CITY OF VICTORIA STORMWATER UTILITY

Rainwater Management Standards

Professional Edition

JUNE 2015

CITY OF VICTORIA

Disclaimer:

If you are intending to undertake rainwater management work, it is recommended that you read through all relevant sections within the Rainwater Management Standards before deciding to move forward. These standards have been developed for use only by Qualified Designers and Qualified Professionals.

This manual will be updated on a regular basis as standards and regulatory requirements change or evolve. Where bylaws, policies, codes, standards, and other documents are referred to within this manual, the most recent edition or amendment applies.

If you are reviewing a printed copy of this document, please check with the City to ensure it is the most current version.

FOR MORE INFORMATION:

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Part 1: Rainwater Management Overview

Approximately 660 mm of rain falls in Victoria every year. In urban settings like Victoria, the natural water cycle is broken when rainwater hits roofs, streets, sidewalks, parking lots and other impervious surfaces.

Rainwater turns into stormwater runoff once it hits paved surfaces. It picks up pollutants, debris and grit. Runoffis also created from activities like washing cars or watering lawns.

The City's stormwater system collects this water through catchbasins and drains. Underground pipes then carry it to the nearest body of water: a creek, an inlet or, in most cases, the ocean. Stormwater has a large impact on water quality, specifically along shorelines and within our harbour.

The stormwater system works to reduce flooding by moving stormwater away from properties and roadways. Large objects and debris are separated in the stormwater system and some of the oil and grit are filtered out. Generally, the quality of the stormwater that enters the system is the same quality that eventually flows into waterways. If the stormwater runoff is polluted it impacts the aquatic and near-shore habitat, environment, and users of that space.

Design Goals

Rainwater management helps to maintain or restore natural water cycles and use rainwater as the resource that it is. The goal is to use rain gardens, green roofs, bioswales and other similar rainwater management methods to slow and clean the rainwater, either capturing it for use in irrigation or within buildings in 'purple pipe' or grey-water systems, or slowly diffusing it back to the natural water table.

By managing rainwater more sustainably, we will:

- Have cleaner water that is discharged to our harbour and beaches,
- Reduce the peaks of runoff that can stress and overwhelm the existing stormwater and increase our climate change resiliency, and
- Expand property owner's understanding of the local water cycle and their interactions with it.

Rainwater Management Planning Tool

A Rainwater Management Planning Tool has been developed to help property owners or their representatives visualize what rainwater management methods may fit on their property. This tool will provide approximate sizing, approximate installation costs and the potential Rainwater Rewards available. The Tool also displays a property's approximate Stormwater Utility bill. Try it out at **victoria.ca/stormwater**.

Rainwater Management Design Target

The rainwater management target for the design standards, based on Victoria's rainfall data, is 32 mm in a 24-hour period. This means that 32 mm of rain on impervious surfaces must be captured and treated in order to meet the requirements of the City's Rainwater Rewards Program. This target is based on managing approximately 90% of Victoria's average annual rainfall in accordance with guidance from Fisheries and Oceans Canada.

How To Use This Document

The Rainwater Management Design Standards for Professionals are a planning and design tool to provide property owners, land developers, or their representatives with the information necessary to properly meet the requirements of the City of Victoria's Rainwater Rewards program.

These Rainwater Management Standards also provide guidance on selecting appropriate rainwater management methods for a site and designing the method so that it meets the City's rainwater management target and can be approved under the Rainwater Rewards program. See Appendix A - Rainwater Rewards Pre-Approval Guide for the information on what is required for approval. Checklists for each rainwater management method have also been developed to help achieve this, and are located in Appendix B.

This document provides guidance for professionals designing and constructing rainwater management methods who need to understand how to meet the City standards for rainwater management methods and to ensure qualification in the Rainwater Rewards program.

This document walks through the steps for design and construction of rainwater management methods, and also allows for variations by Qualified Professionals or Designers.

The City of Victoria has prepared a separate Do-It-Yourself version of the Rainwater Management Standards for low density residential properties (with one to four units). These DIY standards may be used on low density residential properties by property owners or professionals who do not meet the City's definition of "Qualified Professionals" or "Qualified Designers". The DIY design and construction process is simplified and allows for fewer variations but is essentially the same process as for Qualified Professionals.

Rainwater Rewards Process

The overall design process is shown below. These steps are the same, no matter who is doing the design.

Table 1: Rainwater Rewards Process	
Site Assessment	• Use the Site Assessment Checklist in section 2.2 • Identify and measure impervious areas such as pavement and roof area. • Locate discharge points, roof leaders, building sump, storm drain connection, etc. VicMap and its Rainwater Management Planning Tool are a great place to start. • Review terrain for high and low points, direction of water flow. • Note any issues or hazards to be avoided, e.g. trees, unstable soils, steep slopes, bedrock, underground services (pipes or cables) or structures, or boggy areas.
Review the Site Selection Considerations	• Are there ground surface areas where runoff could be routed to methods for water quality treatment? • Can your terrain and landscape accommodate a rainwater management method? • Is there impervious surface that can be converted to permeable paving? Can additional roof or surface area discharge to it? • Is there space for a cistern (above or below ground) where roof water can be directed to it? Do you have a use for collected rainwater? • Could an infiltration chamber be located below yard or pavement where rain garden or swale on the surface cannot be accommodated?
Talk to the City	• Contact the City of Victoria Stormwater Specialist to review your rainwater management ideas and property layout, **stormwater@victoria.ca**; 250.361.0443. • Ask about: zoning restrictions, permitting, inspections, Rainwater Rewards.
Create a Rainwater Management Design for your Property	• Select method(s) and location(s) for site. • Choose standard DIY design or a professional for design (see Table 4: Can this Project be DIY). • If DIY, create a design specific for your property based on the Rainwater Management Standards - Do-It-Yourself for Your Home. • If using a contractor, talk to them about construction constraints. • Notify home insurance company of plans and discuss any concerns. • Size method according to City of Victoria standards. • Refer to Appendix A - Rainwater Rewards Pre-Approval Guide. • If not using standard design, Qualified Professional can develop site-specific design based on parameters in City of Victoria's *Rainwater Management Standards Professional Edition.*
Pre-Approval	• Submit design and completed steps from Appendix A: Rainwater Rewards Pre-Approval Guide to City and obtain all necessary permits and/or approvals prior to construction, including eligibility for the Rainwater Rewards Program.

Table 1: Rainwater Rewards Process	
Construction	• Refer to Appendix B: Installation Checklists • Construct in accordance with requirements outlined in this document and construction best management practices. • Obtain city inspections/approvals as required. • Submit final documents for Rainwater Rewards approval.

Maintenance	• Plan your regular maintenance, including:
	  • landscaping maintenance;
	  • cleaning of sumps;
	  • vacuuming or pressure washing of pervious paving;
	  • checking piping, valves or other parts if possible; and
	  • checking for signs of failure during small rain events.

Rainwater Rewards	Receive Credit and/or Rebate!

Rainwater Rewards

As part of the Stormwater Utility, the City of Victoria has developed a rainwater management incentive program called Rainwater Rewards. Property owners or their representative may apply for credits of up to 40% of the property's stormwater utility charges on an on-going (annual) basis. The value of the incentives vary depending on the amount of rainwater treated, by the effectiveness of the management method, and by property type. Incentives vary for different accepted rainwater management methods and for different types of land uses. Rainwater Rewards available by property type are as follows:

Low density Residential (1–4 dwelling units)

- Eligible for a 10% rainwater management credit
- Accepted rainwater management methods may qualify for significant rebates

Multifamily Residential (5+ dwelling units)

- Eligible for up to 40% rainwater management credit

Civic and Institutional

- Eligible for up to 40% rainwater management credit
- May use Education in conjunction with rainwater management methods for up to an additional 10% credit for a site.

Commercial and Industrial

- Eligible for up to 40% rainwater management credit
- May use Education in conjunction with rainwater management methods for up to an additional 10% credit for a site

For up-to-date details on the Rainwater Rewards program, and how to apply, please go to the City of Victoria website at **victoria.ca/stormwater**.

Introduction to Rainwater Management Methods

Rain Barrels and Cisterns

Rain barrels and cisterns can be used to collect rainwater for reuse. The larger the storage system is, the more water can be used and kept out of the stormwater system. The water collected is non-potable, but can be used to water gardens and lawns or indoors in toilets and urinals. In Victoria, most of the rain falls in the spring and autumn, but the watering needs are highest in the summer so it is beneficial to have a larger storage capacity if the stored water is to be used for irrigation of landscape or garden areas.

- Rain Barrels: A rain barrel is a specialized container, connected to the downspout from a building that is designed to collect and store rainwater for reuse. Rain barrels are only eligible for incentives for low density residential properties (one to four units) under the Rainwater Rewards Program.
- Cisterns: Cisterns or holding tanks collect rainwater and have a larger storage capacity than rain barrels. They can be elevated above ground, placed at ground level or buried underground. Cisterns can be connected to an irrigation system or 'purple pipe' system for indoor use.

Infiltration Chambers

Infiltration chambers are underground tanks or chambers with permeable bottoms that are designed to slowly release water into the ground over time. They primarily act to slowly return rainwater to the natural water table. This water is not reused.

Rain Gardens

A rain garden is a shallow depression that uses soil and plants to manage runoff from hard areas such as roofs, parking lots and driveways. Rain gardens mimic nature by absorbing and filtering stormwater runoff. A rain garden fills up with water and forms a temporary "pond" of stormwater. It naturally filters out the pollutants in the stormwater as the water soaks down through the soil of the rain garden.

The plants and a layer of absorbent soil can hold and evaporate a significant amount of rainwater as well as allow the stored water to slowly seep into the ground. A rain garden can enhance the look of a home or business as it is a landscape feature as well as a rainwater management method.

Permeable Paving

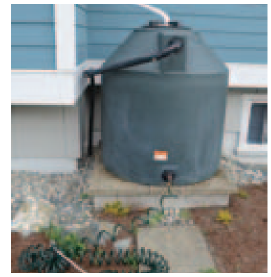
Permeable paving is hard surfacing specifically designed to allow rain to flow through the surface and into the soil below. To increase the volume of runoff that can be directed to the pavers, they can be installed with a drainage pipe and rock reservoir underneath. Permeable paving can be used instead of standard asphalt and concrete for surfacing sidewalks, patios, driveways, or parking areas. It can add character to your site while maintaining access and durability for vehicles and foot traffic.

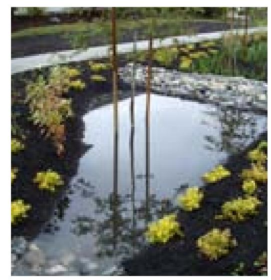
Bioswales

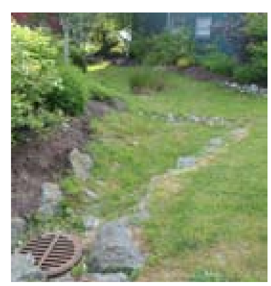
Bioswales are sloped channels that are designed to clean and slow the runoff coming from a roof or driveway. There are a number of different types of bioswales, including grassed channels, dry swales and wet swales. They all use absorbent soil and plants to absorb, filter and infiltrate runoff. As with rain gardens bioswale plantings often include native plants or plants that are drought resistant and can also handle large amounts of water. A bioswale helps to move stormwater from one area to another, while also slowing and cleaning the stormwater.

Green Roofs

A green roof is a specially designed garden that has been planted on top of a waterproof membrane on a roof. Green roofs slow rainwater runoff from the roof, while absorbing and evaporating some of the rainwater. Green roofs also provide many secondary benefits, including space for gardening, and insulation which can reduce heating costs and cooling costs for the building and extending the life of the waterproof roof membrane.







Images top to bottom: rain barrel, cistern, infiltration chamber, rain garden, permeable paving, bioswale

Green roofs are classified into two categories:

- Extensive green roofs have a shallow soil profile of 100 mm (4") to 150 mm (6") and support shallow-rooted plants such as mosses, grasses and sedums;
- Intensive green roofs with soil depths greater than 150 mm (6") are able to support shrubs, trees, vegetables, etc. Increasing the depth of absorbent soil increases the retention capacity.

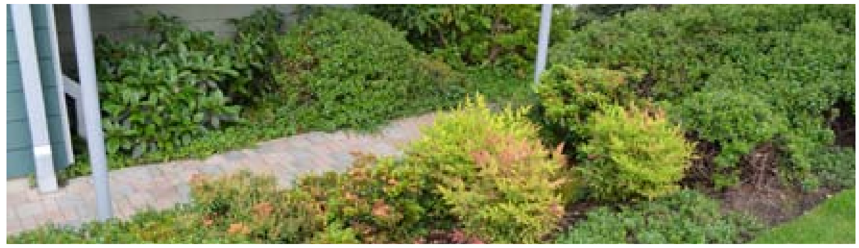
Education

Institutional, civic (not schools), commercial, and industrial properties may be eligible for education credits of up to 10%:

- 5% credit for educating the public through signage describing the rainwater management method(s) they've installed.
- 5% credit for educating employees through annual information sessions (videos, facilitated discussions, literature, and/or presentations relating to the rainwater management method(s) they've installed.

Schools may be eligible for a 10% credit when they incorporate stormwater and rainwater education into their curriculum.

Details relating to the educational components required for acceptance in the Rainwater Rewards program can be found **victoria.ca/stormwater**.


Part 2: Rainwater Management Planning and Site Selection

2.1: Planning for Rainwater Management

Selection of Rainwater Management Methods

As noted in Part 1, the rainwater management methods currently accepted by the City for Rainwater Rewards Program include:

- Rain barrels (Rainwater Rewards only available for low density residential properties);
- Cisterns;
- Rain gardens;
- Bioswales;
- Infiltration chambers;
- Permeable paving;
- Green roofs; and
- Education programs (not a rainwater management method, but may qualify for incentives under the Rainwater Rewards program).

This section discusses the uses of each of these types of rainwater management methods and gives information to help in selecting the methods that are appropriate and beneficial to a particular site.

Once the appropriate methods are selected and locations chosen for a site, detailed sizing and design information may be found in Part 4. It is possible that sizing requirements for specific methods will preclude their use on individual sites due to space limitations. If this is the case for a selected method, the process should return to the selection stage, and another method should be selected.

Note that all rainwater management methods must have an overflow connection to the municipal stormwater system to receive overflow. A backflow preventer may be required on the overflow pipe in accordance with the City's Plumbing Bylaw.

Rain Barrel Site and Selection Considerations

- Rain barrels are only approved for Rainwater Rewards for low density residential lots in the City of Victoria. Other sites may use them but they will not qualify for Rainwater Rewards.
- A typical residential rain barrel design includes an opening in the sealed lid to accept downspout flow, an overflow pipe for when the barrel is full, and a spigot at or near the bottom to attach a hose or faucet. A screen at the opening controls mosquitoes and other insects. Rain barrels can be connected in series to store more rainwater.
- Locate rain barrels on a flat surface next to or near roof downspouts.
- Only collect roof water for reuse. Do not reuse water from parking or pedestrian areas, surface water runoff, or bodies of standing water.
- Roof material can impact the end use of the water collected in your rain barrel or cistern. Currently, no water quality standards for roofing types exist, and few roofing products carry water quality test information. Individual roof products vary. It is important to be mindful that any chemical treatment of a roof, such as moss inhibitors, could be harmful to plants.

Cistern Site and Selection Considerations

- Cisterns must be located where roof water can be directed to the tank. Only collect roof water for reuse. Do not reuse water from parking or pedestrian areas, surface water runoff, or bodies of standing water.
- Flat, stable surfaces must be provided to support the tank and designed for the weight of the tank when full of water. Underground cisterns require flat, stable subgrade, but no constructed base other than crushed rock.
- A cistern is possible in areas where infiltration methods may not be feasible such as steep or hazardous slopes, bedrock, high water table, or contaminated soils.
- An elevated cistern requires design by a qualified professional.
- Cisterns must be connected to the municipal stormwater system for overflow or to a properly designed rainwater management method with an overflow connection to the stormwater system.
- A cistern should only be used where there is a use for the water, enabling the tank to be emptied. This may include irrigation of landscaping or re-use for toilet flushing where there is a consistent demand through the wet season of the year.
- If using the rain water within a building, a professional is required to design and install the required "purple pipe" system.
- Cisterns must meet the setback requirements that apply to the main building within that particular zone. For example, in the R1-B zone (single family dwelling), a cistern can be located as follows:
  - 7.5m (minimum) from the front or rear property line
  - 1.5m from the side yard property line
- Collectively, the total surface area of the buildings, cistern and other structures on a property must not exceed the maximum site coverage permitted in the zone. For example, in the R1-B zone (single family dwelling), the maximum total site coverage is 40%.
- Rain barrels (less than 1,200 litres) do not have setback requirements or site coverage limits.
- Cisterns may not be located on a required parking space. Please check Schedule C of the Zoning Bylaw to determine the required parking for a particular zone. For example, in the R1-B zone (single family dwelling), there must be at least 1 space per dwelling unit.
- Cisterns should be located in an area to minimize any potential negative visual impacts. Other ways to lessen these impacts, such as screening, can be utilized. Screening guidelines are located in Appendix C.
- Roof material can impact the end use of the water collected in your rain barrel or cistern. Currently, no water quality standards for roofing types exist, and few roofing products carry water quality test information. Individual roof products vary. It is important to be mindful that any chemical treatment of a roof, such as moss inhibitors, could be harmful to plants.

Rain Garden Site and Selection Considerations

- Where surface space is available, rain gardens provide the best stormwater treatment value of the methods presented here, and can increase the value of property due to the aesthetic value of the landscaping.
- Rain gardens are utilized for volume capture and stormwater treatment. Treatment is provided by the soil layer and volume capture by infiltration from the rock reservoir.
- A rain garden and bioswale have similar design and functions. A rain garden or series of rain gardens provides more capture of peak flows (due to ponding and plant uptake) and less conveyance of non-captured flows than a bioswale.
- The rain garden must be planted with species adapted to periods of flooding as well as summer drought conditions. Covering the bottom of the rain garden with only river rock/gravel is not acceptable.
- Where space is extremely tight, a straight-sided rain garden, sometimes called a "planter-style" rain garden may be used. This is more expensive as the vertical sides must be formed and supported by a concrete curb or wall. If required, a rain garden can be constructed as a non-infiltration (also called a "flow-through") facility (professional design only).
- Rain gardens can be any shape, including irregular or "organic" shapes.
- Rain gardens should be located where runoff from impervious areas can be directed to them either by overland flow or by pipe. If possible, ground surface impervious areas that are used by vehicle traffic such as driveways and parking lots should be directed to rain gardens in preference over roof areas if the rain garden cannot be large enough to accommodate runoff from both roof and ground surface areas.
- Rain gardens are generally trapezoidal in cross-section, and the flat bottom area or "base area" is used as the measure of the rain garden's size. The area required for side slopes is additional to the base area and the total area including base area and side slopes must be considered for fitting a rain garden into a site.
- The base area of a rain garden should be flat, so it may be difficult to fit a rain garden on a sloped site. A series of "stepped" rain gardens with weirs between them may be used on mild slopes (< 10%). This is similar to a bioswale, but includes deeper ponding and is not designed for conveyance of flows.
- Rain gardens should be situated to minimize crossing utilities as the underground trenches can become conduits for infiltrated water. If it is necessary to cross a utility trench, low-permeability trench dams must be used.
- In order to allow ponding in the rain garden, the outlet or overflow should be raised above the bottom of the rain garden. Plantings or rocks may be used to improve the look of the outlet.
- Rain gardens should be located or designed to not have foot traffic through the rain garden, if possible.
- Rain garden plantings require care and watering until they are established, generally the first 1 to 2 years post installation. Irrigation water must be available for this, even when the plantings are intended to be drought tolerant.

Bioswale Site and Selection Considerations

- Bioswales provide conveyance of runoff as well as treatment and infiltration and may be used in place of a rain garden to allow water to move across a site.
- Bioswales are generally linear in shape, though the width may vary and they may curve if there is space available on the site.
- Bioswales provide less treatment per area than rain gardens and require a larger area to meet the City's Rainwater Management Target.

Infiltration Chamber Site and Selection Considerations

- Infiltration chambers should be used where infiltration is desired and possible but surface area for rain gardens or bioswales is restricted, not available, or not wanted. Typically, infiltration chambers are located below lawn or pavement areas.
- Infiltration chambers may not be located below buildings.
- Infiltration chambers are best used to infiltrate roof runoff, which is generally cleaner than ground surface runoff.
- Inflow to the infiltration chamber is generally through a sump to pre-clean the rainwater before entering the infiltration chamber, reducing the maintenance and extending the lifespan of the system. This may be a standard household sump or a larger sump for a nonresidential site.
- Inflow may also be through a lawn basin, which is a grate-topped sump located in a grassed area.
- The perforated underdrain pipe below the surface must be connected to the municipal stormwater system.
- Infiltration chambers are easier to fit within a site than rain gardens or bioswales as they do not take up surface area, however, they tend to require a larger footprint than rain gardens and are more expensive to construct.

Permeable Paving Site and Selection Considerations

- Different types of permeable paving have different considerations, including ease of construction and cost of installation.
- Permeable paving may be used for any ground surface location that would otherwise be paved with traditional asphalt or concrete. Some types of permeable paving, particularly open-grid systems where a structural grid is filled with gravel or grass, should only be used where there is light vehicle or moderate foot traffic. Traditional gravel driving surfaces and conventional installations of concrete unit pavers are not considered permeable.
- Only Low Density Residential driveways may use planting/driving strips where two strips of traditional impervious concrete are placed to support vehicle wheels and surrounded by grass.
- Manufacturers' instructions for use and installation should be followed for all types of permeable paving and should be considered when choosing a permeable paving option.
- To maximize accessibility for people using mobility aids, sidewalks or other areas using permeable paving should be permeable concrete or asphalt, or interlocking permeable pavers with gaps between blocks of less than 1 cm (0.5 cm preferred).
- Additional impervious area may be directed to permeable paving areas that have been designed with an underdrain so that the additional runoff is treated and infiltrated. Runoff from ground surface impervious area should flow on the pavement surface (sheet flow) to the adjacent permeable paving area so that runoff and pollutants are spread over the area and not concentrated in a small section.
- Runoff from roofs may be connected directly to the perforated pipe underdrain below the permeable paving, or may be discharged to the permeable paving surface in a safe location where the discharge is directed away from the building and will not cause a safety hazard in freezing conditions.
- The overflow connection to the municipal stormwater system will be below the permeable paving and connected to the perforated pipe underdrain. It is not necessary to have a surface overflow.
- Permeable paving should be situated to minimize crossing utilities as the underground trenches can become conduits for infiltrated water. If it is necessary to cross a utility trench, low-permeability trench dams must be used.
- Unless designed specifically as a permeable paver, other types of concrete unit pavers will not be eligible for Rainwater Rewards.

Green Roof Site and Selection Considerations

- Green roofs must be designed by a qualified professional and are not eligible for Rainwater Rewards or recommended for use on Low Density Residential homes.
- Green roofs are suitable for flat or nearly flat roofs. They are not recommended for sloped roofs.
- Green roofs are easiest to design for new construction but may also be retrofitted. A structural engineer must verify that the building structure and roof structure can support the saturated weight of the green roof.
- Building insurance may be a concern for a green roof. Any property owner considering a green roof should contact their insurer to discuss it before initiating any design.
- Some green roof manufacturers and installers provide a warranty for the materials and/or installation. Such warranties allow only specifically approved installers to work on the green roof.
- Green roof plantings require care and watering until they are established, generally the first 1 to 2 years post installation. Access and irrigation to the roof must be available for this.
- Aesthetic value of a green roof is much more significant when the green roof can be seen from taller neighbouring buildings or other vantage points.
- If the structure can support it, intensive green roof plantings and resident or public access can provide much-needed green space and garden space in the dense urban environment.

Table 2: Site Feasibility for Rainwater Management Methods

	Land Use								Suitable for Difficult Sites			Allowable Water Source					Effectiveness		Land Use	
Rainwater Management Method	Low Density (DIY)	Low Density (Professional)	Multifamily Strata	Civic/Institutional	Commercial/Industrial	Parking Lot	Suitable for Retrofit	Limited Land Availability	Steep Slopes	High Water Table	Shallow Soils Over Bedrock	Roof Water	Parking Areas	Pedestrian Areas	Overland Flow – Ground Surface	Piped Flow – Ground Surface	Flow Control	Water Quality	Low Density (DIY)	Low Density (Professional)
Rain Garden	●	●	●	●	●	●	●	○	■	■	■	●	●	●	●	●	●	●	○	○
Rain Garden Raised Planter	■	■	●	●	●	■	●	○	■	■	■	●	●	●	■	●	●	●	○	○
Bioswale	■	■	●	●	●	●	●	○	■	■	■	●	●	●	●	●	●	●	○	○
Permeable Pavement	●	●	●	●	●	●	●	○	■	○	○	○	○	○	○	○	●	●	○	■
Green Roof	■	■	●	●	●	■	■	●	●	●	●	■	■	■	■	■	●	○	■	■
Infiltration Chamber	●	●	●	●	●	■	●	●	○	■	■	●	○	●	■	●	●	○	○	■
Cistern	●	●	●	●	●	■	○	○	●	●	●	●	○	●	■	●	■	■	■	■
Rain Barrels	●	●	■	■	■	■	●	●	●	●	●	●	■	■	■	■	■	■	■	■

Application and Suitability

- ● Most Appropriate
- ○ May be used if opportunities exist
- ■ Not Appropriate/Applicable

Effectiveness

- ● High
- ○ Medium
- ■ Low

Strategies for Rainwater Management In Constrained Sites

Strategies to Accommodate Methods in Limited Space

- Land is a significant cost in the City of Victoria. Integrating rainwater management methods into the overall design of a project when there is an opportunity to do so as part of a larger project or re-development effort makes the best use of limited space on a site and budget.
- Use required landscape areas for rainwater management – make rain gardens and bioswales at the site periphery and in courtyards, rather than mounded landscape areas.
- Consider that even formal, straight-sided urban planters can be designed as rain gardens.
- Design parking medians as infiltration areas rather than raised landscaping.
- Drain small paved areas into small rainwater management methods rather than try to fit a single large method on-site.
- Install permeable paving. Permeable paving of several types is highly suitable for pedestrian areas, overflow parking, and main parking areas.
- Place infiltration chamber or cistern underground, under paved or lawn areas.
- Allow surface storage. Temporary ponding on the surface of rain gardens is approximately three times more efficient than underground storage in a drain rock reservoir due to the volume of space taken up by the rock.
- Develop raised planters as rain planters (flow through planters) for on-slab construction. Note: These systems are not outlined in this document, must be designed and installed under the supervision of a professional to qualify for Rainwater Rewards.
- Install green roof, either intensive or extensive, to provide rainwater management on buildings with flat roofs and parkades.

