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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

Stormwater Source Control Design Guidelines 2023

FINAL REPORT

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Foreword

This document was updated in 2023. This is a revision of the Stormwater Source Control Design Guidelines previously published by the Greater Vancouver Regional District in 2005 and 2012.

Previously, the Greater Vancouver Sewerage and Drainage District contracted with a consortium of landscape architects and engineers in 2003, including:

- Lanarc Consultants Ltd.
- Kerr Wood Leidal Associates Ltd.
- Goya Ngan, Landscape Architect

The research findings were first released in 'Final' form in 2005.

The 2012 update was completed by Kerr Wood Leidal Associates, Ltd. and focused on adding engineering details and sizing to the guidance.

The 2023 update was completed by Kerr Wood Leidal Associates, Ltd. and Lanarc Consultants and focused on adding additional guidance and updates.

All previous versions of the Guidelines are superseded by the 2023 update.

Acknowledgements

It is a rare opportunity for consultants to be given a mandate to search the world for design precedents and guidelines on any subject – and even more so when the subject has worldwide innovation taking place – as is the case in stormwater source controls. The authors want to thank the many organizations and individuals that provided their time and experience to this project. Key organizations included:

- Lanarc Consultants Ltd.
- Kerr Wood Leidal Associates Ltd.
- Goya Ngan, Landscape Architect
- Greater Vancouver Regional District (Client)
- Stormwater Interagency Liaison Group

In particular, we would also like to express our gratitude to the many experts around the world that we contacted – either as a part of this research project or in advance – who gave freely of their time and expertise to help us understand that current state of the art in stormwater source controls.

Thank you.

STORMWATER SOURCE CONTROL DESIGN PROCESS

1 Stormwater Source Control Design Process

Stormwater source controls reduce the runoff that is discharged from a site by managing the water balance at the site level, providing on-site rainfall volume reduction, runoff water quality improvement, and runoff rate control for small, everyday rainfall events that occur frequently in the winter or rainy season in the Metro Vancouver region.

These guidelines assume that the reader understands at a basic level what source controls are and why they should be used, and is looking for further information about how source controls should be designed and implemented for the Metro Vancouver climate and conditions. There is a glossary at the end of the document to assist with understanding and differentiating the common terms.

Just as rainfall hits all areas of a development site, the design of stormwater source controls should be integrated with the entire development concept. This chapter outlines a design process for stormwater source control practices – identifying key steps and their arrangement.

Table 1-1: Stormwater Source Control Design, Construction, Monitoring and Maintenance Process

Project Stage	Objective
Design Targets *for Stormwater Source Controls*	Identify the watershed or local government requirements for stormwater source control, and the related design targets or criteria.
Site Analysis *for stormwater source controls*	Gather critical data: rainfall patterns, existing vegetation cover, infiltration constraints, soils mapping and infiltration tests, and water table elevation. Identify site constraints such as steep slopes, floodplain designation, stream or riparian setback, and green infrastructure network considerations.
Development Concepts *that Integrate Stormwater Source Controls*	Integrate stormwater source controls into the development concept: what mix, and sizing of techniques fit with the site and the land use? Develop Stormwater Management Plan Concept.
Detail Design *of Stormwater Source Controls*	Design and size source controls. Create technical details in plan, cross section, and profile. Incorporate stormwater source controls in construction and maintenance specs. Develop an Operation and Maintenance Plan.
Construction Staging *of Stormwater Source Controls*	Schedule the installation of stormwater source controls to avoid problems with disturbance and sedimentation during construction.
Field Review & Monitoring *of Stormwater Source Controls*	Provide critical field inspections to ensure performance. Use post-construction monitoring and adaptive management to reduce costs.
Post-Construction Maintenance *of Stormwater Source Controls*	Conduct regular maintenance according to the instructions in the Operation and Maintenance Plan.

Do include stormwater source control designers in your design team from the earliest stage of the design process. This will ensure that stormwater source controls are integrated into the development effectively.

