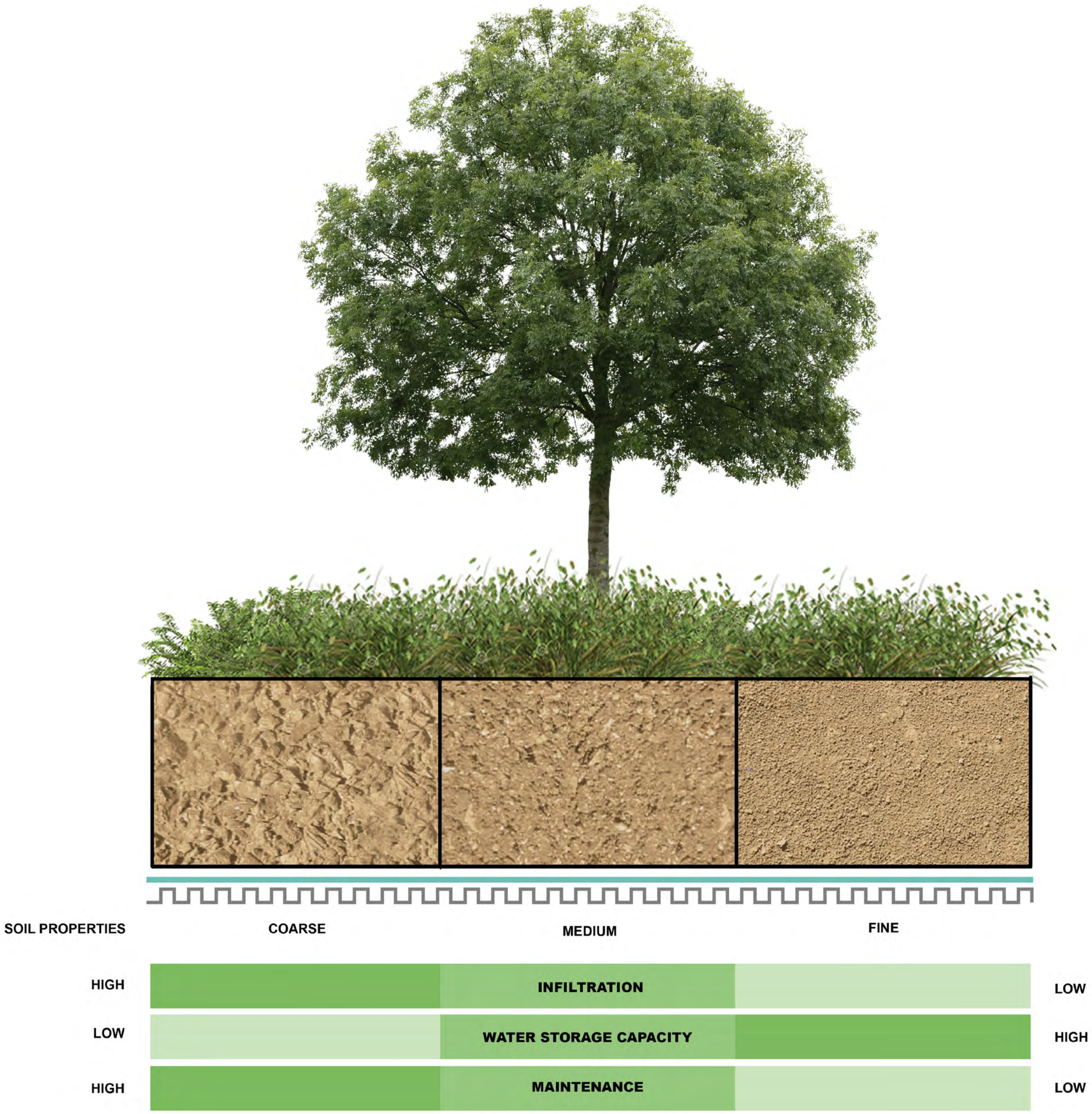


Figure 2.8 - Characteristics of various growing medium coarseness per Canadian Landscape Standards[31]

2.9.5 Growing Medium for Habitat and Biodiversity

Green roof growing medium should be designed to support the vegetation and other habitat features necessary to help sustain a desired level of biodiversity. For example, **diversifying the granule sizes or adding patches of different substrate types** (e.g., sand, gravel) can benefit organisms that need to bask in the sun, bury themselves, or build burrows for their offspring.

Designing for biodiversity may also involve establishing favorable conditions for various species by **adjusting growing medium thickness, utilizing natural and locally sourced materials, and creating topographic variations**. For example, mounds can create different microclimates and microhabitats within the same green roof area (see ***Appendix B: Habitat Enhancement Guide*** for more information).

2.9.6 Maintenance Considerations

A green roof's **growing medium is a complex, living layer requiring regular and ongoing maintenance**. It is recommended to **periodically test and measure the growing medium** components, especially nutrient levels, to enable ongoing readjustments to the maintenance regime.

FIGURE 2.9 - COMPARATIVE CHART OF GREEN ROOF TYPES

	Extensive	**Semi-Intensive**	**Intensive**
Suitable Plant Types	Sedum, Perennials, and Wild Flowers	Groundcovers, Shrubs, and Trees	Groundcovers, Shrubs, and Trees
Growing Media Thickness	Low/Medium Maintenance	High Maintenance	High Maintenance
Growing Media Approx. Weight	Low Up to 2.9 kPa	Varies	Heavy 5.7 kPa to >17 kPa

*Growing medium weight will vary according to product type, substrate depth, where products may be heavier than specified.

GROWING MEDIUM COMPOSITION BY GREEN ROOF TYPE

Extensive green roofs normally contain lightweight porous volcanic growing medium in a diverse range of granular sizes. These blends, as measured by percent of dry weight, are typically higher in mineral material (70 to 80%) and lower in both organic matter (5 to 10%) and sand (10 to 25%).

Intensive green roofs that support trees, shrubs, lawns, and rooftop gardens are typically composed of either lightweight porous volcanic growing medium or a traditional garden blend of river pump sand and compost.

Urban agriculture green roofs typically use a growing medium with a higher amount of organic matter to support the growth of vegetables, small fruits, and herbs.

LOCALLY SOURCED MINERAL MATERIALS

Green roof growing medium should source local material, where possible, to help advance environmental sustainability, support the regional economy, and potentially reduce costs.

For example, white pumice and red scoria are porous, lightweight volcanic rock that improve green roof performance by retaining moisture and nutrients, promoting strong root growth and aeration, and generally supporting plant health. Some sources for these rocks include the Pemberton and Quesnel areas and the Cascade Mountains.

2.10 IRRIGATION

2.10.1 About This Section

Effective irrigation is important for the **establishment, maintenance, and sustainability of green roof systems**. Irrigation requirements for green roofs depend on factors such as plant species selection and associated drought tolerance, growing medium and drainage layer depths, water retention capabilities, local rainfall frequencies and volumes, site exposure, and roof pitch.

Although a green roof can generally obtain most of its water needs throughout its life cycle from rainfall, **irrigation is particularly important for supplementing rainfall within the first growing season** to foster root establishment and vegetation growth. While a green roof usually needs less water once vegetation is established, **sustained periods of drought exceeding six weeks likely require supplemental irrigation to maintain plant health**.

Collaboration between landscape architects, green roof system suppliers, and irrigation consultants is advised to help ensure **irrigation strategies are suited to specific site conditions, vegetation requirements, and life cycle stages**.

What is Included: This section discusses key design considerations for various irrigation methods, including systems with **spray heads, drip lines, capillary mats, and hose bibs**, to meet the water needs of selected plants.

Image (above) - Spray head irrigation

Image (above) - Hose bib

Image (above) - Drip line irrigation

Image (above) - Capillary mat above drain board

2.10.2 Spray Heads

In contrast to irrigation systems with rotating sprinklers, this form of system **delivers water through piping to fixed (non-rotating), interchangeable nozzles (or 'spray heads')**. Spray heads are relatively affordable, easy to install, known for their reliability, and are typically preferred by maintenance crews because any **malfunctions are generally visible and more easily detected** compared to systems that may be partially or completely buried in the growing medium.

Spray heads are prone to **higher water loss** due to wind and evaporation and their effectiveness can be further compromised by **uneven water distribution**, resulting in some plants receiving more water than others.

When designing with spray heads, some considerations include:

- Ensure that the sprinkler system covers all planted areas while also remaining efficient with water usage.
- Inspect sprinkler heads regularly and adjust their positioning as plant growth changes.
- Regularly check for clogged nozzles or leaks.

2.10.3 Drip Lines

Drip line irrigation delivers water efficiently through a **network of perforated tubes** directly to the base of plants. These perforations (or "emitters") **release water slowly** to help ensure that water is absorbed into the soil around the plant's root zone, **minimizing erosion and water waste** from evaporation or runoff.

Drip line systems are **ideal for gardens, green roofs, and agricultural settings** because they provide consistent moisture while reducing overall water consumption. These systems are particularly **recommended when using non-potable water (reuse) systems to supplement irrigation**, as it can help prevent non-potable water from dispersing and potentially causing health concerns. Note that acceptable sources and applications of non-potable water are limited and defined in the **Vancouver Building By-law**.

Given that it can be more challenging to see partially or completely buried drip lines, extra care should be taken to avoid accidental damage from the misuse of gardening equipment or other improper maintenance practices.

When designing with drip lines, some considerations include:

- Periodically flush drip lines to prevent clogging and ensure consistent water flow.
- Regularly inspect connections and emitters for leaks or damage.

2.10.4 Hose Bibs for Manual Watering

A hose bib is a **faucet or spigot installed on the exterior of a building**. Hose bibs can be connected to garden hoses and provide convenient water access, which is helpful for general rooftop maintenance.

Given that irrigation is particularly important for supplementing rainfall within the first growing season to foster root establishment and vegetation growth, hose bibs are essential for enabling manual watering, which can be used in situations where an irrigation system is not provided or has failed. Hose bibs should **be installed as either a primary or backup water source**.

The use of manual watering requires the **enhanced care and attention of the maintenance operators** to ensure that irrigation strategies are suited to specific site conditions, vegetation requirements, and life cycle stages.

When designing with hose bibs, some considerations include:

- Ensure that the hose bibs are properly installed and equipped with appropriate attachments for irrigation purposes.
- Locate hose bibs within approximately 15.25 metres of the green roof to be irrigated. Determine any specified distances by consulting City of Vancouver and other applicable By-laws and policies accordingly.
- Periodically inspect the hose bibs for leaks and repair promptly to prevent water waste and related damage.

2.10.5 Capillary Action

Capillary mats are a **passive irrigation system designed to provide consistent moisture to plants in pots, planters, and green roofs**. The mats are made from absorbent material and are placed below the growing medium and above a water storage layer.

As the growing medium dries out, water is pulled up from the water storage layer, through the mat, and into the growing medium in a manner that avoids oversaturation and maintains consistent moisture for the green roof's root system.

In some applications, the storage layer function can be supplemented or even replaced by the mat itself, which can be made thicker to store higher volumes of water.

When designing with capillary mats, some considerations include:

- Ensure that the mats are in direct contact with the growing medium to allow even moisture distribution across the vegetation root system.

IRRIGATION ON A SLOPED ROOF

Green roof systems constructed on steeper slopes tend to dry out more quickly than those constructed on relatively flat slopes because the water retained in the growing medium drains at a faster rate, resulting in reduced water availability for plants. The impacts of roof slope should be considered and managed when setting automatic or manual irrigation schedules for a green roof.

WATERING RESTRICTIONS

Metro Vancouver's **Drinking Water Conservation Plan (DWCP)** manages the use of drinking water by establishing four stages of region-wide watering restrictions, which are followed and implemented by member municipalities.

Watering restrictions apply to various activities such as watering lawns, trees, shrubs, flowers, and vegetable gardens. Restrictions may be in effect depending on the time of year (Stage 1) and by assessment of Metro Vancouver (Stages 2-4). Stage 1 restrictions, for example, typically come into effect every year from May 1st to October 15th.

For more information, refer to t**he City of Vancouver website** and the **City of Vancouver Drinking Water Conservation By-Law**.

2.11 VEGETATION / HABITAT

2.11.1 About this Section

The components of a green roof should be designed to support desired social and environmental programming objectives while functioning within the opportunities and constraints of the surrounding natural and built environment. Plant selection plays an important role in supporting these objectives, especially those relating to aesthetic and other social functions, rainwater management, reducing the urban heat island effect, and enhancing biodiversity and habitat creation.

Performance is generally increased by **maximizing the variety of plant species and by using species that are naturally adapted to growing conditions found on an exposed rooftop** (see ***Appendix A: Recommended Green Roof Plant List*** for more information).

What is Included: This section discusses key considerations when selecting plants for a green roof, including site characteristics, installation methods, general programming and the role of plants, a closer look at aesthetics and biodiversity, growing medium depth, fire smart planting, irrigation, and maintenance requirements.

2.11.2 Site Characteristics

The green roof design process should address variations and considerations from the surrounding natural and build environment and from the site itself, such as proximity to adjacent buildings, roof orientation, roof slope, and growing medium depth. These considerations influence sun exposure, wind exposure, and other characteristics relevant to plant survival (see ***Section 2.5 Site Variations and Considerations*** for more information). It is important to ensure that the plant species chosen for a green roof have **traits that are compatible with, and adapted to, the site's climatic and associated characteristics**. Some considerations include:

- **Available moisture:** Select drought-tolerant plant species where precipitation, water storage, or irrigation is limited or inconsistent.
- **Sun exposure and shade**: Select plants suited to the roof's solar conditions, as sunlight affects growth and water needs.
- **Wind exposure**: Select wind-tolerant plants to help prevent physical damage in exposed areas.
- **Temperature and Hardiness** (cold and drought tolerance): Select plants that are compatible with rooftop microclimates and able to withstand associated seasonal temperature extremes.
- **Growing medium depth**: Match plant species to the available root space, especially when using growing medium that is relatively shallow (i.e., extensive green roof systems). Avoid using species that may outcompete neighbouring plants or species with aggressive root systems, especially when in close proximity to waterproof membranes.

2.11.3 Designing with Plant Installation Methods

Green roof design should consider the benefits and disadvantages of the various methods for installing, growing, and establishing vegetation, including: modular trays, mats, and built-in-place planting.

1. Pre-Grown Modular Trays

A modular tray is a **rigid container that holds the growing medium and pre-grown vegetation**. The trays can be placed directly onto a roof assembly and are typically designed with an interlocking feature such as a lip or other connector, which enables them to form a system by being clicked or hooked onto adjacent trays.

Benefits of pre-grown modular trays include system stability (connections minimize tray separation), resistance to wind uplift, and relative ease of installation and removal, which also enables the roof assembly to be serviced without disturbing plants. Disadvantages are related to the isolated nature of each tray, which can limit the growing medium depth, require individual watering, and hinder the ability of plants to propagate across the green roof .

2. Pre-Grown Mats

A mat is comprised of **vegetation that is pre-grown onto a thin substrate layer, which is then typically cut into rolls**. The mats are unrolled and installed directly onto either the green roof growing medium or a water retention fleece. Benefits of mats include relatively low cost, the ability to be cut to fit complex roof shapes, ease of installation, and plants being able to access more growing medium compared to trays, thereby enhancing overall health.

Other benefits and disadvantages depend on the method of installation. If installed onto the growing medium, the ease of removal declines, making it more difficult to access and service the underlying roof assembly. Conversely, if installed over a retention fleece and mineral wool layer, the vegetation can be easily rolled away to service the roof assembly, and then rolled back into place.

3. Built-in-Place

The 'built-in-place' method involves **planting seeds, cuttings (pieces of plants), and plugs (small units of young plants) in a previously installed green roof growing medium**. In contrast to modular trays and mats, built-in-place requires time for the seeds, cuttings, and plugs to establish themselves and grow after being planted. Establishment time, which is generally the longest with seeds and shortest with plugs, is reflected in the product cost of each approach.

Benefits of built-in-place relative to trays and mats include initial cost effectiveness, greater opportunities for biodiversity, and more personalized garden designs. Disadvantages include a longer plant establishment time and greater initial plant care. Intensive green roof systems typically use the built-in-place planting method.

2.11.4 Programming: General Considerations

Plant selection should support the intended green roof social and environmental programming objectives. Both desirable and undesirable plant traits should be identified early in the design process to help optimize general programming benefits while also preventing potential conflicts with programming or building envelope requirements. Some considerations include:

- **When programming includes human access to plants**, the plantings should be carefully selected to avoid poisonous species and help ensure human safety. Consideration should also be given to avoid allergenic species that may negatively affect an individual's experience of the amenity space.

- **When programming includes childcare spaces or child access to plants**, the plantings should be carefully selected to avoid poisonous or allergenic species and help ensure human safety. Resources such as the **City of Vancouver's Childcare Design Guidelines** can be consulted for a list of common toxic plants. Consideration should also be given to provide plants that offer visual and, ideally, interactive educational opportunities.

- **When programming includes designing a green roof as an ecological connector**, the plantings should be selected to maximize biodiversity and support habitat creation for insects and fauna (see ***Appendix A: Recommended Green Roof Plant List*** and ***Appendix B: Habitat Enhancement Guide*** for more information).

Example of Undesirable Plant - Digitalis purpurea: Digitalis purpurea or Foxglove, which is commonly found in the Pacific Northwest, contains some toxic compounds and is not recommended for use with accessible green roofs and childcare facilities.

Example of Desirable Plant - Fragaria chiloensis: A ground cover such a Fragaria chiloensis may be better suited to childcare settings as it is a native, non-toxic, low-growing plant that offers edible fruit, seasonal flowers, and hands-on sensory engagement, while being resilient and easy for children to observe and care for in Vancouver's climate.

2.11.5 Programming: A Closer Look at Aesthetics

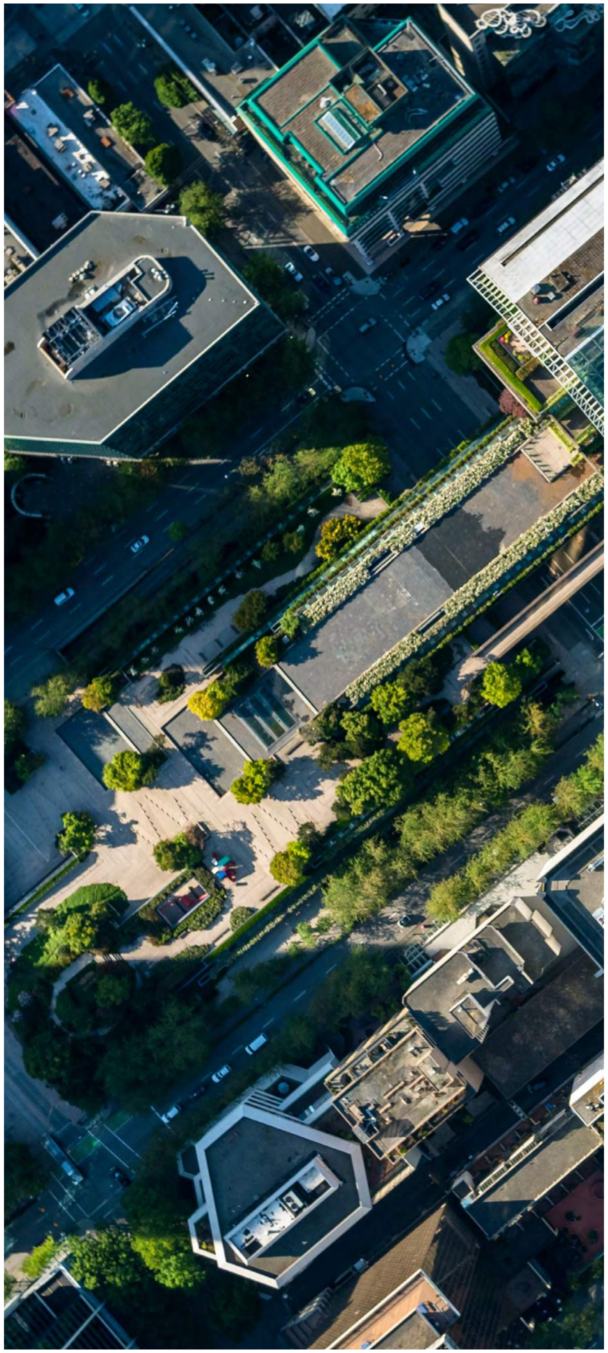
Aesthetics refer to a green roof's visual appeal, which is influenced by the surrounding natural and built environment, solar exposure, seasonality, and by onsite vegetative characteristics such as vegetation type, variety, placement, seasonality, interaction with hardscape elements, perceived functionality, and general visibility.

When designing for aesthetics, it is helpful to **consider two distinct plant growth phases: the plant establishment period and post-establishment period**. The establishment period duration is influenced by the choice of planting method. Whereas some methods use pre-grown mature plants, other methods use less attractive seeds or plugs (young plants), which take time to grow and establish themselves. Communicating to owners how aesthetics can be impacted by the choice of planting method will help manage project expectations.

Post-establishment period aesthetics are also influenced by the choice of planting methods, which vary in their flexibility regarding plant arrangements (see ***Section 2.11.3 Designing with Plant Installation Methods*** for more information).

The desired aesthetics are also influenced by the vegetative characteristics, interaction with hardscape elements, and desired functionality. When programming includes human access and use, some considerations include:

- **Utilize multi-functional vegetation such as plants and trees** that provide shade through dense foliage or broad canopies. These features can offer protection from the sun, help reduce noise from nearby traffic, and provide residents with a sense of privacy in high density urban environments. Properly selected plantings can therefore provide both desired functionality (shade, quiet, private) and contribute to green roof aesthetics.



2.11.6 Programming: A Closer Look at Biodiversity

Biodiversity is the variety and abundance of living organisms, including plants, animals, fungi, and microorganisms. Habitat and biodiversity are important because they provide the foundation for a healthy, habitable, and resilient environment that provides humans with spiritual experiences, food, and other benefits.

Enhancing biodiversity in a green roof design requires an understanding of the ecological value of both individual plant species and planting combinations, which include monocultures (the same species planted together) and polycultures (different species planted together). **Polycultures provide multiple benefits by creating habitat, differing bloom and fruiting periods, food sources, and ecological niches that support insects, pollinators, and birds.**

Greater biodiversity also contributes to enhanced ecosystem stability and resilience when confronted with various natural or human-induced disturbances such as drought. Differing blooming periods throughout the year also contribute to increased visual interest.

To support biodiversity and long-term resilience, it is beneficial to **favour polycultures by including a wide variety of plant types** such as succulents, bulbs, grasses, annuals, and perennials (see ***Appendix A: Recommended Green Roof Plant List*** and ***Appendix B: Habitat Enhancement Guide*** for more information).

2.11.7 Plant Selection and Growing Medium Depth

Root depth can vary significantly among different plant species. **Selecting species with root depths that do not exceed the available growing medium depth** helps ensure that plants have space for healthy root development, can anchor securely, access nutrients effectively, and better withstand environmental stresses such as drought.

Deeper-rooted plant species require a relatively deeper growing medium, which is typically associated with heavier, intensive green roof systems. In contrast, **shallow-rooted plant species** are suitable for use in a relatively shallow growing medium typically associated with extensive green roofs.

2.11.8 Fire Smart Planting

Plant selection, growing medium characteristics, and associated maintenance requirements should help minimize fire risk, which helps to protect both the structure and surrounding environment. Some considerations include:

- **Reduce fuel load by avoiding flammable materials**, where feasible.
- **Reduce fuel load by lowering the organic matter content in growing medium**, where feasible. Be aware that reductions in organic matter, which acts as a reservoir for essential nutrients, will also limit planting choices to the hardier species that can thrive in these environments.
- **Choose drought-tolerant plant species** that can retain moisture with minimal irrigation and remain alive, particularly during periods of drought or extreme heat.
- **Maintain plant species and a moist growing medium**, using irrigation, when necessary, particularly during periods of drought or extreme heat.
- **Integrate fire breaks**, such as gravel strips, paving slabs, or other suitable non-vegetated areas at appropriate intervals between plant zones to limit the spread of a fire.
- **Utilize proper waste disposal practices** to help prevent accidental ignition on or near green roofs. Depending on the specific programming needs and applicable bylaws, practices may include, as example, designated containers for cigarette butts and other flammable litter.

Image (above) - Example of a fire break created using granular materials to interrupt continuous vegetative cover on a roof, helping to reduce fire spread and improve overall rooftop fire resilience.

FIRE RISK PREVENTION GUIDELINES FOR LANDSCAPE DESIGN

A range of fire risk prevention guidelines for landscape design are available online, including the **FireSmart BC Landscaping Guide** and the **FLL guidelines**, both of which provide direction on plant selection, layout, and maintenance to reduce fire risk while supporting functional and resilient landscapes.[27,32]

Image (above) - Fire-resistant plant species, such as sedums, are well suited to fire-smart rooftop landscapes due to their ability to thrive with minimal irrigation while retaining moisture within their foliage, helping reduce ignition risk and support resilient planting design.

2.11.9 Irrigation

Different plant species have varying water requirements, which impact irrigation needs, associated maintenance, and project budget. Drought-tolerant species, which can thrive in an environment with little or no additional water from irrigation, are suitable for projects that have limited water access or that prefer a design that prioritizes low-maintenance. In contrast, species with higher water requirements will likely require a reliable irrigation system, and associated maintenance, to help support growth and long-term performance.

Plant selection must therefore consider and **reconcile both desired social and environmental programming needs** with the **potential for additional cost and maintenance of supporting irrigation systems**.

2.11.10 Plant Selection and Maintenance

Ongoing maintenance requirements can vary significantly among different plant species. Maintenance activities typically include routine care such as watering, fertilization, and pest control to support ongoing plant health. Maintenance can also include pruning, plant replacement, and regular removal of invasive species to help preserve green roof function and aesthetics. **Plant selection at the design stage should reflect anticipated available maintenance resources**.

Species with relatively lower maintenance needs are suitable for projects that prefer a design that prioritizes lower-maintenance effort. In contrast, species with higher maintenance needs will require higher levels of maintenance effort. Regardless of planting choices, it is critical to note that **all green roofs will require a minimum level of ongoing maintenance** to help ensure long-term performance.