Strategies When Infiltration is Undesirable

- For areas where infiltrated water could cause geotechnical concerns, or where contaminated soils are known to be, use cisterns that re-use rainwater for irrigation or indoor “purple pipe” systems.
- Some methods can be designed as flow-through facilities that provided filtration but not infiltration, including rain gardens and bioswales (see note in previous section).
- For pavement areas sloping toward the building, use permeable pavement or intercept runoff using a catch basin or a linear drain and pipe runoff to a downslope facility to prevent impacts to foundation drains.
- Install green roof, either intensive or extensive, to provide rainwater management on buildings with flat roofs and parkades.

2.2: Site Assessment

The goal of a site assessment is to identify opportunities and information used to select, plan, design, and construct rainwater management methods.

Site Assessment Checklist

The following is a list of site features that should be identified to help assess the site and the suitability of different methods. A good starting point may be to use the Rainwater Management Planning Tool or VicMap. Both can be accessed at **victoria.ca/stormwater**.

- ☐ Identify the project site's high and low elevation points and note the general flow path of water across your site;
- ☐ Identify soil characteristics (e.g. well or poorly draining, sandy or clayey), rock outcrops, and terrain breaks, including retaining walls;
- ☐ Determine downspout and storm drain connection locations;
- ☐ Determine roof outline, delineate roof areas feeding each downspout, and note water flow direction across roof areas;
- ☐ Delineate all driveway, patio, parking, sidewalk and other impervious (hardscape) areas and identify drainage paths and discharge points of the hardscape areas;
- ☐ Note wet areas; and locations known to collect water (typically in the winter months);
- ☐ Note surface discharge to or from adjacent lots and if any water flows onto your site from a neighbour's property during rainy periods;
- ☐ Note location of municipal stormwater main nearest to property (usually fronting) using VicMap;
- ☐ Note the location of all utilities (may include underground pipes such as water, sewer, and gas, and cables and overhead wires) and other underground infrastructure from VicMap or by calling BC OneCall;
- ☐ Note existing tree locations to avoid, including protected or significant trees (see City of Victoria's Tree Preservation Bylaw);
- ☐ Location of steep slopes (>15%)
- ☐ Location of shoreline/natural boundary edges and associated setback requirements;
- ☐ Location of any Statutory Rights of Way from property survey and/or VicMap; and
- ☐ Landscaping and other features that may influence the selection and design of on-site rainwater management.
- ☐ Identify any setbacks required based on property's land use zone.

Figure 1: Site Assessment Example

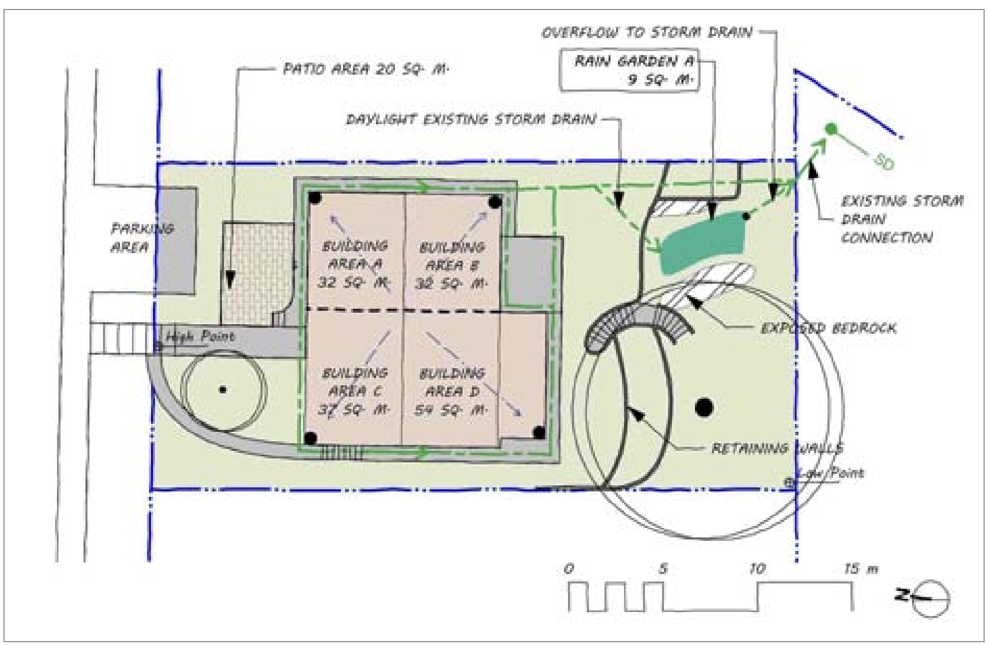
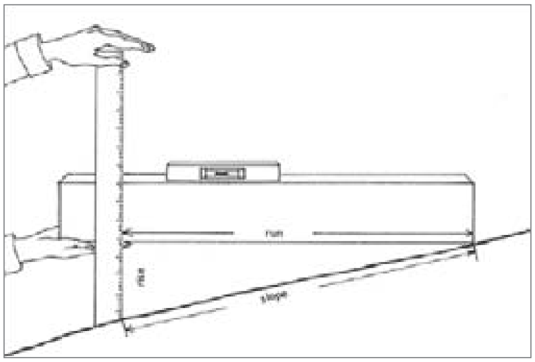


Figure 2: How to Measure a Slope



A site assessment may involve estimating, measuring and testing to better understand conditions on site; for example:

- Measuring areas of impervious (hardscape) and pervious (landscape) surfaces – this may be done with tape measure or with a scaled site plan (if available) or by using the Rainwater Management Planning Tool available online at **victoria.ca/stormwater**;
- Estimating site slope – this requires a measurement of elevation drop (rise) over the length of the slope and measurement of the distance (run) for that drop (see illustration). Slope = rise ÷ run x 100%; and
- Testing soil infiltration capacity – see below.

Subsurface Soil Testing

This document assumes an infiltration rate of 2 mm/hr. If desired, a percolation test may be performed and the test must be documented, including the conditions under which it was performed, and the results for submitted to the City. The percolation test procedure is outlined in Appendix D.

If percolation rates are more favorable than those assumed in this document, it may be possible to alter the design of rainwater management methods to reflect the tested percolation rate, as described in each methods' section.

If the property has shallow bedrock, this test does not apply (see Site Constraints).

Site Constraints and Considerations

Site constraints are identified at the site assessment stage. Some constraints prohibit proceeding with certain types of rainwater management methods and other constraints can be addressed or overcome with proper planning and design strategies. This may require involvement of a qualified professional.

Example: The management of rainwater runoff must carefully consider site conditions as well as adjacent off site conditions, particularly where slope instability might be cause for concern or where the water table is high. Recharging shallow groundwater near bluffs and steep slopes may increase slope instability, or recharging groundwater where the water table is too near the surface could be a limiting factor for application of rainwater management methods on some sites. For this reason, rain gardens and others methods may not be appropriate without additional expert help to address site constraints.

Figure 3 illustrates three different site conditions and basic scenarios where additional professional input will be required to select and design appropriate rainwater management methods.

Note: This guidance does not explicitly define or deal with geotechnical hazards or contaminated sites. The recommended setbacks are intended to reduce the risks where hazards are known, but geotechnical or hydrogeotechnical expertise is required to identify, assess, and properly mitigate these hazards. If there is any geotechnical concern for rainwater management implementation, a geotechnical professional must be consulted.

Trees

Placing rainwater management methods within a tree's root zone, or removing a tree to accommodate a method should be avoided. In certain cases where protected or significant trees are involved, the tree and its root zone must not be impacted.

Required: Consult the City of Victoria's Tree Preservation Bylaw, or the Stormwater Specialist if your rainwater management design may impact a tree.

Hazardous Slopes

The implementation of rainwater management methods that encourage infiltration is prohibited in hazardous areas of potential slope instability. Infiltration from methods may further reduce the stability of these hazardous slopes.

Required: Adequate setback for infiltration from the top of these slopes should be delineated by a qualified professional engineer. A minimum setback of 150 m is required in the absence of better information. It should be communicated to the engineer how much volume of water is expected to be infiltrated by the on-site rainwater management methods as the small infiltration volumes from methods are generally lower hazard than may be expected by the engineer.

Steep Slopes

Existing or proposed steep slopes can be a constraint to infiltration. Designers must consider the stability of the slope, and the interaction of deep and shallow groundwater interflow on the stability of slope. The definition of "steep" may vary, but for infiltration designs, slopes of 5% to 15% can make it more challenging to fit infiltration into a constrained site. Slopes greater than 15% are generally considered "steep" and infiltration methods up-gradient of steep slopes require professional design and construction.

Required: infiltration methods within 100 m of steep slopes, or that direct surface or groundwater at a steep slope area are prohibited unless reviewed and deemed acceptable by an engineer with geotechnical or hydrogeological expertise. This may require looking for steep slopes several lots away from the property in question.

Overflows

Required: All rainwater management methods must be designed with an overflow connection to ensure the facility overflows to the municipal stormwater system, and does not discharge to or through adjacent sites. A backflow preventer may be required on the overflow pipe in accordance with the City's Plumbing Bylaw (Bylaw No. 04-067). Engineered rock pits are also an option to direct overflow where no stormwater main fronts the property.

Groundwater Protection

It is important to consider the potential impact of rainwater management methods on groundwater contamination and the potential influences on existing water wells in the vicinity.

Required: A hydrogeologist must be consulted for any site where drinking water wells are located within 30 m of proposed infiltration facilities to confirm that infiltrated water does not put groundwater resources at risk. There should be very few of these in the City of Victoria as potable water is supplied by the City water system.

Utility Trenches

Trench dams are to be used as barriers between the infiltration reservoir and utility piping (usually service lines to the building) in order to prevent infiltrated water from short-circuiting through the high permeability material used in utility trenches and potentially causing damage downslope.

Required: Infiltration methods that intersect utility trenches must have low permeability trench dams to separate the two and inhibit flows.

Contaminated Soils and Pollution Hot Spots

Infiltration should not be undertaken directly from land uses that present a high risk of pollution such as automotive service yards. These land uses should employ spill control facilities (such as oil/water separators and oil interceptors) that may drain to rainwater management methods if enough protections are put in place.

Contaminated sites are also restricted for infiltration, and no infiltration methods should be installed on sites with contaminated soils. A minimum setback of 30 m should be used for installation of infiltration methods up-gradient of a contaminated site or landfill. If a large infiltration rainwater management method is anticipated for the up-gradient site a larger setback distance may be needed, to be determined by a qualified professional.

Required: For sites that are known to be contaminated, rainwater management methods should be considered on an individual-case basis and qualified professionals must be consulted.

High or Seasonable High Water Table

Infiltration methods should not be used where there is known to be a high water table, even if only seasonally, as the methods need to be able to drain into surrounding subsurface soils during the wet season. If only a portion of a site is known to have a seasonally high water table, there may be other areas on the site that are more suitable for an infiltration method.

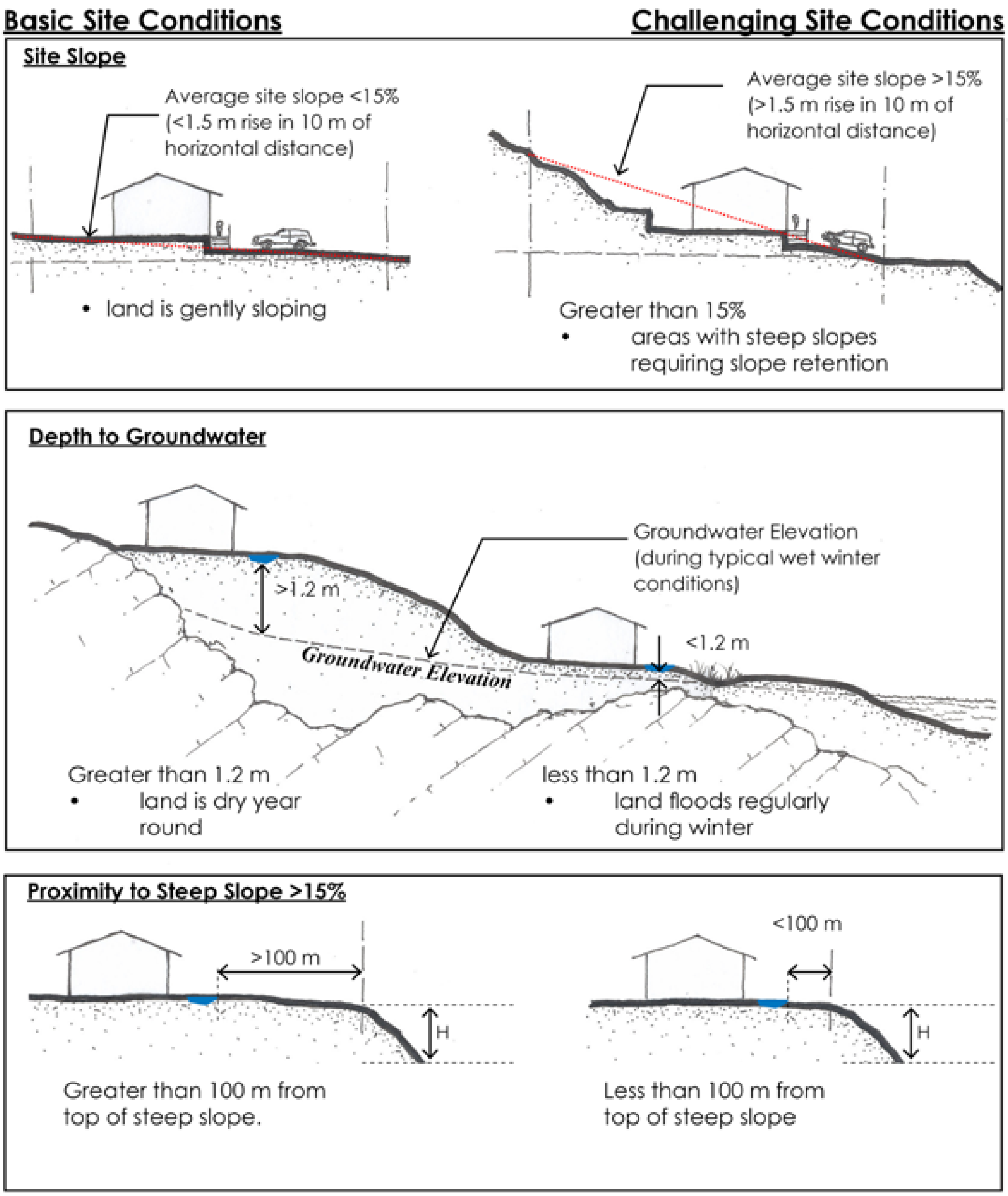
Required: The infiltration facility must have a minimum of 600 mm of separation between the bottom of the infiltration reservoir and the top of the high water table.

Shallow or Surface Bedrock

Infiltration requires subsurface soil layers to be able to drain water so it is not recommended to install infiltration methods in areas where there is surface or shallow bedrock or cemented soil layers.

Required: The infiltration method must have a minimum of 600 mm of soil below the bottom of the infiltration reservoir.

Figure 3: Site Conditions



Entrances and Parking

Required: Ensure rainwater management method is not blocking access/egress to rear yard or exits/entrances, or blocking or displacing parking spaces or driveways.

Table 3: Setback and Minimum Values Summary

	Setback or Minimum Required
Infiltration setback from building foundation	5 m
Infiltration setback from steep (> 15%) slope	30 m minimum
Vertical and horizontal clearance from utilities	1.5 m
RMM setback from natural boundary/shoreline	10 m
Infiltration setback from drinking water well/spring	30 m minimum OR as directed by a hydrogeologist
Infiltration setback up-gradient from landfill or contaminated site	30 m
Rainwater Management Method near a protected or significant tree (see the City's Tree Preservation Bylaw)	Outside protected root zone
Vertical separation from bottom of infiltration RMM to high water table	0.6 m for catchments < 900 m^2 1.0 m for catchments > 900 m^2 OR as directed by qualified professional

2.3: Professional Design Requirements

Professional Design Qualifications and Requirements

In many circumstances site constraints and project complexity will warrant use of a Qualified Designer or a Qualified Professional in order to meet rainwater management objectives and the City of Victoria Rainwater Management Standards. The term "professional" used in this document includes both Qualified Designers and Qualified Professionals.

"Qualified Designer" means an individual who demonstrates to the satisfaction of the Director of Engineering and Public Works for the City that he or she has the training and experience necessary to design and oversee the installation of a rainwater management method. Contact the City's Stormwater Specialist to discuss this process.

"Qualified Professional" means an applied scientist or technologist, acting alone or together with another qualified professional, if:

(i) The individual is registered in good standing in British Columbia with an appropriate professional organization constituted under an Act, acting under that association's code of ethics and subject to disciplinary action by that association,

(ii) The individual's area of expertise is recognized by the individual's professional organization as one that is acceptable for the purpose of performing a professional service for design of rainwater management methods, and

(iii) The individual is acting within the individual's area of expertise.

Qualified Professionals include but are not limited to:

- **Landscape Architects** – registered or licensed to practice as a qualified landscape architect under a recognized professional association (within BC the BCSLA and CSLA); and
- **Professional Engineers** – registered or licensed to practice as a professional engineer, under the Engineers and Geoscientists Act (APEGBC).

When is Do-It-Yourself appropriate?

The City of Victoria has developed two levels of design and construction for rainwater management methods based on property type, site complexity, and the level of complexity in the method utilized. The following outlines the two levels:

- DIY Projects – low density residential (1– 4 units) projects that use standard rainwater management methods outlined in the DIY Standards document and meet all of the requirements for Basic Site Conditions in Table 4 can be developed and submitted by the Home Owner or a representative such as a Qualified Designer or Qualified Professional.
- Professional Projects – any project with challenging site constraints, complex rainwater management method designs, or those other than low density residential must be completed by a Qualified Designer or Qualified Professional.

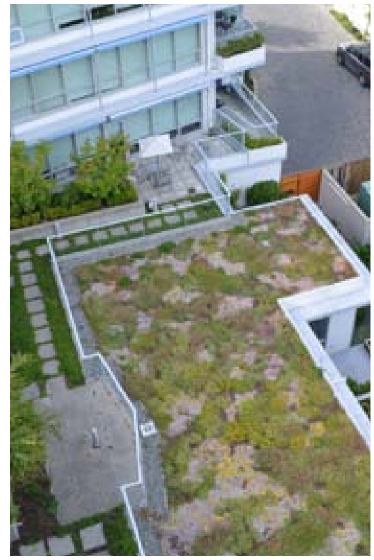
In order to meet what are considered basic site conditions a project must meet all site constraints.

Projects with impervious surface areas greater than 300 sq.m. (including roof, driveway, etc.) must be designed by a professional.

For your reference, see Table 4 on the next page to determine if the project is eligible for DIY.

Table 4: Can this Project be DIY Checklist			
		DIY Allowed	Professional Only
Land Use		☐ Low Density Residential (1 – 4 Dwelling Units) ☐ Impervious surface area < 300 m^2	☐ Multi-family Residential (5+ Dwelling Units) ☐ Civic and Institutional ☐ Commercial and Industrial ☐ Impervious surface area ≥ 300 m^2
Site Conditions	Depth to Groundwater	☐ Greater than 1.2 m (land is dry year round)	☐ less than 1.2 m (land floods regularly during winter)
Site Conditions	Proximity to Hazardous Slopes	☐ Method is greater than 150 m from top of known hazardous slope	☐ Method is less than 150 m from top of known hazardous slope
Site Conditions	Proximity to Steep Slopes	☐ Method is greater than 100 m from top of steep slope (>15%)	☐ Method is less than 100 m from top of steep slope (>15%)
Site Conditions	Bedrock on Site	☐ No known or visible bedrock	☐ Visible or known bedrock
Site Conditions	Contaminated Soils	☐ No known contaminated soils or buried oil tanks or ☐ Rain Barrel or Cistern is planned	☐ Known contaminated soils or buried oil tanks
Site Conditions	Available Stormwater Main	☐ Stormwater main fronting or adjacent to property (VicMap)	☐ No stormwater main fronting or adjacent to property
Type of Rainwater Management Method to be installed		☐ Rain garden (slopes <5%) ☐ Infiltration chamber (rock) ☐ Permeable concrete unit paving (slopes <8%) ☐ Rain barrel ☐ Cistern at grade (plumbed for gravity irrigation)	☐ Methods requiring advanced design, e.g.: green roof (intensive and extensive), rain planters, cisterns below or above grade or plumbed for indoor use/irrigation, infiltration chamber (open), bioswale, permeable concrete unit paving (slope >8%)
Who can prepare the design?		If **all** of the conditions in the above column apply to your site, and only Standard Methods are used, the project can be designed by the • Home Owner or • Qualified Designer or • Qualified Professional	If **any** of the conditions in the column above apply to your site, the plans must be designed by a • Qualified Designer or Qualified Professional
Who can build the project?		The project can be built by the • Home Owner or • Contractor/Professional	If **any** of the conditions in the column above apply to your site, the project **must** be built by a • Contractor/Professional
Documentation Requirements		• Concept Plan of Site and Methods • Sizing Calculation Sheet • Standard DIY Design to be used	• Concept Plan of site and methods • Construction Details and Plans • Sizing Calculation Sheet





Part 3: Permit, Inspection and Approval Requirements

When a rainwater management project is undertaken with the intent of being approved for Rainwater Rewards, all associated permits required for the project will be streamlined through the Rainwater Rewards application to help simplify the process for the applicant. Alternatively, when the rainwater management work is part of a larger project requiring Building and/or Development Permits, those standard permitting processes will apply.

To achieve this, all rainwater management method designs must be submitted to the Stormwater Specialist for pre-approval before any site preparation or construction. Doing this will help to ensure the design:

- meets the requirements laid out in this document and Rainwater Rewards eligibility can be identified
- is distributed for review to applicable departments in the City (plumbing, zoning, electrical) prior to construction
- will be eligible for exemptions from development permit, heritage and zoning restrictions

Once reviews are complete, pre-approval will be granted, or a deficiency list will be provided to identify shortcomings that would prevent approval. When design deficiencies are addressed the design can be resubmitted for pre-approval.

When pre-approval is received, site work can start. The Stormwater Specialist will help identify and coordinate required inspections and documentation to ensure all requirements can be met. These requirements will vary depending on project location and complexity, but some of the components are generally identified below.

Possible inspection times:

- prior to breaking ground
- prior to back filling
- at completion

Possible inspection items:

- overflow connections
- drip valves
- trench depths
- appropriate material specification
- growing medium composition
- piping size, orientation and grades
- pumps
- site coverage
- setbacks

Potential documentation requirements for Rainwater Rewards approval could include:

- finalized design drawing of rainwater management method
- material and labour receipts and invoices
- photographs at key construction phases
- finalized as-built drawing of actual construction
- calculation sheets
- maintenance plan

As a general guide to help ensure installation requirements are met, refer to the rainwater management method installation checklists located in Appendix B.



Part 4: Professional Design and Sizing Approach

The primary design objective of the City of Victoria's Rainwater Management Standard is to provide water quality treatment for 90% of the average annual rainfall that is directed through rainwater management methods. The secondary design objective is to reduce the volume of runoff that enters the City's sewer system by encouraging infiltration, evaporation and reuse through the use of rainwater management methods. To achieve this, rainwater management methods must be designed meet the City's Rainwater Management Target to treat and/or capture 32 mm of rainfall in a 24 hour period.

This Professional Rainwater Management Standards document provides sizing, design, and construction requirements for rainwater management methods to qualify for Rainwater Rewards. It is intended to help Qualified Designers and Qualified Professionals understand how to design rainwater management methods that are sized appropriately to meet the rainwater management target and fulfill the City's needs for rainwater management methods.

This section provides design information to Qualified Professionals and Qualified Designers that will help to achieve the City of Victoria's rainwater management goals and reduce the stormwater impacts on downstream receiving waters.

Alternatively, when project complexities allow, a low density residential property owner may choose to undertake rainwater management work on their own, as outlined in Table 4. In doing so, the property owner must follow the DIY version of these Rainwater Management Standards. In all other instances, the property owner must hire a Qualified Designer or Professional, who in turn may use the DIY version to accomplish the depicted designs, or this Professional version for more flexibility.

Professional Standards

The Professional design standards are intended to provide the necessary sizing and design requirements such that any Qualified Designer or Qualified Professional (collectively referred to as professionals) will be able to design a rainwater management method that meets the City's needs.

Qualified Professionals may provide any design for a rainwater management method meeting the 32 mm target that they are willing to seal in accordance with their professional accreditation. Qualified Designers must design within the requirements of these standards.

This section includes sizing and design guidance for professionals to use; it is less detailed and assumes a higher level of familiarity with terms and knowledge of rainwater management than the DIY design standards. There are also more options for design and sizing discussed than are allowed for DIY use.

This document may be applied to any type of property, including low density residential, by a Qualified Designer or Qualified Professional.

For more detailed information including step-by-step installation guides for rainwater management methods, professionals may use and refer to the DIY Rainwater Standards.

Whether or not a rainwater management method is designed or constructed by a homeowner using the DIY standards or by professionals, the documentation of the design and construction required by the City to apply for Rainwater Rewards will be the same. Property owners and professionals assisting them should be sure they are aware of the documentation required at the beginning of the project, as it may be impossible to go back and obtain photos or other documentation once construction is complete.

Though professionals will generally be familiar with common construction and rainwater management terminology, the Glossary of Terms (Part 6) may helpful to be sure of the usage of terms in this document.

Installation checklists (Appendix B) were also developed as a general guide to help achieve compliance with these standards. They are primarily for do-it-yourself installations, but are included here for reference.

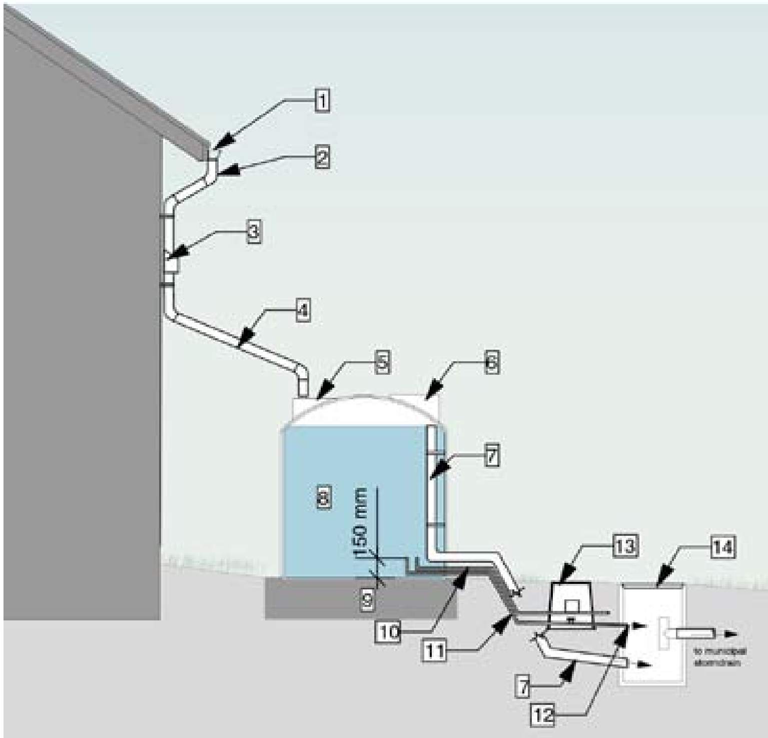
Cisterns

Cisterns collect rainwater for reuse. They provide some flow control and volume reduction benefits but do little to treat runoff quality.