Don't wait to incorporate stormwater source controls after everything else is decided. This will lead to more difficult or expensive design solutions, greater land requirements, and will create significant redundancy and revisions in design effort.

The key disciplines involved in source control design are civil/environmental engineers, geotechnical engineers, and landscape architects. A team approach is encouraged to ensure that the facilities are designed properly and perform as intended and are aesthetically pleasing and suitable for the subject community.

1.1 Design Targets for Stormwater Source Controls

Design targets set a standard for source control design in order to achieve particular goals. An ISMP sets design targets to protect a specific watercourse or watershed from impacts of development such as flooding, stream erosion, loss of fish habitat, and reduced water quality. Other entities, such as local governments, DFO, or First Nations, set targets with the same goals, that may be applied over a smaller or a wider area.

Note that design targets for source controls focus on small, frequently-occurring rainfall events. and the guidance in this document does not include design for larger design storms that might be used for sizing other types of stormwater facilities or conveyance.

1.2 ISMPs and Source Control Design

Municipalities in Metro Vancouver are undertaking Integrated Stormwater Management Plans (ISMPs) on a watershed basis, as required by the ILWRM (2010). The ISMPs meet community needs and allow development and re-development to occur, while preserving watershed health as a whole. These watershed-scale studies identify objectives and proposed techniques for flood control, fish habitat protection, water quality protection or improvement, and more. Many ISMPs will create source control design and implementation targets and strategies for watersheds or parts of watersheds.

Developed ISMPs may stipulate watershed-specific stormwater design criteria and targets. Watershed-specific criteria govern in any watershed where source control design criteria is defined as part of an ISMP or similar watershed plan. Some municipalities may use other planning processes, such as Neighbourhood Concept Plans (NCPs) to designate criteria and targets at a finer scale than the ISMPs, and that would supersede ISMP criteria.

Large-scale developments may also be required to create Stormwater Management Plans that identify, in more detail, the role of stormwater source controls for a specific area or development. Stormwater Management Plans may also set 'rainfall capture targets' for roads and development parcels, to set out the amount of rainfall that should be captured on a development site, by infiltration, evaporation, or re-use. Stormwater Management Plans, ISMPs and any other relevant requirements should be reviewed prior to development planning.

1.3 Local Governments in Metro Vancouver

Each municipality in Metro Vancouver can regulate stormwater design and set design targets and criteria in municipal bylaws. Municipal bylaws may set the criteria for design of source controls along with other stormwater design guidance. Municipal criteria govern (rather than provincial) in any municipality that has defined source control design criteria, but do not supersede watershed– or site–specific criteria.

Municipal requirements related to stormwater source controls may also be provided in documents other than bylaws, including design manuals, neighbourhood guidelines, standard drawings, construction specifications, development bulletins and guidelines, and more. Developers should contact municipal staff to confirm the location of the most recent requirements or guidance.

1.4 Fisheries and Oceans Canada

The Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat, 2001 from Fisheries and Oceans Canada (DFO) outlines a three-fold stormwater criteria:

Table 1-2: DFO Stormwater Guidelines

Objective	Target
Volume Reduction	Retain the 6-month/24-hour post-development volume from impervious areas on-site and infiltrate to ground. If infiltration is not possible, the rate-of-discharge from volume reduction Best Management Practices (BMPs) will be equal to the calculated release rate of an infiltration system.
Water Quality	Collect and treat the volume of the 24-hour precipitation event equalling 90% of the total rainfall from impervious areas with suitable BMPs.
Detention or Rate Control	Reduce post-development flows (volume, shape, and peak instantaneous rates) to pre-development levels for the 6-month/24-hour, 2-year/ 24-hour, and 5 year/24-hour precipitation events.
Notes: Flood conveyance events are not addressed in the DFO guidelines but are stipulated by municipalities.	