Given the importance of ongoing maintenance, an **operations and maintenance plan** should also be developed during the design phase to guide inspection schedules, vegetation management, and drainage upkeep. The plan should include a list of installed species with associated care requirements such as irrigation needs, pruning frequency, and replacement timelines.
Plant selection must therefore consider and **reconcile both desired social and environmental programming needs** with the **cost and effort of anticipated maintenance needs.**

2.12 LIGHTING DESIGN

2.12.1 About this Section

Outdoor artificial lighting design can transform green roofs into inviting and dynamic nighttime spaces by **enhancing aesthetics, functionality, accessibility, and safety**. For example, thoughtfully designed lighting can help facilitate the use of social gathering spaces, create a pleasant ambiance, and highlight architectural and hardscape features.

Artificial lighting can also **negatively impact wildlife and certain plants** that are sensitive to natural light/dark cycles. For example, nighttime light pollution caused by artificial light sources can disrupt plant photosynthesis and growth, attract insects, and disorient migratory birds and bats.[33,34,35,36,37]

Therefore, it is important to **design green roof lighting to enhance aesthetics and other social programming needs while also minimizing impacts to wildlife and plants** (see **City of Vancouver Bird Friendly Design Guidelines** for more information). Collaboration among lighting consultants, landscape architects, and ecologists is essential to coordinate outdoor lighting design with both indoor light sources and green roof landscape design.

What is Included: This section discusses essential lighting design considerations for green roofs, including integrating lighting with architectural and hardscape features, reducing glare, selecting warmer colour temperatures, incorporating lighting timer controls, and minimizing light pollution where possible.

2.12.2 Integrate Lighting

Lighting fixtures should be incorporated and, ideally, physically **integrated into hardscape features**, such as pathways, patios, and retaining walls, to enhance aesthetics and functionality while minimizing light usage.

Low-profile lighting fixtures can efficiently illuminate edges, mark pathways and accessible areas, and help reduce light received by planted areas.

2.12.3 Warmer Colour Temperatures

Colour temperature, measured in kelvins (K), describes the tone of a light source. Lower temperatures are described as “warmer” and higher temperatures are described as “cooler”.

Avoid white and blue lights and use light sources with warmer colour temperatures (3000K or less), as these will better harmonize with the natural light that occurs during dusk and dawn, reduce brightness, limit light pollution, and minimize insect attraction.

2.12.4 Reduce Glare

Glare is typically produced by excessive brightness, contrast, or reflective light and negatively impacts humans, plants, and wildlife.

Where possible, reduce glare by carefully placing lighting fixtures and by **using fixtures, lenses, or diffusing covers that provide softer lighting**.

Image (above) - Intergrated pathway lighting

Image (above) - Range of lighting temperatures

Image (above) - Example of lighting glare

2.12.5 Minimize Light Pollution

“Light pollution” or “light spill” refers to the unintended spread or dispersion of light beyond the intended target area, which wastes energy, increases glare, and negative impacts humans, plants, and wildlife.

Minimize light pollution by **prioritizing low profile lighting fixtures**, keeping other necessary lighting less than 4m above the area to be illuminated, and selecting **shielded fixtures** to direct light downward onto intended surfaces, such as pathways and architectural features (refer to ***Figure 2.10***).

2.12.6 Lighting Timer Controls

Where possible, include a **timer or controller** to schedule lights to remain dimmed or inactive during periods of low visitor activity.

Figure 2.10 - Diagram of fixture shielding and impact on light spill

2.13 ACCESS AND SAFETY DESIGN

2.13.1 About this Section

Green roof design requires thoughtful consideration be given to access and safety to support both intended programming needs and ongoing rooftop maintenance requirements. **Access** must be planned early in the design process to ensure that rooftop occupants and maintenance personnel can move safely and efficiently throughout the space. **Safety features** are also essential to support rooftop access and include **passive systems**, such as guardrails, that offer continuous protection to all occupants, and **active systems**, such as fall arrest equipment, that are used by trained individuals.

Where human access is proposed, roofs must comply with all applicable requirements, including those relating to safety, accessibility, and building code (see **Vancouver Building By-law** for specific provisions).

What is Included: This section discusses design practices for rooftop safety and access, including considerations for both rooftop occupancy and maintenance needs. Topics include access routes, exits, and safety systems, including both passive and active fall protection measures. Any references to building code or other requirements are for general illustrative purposes only (see ***Section 1.1.5 Disclaimer*** for more information).

2.13.2 Rooftop Occupancy Access

Rooftop occupancy access refers to the provision of safe, code-compliant routes and exits for rooftops that are **intentionally designed for human use**, including amenity spaces, terraces, gardens, and other programmed spaces. Access requirements will vary depending on the size and intended function of the rooftop.

Generally, if a rooftop is designed to accommodate more than 60 occupants, at least two separate means of egress must be provided at different locations to help ensure that one exit remains accessible in an emergency. All exits must comply with the applicable design standards for exit stairs.

2.13.3 Rooftop Maintenance Access

Maintenance access should be planned as an integral part of the green roof design to ensure that operations and maintenance staff can safely and efficiently perform required tasks with minimal disruption to building occupants or rooftop users.

When designing for rooftop maintenance access, some considerations include:

- **Provide building access** through a common area or service corridor to reduce reliance on coordinating with building management, occupants, or strata.
- **Include, along access routes, passive and/or active safety systems**, such as guardrails, fall protection equipment, and other life safety measures, to help reduce the risk of injury during rooftop maintenance.
- **Integrate access points** such as stairs, ladders, or elevators into the design to help ensure safe and convenient roof access.
- **Design routes to accommodate transport of tools, equipment, and materials** typically required for operations and maintenance activities.
- **Ensure accessible paths of travel** with stable, firm, and slip-resistant surfaces where applicable.
- **Consider weather protection and adequate lighting** along access routes to support safe year-round maintenance.
- Ensure compliance with all applicable regulations for safety and access, including the **Vancouver Building By-law (VBBL)**.

2.13.4 Passive Safety Systems

Passive safety systems, such as guardrails and safety nets, are fixed features that offer continuous fall protection to all occupants without requiring specialized user knowledge or actions. **Guardrails are the most common and preferred form of passive fall protection**. They are typically required by building and safety codes for all accessible rooftops where there is a risk of falling.

In some cases, taller guardrails may be required. For example, rooftops with childcare facilities must have guardrails at least 2.4 metres (8 feet) in height, as these spaces are designed for active use and may include elevated play equipment (see **Vancouver Coastal Health - Design Resource for Child Care Facilities (2023)** for more information).

2.13.5 Active Safety Systems

Active fall protection measures, such as fall arrest equipment, require specialized user knowledge and engagement. These systems may involve wearing a full-body harness and connecting to designated anchor points. **They are typically used to supplement passive systems or when passive systems are not included in the rooftop design**, which occurs more frequently on green roofs intended for maintenance-only access.

In such cases, active measures like lifelines, travel restraint systems, or fixed anchor points should be incorporated to help ensure worker safety. These systems must be carefully integrated into the roof's design and consider factors such as roof layout, access points, and structural support.

ENSURING PROPER WASTE DISPOSAL

Proper waste disposal on a green roof is essential for protecting the environment and extending the roof's lifespan. **Litter and non-biodegradable materials can leach harmful chemicals into the growing medium**, impeding plant growth and damaging vegetation. These materials also pose risks to wildlife, as small animals and birds may ingest or become entangled in debris.

Cigarette butts are particularly hazardous due to their potential to cause fire damage, especially during dry periods when vegetation on green roofs can become flammable. Installing designated disposal bins in permitted smoking areas can help reduce this risk by providing a safe place for smokers to discard waste. In addition to preventing environmental harm, proper waste management helps ensure green roofs remain clean, functional, and safe over the long term, while supporting their aesthetic, ecological, and economic value.

CHAPTER 3
INSTALLATION

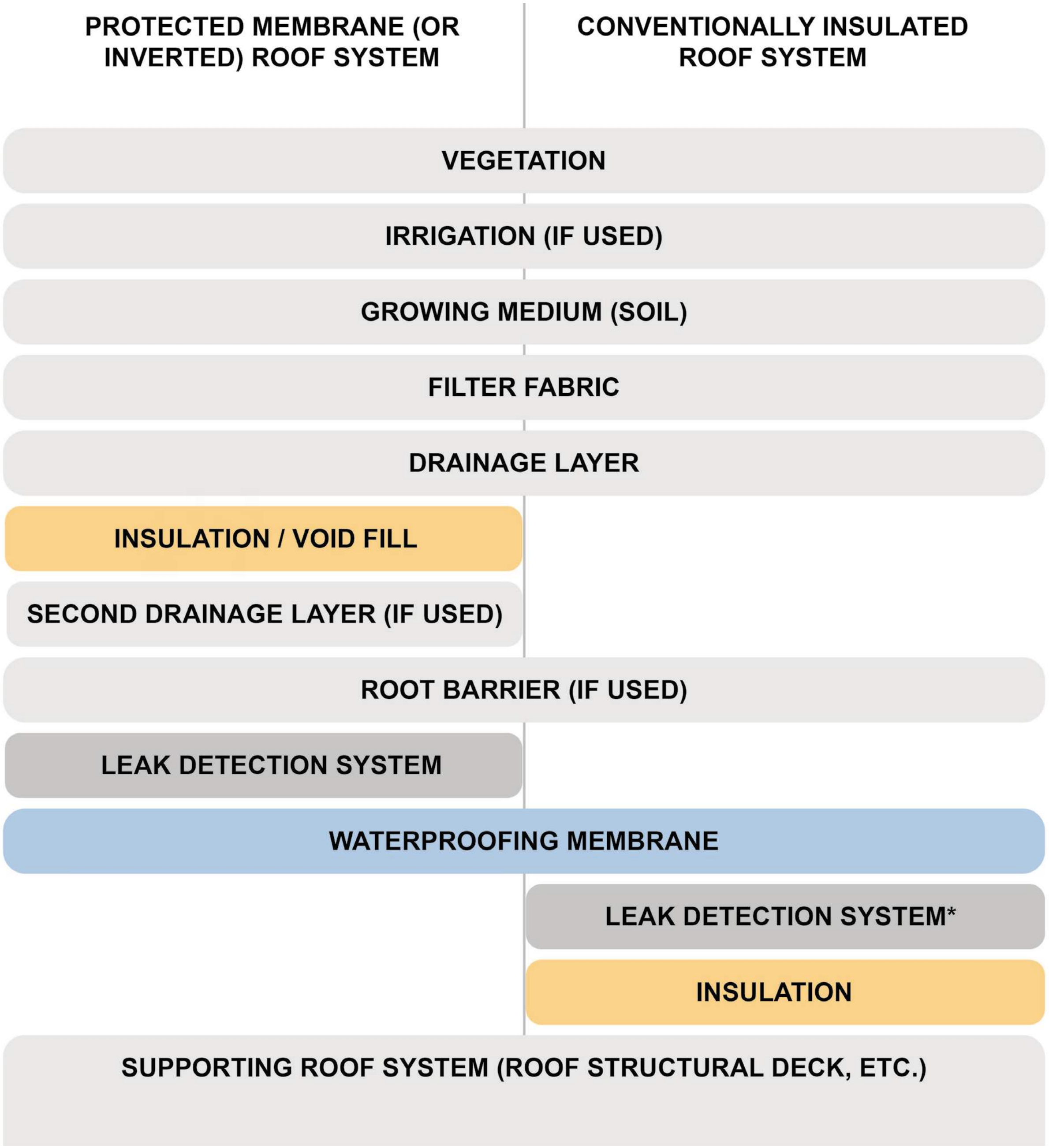
3.1 ABOUT THIS CHAPTER

3.1.1 Introduction

The installation of a green roof is an interdisciplinary effort that requires coordination and communication. Contractors and teams responsible for installing green roofs should be adequately trained and have appropriate professional and industry certifications to perform the work.

3.1.2 What is Included

This chapter discusses sequencing and scheduling when installing green roof components, coordinating with other trades, delivery and placement of materials, and protecting the roof membrane.



**Placement of leak detection in a conventionally insulated roof will vary depending on the system or product used.*

Figure 3.1 - Diagram of green roof layers by roof system type

3.2 COMPONENT INSTALLATION

3.2.1 General Installation Considerations

The **installation of green roof components should ideally proceed after the installation of other major rooftop building components** to minimize potential damage from foot traffic and related trades activities.

The installation sequence of green roof component layers can vary depending on the type of roof system being constructed. The typical installation sequence (bottom to top) for a protected membrane (or inverted) roof and a conventionally insulated roof are shown in ***Figure 3.1***

A protected membrane roof places insulation above the waterproofing membrane, which is then better protected from temperature changes. **A conventionally insulated roof places insulation below the waterproofing membrane**, which makes it potentially more vulnerable to damage during green roof installation. In this latter circumstance, it is even more important to use well-trained installers.

Component layers may be installed individually (**built-up system**) or in pre-formed combinations (**mats or modular tray systems**).

3.2.2 Protecting the Waterproof Membrane

Working with care and preventing damage to waterproof membranes during the installation of a green roof is critical to ensure long-term performance of the system. When installing waterproof membranes, some considerations include:

- **Sun Exposure** - Certain waterproof membrane products are not designed for prolonged sun exposure, which could void warranties and degrade the material. Scheduling gaps can occur for a variety of reasons such as availability of materials or weather conditions. Should this occur after installing a waterproof membrane, it is essential to minimize exposure time by installing protective layers within the time frame specified in the manufacturer standards.

- **Mechanical Fasteners** - Some conventionally insulated roofs are installed using mechanical fasteners, which are used to secure the waterproofing membrane or other material layers to the roof deck. It is not typically recommended to use mechanical fasteners for green roof applications. Fully adhered conventional roof systems are a better choice for supporting green roofs.

  If mechanical fasteners are used, these should be used only for layers below a thick, rigid, puncture-resistant overlay panel to prevent damage to the membrane during installation and over the lifespan of the green roof. Keeping mechanical fasteners below a protective overlay protects the membrane, preserving the roof’s waterproofing and insulation integrity.

3.2.3 Water Vapour, Insulation, And Root Barrier Placement

Root barriers are not vapour permeable. Consequently, **when installing a green roof on an inverted roof assembly, the root barrier should always be placed immediately above the roof membrane and below the insulation**. If it is located higher up in the green roof system (e.g. above the insulation), it will act as a drainage plane and potentially trap water vapour below it. Given that insulation performance decreases with higher moisture levels, this arrangement may lead to a building that is less energy efficient.

It is therefore important to coordinate the proper placement of root barriers with roof installers prior to commencement of their work.

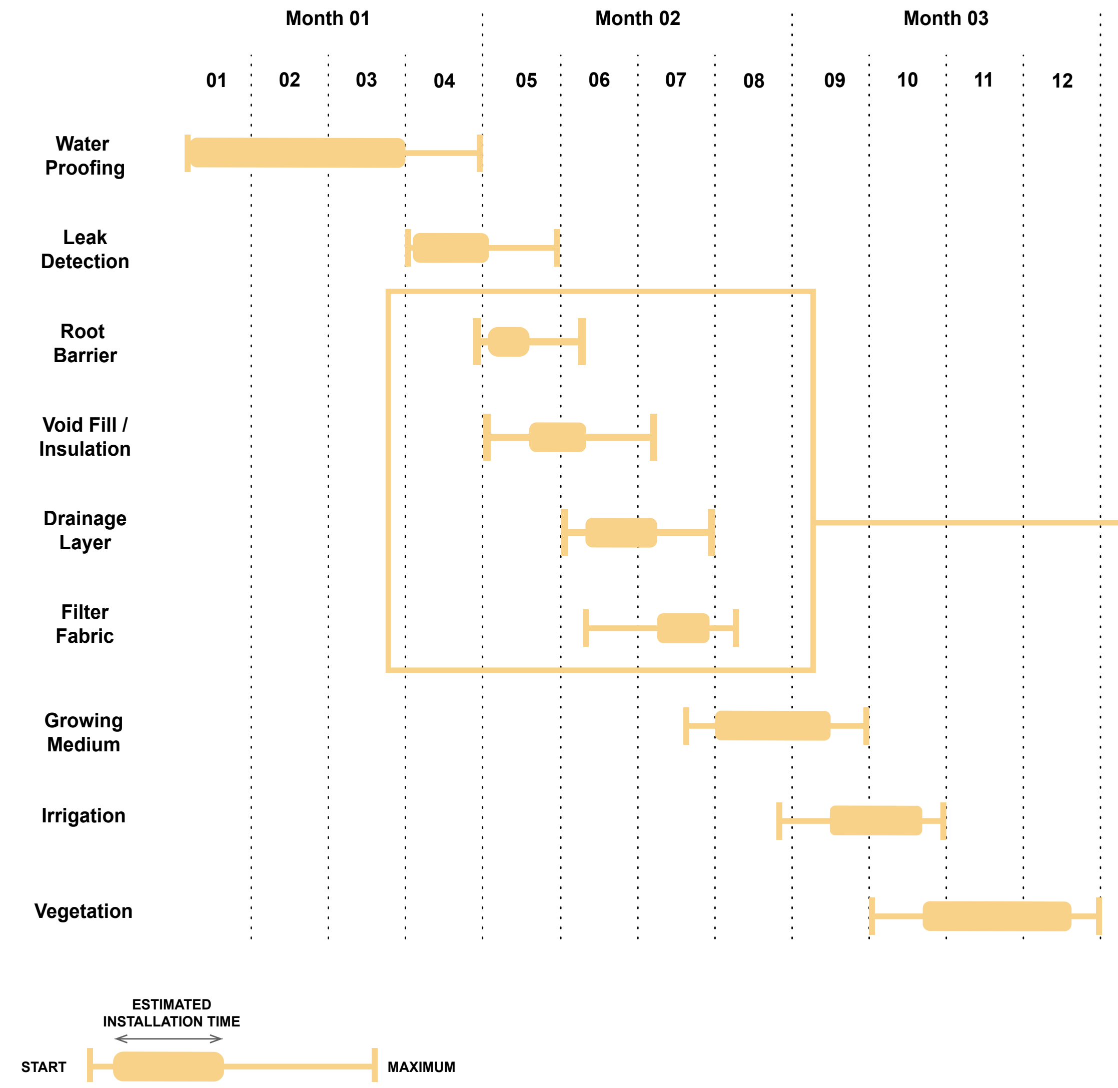
3.2.4 Scheduling Plant Installation

To ensure that plant materials are not damaged by other construction activities, planting is typically undertaken after the other hardscape components of the green roof are installed.

It is also important to consider weather conditions when installing plants to maximize their chance of survival. Excessively **cold weather** may shock plants and prevent them from properly establishing. Conversely, hot and dry **summer weather**, which dries out the growing medium at a faster rate, will likely require that irrigation measures be in place at the time of planting.

3.3 CONSTRUCTION TIMELINE EXAMPLE

The timeline below illustrates the sequencing of construction activities for an intensive green roof associated with an outdoor childcare space in Vancouver. The size of the rooftop space is approximately 800 m^2. The timeline was also used to coordinate green roof component installations with other structural, paving, and furnishing works external to the vegetated areas.



OVERLAPPING INSTALLATION TIMES

To counter the effects of wind uplift, it may be necessary to weigh down certain lightweight materials immediately after installation. It is therefore common for heavier components to be laid down on top of the lightweight components.

For example, some growing media may be placed over the root barrier, drainage, insulation layer, and filter fabric to prevent these layers from being displaced by the wind. As a result, the sequencing of these component installations will likely overlap.

3.4 COORDINATING WITH OTHER TRADES

Trades coordination should include clarifying individual scopes of work (and associated responsibilities) and coordinating the scheduling and sequencing of individual activities.

Prior to installing a green roof, the green roof installation team should inspect and be satisfied with the completion of the structural work and the installation and testing of the waterproofing membrane. The green roof team should expect a handover process from the general contractor and the roofing contractor **indicating that the structural and envelope scopes of work and integrity scans on the waterproofing layer have been properly completed**.

The green roof installation team should ensure that any work that is required prior to the installation of the green roof is reviewed with, and conveyed to, the general contractor.

An even higher level of coordination is recommended between the installation team and general contractor **when dealing with sloped roofs** as the slope stabilization anchors need to be installed directly to the structure, typically after initial waterproofing, with another round of waterproofing following the installation of the anchors.

3.5 MATERIALS DELIVERY AND PLACEMENT

The delivery of materials should be coordinated with the general contractor and overall project schedule. The locations for staging and stockpiling, and the method of delivery to the roof, will be project specific. In taller buildings, **a crane may be needed to deliver green roof materials to the rooftop**, especially heavier loads such as growing media and trees. Given the significant cost associated with maintaining a crane on site, coordinating the delivery of green roof materials to taller buildings is even more important when maximizing cost efficiencies.

Should any green roof components be installed while waiting for heavier components to arrive by crane (or other delivery method) then **planning considerations should be in place to ensure that these materials are secure and, in the case of plant material, can survive on site**. One consideration includes ensuring that team members have access to water and are able to maintain the plants.

The stockpiling of materials can create heavy point loads and should be avoided or minimized. Any proposed stockpiling of materials, including details such as locations and other relevant parameters, should be shared, coordinated with, and approved by the structural engineer. It is recommended that any materials brought up to the roof be installed immediately.

3.6 OCCUPATIONAL HEALTH AND SAFETY

Prior to roof access and installation, the green roof contractor and installation team should ensure that fall protection or arrest measures are in place. In case permanent fall protection measures are not yet in place, temporary fall protection elements should be discussed with the general contractor.

CHAPTER 4

OPERATIONS AND MAINTENANCE

4.1 ABOUT THIS CHAPTER

4.1.1 Introduction

Regular and proactive maintenance practices are essential for maximizing the functionality, benefits, and lifespan of a green roof.

Frequent inspections help identify issues such as vegetation health problems, irrigation performance issues, and drainage or structural concerns, allowing for timely interventions. **Vegetation management** involves tasks such as weeding, pruning, undertaking soil analyses, fertilizing, and even replacing plants when necessary. **Irrigation issues** include topics such as leaks or proper irrigation coverage.

Drainage concerns include avoiding soil saturation and ponding by preventing drainage blockages. In addition, maintaining the integrity of the waterproof membrane and drainage layers, ideally with the aid of leak detection systems, is important for helping to prevent leaks.

4.1.2 What is Included

This chapter includes common maintenance considerations associated with green roofs, such as establishment maintenance, routine inspections, plant and fertilizer management, drainage channels, irrigation systems, electronic leak detection systems, human access, and maintenance manuals.

4.2 ESTABLISHMENT MAINTENANCE

As with vegetation planted in the ground, vegetation on green roofs will also require a period of establishment and maintenance. **Establishment refers to the time required for newly planted vegetation to develop root systems and adapt to the green roof environment**. This period is crucial for plants to become fully integrated into the green roof system, establish resilience against environmental stresses, and help ensure long-term survival and growth. Some considerations include:

- **Vancouver's Climate** – Plant establishment in the Pacific Northwest can vary depending on the type of plant and specific conditions. Generally, **it takes about one to two growing seasons for most plants to establish** themselves.
- **Method of Irrigation** – Establishment maintenance is particularly important if the design of the green roof system does not include an automatic irrigation system, as **watering during establishment is a critical aspect of plant health**.
- **Season of Planting** – While planting is possible for most of the year in Vancouver's climate, prolonged cold, heat, or drought could pose a threat to plant health, especially during the establishment period. Proper care during this time is essential to support the successful integration and longevity of green roof vegetation. **Generally, early spring and early fall are the ideal times to plant**.
- **Method of Planting** – **The method of planting will affect the amount and duration of establishment maintenance required**. Pre-grown mats and trays that contain mature plants with high initial vegetation coverage will establish on the roof, with minimal maintenance, within one growing season. By comparison, built-in-place plants will likely require more maintenance and a longer establishment period. This is especially true of small plugs, cuttings, and seeds, which may take two years to establish depending on the species of plant.

4.3 REMOVAL OF UNDESIRABLE PLANTS

As with all vegetated areas, green roofs can be susceptible to encroachment of weeds and undesirable plant species, sometimes called "volunteer" plants. These **undesirable species can compete with desirable plants for nutrients and water**. Strategic removal of these species is essential for maintaining the health and appearance of the green roof. Some considerations include:

- A properly trained green roof maintenance team should conduct at least four (4) and preferably six (6) visits a year to determine if volunteer plants or weeds present on the roof should be removed or are suitable for the particular green roof's ecology, scale, growing conditions, and other relevant considerations.

4.4 PLANT HEALTH

Ensuring the proper growth of desirable plants on a green roof requires periodic inspection of their health and condition. Issues such as nutrient deficiencies, pests, and diseases can all impact plant growth. **Regular inspections and appropriate interventions can occur during the routine maintenance activities**.

Any dead or dying plants should be removed to allow space for the growth of the healthy plant population. That said, **care should be made to distinguish between dead and dying plants and other design items purposely placed to create microhabitats and enhance biodiversity** (see ***Appendix B: Habitat Enhancement Guide*** for more information).

4.5 FERTILIZATION AND NUTRIENT MANAGEMENT

Green roofs may require periodic fertilization to replenish nutrients in the growing medium. **A soil analysis should be performed to determine nutrient levels and ascertain what nutrients may be lacking**. From this analysis, a fertilization plan can be developed to help address any nutrient deficiencies, sustain plant health, and promote optimal growth. Some considerations include:

- **Extensive green roofs** typically contain small hardy plants that have lower nutrient needs and therefore require less fertilizing to ensure plant health.
- **Intensive green roofs** typically contain larger perennials, shrubs, and trees that have higher nutrient needs and therefore require more fertilizing to ensure plant health.

USE OF SYNTHETIC FERTILIZERS

A great level of care is required when deciding on the type and method of fertilization to use on a green roof. Two issues are relevant:

First, any rainwater that moves through a green roof growing medium will make its way into the city sewer system. Second, synthetic fertilizers often contain high concentrations of soluble nutrients, which could leach into rainwater runoff during rain events. If not properly treated, this runoff can contribute to water pollution in nearby water bodies, leading to impaired water quality.