Stormwater can be collected and reused for non-potable water uses within a house or building, or for landscape irrigation purposes. Uses can include toilet or urinal flushing, landscape irrigation or a combination of the two. All toilets and water supplies (hose bibs) must have permanent signage that notifies users of non-potable water. Any such system must obtain a plumbing permit and inspection. Pumped irrigation systems and water reuse plumbing fixtures require a reduced pressure backflow assembly on the water service, also requiring a plumbing permit and inspection.

The cistern should be installed such that it stores water for irrigation during the dry months (May to September). During the wet months (October to April) a valve is opened so that the cistern slowly drains, slowing/attenuating flows between rain events or storms.

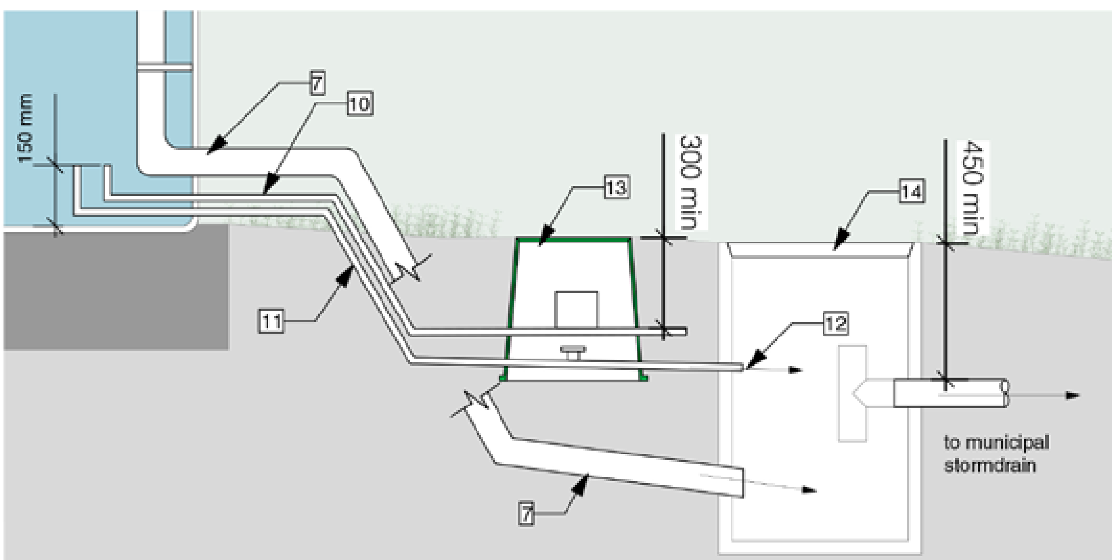
Figure 4: Cistern/Rain Barrel – Downspout Connection



Above Ground Cistern Materials

1. Gutter
2. Building rainwater leader/downspout
3. Inline debris removal device
4. Diversion pipe to rain barrel/cistern
5. Rain barrel/cistern fill opening
6. Self-venting lid
7. Overflow to sump
8. Cistern/rain barrel
9. Compacted base
10. 25 mm diameter to irrigation system. Pump and filter (not shown) installed on either interior or exterior of rain barrel/cistern.*
11. 25 mm diameter winter drain pipe, with valve.
12. Orifice with screw on adapter at end of winter drain pipe
13. Irrigation valve box
14. Sump**

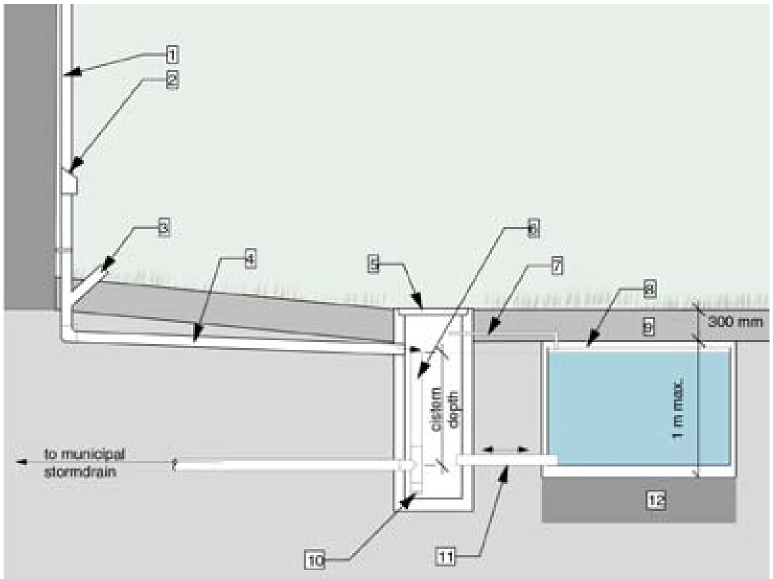
Figure 5: Cistern – Pipe Connections



** An irrigation system is not required if the homeowner chooses to install a hose bib for hand watering.*

***Sump is shown as a location to bring the winter drain and the overflow together prior to connection to the municipal stormwater system and allow for access and cleanout of the piping. A sump is not required if the homeowner chooses to use a below ground tee connection instead.*

Figure 6: Underground Cistern



Below Ground Cistern Materials

1. Building rainwater leader/downspout
2. Inline debris removal device
3. Clean out
4. Gravity flow to storage
5. Sump
6. Overflow pipe
7. Air release pipe
8. Underground cistern
9. Growing medium
10. Orifice
11. Flow pipe
12. Compacted base

Sizing

Assumptions for Sizing Approach:

- In general, cisterns are sized through water balance modeling that take into account water supply (rain) and water demand (irrigation and/or toilet flushing) on a fixed time step; e.g.: daily time step.
- If cisterns are only being used for irrigation, the simplified sizing approach presented here should be used for sizing. If they are being used to supply water to a purple pipe system (i.e. for toilet flushing or other use internal to a building), a Qualified Professional should size the cisterns and perform water demand calculations specific to the building use and occupancy. The maximum time step recommended for water balance calculations for cistern sizing is a daily time step.
- The simplified sizing for irrigation is based on a 4 day drain time for the cistern in the wet months (October to April) and use of the water stored in the cistern for irrigation during the dry month (May to September). During the winter months, the cistern provides some detention via the orifice outlet outflow. During the summer months, the cistern provides volume reduction through reuse/irrigation.

  Some water quality benefits are provided by cisterns as ground surface runoff has to be conveyed through a sump prior to entering the cistern.
- The simplified sizing is based on the principle that only 10% of the average annual rainfall is permitted to overflow the cistern volume directly to the storm sewer system.
- For the simplified sizing approach, the size of the cistern is dependent on the upstream impervious area (roof, patio, and driveway) that drains to the cistern and a minimum irrigated land that will be serviced by the cistern during the summer months.

Sizing for Water Quality

Cisterns are rainwater reuse and volume reduction facilities. Water quality improvement from use of cisterns comes from settling out particles in a sump prior to runoff entering the cistern, as well as reuse (water reused for irrigation will be treated once it infiltrates through soil). For ground surface runoff, a Qualified Professional must size a sump appropriate for the inflow from the impervious surface, which will not be the same value as the rainwater management design target.

Sizing for Capture and Infiltration

Sizing for rainwater management target: Limit overflow to 10% annually

1. Determine the available pervious area that will be used for irrigation (watered area).
2. Determine the impervious area that will be directed to the cistern.
3. Ratio of watered area to impervious area should not be smaller than 2:1.
4. Provide 0.025 m^3 of storage per 1 m^2 of impervious area being directed to the cistern.

Design Standards

1. Cisterns can be located above ground or underground, depending on the site and the preference for aesthetics (underground) or minimizing construction (above ground, at grade). Cisterns can also be elevated, but the structure for support of an elevated cistern must be designed by a Professional Structural Engineer.
2. Clean runoff such as roof runoff is preferred for a cistern, however any impervious area (roof, driveway, patio, etc.) can be directed to the cistern. Whatever pollutants are in the runoff will be distributed in the re-used water, so property owners must be careful to prevent contamination of runoff from impervious surfaces. Roof water should be piped to the cistern and not directed to it by overland flow.
3. All ground surface runoff should be conveyed through a sump prior to entering the cistern.
4. An overflow to the storm system is required. Generally the overflow is connected through the main building sump if available.
5. If the cistern is to be used for irrigation, it is required to have an orifice outlet to drain water to the storm sewer system. The orifice should be designed to drain the full volume of the cistern in 4 days during the winter months.
6. A professional engineer may be required for underground installations of large tank cisterns. Tank manufactures should provide guidance when an engineer may be required. Open chamber modular-type cisterns may not require a professional engineer for design but require a knowledgeable contractor for installation.

Rooftop Cisterns

- Rooftop cisterns and their supporting structures are treated as mechanical features and as such, are excluded from height calculations for the Zoning Bylaw, provided they don't exceed 9,000 litres (1,980 imp. gallons).
- Place cisterns in the centre of roofs where possible, to minimize visibility from adjacent properties and the street. A structural engineer is needed to ensure the roof or platform can support the cistern.

Where rooftop cisterns are visible from the street or adjacent buildings, think about ways to enhance the design and softening the visual impact through Screening Considerations mentioned below.

Construction Considerations

- Construction Phasing: construction of the cistern and its associated pipe connections and sumps should be scheduled for just before surface paving and final landscaping.
- Location: cisterns should not be installed in: a concave area where water could collect around the base, in the path of surface water runoff, or in an area prone to high winds.
- Foundation: if a foundation is required, foundation should be flat and capable of supporting the cistern weight when full of water.
- Pipe Sloping: ensure all connecting pipes should have positive drainage (minimum 1%) except that connecting the cistern to the sump, which should be level.
- Manufacturer's Instructions: install according to the manufacturer's installation instructions.





Screening Considerations

Where cisterns will be visible to neighbours or the street, consider ways to soften their appearance through landscaping or other design features. Cisterns should complement the overall design and character of your property while retaining functionality. You will need to be able to access your cistern for routine maintenance.

- Consider screening cisterns with plants or bushes, such native, drought tolerant species, vines or food plants (e.g. hops, berries).
- Cisterns can be screened with trellis panels, wooden panels or wrought iron panels.
- Cisterns can be integrated into a building by locating them under decks or behind existing out-buildings such as sheds or garages.
- There are examples of cisterns that have been finished with galvanized metal, concrete, masonry or wood cladding, and complement the style and character of the property.
- Consider incorporating elements that complement the character of the property, such as metalwork into the cistern.

More cistern screening guidance, examples and ideas are available in Appendix C.

General Specifications

1. Setbacks: Cisterns must meet all minimum setbacks outlined in Part 2.
2. One or more debris removal devices should be used in the catchment system to remove debris (normally particles 200 – 500 microns and larger).
3. Overflow required, PVC sewer pipe minimum CSA rated ≤ 35 SDR. 100 mm diameter minimum, with connection to municipal stormdrain.
   a. Protect from debris and sediment with strainer or grate.
   b. A backflow preventer may be required in accordance with the City's Plumbing Bylaw.
4. Cisterns should be:
   a. Installed on a level compacted base, according to manufacturer's recommendations:
   b. Dark-colored, UV-resistant, polyethylene or fibreglass preferred.
   c. Inlet/fill opening to be screened to keep debris out of the tank.
   d. All pipe openings to be sealed with waterproof seal, grommet or barb fitting.
5. Compacted base should be compacted to 95% Standard Proctor Density. Compacted base is generally constructed with clean crushed rock materials, but may be other materials such as concrete. Base must be constructed in accordance with cistern/rain barrel manufacturer's recommendations.
6. All solid pipe to be PVC sewer pipe minimum CSA rated ≤ 35 SDR.
7. Irrigation supply to be minimum 25 mm diameter, installed with minimum 1% grade
   a. Pump and filter for irrigation system to be installed on exterior of rain barrel or cistern.
8. Winter drain pipe to be max 25 mm diameter, installed level to flow control sump;
   a. Winter drain pipe to be connected to valve. Valve may be manual valve controlling flow to flow control sump (shown) of garden hose faucet, if draining to rainwater management method or other safe location.
   b. Winter drain pipe to have 10 mm orifice with screw adapter installer at outlet to flow control sump.

9. Underground valves, pumps, and filters to be accessible through irrigation valve box with a minimum of 50 mm clearance between box and valves. Install 100 mm compacted base under box.
10. Sump shall be concrete, plastic, or other non-degradable box with strength suitable to withstand surface loads.
11. Outlet pipe shall be PVC sewer pipe minimum CSA rated ≤ 35 SDR. 100 mm diameter minimum complete with PVC backflow preventer valve (if required as per City Plumbing Code). Outlet pipe must have minimum 1% grade and follow the Plumbing Code.
12. All cistern hose bibs must be identified with signage indicating for “non-potable usage only”.

Maintenance

- Keep the drainage pathway to the cistern clear. Remove leaves and other debris from the roof gutter, clean out sump.
- Clean gutters annually. Fine-mesh gutter covers or frequent cleaning will reduce the sediment and debris deposited into the cistern.
- Install a debris removal device that is sized to handle peak water flow from the roof areas it drains, to reduce maintenance.
- Cleaning of cistern recommended every three to five years, for non-potable outdoor and indoor use. This requires draining the cistern and scrubbing to remove dirt and algae on the surfaces, as well as on valves and piping that can be accessed and cleaned. Use only mild, biodegradable soaps, not strong chemicals or detergents as they can harm plants.

Rain Gardens

Essential Components

1. Concave surface
2. Rainwater input
3. Living plants
4. Growing medium
5. Reservoir (Rain Garden with Reservoir only)
6. Drain or outlet (overflow & porous base)

A rain garden without rock reservoir and rain planters provide volume capture and rainwater treatment, provided by soil layer, surface ponding, and plant uptake. Trees can be planted in all rain gardens without rock reservoirs and rain planters.

A rain garden with rock reservoir provides volume capture and rainwater treatment, provided by soil layer, surface ponding, and plant uptake. Additional volume capture and infiltration capacity is provided by a reservoir layer. The reservoir can be constructed with growing medium, sand, or rock. Trees cannot be planted in rain gardens with rock reservoirs.

Figure 7: Rain Garden Plan

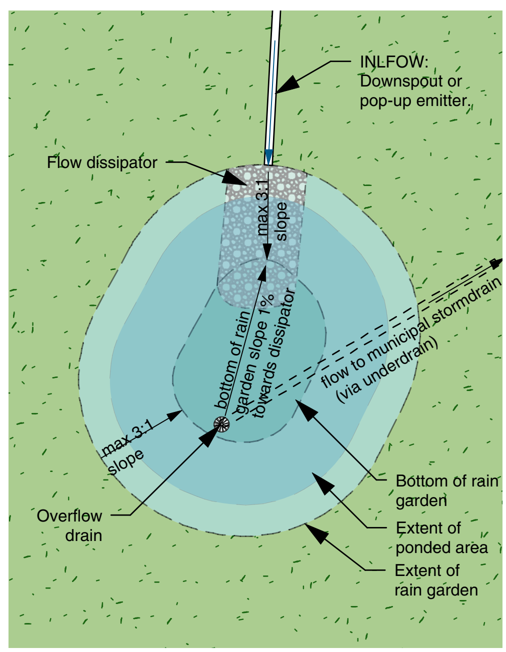
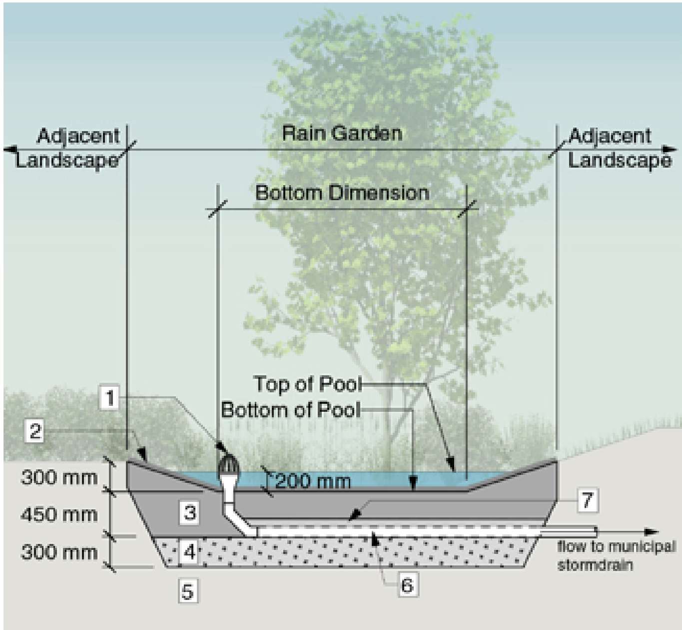


Figure 8: Rain Garden without Reservoir Detail



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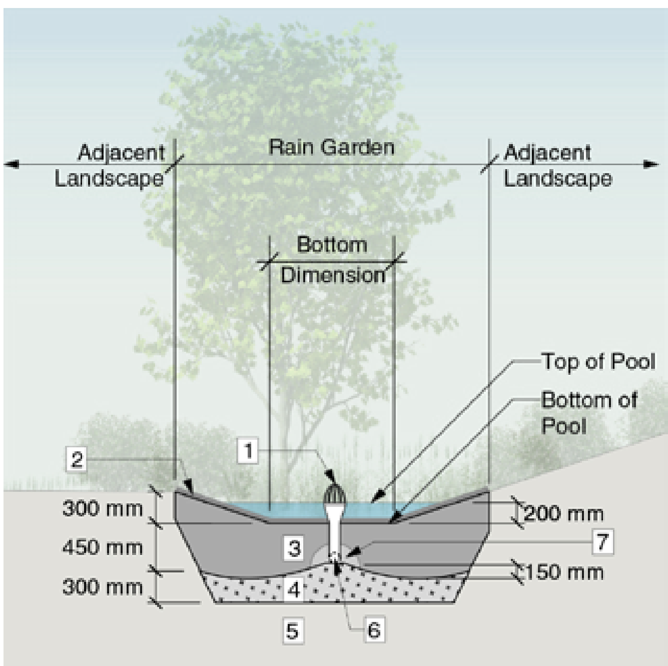


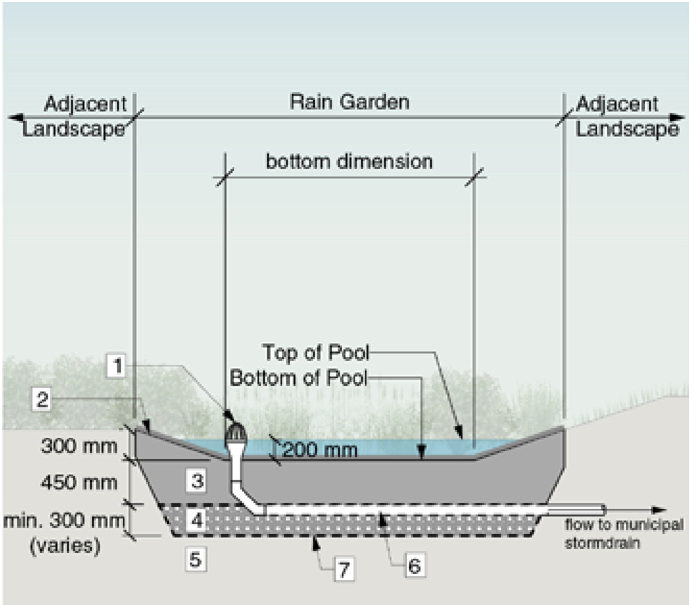
Cross Section

Rain Garden Materials

1. Overflow drain, 200 mm domed grate and adapter
2. Composted mulch, 50 – 70 mm depth
3. Bio-retention growing medium, 450 mm depth
4. Scarified/tilled subgrade, 300 mm depth
5. Existing subgrade/native material
6. 100 mm diameter (min) perforated pipe
7. 25 mm diameter drain rock, 100 mm depth

Note: Flow dissipator inlet options and pop-up emitter details are located at the end of this section.

Figure 9: Rain Garden with Reservoir Detail



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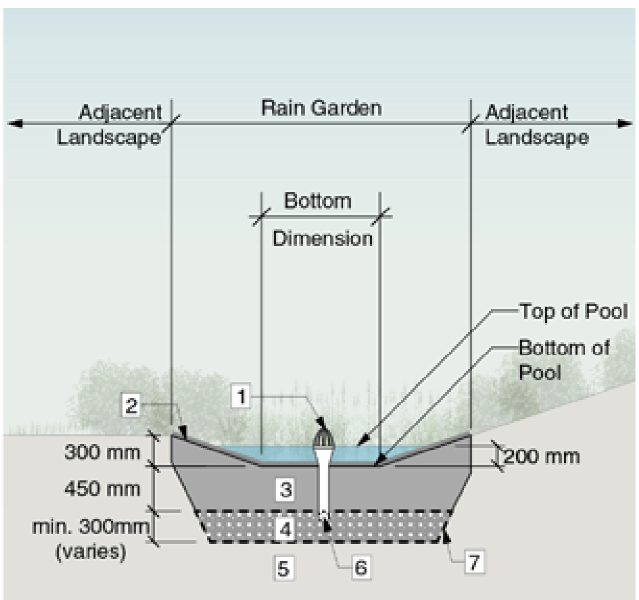


Cross Section

Rain Garden Materials

1. Overflow drain, 200 mm domed grate and adapter
2. Composted mulch, 50 – 70 mm depth
3. Bio-retention growing medium, 450 mm depth
4. Reservoir base
5. Existing subgrade/native material
6. 100 mm diameter (min) perforated pipe
7. Non-woven geotextile on bottom, sides, and top drain rock

Note: Flow dissipator inlet options and pop-up emitter details are located at the end of this section.

Sizing

Assumptions for Sizing Approach:

1. The Rain Garden area is sized based on the upstream impervious area that it serves. This relationship is defined by the Sizing Factor: the ratio of base area of the rain garden to upstream impervious area (also called catchment area). Two approaches for calculating the sizing factor are allowed:
   a. Size the rain garden for water quality treatment based on 32 mm of rainfall flowing through the growing medium of the rain garden with the assumption that the long-term hydraulic conductivity of the growing medium is 20 mm/hr. This approach results in a sizing factor of 5%, when 200 mm of ponding is allowed to drain in 48 hrs from start of rainfall event.
   b. Calculating Sizing Factor to capture and infiltrate 32 mm of rainfall. Sizing Methodology is presented below.
2. The minimum allowable sizing factor for rain gardens is 5%. This minimum is based on water quality treatment standards for the City of Victoria. The rain garden base area should always be at least 5% of the impervious catchment area draining to it. Rain gardens smaller than this are more prone to failure.
3. The sizing process provides the base area of the rain garden, which is the flat area at the bottom with uniform layers of mulch, growing medium and drain rock. Sizing by these methods does not account for any infiltration benefit provided by the sloped sides of the rain garden.

Sizing Methodology for Water Quality:

4. Use a sizing factor of 5%. This sizing factor assumes a long-term hydraulic conductivity of 20 mm/hr, and 200 mm ponding.

Sizing Methodology for Infiltration:

5. Determine the maximum depth for the rock reservoir based on measured subsurface soil infiltration rate for the site and round down to the nearest 50 mm increment for constructibility; allowable depth range is 300 to 2000 mm. If the infiltration rate is not being measured at the site, then assume a value of 2 mm/hr for saturated hydraulic conductivity (Ks) which results in a maximum allowable rock depth of 550 mm.

   $D_R = 274.3 \times K_S$

   Where:

   D_R = Depth (thickness) of rock reservoir (mm)

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr)

6. If sizing for capture, use the following equation to determine the Base Area (bottom area) of Rain Garden and rock reservoir required by finding the sizing factor for the site. Choose any value for the depth of rock reservoir within the allowable depth range and under the maximum allowable calculated in the previous step. Deeper rock reservoirs allow for smaller rain garden base areas (to a minimum of 5% of the catchment area):

   $\text{Sizing Factor} = [(24 \times K_S + n_R \times D_R + n_S \times D_S + D_P) / 32 - 1]^{-1}$

   Where:

   Sizing Factor = Percent of impervious tributary area required as base area of rain garden (unit less)

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr); suggested value = 2 mm/hr

   D_R = Depth (thickness) of rock or sand reservoir (mm)

   n_R = Porosity of Reservoir Layer (unit less); standard value for drain rock = 0.35; standard value for sand = 0.25

   n_S = Porosity of Soil (unit less) ; standard value for Soil = 0.2

   D_S = Soil depth (thickness in mm); minimum value = 450 (mm)

   Assumptions:

   D_P = Depth of ponding (mm); 200 mm standard

7. Check that the sizing factor calculated is greater than or equal to 5%. If the calculated sizing factor is less than 5% – use 5%. If the calculated sizing factor exceeds the minimum, reduce the depth of your rock trench until the minimum allowable depth or the minimum sizing factor is reached. Rain Garden performance may exceed the design target.

8. To find the Rain Garden Base Area:

   Base Area = Impervious Area x Sizing Factor

9. Calculate the footprint of the facility based on the Base Area and side slopes:

   Footprint of Rain Garden = Base Area + Side Slope Area

   Add additional area for side slopes according to the shape of the rain garden and the chosen side slopes; e.g. add [2 x slope x Rain Garden depth (m)] to each dimension of the base area to determine total footprint area.

Design Standards

10. Inflows should be via overland flow wherever possible. Where inflow is from curb cuts or point (pipe) discharge, a transition area at the inflow point(s) should incorporate erosion control and flow dispersion to distribute flow to the full Rain Garden area.
11. Clean water (roof water and pre-treated water) can be piped directly to the rock reservoir – this option would require a catch basin either in the rain garden or upstream of the rain garden. For small applications only (rain garden ≤ 5 m^2) a pop-up emitter may be used to pipe roof runoff to the rain garden surface without first going through a catch basin.
12. A non-erodible outlet or spillway must be established to discharge overflow to the stormwater system. This often takes the form of a grated inlet raised above the Rain Garden invert to create the ponding depth.
13. Rain Garden depth includes ponding depth (depth to overflow level), an additional surcharge allowance (100 mm is common) to prevent overflow to the roadway or surrounding area, and sediment accumulation allowance (may be 3 mm/yr or more depending on loading). Rain Garden depth = ponding depth + surcharge allowance + sediment accumulation allowance.
14. Create a depression near the inflow to slow and pool incoming runoff. Most coarse sediment will be deposited in the depression, making annual sediment removal easier. Do not plant trees or shrubs in this area as it makes sediment removal more difficult.
15. Growing medium soil depth: 450 mm minimum for most applications. Treatment soil should have a minimum infiltration rate (lab tested) of 50 mm/hr, which is assumed in the sizing approaches in this document.
16. Avoid utility or other crossings of the Rain Garden. Where service trenches must be constructed crossing below or through the rain garden, install trench dams at exits to avoid infiltration water flowing into the service trench.
17. Drain rock reservoir and subdrain may be omitted where infiltration tests by a qualified professional taken at the level of the base of the proposed construction show an infiltration rate of 20 mm/hr or greater.