Source controls address volume reduction and water quality aspects of the guidelines. To meet DFO guidelines source controls should be designed to capture and hold on-site the 6-month, 24-hour post-development flow volume. An analysis of rainfall data from a number of Metro Vancouver climate stations shows that the 6-month, 24-hour event ranged from 67% to 76% of the 2-year, 24-hour event volume, with an average of 72%. This result is consistent with other regional results (Washington State, 2005) and can be used in the absence of site-specific data. This approach gives a capture target in mm of rainfall for a 24-hour event.

Generally, the capture of 90% of total rainfall (DFO Water Quality Criterion) must be determined using continuous simulation modeling (modelling of performance using a real rainfall record of 1 or more years). Extensive continuous simulation water balance modeling for source control design[1] was done using 15-minute rainfall records for three long-term gauges representing the range of annual rainfall across the region: White Rock (1100 mm annual rainfall), Kwantlen in Surrey (1600 mm annual rainfall), and Burke Mountain in Coquitlam (2100 mm annual rainfall). The results of this effort have shown that capture of 72% of the 2-year, 24-hour event volume (in mm rain per 24 hours) and capture of 90% of average annual rainfall (using continuous simulation) are roughly equivalent in the Metro Vancouver region. These criteria generate equivalent sizing for a given type of facility.

Note that DFO approval is often required for discharge of stormwater from a development site to a receiving water through a new outfall, and it is recommended that the DFO guidelines be applied for design of stormwater source controls in projects that are subject to DFO review.

[1] As part of work for the 2012 update of the Stormwater Source Control Design Guidelines