For these reasons, it is strongly recommended to avoid using synthetic fertilizers on green roofs. Compost and organic slow-release fertilizers are among the preferred available options. If choosing synthetic fertilizers, use controlled release fertilizers (CRF) as they release nutrients in an amount, and at a rate, that better aligns with plant uptake needs, thereby minimizing excess nutrient leaching in runoff.

4.6 CLEARING DRAINAGE CHANNELS

A properly functioning drainage system is essential for ensuring effective water management on green roofs. **Clogged or malfunctioning drainage systems can lead to excess water that could saturate (waterlog) the growing medium, compromise plant health, pond on the roof, and potentially damage the roof's structural integrity**. The periodic clearing of debris from the roof drains is necessary to help avoid these issues.

4.7 MAINTENANCE OF IRRIGATION SYSTEMS

Regular maintenance of automatic irrigation systems, if present, is necessary and includes checking for leaks, adjusting watering schedules based on site conditions, and ensuring proper coverage. Some considerations include:

- Undertake periodic inspections of **irrigation lines** and initiate immediate repair of any leaks to help avoid water wastage and waterlogging of the growing medium.
- **Smart controllers or traditional irrigation timers** may experience malfunctions, programming errors, or sensor failures. Regular checks and troubleshooting of the controllers will help prevent irrigation-related issues.
- Inefficiencies in the irrigation system can lead to overwatering in some areas and underwatering in others. Adjustments to the system design, spray head orientation, or irrigation schedule may be needed to achieve a consistent and **uniform water distribution**.
- Ensure irrigation systems are **decommissioned** (winterized) prior to the cold season to avoid frozen and damaged water pipes. The systems are **recommissioned** in, typically, April or May.

Close inspection of the green roof's irrigation system during seasonal commissioning and decommissioning can ensure that the system is reviewed for failures and inefficiencies at least twice per year.

4.8 LEAK DETECTION SYSTEMS

If the waterproofing layer fails, it is likely that portions of a green roof will need to be removed to access the roof membrane and address the leak. To help minimize potential water damage and associated remediation costs, **it is recommended that green roofs be fitted with an electronic leak detection system (ELD)**, which uses an electrified sensor grid to identify leaks. There are two types of ELD systems: Active and Passive. Some considerations include:

- Each system helps to limit the repair disturbance to a green roof by pinpointing the location of the leak. Each system differs primarily in when the sensor grid collects and sends data.
- **A Passive system** uses an ELD grid that is not connected to a power supply and therefore not able to send monitoring data in real time. Instead, it requires a user to periodically visit the site, power the system with an external device, and observe real time data. Consequently, **membrane leaks will likely only be suspected after water has been observed entering a building's interior**.
- **An Active monitoring system** uses an ELD grid connected to a power supply and is able to continuously (e.g. 'actively') send monitoring data to a remote receiver. The additional system cost must be assessed against the **benefits of receiving a membrane leak alert in real time**, which helps minimize potential water damage and remediation costs by enabling faster responses and repairs
- In the event of a suspected leak, it is recommended that the building manager consult an ELD technician, roofing contractor, and green roof maintenance contractor. The ELD system data should be reviewed to help identify the location of the suspected leak, narrow the scope of repair work, and minimize disturbance to the green roof (see ***Section 2.7 Roofing and Waterproofing*** for more information on ELDs).

4.9 MAINTENANCE ACCESS

It is imperative to provide safe access for personnel who are conducting inspections, maintenance, or related activities on a roof. Some considerations include:

- Safety issues and concerns such as the distance to rooftop edges, the presence of fall arrest anchors, potential trip hazards and deficiencies should be regularly assessed to help ensure the well-being of maintenance personnel.
- **Green roof maintenance personnel should also ensure the presence of proper and adequate fall protection and safety measures** prior to undertaking their work.
- Safe transport of tools and equipment to conduct maintenance work, including consideration of how materials are moved to and across the roof.

Refer to **WorkSafe BC and OHS Guidelines Part 11: Fall Protection** for more information on safety measures when working at height.

4.10 MAINTENANCE MANUALS

Maintenance manuals serve as essential records for the operation and upkeep of a green roof project. These manuals, customary in construction practices, play a pivotal role in ensuring that the green roof system functions optimally and remains in good condition over time. When handed over to the owner at the conclusion of the construction warranty period, **these manuals provide comprehensive guidance on how to maintain the green roof effectively**.

Maintenance manuals typically include vital documents such as:

- Descriptions of original design intent and product sheets for specified materials used in construction
- Detailed as-built drawings outlining the layout and components of the green roof system
- Landscape maintenance schedules identifying tasks and frequency for ongoing care

It is also useful for maintenance manuals to include **re-planting procedures** should re-planting be needed to help address unforeseen impacts to plants from sources such as invasive species, pests, diseases, or even general roof maintenance activities.

RECOVERY OF THE NICKEL BUILDING GREEN ROOF

Below are images of the green roof on the Nickel Building, which is located at 285 West 5th Avenue in the Mount Pleasant neighborhood of Vancouver. The vegetation experienced a decline in the years following its installation, likely due to a lack of sufficient nutrients in the growing medium. A thin layer of compost and additional seeding was placed on top of the existing plant layer. The roof began to see signs of recovery within the following growing season. None of the other green roof components were serviced as part of this recovery.

Before:

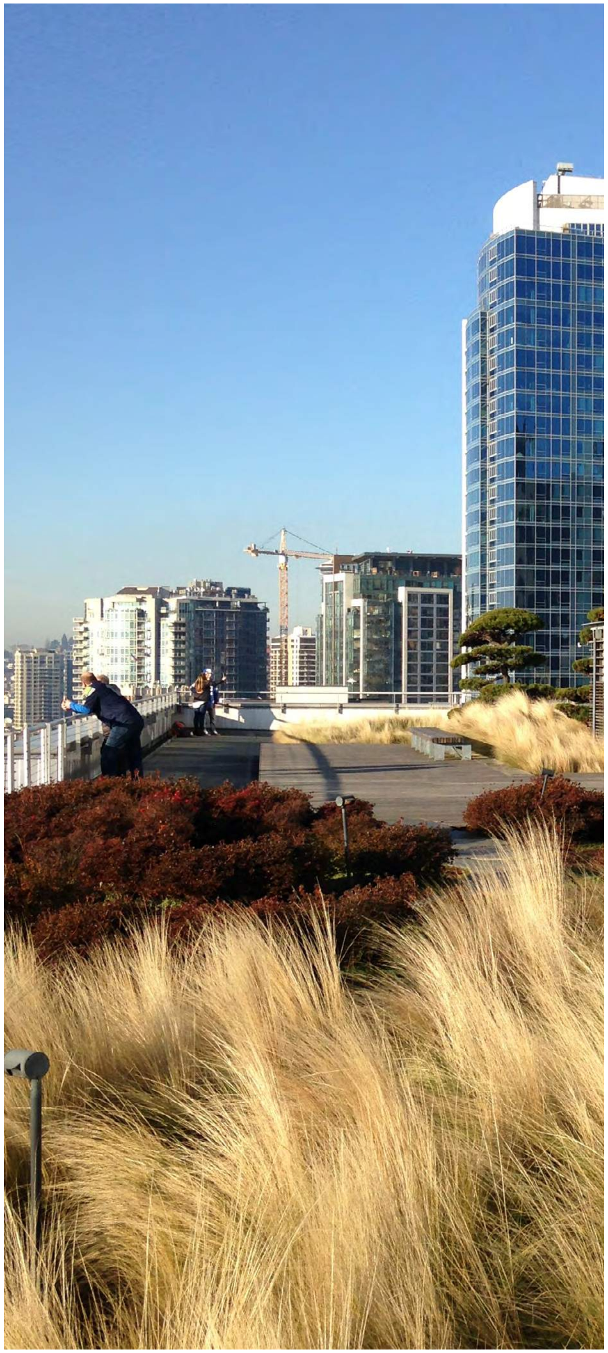
After:

Images courtesy of © 2024 Architek

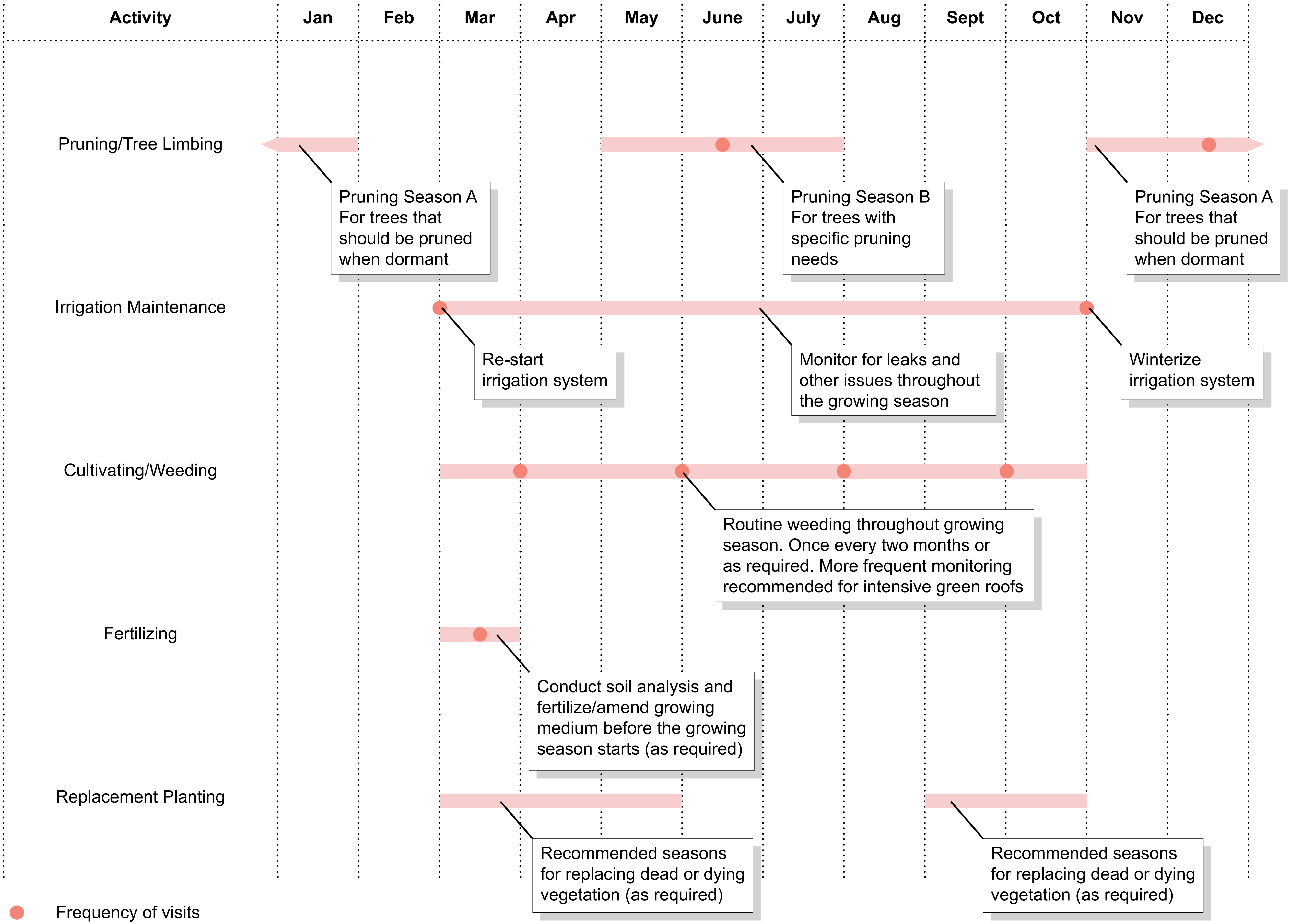
4.11 RECOVERY OF EXISTING ROOFS

Green roofs that adhere to these best practices in design, installation, and maintenance are likely to thrive and succeed. However, unforeseen circumstances can still have negative impacts on vegetation. Fortunately, there are often simple and cost-effective solutions to address these impacts and revitalize vegetation on a green roof. Some considerations include:

- The recovery process begins with a thorough investigation to identify the underlying causes of failure.
- **Amending Growing Medium** - Growing medium may require some amendments or, in some cases, complete replacement if not designed properly. Over time, the growing medium can also degrade or lose its essential nutrients, which may compromise plant health and green roof performance. A soil analysis should be conducted to determine what nutrients may be lacking in the growing medium. This will help determine whether the growing medium should be amended or replaced.
- **Adjusting Irrigation** - Irrigation systems should be inspected for leaks and other performance issues that may have led to the decline of plant health.
- **Removing Invasive Species and Pests** - Vegetated areas should be inspected for plant type and health, pests, and diseases. Any plants causing harm to the health of a green roof should be identified and removed. Similarly, any pests or diseases potentially affecting plant health should be identified and managed accordingly.
- **Keeping Functional Roof Components** - In many cases, the foundational assembly layers, such as the drainage layer, root barrier, and waterproof membrane, can remain intact if they are undamaged and functioning properly. These layers are designed for durability and, when maintained, provide a solid base for reestablishing plantings without the need for significant modifications.



EXAMPLE: GREEN ROOF LANDSCAPE MAINTENANCE SCHEDULE



Pruning Season A For trees that should be pruned when dormant

Pruning Season B For trees with specific pruning needs

Pruning Season A For trees that should be pruned when dormant

Re-start irrigation system

Monitor for leaks and other issues throughout the growing season

Winterize irrigation system

Routine weeding throughout growing season. Once every two months or as required. More frequent monitoring recommended for intensive green roofs

Conduct soil analysis and fertilize/amend growing medium before the growing season starts (as required)

Recommended seasons for replacing dead or dying vegetation (as required)

Recommended seasons for replacing dead or dying vegetation (as required)

● Frequency of visits

▨ Timeframe for conducting maintenance

CHAPTER 5
WARRANTY AND MANAGING LIABILITY

5.1 ABOUT THIS CHAPTER

5.1.1 Introduction

Ensuring the ongoing performance and longevity of a green roof is important because it represents an **environmental, social, and economic asset** for a building owner.

A **warranty** is a written promise issued by a manufacturer or seller, to the purchaser of a good or service, that promises repair or replacement of that good or service, if necessary, within a specified period of time. Warranties may also cover workmanship.

A **guarantee** is a product issued by a third party that offers coverage on behalf of the material or system manufacturer, together with the installer.

Green roof warranties and guarantees typically offer protection against various risks associated with both materials and workmanship, thereby helping to mitigate potential liabilities related to defects or failures.

Understanding green roof warranties and guarantees, and adhering to best practices can therefore **help reduce risks** for building owners. By aligning with industry standards for design, installation, and maintenance, and proactively managing the green roof, building owners can maximize the benefits of these warranties, protect their investment, and ensure the green roof continues to deliver its intended environmental, social, and economic benefits throughout its service life.

5.1.2 What is Included

This chapter discusses managing liability with various warranties, including contractor warranties, product warranties, new home warranties, and building envelope inspection warranties. The Roofing Contractors Association of British Columbia (RCABC) RoofStar Vegetated Roof Guarantee program is also introduced.

5.2 WARRANTIES, COVERAGE, AND PROJECT LIFE CYCLE

The following table summarizes the warranties described in this Chapter, what they typically cover, how they relate to one another, and where they occur in the project life cycle (design, installation, and maintenance).

Warranty	What it Covers
Contractor (workmanship) Warranty	• Maintaining the green roof (typically 1-2 years) • Green roof labour (typically 1-2 years) • Green roof materials (typically 1-2 years)
Manufacturer/Supplier Warranty (also known as a product/materials Warranty)	• Green roof materials (years vary by product)
New Home Warranty Insurance	• Labour (up to 2 years) • Materials (up to 2 years) • Building envelope, including water penetration (5 years) • Building structure (10 years)
Renovation of Existing Building Envelope Warranty	• Labour (2 years) • Materials (2 years) • Building envelope, including water penetration (5 years)
RCABC Vegetated Roof Guarantee	• 2-year systems-based guarantee for vegetated roofs, when paired with a RoofStar Roof Guarantee • Applies to green roofs constructed by RCABC member contractors, using RCABC-accepted systems listed in the Roofing Practices Manual (RPM), and maintained by the installer. • For extensive systems using pre-grown vegetation mats or trays, coverage may also extend to vegetation.

5.3 CONTRACTOR WARRANTY

After a green roof project is completed, construction contractors typically provide a warranty period that covers labour and materials and generally lasts 1 to 2 years. During this time, the contractor is also responsible for maintaining the green roof and addressing any issues that may arise from the installation/ construction process. At the end of the warranty period, maintenance may transition to either a specialized team or the building's facility management. It is therefore important to ensure a smooth handover to maintain the green roof's performance.

5.4 MANUFACTURER (PRODUCT) WARRANTY

Various products specified in a green roof system often come with their own manufacturer or supplier warranties that provide coverage for degradation, defects, or failures in the materials. These product warranties are a critical aspect of the overall green roof warranty strategy, as they offer specific protections beyond the general contractor warranty. Products that typically include their own warranties are:

Filter fabrics and geotextiles: Protects against wear and tear and helps ensure effective separation and filtration.

Insulation: Guarantees thermal performance and integrity over time.

Roof membranes: Covers water-tightness and protection against leaks.

Drainage layers: Helps ensure proper water flow and prevention of waterlogging.

Roof paving assemblies: Protects against cracking, displacement, and other forms of deterioration.

Irrigation systems: Covers the functionality and durability of components and helps ensure consistent water delivery.

Leak-detection systems: Guarantees early detection of leaks to prevent damage to the underlying structure.

Understanding and coordinating these product warranties helps identify any warranty gaps, helps ensure that potential issues are addressed within the warranty periods, minimizes the risk of costly repairs, and helps ensure the green roof continues to meet its intended performance standards.

5.5 RCABC ROOFSTAR VEGETATED ROOF GUARANTEE PROGRAM

The Roofing Contractors Association of British Columbia (RCABC) advances best practices, guarantees, and protection of the public interest in roofing and related industries. RCABC members include manufacturers, suppliers, and contractors.

The RCABC RoofStar Vegetated Roof Guarantee Program provides robust protection for roofing systems, ensuring that both installation and materials meet high quality standards. This warranty is particularly beneficial when seeking building insurance for new developments, as it demonstrates a commitment to maintaining the integrity of the roof structure.

The RoofStar Guarantee also includes periodic inspections of roof performance at specified intervals, which helps to identify and address potential issues before they may become a greater concern. This ongoing oversight can help reassure building insurers that the roof is properly installed and well-maintained, reducing the risk of future claims and enhancing the overall security of the property.

RCABC ROOFING CONTRACTORS ASSOCIATION OF BRITISH COLUMBIA | RoofStar GUARANTEED. BETTER.

Find out more:
https://www.rcabc.org

5.6 NEW HOME WARRANTY INSURANCE

In British Columbia, the Homeowner Protection Act mandates that all new homes must carry third party 2-5-10 home warranty insurance, which includes coverage for defects in materials and labour (2 years), the building envelope (5 years), and structural components (10 years). The building envelope includes all the building components (e.g. foundations, exterior walls, windows, doors, and roofs) that separate the indoors from the outdoors. The warranty is attached to the home and not the owner.

For projects featuring green roofs, it is crucial to work closely with home warranty insurance providers to help address potential concerns and ensure that the roof is designed and installed to standards that meet their requirements for warranty coverage.

Find out more:
Search for new home warranty insurance at https://www.bchousing.org

5.7 EXISTING BUILDING ENVELOPE RENOVATION WARRANTY

When retrofitting a green roof onto an existing structure, it is essential to secure a building envelope renovation warranty to ensure coverage for renovations that impact the building envelope and protect against water penetration. This warranty provides a minimum coverage of 2 years on labour and materials and 5 years on the building envelope, including water penetration. Coverage begins once the renovation is substantially complete.

Before beginning construction, a contractor must obtain third-party warranty insurance, be licensed as a residential builder, and be classified specifically as a building envelope renovator. Close collaboration with authorized home warranty insurance providers is necessary to ensure the green roof meets all standards for coverage. This process safeguards the integrity of the building and ensures compliance with the Homeowner Protection Act's requirements.

Find out more:
Search for building envelope insurance at https://www.bchousing.org

CHAPTER 6

DESIGN SCENARIOS

6.1 ABOUT THIS CHAPTER

6.1.1 Introduction

Depending on the growing medium depth, choice of plants, and other features, green roofs can be designed to hep provide a range of environmental, social, agricultural, and economic benefits. Green roofs can help manage rainwater on site, reduce urban heat island effects by creating cooler rooftop surfaces, and enhance biodiversity and habitat.

Green roofs can also be designed to complement amenity, childcare, and urban agricultural spaces, increase access to nature, and expand educational opportunities. By transforming rooftops into attractive and accessible green spaces, green roofs can help promote social interaction and increase health and well-being. **Green roofs are so useful because they mimic nature and are multi-functional** (see ***Chapter 1: Background*** for more information).

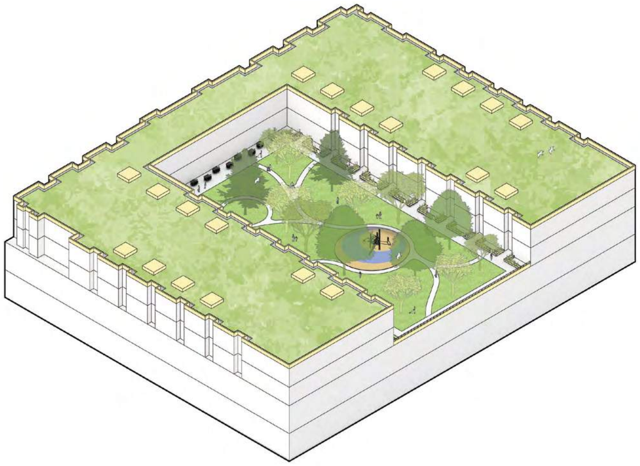
This chapter combines best practices learnings and applies them to four design scenarios.

6.1.2 What is Included

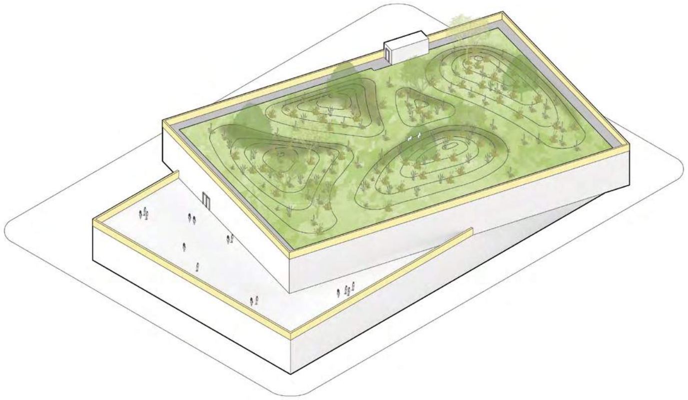
Each design scenario emphasizes one of these primary co-benefits: **managing rainwater, enhancing habitat and biodiversity, providing amenity and other social spaces, and supporting urban agriculture**. Note that because green roofs are multi-functional, each scenario is also providing other co-benefits beyond its primary performance purpose.

Design scenarios include a general description, roof details, and associated axonometric, elevation, and plan views. Information is also provided on the scenario's primary co-benefit and on managing rainwater.