Construction

Avoid over compaction and plugging! The overriding concerns for construction of infiltration methods are that the subsurface must not be glazed or compacted and the materials must be kept clean and free of fines.

Construction Phasing:

- Leave construction of rain garden and bioswale to the end of the overall construction timeline to avoid soil compaction or plugging of the growing medium by silts and clays by construction activity.
- Divert water away from rain garden until installation of rain garden, including plant material, is fully complete.

Subgrade/Native Soil:

- Subgrade must be free of water, mud, and soft clay prior to installation of growing medium.
- Subgrade to be scarified to a depth of 200 mm to help facilitate infiltration prior to installation of any rock, sand or growing medium.

Grading:

- The bottom of the rain garden should be nearly flat with a grade no greater than 1% sloping towards the location where water enters. Any positive slope from the base of the rain garden where water enters the facility (inlet) to the point of discharge (outlet) will lead to erosion. To avoid positive slope towards the point of discharge make sure the bottom elevation where water enters the rain garden is 50 mm lower than the bottom elevation adjacent to the overflow drain or a maximum slope of 1%.
- Side slopes to have maximum slope of 3:1. Where required install slope retention to achieve grades.

Drain Rock:

- Prevent natural or fill soils mixing with the infiltration drain rock.
- Install infiltration drain rock in 300 mm lifts and compacted to eliminate voids between the geotextile and surrounding soils.
- Rock should be wrapped on all sides with filter cloth to prevent the surrounding soil or above growing medium from moving into the rock trench, reducing water-holding capacity. Overlap the filter fabric by 600 mm.

Growing Medium:

- Place growing medium immediately following either construction of rock reservoir or scarification of subsurface soils. Compact just to be firm against deep foot-printing. Do not over compact. If the growing medium is left exposed to elements for more than a few hours, the surface will require scarification prior to seeding or planting.
- Install growing medium in 200 mm lifts and compact with lawn roller.

Figure 10: Downspout to Flow Dissipator

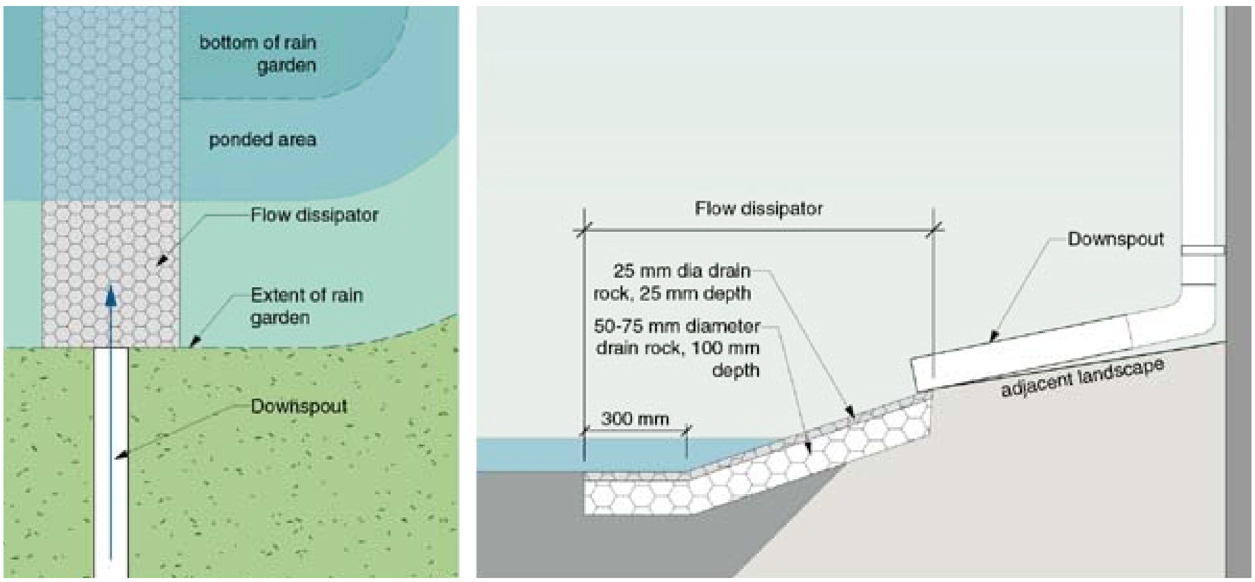


Figure 11: Curb Inlet with Flow Dissipator

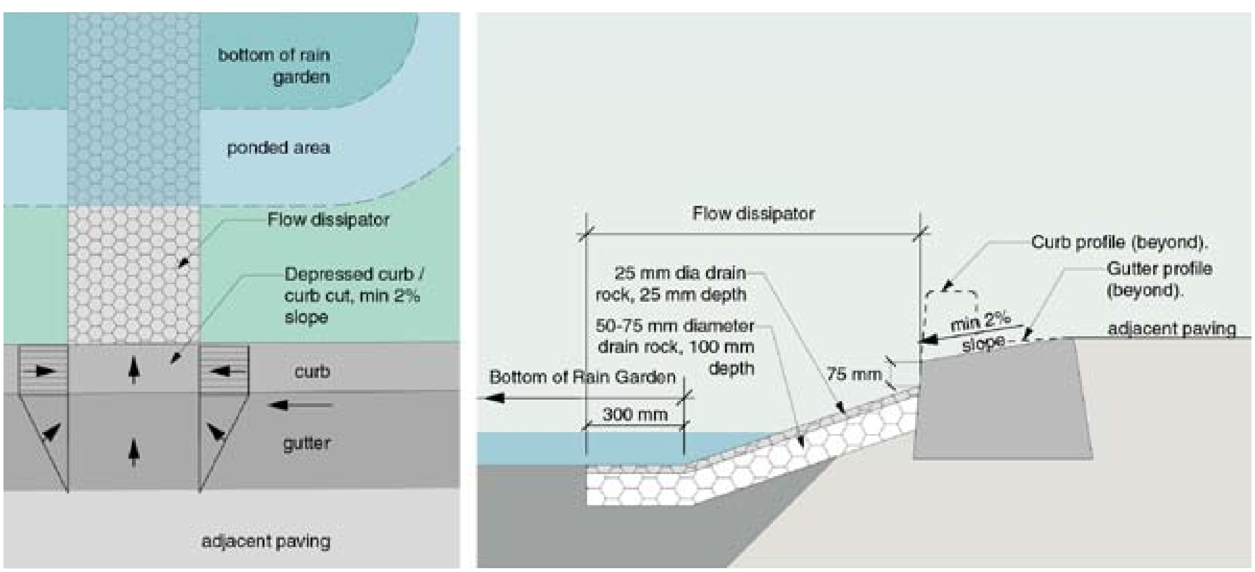
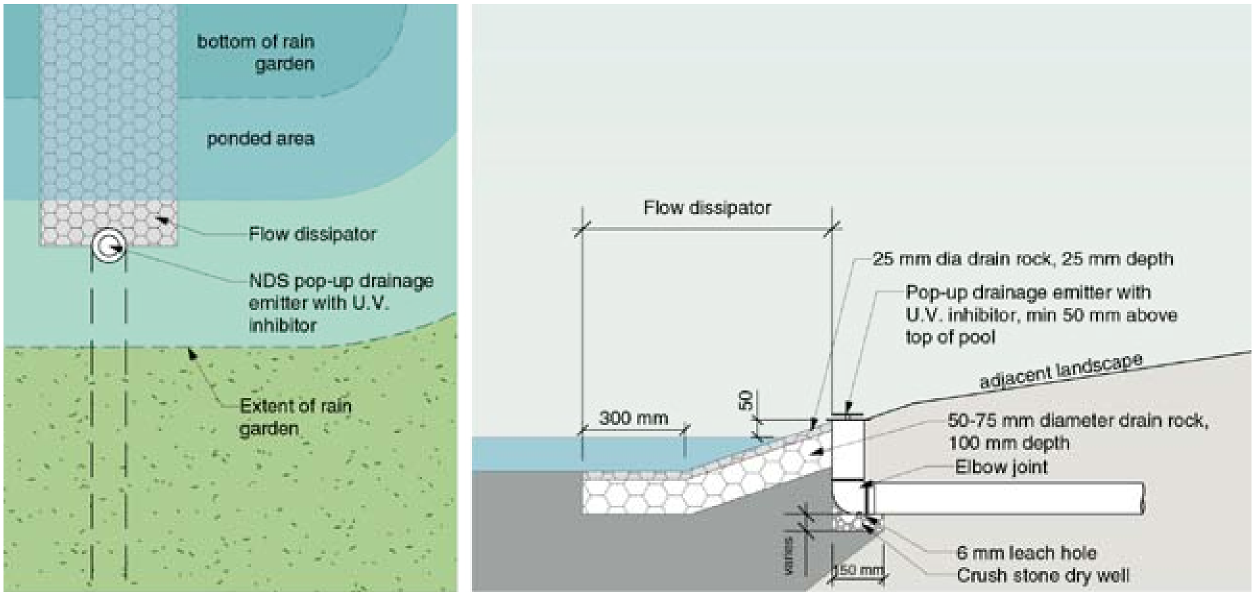


Figure 12: Pop-Up Emitter to Flow Dissipator



Mulch:

- Apply organic mulches at a depth of 50 mm.

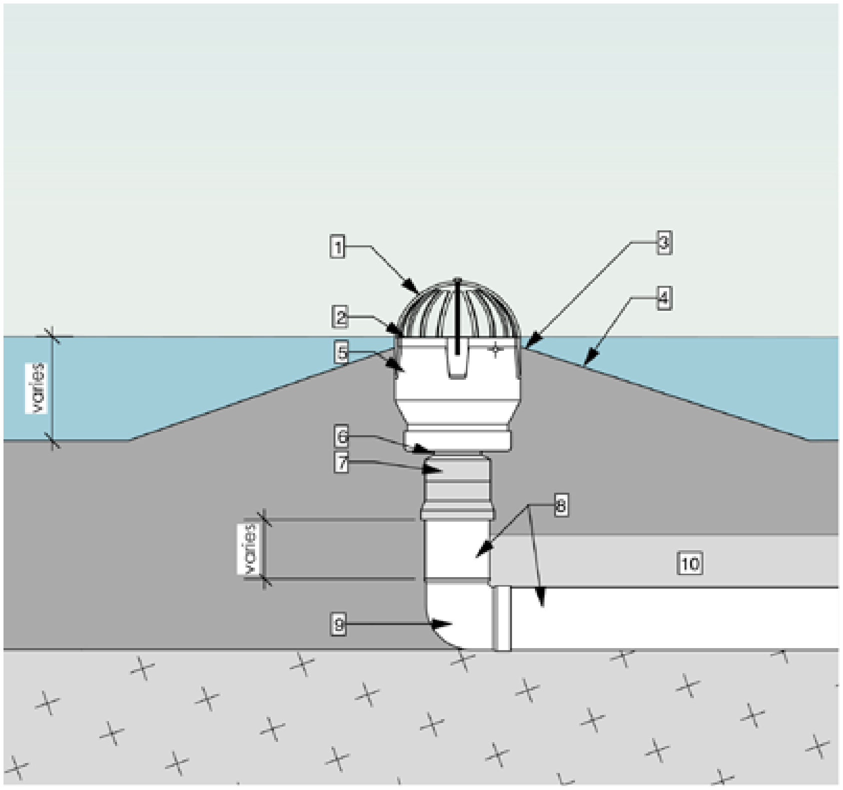
Service Trench Crossing:

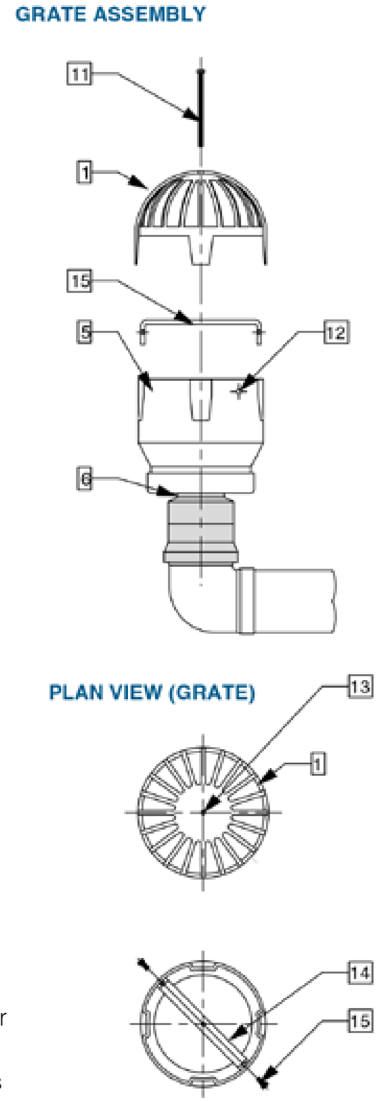
- Any service trench crossings must have trench dams properly installed. Compacted impervious backfill (glacial till or clay) must fill entire width of service trench and extend to 200 mm above the top the Service trench.

Planting:

- The bottom of the rain garden must be planted. Covering the bottom of the rain garden with rock is NOT acceptable (planting is essential for the rain garden to function properly).

Figure 13: Overflow Assembly with Domed Grate

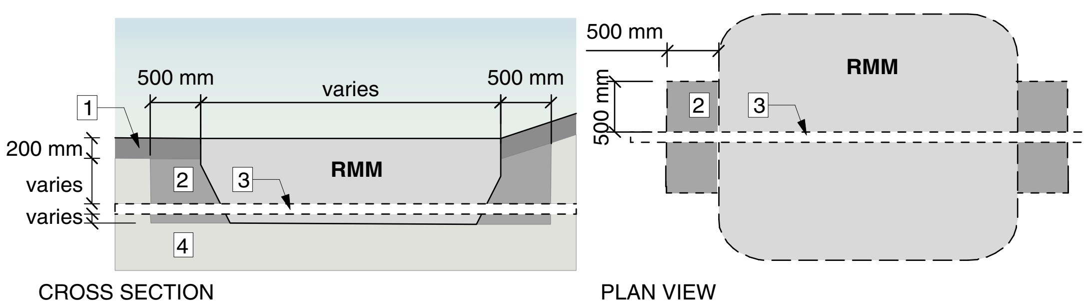




Materials

1. 200 mm locking dome grate, ductile iron
2. Drain invert elevation
3. Finished grade, growing medium
4. Max 3:1 slope
5. In line drain
6. Watertight joint
7. Adapter to fit 4 PVC pipe
8. 100 mm dia pipe
9. Elbow joint
10. 25 mm dia drain rock
11. Hex bolt, zinc-plated steel
12. Drill hole through 2 places for fasters
13. Drill hole through for hex bolt
14. 200 mm ductile iron grate lock bar
15. Socket head cap screw (allen head), black steel. 2 places

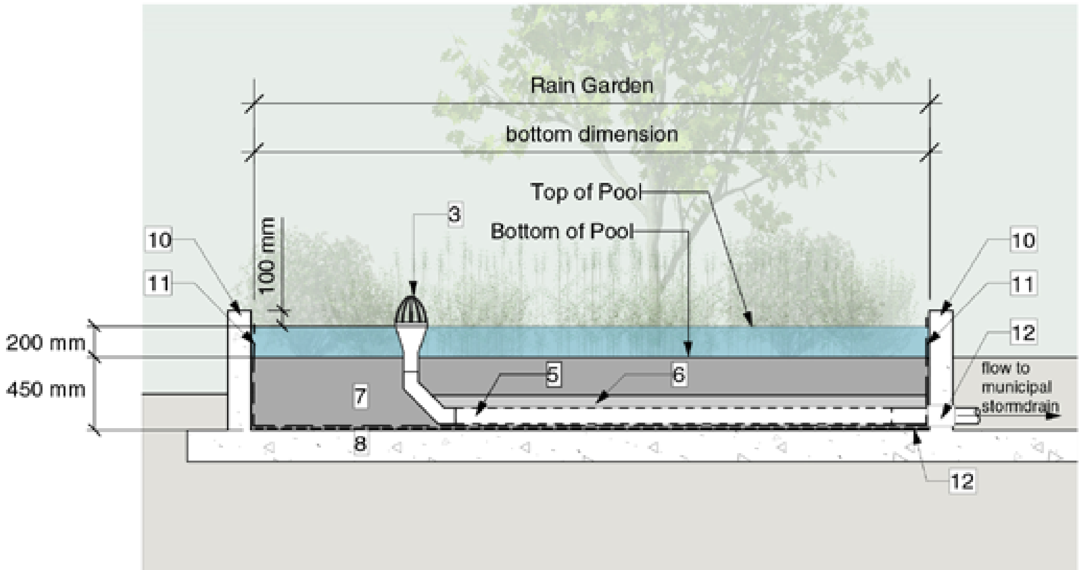
Figure 14: Typical Service Trench Crossing



Materials

1. Growing medium, min 200 mm depth
2. Compacted impervious backfill (glacial till or clay) for entire service trench width
3. Underground pipe crossing (water, gas, sewer, etc.)
4. Native subgrade

Figure 15: Rain Garden Planter On Slab



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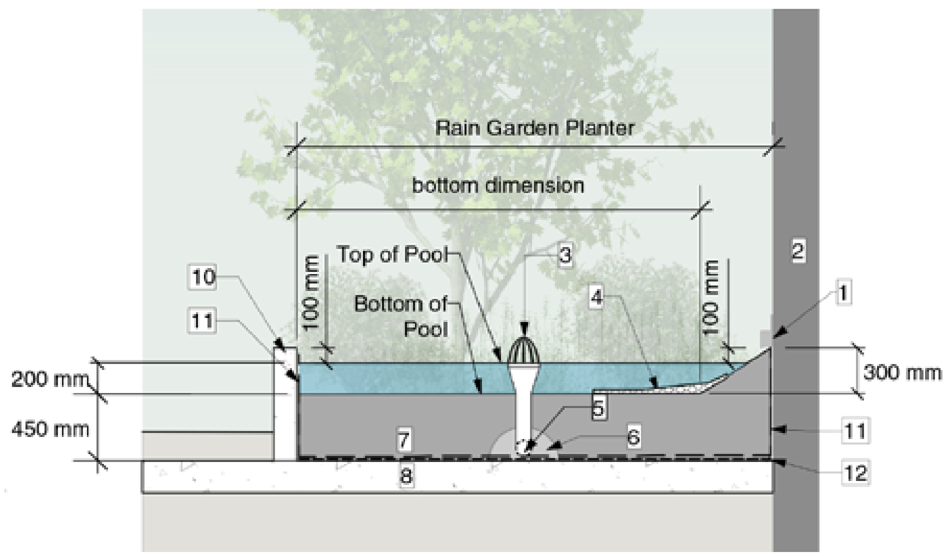
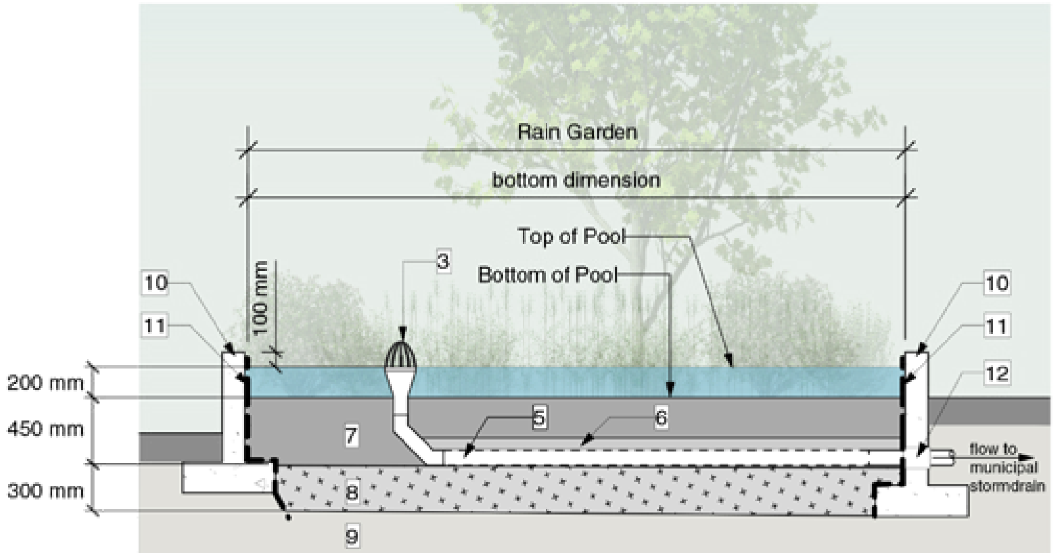


Cross Section

Rain Garden Planter on Slab Materials

1. Building downspout or scupper, max 100 mm above top of pool
2. Structural wall
3. Overflow drain, 200 mm domed grate and adapter
4. Gravel flow dissipator
5. 100 mm diameter perforated pipe
6. 25 mm dia drain rock, 100 mm depth
7. Bioretention growing medium, 450 mm depth
8. Building slab
9. Structural retaining wall
10. Root barrier
11. Waterproof PVC boot and clamp
12. Drain board

Figure 16: Rain Garden Planter



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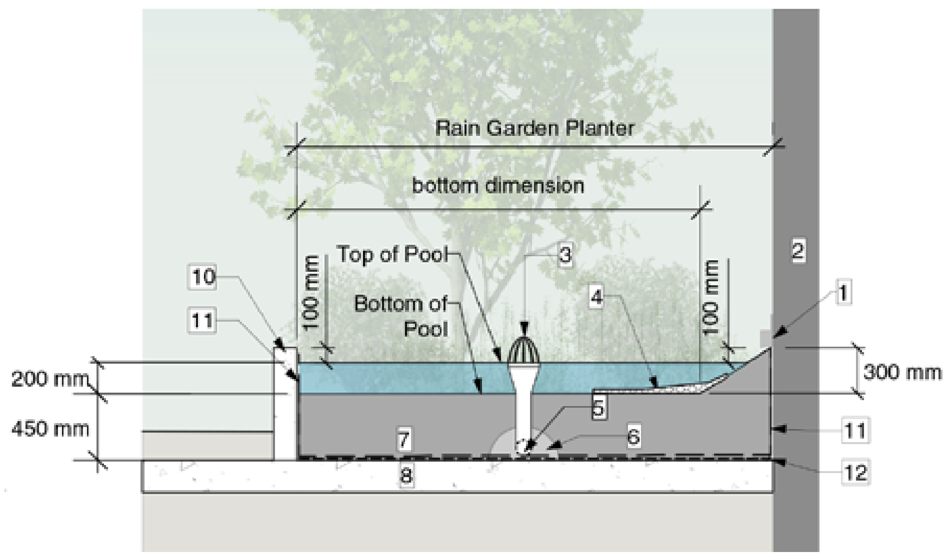


Cross Section

Rain Garden Planter Materials

1. Building rainwater leader/downspout
2. Structural wall
3. Overflow drain, 200 mm domed grate +
4. Gravel flow dissipator
5. 100 mm diameter perforated pipe
6. 25 mm dia drain rock, 100 mm dept
7. Bioretention growing medium, 450 mm
8. Scarified sub-soil, 300 mm depth
9. Existing sub-grade
10. Structural retaining wall
11. PVC liner
12. Waterproof PVC boot and clamp

General Specifications

1. Dimensions:
   a. Depth of basin (from top of growing medium to overflow elevation): 200 mm.
   b. Bottom of rain garden (flat area) width: minimum 1.0 m. (1.0 m – 3.0 m, preferable).
   c. Length-width ratio of 2:1.
   d. Side slopes of rain garden: 3:1 maximum.
2. Setbacks: Rain garden must meet all minimum setbacks outlined in Part 2.
3. Inflow:
   a. Grade the impervious area towards the rain garden. At point-source inlets, install flow dissipator such as rock cobble to transition from inlets to growing medium.
4. Overflow drain required, with connection to municipal stormdrain or engineered rock pit where no stormwater main fronts property.
   a. Protect from debris and sediment with domed grate.
   b. Allow 100 mm freeboard between the inlet elevation and the maximum ponded elevation (overflow elevation).
   c. A backflow preventer may be required in accordance with the City's Plumbing Bylaw.
5. Mulch to be leaf mold, compost, shredded garden waste, well composted bark or mild, well composted manures.
6. Bioretention Growing Medium, 450 mm depth:
   a. Must be obtained from a supplier to meet the following specifications:

Table 5: Bioretention Growing Medium Specs

Particle Size Classes	Percent Dry Weight of Mineral Fraction
Coarse Gravel (particles greater than 19 mm and less than 40 mm)	0 to 1%
All Gravels (particles greater than 2 mm and less than 40 mm)	10 to 25%
Sand, Silt, Clay & Organic components measured from remaining non gravel portion of sample (% dry weight)	
Sand* (particles greater than 0.05mm and less than 2 mm)	60 to 70%
Combined Silts and Clays (particles less than 0.05 mm)	10 to 20%
Organics (particles less than 2 mm)	15 to 20%

   b. Install growing medium in 200 mm lifts and compact with lawn roller. Do not over-compact or this will decrease ability to infiltrate water.

   *Note: Growing medium to be manufactured with '2 mm minus' sand to reduce gravel content in the soil. 2 mm minus sand is available from most local quarries upon request.

7. Scarified subgrade to 300 mm depth.
8. Perforated pipe to be 100 mm diameter PVC with minimum 2 rows of 5 mm (1/2 inch) holes.
9. Outlet pipe shall be PVC sewer pipe minimum CSA rated ≤ 35 SDR. 100 mm diameter minimum complete with PVC backflow preventer valve (if required) as per City Plumbing Code. Pipe must have minimum 1% grade and follow the Plumbing Code.
10. Waterproof Liner: Shall be 30mil PVC liner or equivalent (Rain Garden Planter only).
11. Drainage board (Rain Garden Planter only) to be non-woven geotextile, Sopradrain 10G or approved equivalent.
12. Root barrier (Rain Garden Planter only) to be woven geotextile, Sopradrain Microfab or approved equivalent.