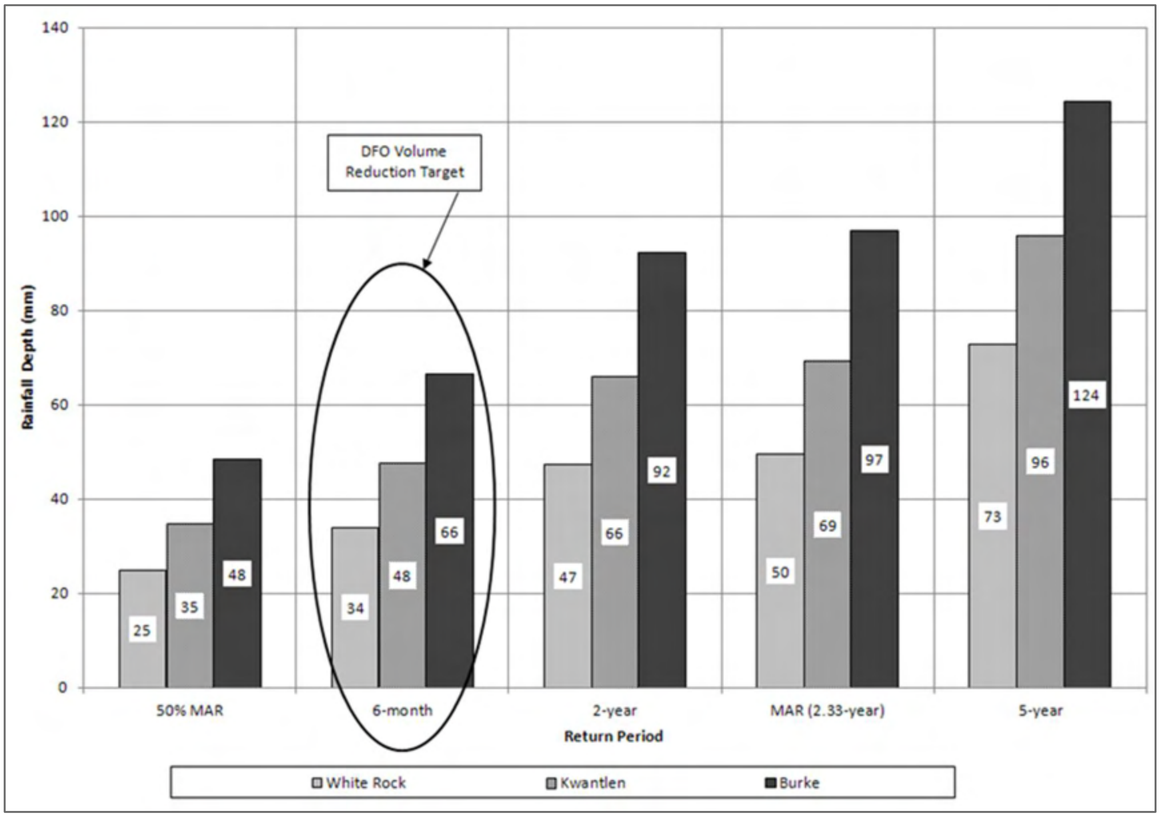


Figure 1-A: 24 Hour Rainfall Depths for Selected Monitoring Stations in Metro Vancouver

1.5 Province of BC

The Ministry of Water, Air, and Land Protection released Stormwater Planning: A Guidebook for British Columbia in 2002; the stormwater guidelines are summarized as follows.

Table 1-3: Stormwater Criteria from Provincial Stormwater Guidebook

Objective	Target
Runoff Volume Reduction and Water Quality Control	Capture 0 to 50% of the MAR [(1)] (90% of the rainfall volume in a typical year) at the source (building lots and streets) and infiltrate, evaporate, or reuse it.
Runoff Rate Reduction	Store 50% to 100% of MAR runoff and release at a rate that approximates the natural forested condition. Decrease the erosive impact of the large storm events.
Peak Flow Conveyance	Ensure that the drainage system is able to convey extreme storm events (up to 100-yr. return period) with only minimal damage to public and private property.
Notes: 1. MAR is Mean Annual Rainfall Event (i.e., approximately a 2.33-year, 24-hour storm event – refer to Guidebook).	

In the absence of guidance from the municipality where a site is located, the selection of one of these sets of criteria (DFO or Province of BC) is the decision of the designer.

1.6 Data Needs for Source Control Design

1.6.1 Rainfall Data

Rainfall data can be obtained from representative climate stations closest to the subject site. Three types of rainfall data are used in the analysis and design of source controls:

- Numerical values taken from the intensity-duration-frequency (IDF) curves to determine rainfall depth (in mm) for a specific duration and return period (e.g., the 2-year, 24-hour event). This rainfall depth can be used in simplistic calculations to roughly determine the rainfall-runoff capture volume for the subject site.
- Hourly or sub-hourly (1-, 5-, 15-minute) rainfall data, either for a significant length of record (e.g., ten years or more) or for a defined "typical year" extracted from the period of record. This is used for hydrologic computer modelling in the sizing of source controls.
- IDF curves are also used to determine extreme flows that would occur during flood events (e.g. 10-year or 100-year events). Source controls must provide adequate overflows to accommodate large events. Flood event flows are quantified using the Rational Method or using hydrologic computer modelling of design storm events.

IDF curves are available from a variety of sources and are updated periodically. Municipal drainage design criteria or bylaws, Metro Vancouver, and Environment Canada are potential sources for IDF curves.

1.6.2 Surficial Soils Mapping and Infiltration/Conductivity Values

Infiltration rate and *hydraulic conductivity* are used more-or-less interchangeably when talking about the rate of flow of water in soil, however they have different meanings (see Glossary). For design of source controls, it is the subsurface soil saturated hydraulic conductivity that is the more representative a value for design and when "infiltration rate" of soil is noted, it is really the saturated hydraulic conductivity that should be used. Sources for this information include the following.

General soils mapping for the Lower Mainland area can be found on:

- GeoMap Vancouver, Geological Map of the Vancouver Metropolitan Area, Geological Survey of Canada Open File 3511, 1998.
- 1:50,000 surficial geology mapping, Geological Survey of Canada, 1980.
- Municipalities also may have soil mapping.

These maps provide generalized information only and are appropriate for planning level studies only. Site specific soils and subsurface saturated hydraulic conductivity information should be obtained by a geotechnical engineer at the design phase.