Scenario 1:
Managing Rainwater

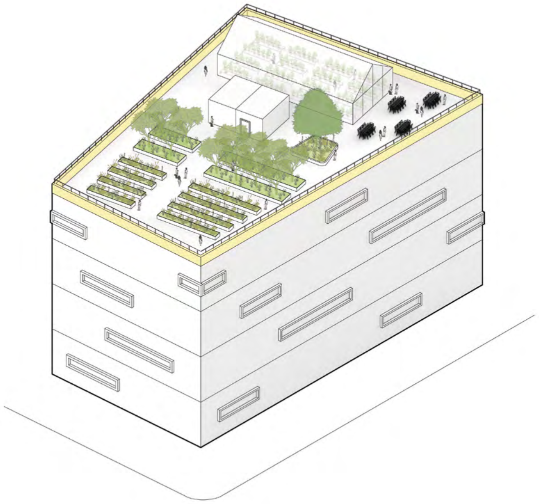


Scenario 2:
Enhancing Habitat And Biodiversity



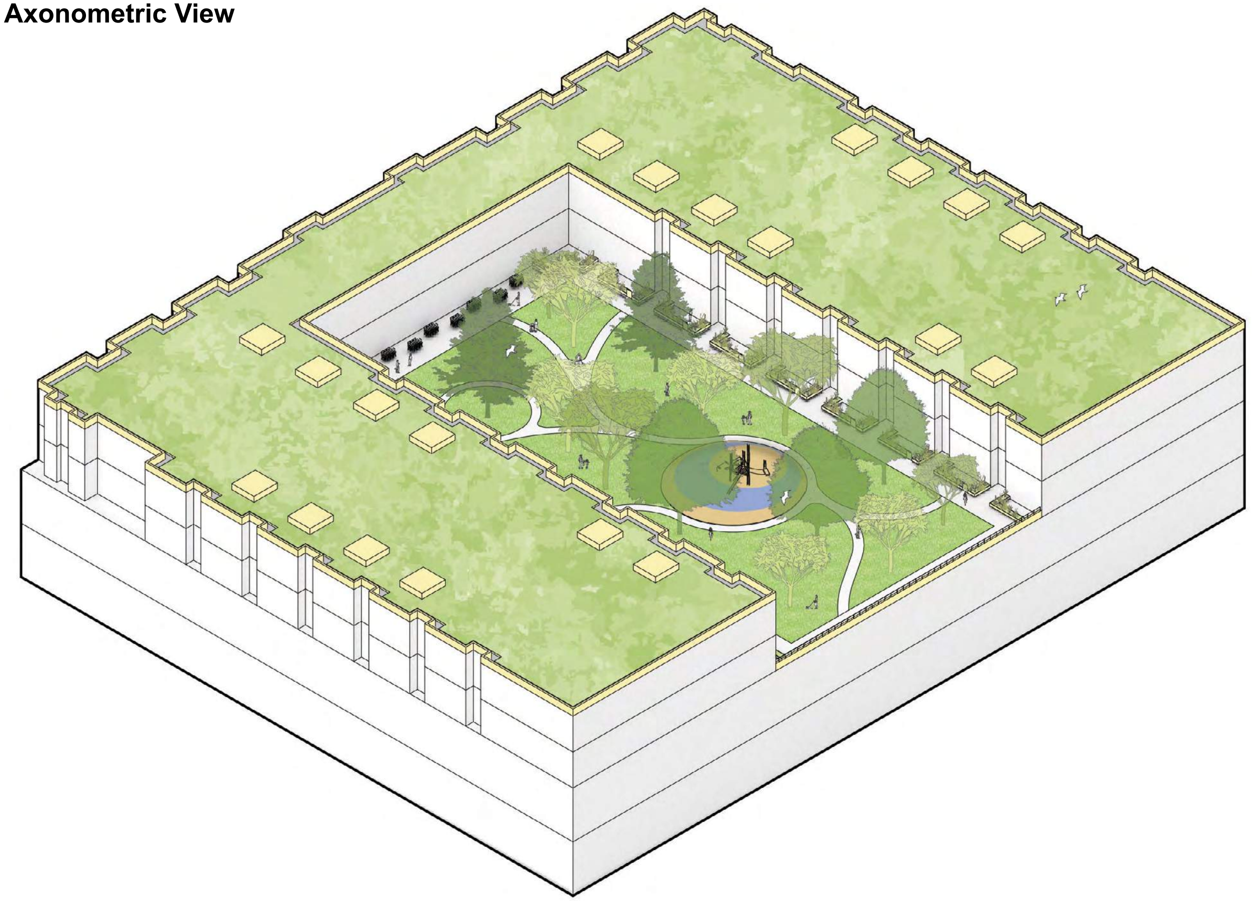
Scenario 3:
Providing Amenity and Other Social Spaces

Scenario 4:
Supporting Urban Agriculture

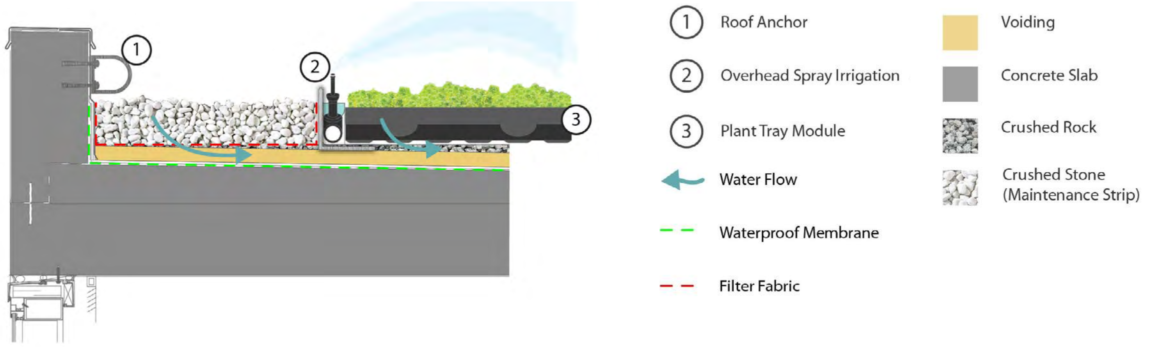


6.2 DESIGN SCENARIO - MANAGING RAINWATER

Axonometric View



Roof Detail



Introduction

This design scenario uses both extensive and intensive green roofs to manage rainwater on a mixed-use development that includes big-box retail at grade and residential units above the ground floor. Limited space is available for ground-level rainwater infiltration.

Objectives

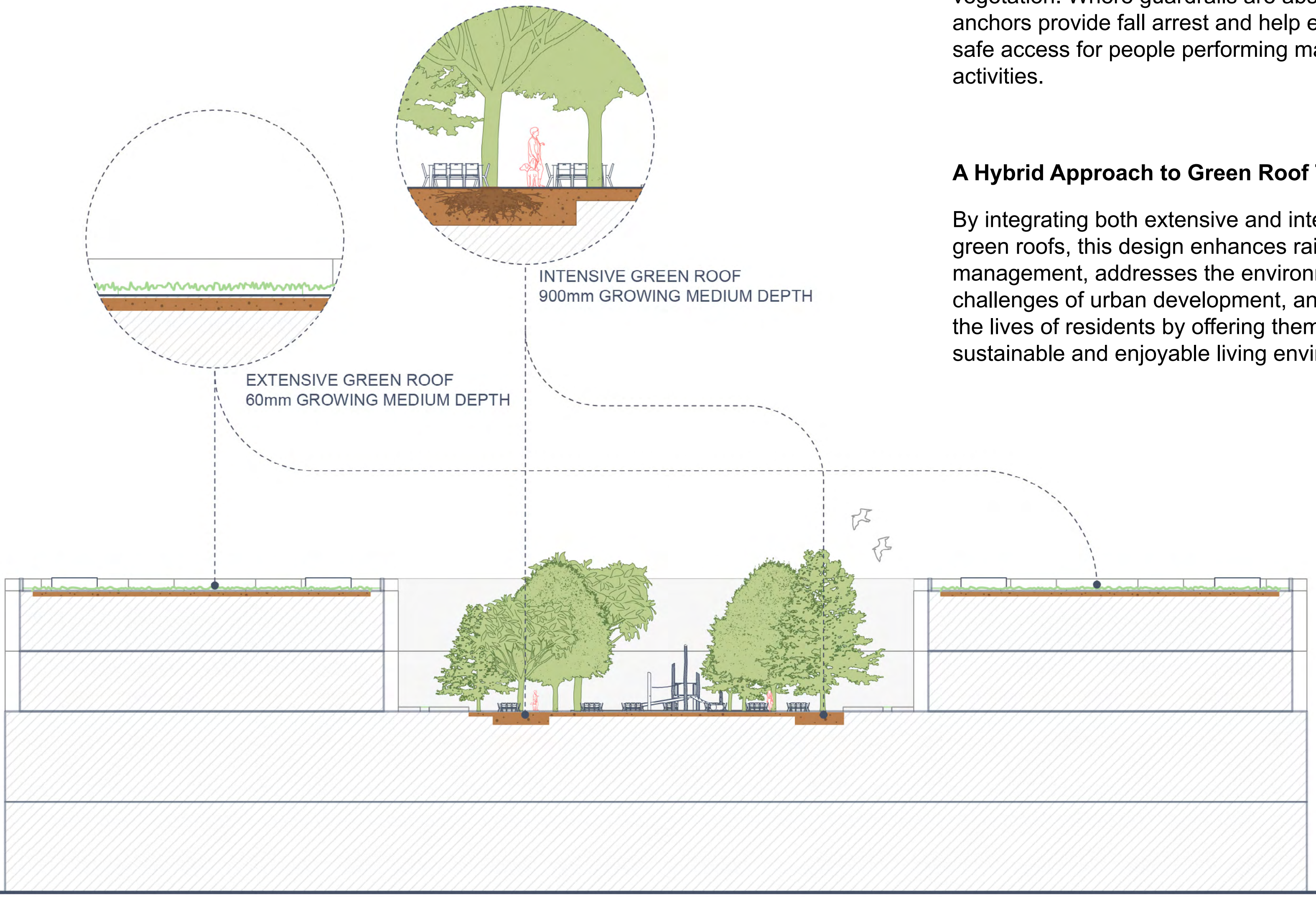
- **Primary:** Manage Rainwater
- **Secondary:** Provide amenity and other social spaces. Enhance habitat and biodiversity
- **Tertiary:** Realize other co-benefits

Description

The **extensive green roof** is positioned over the residential level and utilizes a modular tray system. This tray system is particularly advantageous for managing rainwater across a large portion of the building footprint, especially when there is limited space for ground-level landscaping and infiltration. These retention practices help reduce the volume of water leaving the site and entering the sewer system and also contribute to various sustainability objectives such as mitigating urban heat island effects and improving air quality.

Below the residential level, an **intensive green roof** is designed to serve as a communal amenity space. This lower rooftop terrace features a variety of elements, including a lawn, trees, playground equipment, and seating areas. The deeper growing media (soil) layers required for an intensive green roof support the growth of larger plants and trees, creating a lush, park-like environment that enhances the quality of life for building occupants.

6.2 DESIGN SCENARIO - MANAGING RAINWATER



Green Roof Elevation

Fall Arrest and Maintenance Strips

The **Roof Detail** features a modular tray system with integrated irrigation for the extensive green roof. A 300 mm maintenance strip provides access to the roof membrane without disturbing vegetation. Where guardrails are absent, roof anchors provide fall arrest and help ensure safe access for people performing maintenance activities.

A Hybrid Approach to Green Roof Types

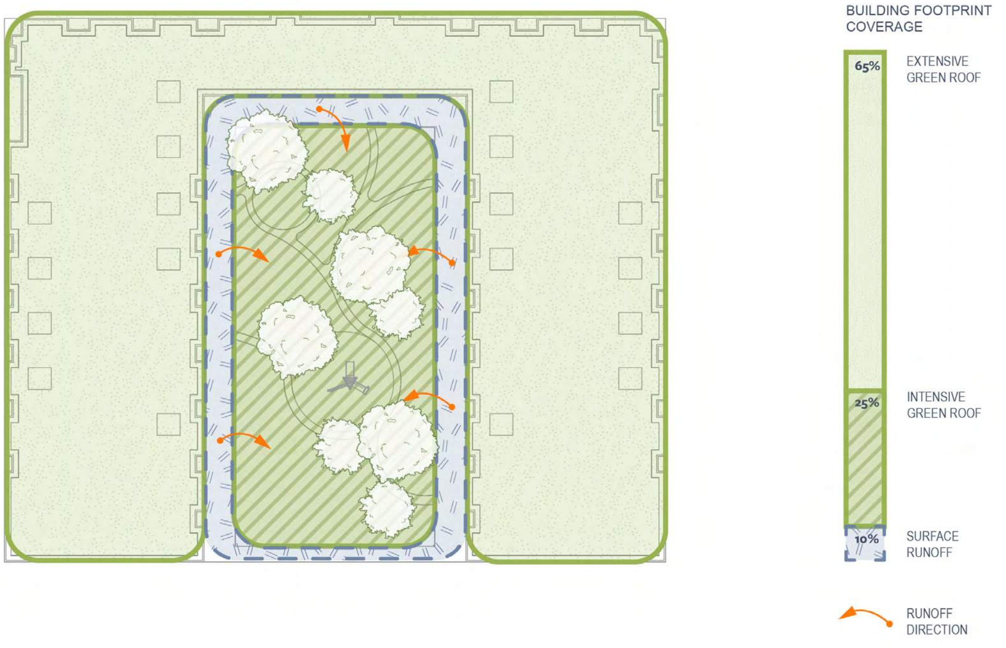
By integrating both extensive and intensive green roofs, this design enhances rainwater management, addresses the environmental challenges of urban development, and enriches the lives of residents by offering them access to a sustainable and enjoyable living environment.

6.2 DESIGN SCENARIO - MANAGING RAINWATER

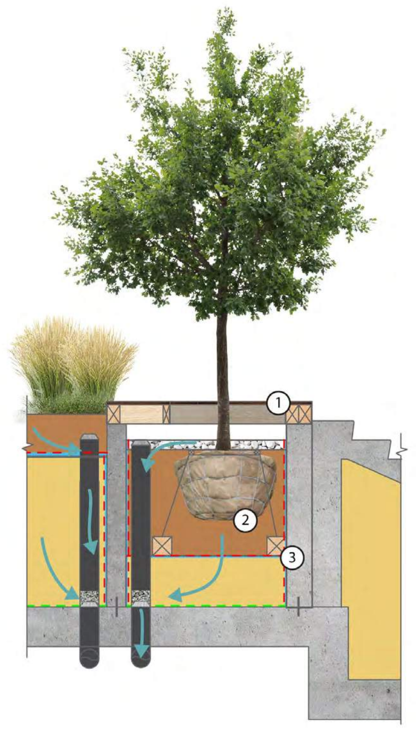
Managing Rainwater

The roof is also designed to direct run-on from adjacent paved areas to the intensive planting zones. By channeling excess water to deeper growing media (soil) layers in these areas, **the design allows a larger portion of the building's footprint to effectively manage rainwater**.

Plan View



Roof Detail



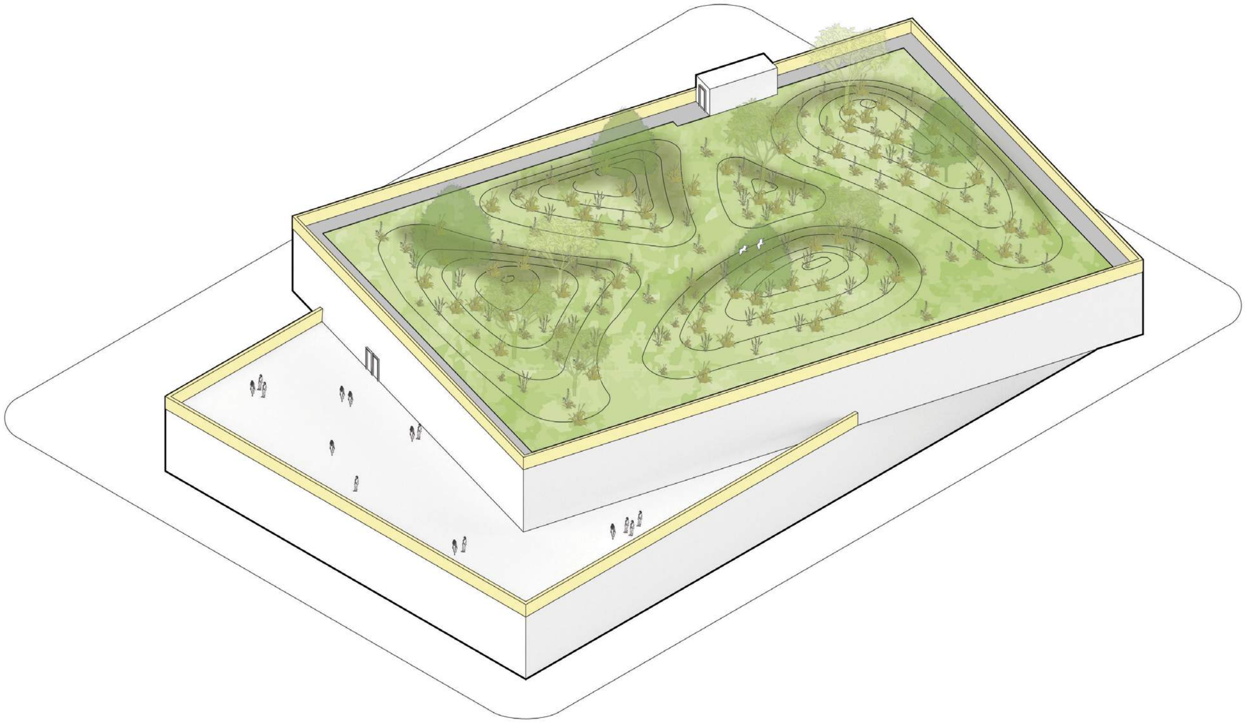
Tree Stabilization and Bi-level Roof Drains

The **Roof Detail** illustrates the use of **deadman anchors** for securing the trees planted on the intensive green roof. By preventing tilt and other movement, the anchors help ensure healthy root development.

The Roof Detail also illustrates how **bi-level roof drains** are designed and used to prevent waterlogging. These drains allow excess water to drain from the surface while maintaining adequate moisture for plant health. The system effectively manages water levels, ensuring that trees and other deep-rooted plants thrive without risking root rot or oversaturation.

6.3 DESIGN SCENARIO - ENHANCING HABITAT AND BIODIVERSITY

Axonometric View



Introduction

This design scenario uses a semi-intensive green roof with varying growing media (soil) depths and associated plantings to enhance habitat and biodiversity on a community or recreation center. The layout spatially delineates the rooftop into distinct 'islands' of intensive areas surrounded by extensive areas. In this scenario, habitat objectives limit human access.

Objectives

- **Primary:** Enhance habitat and biodiversity
- **Secondary:** Manage rainwater
- **Tertiary:** Realize other co-benefits

Description

The rooftop of a community or recreation center represents a unique opportunity to create a vibrant, biodiverse habitat that supports local wildlife and enhances the building's environmental performance. This **semi-intensive green roof is designed with varying growing medium depths, allowing for a diverse range of plant species**. For example, deeper areas support smaller shrubs and native grasses, while shallower areas support drought-resistant ground covers and flowering plants.

These variations **mimic the natural environment by creating a mosaic of habitats** with different micro-climates such as sunny, wind-sheltered areas and cooler, shaded areas. These various habitats also enhance biodiversity by providing food and shelter that attract and support birds, pollinators such as bees and butterflies, and other beneficial species.

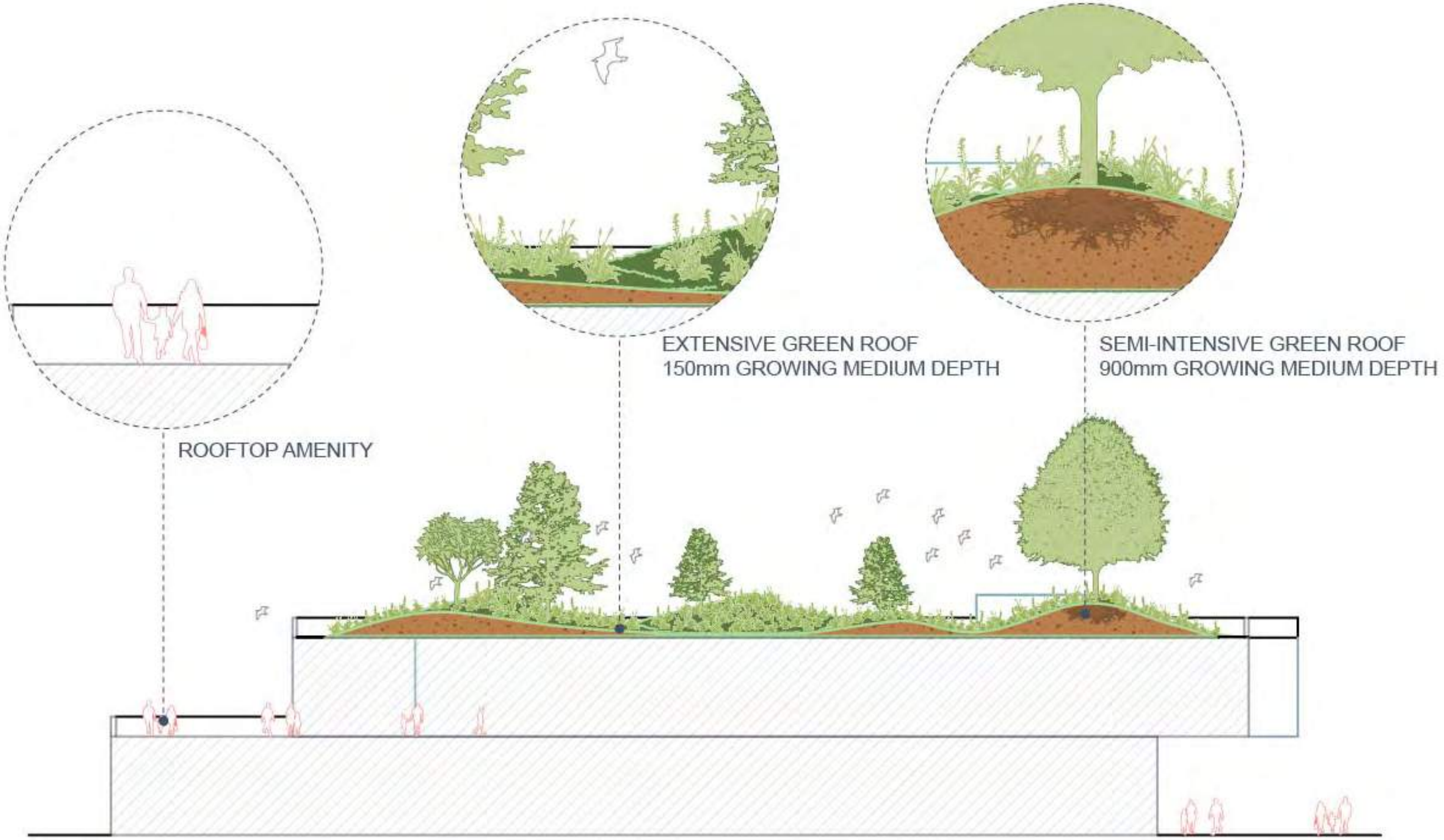
The varying growing media (soil) depths can also be strategically placed across the green roof to **better accommodate the building's load-bearing capacities**.

Although this green roof is not intended for human access, it is designed with **safety features such as roof anchors and designated service paths** that provide maintenance crews with safe access for periodic maintenance and plant care. By enabling safe maintenance activities, these safety features help ensure that the green roof can preserve its ecological function.

6.3 DESIGN SCENARIO - ENHANCING HABITAT AND BIODIVERSITY

A Habitat for Non-Humans

This semi-intensive green roof transforms an urban rooftop into a thriving ecological space that enhances habitat and biodiversity and provides other co-benefits.



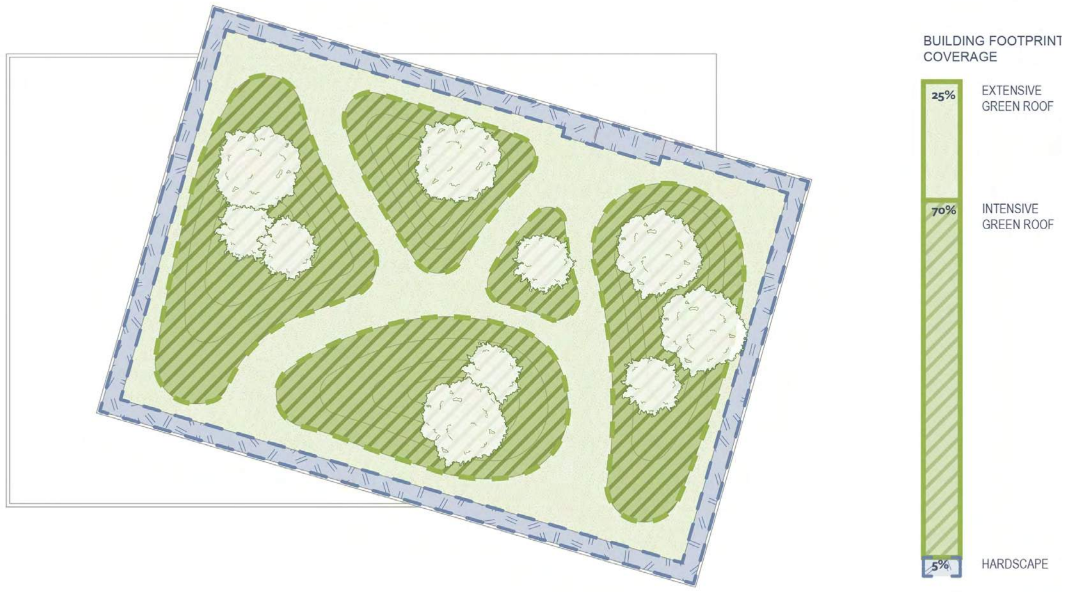
Green Roof Elevation

6.3 DESIGN SCENARIO - ENHANCING HABITAT AND BIODIVERSITY

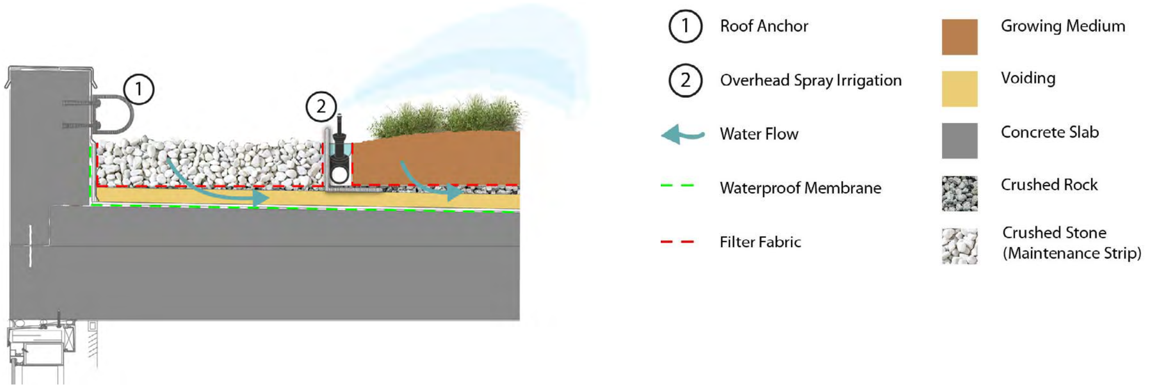
Managing Rainwater

Although all of the contiguous green roof areas, with their varying soil depths, can help manage rainwater, only specific green areas or zones are designed for this function. Other areas are designed for a habitat-centric function. This hybrid approach allows for effective rainwater management within designated green zones while also optimizing ecological benefits in other zones.