Plant List

Latin name (common name)

Tree Species – bottom or edge of rain garden:

- Acer circinatum[1] (Vine Maple)
- Acer rubrum (Red Maple)
- Cercidiphyllum japonicum (Katsura)
- Cercis canadensis (Eastern Redbud)
- Chamaecyparis nootkatensis 'Pendula' (Nootka False Cypress)
- Nyssa sylvatica (Tupelo)

Trees cannot be planted in rain gardens with rock reservoirs.

Edge of Rain Garden Species:

- Cistus x corbariensis* (White Rockrose)
- Gaultheria shallon*[1] (Salal)
- Lonicera pileata* (Box-leaf Honeysuckle)
- Mahonia aquifolium*[1] (Oregon Grape)
- Myrica californica*[1] (Pacific Wax Myrtle)
- Rosa nutkana*[1] (Nootka Rose)
- Polystichum munitum*[1] (Sword Fern)
- Symphoricarpos alba[1] (Snowberry)
- Vaccinium ovatum*[1] (Evergreen Huckleberry)
- Viburnum davidii* (David's Viburnum)

Bottom of Rain Garden Species:

- Carex obnupta *[1] (Slough Sedge) shade only
- Carex stipata*[1] (Awl Fruited Sedge) sun/shade
- Cornus sericea 'Kelseyii' (Dwarf Red Dogwood)
- Iris setosa*[1] (Dwarf Arctic Iris) sun/shade
- Juncus 'Carmen's Grey*(Carmen's Grey Rush) sun/part shade
- Miscanthus sinensis 'Adagio'* (Dwarf Maiden Grass) sun/part shade
- Myrica gale*[1] (Bog Myrtle)
- Schizostylis coccinea 'Oregon Sunset'* (Crimson Flag) sun/shade
- Consult with local nursery for more suggestions.

*Generally considered to be deer resistant shrub/grass/perennial species

[1]Species native to Pacific Northwest coast.

Maintenance

Rain gardens must be protected from foot traffic as well as vehicles and other loads, especially during wet conditions. This is to prevent compaction and preserve the infiltration capacity of the soil.

General Maintenance During Establishment Period (first one to two years):

- Water the rain garden regularly for the first one to two years, until plants are well established.
  - Water deeply, but not frequently, every week or as needed. The top 150 to 300 mm of soil should be moist.
  - Use soaker hoses or irrigation system if possible; if not, use slow-release watering devices such as tree bags to water trees and shrubs
- Every other week during spring and summer (growing season):
  - Weed control – remove weeds by hand as needed and dig or pull weeds out by the roots before they go to seed to control their spread.

- On a monthly basis during spring and summer (growing season):
  - Check irrigation coverage and adjust as needed to ensure all plants are getting the water they need; and
  - Remove debris, including garbage, broken branches and dead vegetation, and any excess accumulation of sediment.
- Every other week during fall and winter (rainy season):
  - Inspection and debris removal from inflow and overflow (leaf fall in planting areas need not be cleared); and
  - Inspection and correct of erosion problems. Armor erosion areas with small stones.
- Bi-annual (spring and fall):
  - Check mulch depth and add mulch or coarse compost by hand as required. Mulch depth should be uniform 50 – 75 mm depth;

  Do not mound mulch against woody trunks; and
  - Add compost and cultivate into the soil.

General Maintenance After Establishment Period:

- Water plants during drought conditions or as needed to maintain plant cover
- Monthly inspection for:
  - Weeds and debris (sediment and vegetative litter); and
  - Erosion and ponding problems.
- If you notice excessive ponding (more than 48 hrs), investigate cause. Look for clogs and check connections and grades.
  - Clean sump and pipes of sediment and debris;
  - Remove leaves clogging the outlet or matted in the bottom of the rain garden;
  - Assess if fine sediment is clogging the growing medium and remove and replace if required; and
  - Assess if water is coming into the rain garden from unexpected sources, either the catchment area has increased or another area has been routed to the rain garden that was not part of the original design – if so and the extra water is having an adverse impact on the plants and soil the extra water must be diverted to the stormwater system.
- If you notice erosion on the slopes of the rain garden:
  - Investigate the source of flows to that area and whether the flow is entering as it should or is concentrating somewhere that it should not outside the rain garden. Correct as needed.
  - If erosion is caused by flow that is too fast, consider ways of slowing the flow or using rocks to protect the soil where the erosion is occurring.

Annual Maintenance Recommended:

- Soil test to determine nutrient requirements in spring (fertilization regime);
- Pruning of rain garden rushes (Juncus species) just below seed heads in November/December; and
- Pruning of trees to direct growth or correct structural problems during winter (dead, damaged, or diseased branches can be removed as needed throughout the year).

Bioswales

A bioswale system combines aspects of grass swales and infiltration trenches. The surface component of a bioswale is a shallow planted channel, accepting flows from areas of adjacent paved surfaces such as roads and parking. The bioswale is designed to convey runoff through a site while allowing it to infiltrate through a soil bed and into the ground.

Sizing

Assumptions for Sizing Approach:

- The bioswale area is sized based on the upstream impervious area that it serves. This relationship is defined by the Sizing Factor: the ratio of base area of the bioswale to upstream impervious area (also called catchment area). Two approaches for calculating the sizing factor are allowed:
- Size the bioswale for water quality treatment based on 32 mm of rainfall flowing through the growing medium of the bioswale with the assumption that the long-term hydraulic conductivity of the growing medium is 20 mm/hr. This approach results in a sizing factor of 7%.
- Calculating Sizing Factor to capture and infiltrate 32 mm of rainfall. Sizing Methodology is presented below. The equation for sizing bioswales for capture in its most general form is presented below. Multiple design options for bioswales are included in these standards. Simplify the following equation based on the type of bioswale that you are designing. For example if you are designing a bioswale with a sand reservoir or a bioswale without a reservoir, then you do not need to consider depth of rock trench in your calculations (DR=0):

  Sizing Factor = $[(24 \times K_S + n_R \times D_R + n_S \times D_S + n_{sand} \times D_{sand})/32 - 1]^{-1}$

  Where:

  Sizing Factor = Fraction of tributary impervious area required as base area for the Bioswale (unit less)

  K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr); suggested value 2 mm/hr

  n_R = porosity of drain rock in reservoir (unit less); suggested value 0.35

  D_R= Depth (thickness) of rock reservoir (mm)

  n_S = porosity of soil layer (unit less); suggested value 0.2

  D_S = Soil layer depth (thickness); standard value = 300 or 450 (mm) depending on planting needs

  n_{sand} = porosity of sand layer (unit less); suggested value 0.25

  D_{sand} = Depth (thickness) of sand (mm)

  Assumptions:

  R = Rainfall capture depth (mm); design target is 32 mm

- The minimum allowable sizing factor for bioswales is 7%. This minimum is based on water quality treatment standards for the City of Victoria. The Bioswale base area should always be at least 7% of the impervious catchment area draining to it.
- The sizing process provides the base area of the Bioswale, which is the flat area at the bottom with uniform layers of growing medium and rock/sand reservoir. Sizing by these methods does not account for any infiltration benefit provided by the sloped sides of the Bioswale.

Sizing for Water Quality

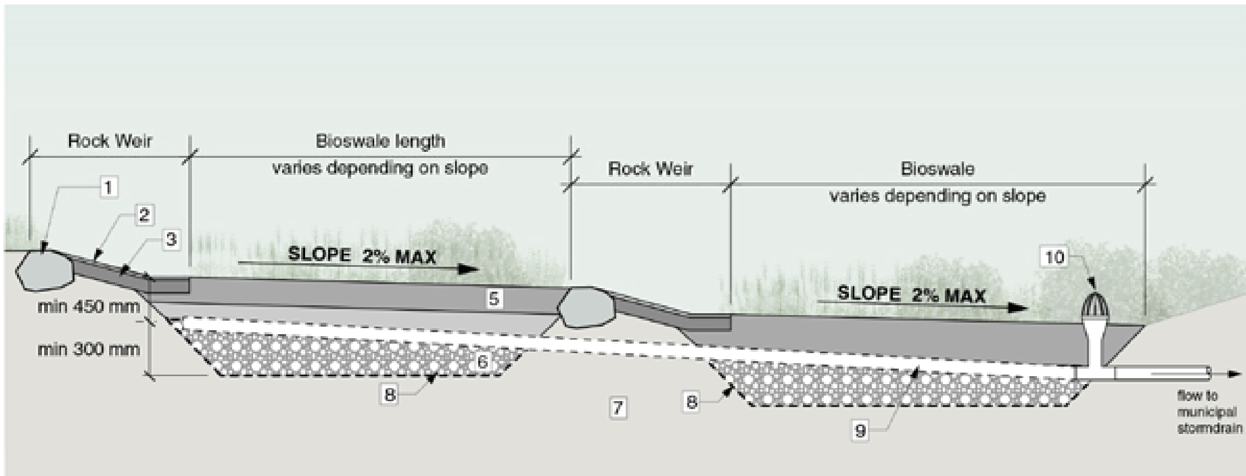
- Use a sizing factor of 7%. This sizing factor assumes a long-term hydraulic conductivity of 20 mm/hr. Water quality bioswales must have an underdrain bedded in a 300 mm drain rock layer.

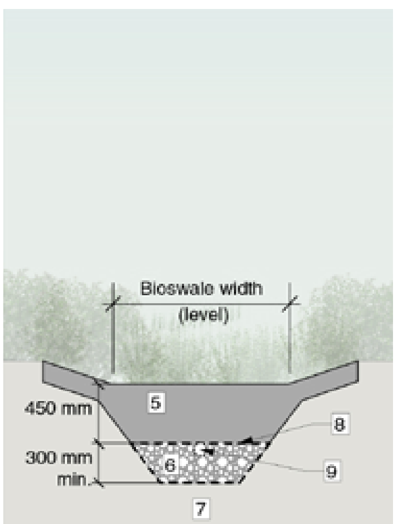
Sizing for Capture and Infiltration

Option 1: Bioswale with Rock Reservoir

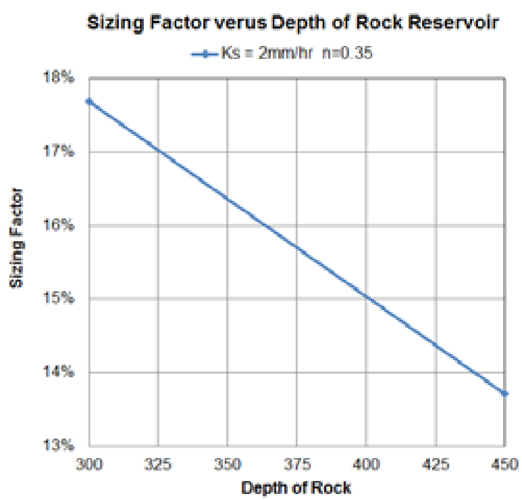
The surface soils and drain rock reservoir are sized to treat and infiltrate the rainwater management target volume of water. A perforated drain placed near the top of the drain rock reservoir provides an underground overflow, which also maintains drainage of any adjacent pavement base courses. The bioswale may include weir structures to slow runoff flow and allow it to infiltrate while providing conveyance for larger storm events to a surface outlet.

Figure 17: Bioswale With Reservoir Detail





Bioswale with reservoir cross section



Bioswale Materials

1. Rock weir (300 – 400 mm dia)
2. 25 mm dia drain rock, 25 mm depth
3. 50 – 75 mm dia drain rock, 100 mm depth min
4. Composted mulch, 50 – 70 mm depth
5. Bio-rentention growing medium, 450 mm depth min
6. Reservoir, min 300 mm depth
7. Existing subgrade/native material
8. Non-woven geotextile on bottom sides, and top of drain rock
9. 100 mm diameter (min) perforated pipe
10. Overflow drain, 200 mm domed grate and adapter

Sizing for depth capture criteria: 32 mm in 24 hrs

1. Determine the maximum depth for the rock reservoir based on measured subsurface soil infiltration rate for the site and round down to the nearest 50 mm increment for contractibility; allowable depth range is 300 to 2000 mm. If the infiltration rate is not being measured at the site, then assume a value of 2 mm/hr for saturated hydraulic conductivity (Ks) which results in a maximum allowable rock depth of 550 mm.

2. Determine the maximum rock depth according to the drain time (4 days allowed maximum) and round down to the nearest 50 mm increment for contractibility; allowable depth range is 300 to 2000 mm:

   $D_R = 96\ Ks/\ n$

   Where:

   D_R = Maximum recommended depth (thickness) of rock reservoir (mm)

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr) (suggested value 2 mm/hr)

   Assumptions:

   n = porosity of drain rock in reservoir (unit less, e.g. 0.35, typical)

3 Use the following equation to determine the base (bottom) area of the bioswale required by finding the sizing factor for the site. Choose any value for the depth of rock reservoir within the allowable depth range and under the maximum allowable calculated in the previous step:

   Sizing Factor = $[(24 \times K_S + n_R \times D_R + n_S \times D_S + n_{sand} \times D_{sand})/32 - 1]^{-1}$

   Where:

   Sizing Factor = Fraction of tributary impervious area required as base area for the Bioswale (unit less)

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr); suggested value 2 mm/hr

   n_R = porosity of drain rock in reservoir (unit less); suggested value 0.35

   D_R = Depth (thickness) of rock reservoir (mm)

   n_S = porosity of soil layer (unit less); suggested value 0.2

   D_S = Soil layer depth (thickness); standard value = 300 or 450 (mm) depending on planting needs

   n_{sand} = porosity of sand layer (unit less); suggested value 0.25

   D_{sand} = Depth (thickness) of sand (mm)

   Assumptions:

   R = Rainfall capture depth (mm); design target is 32 mm

   Assuming Ks of 2 mm/hr and growing medium (soil) depth of 300 mm, the chart on the previous page shows the relationship between depth of rock reservoir and sizing factor.

4. Check that the sizing factor is greater than or equal to 7%. If the calculated sizing factor is less than 7%, use 7%. If the calculated sizing factor exceeds the minimum, reduce the depth of the rock trench until minimum allowable depth or the minimum sizing factor is reached. Bioswale performance may exceed the design target.

5. To find the swale base area:

   Base Area = Impervious Tributary Area x Sizing Factor

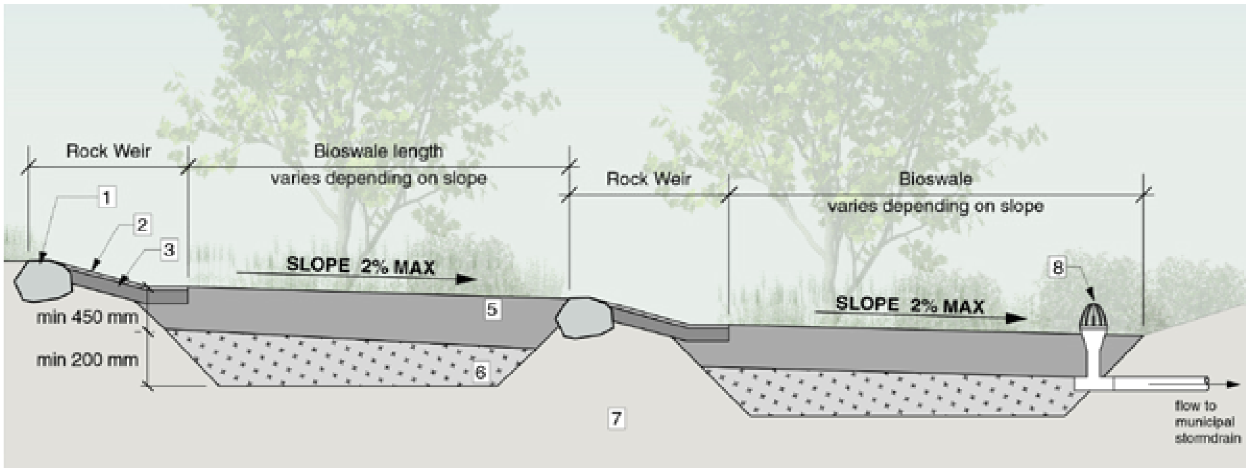
6. Calculate the footprint of the facility based on the Base Area and side slopes. Footprint of Bioswale = Base Area + Side Slope Area. Add additional area for side slopes according to the shape of the swale and the chosen side slopes; e.g. add [2 x slope x Bioswale depth (m)] to each dimension of the base area to determine total footprint area.

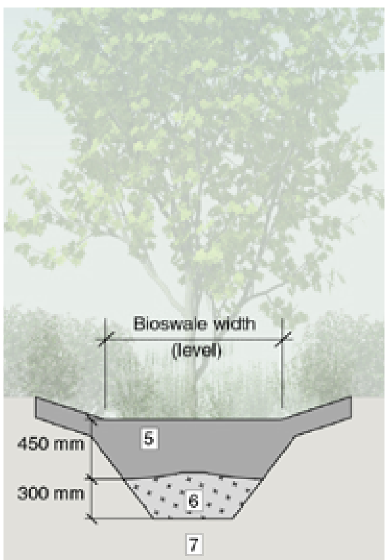
Option 2: Bioswale with Growing Medium Only

Sizing for depth capture criteria: 32 mm in 24 hrs

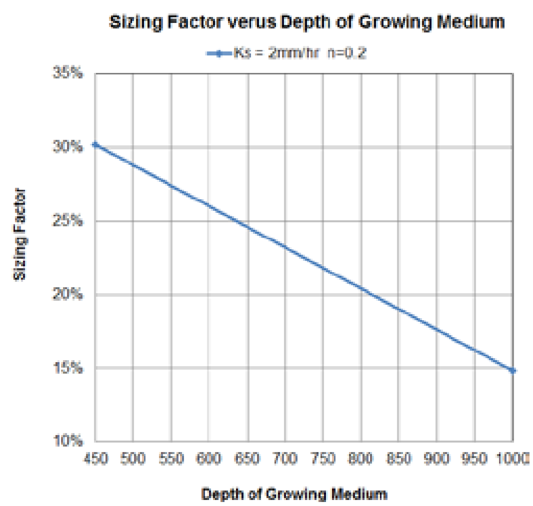
Based on the sizing equation, the following chart shows the relationship between depth of growing medium and sizing factor (assuming a K_S value of 2 mm/hr and a growing medium porosity of 0.2):

Figure 18: Bioswale Without Reservoir Detail





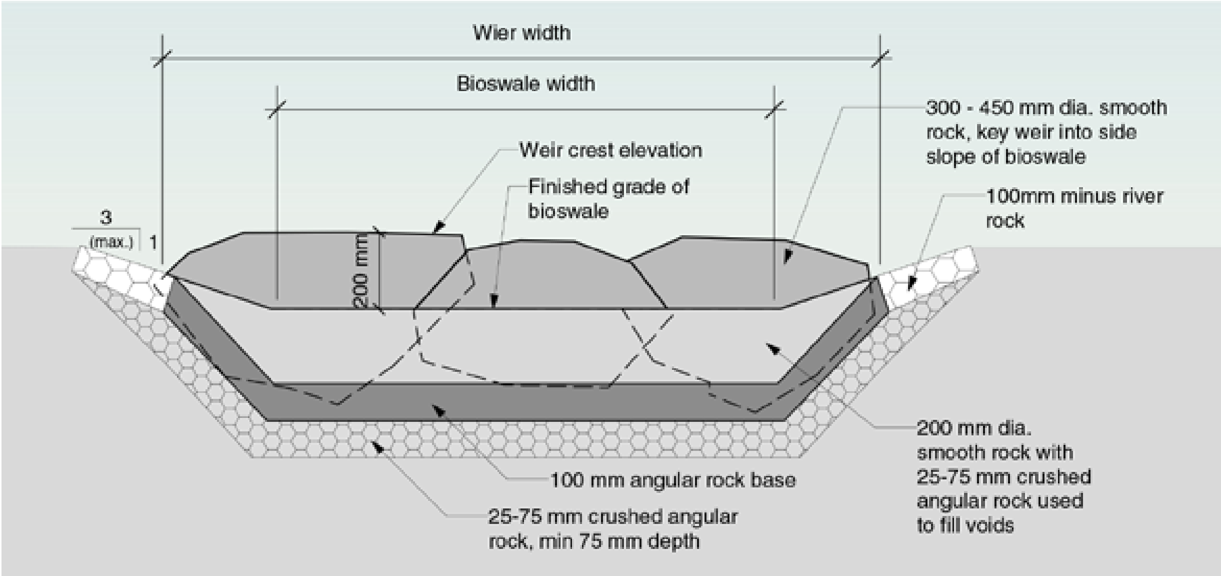
Bioswale cross section



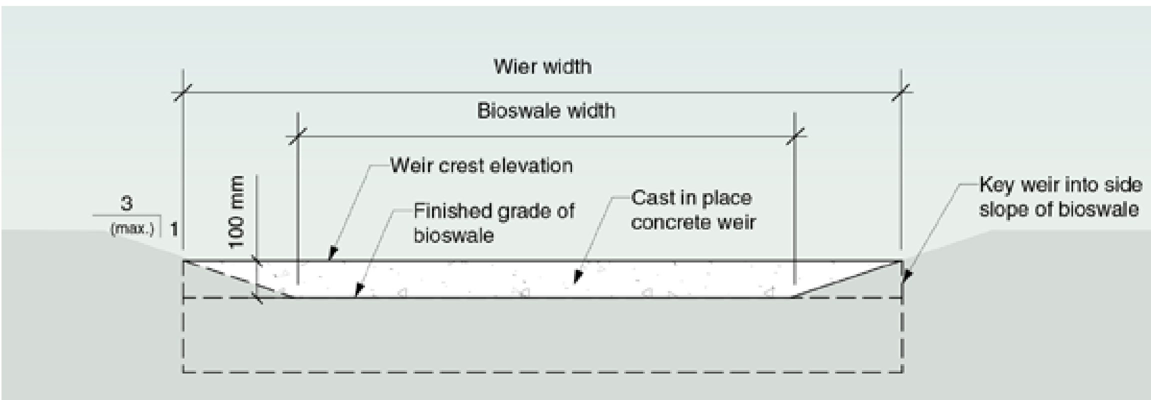
Bioswale Materials

1. Rock weir (300 – 400 mm dia)
2. 25 mm dia drain rock, 25 mm depth
3. 50 – 75 mm dia drain rock, 100 mm depth min
4. Composted mulch, 50 – 70 mm depth
5. Bio-rentention growing medium, 450 mm depth min
6. Scarified/tilled subgrade, 200 mm depth minimum
7. Existing subgrade/native material
8. Overflow drain, 200 mm domed grate and adapter

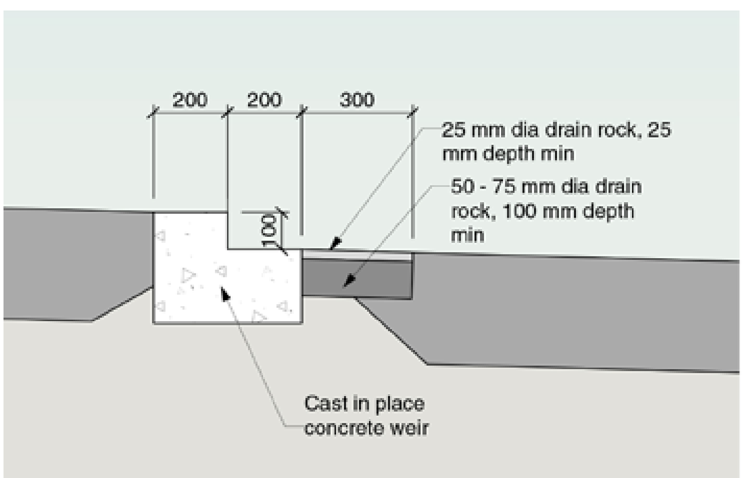
Figure 19: Weir Detail



Rock weir section



Cast in place concrete weir section

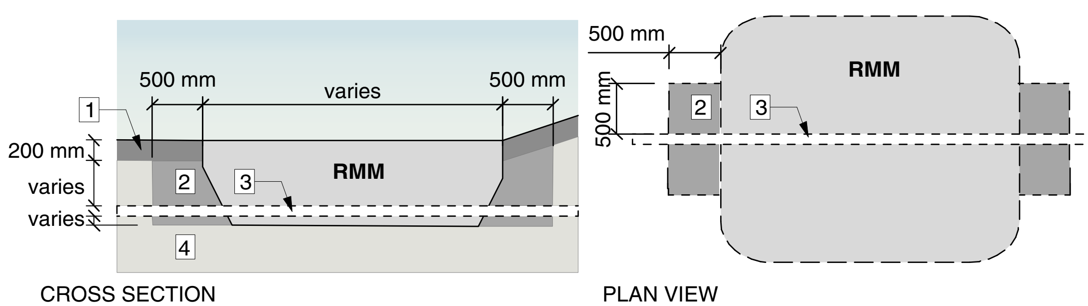


Cast in place concrete weir profile

Design Standards

1. The Bioswale should be sized based on bottom or base area of the swale, as the effective area for treatment and infiltration in the swale.
2. Inflow to the swale should ideally be distributed sheet flow along the length of the swale. Provide non-erodable material for erosion and scour protection, sediment cleanout basins, and weir flow spreaders at point-source inlets.
3. Provide erosion control, vegetated or otherwise, along all sides of weirs and at drainage inlets.
4. Design stormwater conveyance using Manning's formula, with attention to erosion of soils and vegetation and channel stability during maximum flows.
5. Longitudinal slope of the swale should be between 1 – 2%.
6. For longitudinal slopes of 2 – 10%, the swale length may be broken up by terraces (steps) or weirs of up to 300 mm height to reduce the slope; 200 mm or less is preferred. Splash pads of cobble-sized rock (or similar) must be included below each step or weir to prevent erosion.
7. Where weirs are used to reduce the longitudinal slope, swale longitudinal slope should be 1-2%, or dished, between weirs.
8. Weirs must have level top to spread flows and avoid channelization, keyed in 100 mm minimum.
9. Minimum freeboard to adjacent paving: 100 mm or in accordance with swale conveyance design.
10. Drain rock reservoir bottom shall be level. Where weirs are used the bottom of the reservoir must be level between the weirs.
11. Underground weirs of undisturbed native material or constructed trench dams shall be provided to create underground pooling in the reservoir sufficient for infiltration performance.
12. A non-erodible outlet or spillway must be established to discharge overflow.
13. Avoid utility or other crossings of the swale. Where service trenches must be constructed crossing below or through the swale, install trench dams at exits to avoid infiltration water flowing into the service trench.

Figure 20: Typical Service Trench Crossing



1. Growing medium, min 200 mm depth
2. Compacted impervious backfill (glacial till or clay) for entire service trench width
3. Underground pipe crossing (water, gas, sewer, etc.)
4. Native subgrade

Construction

Avoid Over Compaction and Plugging! The overriding concerns for construction of infiltration methods are that the subsurface must not be glazed or compacted and the materials must be kept clean and free of fines.

Construction Phasing:

- Leave construction of rain garden and bioswale to the end of the overall construction timeline to avoid soil compaction or plugging of the growing medium by silts and clays by construction activity.
- Divert water away from rain garden until installation of rain garden, including plant material, is fully complete.