On-site testing for subsurface saturated hydraulic conductivity is needed at the elevation (depth) of the proposed infiltration facility. The BC Environment Percolation Test Requirements recommend using the double ring infiltrometer testing methodology. Subsurface soil saturated hydraulic conductivity rates should be reported in mm/hr.

Literature values for saturated hydraulic conductivity are shown in Table 1-4 below, for reference only. Tested in-situ saturated hydraulic conductivity should be used for design.

A "correction" or "safety" factor can be applied to the determined subsurface soil saturated hydraulic conductivity rate to allow for average soil variability, potential for construction impacts to soil structure. Selection of a correction factor is based on the judgement of the designer; typical safety factors range between 2 and 8.

Table 1-4: Typical Literature Hydraulic Conductivity Rate Ranges

USDA Soil Class	Saturated Hydraulic Conductivity (mm/hr)
Sand	150 – 500
Loamy Sand*	50 – 150
Sandy Loam*	15 – 110
Loam	5 – 75
Silt Loam	2 – 25
Sandy Clay Loam	1.5 – 15
Clay Loam	0.5 – 12
Silty Clay Loam	0.5 – 10
Sandy Clay	0.5 – 8
Silty Clay	0 – 6
Clay	0 – 5

*These are target soil textures for growing medium which represent a good balance between infiltration performance and water retention capabilities.

Monitoring of installed source control facilities in urban areas (KWL, 2006) has shown that even in till and clay soils, observed infiltration rates tend to approach 1 mm/hr. This is due to the fractured nature of the subsurface in urban areas due to utilities, footing drains, and other excavations that allow a tiny bit more water to move through the subsurface than would naturally occur through the in-situ soils. Therefore, designers must use care in using literature or tested soil infiltration rates for design.

For the simplified sizing approaches developed for these guidelines (Appendix B), it is assumed that 1 mm/hr saturated soil hydraulic conductivity will be used as a minimum for design of most source controls in poor soils. Simplified source control design options using a flow restrictor use 0.5 mm/hr as the minimum subsurface soil saturated hydraulic conductivity considered.

1.7 Considerations and Constraints for Stormwater Source Controls

1.7.1 Limitations and Precautions to Implementing Source Controls

Hazardous Slopes: The implementation of source controls is prohibited in hazardous areas of potential slope instability. Source controls encourage infiltration that saturate soils and may further reduce the stability of these hazardous slopes. Adequate setbacks for infiltration from the top of these slopes should be delineated by a qualified geotechnical engineer.

Overflows: As with all drainage works, source controls should be designed to ensure that facility overflows drain to the municipal minor/major drainage system or natural drainage path, and do not discharge to or through adjacent sites. Emergency overflows should be designed as a part of all source controls.

Groundwater Protection: It is also important to consider the impacts of groundwater contamination and the presence and potential influences on existing water wells in the vicinity. A hydrogeologist should be consulted for any site where wells are located near proposed infiltration facilities to confirm that infiltrated water does not put groundwater resources at risk. As the pollutant loading from different land uses can vary significantly, designers should also consider the land use of the contributing drainage area when determining groundwater protection strategies.

Utility Trenches: Municipal utilities may have a variety of different setback and protection requirements for protecting utility trenches and utility infrastructure from the impacts of infiltration from nearby source controls. These requirements should depend on the risk posed by infiltration near these systems and the offset distances for infrastructure replacement. Source controls installed near sensitive utility corridors may require partial lining with an impermeable membrane to direct system discharge away from the utility. Utilities installed near existing source controls should consider protective measures within their utility trenches.

Permeable utility trenches that intercept source controls should be sealed off with low permeability fill trench dams. This prevents accumulated water from short-circuiting through the utility trench potentially causing damage down-slope.

1.7.2 Constraints to Infiltration Techniques

All sites in Metro Vancouver can incorporate some form of stormwater source control. Even in dense sites or poorly draining soils solutions like green roofs, flow through planters or infiltration techniques with flow restrictors can be used.