Plan View



Roof Detail



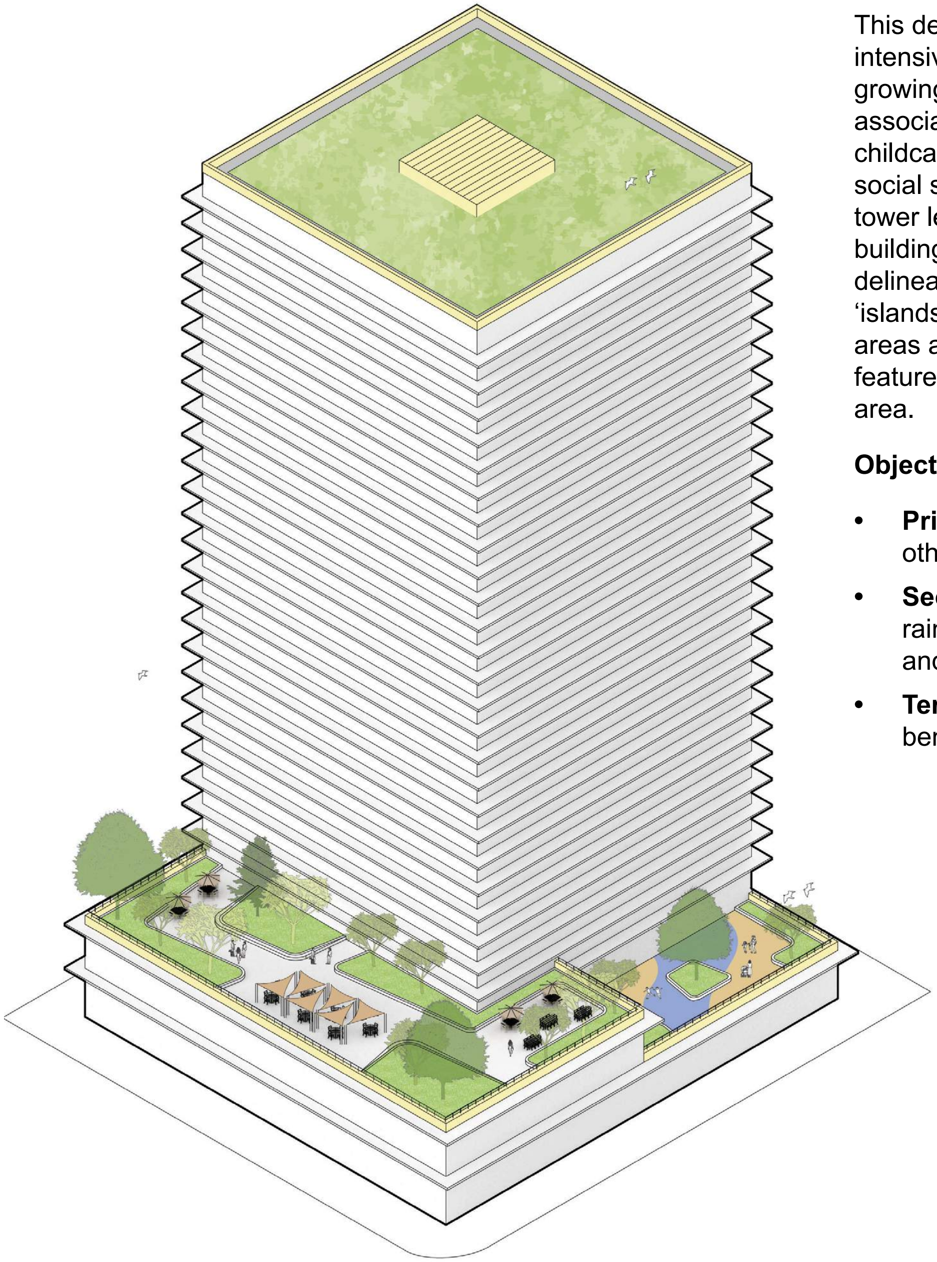
Maintenance Strip and Fall Arrest Anchor

The **Roof Detail** illustrates the use of a 300mm-wide **maintenance strip** that runs along the perimeter of the green roof. This strip is composed of non-vegetated material and provides access to the underlying roof membrane for inspection and repairs without disturbing the planted areas. The maintenance strip also serves as a buffer zone by reducing the potential for root intrusion into the membrane and simplifying the management of the roof's edge conditions.

Additionally, the roof detail includes strategically placed **roof anchors**, which are essential for fall arrest systems in areas where guardrails are not present.

6.4 DESIGN SCENARIO - PROVIDING AMENITY AND OTHER SOCIAL SPACES

Axonometric View



Introduction

This design scenario uses a semi-intensive green roof with varying growing media (soil) depths and associated plantings to enhance childcare, amenity, and other social spaces on the podium and tower levels of a dense residential building. The layout spatially delineates the podium into distinct ‘islands’ of intensive green roof areas and hardscape. The tower features an extensive green roof area.

Objectives

- **Primary:** Provide amenity and other social spaces
- **Secondary:** Manage rainwater, Enhance habitat and biodiversity
- **Tertiary:** Realize other co-benefits

Description

Residential towers over top of a larger building footprint (or podium) are a common building typology in dense urban areas. This typology has the potential to **enhance both functionality and aesthetics at the podium level by integrating intensive green roofs as roof garden features**. This carefully planned space integrates diverse vegetation, including trees, shrubs, and flowering plants, to create a vibrant, multi-use environment that serves residents and supports urban biodiversity at a smaller scale.

A key component of the design is an **outdoor play area dedicated to a childcare center** within the building. This section of the roof incorporates natural elements, such as shaded tree canopies, vegetation, and soft, resilient ground cover, that provide children with a stimulating and safe environment to play and learn in, connect with nature, and interact with their surroundings in a meaningful way.

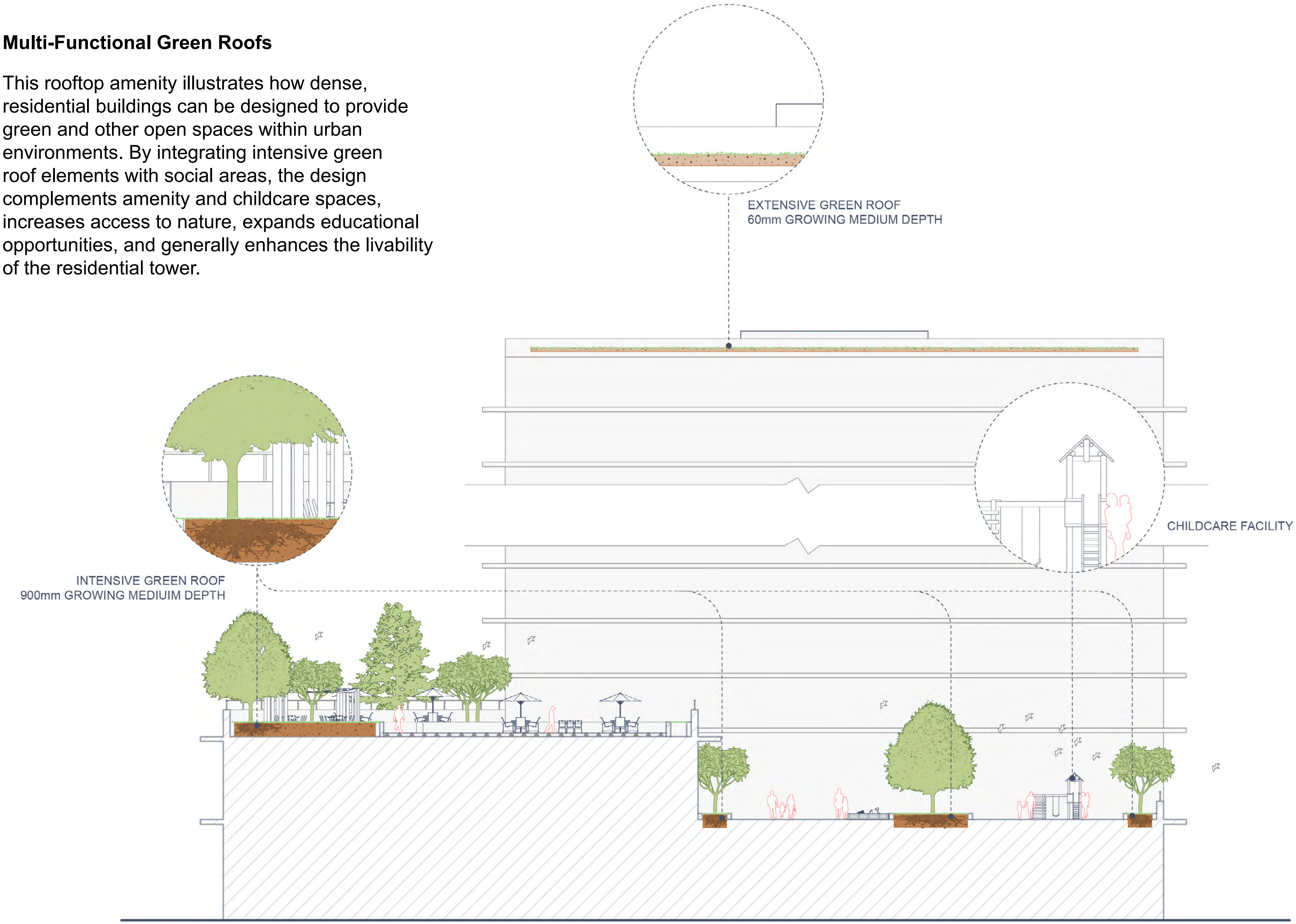
An upper-level terrace is allocated for **outdoor social spaces**, which caters to building residents. These areas are equipped with comfortable seating, picnic tables, and landscaped garden elements to create an inviting and functional space for social gatherings. The **tower level** is covered with an extensive green roof.

The use of high-quality, durable materials and thoughtful planting design ensures that the social areas are both aesthetically pleasing and practical for year-round use.

6.4 DESIGN SCENARIO - PROVIDING AMENITY AND OTHER SOCIAL SPACES

Multi-Functional Green Roofs

This rooftop amenity illustrates how dense, residential buildings can be designed to provide green and other open spaces within urban environments. By integrating intensive green roof elements with social areas, the design complements amenity and childcare spaces, increases access to nature, expands educational opportunities, and generally enhances the livability of the residential tower.



Green Roof Elevation

6.4 DESIGN SCENARIO - PROVIDING AMENITY AND OTHER SOCIAL SPACES

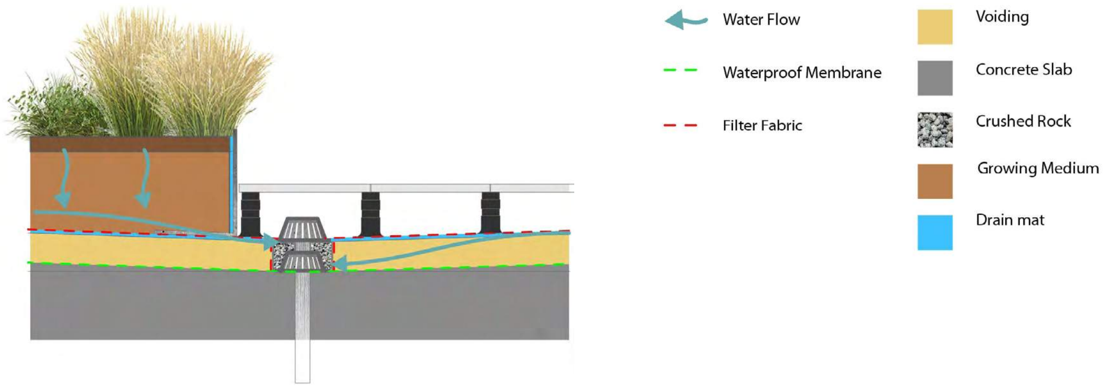
Managing Rainwater

Although managing rainwater is not the podium rooftop’s primary function, the roof does incorporate some features to address this issue.

For example, less vegetated areas of the roof are designed with deeper growing medium profiles that can receive and absorb run-on from nearby hardscape surfaces. The deeper growing mediums associated with these sections enhance retention and help reduce the volume of water leaving the site and entering the sewer system.

Plan View

Roof Detail

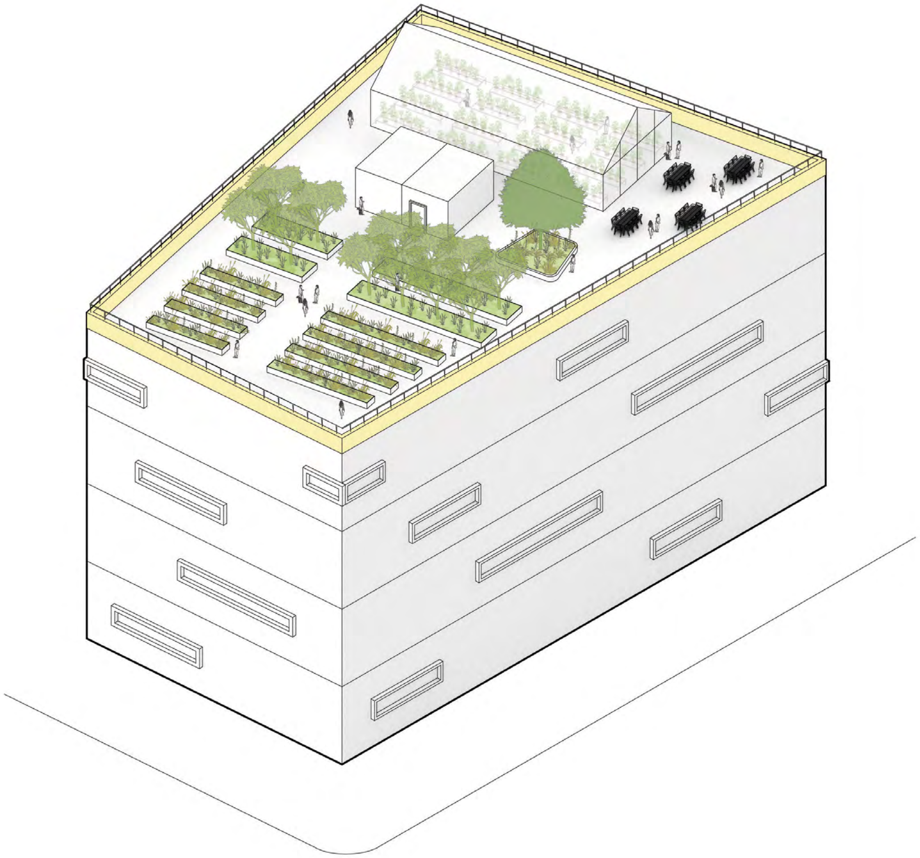


Roof Drains

The **Roof Detail** illustrates how rainwater can be managed even when roof drains are not directly aligned with planter locations. In these circumstances, the planter area is designed with a gentle slope that directs water from the planters toward the adjacent roof drains. Ensure that the planter edges are shaped to facilitate this flow and that the surrounding roof surface is graded appropriately to channel water effectively. This method can help prevent waterlogging and maintain efficient drainage across the roof.

6.5 DESIGN SCENARIO - SUPPORTING URBAN AGRICULTURE

Axonometric View



Introduction

This design scenario provides an urban agriculture amenity on the rooftop of a mid-rise residential building. The layout includes raised planter beds, storage space, and a dedicated green house.

Objectives

- **Primary:** Support Urban Agriculture
- **Secondary:** Provide amenity and other social spaces, Enhance habitat and biodiversity, Manage rainwater
- **Tertiary:** Realize other co-benefits

Description

The rooftop of this mid-rise residential building is designed to provide a dynamic urban agriculture amenity that allows tenants to grow their own fresh produce, learn about agriculture, contribute to food security, and create a connection to nature. Gardening also creates social spaces that encourage community interaction and well-being.

The rooftop features **designated growing areas**, including raised garden beds and container gardens, where residents can cultivate a diverse range of plants, such as vegetables, herbs, flowers, and ornamentals. **Green roofs that support agriculture can also be planted to support pollinators** (see ***Appendix B: Habitat Enhancement Guide***). Did you know that roughly one-third of our food depends on pollinators?

Additionally, the rooftop includes space for a **greenhouse structure**, providing a controlled climate for plants to grow year-round, regardless of weather conditions. This feature supports the cultivation of a wider variety of plants and offers opportunities for educational workshops and community gardening events. Greenhouses require both the construction of adequate shelters and well-designed heating, ventilation and air conditioning (HVAC) systems.

To support these activities, the design includes convenient **storage space** for gardening tools, ensuring that residents have easy access to necessary equipment for planting and maintenance. **Conveniently located hose bibs provide water access**, which enables residents to efficiently irrigate their plants and maintain healthy growth.

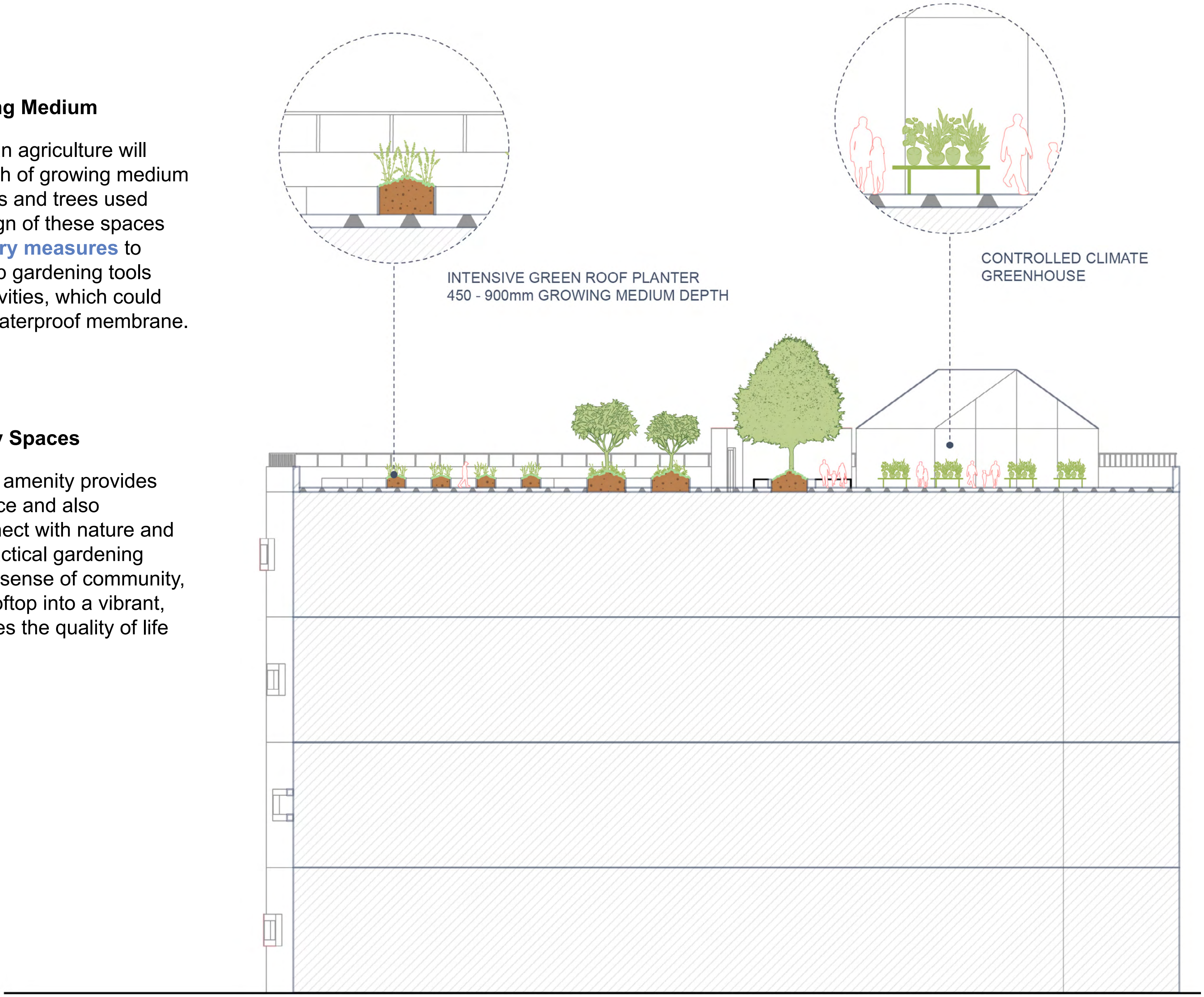
6.5 DESIGN SCENARIO - SUPPORTING URBAN AGRICULTURE

Providing Sufficient Growing Medium

Note that a roof used for urban agriculture will usually require a greater depth of growing medium (450 mm – 900 mm) for plants and trees used for food production. The design of these spaces should consider **precautionary measures** to allow for the safe use of sharp gardening tools and related food-growing activities, which could potentially damage a roof's waterproof membrane.

Green Roofs as Community Spaces

The rooftop urban agriculture amenity provides fresh produce and green space and also encourages residents to connect with nature and each other. By integrating practical gardening infrastructure and fostering a sense of community, this design transforms the rooftop into a vibrant, functional space that enhances the quality of life for building occupants.



Green Roof Elevation

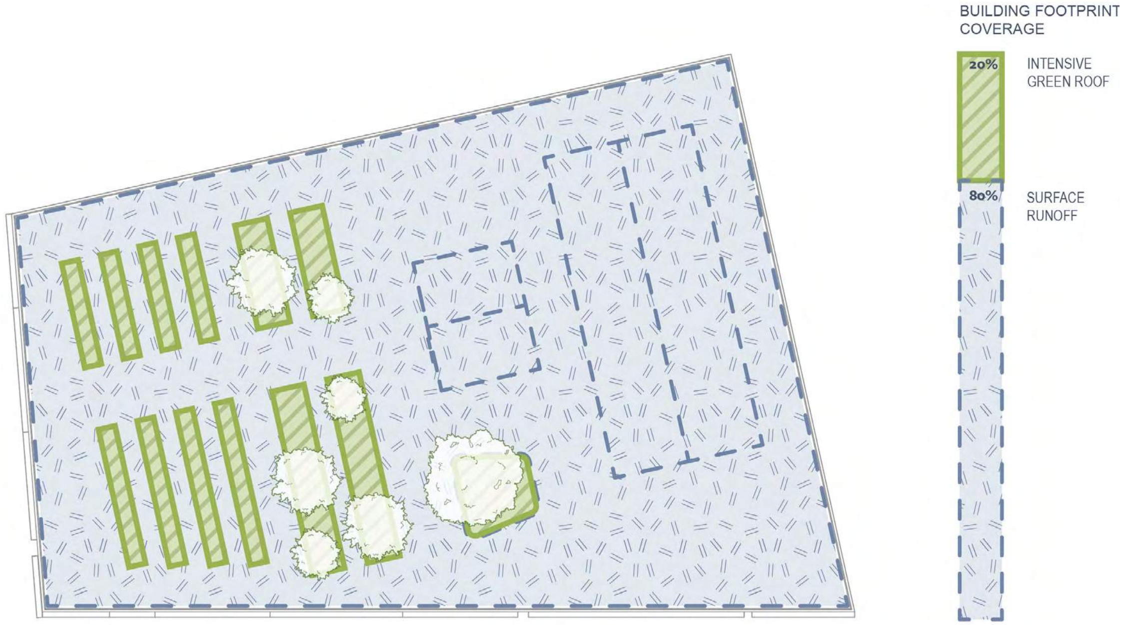
6.5 DESIGN SCENARIO - SUPPORTING URBAN AGRICULTURE

Managing Rainwater

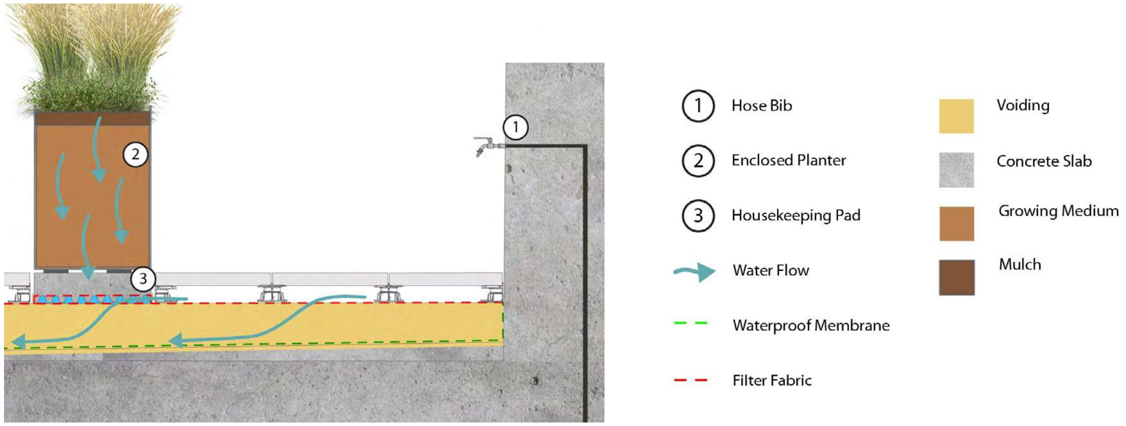
Given that the primary objective is creating usable and engaging spaces that enable gardening and related social activities, the design allocates substantial space for garden plots, seating areas, and circulation paths. These latter activities utilize surfaces that are less permeable, which limit the roof's potential for rainwater management.

Although the roof includes provisions such as drainage layers and overflow systems, this design scenario demonstrates that it is not always possible to maximize all potential co-benefits in a rooftop space. Nevertheless, careful planning and design can optimize these collective co-benefits based on the desired rooftop program.

Plan View



Roof Detail



Elevated Planter and Water Access

The **Roof Detail** illustrates an elevated planter system designed to facilitate gardening activities. The system is supported by a structural frame that raises the planter above the underlying architectural roof assembly, which helps to ensure that the membrane and insulation layers remain shielded from potential damage. Adjacent to the planter, a hose bib is strategically placed to provide easy access to water for irrigation.

APPENDIX A

Recommended Green Roof Plant List for Vancouver

TABLE OF CONTENTS

1.0 ABOUT THIS LIST

1.1 Purpose

The **Recommended Green Roof Plant List** (the Plant List) is a design resource intended to provide practitioners with information that helps advance both quality and performance when undertaking a green roof project. Specifically, the Plant List provides information about suitable plants to use on green roof projects in the Vancouver region.

Plant suitability considers factors such as ecological compatibility with our regional climate, historic performance on other rooftops in Vancouver, ability to support pollinators and enhance urban biodiversity, foster ecosystem connectivity, and provide other ecological and aesthetic benefits.

1.2 Objectives

Green roofs have been successfully constructed in Vancouver for many years. The objectives of the Plant List are to:

- Promote **education**
- Encourage designs that optimize the **multi-functional benefits and performance** of green roofs
- Help enhance the **quality and resilience** of green roofs through the major life cycle stages of design, installation, and maintenance
- Help practitioners choose plantings that support and **optimize ecological compatibility, biodiversity, aesthetics, and other project-specific requirements**

It is envisioned that this information will help lead to even more resilient and multi-functional green roofs on suitable building projects in the City of Vancouver.

1.3 What is Included

The Green Roof Plant List prioritizes **native plant** species that support pollinators and contribute to local ecosystem health, but also includes non-native species with similar benefits.