Subgrade/Native Soil:

- Subgrade must be free of water, mud, and soft clay prior to installation of growing medium.
- Subgrade to be scarified to a minimum depth of 200 mm to help facilitate infiltration prior to installation of any rock, sand or growing medium.

Drain Rock:

- Prevent natural or fill soils mixing with the infiltration drain rock.
- Install infiltration drain rock in 300mm lifts and compacted to eliminate voids between the geotextile and surrounding soils.
- Rock should be wrapped on all sides with filter cloth to prevent the surrounding soil or above growing medium from moving into the rock trench, reducing water-holding capacity. Overlap the filter fabric by 600 mm.

Sand:

- Filter cloth is not required when using sand as the reservoir material.
- Install sand in 200 mm lifts and lightly compact with a lawn roller as per growing medium installation specifications.

Growing Medium:

- Place growing medium immediately following either construction of rock reservoir or scarification of subsurface soils. Compact just to be firm against deep foot-printing. Do not over compact. If the growing medium is left exposed to elements for more than a few hours, the surface will require scarification prior to seeding or planting.
- Install growing medium in 200 mm lifts and compact with lawn roller.

Service Trench Crossing:

- Any service trench crossings must have trench dams properly installed. Compacted impervious backfill (glacial till or clay) must fill entire width of service trench and extend to 200 mm above top of the service trench.

Planting:

- The bottom of the Bioswale must be planted. Covering the bottom of the Bioswale with rock is NOT acceptable (planting is essential for the Bioswale to function properly).

General Specifications

1. Provide protection from all vehicle traffic, equipment staging, and foot traffic in proposed infiltration areas prior to, during, and after construction.
2. Dimensions:
   a. Width of Swale: 600 mm – 900 mm.
   b. Depth of swale: 100 mm ponding depth and a minimum freeboard 100 mm. (Total minimum depth 200 mm)
   c. Longitudinal slope of entire swale: max. 15%
   d. Slope of Bioswale area: <0.5%
   e. Side slopes of swale: 3:1 maximum.
3. Inflow:
   a. Grade the impervious area towards the bioswale. At point-source inlets, install flow dissipator, to transition from inlets to growing medium.

4. Overflow drain required, with connection to municipal stormdrain or engineered rock pit where no stormwater main fronts property.

   a. Protect from debris and sediment with domed grate.

   b. Allow 100 mm freeboard between the inlet elevation and the maximum ponded elevation (overflow elevation).

   c. A backflow preventer may be required in accordance with the City's Plumbing Bylaw.

5. Mulch to be leaf mold, compost, shredded garden waste, well composted bark or mild, well composted manures.

6. Bioretention Growing Medium, 450 mm depth:

   a. Must be obtained from a supplier to meet the following specifications:

Table 6: Bioretention Growing Medium Specs	
Particle Size Classes	Percent Dry Weight of Mineral Fraction
Coarse Gravel (particles greater than 19 mm and less than 40 mm)	0 to 1%
All Gravels (particles greater than 2 mm and less than 40 mm)	10 to 25%
Sand, Silt, Clay & Organic components measured from remaining non gravel portion of sample (% dry weight)	
Sand* (particles greater than 0.05 mm and less than 2 mm)	60 to 70%
Combined Silts and Clays (particles less than 0.05 mm)	10 to 20%
Organics (particles less than 2 mm)	15 to 20%

   b. Install growing medium in 200 mm lifts and compact with lawn roller. Do not over-compact or this will decrease ability to infiltrate water.

   *Note: Growing medium to be manufactured with '2 mm minus' sand to reduce gravel content in the soil. 2 mm minus sand is available from most local quarries upon request

7. Scarified subgrade to 200 mm depth minimum.

8. Perforated pipe to be 100 mm diameter PVC with minimum 2 rows of 5 mm (1/2 inch) holes, grade pipe at minimum 1% slope.

9. Outlet pipe shall be PVC sewer pipe minimum CSA rated ≤ 35 SDR. 100 mm diameter minimum complete with PVC backflow preventer valve (if required) as per City Plumbing Code. Pipe must have 2% grade and follow the Plumbing Code.

10. Rock weirs: Shall be placed according to facility design. Rock weirs must span the bottom of the swale. Rock weir height can vary and will vary with design and site conditions. Height will be less than 450 mm. The crest of the downstream rock weir should be equal to or higher than the base of the rock weir immediately upstream (see profile). This will ensure rock weir stability during all flows.

11. Sand to be hard, granular sharp sand well washed and free of impurities, chemicals or organic matter.

12. Geotextile to be Amoco 4545 or approved equivalent, installed with 600 mm minimum overlap at all joints.

13. Drain rock to be:

   a. Rock for trench can be angular or round stone containing no fines. Many stone sizes may be acceptable as long as the minimum porosity of the trench is 0.35.

Plant List

Latin name (common name)

Tree Species – bottom or edge of Bioswale:

- Acer circinatum[1] (Vine Maple)
- Acer rubrum (Red Maple)
- Cercidiphyllum japonicum (Katsura)
- Cercis canadensis (Eastern Redbud)
- Chamaecyparis nootkatensis ‘Pendula’ (Nootka False Cypress)
- Nyssa sylvatica (Tupelo)

Trees cannot be planted in Bioswales with rock reservoirs.

Edge of Bioswale Species:

- Cistus x corbariensis* (White Rockrose)
- Gaultheria shallon*[1] (Salal)
- Lonicera pileata* (Box-leaf Honeysuckle)
- Mahonia aquifolium*[1] (Oregon Grape)
- Myrica californica*[1] (Pacific Wax Myrtle)
- Rosa nutkana*[1] (Nootka Rose)
- Polystichum munitum*[1] (Sword Fern)
- Symphoricarpos alba[1] (Snowberry)
- Vaccinium ovatum*[1] (Evergreen Huckleberry)
- Viburnum davidii* (David’s Viburnum)

Bottom of Bioswale Species:

- Carex obnupta *[1] (Slough Sedge) shade only
- Carex stipata*[1] (Awl Fruited Sedge) sun/shade
- Cornus sericea ‘Kelseyii’ (Dwarf Red Dogwood)
- Iris setosa*[1] (Dwarf Arctic Iris) sun/shade
- Juncus ‘Carmen’s Grey*(Carmen’s Grey Rush) sun/part shade
- Miscanthus sinensis ‘Adagio’* (Dwarf Maiden Grass) sun/part shade
- Myrica gale*[1] (Bog Myrtle)
- Schizostylis coccinea ‘Oregon Sunset’* (Crimson Flag) sun/shade
- Consult with local nursery for more suggestions.

*Generally considered to be deer resistant shrub/grass/perennial species

[1]Species native to Pacific Northwest coast.

Maintenance

Bioswales must be protected from foot traffic as well as vehicles and other loads, especially during wet conditions. This is to prevent compaction and preserve the infiltration capacity of the soil.

General Maintenance Standards During Establishment Period (first one to two years):

- Water the bioswale regularly for the first one to two years, until plants are well established.
  - Water deeply, but not frequently, every week or as needed. The top 150 to 300 mm of soil should be moist.
  - Use soaker hoses or irrigation system if possible; if not, use slow-release watering devices such as tree bags to water trees and shrubs
- Every other week during spring and summer (growing season):
  - Weed control – remove weeds by hand as needed and dig or pull weeds out by the roots before they go to seed to control their spread.
- On a monthly basis during spring and summer (growing season):
  - Check irrigation coverage and adjust as needed to ensure all plants are getting the water they need; and
  - Remove debris, including garbage, broken branches and dead vegetation, and any excess accumulation of sediment.
- Every other week during fall and winter (rainy season):
  - Inspection and debris removal from inflow and overflow (leaf fall in planting areas need not be cleared); and
  - Inspection and correct of erosion problems. Armor erosion areas with small stones.
- Bi-annual (spring and fall):
  - Check mulch depth and add mulch or coarse compost by hand as required. Mulch depth should be uniform 50 – 75 mm depth;

    Do not mound mulch against woody trunks; and
  - Add compost and cultivate into the soil.

General Maintenance Standards After Establishment Period:

- Water plants during drought conditions or as needed to maintain plant cover
- Monthly inspection for:
  - Weeds and debris (sediment and vegetative litter); and
  - Erosion and ponding problems.
- If you notice excessive ponding (more than 48 hrs), investigate cause. Look for clogs and check connections and grades.
  - Clean sump and pipes of sediment and debris;
  - Remove leaves clogging the outlet or matted in the bottom of the bioswale;
  - Assess if fine sediment is clogging the growing medium and remove and replace if required; and
  - Assess if water is coming into the bioswale from unexpected sources, either the catchment area has increased or another area has been routed to the bioswale that was not part of the original design – if so and the extra water is having an adverse impact on the plants and soil the extra water must be diverted to the stormwater system.
- If you notice erosion on the slopes of the bioswale:
  - Investigate the source of flows to that area and whether the flow is entering as it should or is concentrating somewhere that it should not outside the bioswale. Correct as needed.
  - If erosion is caused by flow that is too fast, consider ways of slowing the flow or using rocks to protect the soil where the erosion is occurring.

Annual Maintenance Recommended:

- Soil test to determine nutrient requirements in spring (fertilization regime);
- Pruning of rushes (Juncus species) just below seed heads in November/December; and
- Pruning of trees to direct growth or correct structural problems during winter (dead, damaged, or diseased branches can be removed as needed throughout the year).

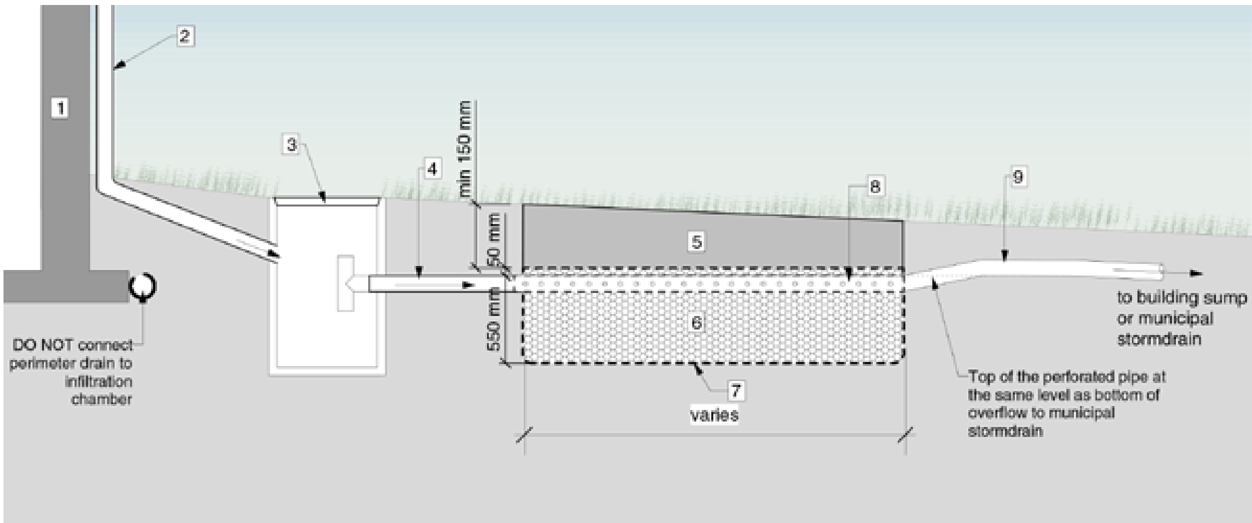
Infiltration Chambers

An infiltration chamber system typically includes an inlet pipe or water source, catch basin sump, infiltration chamber, overflow to the storm sewer system and perforated distribution pipe (for rock-filled structures). Two types of infiltration chambers are considered here: rock-filled structures and open chamber type systems. These two types are shown as underground rock pits of any shape, and underground open chamber systems.

- A rock infiltration chamber/trench is an underground water storage facility constructed with course aggregate.
- An open infiltration chamber/infiltration tank is an underground water storage facility constructed with manufactured modular structures to create large void spaces for temporary storage of stormwater.

In both types water fills the void spaces, and the facility will typically be designed to exfiltrate this water into the surrounding soil.

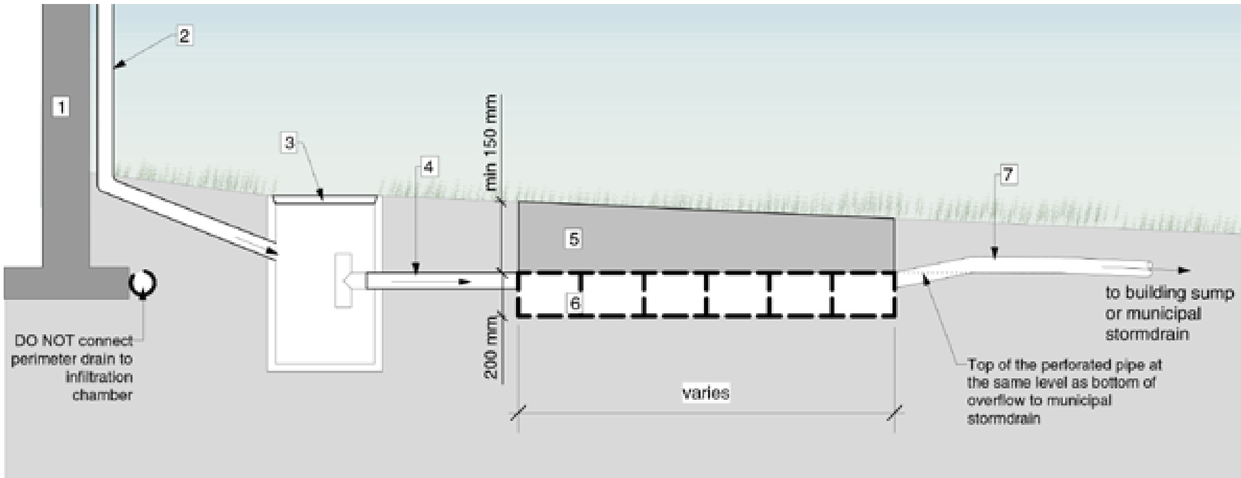
Figure 21: Rock Infiltration Chamber Detail



Rock Filtration Chamber Materials

1. Structural wall
2. Building rainwater leader/downspout
3. Infiltration chamber sump
4. Solid pipe to infiltration chamber
5. Growing medium
6. Drain rock, 550 mm depth
7. Non-woven geotextile on bottom, sides and top of drain rock
8. 100 mm diameter (min) perforated pipe
9. Solid overflow pipe complete with PVC backflow preventer valve (if required) as per City Plumbing Code.

Figure 22: Open Infiltration Chamber Detail



Open Filtration Chamber Materials

1. Structural wall
2. Building rainwater leader/downspout
3. Infiltration chamber sump
4. Solid pipe to infiltration chamber
5. Growing medium
6. Open crate chamber system, 200 mm depth
7. Non-woven geotextile on bottom, sides and top of drain rock
8. Solid overflow pipe complete with PVC backflow preventer valve (if required) as per City Plumbing Code.

Sizing

Assumptions for Sizing Approach:

- For these sizing approaches, the Infiltration Chamber is assumed to be a rectilinear underground facility defined by a Base Area which is the same as the footprint, and a depth of rock in the trench or depth of an open chamber system. Depth of cover over the rock trench/open chamber is not considered for sizing.
- In general, the Infiltration Chamber is sized based on the upstream impervious area that it serves. Similar to the Rain Garden, this relationship can be defined by the ratio of pervious area to impervious area (i.e. sizing factor). For the simplified sizing approaches here, this represents the ratio of Base Area (bottom area) of the Infiltration Chamber to upstream impervious area (also called catchment area).
- If subsurface soils are thought to be well-draining, the infiltration rate of the soil should be measured if possible, to reduce the area of infiltration required, and the size and cost of the infiltration chamber.
- Minimum allowable sizing factor is 2%. This minimum is required to maintain the infiltration surface for the long term life of the facility.

Sizing for Water Quality

Infiltration chambers are volume reduction or capture facilities. Water quality improvement from use of infiltration chambers comes from settling out particles in a sump prior to runoff entering the infiltration facility, as well as the infiltration of water into the subsurface. For ground surface runoff, a Qualified Professional must size a sump appropriate for the inflow from the impervious surface, which will not

be the same value as the rainwater management design target. For roof runoff only, a sump is also recommended to allow access to the piping for cleanout, but does not need to be sized for settling of particulate.

Sizing for Capture and Infiltration

1. Determine the maximum depth (thickness) for the chamber (not including depth of cover) based on measured subsurface soil infiltration rate for the site and the porosity of the infiltration media and round down to the nearest 50 mm increment for constructability; allowable depth range is 300 to 2000 mm. If the infiltration rate is not being measured at the site, then assume a value of 2 mm/hr for saturated hydraulic conductivity (K_S) which results in a maximum allowable rock depth of 550 mm.

   $D_R = 96\ K_S/n$

   Where:

   D_R = Maximum recommended depth (thickness) of media (mm)

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr) (default value 2 mm/hr)

   n = Porosity of media in the reservoir (e.g. 0.35 for drain rock or 0.95 for typical open crate system) (unitless)

2. Use the following equation to determine the base (bottom) area of the chamber required by determining the sizing factor for the site:

   $\text{Sizing Factor} = 32 / (24 \times K_S + n \times D_R)$

   Where:

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr) (default value: 2 mm/hr)

   D_R = Depth (thickness) of rock reservoir or Depth of Open Chamber System (mm)

   n = Porosity of media in the reservoir (e.g. 0.35 for drain rock or 0.95 for typical open crate system) (unit less)

3. To find the chamber area:

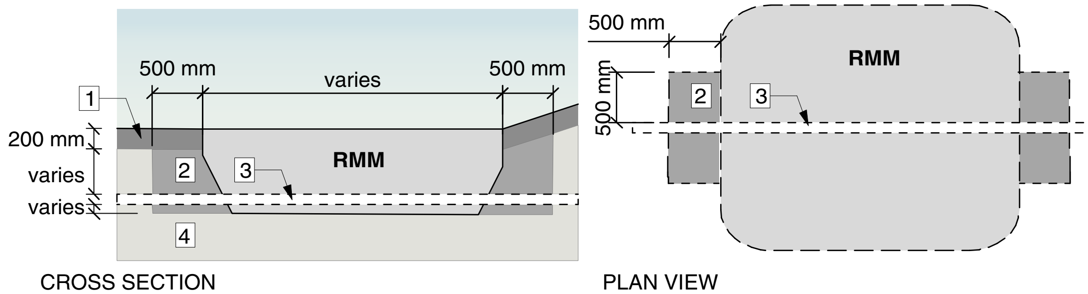
   Base Area = Impervious Tributary Area x Sizing Factor

4. Check that the sizing factor calculated is above the minimum of 2%. If the calculated sizing factor is greater than 2%, reduce the depth of the rock trench until either the minimum allowable depth or the minimum sizing factor is met.

Design Standards

1. Any runoff directed to an infiltration chamber that is covered by pavement should be routed through a sump (see point 4) prior to discharge to the infiltration chamber. If any ground surface runoff is to enter the system, provide pre-treatment and upstream erosion control to avoid sedimentation in the infiltration chamber.
2. To avoid groundwater pollution, do not direct untreated polluted runoff to infiltration chamber:
   a. Direct clean runoff (roof, non-vehicle paving) to infiltration chamber.
   b. For polluted runoff (roads, parking areas, other pollution sources), provide upstream facility (Oil/Grit Separator, Rain Garden or Bioswale) for pollutant reduction prior to release to infiltration chamber.
   c. Identify pollutant sources other than vehicles, particularly in industrial/commercial hotspots, that require pre-treatment or source control upstream of this method.
3. Infiltration chamber perforated distribution pipe (if using) and bottom of infiltration media to be installed level.
4. A bypass or overflow connection to the municipal storm sewer must be included in the facility design to accommodate flows in excess of the design infiltration volume.
5. Avoid utility or other crossings of the infiltration chamber. Where service trenches must be constructed crossing below or through the infiltration chamber, install trench dams at exits to avoid infiltration water flowing into the service trench.

Figure 23: Service Trench Crossing



1. Growing medium, min 200 mm depth
2. Compacted impervious backfill (glacial till or clay) for entire service trench width
3. Underground pipe crossing (water, gas, sewer, etc.)
4. Native subgrade

Construction Considerations

- Construction Phasing: construction of the infiltration trench and its associated pipe connections should be scheduled for just before surface paving to avoid over compaction and/or plugging of the facility with sediment.
- Scarifying Subgrade: scarify the excavation subgrade to a depth of 200 mm so that the surface is loose and friable prior to placing filter fabric or growing media infiltration media.
- Filter Cloth: drain rock should be wrapped on all sides with filter cloth to prevent the surrounding soil or above topsoil from moving into it, reducing its water-holding capacity. Open chamber (crate-type) systems should also have the media fully wrapped with filter cloth to protect from sedimentation in accordance with the manufacturer's instructions.
- Backfill: place backfill over filter fabric.
- Service Trench Crossing: Any service trench crossings must have trench dams properly installed. Compacted impervious backfill (glacial till or clay) must fill entire width of service trench and extend to 200 mm above the top of the service trench.

General Specifications

1. Minimum depth of 600 mm is required from base of infiltration chamber to water table or solid bedrock.
2. Service trench crossing: Any service trench crossings must have trench dams properly installed, using compacted impervious materials, for entire trench width and extend to 200 mm above the top of the service trench.
3. Two separate chambers in Duplex and three chambers in Triplex are acceptable.
4. Sump shall be concrete, plastic, or other non-degradable box with strength suitable to withstand surface loads.
5. Solid pipe to be CSA B182. Grade pipe at minimum 1% slope.
6. Perforated pipe to be 100 mm diameter PVC with minimum 2 rows of 5 mm (1/2 inch) holes. Grade perforated pipe at minimum 1% slope.
7. Geotextile to be Amoco 4545, installed with 600 mm minimum overlap at all joints.
8. Drain rock, minimum 550 mm depth to be angular or round stone containing no fines. Many stone sizes may be acceptable as long as the minimum porosity of the trench is 0.35.
9. Open chamber system, 200 mm depth:
   a. May be any system designed and manufactured for infiltration chamber use. Specific requirements for different manufacturers' products may make some systems more or less appropriate for individual sites. A Qualified Professional must review and approve specific products for open chamber infiltration systems and design the infiltration chamber system in accordance with the manufacturer's specifications of the chosen product.
10. Outlet pipe shall be PVC sewer pipe minimum CSA rated ≤ 35 SDR. 100 mm diameter minimum complete with PVC backflow preventer valve (if required) as per City Plumbing Code. Pipe must have minimum 1% grade and follow the Plumbing Code.

Maintenance

- Inspect sumps annually and clean as required. Sediment should be removed from the sump bottom and floatables removed from the water surface.
- If the infiltration chamber has an observation port, check periodically every few years during dry weather to be sure that water is not remaining in the chamber for more than 4 days after a rain event.
- If the water is not draining from the chamber then the infiltration surface is clogged. There is no repair for this except removal of the existing chamber, rehabilitation of the subsurface soils (if possible) and replacement of the chamber.

Permeable Paving

Typically permeable paving refers to a surface layer of paving with a base layer and a subbase layer that allows rainfall to percolate through the pavement into underlying subgrade (underlying soil).

Permeable pavers may be designed with a rock reservoir and underdrain to allow storage or runoff.

The surface component of permeable paving can be:

- Porous asphalt or porous concrete, where fines are not included in the mix, providing a high void ratio that allows water to pass through. This is the most expensive of the options for permeable paving and it generally requires trained and certified contractors for installation.
- Concrete grid pavers, where a structural load bearing matrix has large voids that are filled with permeable material – usually open graded gravel or soil – and may have grass growing in the void spaces. Traditional gravel driving surfaces are not considered permeable.
- Permeable unit pavers, made up of impervious concrete modular pavers with gapped joints that allow water to percolate between the pavers.

Permeable unit pavers are assumed for the basis for design in this section, as they have been used with consistent success and are a durable and easily installed alternative to traditional impervious paving.

Permeable pavement can be designed for a range of uses, from foot traffic only to heavy vehicle loading. Heavy vehicle loading and frequent vehicle traffic must be specifically designed for with the assistance of a Professional Engineer with experience of designing pavements for the expected loading.

Pervious/permeable unit paving is a permeable paving system constructed with specialized impervious modular pavers. The pavers are designed to have gapped joints between pavers which are filled with porous joint stabilizer. Water percolates between the pavers to the base material or reservoir below.

Basic Permeable Unit Paving areas do not have a rock reservoir and underdrain system. Runoff percolates through the paving system and infiltrates the subgrade below. Basic Permeable Unit Paving areas can manage only the rain that falls directly on it. Permeable Unit Paving areas with rock reservoir and underdrain system can manage runoff from other impervious paving and roof surfaces. Runoff percolates through the paving system and infiltrates the reservoir before entering the subgrade below, and the underdrain carries overflow to the municipal stormwater system.

Sizing

Assumptions for Sizing Approach:

- Permeable pavement designs may be one of two types.
- With reservoir – permeable paving is designed with a rock reservoir and perforated subdrain below the surface to maximize the infiltration capacity of the system.
- Without reservoir – permeable paving is designed with only the manufacture's recommended bedding courses below the pavement and no reservoir or subdrain.
- Permeable paving can only accept runoff that directly falls onto it unless it is built with a rock reservoir with underdrain or unless it is sized by a Qualified Professional where the measured subgrade infiltration rate is greater than 2 mm/hr.
- Permeable paving is sized to infiltrate the rain that falls directly on it and runoff from a limited area of upstream impervious surface. The minimum ratio of permeable paving to impervious area (sizing factor) allowed is 20%.

Sizing for Water Quality

- Sizing approach to meet City of Victoria's water quality target is the same as the approach to meet volume capture and infiltration targets.
- There is no reduction in sizing for water quality sizing in the case of permeable paving.

Sizing for Capture and Infiltration

Permeable Unit Paving with Rock Reservoir

1. Determine the maximum depth for the rock reservoir based on measured subsurface soil infiltration rate for the site and round down to the nearest 50 mm increment for contractibility; allowable depth range is 300 to 2000 mm. If the infiltration rate is not being measured at the site, then assume a value of 2 mm/hr for saturated hydraulic conductivity (K_S):

   $D_R = 274.3 \times K_S$

   Where:

   D_R = Maximum recommended depth (thickness) of drain rock reservoir (mm)

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr) (suggested minimum value 2 mm/hr)

   Note that where the subsurface soil hydraulic conductivity is 2 mm/hr, the maximum rock depth required is 400 mm, limited due to 20% minimum sizing factor.