The Plant List highlights approximately 95 plants suitable for use on green roofs in the Vancouver climate. Plants are organized into four sections based on ranges of **growing medium depth**:

<150 mm

150 - 300 mm

300 - 450 mm

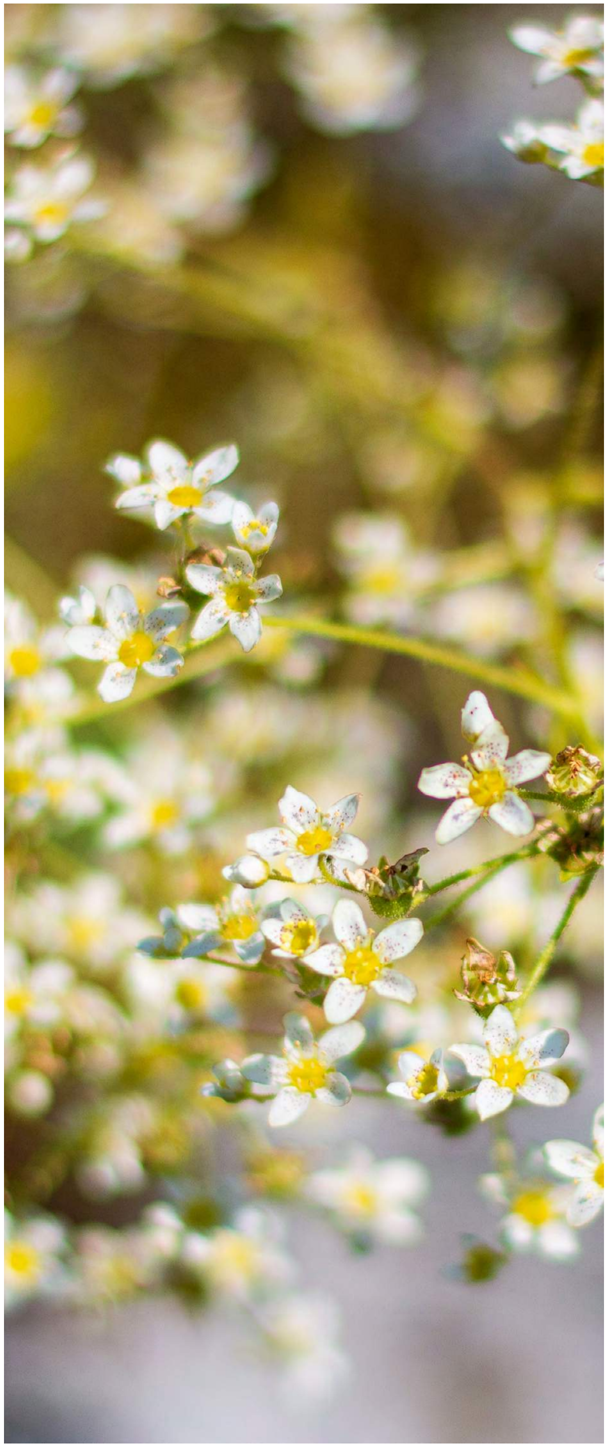
450 - 900 mm

>900 mm

For each plant, information is provided on the following characteristics:

- Photos
- Scientific Name
- Common Name
- Habit (size/ shape)
- Height
- Seasons of Bloom
- Drought Tolerance
- Host Plant
- Pollinators

The Plant List is envisioned to be used with ***Appendix B: Habitat Enhancement Guide*** to help optimize the ecological, aesthetic, and other benefits of green roof projects.



2.0 PLANT CHARACTERISTICS

2.1 Why Prioritize Native Plant Species?

Native plants are indigenous species that have evolved and occur naturally in a particular area, ecosystem, or habitat. Native plants are well-adapted to the climate and other local ecological conditions. The species in the Plant List are predominantly native to coastal BC because native plants are well adapted to (and part of) regional ecosystems, providing nourishment, habitat, and nesting opportunities for pollinators and other species.

Cultivation refers to the process of altering characteristics of plant species, such as size and growth rates, to meet human needs. Ornamental plants are non-native plants that have been cultivated and primarily introduced for aesthetic purposes. Some ornamental plants may provide few, if any, of the ecological functions provided by native plants. In general, highly cultivated plants should always be assessed for their ecological benefits before being specified for use on a green roof project.

Non-native (exotic) plants are those that have been introduced to an area where they are not naturally found. Many non-native plants also support pollinators, are resilient in drier, seasonal urban environments, and do not exhibit invasive tendencies. Yet other non-native plants do exhibit invasive tendencies. If similarly performing native and non-native species are available, this Plant List recommends prioritizing native species.

🌿 Species native to the Pacific Northwest are indicated with the following symbol in this appendix.

2.2 Growing Medium Depth

Growing medium (soil) is a material composed primarily of organic and mineral components used in plant containers, green roofs, and landscaping projects. Growing medium provides many functions, including retaining rainwater, acting as an oxygen and nutrient reservoir, anchoring plant roots, and generally supporting plant growth.

Different plant species are adapted to different growing medium depths. Soil depth is therefore an important factor to consider when choosing suitable plant species for a proposed green roof. Consequently, correct plant selection is most critical when dealing with shallow soil depths. In contrast, a green roof with more than 900 mm growing medium depth will likely accommodate plantings similar to what one might find in a garden at ground level. Although plants that are most suitable for shallow depths also perform well in deeper soils, they may be challenged by competition from larger plants.

2.3 Host Plants

Plants featured in the Plant List are also identified by their ability to host certain insects and support pollinators. These characteristics are informed by resources from Pollinator Partnership.

What is a **host plant**? Some insects require a specific plant (genus or species) to provide essential resources such as food and habitat during their life cycle. These insects are known as 'specialist species' because they can only survive in specific environments. In contrast, 'generalist species' can use a broader range of plant materials from more diverse habitats. Without their host plant, specialists and their populations will disappear. The monarch butterfly is a specialist with which many people may be familiar. Their larvae (caterpillars) feed exclusively on milkweed leaves. A number of BC's native bees and moths also require specific larval host plants to complete their life cycles. Landscapes that support specialist species will also benefit generalists (including honeybees).

2.4 Supporting Pollinators

What is a **pollinator**? A pollinator is anything that helps carry pollen from the male part of the flower (stamen) to the female part of the same or another flower (stigma). This process must occur for the plant to become fertilized and produce fruits, seeds, and young plants. Some plants are self-pollinating, while others may be fertilized by pollen carried by wind, water, insects and animals such as bees, butterflies, flies, moths, wasps, birds, and small mammals.

More than 75 percent of all the flowering plants on earth, including more than 1,200 food crops and 180,000 different types of plants, are pollinated by insects and animals. The efforts of pollinators are necessary for providing approximately one out of every three bites of food you eat.[1]

3.0 REFERENCES AND RELATED INFORMATION

3.1 List Not Exhaustive

The Plant List is not exhaustive. Where several species (spp.) in a genus are suitable, only the genus name is given (e.g., Ribes spp. for various currant and gooseberry species). spp. = various species in the genus.

3.2 Habitat Range

Many of the plants in the list have habitat ranges that extend as far south as Oregon and as far west as eastern Vancouver Island. This range was considered suitable based on its ecological similarity to the Vancouver context.

3.3 Historic Performance

Most of the plants have been observed by a variety of professionals to be successful on green roofs in Vancouver. Some of the plants are known to thrive in similar habitats, are commercially available, and provide resources for pollinators and other species.

3.4 References

The Plant List is derived from reference sources provided by research and advocacy groups that focus on green roofs and urban biodiversity. The reference sources include Pollinator Partnership[2,3], The Native Bee Society of BC[4], Oregon State University Extension Service[5], The Xerces Society for Invertebrate Conservation[6], and the Invasive Species Council of BC[7]. See ***Appendix D: Bibliography*** for more information.

RECOMMENDED GREEN ROOF PLANTS FOR **<150mm** GROWING MEDIUM DEPTH

ANNUALS

Photos

			Seasons of Bloom														
Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Clarkia amoena Godetia, Farewell-to-Spring (01)	Annual forb	0.3 - 0.5m			■	■	■							Partial shade	●	Spring bees	🌿
Collinsia parviflora Small-Flowered Blue-Eyed Mary (02)	Annual forb	0.1 - 0.4m		■	■	■								Full shade	●	Spring bees	🌿
Gilia capitata Bluefield Gilia (03)	Annual forb	0.3 - 0.6m					■	■	■				●	Full sun		Bees	🌿
Plectritis congesta Sea Blush (04)	Annual forb	0.1 - 0.6m				■	■	■	■				●	Full sun to partial shade	●	Spring bees	🌿

BUILBS / GEOPHYTES

Photos

			Seasons of Bloom														
Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Allium cernuum Nodding Onion (01)	Clumping	0.4m				■	■	■						Full sun to partial shade	●	Bees, butterflies, hummingbirds	🌿
Brodiaea coronaria Harvest Brodeiaea (02)		<0.3m					■	■	■	■				Partial shade	●	Bees, butterflies, flies	🌿
Camassia leichtlinii Great Camas (03)	Clumping	0.6 - 0.9m				■	■							Full sun to partial shade		Bees	🌿
Camassia quamash Common Camas (04)	Clumping	0.2 - 0.7m				■	■							Full sun		Spring bees Bees, butterflies	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS FOR **<150mm** GROWING MEDIUM DEPTH

PERENNIAL HERBACEOUS

Photos

			Seasons of Bloom														
Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Achillea millefolium occidentalis Western Yarrow (01)		0.3 - 0.9m					▬	▬	▬	▬	▬	▬		Full sun to partial shade		Bees, flies, moths	🌿
Armeria maritima Sea Thrift (02)		0.1 - 0.5m				▬	▬							Full sun		Yes	🌿
Fragaria chiloensis Beach Strawberry (03)	Creeping	<0.3m						▬					●	Full sun to partial shade		Bees	🌿
Fragaria vesca Wood Strawberry (04)	Creeping	<0.3m					▬	▬					●	Full sun to partial shade		Bees	🌿
Fragaria virginiana Virginia Strawberry (05)	Creeping	<0.3m				▬	▬	▬	▬				●	Full sun to partial shade		Bees, butterflies	🌿
Penstemon davidsonii Davidson's Penstemon (06)	Creeping	<0.3m						▬	▬				●	Full sun	●	Bees, hummingbirds	🌿
Penstemon serrulatus Cascade Beardtongue (07)	Creeping						▬	▬	▬				●	Partial shade	●	Bees	🌿
Sedum divergens Spreading Stonecrop (08)	Creeping							▬	▬				●	Full sun		Bees, butterflies, files	🌿
Sedum lanceolatum Lance-Leaved Stonecrop (09)	Creeping					▬	▬	▬	▬				●	Full sun		Bees	🌿
Sedum oreganum Oregon Stonecrop (10)	Creeping						▬	▬	▬				●	Full sun		Bees	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS FOR **<150mm** GROWING MEDIUM DEPTH

PERENNIAL HERBACEOUS

Photos

			Seasons of Bloom														
Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Festuca ovina vulgaris 'Quatro' Quatro Sheeps Fescue (01)	Bunchgrass	0.2 - 0.3m											●	Full sun to partial shade		Yes	
Festuca rubra Creeping Red Fescue (02)	Bunchgrass	0.3 - 0.6m											●	Full sun to partial shade		Yes	🌿
Koeleria macrantha June Grass (03)	Bunchgrass	0.3 - 0.6m											●	Full sun		Yes	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **150 - 300mm** GROWING MEDIUM DEPTH

ANNUALS

Photos


01


02


03


04


05

Scientific Name Common Name	**Habit**	**Height**	**Seasons of Bloom**										**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**					
Clarkia amoenia Godetia, Farewell-to-Spring (01)	Annual forb	0.3 - 0.5m			■	■	■							Partial shade	●	Spring bees	🌱
Collinsia parviflora Small-Flowered Blue-Eyed Mary (02)	Annual forb	0.1 - 0.4m		■	■	■								Full shade	●	Spring bees	🌱
Collomia grandiflora Grand Collomia (03)	Annual forb	0.4 - 0.6m			■	■	■	■	■					Partial shade		Bees	🌱
Gilia capitata Bluefield Gilia (04)	Annual forb	0.3 - 0.6m					■	■	■				●	Full sun		Bees	🌱
Plectritis congesta Sea Blush (05)	Annual forb	0.1 - 0.6m				■	■	■	■				●	Full sun to partial shade	●	Spring bees	🌱

🌱 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **150 - 300mm** GROWING MEDIUM DEPTH

BUILBS / GEOPHYTES

Photos


01


02


03

Scientific Name Common Name	**Habit**	**Height**	**Seasons of Bloom** **F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Allium cernuum Nodding Onion (01)	Clumping	0.43m				■	■	■						Full sun to partial shade	●	Bees, butterflies, hummingbirds	🌿
Brodiaea coronaria Harvest Brodeiaea (02)	Bunching	<0.3m					■	■	■	■				Partial shade	●	Bees, butterflies, flies	🌿
Camassia quamash Common Camas (03)	Bunching	0.2 - 0.7m				■	■							Full sun	●	Bees, butterflies	🌿

PERENNIAL HERBACEOUS

Photos


01


02


03


04

Scientific Name Common Name	**Habit**	**Height**	**Seasons of Bloom** **F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Achillea millefolium occidentalis Western Yarrow (01)		0.3 - 0.9m					■	■	■	■	■	■	●	Full sun to partial shade	●	*Bees, flies,* moths	🌿
Anaphalis margaritaceae Pearly Everlasting (02)		0.3 - 0.9m					■	■	■	■	■		●	Full sun to partial shade		Bees, butterflies	🌿
Aster alpigenus Alpine Aster (03)	Taproot, tufted	0.1 - 0.3m				■	■	■					Once established	Full sun		Bees	
Chamerion angustifolium Fireweed (04)	Rhizome	0.6 - 1.5m						■	■	■	■		●	Full sun to partial shade		Bees, butterflies, moths	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **150 - 300mm** GROWING MEDIUM DEPTH

PERENNIAL HERBACEOUS

Photos


05


06


07


08


09


10


11


12


13


14

Scientific Name Common Name	**Habit**	**Height**	**Seasons of Bloom**										**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**					
Coreopsis lanceolata Lanceleaf Coreopsis (05)	Taproot, tufted				■	■	■						●	Full sun	●	Bees, butterflies	
Echinacea purpurea Purple Coneflower (06)	Taproot, tufted	0.6 - 1.2m					■	■	■	■	■		●	Full sun to partial shade		Bees, butterflies	
Eschscholzia californica California Poppy (07)	Low-spreading	0.1 - 0.3m			■	■	■	■	■	■			●	Full sun		Bees	
Erigeron compositus Cut-Leaved Daisy (08)	Taproot, tufted	0.1 - 0.3m				■	■						●	Partial shade		Bees, butterflies, flies	🌿
Eriogonum umbellatum Sulphur Buckwheat (09)	Bunching	0.3 - 1.8m					■	■	■				●	Full sun to partial shade		Bees, butterflies, moths	🌿
Eriophyllum lanatum Wooly Sunflower (10)	Bunching	0.3 - 0.6m				■	■						●	Full sun to partial shade		Bees, flies	🌿
Fragaria chiloensis Beach Strawberry (11)	Creeping	<0.3m						■					●	Full sun to partial shade		Bees	🌿
Fragaria vesca Wood Strawberry (12)	Creeping	<0.3m					■	■					●	Full sun to partial shade		Bees	🌿
Fragaria virginiana Virginia Strawberry (13)	Creeping	<0.3m				■	■	■	■				●	Full sun to partial shade		Bees, butterflies	🌿
Grindelia integrifolia Puget Sound Gumweed (14)	Bunching	0.2 - 0.8m					■	■	■	■	■	■	●	Full sun		Bees	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **150 - 300mm** GROWING MEDIUM DEPTH

PERENNIAL HERBACEOUS

Photos


15


16


17


18


19


20


21


22


23


24

			Seasons of Bloom														
Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Grindelia stricta Entire-Leaved Gumweed (15)	Bunching	0.2 - 0.8m					■	■	■	■	■	■	●	Full sun		Bees	🌱
Monarda fistulosa Bee Balm (16)	Bunching	0.6 - 1.2m					■	■	■				●	Full sun to partial shade		Bees, butterflies, hummingbirds	
Phacelia sericea Silky Phacelia (17)	Taproot, tufted	0.1 - 0.4m				■	■	■	■				●	Partial shade	●	Bees	🌱
Penstemon serrulatus Cascade Beardtongue (18)	Creeping						■	■	■				●	Partial shade	●	Bees, butterflies, hummingbirds	🌱
Potentilla anserina 'Pacifica' Silverweed (19)	Rhizome					■	■	■	■	■			●	Full shade		Bees	
Ranunculus occidentalis Western Buttercup (20)	Creeping				■	■	■						●	Partial shade		Bees	🌱
Rudbeckia hirta Black-Eyed Susan (21)	Bunching	0.6 - 0.9m					■	■	■	■			●	Full sun		Bees, hummingbirds	
Sedum divergens Spreading Stonecrop (22)	Creeping							■	■				●	Full sun		Bees, butterflies, flies	🌱
Sedum lanceolatum Lance-leaved Stonecrop (23)	Creeping						■	■	■				●	Full sun		Bees	🌱
Sedum oreganum Oregon Stonecrop (24)	Creeping					■	■	■	■				●	Full sun		Bees	🌱

🌱 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **150 - 300mm** GROWING MEDIUM DEPTH

PERENNIAL HERBACEOUS


25


26


27

Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**
							Seasons of Bloom									
Solidago lepida Canada Goldenrod (25)	Rhizome	0.4 - 1.5m							🟨	🟨	🟨		●	Full sun		Bees, butterflies 🌿
Symphyotrichum lanceolatum White Panicle Aster (26)		0.6 - 1.5m							⬜	⬜			●	Full sun to partial shade	●	Bees, flies
Symphyotricum subspicatum Douglas' Aster (27)	Rhizome	0.5 - 1.5m						🟪	🟪	🟪			●	Full sun to partial shade		Bees, butterflies 🌿

PERENNIAL WOODY


01


02

Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**
							Seasons of Bloom									
Arctostaphylos uva-ursi Kinnikinnick (1)	Creeping				⬜	⬜	⬜						Once established	Full sun to partial shade		Bees, beetles 🌿
Thymus praecox Creeping Thyme (02)	Creeping	0.1 - 0.2m					🟪	🟪	🟪	🟪			●	Full sun		Bees

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **150 - 300mm** GROWING MEDIUM DEPTH

GRAMINOID

Photos


01


02


03


04

Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**
			Seasons of Bloom													
Calamagrostis stricta Slimstem Reed Grass (01)	Loose tuft	0.2 - 0.6m											●	Full sun		
Festuca ovina vulgaris ‘Quatro’ Quatro Sheeps Fescue (02)	Bunchgrass	0.2 - 0.3m											●	Full sun to partial shade		
Festuca rubra Creeping Red Fescue (03)	Bunchgrass	0.3 - 0.6m											●	Full sun to partial shade		🌿
Koeleria macrantha June Grass (04)	Bunchgrass	0.3 - 0.6m											●	Full sun		🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **300 - 450mm** GROWING MEDIUM DEPTH

ANNUALS

Photos

Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Clarkia amoena Godetia, Farewell-to-Spring (01)	Annual forb	0.3 - 0.5m			■	■	■							Partial shade	●	Spring bees	🌱
Collinsia parviflora Small-Flowered Blue-Eyed Mary (02)	Annual forb	0.1 - 0.4m			■	■	■							Full shade	●	Spring bees	🌱
Gilia capitata Bluefield Gilia (03)	Annual forb	0.3 - 0.6m				■	■	■					●	Full sun	●	Bees	🌱
Plectritis congesta Sea Blush (04)	Annual forb	0.1 - 0.6m			■	■	■						●	Partial shade	●	Spring bees	🌱

BUILBS / GEOPHYTES

Photos

Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Allium cernuum Nodding Onion (01)	Clumping	0.4m				■	■	■						Full sun to partial shade	●	Bees, butterflies, hummingbirds	🌱
Brodiaea coronaria Harvest Brodeiaea (02)	Bunching	<0.3m					■	■	■	■				Partial shade	●	Bees, butterflies, flies	🌱
Camassia leichtlinii Great Camas (03)	Clumping	0.6 - 0.9m				■	■							Full sun to partial shade	●	Bees	🌱
Camassia quamash Common Camas (04)	Clumping	0.2 - 0.7m				■	■							Full sun	●	Bees, butterflies	🌱

🌱: Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **300 - 450mm** GROWING MEDIUM DEPTH

PERENNIAL HERBACEOUS

Photos

Scientific Name Common Name	**Habit**	**Height**	**Seasons of Bloom**										**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**					
Lonicera ciliosa Orange Honeysuckle (01)	Trailing vine	3 - 6m				■	■	■					●	Full sun to full shade		Bees, Hummingbirds	🌿
Lonicera hispidula Pink Honeysuckle (02)	Herbaceous vine	0.9 - 1.8m					■	■	■				●	Full sun to full shade		Hummingbirds	🌿

PERENNIAL WOODY

Photos

Scientific Name Common Name	**Habit**	**Height**	**Seasons of Bloom**										**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**					
Arctostaphylos uva-ursi Kinnikinnick (01)	Creeping					■	■						●	Full sun to partial shade		Bees, beetles	🌿
Ceanothus sanguineus Redstem Ceanothus (02)	Deciduous shrub	0.9 - 3m				■	■	■					●	Full sun to partial shade		Bees, flies, moths butterflies	🌿
Holodiscus discolor Oceanspray (03)	Deciduous shrub	0.9 - 6m					■	■					●	Full sun to partial shade		Bees, butterflies, flies	🌿
Mahonia nervosa Cascade Barberry (04)	Evergreen shrub	< 0.9m		■	■	■	■							Full sun to full shade		Bees	🌿
Penstemon fruiticosus Bush Penstemon (05)	Semi-evergreen shrub	0.15m				■	■	■					●	Full sun	●	Bees	🌿
Penstemon serrulatus Cascade Beardtongue (06)	Creeping						■	■	■				●	Partial shade	●	Bees	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS FOR **300 - 450mm** GROWING MEDIUM DEPTH

PERENNIAL WOODY

				Seasons of Bloom														
Photos	**Scientific Name** Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
 07	***Ribes spp.*** Currants and Gooseberries (07)				■	■	■	■						●	Full sun to partial shade		Bees, butterflies, hummingbirds,	🌿
 08	***Ribes sanguineum*** Red-Flowering Currant (08)	Deciduous shrub				■	■	■						●	Full sun to partial shade		Bees, butterflies, hummingbirds,	🌿

GRAMINOID

				Seasons of Bloom														
Photos	**Scientific Name** Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
 01	***Calamagrostis stricta*** Slimstem Reed Grass (01)	Loose tuft	0.2 - 0.6m											●	Full sun			🌿
 02	***Festuca rubra*** Creeping Red Fescue (02)	Bunchgrass	0.3 - 0.6m											●	Full sun to partial shade		Yes	🌿
 03	***Koeleria macrantha*** June Grass (03)	Bunchgrass	0.3 - 0.6m											●	Full sun		Yes	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **450 - 900mm** GROWING MEDIUM DEPTH

PERENNIAL HERBACEOUS

Photos

Seasons of Bloom

Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Lonicera ciliosa Orange Honeysuckle (01)	Trailing vine	3 - 6m				🟧	🟧	🟧					●	Full sun to full shade		Bees, hummingbirds	🌿
Lonicera hispidula Pink Honeysuckle (02)	Herbaceous	0.9 - 1.8m					🟪	🟪	🟪				●	Full sun to full shade		Hummingbirds	🌿
Symphyotrichum lanceolatum White Panicle Aster (03)		0.6 - 1.5m							⬜	⬜			●	Full sun to partial shade	●	Bees, flies	🌿

PERENNIAL WOODY

Photos

Seasons of Bloom

Scientific Name Common Name	**Habit**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
Ceanothus sanguineus Redstem Ceanothus (01)	Deciduous shrub	0.9 - 3m				🟧	🟧	🟧					●	Full sun to partial shade		Bees, flies, moths butterflies	🌿
Holodiscus discolor Oceanspray (02)	Deciduous shrub	0.9 - 6m					⬜	⬜					●	Full sun to partial shade		Bees, butterflies, flies	🌿
Mahonia nervosa Cascade Barberry (03)	Evergreen shrub	< 0.9m		🟨	🟨	🟨	🟨							Full sun to full shade		Bees	🌿
Taxus spp. Yew species (04)	Evergreen shrub	3m											Once established	Full sun to partial shade			

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
FOR **450 - 900mm** GROWING MEDIUM DEPTH

PERENNIAL WOODY

Photos	**Scientific Name** Common Name	**Habit**	**Height**	**Seasons of Bloom**										**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
				F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**					
	***Ribes spp.*** Currants and Gooseberries (01)				▬	▬	▬	▬						●	Full sun to partial shade		Bees, butterflies, hummingbirds,	🍃
	***Ribes sanguineum*** Red-Flowering Currant (02)	Deciduous shrub				▬	▬	▬						●	Full sun to partial shade		Bees, butterflies, hummingbirds,	🍃

GRAMINOID

Photos	**Scientific Name** Common Name	**Habit**	**Height**	**Seasons of Bloom**										**Drought Tolerant**	**Sun Exposure**	**Self-Seeding**	**Pollinators**	
				F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**					
	***Calamagrostis stricta*** Slimstem Reed Grass (01)	Loose tuft	0.2 - 0.6m											●				🍃
	***Festuca rubra*** Creeping Red Fescue (02)	Bunchgrass	0.3 - 0.6m											●			●	🍃
	***Koeleria macrantha*** June Grass (03)	Bunchgrass	0.3 - 0.6m											●			●	🍃

🍃 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

DECIDUOUS

Photos


01


02


03


04


05


06


07


08


09


10

Scientific Name Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**	
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**				
Acer campestre ‘Evelyn’ Queen Elizabeth Hedge Maple (01)	10	9			🟨								Dry to Medium	Full sun	Provides shelter and nesting opportunities for butterflies, moths, pollinators and songbirds	
Acer circinatum Vine Maple (02)	4.6m	4.6m											Medium	Partial shade to full shade	Provides shelter and nesting opportunities for moths and pollinators	
Acer davidii Snakebark Maple (03)	6m	9m											Medium	Full sun to partial shade	Supports pollinators. Provides nesting opportunities for small birds	
Acer glabrum Douglas Maple (04)	3m	6m											Medium to Moist	Partial sun to partial shade	Supports pollinators. Provides nesting opportunities. Is a wildlife food source	🌿
Acer japonicum Full Moon Maple (05)	4m	5m											Moist	Partial shade to full shade	Provides shelter and nesting opportunities for songbirds. Supports a variety of insect life	
Acer palmatum Japanese Maple (06)	3m	3.5m											Medium	Full sun to partial shade	Provides shelter and nesting opportunities for moths, pollinators and songbirds	🌿
Acer tataricum ‘Hot Wings’ Hot Wings Tatarian Maple (07)	4.5m	4.5m											Dry to Medium	Full sun to partial shade	Supports pollinators. Provides shelter and perching opportunities for birds	
Aesculus x carnea ‘Briotii’ Ruby Red Horsechestnut (08)	9m	10m											Moist	Full sun	Supports bees and hummingbirds	
Amelanchier spp. Serviceberry species (09)	3m	3m			🟪								Medium	Full sun to partial shade	Fruits are attractive to birds. Approximately 120 species of butterflies and moths feed on the tree. Supports native bees.	🌿
Betula nigra River Birch (10)	12m	12m											Medium to Moist	Full sun	Provides shelter for butterflies, moths, small mammals and songbirds. Is a wildlife food source	

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

DECIDUOUS

Photos


11


12


13


14


15


16


17


18


19


20

			Seasons of Bloom												
Scientific Name Common Name	**Spread**	**Height**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**Water Needs**	**Sun Exposure**	**Habitat Value**
Carpinus betulus European Hornbeam (11)	9m	12m											Medium	Full sun to partial shade	Provides shelter for moths, small mammals, and songbirds
Carpinus caroliniana American Hornbeam (12)	6m	6m											Medium	Partial shade to full shade	Provides shelter for butterflies, pollinators, small mammals, and songbirds
Carpinus japonica Japanese Hornbeam (13)	6m	6m				🟨	🟨						Medium	Partial shade to full shade	
Cercidiphyllum japonicum Katsura Tree (14)	8m	12m				🟨	🟨						Medium	Full sun to partial shade	Supports pollinators
Cercis canadensis Eastern Redbud (15)	8m	6m				🟪							Medium	Full sun to full shade	Supports bees, butterflies pollinators, and specialized bees
Cornus alternifolia Pagoda Dogwood (16)	3m	6m				🟨							Moist	Partial shade to full shade	Supports bees, butterflies, moths, pollinators, small mammals, songbirds, and specialized bees
Cornus controversa Giant Pagoda Dogwood (17)	6m	8m				🟨							Moist	Full sun to partial shade	Supports butterflies, pollinators, small mammals, songbirds, and specialized bees
Cornus kousa Kousa Dogwood (18)	4.5m	4.5m											Medium	Full sun to partial shade	Supports bees, pollinators, songbirds, specialized bees, with wildlife cover/habitat. Is a wildlife food source
Cornus kousa var. chinensis Chinese Dogwood (19)	4.5m	4.5m											Medium	Full sun to partial shade	Supports bees, pollinators, songbirds, specialized bees, with wildlife cover/habitat. Is a wildlife food source
Cornus mas Cornelian Cherry (20)	4m	6m											Dry to medium	Full sun	Supports small mammals, songbirds, and specialized bees. Is a wildlife food source

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

DECIDUOUS

Photos	Scientific Name Common Name	Spread	Height	Seasons of Bloom										Water Needs	Sun Exposure	Habitat Value
				F	M	A	M	J	J	A	S	O	N			
 21	***Cornus x elwinortonii ‘Starlight’*** ‘Starlight’ Dogwood (21)	5.5m	4.6m							🟨				Medium	Partial shade	Supports pollinators. Is a wildlife food resource
 22	***Cornus x rutgensis ‘Stellar Pink’*** ‘Stellar Pink’ Dogwood (22)	4.5m	4.5m					🟨						Medium	Full sun to partial shade	Supports pollinators, bees and songbirds
 23	***Cornus x ‘Venus’*** ‘Venus’ Dogwood (23)	5.5m	4.6m		🟨									Medium	Full sun to partial shade	Supports pollinators and native birds. Provides nesting opportunities for small birds
 24	***Fagus sylvatica*** European Beech (24)	10m	15m			🟨								Medium	Full sun to partial shade	Is a wildlife food source
 25	**Gingko biloba** Maidenhair Tree (25)	9m	15m	🟥										Medium	Full sun	Provides shade and nesting opportunities
 26	**Gleditsia triacanthos** Honey Locust (26)	18m	18m		🟪	🟪								Medium	Full sun	Supports bees, butterflies, moths, and small mammals. Is the larval host plant for the Silver-spotted Skipper
 27	***Hammamellis x intermedia ‘Arnold’s Promise’*** Arnold’s Promise Witch Hazel (27)	3m	4m				🟨							Moist	Partial shade to full shade	Supports native bees (e.g., mining bees, bumblebee queens), and hoverflies
 28	***Koelreuteria paniculata*** Golden Rain Tree (28)	8m	8m			🟨								Medium	Full sun	Supports bees and pollinators. Is a wildlife food source
 29	***Lagerstroemia natchez*** Natchez Crape Myrtle (29)	4.5m	6m					🟨						Dry to Medium	Full sun	Supports native bees, honeybees, and butterflies. Provides perching and nesting opportunities for urban birds.
 30	***Maackia amurensis*** Amur Maackia (30)	6m	6m				🟨							Medium	Full sun to partial shade	Highly attractive to bees, especially native solitary bees and bumblebees.

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

DECIDUOUS

Photos

Scientific Name Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**			
Magnolia kobus Kobus Magnolia (31)	9m	12m							🟨				Moist	Full sun to partial sun	Supports bees and songbirds. Provides nesting opportunities for birds
Magnolia sieboldii Oyama Magnolia (32)	4m	4m					🟨						Moist	Partial sun to full shade	Supports bees (e.g. native solitary bees and bumblebees)
Magnolia x soulangiana Saucer Magnolia (33)	10m	6m		🟨									Moist	Full sun to partial sun	Provides the larval food source for saddleback caterpillar. Supports bees
Malus spp. Crabapple (34)	4.5m	6m			🟨								Medium	Full sun	Supports pollinators bees, butterflies, moths, small mammals, and songbirds
Malus x 'JFS-KW5' Royal Raindrops Crabapple (35)	4.5m	6m	🟥										Moist	Full sun	Supports native bees, honeybees, and hoverflies. Is a wildlife food source
Malus 'Schmidtcutleaf' Golden Raindrops Crabapple (36)	4.5m	6m		🟪	🟪								Moist	Full sun	Supports pollinators and birds (e.g. waxwings, thrushes, american robins). Is a wildlife food source.
Parrotia persica Persian Ironwood (37)	6m	6m				🟨							Medium	Full sun	Supports pollinators. Provides shelter and nesting opportunities for small birds.
Pistacia chinensis Chinese Pistache (38)	8m	12m			🟨								Dry to Medium	Full sun	Provides shelter and nesting opportunities for small birds. Is a wildlife food source
Prunus spp. Plum (39)	4.5m	4.5m					🟨						Dry to Medium	Full sun to partial shade	Provides wildlife shelter/ habitat. Supports bees, butterflies, pollinators, small mammals, and songbirds
Quercus palustris 'Green Pillar' Green Pillar Pyramidal Pin Oak (40)	2m	8m				🟨							Medium to moist	Full sun	Is a food source for squirrels, jays, woodpeckers, and ducks. Provides nesting opportunities for birds

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

DECIDUOUS

Photos	**Scientific Name** Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**
				F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**			
 41	***Quercus x bimundorum 'Crimschmidt'*** Crimson Spire Oak (41)	4m	13m							🟨				Medium	Full sun	Supports pollinators. Provides nesting/habitat opportunities for birds. Is a wildlife food source
 42	***Quercus x warei 'Long'*** Regal Prince Oak (42)	5m	13m					🟨						Medium	Full sun	Supports pollinators. Is a food source for birds and mammals. Provides nesting opportunities for songbirds
 43	***Robinia pseudoacia 'Frisia'*** Frisia Locust (43)	6m	9m		🟨									Dry to Medium	Full sun to partial shade	Supports bees, butterflies, hummingbirds, pollinators, and small mammals
 44	***Sorbus spp.*** Mountain-Ash (44)	2.5m	6m			🟨								Medium	Full sun	Supports birds, mammals, insects and pollinators
 45	***Stewartia pseudocamellia*** Japanese Stewartia (45)	4.5m	6m	🟥										Medium	Partial shade to full shade	Supports pollinators and bees
 46	***Styrax japonica*** Japanese Snowbell (46)	6m	6m		🟪	🟪								Medium	Full sun to partial shade	Supports pollinators, bees, hummingbirds and songbirds
 47	***Styrax obassia*** Fragrant Snowbell (47)	3m	6m				🟨							Moist	Partial shade to full shade	Provides wildlife shelter/ habitat for pollinators
 48	***Syringa reticulata*** Japanese Tree Lilac (48)	4m	6m			🟨								Dry to Medium	Full sun	Supports pollinators, butterflies and hummingbirds
 49	**Tilia tomentosa 'Sterling'** Sterling Silver Linden (49)	10m	15m					🟨						Dry to Medium	Full sun	Supports bees, butterflies, and pollinators
 50	**Zelkova serrata** Japanese Zelkova (50)	6m	12m				🟨							Medium to moist	Full sun	Provides shade and nesting opportunities for pollinators

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

EDIBLE FRUIT TREES

Photos

Scientific Name Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**			
Ficus carica 'Brown Turkey' Brown Turkey Edible Fig	3m	5m											Dry to Medium	Full sun	Supports insects, wasps and birds
Ficus carica 'Desert King' Desert King Edible Fig	3m	5m											Dry to Medium	Full sun	Supports insects, wasps and birds

BROADLEAF EVERGREENS

Photos

Scientific Name Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**			
Arbutus unedo Strawberry Tree (01)	3m	3m											Dry to Medium	Full sun to partial shade	Is a wildlife food source
Magnolia grandiflora Southern Magnolia (02)	9m	18m											Medium	Full sun to partial shade	Is a wildlife food source. Supports pollinators, small mammals, and songbirds
Magnolia virginiana Sweet Bay Magnolia (03)	4m	6m											Medium to Moist	Full sun to partial shade	Is a wildlife food source. Supports butterflies, hummingbirds, small mammals, and songbirds
Prunus lusitanica Portugal Laurel (04)	3m	6m											Medium	Full sun to partial shade	Supports butterflies. Is a larval host plant to eastern tiger swallowtail (Papilio glaucus)
Quercus ilex Holm Oak (05)	8m	8m											Medium	Full sun to partial shade	Supports pollinators and birds. Is a food source for birds.

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

CONIFERS - SMALL / MEDIUM

Photos


01


02


03


04


05


06


07


08


09


10

Scientific Name Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**			
Abies koreana ‘Horstmann’s Silberlocke’ Horstmann’s Silver Korean Fir (01)	2m	4m											Moist	Full sun	Provides shelter and nesting opportunities
Chamaecyparis obtusa ‘Gracilis’ Slender Hinoki Cypress (02)	0.8m	1.5m											Medium	Full sun to partial shade	Provides shelter and nesting opportunities
Chamaecyparis pisifera ‘Boulevard’ Boulevard Cypress (03)	0.8m	2m											Medium	Full sun to partial shade	Provides shelter and nesting opportunities
Cryptomeria japonica ‘Black Dragon’ Black Dragon Japanese Cedar (04)	1.5m	3m											Moist	Full sun to partial shade	Provides shelter and nesting opportunities
Juniperus chinensis ‘Torulosa’ Kaizuka Chinese Juniper (05)	2m	5m											Dry to Medium	Full sun	Provides food, shelter, and nesting opportunities for birds
Juniperus scopulorum* Rocky Mountain Juniper (06)	1.2m	3m											Medium	Full sun	Supports butterflies and songbirds. Provides wildlife shelter/habitat. Is a wildlife food source
Picea omorika ‘Nana’ Serbian Spruce (07)	1.2m	1.2m											Medium	Full sun	Supports birds. Provides shelter for rabbits and birds.
Pinus cembra ‘Glauca Nana’ Swiss stone pine (08)	0.6m	1.5m											Medium	Full sun	Supports moths, small mammals, and songbirds
Pinus densiflora ‘Umbraculifera’ Tanyosho Pine (09)	3m	3m											Dry to Medium	Full sun	Provides shelter and nesting opportunities
Pinus mugo Mugo Pine (10)	0.7m	0.9m											Medium	Full sun	Provides wildlife shelter/ habitat for moths, small mammals, and songbirds

*Plant height and spread will vary widely according to cultivar and species selected

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

CONIFERS - SMALL / MEDIUM

Photos	Scientific Name Common Name	Spread	Height	Seasons of Bloom F	M	A	M	J	J	A	S	O	N	Water Needs	Sun Exposure	Habitat Value
 	***Pinus parviflora 'Glauca'**** Japanese White Pine (11)	0.9m	1.8m											Medium	Full sun	Provides shelter and nesting opportunities
	Pinus uncinata Mountain Pine (12)	2m	4m											Dry to Medium	Full sun	Provides shelter and nesting opportunities for birds and small mammals. Is a wildlife food source.
	***Thuja occidentalis**** White Cedar (13)	1.2m	6m											Medium	Full sun to partial shade	Provides shelter and nesting opportunities for small mammals, and songbirds

*Plant height and spread will vary widely according to cultivar and species selected

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

CONIFERS - LARGE

Photos

Scientific Name Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**	
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**				
Abies fraseri Fraser Fir (01)	3m	9m											Medium	Full sun to partial shade	Provides shelter and nesting opportunities. Is a wildlife food source	
Callitropsis nootkatensis Yellow Cedar (02)	3m	12m											Medium	Full sun to partial shade	Provides shelter and nesting opportunities	🌿
Cryptomeria japonica 'Yoshino' Yoshino Japanese Cedar (03)	4m	12m											Moist	Full sun to partial shade	Provides shelter and nesting opportunities	
Picea abies Norway Spruce (04)	7.6m	12m											Medium	Full sun	Supports small mammals, songbirds, and moths. Provides nesting and shelter opportunities	
Picea abies 'Cupressina' Colorado Spruce (05)	4m	12m											Dry to Medium	Full sun	Provides shelter and nesting opportunities	
Picea orientalis Oriental Spruce (06)	1.2m	3m											Medium	Full sun	Provides nesting opportunities for birds and songbirds. Provides winter cover for small mammals	
Picea sitchensis Sitka Spruce (07)	6m	15m											Medium	Full sun	Provides food and nesting opportunities for small mammals, songbirds, and eagles	🌿
Pinus cembra Swiss Stone Pine (08)	6m	15m											Dry to Medium	Full sun	Supports moths, small mammals, and songbirds. Provides nesting and shelter opportunities	
Pinus contorta Shore Pine (09)	6m	6m											Low / Dry	Full sun	Is a wildlife food source. Provides nesting opportunities for many birds, small mammals, and butterflies	🌿
Pinus nigra Black Pine (10)	6m	12m											Medium	Full sun	Supports moths, small mammals, and songbirds	🌿

🌿 : Species native to Pacific Northwest

RECOMMENDED GREEN ROOF PLANTS
TREES <900mm GROWING MEDIUM DEPTH

CONIFERS - LARGE

Photos


01


02


03

Scientific Name Common Name	**Spread**	**Height**	**Seasons of Bloom**										**Water Needs**	**Sun Exposure**	**Habitat Value**
			F	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**			
Pinus sylvestris Scotch Pine (11)	9m	9m											Medium	Full sun	Supports moths, small mammals, songbirds. Provides wildlife shelter/habitat. Is a wildlife food source
Sciadopitys verticillata Umbrella Pine (12)	4.5m	6m											Medium	Full sun	
Thuja plicata Western Red Cedar (13)	4.5m	15m											High / Moist	Full sun to partial shade	Provides food, shelter and nesting opportunities for wildlife 🌱

🌱 : Species native to Pacific Northwest

APPENDIX B

Habitat Enhancement Guide

TABLE OF CONTENTS

1.0 ABOUT THIS DOCUMENT

1.1 Purpose

The **Habitat Enhancement Guide** (the Guide) is a design resource intended to provide practitioners with information that helps advance both quality and performance when undertaking a green roof project. Specifically, the Guide provides information to help create purposeful designs that enhance habitat and biodiversity on green roof projects in the Vancouver region.

Biodiversity is the variety and abundance of living organisms on the planet. Habitat and biodiversity are important because they provide the foundation for a healthy, habitable, and resilient environment that provides humans with, for example, spiritual experiences, food, and other benefits (*see* ***Section 2.0 Why is Biodiversity Important?*** *for more information*). When properly designed, green roofs can help offset habitat loss and support biodiversity.

1.2 Objectives

Green roofs have been successfully constructed in Vancouver for many years. The objectives of the Habitat Enhancement Guide are to:

- Promote **education**.
- Encourage designs that optimize the **multi-functional benefits and performance** of green roofs
- Help enhance the **quality and resilience** of green roofs through the major life cycle stages of design, installation, and maintenance
- Help practitioners develop habitat designs with associated plantings that support and **optimize ecological compatibility, biodiversity, aesthetics, and other project-specific requirements**.

It is envisioned that this information will help lead to even more resilient and multifunctional green roofs on suitable building projects in the City of Vancouver.

1.3 What is Included

The Habitat Enhancement Guide includes information that helps address the topics stated under Purpose and Objectives and was primarily developed by industry professionals. Content is informed by a bibliography of relevant literature (see ***Appendix D: Bibliography***).

The Guide is organized into six sections and includes content on the importance of biodiversity, designing for biodiversity, and how to support specific species on green roofs in Vancouver.

Section 2 provides an overview of ecosystem services, the benefits we gain for those services, and how biodiversity helps to enhance those ecological, social, and economic benefits.

Section 3 discusses the concepts of local and novel ecosystems, and the biodiversity design objectives for green roofs.

Section 4 discusses designing for specific species, with particular consideration given to birds, native bees, other pollinators, and other insects.

Section 5 contains the habitat enhancement guidelines, which emphasize growing media (depth, topography, and composition), vegetation diversity, and habitat structures.

The Habitat Enhancement Guide is envisioned to be used with the **Recommended Green Roof Plant List** (see ***Appendix A***) and the **City of Vancouver Bird Friendly Design Guidelines** to help optimize the ecological, aesthetic, and other benefits of green roof projects.

2.0 WHY IS BIODIVERSITY IMPORTANT?

2.1 Background

Ecosystems contain biotic (living) organisms and abiotic (non-living) components that are linked together through nutrient cycles and energy flows. Examples of ecosystems at different geographic scales include ponds, coral reefs, wetlands, forests, and the earth itself.

2.2 Ecosystem Services

Ecosystems provide essential supportive, regulating, provisioning, and cultural ecosystem services. Supportive services are necessary for the production of other ecosystem services. Regulating services include the benefits obtained from regulation of ecosystem processes.

Provisioning services are the products obtained from ecosystem services. Cultural services include the non-material benefits obtained from ecosystems.[1] Examples include:

Supportive
- Soil formation
- Nutrient storing and cycling
- Primary production of organic material (foundation of species' food chains and all other life on earth)

Regulating
- Pollination of crops and other plants
- Water purification
- Regulation of climate, disease, and the water cycle

Provisioning
- Food, Fresh water
- Fuelwood, Fiber
- Biochemicals, Genetic material

Cultural
- Spiritual and religious, Heritage
- Recreation, Ecotourism
- Aesthetic, Inspirational, Education

Maintaining ecosystem health and the services they provide are critical for the survival of life on earth.

2.3 Biodiversity

Within a particular habitat or ecosystem, **biodiversity is the variety and abundance of living organisms, including plants, animals, fungi, and microorganisms**.

A more biodiverse ecosystem is better able to generate various ecosystem services that provide human societies with, as example, a habitable environment, food, construction materials, medicinal plants, and other items. A more diverse environment also contributes to enhanced spiritual and aesthetic experiences.

Greater biodiversity also contributes to enhanced ecosystem stability and resilience when confronted with various natural or human-induced disturbances such as fire, floods, drought, or loss of habitat from land development. Stronger and more frequent disturbances from anticipated changes in our climate make maintaining or enhancing biodiversity even more relevant.

Finally, the various plants, animals, and other organisms that make up our environment have value in their own right, regardless of the use they may provide to humans.

Canada is one of 193 nations that signed the Convention on Biological Diversity (CBD) and is therefore committed to "effective and urgent action to halt the loss of biodiversity".[2]

At present, however, "[d]windling [species] population sizes and range shrinkages amount to a massive [human] erosion of biodiversity and of the ecosystem services essential to civilization".[3]

3.0 GREEN ROOFS DESIGNED FOR BIODIVERSITY

3.1 Background

In this era of urbanization and biological impoverishment, **green roofs should be seen as small ecosystems on buildings that provide several benefits** such as improving air quality, managing rainwater, reducing urban heat, providing or complementing amenity space, and increasing access to nature.

Green roofs are also suitable as habitats for many animal and plant species that are able to access and survive on roofs. A network of green rooftops in a hard urban landscape can soften the visual impacts of the built environment, provide habitat, and support biodiversity.

Designing green roofs for biodiversity includes small but intentional adjustments that can align with the constraints of the structure and may not require additional cost. For example, introducing a diversity of substrates or growing media can create habitat for ground-nesting bees and spiders. Including dead wood can create habitat for arthropods that provide food for birds and other organisms. Including perches on rooftops can attract birds by providing places for resting, preening, and hunting.

3.2 Learning from Sedums

The idea of designing green roofs to enhance biodiversity arose from the knowledge that shallow, non-Sedum-dominated vegetated roofs can support greater diversity than conventional Sedum-dominated vegetated systems. Various forms of wildlife will respond positively to variations in growing medium (composition, depth, and heterogeneity), vegetation (diversity, cover), and habitat provisions (e.g., structures providing opportunities to bask, perch, hide, nest). **Green roofs designed to enhance biodiversity provide nesting habitat and food sources for spiders, bees, and birds**.

3.3 Learning from Local Habitats

Early designers of extensive green roofs in BC referred to habitat templates, or comparable local habitats in nature, for guidance on plant selection. Today, many of those native plant species are still used on green roofs.

The vegetation on extensive green roofs in the Vancouver region grow in conditions comparable to those experienced in the rocky and exposed ecosystems of south-western BC.

Examples of these ecosystems include:

1. Coastal bluff
2. Garry oak and associated ecosystems
3. Low-elevation montane

These ecosystems share similar or common habitat elements, including open and exposed growing conditions with minimal to no tree cover, predominantly mineral soils, slow rates of decomposition, high floral diversity of herbaceous plant species, and associated biodiversity.

Urban ecosystems are not able to fully recreate native habitat. However, if designed correctly, they can create the conditions to support native species.

3.4 Biodiversity Design Objectives

Green roof projects that include biodiversity enhancement should consider various contextual factors, including the capacity for a site to support habitat, the threats to natural habitat in the surrounding area, mitigation concerns, relevant government policies, and the personal interests of the designer or building owner.

Biodiversity enhancement can adopt different objectives, each of which may vary in terms of site assessment and design complexity. Some examples of biodiversity objectives include:

- Enabling natural colonization
- Enhancing general ecosystem function
- Creating a specific plant community
- Providing habitat for a specific species
- Supporting adjacent ecosystems

4.0 DESIGNING FOR SPECIFIC SPECIES

4.1 Background

Green roofs can be designed to attract and support specific birds and insects, whether they are native, rare, or passing through along a migration route. Research programs in Switzerland demonstrate that green roofs can even compensate for the lost habitat used by rare and endangered species[4,5,6].

Some spiders, beetles, grasshoppers and bees that are stenoecious, meaning they can only live in a restricted range of habitats, have also been found to establish populations on green roofs. However, the majority of organisms that utilize green roofs will use it as a stepping stone for foraging (looking for food) rather than nesting.

This section refers to specific (desired) animal groups that are mobile and that can colonize and establish populations on green roofs.

Three groups are discussed: 'Birds', 'Native Bees and Other Pollinators', and 'Other Insects'.

4.2 Birds

4.2.1 Overview

Although the principal reason that birds visit green roofs is to forage, many ground-nesting birds will also inhabit green roofs. Green roofs designed for biodiversity can host high densities of invertebrates in otherwise impoverished urban landscapes. Although green roofs cannot replace ground-level green spaces, many elements can be incorporated into the design that benefit migratory and breeding birds.

When designing green roofs for birds, some considerations include:

- **Native plants are best** - They co-evolved with native invertebrates and therefore host far more invertebrates than non-native plants.
- **Diversity of habitats adds richness** – Greater diversity of habitat types means more invertebrates, and more food for birds.
- **Roof surroundings** - The abundance and richness of birds using a green roof will relate to its location within the landscape (i.e., a green roof adjacent to a large park with high-quality habitat may not be as beneficial as one isolated within the urban landscape).
- **Roof size** - Larger areas increase available habitat, and diversity of habitat, which supports different species (and their interactions), and increases biodiversity.

4.2.2 Foraging and Migrating Birds

At certain times of the year, over a billion birds migrate past Vancouver along the Pacific Flyway. Such feats of migration require significant amounts of energy. When the birds make their brief stopover, they need food (usually invertebrates) to replenish their fat reserves for the next leg of their journey. Since most migratory birds travel at night, they are inevitably drawn to the light of the cities that have been built along this route.

Much of the foraging habitat that migratory birds previously found in the Vancouver area has been replaced by streets, sidewalks, and conventional roofs. Green roofs can help fill this ecosystem gap created by urbanization.

4.2.3 Ground-Nesting Birds

Ground-nesting birds will use green roofs to build their nests if certain crucial elements are provided that enable their offspring to survive the harsh rooftop conditions. These elements include:

- Water
- Shelter/refuge (from sun, predators)
- Food (invertebrates)

A 6-year study observed that a ground-nesting bird, the lapwing (*Vanellus vanellus*), used extensive green roofs for nesting but that the hatched chicks would not have the means to survive without the provision of water and nourishment.[4] Survival was improved by providing permanent sources of fresh water in small basins placed within the green roof growing media (and replenishing as necessary), and by planting flowering plants that attracted insects to the roof.