2. Use the following equation to determine the Base Area (bottom area) of Permeable Paving and rock reservoir required by finding the sizing factor for the site. Choose any value for the depth of rock reservoir within the allowable depth range and under the maximum allowable depth calculated in the previous step:

   Sizing Factor = $[(24 \times K_S + D_R \times n)/32-1]^{\wedge}(^{-1})$

   Where:

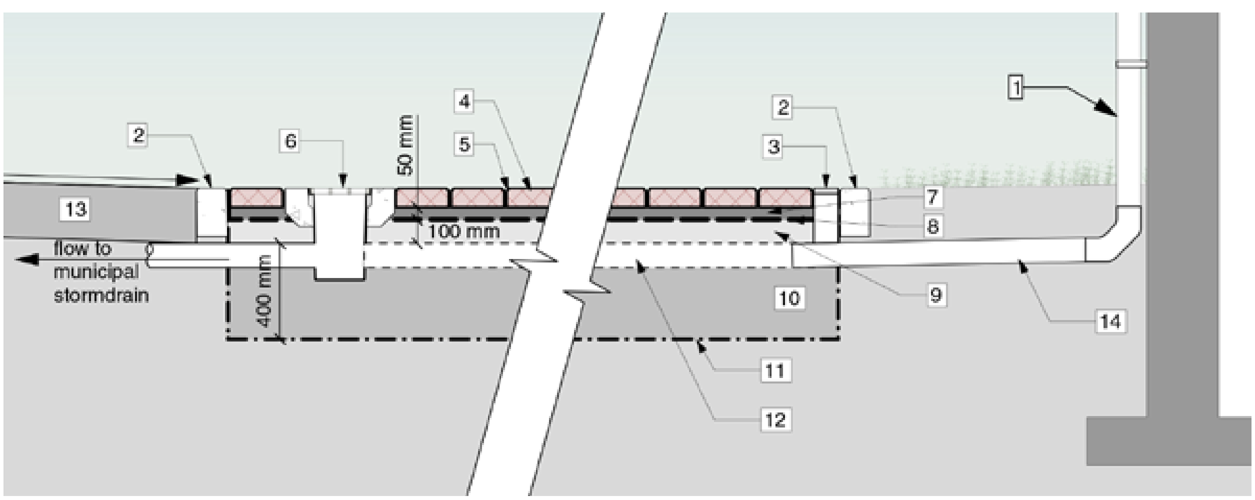
   Sizing Factor = Fraction of impervious tributary area that must be permeable pavement to receive and treat runoff (unit less)

   K_S = Saturated hydraulic conductivity of subsurface soil (mm/hr) (suggested value 2 mm/hr)

   D_R = Depth (thickness) of rock reservoir (mm)

   n = porosity of drain rock in reservoir (unit less, e.g. 0.35)

Figure 24: Pervious Paver With Reservoir Detail



Permeable Unit Paving With Rock Reservoir Materials

1. Downspout
2. Curb/edge restraint
3. Clean out with cap
4. Permeable concrete unit paving stone
5. Joint stabilizer
6. 200 mm square catch basin – only required as an overflow for safety where adverse slope drains towards a building.
7. Paver bedding course, 50 mm depth (open graded)
8. Non-woven geotextile
9. Upper reservoir open-graded base 100 mm depth
10. Reservoir sub-base (open graded), 400
11. Woven geotextile on bottom and sides of reservoir
12. Perforated drain pipe, 100 mm dia min.
13. Impervious paving
14. Piped downspout connection

3. Check that the sizing factor calculated is above the minimum 20%. If the calculated sizing factor is greater than 20%, you may reduce the depth of your rock trench until either the minimum allowable depth or the minimum sizing factor is met.
4. To find the Permeable Paving area:

   Permeable Paving Base Area = Impervious Tributary Area x Sizing Factor

Permeable Unit Paving without Rock Reservoir

1. Permeable paving can be constructed without a rock reservoir and underdrain. In such cases, unless a high subsurface soil infiltration rate has been measured on the site, the permeable paving can only accept rainfall that directly falls on to its surface. Runoff from impervious areas cannot be directed to permeable paving without a rock reservoir and underdrain when the subsurface soils have an infiltration rate of 2 mm/hr or less.
2. Select a commercial permeable paving product. Product must be designed and installed in accordance with manufacturer's recommendations and requirements grading, sub-base and bedding materials, etc.
3. Note that if a default K_S value of 2 mm/hr is assumed, the subsurface infiltration rate alone is sufficient to meet the rainwater management design target when there is no additional runoff directed to the permeable paving.
4. In areas where a subsurface percolation test has been done by a professional at the site where the permeable paving is to be installed, a Qualified Professional can calculate the water loading that the subsurface soils can accept:

   Sizing Factor = $1/((24 \times K_S)/R - 1)$

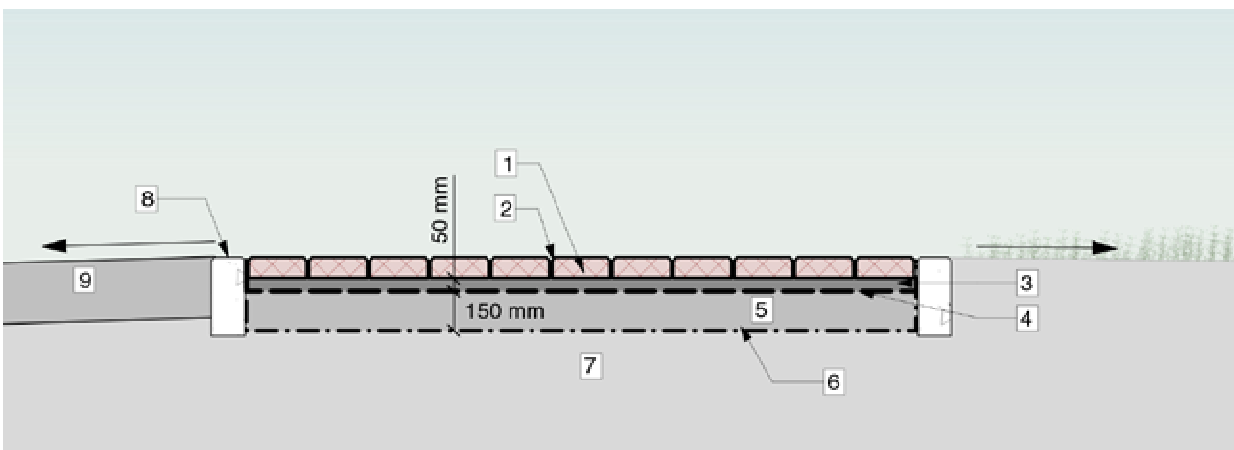
   Where:

   Sizing Factor = Fraction of impervious tributary area that must be permeable pavement to receive and treat runoff (unit less)

   K_S = Measured saturated hydraulic conductivity of subsurface soil (mm/hr)

   Note that Sizing Factor must still be a minimum of 0.2 or 20%

Figure 25: Permeable Paver Without Reservoir Detail



Permeable Unit Paving Materials
1. Permeable unit paving stone
2. Joint stabilizer
3. Open-graded paver bedding course, 50 mm depth
4. Non-woven geotextile
5. Open-graded base, 150 mm depth
6. Woven geotextile
7. Existing subgrade/native material
8. Curb/edge restraint
9. Impervious paving

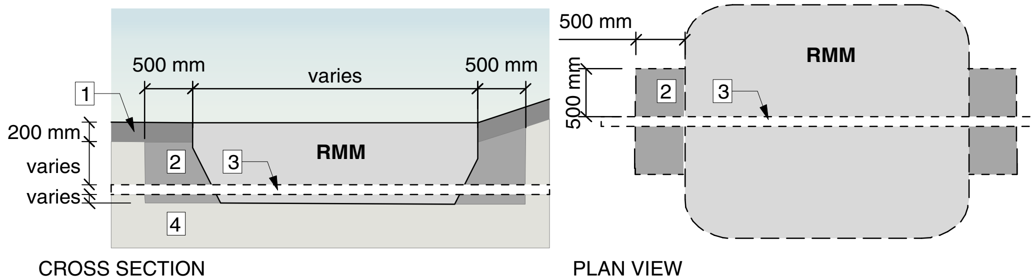
Design Standards

1. For design for vehicle loading, more soils information may be required. Additional testing may include soil subgrade sampling and analysis and should be conducted under the supervision of a professional engineer knowledgeable in the local soils.
2. The pavement should be downslope from building foundations, and the foundations should have adequate footing drains.
3. To avoid surface plugging and long-term pollution problems, it is critical to protect permeable pavements from pollutants and sediment both during and after construction. In addition, identify pollutant sources, particularly in industrial/commercial hotspots, that require pre-treatment or source control upstream of permeable pavements as severe contaminations and surface plugging may not be remediable and could require replacement of the pavement and base materials.
4. For draining roof water to permeable pavers, an underground reservoir is required and the roof water must be either piped to the reservoir directly or discharged to the paver surface in a safe location such that the discharge is directed away from the building and will not cause a safety hazard in freezing conditions.
5. Provide edge restraint to contain the pavers, similar to standard unit paving. Edge restraints that use spikes are not recommended.
6. Paver bedding material shall be wrapped with geotextile filter cloth on bottom and all sides. This is critical to the water quality performance of the pavement, and also keeps any intrusion of fines near the surface, where localized clogging could be repaired by replacing only the aggregate above the filter cloth, patching the cloth, and reusing the pavers.
7. Bottom of reservoir or bottom of sub-base (if no reservoir) should be flat to encourage infiltration. In sloped areas, this may not be possible, and the bottom may be stepped with minimum depth of reservoir equal to the design depth and trench dams to contain water between the stepped sections of the reservoir. This will look similar to the stepped reservoir below the Bioswale.
8. If the pavement is being designed for heavy loads, optional reinforcing grids (geogrid) may be included in the pavement sub-base.
9. Avoid utility or other crossings of the permeable pavement area. Where service trenches must be constructed crossing below or through the reservoir, install trench dams at exits to avoid infiltration water flowing into the service trench.

Construction

- Construction Phasing: install permeable pavement after all building and landscaping has been completed. Where this is impractical, protect permeable paving from sediment during construction to minimize clogging.
- Scarifying Subgrade: scarify the excavation subgrade to a depth of 200 mm so that the surface is loose and friable prior to placing infiltration media.
- Service Trench Crossing: Any service trench crossings must have impervious backfill barriers (trench dams) properly installed. Compacted impervious backfill (glacial till or clay) must fill entire width of service trench and extend to 200 mm above top of retention trench.
- The following considerations can be superseded by the manufacturer's instructions:
  - The subgrade must be compacted as required for the design loading of the pavement.
  - Excavation, grading and compaction equipment shall be selected to minimize the potential for over-compaction.
  - Reservoir drain rock and any other base layers shall be installed in 100 to 150 mm lifts and compacted as required.
- Filter Cloth: Rock reservoir below the pervious paving (as well as any coarse base layers) should be wrapped on all sides with filter cloth to prevent the surrounding soil or above bedding material from moving into the rock reservoir, reducing water-holding capacity.
- Permeable Paving: install permeable paving (i.e. base layers, bedding layer and pavers) according to the manufacturer's instructions.

Figure 26: Service Trench Crossing



1. Growing medium, min 200 mm depth
2. Compacted impervious backfill (glacial till or clay) for entire service trench width
3. Underground pipe crossing (water, gas, sewer, etc.)
4. Native subgrade

General Specifications

1. Minimum depth of 600 mm is required from the bottom of the permeable paving excavation to water table or solid bedrock.
2. Provide edge restraint to contain pavers on all edges. Most manufacturers have a recommended edge restraint system.
3. Pavers:
   a. Permeable Interlocking Concrete Pavers meeting CSA A231.2, designed and tested by the manufacturer for use as part of a permeable unit paving system with a initial infiltration rate >280 mm/hr and a maintained >28 mm/hr infiltration rate over the pavement life.
   b. Install pavers to manufacturer's instructions.
   c. Pavers to be 80 mm thick for all driveable surfaces.
   d. Permeable Unit Paving surface slope should be 1% minimum to avoid ponding on the surface.
4. Joint Stabilizer:
   a. As per manufacturer's recommendations, for the selected pavers.
5. Aggregates:
   a. Base and bedding materials must be clear crushed open-graded aggregates. Percentage of angular and sub-angular particles greater than 90%. Do not use rounded river gravel.
6. Paver bedding course, 50 mm depth:
   a. Shall be open-graded crush 5 mm aggregate (or ASTM No. 8 – no sand).
7. Open-Graded base, 100 mm depth:
   a. Shall be clean crushed stone graded from 10 mm to 6 mm, installed in lifts/layers no deeper than 150 mm and compacted.
8. Open-Graded Reservoir, 400 mm depth:
   a. Shall be clean crushed stone graded from 5 mm to 20 m, installed in lifts/layers no deeper than 150 mm and compacted.
9. Non-woven geotextile to be installed between Open-Graded base and paver bedding course
   a. Non-woven geotextile: synthetic material, that conforms to manufacturer's recommendations.
10. Open-Graded Reservoir shall be lined with woven geotextile filter cloth on bottom and sides.
    a. Woven geotextile: synthetic material, that conforms to manufacturer's recommendations.
11. Perforated pipe to be 100 mm diameter PVC with minimum 2 rows of 1/2 inch holes.
12. Outlet pipe shall be PVC sewer pipe minimum CSA rated ≤ 35 SDR. 100 mm diameter minimum complete with PVC backflow preventer valve (if required) as per City Plumbing Code. Pipe must have minimum 1% grade and follow the Plumbing Code.

13. Subgrade/native soil should be compacted to 95% standard proctor density.
14. Service trench crossing: Any service trench crossings must have trench dams properly installed, using compacted impervious materials, for entire trench width and extend to 200 mm above the top of the service trench.

Maintenance

Successful maintenance for permeable paving includes regular removal of sediment, debris and excess moss for the surface of the permeable paving to prevent clogging of the surface pores that allow water to drain through.

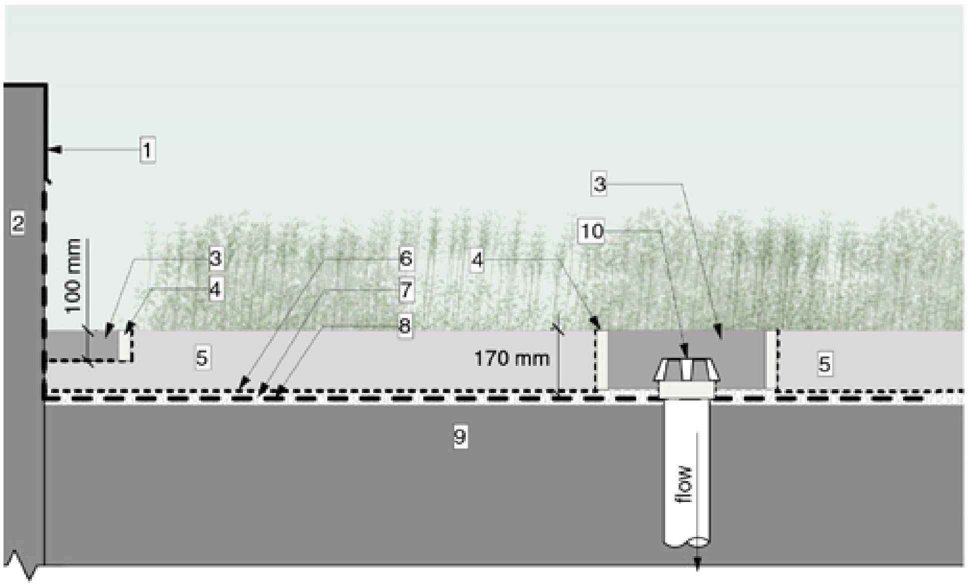
- For small areas: sweep surface semi-annually or vacuum with a shop vac. Take care not to dislodge and remove small aggregate from between permeable paver block or from within paver grids.
- For large areas: vacuum sweep pervious paving when ponding on the surface is observed, or once every year.
- Remove excess moss during the summer when it is dry by using a stiff broom or, for large areas, a power washer with rotating brushes.
- Remove accumulations of organic debris and leaf litter in the fall or as needed.
- Underdrain sump or building sump (if any – will not be present for permeable pavement that has no underdrain) should be inspected and cleaned annually or as required.
- Winter care:
  - Snow should not be stockpiled on permeable pavement.
  - Snow removal should be done by hand whenever possible to avoid damage to the surface of the permeable paving; alternatively plow blades should be raised on skids or rollers; environmentally friendly chemical de-icers, e.g. salt or molasses based may be used in moderation.
  - Sand and cinders should not be used on permeable paving, but if they are accidentally applied, the sediment should be swept or vacuumed up as soon as possible.
- If surface appears clogged and ponding is present, there are several options to remediate the surface:
  - Perform annual sweeping and/or vacuuming and see if that removes the problem;
  - Pressure wash the surface with a hand-held pressure washer, then vacuum sweep the surface; and
  - Use a power washer with rotating brushes to clean the surface, then sweep or vacuum to remove sediment.
- Clean up harmful material spills immediately to prevent contamination of runoff going to the stormwater system and the aggregate layers and soil below the pavement.
- Adjacent landscaping areas must be stabilized so that soil is not eroding and depositing on the permeable pavement.
- Landscaping materials including soil, sand, compose mulch and fertilizer must not be stockpiled on permeable pavement.
- If surface is broken or paver blocks or grids become uneven and the surface is no longer flat, the surface may become a trip hazard:
  - Try to determine causes of damage. Causes may include heavy vehicles or higher vehicle speeds than intended by design; dislodging by maintenance or other vehicles; movement of base courses that were not fully compacted or inappropriately sized; or disruption from tree roots.
  - Remove causes of damage as needed.
  - Remove and re-set uneven portion of paving. Take care that and material clogged with fines is removed, and the area and new materials are protected from sediment during the repair process.
  - If the area is very small relative to the overall size of the facility, impervious asphalt or concrete may be used to replace permeable asphalt or concrete pavement sections. If the area is large enough to affect the overall performance of the facility, the area must be replaced with the same permeable surface to maintain the function of the facility.

Green Roofs

Green roofs are a lightweight vegetated roof system comprised of waterproofing material, growing medium, and specially selected plants.

Green roofs fall into two categories, 'intensive' or 'extensive' systems, depending on the plant material and planned usage for the roof area.

Figure 27: Green Roof Detail



Green Roof Materials

1. Flashing
2. Parapet (edge of building)
3. 25 – 40 mm dia round stone
4. Separation structure
5. Green roof growing medium
6. Root barrier
7. Drainage mat
8. Waterproof membrane
9. Structural roof deck, sloped to drain
10. Overflow drain

Sizing

Sizing for Water Quality

Green Roofs are not sized for water quality improvement. For the City of Victoria, green roof must be capable of capturing and evaporating the rainwater management target volume of 32 mm in 24 hours on the area of the green roof. No other impervious area runoff may be directed to the green roof.

Sizing for Capture and Infiltration

Sizing for rainwater management target: 32 mm in 24 hrs

Green roof manufacturers specify a water storage capacity for their products. Select a green roof product with minimum water storage capacity of 32 mm.

For example: XeroFlor XF301 Standard Green Roof system is a commonly available sedum and felt mat green roof and has a water storage capacity of 36 mm. A growing medium based green roof would need to have approximately 170 mm of soil depth in order to achieve the rainwater management target with 32 mm of water storage capacity.

Design Standards

1. Good quality waterproofing material approved (and warrantied) for use in a green roof should be used on the roof surface.
2. Growing medium of adequate fertility and drainage capacity at depths of 100 – 150 mm may be applied.
3. The building structure must be designed to support the full saturated weight of the green roof. If an intensive green roof with public access is planned the live load of people and furniture must also be considered.
4. Vegetation should be self-sustaining, without the need for fertilizers or pesticides. Ninety-percent plant coverage should be achieved within 2 years.
5. Temporary irrigation to establish plants is recommended. Irrigation may be required for the first one to two years post installation.
6. A maximum of 10% of the green roof can be composed of non-vegetated material (gravel, pavers for maintenance path, etc.). This is relative to the green roof system itself, and is not related to coverage of the roof as a whole for the purposes of the City's Rainwater Rewards program. Areas covered by other structures (patios, mechanical structures) are not considered part of the green roof area. Runoff from other impervious surfaces or areas of the roof cannot be directed towards the green roof but must be conveyed off the roof or managed separately.
7. Roofs with less than 2% slope require special drainage construction.
8. Green Roof vegetation should be:
   - Drought-tolerant, requiring little or no irrigation after establishment;
   - Self-sustaining, without the need for fertilizers, pesticides, or herbicides;
   - Able to withstand heat, cold, and high winds;
   - Very low-maintenance, needing little or no mowing or trimming;
   - Perennial or self-sowing;
   - Fire-resistant; and
   - Comprised of a minimum of 50% evergreen species.
9. Both extensive and intensive green roofs are only to be accessed for maintenance purposes. Further use of the space such as seating, planter boxes or general/public access is considered a roof deck and subject to the zoning requirements for roof decks. Check the zoning bylaw for zone-specific regulations. Safety elements such as railings that are added to access the green roof are not subject to height requirements.

Construction Considerations

Green roof must be installed by a certified green roof installer.

- Avoid over compacting the growing medium during construction.
- Growing medium shall be isolated from sedimentation during construction.
- Waterproof membrane, drainage matt, and root barrier shall be checked prior to placement of overlying materials. Any gouges, tears, or stretching shall be repaired in accordance with manufacturer's recommendations.
- Penetrations through waterproof membrane and root barrier shall be checked. Structures which penetrate the water proof membrane and root barrier to be in accordance with manufacturer's recommendations.
- Stockpiling of soil or rock material shall not be permitted on roof structure.
- Temporary or permanent point loads from bracing, supports, equipment, and material storage shall not be permitted on drainage matting, root barrier, or waterproof membrane unless shown in an approved plan set.
- Flood testing and/or electric field vector mapping to verify the integrity of the membrane before and after green roof materials are installed is highly recommended.

General Specifications

1. Green Roof Growing Medium:
   a. To be to BC Standard for Extensive Green Roofs 'Growing Medium Type 1P: Extensive Green Roof-Inaccessible', or growing medium as approved by green roof system manufacturer.
2. A maximum of 10% of the green roof can be composed of non-vegetated material (gravel, pavers for maintenance path, etc.).
3. Areas covered by other structures (patios, mechanical structures) are not considered part of the green roof area.

Table 7: Characteristics of Intensive and Extensive Roof Gardens

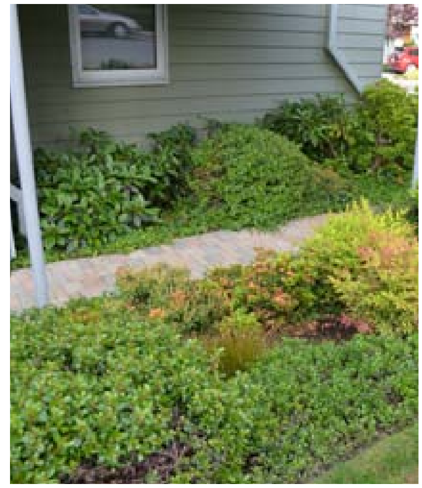
	Intensive Roof Garden	Extensive Roof Garden
Growing Medium Depth	150 to 600 mm	100 to 150 mm
Plant Material	Trees/shrubs/groundcovers	Groundcovers (grass/moss/sedums)
Roofing System Weight	Heavy	Light
Slope	Typically flat	Flat to 25% maximum
Stormwater Management	Evapotranspirates 50 to 100% of the precipitation*	Evapotranspirates 10 to 100% of the precipitation*
Landscape Maintenance Requirements	Intensive with permanent irrigation system	Low with establishment irrigation only
Landscape Characteristic	Parkland landscape, accessible to the public, public open space	No public access, visual amenity from taller buildings

*seasonal variation

Maintenance

An Operations and Maintenance Manual for the Green Roof including vegetation and other maintenance should be prepared by the designer as part of the design process. Basic general maintenance for green roofs is described below:

- Water the green roof regularly for the first 1–2 years, until plants are well established.
- Green Roofs may require permanent irrigation systems, depending on site conditions and plant material. Be aware that many green roof plants will turn brown during dry periods and revive during wet periods; once established they may not require ongoing irrigation.
- No herbicides should be used on a green roof, and fertilizers must be used carefully and sparingly. Pesticides should not be required and should not be used unless absolutely necessary.
- On a monthly basis:
  - Weed control, particularly for trees that could penetrate the waterproof membranes, and for invasive species such as blackberries that can take over the plant population of the green roof;
  - Irrigation coverage check (adjustments as needed); and
  - Debris removal.
- On an annual basis:
  - Replace dead plants
  - Check and clean out roof drains – at least once a year and ideally twice or more per year.
  - Check for any spots where the membrane is exposed and make sure those spots are covered so that the membrane is protected with growing medium and vegetation.
- If leaks occur:
  - While rare, leaks can occur with green roofs as with any other roof. Small areas of green roof can be removed and replaced to repair leaks in the membrane, if required.

Part 5: General Maintenance Guidance for Rainwater Management

Maintenance of rainwater management methods is often cited as a concern, but is generally not onerous when they are properly designed and installed. The recurring maintenance tasks required for methods are listed below. The “Low Impact Development Technical Guidance Manual for Puget Sound” is available online at: **http://www.psp.wa.gov/stormwater.php**. This document has photos of “good” and “poor” maintenance of many rainwater management methods in “Appendix 4 – Maintenance of Low Impact Development Facilities” and is a good visual reference if needed.

The maintenance requirements outlined in each section in Part 4 are important to keep rainwater management facilities functioning properly, and also to remain eligible for the incentive program.

Before maintenance activities commence, the persons doing maintenance must be familiar with the rainwater management methods they are maintaining, including:

- Basic structure and function of the methods;
- Design, as-built or other knowledge of the intended appearance of the methods;
- Understanding of the maintenance items required; and
- Understanding of basic indicators of functional problems that may require remediation, rather than just routine maintenance.

This information should be communicated by the property owner to those who will be maintaining the rainwater management methods, whether they are paid maintenance staff or the owner’s friends or family.

Long-Term Maintenance Arrangements

Rainwater management methods rely on appropriate maintenance for their longevity and performance. Where rainwater management methods are situated on private land, local governments may put maintenance agreements or covenants in place to ensure appropriate long term maintenance. Key ingredients of these include the items in the above lists. This generally applies to large facilities and multiple installation sites, and the intent is to ensure that rainwater management methods will be properly maintained throughout their lifespan even when properties change ownership.

Part 6: Glossary of Terms

Definitions of technical and common terms for rainwater management design and construction

Amended soil – A soil that has an amendment such as sand or compost added to increase the infiltration capacity and/or water retention capabilities.

Bioretention – growing medium

Bioswale – A shallow landscaped channel with or without a reservoir beneath, which captures stormwater runoff and allows it to soak into the soil and subsurface ground below. Similar to a rain garden, but provides conveyance of water across a site similar to a ditch.

Cistern – a rainwater storage tank with 1200 litres minimum capacity that allows rainwater to be used.