Small, simple shelters were also provided for chicks to find respite and protection from the sun and from birds of prey.

4.2.4 Bird-Friendly Building Design

Creating habitat for birds should be accompanied by offsetting any risks posed by the building. Windows and glass railings can be fatal to birds. Bird collisions with glass are a serious problem that continues to contribute to the alarming decline of birds in North America.
Bird collisions can be prevented by making glass visible to birds. Although products like single-bird decals do not work, a range of available products have been field-tested and are proven to reduce collisions. Some considerations include:

- Cover glass with a pattern spaced apart by 2 inches or less (as birds will try to fly through larger spaces).
- Bird-safe films (many of which look like small stickers) can be applied to the exterior of existing glass to prevent collisions. These films can be visible (like Feather Friendly or Solyx) or invisible to humans, but visible to birds because of ultraviolet properties (like Bird Divert).
- Glass products with built-in bird-safe properties are available and, as with the films, can be visible or invisible to humans.
- Any product used to reduce collisions should have an assigned Threat Factor of 30 or less (as tested by the American Bird Conservancy).

4.2.5 Undesirable birds

In Vancouver and its surrounding region, **crows are considered some the most destructive birds to newly planted green roofs**. Whether playing or searching for food, crows will remove plugs and examine other plantings. Given the size of Vancouver's crow population, the damage can be significant when large numbers descend on a new installation, which is common during the non-breeding season (i.e., autumn through spring).[7]

Methods to prevent removal of plugs may include pinning the plugs down using simple tools like chopsticks or metal irrigation pins (**with extra care not to damage the waterproofing membrane**).

In addition to physical methods, multi-sensory electronic systems (amplified sound and lasers) have been shown to reduce the interest of crows in treated locations. Amplifying recorded sounds, such as the call of a predatory bird (e.g., peregrine falcon) and the distress calls from ravens and crows, makes birds uneasy. Combining the sounds with lasers, to which many birds are strongly averse, and using a timer that targets dawn, dusk, and other random periods, was found to reduce crow damage on a new green roof installation at BCIT[7].

Other birds considered to be undesirable are not necessarily destructive (or are only destructive at certain times) to green roofs. For example, Canada geese and gulls will use green roofs, but only become a nuisance through territorial behaviour when nesting. Chemical methods, in the form of repellent sprays, have been used to repel geese. However, it should be ensured that any chemical methods are strictly organic, not toxic to humans or wildlife, and adhere to all applicable laws.

Visual deterrents, like coyote decoys, can be effective for goose control, especially when the decoy is moved periodically.

4.3 Native Bees and Other Pollinators

4.3.1 Overview

A pollinator is anything that helps carry pollen from the male part of the flower (stamen) to the female part of the same or another flower (stigma). This process must occur for the plant to become fertilized and produce fruits, seeds, and young plants. Pollination is an essential ecosystem service, both to agriculture and nature. There are many pollinators in BC, including bees, flies, moths, beetles, wasps, butterflies and birds.

The province of BC has over 600 species of native bees, as well as the largest diversity of butterflies (187 known species) in Canada. Native bees are crucial pollinators, yet are declining worldwide. Given that they are highly mobile, can visit a range of flowers (polylectic), and are adapted to using separate nesting and foraging resources, **green roofs can play a particularly useful role in helping to maintain native bee populations**.[8]

Food type	Resource provided
Flowers	Nectar (high in sugar and necessary amino acids, important for a healthy diet)
Flowers	Pollen (high in protein, important for a healthy diet)
Flowers	Pollen for offspring (pollen specialists rely on specific plant genera or species for their young)
Fallen fruits	Food for bees, beetles and butterflies
Specific host plants	Essential for the larvae (caterpillars) of certain pollinators, especially butterflies

Table B.1 Different types of forage material provide different food resources. Adapted from Pollinator Partnership.[8]

Most native bees are solitary, and all of them nest in tunnels or burrows. The vast majority have brief lives focused on provisioning for offspring they will never meet. Native bees do not produce honey, nor do they build hives. In contrast, honeybees, which are classified as livestock, produce honey and build hives. Studies increasingly recognize that honeybees out-compete native bees for habitat and forage.[9] Green roofs designed to enhance habitat and biodiversity should therefore consider prioritizing the needs of native bees.

4.3.2 Generalist and Specialist Pollinators

When designing a green roof as a pollinator meadow, it is important to understand the difference between generalist and specialist pollinators. Specialists require a specific 'host' plant (genus or species) to complete their life cycle, without which they will disappear. Many butterflies and moths, for example, require specific host plants at their larval stage. In contrast, generalists (including honeybees) can use whatever plant material is available. Landscapes that support specialist bees also benefit generalists, who have less restricted floral palates.[9]

Given that bees are highly mobile and can forage for flowers vertically between green roofs and at ground level, they are presumed to benefit more from green roofs than other insect species.[10]

4.3.3 General Design Considerations

When designing green roofs for native bees and pollinators, some considerations include:

- **Cultivated Plants** – Plants provide nourishment and living spaces for pollinators. Some plants provide essential habitat while others do not. While some cultivated forms are advantageous for bees and other pollinators, **highly cultivated forms should be assessed for their ability to provide environmental benefits** before being utilized in a green roof project.
- **Foraging and Nesting Resources** – **Research has found that bees respond well to green roofs designed to provide both foraging and nesting resources**. Structurally heterogeneous vegetation (i.e. plants that varies in size and shape) has been shown to support greater species richness of invertebrates, especially bees.[11,12] In Chicago, a survey comparing bee communities on six green roofs, six parks, and six prairie sites found that the green roof planted with native prairie species had the higher recorded individual bees and bee species, and also had the higher plant diversity than other green roofs that were studied.[12]
- **Suitable Growing Media and Wild Ground-Nesting Bees** – While ground-nesting wild bees have been found in greater abundance than above-ground nesting bees on green roofs, research has yet to confirm if wild bees actually nest on green roofs. Bees observed foraging on green roofs may be actually nesting in the surrounding landscape.[13] Nevertheless, if suitable soil is provided, it is likely that **wild ground-nesting bees typically found in urban areas might use green roofs for nesting**.
- **Diverse Plant Palettes** – **Bees need pollen and nectar throughout the season, so diverse plantings are most valuable because they prolong blooming periods in a garden**. By contrast, near-monoculture Sedum roofs only flower for a short period. Extensive green roofs are often synonymous with Sedum roofs, as these succulent plants can tolerate shallow, mineral soils, frequent drought, and no shade. These systems will support taller herbaceous species, too, and diversifying to create a Sedum meadow can benefit both the roof's resilience and the pollinators who might visit. During periods of extended drought, the succulents will flourish, while wetter periods will promote the forbs and grasses. Diversifying functional plant types in this way can provide more blooms and microclimates throughout the season, while also benefiting bees.
- **Native vs. Non-Native Sedums** - BC is home to several native Sedums that grow well on green roofs, and which are the essential host plants for some butterflies (e.g., Moss' elfin). However, non-native Sedums are more readily available, especially for pre-grown systems. Like all choices, the use of non-native Sedums has consequences. Observations of an experimental green roof in downtown Toronto suggested that **native bees may be disadvantaged in cities with a prevalence of Sedum-dominated green roofs** because exotic bee species were observed to collect significantly greater loads of Sedum pollen.[14]

4.3.4 Habitat Characteristics that Encourage Nesting

In contrast to honeybees (which are non-native), native bees do not use hives, nor do they make honey. Of BC's 600+ native bees, 70% build their nests in the ground and 30% nest in cavities (e.g., pithy stems, wood).[9]

Most pollinators have very small home ranges, especially small bees. However, bees and pollinators do get around, sometimes traveling surprising distances. Consequently, they will likely find and investigate any constructed habitat. Whether these pollinators will remain depends on the characteristics of the nesting habitat, including both materials and space.

Cavity-nesting bees will use plants with hollow stems to over-winter and to raise their progeny (offspring). Some plants have hollow, pithy stems that can be easily excavated (e.g., *Helianthus* spp., *Rosa* spp., *Rubus* spp., *Sambucus* spp., *Symphoricarpos* spp., as well as *Sedum telephium* 'Autumn joy'). Cavity-nesting bees build their nests in trees, shrubs, logs, and grasses. To create their brood cells, they require mud, resin, and leaves.

Ground-nesting bees need sandy and patchy soil, free from excessive maintenance or pesticide application. They will construct burrows or tunnels under thatched ground or at the base of bunchgrasses, which provide shelter and workable soil. They will re-purpose abandoned rodent burrows and bird nests.

Finally, although **grasses and sedges** are wind-pollinated, they also provide food and nesting opportunities. As mentioned previously, bunching species, such as native bunch grasses, are particularly useful for providing nesting and shelter for some ground-nesting bees. In addition, some bunching species serve as larval host plants for native butterflies and moths.[15] Numerous butterflies and moths also rely on native bunch grasses and sedges for their life cycles.

4.3.5 Forage

The term "forage" refers to food supply. Bee forage consists of nectar and pollen from blooming plants within flight range. To benefit native bees and other pollinators, meadows must provide forage that is nutritious, diverse, nearby, timely, and non-toxic. As shown in ***Table B.1***, different types of forage material provide different food resources. Note that many of these resources can be provided by flowers.

4.4 Other Insects

Insects are at the base of complex ecological food webs in agricultural, natural, and urban areas, and are therefore crucial to ecosystem and biosphere function. **Beyond pollination, insects provide critical ecosystem services** like:

- Nutrient cycling and decomposition (springtails, millipedes, beetles)
- Predation of pest species (spiders, solitary wasps, dragonflies and damselflies)
- Food for other species (like birds)

Some species, particularly those soil-dwellers important for nutrient cycling and decomposition can be permanent inhabitants of green roofs. Planning for their survival can ensure that their populations can colonize and persist.

5.0 HABITAT ENHANCEMENT GUIDELINES FOR GREEN ROOFS IN VANCOUVER

5.1 Background

Three design factors are important for creating biodiverse green roofs:

- Varying the depth, topography, and composition of the growing medium
- Diversifying the vegetation
- Using habitat structures to create niche spaces for organisms

5.2 Depth, Topography, and Composition of Growing Medium

Greater growing medium depth allows for a wider range of plant species, which can help enhance biodiversity on a green roof. However, the additional weight of the growing medium may require enhanced structural support and associated costs.

Alternatively, varying the growing medium depth (and surface topography) can also help enhance biodiversity, but with relatively less weight, structural support, and associated costs. Deeper depths can also be potentially aligned with roof sections that can support additional load. For example, **mounds are comprised of both shallow and deep growing medium areas, which create different micro climates that support different micro habitats.** Whereas shallow areas are suitable for the establishment of sparse vegetation, deeper areas may be more suitable for taller, denser vegetation (***Figure B.1***).

Varying the composition of the growing medium can also enhance biodiversity. For example, diversifying the granule sizes in the substrate or adding additional patches of different substrate types (e.g., sand, gravels) can benefit organisms that require places to bask in the sun, bury themselves, or build underground burrows for their young. The vegetation-free zones that serve as fire breaks or surround maintenance access points may also support similar habitat requirements for some organisms, provided this activity does not undermine the function of these zones.

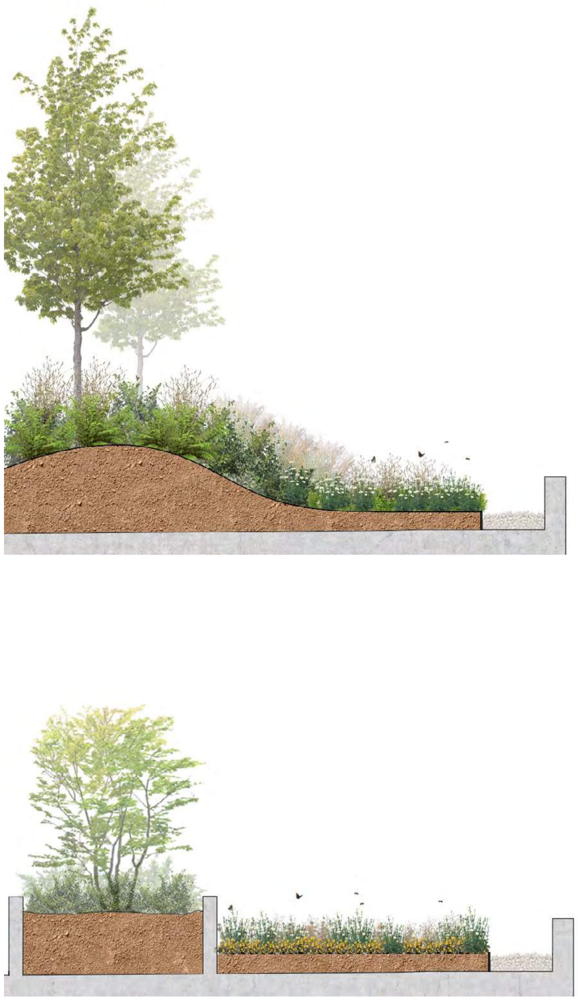


Figure B.1 - Varying growing medium depth can help enhance biodiversity on a green roof.

5.3 Vegetation Diversity

Plants are important for enhancing biodiversity. Diversifying vegetation involves increasing both plant species and plant forms (succulents, herbaceous perennials, woody plants, coniferous, deciduous. etc.). Vegetation diversity increases the opportunities for activities such as pollination, obtaining food and nutrients, nesting, perching, and finding shade. Intensive green roofs are generally better for enhancing biodiversity because they can accommodate deeper growing medium depths, which can support a wider range of vegetation types and sizes, including trees and shrubs. Nevertheless, extensive green roofs can also enhance biodiversity by supporting important habitat without woody species, such as meadows and grasslands.

Extensive green roofs are commonly planted with succulent Sedums, sometimes involving very few species or cultivated types. Keeping monocultures healthy generally requires careful maintenance and monitoring. **If a green roof was installed with pre-grown Sedum products (tiles, modules), there are ways to enhance biodiversity by diversifying the vegetation**. Vancouver has some very successful examples of Sedum roofs that were also planted with herbaceous perennials at the time of installation. Coastal BC is also fortunate to have several native species from the genus Sedum (see ***Appendix A: Recommended Green Roof Plant List for Vancouver*** for more information).

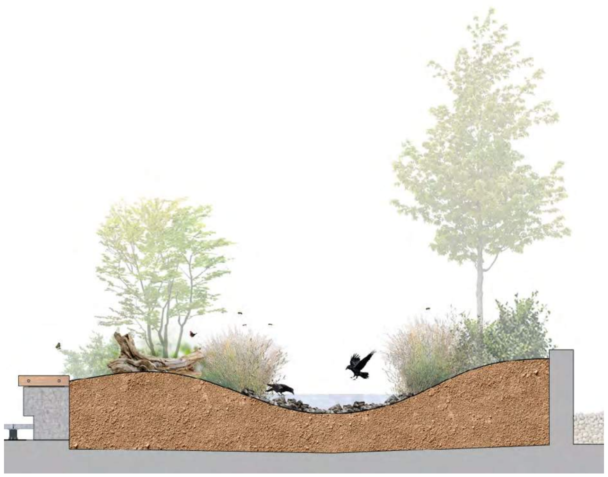


Figure B.2 - Water features can help diversify plant species on a green roof and provide havens for birds, pollinators and insects that depend on water sources for survival.

WHY USE NATIVE SPECIES?

Studies in Canada demonstrate high survival rates for native species on non-irrigated green roofs, highlighting their suitability for regional climate extremes. Diverse varieties of birds, butterflies and animals, have similarly adapted to using native plant species and are attracted by their presence on a green roof. [16]

5.4 Habitat Structures and Niche Spaces

The inclusion of natural elements such as wood, piles of stones, or sandy patches can attract species to utilize a green roof as habitat. **Such features will help to create microclimates and microhabitats, which can be important places of refuge during periods of extreme heat or drought**. Tree or shrub branches can provide shade, physical connections, resting sites and perches for birds, and habitat for the invertebrates that some birds feed on.

Pre-fabricated structures, like nesting boxes for bats, birds, and bees, can be added to encourage species to nest and breed on the roof. However, such boxes should only be installed with the assurance that they will be diligently maintained. Otherwise, these structures may become breeding grounds for pathogens and disease.

BALANCING BIODIVERSITY TARGETS WITH PLANT NEEDS

While maximizing the variety of plant species can increase biodiversity, it is also helpful to group plants with similar requirements such as drought tolerance, nutrient levels, and growing medium acidity together in a given planted area. This approach will help improve plant maintenance activities and plant survivability.

APPENDIX C

Glossary

Biodiversity
The variety and abundance of living organisms in a particular habitat or ecosystem, including plants, animals, fungi, and microorganisms, which contributes to ecosystem stability and resilience. It includes organisms in both marine and terrestrial ecosystems within the City of Vancouver.

Combined Sewer Overflow (CSO)
The discharge of untreated sewage and stormwater from a combined sewer system into a water body when the capacity of the sewer system is exceeded during heavy rainfall or snowmelt.

Dead Load
The static, permanent load exerted by the weight of a structure, including its own weight and the weight of fixed components such as walls, floors, and roofs.

Electronic Leak-Detection (ELD)
A method of detecting leaks in waterproofing membranes or containment systems using electronic sensors or detectors to identify areas of moisture intrusion and potential water damage.

Evapotranspiration
The combined process of water evaporation and transpiration. Evaporation is the process that changes water from a liquid to a gas (vapour). It typically occurs from soil surfaces, the groundwater table, and from bodies of water like lakes and the oceans. Transpiration is the process where plants take up liquid water from the soil and release water vapour from their leaves.

Extensive Green Roof
Vegetated roof assemblies characterized by their relatively shallow growing medium (soil) depth, which supports a plant diversity usually consisting of sedums, perennials and wildflowers.

Extensive roofs are typically not designed with human access in mind. Water retention, urban heat reduction, and maintenance may be relatively lower compared with intensive green roofs.

Their relatively lower weight does not require significant structural support enhancements, which makes them suitable for most new buildings, and particularly suitable when retrofitting existing buildings. Irrigation may not be required (see also Intensive Green Roof and Semi-intensive Green Roof).

Green Rainwater Infrastructure (GRI)
An approach to managing light and intermediate rainstorm intensities that emphasizes the use of natural and engineered systems such as trees, green roofs, bioswales, and permeable pavements to capture, absorb, and treat rainwater close to its source.

GRI systems help to improve air and water quality, reduce heat impacts, and enhance biodiversity and habitat. GRI can also provide other benefits such as complementing amenity, childcare, and urban agricultural spaces, increasing access to nature, and expanding educational opportunities.

Green roofs and other GRI are so useful because they mimic nature and are therefore multifunctional.

Green Roof Program
A framework that reflects the scale and budgetary constraints of the larger development project and defines the objectives, uses, and functions of a green roof. The program guides decisions related to design, installation, and ongoing maintenance, focusing on optimizing resources while meeting project goals. Green roof programming objectives, uses, and functions emphasized in this document include rainwater management, habitat and biodiversity, social amenity space with human access, and urban agriculture.

Growing Medium
A material composed primarily of organic and mineral components used in plant containers, green roofs, and landscaping projects to retain rainwater, act as an oxygen and nutrient reservoir, anchor plant roots, and generally support plant growth. Growing medium and media (plural) are used interchangeably in this document.

Habit
Habit refers to the general appearance, form, shape, and size of a plant species. Examples include ‘arborescent’ (tree-like), ‘shrubby’, ‘climbing’, and ‘trailing’ (spreading along the ground).

Host Plant
Some insects require a specific plant (genus or species) to provide essential resources such as food and habitat during their life cycle. These insects are known as ‘specialist species’ because they can only survive in specific environments. In contrast, ‘generalist species’ can use a broader range of plant materials from more diverse habitats.

Without their host plant, specialists and their populations will disappear. The monarch butterfly is a specialist with which many people may be familiar. Their larvae (caterpillars) feed exclusively on milkweed leaves. A number of BC’s native bees and moths also require specific larval host plants to complete their life cycles.

Integrated Photo-voltaic Green Roof
Integrated photovoltaic green roofs, also called “biosolar” green roofs, combine vegetated roof assemblies with photo-voltaic solar panels on a shared roof space. If photo-voltaic solar panels become too hot, they become less efficient.

Green roofs can also help increase renewable energy production by cooling the ambient temperature of rooftops and providing a more suitable operating climate for the panels.

Intensive Green Roof
Vegetated rood assemblies characterized by their relatively deep growing medium (soil) depth, which supports a greater plant diversity usually consisting of shallow vegetation, bushes, shrubs, and even small trees.

Intensive roofs are typically designed with human access in mind. Water retention, urban heat reduction, and maintenance may be relatively higher compared with extensive green roofs.

Their higher saturated soil weight usually requires structural support enhancements, which is a consideration to be assessed against enhanced social and ecological benefits. Irrigation is likely required (see also Extensive Green Roof and Semi-intensive Green Roof).

Irrigation
The artificial application of water to growing medium or vegetation to supplement rainfall and maintain optimal moisture levels for plant growth and landscape maintenance.

Live Load
The dynamic and temporary load exerted on a structure by moving or variable forces, such as occupants, furniture, equipment, and environmental conditions.

Mass Timber
A type of engineered wood product made from large solid wood panels or beams, such as cross-laminated timber (CLT), glued-laminated timber (glulam), or laminated strand lumber (LSL). Mass timber is used for high-rise buildings and sustainable construction.

Perennials
Herbaceous plants that live for multiple years, often returning each growing season from their root systems. They come in a variety of forms, including grasses, flowers, and groundcovers. In contrast, Annuals live for only one year.

Photo-voltaic (PV) Panel
A device that generates renewable energy by using semiconductor materials to convert sunlight into electricity.

Pollinator
A pollinator is anything that helps carry pollen from the male part of the flower (stamen) to the female part of the same or another flower (stigma). This process must occur for the plant to become fertilized and produce fruits, seeds, and young plants.

Some plants are self-pollinating, while others may be fertilized by pollen carried by wind, water, insects and animals such as bees, wasps, moths, butterflies, birds, flies and small mammals, including bats.

More than 75 percent of all the flowering plants on earth, including more than 1,200 food crops and 180,000 different types of plants, are pollinated by insects and animals. The efforts of pollinators are necessary for providing approximately one out of every three bites of food you eat.

Rainwater Run-Off
When rain falls onto the ground, it soaks into the soil, is absorbed by plants and trees, evaporates into the air, or flows along the surface as rainwater runoff to receiving water bodies. Rainwater run-off that flows over impermeable surfaces such as pavement picks up pollutants and can contribute to flooding and erosion, lower water quality, and harm aquatic life.

Rainwater Run-On
The rainwater that is collected from surrounding surface areas and redirected onto a specific area, or into a storage layer or tank.

Rainwater Detention
The temporary storage and controlled release of excess rainwater on-site to prevent flooding and reduce the associated impact on downstream areas. Detention may be achieved with soils, green roof growing medium, blue-green roof shallow water reservoirs, detention basins, or tanks. Detention practices slow down but do not reduce the volume of water leaving a site and entering a sewer system.

Rainwater Retention
The temporary storage and use of rainwater on-site. Retention may be achieved with trees, plants, and other GRI such as green roofs (evaporation, transpiration), retention ponds (evaporation, ground infiltration) and cisterns (reuse). Retention practices reduce the volume of water leaving a site and entering a sewer system.

Retrofit
The process of upgrading or modifying existing roof structures to incorporate green roof components and features. This may involve adding layers of waterproofing membranes, drainage systems, growing medium, and vegetation to an already existing roof surface.

Roof Structure
The framework or support system of a building's roof, including beams, trusses, rafters, and joists, which provides stability and distributes loads to the building's walls.

Sedum
A genus of flowering plants that are often characterized by their succulent leaves and low-growing, spreading habits. Sedums are valued for their ability to thrive in harsh environmental conditions, including poor soil quality and drought.

Sedums provide several ecological benefits such as absorbing carbon dioxide and other air pollutants, promoting biodiversity by attracting pollinators, and contributing to rainwater management. Non-sedum dominated vegetated roofs with greater plant variety may enhance overall biodiversity.

Semi-Intensive Green Roof
Hybrid vegetated roof assemblies that can include both extensive and intensive sections with associated ranges of growing medium depth, plant diversity, and other characteristics. A broad plant diversity usually consists of sedums, perennials, wildflowers, shallow vegetation, bushes, shrubs, and even small trees.As with Intensive Green Roofs, structural reinforcement is a consideration to be assessed against enhanced social and ecological benefits. Irrigation is likely required (see also Extensive Green Roof and Intensive Green Roof).

Shrubs
Woody plants characterized by multiple stems and typically reaching heights ranging from several centimeters to several meters. They encompass a wide variety of species and offer diverse ecological benefits, including providing habitat and food sources for wildlife, improving air quality, and supporting tree health.

Urban Agriculture
The practice of growing and distributing food within urban areas that enables community members to grow their own produce, learn about agriculture, shorten food supply chains and reduce carbon emissions, contribute to food security, participate in community interaction, and create a connection to nature. Examples of urban agriculture include larger-scale urban farms, community gardens and orchards, smaller gardening plots, farmers markets, processing and composting facilities, and rooftop gardens and farms.

Urban Forest
The collection of trees and vegetation within an urban area, including parks, green spaces, street trees, and private gardens, which provides environmental, social, and economic benefits to the community.

Urban Heat Island Effect
The urban heat island (UHI) effect occurs when trees and other natural landscapes are replaced by buildings and surfaces that absorb, retain, and emit relatively more energy from the sun, causing ambient temperatures to rise beyond typical values in surrounding areas. These temperature increases can result in thermal discomfort, increased building energy demands for cooling, and conditions that can affect the survivability of plants, insects and animal species. Climate-related challenges such as droughts and extreme heat are anticipated to magnify this issue.

Wood Frame
A construction method commonly used in residential and light commercial buildings where the structural framework, including studs, joists, and beams, is primarily made of wood.

APPENDIX D

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