Compaction – The process in which a stress (force) applied to a soil causes densification as air is displaced from the void spaces between the soil grains. Compaction is often achieved with a roller or mechanical tamper

Conveyance – A way to transport water from one point to another; conveyance methods include pipes, ditches, and channels.

Freeboard – The vertical distance between the design water surface elevation (overflow elevation) and the top of the rainwater management method.

Friable – A word used to describe soil that is easily crumbled or broken apart.

Geotextile – can be woven or non-woven, also known as filter cloth or fabric that when used properly, will reinforce and filter without clogging. To be Amoco 4545 or equivalent.

Glazing of soil – Process by which rainfall or water or surface traffic make the surface of soil smoothed and less pervious, so that the infiltration of water through the surface is reduced.

Growing medium – Soil mixture made up of sand, loam, and compost; used in rainwater management methods to support vegetation and to filter runoff.

Hardscape – The impervious areas of a site that are not roof; includes driveway or parking areas, walkways, patios, or any other impervious surface that sheds water; contrasts to 'landscape' areas of the lot that are covered with soil and vegetation.

Hydraulic conductivity – or saturated hydraulic conductivity – A property of saturated soil that enables water to move through it; often equated to or used as a measure of infiltration rate.

Impervious – A surface that does not allow water to pass though; includes surfaces such as roofs and driveways.

Infiltration – The downward entry of water through a soil surface and into the soil. Infiltration is often expressed as a rate (millimetres per hour), which is determined though an infiltration test.

Inlet – A way for entering; an opening or pipe to allow water into a rainwater management method.

Invert – The lowest point on the inside of a pipe, or the bottom elevation of a channel or rain garden.

Loam – A rich soil consisting of sand and clay and decaying organic matter.

Low density residential – A land use category comprising one to four dwelling units on a single lot.

Outlet – A place or opening though which something is let out; an opening or pipe to allow water to leave a rainwater management method.

Overland flow – Overland flow is another term for surface runoff. Rainwater can be directed to rainwater management methods via overland flow on paved surfaces or grassed areas.

Perforated pipe – Pipe with holes or slots in the pipe.

Permeability – The ease with which water penetrates or passes through a layer of soil or porous medium; can also be referred to as perviousness and is related to the size and continuity of the void spaces in soils.

Permeable/Pervious/Porous pavement or paving – (these terms are often used interchangeably in the literature) a hardened surface that allows water to percolate through to the underlying subgrade soils, or to a reservoir where water is stored and either infiltrated to the underlying subgrade or removed by an underdrain. The surface component can be:

- Porous asphalt or concrete, where fines are not included in the mix, providing a high void ratio that allows water to pass through.
- A structural load-bearing matrix made of concrete with large voids that are filled with permeable material, usually gravel or soil; the latter often have grass. Also known as gravel or grass pavers.
- Permeable unit pavers made of impervious concrete blocks with gapped joints that allow water to percolate between the pavers; also called modular pavement or pervious interlocking concrete pavement.

Porosity – Similar to void ratio, this is the portion of a volume of material such as soil or rock that is empty spaces between particles; usually expressed as a percentage of the total volume.

Professional – a term used in this document to collectively refer to Qualified Designers and Qualified Professionals as a group.

Qualified Designer – means an individual who demonstrates to the satisfaction of the Director of Engineering that he or she has the training and experience necessary to design and oversee the installation of a rainwater management method.

Qualified Professional – means an applied scientist or technologist, acting alone or together with another Qualified Professional, if:

- the individual is registered in good standing in BC with an appropriate professional organization constituted under an Act, acting under that association's code of ethics and subject to disciplinary action by that association;
- the individual's area of expertise is recognized by the individual's professional organization as one that is acceptable for the purpose of performing a professional service for the design of rainwater management methods; and
- the individual is acting within the individual's area of expertise.

Rain Barrel – a rainwater storage tank or combination of tanks with 350 litres minimum capacity that allows rainwater to be used.

Rain garden – A shallow landscape depression with an amended soil mix and plants that is designed to capture stormwater runoff or rainwater from nearby contributing impervious areas and allows the water to soak into the soil and the subsurface ground below.

Scarified subgrade – Subgrade of which the surface has been loosened or broken up.

Scarify – To scarify is to loosen, break or roughen the surface of soil. Can be done with a rototiller (small areas) or a cultivator (large areas).

Screed – To smooth a surface or layer so it is even.

Sheet flow – Similar to overland flow, but where the flow is widespread and not constricted.

Sizing Factor – A sizing multiplier that allows simple sizing for rainwater management methods based on the area of impervious surface that is generating runoff.

Softscape – refers to the elements of a landscape that comprise live, horticultural elements. Softscaping can include, flowers, plants, shrubs, trees, flower beds, etc.

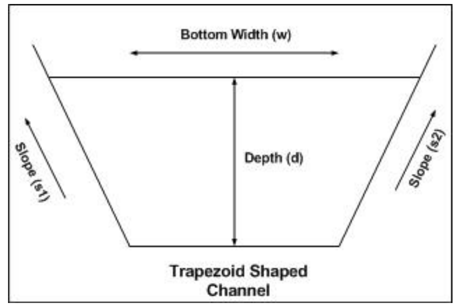
Subgrade – The underlying ground beneath any constructed feature; often called native soil as it is material that was in place before an excavation or construction started. Typically this is the bottom of an excavation for construction and is the underlying base for the construction which goes on top.

Subsurface – Below the surface, underground.

Sump – similar to a catch basin where runoff is directed to control and clean the flow.

Trapezoidal shape – A four sided shape that has two sides that are parallel and two sides that are not parallel.
In stormwater, a trapezoidal channel has a base that is narrower than the parallel top.

Trapezoidal shape



Underdrain – plastic pipes with holes drilled though one side, installed either on the top of the rock trench or bottom of an infiltration rainwater management method with no rock trench, which are used to collect and remove excess runoff.

Unit paving – Also referred to as pavers or paving stones, unit paving uses concrete blocks to create a surface for roads, driveways, patios and other outdoor platforms

Void ratio – Similar to porosity, this is the fraction of the volume of the void (or 'empty') spaces in the soil over the total volume of soil; value is between 0 and 1.

Appendix A – Rainwater Rewards Pre-Approval Guide

This guide has been provided to assist applicants in the process for pre-approval for the Rainwater Rewards program. For more information, please refer to Table 1: Rainwater Rewards Process.

Please follow the steps below (for site assessment, method selection, sizing calculation and design drawing) and submit with your Rainwater Rewards application.

To qualify for the Rainwater Rewards incentives, pre-approval must be granted prior to commencing any work. For more information, please contact the City's stormwater specialist at **stormwater@victoria.ca** or 250.361.0443.

All references to the City of Victoria's Rainwater Management Standards – Professional Edition are available at **victoria.ca/stormwater**.

1. Site Assessment

Please complete the site assessment checklist found on page 13 of the Rainwater Management Standards-Professional Edition. Complete a site assessment drawing (see Figure 1: Site Assessment Example), using an aerial photo of the property from VicMap (or similar), or a scaled hand drawing.

2. Choosing a Rainwater Management Method

To choose an appropriate rainwater management method for the site, please review Part 2: Rainwater Management Planning and Site Selection. Consider the following:

- Site and Selection Considerations
- Table 2: Site Feasibility for Rainwater Management Methods.

3. Sizing Calculation

Each rainwater management method has its own sizing calculation.

Ensure you consider site setback requirements (page 14, Table 3: Site Setback and Minimum Values summary) when sizing your rainwater management method. Ensure zoning setback requirements are met for installation of cisterns.

Sizing Calculations for each rainwater management method can be found in Part 4: Professional Design and Sizing Approach.

4. Design Drawing

Please provide a plan drawing with dimensions outlining where the rainwater management method will be located. Tip: you can use your site assessment drawing as a starting point.

5. Submit for Pre-Approval

Please submit to following completed documents for pre-approval for the Rainwater Rewards program:

- Rainwater Rewards Application form
- Site assessment drawing
- Sizing calculations
- Design drawing

Appendix B – Installation Checklists

How to use these Checklists

When you are constructing your rainwater management methods, it is necessary to follow the steps outlined in the City of Victoria's Rainwater Management Standards. These checklists are specific for the Professional edition, and are intended to highlight the key installation details to be met. Please ensure you have received pre-approval for the Rainwater Rewards program prior to starting construction. Once construction is completed, please submit photos and any invoices to **stormwater@victoria.ca** for your client to receive their Rainwater Rewards incentive.

Cistern Installation Checklist	Completed	Photo
General		
Ensure all manufacturers' installation requirements are met		NA
Ensure Rainwater Management Standards document is followed throughout design, installation, and maintenance processes		NA
Ensure installed cistern is secured for safety if applicable		NA
Subgrade		
Ensure subgrade is level and able to support the weight of the full cistern, using sufficient support (concrete, crushed rock, etc.) if subgrade is soft		
Confirm underground cistern location and elevation is correct related to inlet and outlet piping		
Piping, Overflow and Connection to City Stormwater System		
Ensure tanks in series are properly connected together (if applicable)		
Confirm roof rainwater downspouts are correctly connected to cistern		
Confirm overflow connection to City stormwater system is correctly installed		
Confirm seasonal slow release drain valve is correctly installed		
Overall Site		
Ensure zoning setbacks are met		NA
Ensure supporting structure of elevated cistern is built to the professionally-designed specification		NA
Materials		
Ensure cistern is correct capacity and product type for intended use		NA

Bioswale Installation Checklist	Completed	Photo
General		
Ensure Rainwater Management Standards document is followed throughout design, installation, and maintenance processes		NA
Subgrade		
Subgrade excavated to correct depth and levelled		
Base area scarified as a final step prior to subsequent installations (perforated pipe, growing medium, etc.) to minimize compaction of base area		
Rock Trench Layer (if applicable)		
Confirm rock trench size and thickness are correct		NA
Confirm that rock trench base is on scarified native soil		
Confirm placement and overlaps of filter fabric in rock trench complete with proper placement of rock/sand sections		
Growing Medium		
Ensure growing medium is placed in bioswale 200mm at a time		
Confirm placement of growing medium is to correct thickness and compacted per specifications (not over compacted)		NA
Piping, Overflow and Connection to City Stormwater System		
Confirm placement and elevation of inlet, building drainage sump (if applicable), underdrain, and overflow connection to City stormwater system		
Confirm roof rainwater downspouts directed to bioswale are adequately dissipated to not cause erosion/damage		
Ensure weir installations are correct		
Confirm overflow connection to City stormwater system is installed correctly		
Service Trench Crossing		
Confirm that any service trench crossings have had impervious backfill barriers properly installed		
Overall Site		
Avoid over-compaction and plugging to ensure infiltration capacity		NA
Confirm rain garden side slopes are angled correctly		
Confirm installation of bioswale planting		
Ensure final lot grading meets plan for directing surface flows to bioswale		NA
Materials		
Confirm PVC piping, concrete products, and drainage grates meet specifications		NA
Confirm geotextile filter cloth meets specifications		NA
Confirm stone for rock trench has proper gradation, is clean and free of all fines		NA
Growing medium to have written confirmation of mixture requirements		NA
Ensure sand is clean-washed fill sand		NA

Rain Garden Installation Checklist	Completed	Photo
General		
Ensure Rainwater Management Standards document is followed throughout design, installation, and maintenance processes		NA
Subgrade		
Subgrade excavated to correct depth and levelled		
Base area scarified as a final step prior to subsequent installations (rock trench, perforated pipe, growing medium, etc.) to minimize compaction of base area		
Rock Trench Layer (if applicable)		
Confirm length, width, and depth of trench are correct		
Confirm that rock trench base is on scarified native soil/subgrade		
Confirm placement and overlaps of filter fabric in rock trench complete with proper placement of rock/sand sections		
Growing Medium		
Ensure growing medium is placed in rain garden 200mm at a time		NA
Confirm placement of growing medium is to correct thickness and compacted per specifications (not over-compacted)		NA
Piping, Overflow and Connection to City Stormwater System		
Confirm placement and elevation of inlet, building drainage sump (if applicable), underdrain, and overflow connection to City stormwater system		
Confirm roof rainwater downspouts directed to rain garden are adequately dissipated to not cause erosion/damage		
Confirm overflow connection to City stormwater system is installed correctly		
Service Trench Crossing		
Confirm that any service trench crossings have had impervious backfill barriers properly installed		
Overall Site		
Ensure final lot grading meets plan for directing surface flows to rain garden		NA
Confirm rain garden side slopes are angled correctly		
Materials:		
Confirm PVC piping, concrete products, and drainage grates meet specifications		NA
Confirm geotextile filter cloth meets specifications		NA
If using a rock trench, confirm rock has proper gradation, is clean and free of all fines		NA
Growing medium to have written confirmation of mixture requirements		NA
Ensure sand is clean - washed fill sand		NA

Infiltration Chamber Installation Checklist	Completed	Photo
General		
Ensure all manufacturers' installation requirements are met		NA
Ensure Rainwater Management Standards document is followed throughout design, installation, and maintenance processes		NA
Subgrade		
Subgrade excavated to correct depth and levelled		
Base area scarified as a final step prior to subsequent installations (perforated pipe, drainage rock, etc.) to minimize compaction of base area		
Confirm infiltration chamber location and elevation is correct to incoming and outlet piping		
Rock/Drainage Layer		
Confirm rock trench size and volume are correct if applicable		NA
Confirm that rock trench base is on scarified native soil		
Confirm placement and overlaps of filter fabric in rock trench complete with proper placement of rock/sand/chamber sections		
Piping, Overflow and Connection to City Stormwater System		
Confirm placement and elevation of inlet, building drainage sump (if applicable), perforated pipe, and overflow connection to City stormwater system		
Confirm roof rainwater downspouts are correctly connected to sump, perforated pipe, flow control manhole, etc. if applicable		
Confirm overflow connection to City stormwater system is installed correctly		
Service Trench Crossing		
Confirm that any service trench crossings have had impervious backfill barriers properly installed		
Overall Site		
Ensure final lot grading meets plan for directing surface flows to on-site drainage sump and/or infiltration chamber		NA
Materials		
Confirm PVC piping, concrete products, etc. meet specifications		NA
Confirm geotextile filter cloth meet specifications		NA
Confirm stone for rock trench has proper gradation, is clean and free of all fines if applicable		NA
Growing medium to have written confirmation of mixture requirements		NA
Ensure infiltration chamber products are correct capacity and product type for intended use		NA

Permeable Paving Installation Checklist	Completed	Photo
General		
Ensure Rainwater Management Standards document is followed throughout design, installation, and maintenance processes		NA
Ensure permeable paving is installed to the manufacturer's instructions		NA
Subgrade		
Subgrade excavated to correct depth, levelled and compacted as required		
Rock/Drainage Layer		
Confirm rock trench size and thickness are correct if applicable		NA
Confirm placement and overlaps of filter fabric in rock trench complete with proper placement of rock/sand sections if applicable		
Confirm gravels for permeable pavers including optional reinforcing grids are placed and compacted properly		
Piping, Overflow and Connection to City Stormwater System		
Confirm placement of building drainage sump (if applicable), and connections to underdrain		
Confirm overflow connection to City stormwater system is installed correctly		
Service Trench Crossing		
Confirm that any service trench crossings have had impervious backfill barriers properly installed		
Overall Site		
Ensure final lot grading meets plan for directing surface flows to on-site drainage sump and/or permeable paving		NA
Materials		
Confirm pavers used are specifically designed and certified as permeable		
Confirm PVC piping, and concrete products meet specifications		NA
Confirm permeable pavement materials including pavers and reinforcing grids (if needed) meet specifications		NA
Confirm geotextile filter cloth meets specifications		NA
Ensure gravel base and permeable paving gravels meet specifications		NA
Ensure sand is clean-washed fill sand if applicable		NA

Green Roof Key Installation Detail Checklist	Completed	Photos
General		
Ensure Rainwater Management Standards document is followed throughout design, installation, and maintenance processes		NA
Ensure green roof is installed to the manufacturer's instructions		NA
Growing Medium		
Confirm placement of growing medium is to correct thickness		
Piping, Overflow and Connection to City Stormwater System		
Confirm overflow connection to City stormwater system is installed correctly		
Overall Site		
Roof and structural inspections to support additional loading		NA
Materials		
Ensure all green roof materials are as specified in the design		NA

Appendix C – Cistern Screening Guidelines

City of Victoria Rainwater Management Standards

Screening Guidelines for Cisterns

What is a Cistern?

- Cisterns are holding tanks that collect rainwater for later use.
- Under the Rainwater Rewards Program, rainwater harvesting tanks with at least 1,200 litres (264 imp. gallons) capacity are considered cisterns. The top surface area must be less than 15m^2 (161 ft^2) in area.
- They can be placed at ground level, buried underground, on a platform or rooftop.

Purpose of the Screening Guidelines

Cisterns play an important role in rainwater management by collecting rainwater and keeping this water out of the stormwater system. However, cisterns can be big and bulky, and could be considered visually intrusive in certain cases. Some careful thought about the cistern's location and appearance is important.

To help achieve this, these guidelines provide information on locating cisterns, as well as well as suggestions for screening cisterns.

These guidelines promote:

- Cisterns that are both functional and complement the style and character of your property
- Cisterns that minimize visual impacts on neighbours and views from the street.

Siting

Here are some cistern siting considerations relating to appearance and zoning. For all cistern siting requirements, please refer to section 2.1 of the City of Victoria's *Rainwater Management Standards*,

- Cisterns must meet the setback requirements that apply to the main building within that particular zone. For example, in the R1-B zone (single family dwelling), a cistern can be located as follows:
  - 7.5m (minimum) from the front or rear property line
  - 1.5m from the side yard property line
- Collectively, the total surface area of the buildings, cistern and other structures on a property must not exceed the maximum site coverage permitted in the zone. For example, in the R1-B zone (single family dwelling), the maximum total site coverage is 40%.
- Rain barrels (1,200 litres or less) do not have setback requirements or site coverage limits.
- Cisterns may not be located on a required parking space. Please check Schedule C of the Zoning Bylaw to determine the required parking for a particular zone. For example, in the R1-B zone (single family dwelling), there must be at least 1 space per dwelling unit.

Slim cistern

Appearance

- Think about where the cistern will be located and the style of cistern that will work best for your property.
- Cisterns come in many different shapes and sizes. Some fit snugly against a building; others are designed to be out in the open.

Round cistern

Tips for Screening

Where cisterns will be visible to neighbours or the street, consider ways to soften their appearance through landscaping or other design features. Cisterns should complement the overall design and character of your property while retaining functionality. You will need to be able to access your cistern for routine maintenance.

Consider screening cisterns with plants or bushes, such native, drought tolerant species, vines or food plants (e.g. hops, berries).

- Plantings can soften the appearance of a cistern
- Cisterns can be screened with trellis panels, wooden panels or wrought iron panels
- Cisterns can be integrated into a building by locating them under decks or behind existing out-buildings such as sheds or garages.
- There are examples of cisterns that have been finished with galvanized metal, concrete, masonry or wood cladding, and complement the style and character of the property.

Cistern with plantings

Wood panels adding character and screening

Screening complementing the style of a traditional residence

Cistern located under a porch

Use of wood cladding

A metal cistern that complements the contemporary character of a building

Cistern that fits into a commercial area

Rooftop Cisterns

Placement and Appearance

- Place cisterns in the centre of roofs where possible, to minimize visibility from adjacent properties and the street. A structural engineer is needed to ensure the roof or platform can support the cistern.
- Where rooftop cisterns are visible from the street or adjacent buildings, think about ways to enhance the design and softening the visual impact through design features mentioned above.

The appearance of rooftop cisterns can be softened with landscaping and careful choice of materials.

The appearance of rooftop cisterns can be softened with landscaping and careful choice of materials.

Height Limits

- Rooftop cisterns and their supporting structures are treated as mechanical features and as such, are excluded from height calculations for the Zoning Bylaw, provided they don't exceed 9,000 litres (1,980 imp. gallons).

Development Permits

- On a property that contains an existing building, new cisterns under 9,000 litres (1,980 imp. gallons) that have been approved under the Rainwater Rewards Program will not require a Development Permit. New cisterns 9,000 litres (1,980 gallons) and over will require a Development Permit.
- When a cistern is installed as part of a new building construction in an area that requires a Development Permit, the design of cisterns will be reviewed as part of the overall design guidelines applicable for the site.
- Single family dwellings do not normally require Development Permits.

Cistern that complements the industrial character of a development

Cistern that complements the industrial character of a development

Photo Credits:

http://www.google.ca/imgres?imgurl=http://www.rwh.in/rainwatr/cistern.jpg&imgrefurl=http://www.rwh.in/&h=768&w=1024&tbnid=ULy477QQ6Ci1aM:&zoom=1&docid=r-nrW_khQ9L_QM&ei=-OYaVfLwKor3oATa5IKoDw&tbm=isch&ved=0CH0QMyhCMEI

http://ecourbanllc.com/wp-content/uploads/2013/10/EcoProduct-1300-Gallon-Cistern-Square-cropped-300x300.jpg

https://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0CAcQjRw&url=https%3A%2F%2Fwww.pinterest.com%2Fklvm7788%2Fbackyard-design-ideas%2F&ei=tegaVd_uBYbUoASvxoKgDw&bvm=bv.89744112,d.cGU&psig=AFQjCNGXJE-ftsePcANATrRswMISHljKrQ&ust=1427913241995263

http://gardenmentors.com/wp-content/uploads/2009/10/2009_10_cistern2.jpg

https://s-media-cache-ak0.pinimg.com/474x/b8/6d/92/b86d925b757cce2d5165a93eedb78528.jpg

http://www.siteselection.com/ssinsider/snapshot/images/Cistern_18321_2.jpg

http://rainbank.info/design

Appendix D – Percolation Test Procedure

City of Victoria Rainwater Management Standards

Introduction

The following procedure was adapted from the Province of British Columbia's Sewerage System Standard Practice Manual, Version 3 (2014). Although the Province's procedure was developed for septic system installations, the procedure can also be used for rainwater management method installations.

The entire document is available for reference at:

http://www2.gov.bc.ca/gov/topic.page?id=C2F3DBA2AF8C4B9DAB7FC2C3A87D63E3

The results from the Percolation Test Procedure below may be used by a property owner, Qualified Designer, or Qualified Professional to inform the suitability of the rainwater management method in that location, or by a Qualified Professional to alter the design within the limits defined in the City of Victoria's *Rainwater Management Standards Professional Edition*.

Percoaltion Test Procedure

Use the following instructions to conduct a percolation test. This is the procedure for a percolation test in BC.

1. Perc test holes should be made at points and elevations selected as typical in the area of the proposed infiltration rainwater management method.
2. Typically, test holes are to be dug at each end of the area of the absorption field and near the centerline. Testing of the receiving area may also be necessary. Further holes could be needed, depending upon the nature of the soil, the results of the first tests and the size of the proposed dispersal area.
3. Test holes should be 30 cm (12") square or 36 cm (14") round and excavated to the proposed depth of the rainwater management method (or as instructed by the designer). It is generally easiest to dig a larger hole part way down, then dig a 18 to 20 cm (7 to 8") deep accurately sized test hole in the base of the larger hole.
4. To make the percolation test more accurate, any smeared soil should be removed from the walls of the test holes. This is best achieved by digging the hole approximately 5cm undersized (2") and then enlarging the hole to the accurate size as follows: using a rigid knife, insert the blade into the top side of the hole opposite you approximately 2.5cm (1") deep, holding the blade with its cutting edge vertical. Pull the blade away to break out a chunk of soil, repeat about an inch (2.5cm) apart around the hole, then repeat for another "ring" below until reaching the base. The result will be a hole with a ragged inner surface which looks like a freshly broken clod of soil.
5. The base of the hole should be cleaned of debris and be approximately flat. To achieve this, use a metal scoop or similar. It should also be picked to present a natural surface. Note that a picking action (use a pointed tool) is needed, not a scratching action (which just produces smears that are indented).
6. Place 5 cm (2") of clean fine gravel in the bottom of the hole. If the sidewalls are likely to collapse, use a paper basket to support the sidewalls (see note below). Place a piece of white plastic or similar provided with clear marks at 5" and 6" from the bottom of the test hole prior to adding the gravel. For greater accuracy a float and pointer arrangement can be set up.
7. If the soil contains considerable amounts of silt or clay, and certainly for any soil with "clay" as part of the texture description, the test holes should be pre-soaked before proceeding with the test. Pre-soaking is accomplished by keeping the hole filled with water for 4 hours or more. The water should be add carefully and slowly to avoid disturbing the soil (including the sidewall soils). The test should be carried out immediately after pre-soaking;
8. To undertake the test, fill the test hole (the accurately sized test hole) with water. The water should be added carefully and slowly to avoid disturbing the soil (including the sidewall soils). When the water level is 5" or less from the bottom of the hole, refill the hole to the top. No recording of time needs be done for these two fillings.
9. When the water level after the second filling (procedure (8)) is 5" or less from the bottom of the hole, add enough water to bring the depth of water to 6" or slightly more. Note that these measurements are from the base of the soil bottom (using the marker installed in step (6)), not the gravel layer.
10. Observe the water level until it drops to the 6" depth, at precisely 6", commence timing, when the water level reaches the 5" depth, stop timing, record the time in minutes.

11. Repeat procedures (9) and (10) until the last 2 rates of fall do not vary more than 2 minutes per inch or by more than 10% (whichever is less).
12. Report slowest rate for each hole.
13. Backfill the holes with the excavated soil and flag and label their locations so you can pick them up for the plan.

If a test hole is discarded due to flow in a root channel or similar, record the information and make a replacement test. If there is a large variation (greater than or equal to 50%) between tests in the same soil layer, increase the number of tests.

Paper basket to protect hole

If sidewalls of the hole are likely to collapse, one option is to make a paper basket to protect and support the sidewalls as follows:

1. Cut the bottom out of a large paper bag (grocery bag) and cut the bag open along a side.
2. Lay bag on a soft surface. Punch holes in the bag about 5 to 7.5 cm (2 to 3 inches) apart using a pencil or similar.
3. Roll into a tube, with the short dimension being the axis of the tube, and place in the test hole.
4. Open the tube until the paper is in contact with the sidewalls of the test hole, then roll the top of the tube over to stiffen it.
5. After placing the tube in the hole, place the plastic marker and add the base gravel layer.

Percolation rate for design

Select the percolation rate to be used for the rainwater management method. This will be the median (middle) value from all the tests conducted.

Percolation test form

Location (address):								File #:
Date:		Tested by:						
Weather:								
Test number	Depth of base of hole from surface (cm)	Timings, mins per inch for water to drop from 6" to 5" from base of hole.						Lowest rate (min per inch)
		#1	#2	#3	#4	#5	#6	
1								
2								
3								
4								
5								
6								
7								
8								
							Percolation rate:	
Notes:								

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