The most cost and space effective techniques will be those that rely on significant infiltration into site soils. To determine if infiltration-based source controls are advisable on the development site, professional geotechnical engineers, hydrogeologists, and designers should identify site or neighbourhood features that may act as constraints.

The Infiltration Constraints outlined below provide a partial list of constraints that may need to be considered in source control design.

1.7.3 Infiltration Constraints

- Drinking Water Wells: Infiltration should be separated from drinking water wells, against both surface water intrusion and ground water pollution. Standards for separation may vary by municipality, soil conditions, and well operation, but should, at a minimum, equate to the separation required between septic fields and drinking water wells by BC Ministry of Health. At time of writing, this separation was a minimum of 30.5 m horizontally.

- Land Uses that are Pollutant Hot Spots: Infiltration should not be undertaken from land uses that present a high risk of groundwater pollution e.g., automobile service yards, wrecking yards, sites storing industrial chemicals or wastes, unless appropriate pre-treatment is included.
- Contaminated Soils: Sites that have previously contaminated soils will need geotechnical analysis to determine if they can be remediated, and if they are suitable for infiltration once remediated.
- Seasonally High Water Table: For infiltration to be effective, the bottom of the infiltration facility should be at least 600 mm above seasonally high water table. Site test holes and mapping should be completed if areas of high water table are indicated.
- Shallow Bedrock: Infiltration may be constrained by shallow bedrock, or by cemented layers in soils. The infiltration facility bottom should be at least 600 mm above monolithic, unfractured bedrock. Note, however, that many types of bedrock including fractured sandstone are highly pervious and suitable for infiltration. Some other types of bedrock e.g., karst limestone, are excessively permeable, and infiltration directed at them may need careful pre-treatment for water quality. Some cemented layers in soils are underlain by highly permeable strata, and facilities can be designed to remove pollutants from surface water and then infiltrate it to these deeper permeable soils.
- 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 the slope. Infiltration designs within 30m (or greater in some areas) of steep slopes, or that direct surface or groundwater at a steep slope area are prohibited unless reviewed and deemed acceptable by engineers with experience in geotechnical engineering.
- Unstable Soils: The stability of soils for foundation conditions or against mass slumping may be affected by infiltration. If expandable clays are present on a site, geotechnical advice should be sought on setbacks from infiltration facilities to foundations – 3-5m setback distances are common. Other unstable soils, such as peat or organic muck, may be affected by increased water content related to infiltration, and geotechnical advice should be sought.
- Riparian Area or other Protected Habitat: Infiltration techniques that require excavation are commonly restricted in areas of protected habitat. However, non-invasive techniques that provide drain/soil/compost check dams to create vernal pools, or facilities outside the protected area that allow treated runoff to distribute and slowly flow through the protected area are appropriate.

1.8 Strategies to Deal with Limited Infiltration Rates

There are a wide variety of soil conditions in Metro Vancouver, and infiltration rates will vary considerably. Depending on soil conditions, various designs of full or partial infiltration source controls are appropriate.

1.8.1 "Non-Infiltrating" Geotechnical Report

Concerns sometimes arise when geotechnical testing has been done for a site and the geotechnical report has labelled the site "non-infiltrating" or may recommend that no infiltration be used on the site. The geotechnical engineer may make this determination for a few different reasons, such as:

- Infiltration is considered hazardous for this site due to local conditions such as proximity to a ravine, a slope stability concern near a bluff or other steep slope, or if the soil type is a dissolvable material (e.g., Karst limestone), or contains swelling clay or other material that performs adversely when water is introduced;
- Infiltration is not possible, e.g., the site is located on bedrock, or the permanent water table is too high to allow infiltration; and
- Native subsurface soil saturated hydraulic conductivity rate is very low, which may mean anything from 25 mm/hr to less than 1 mm/hr, depending on the experience context of the geotechnical engineer.

In either of the first two conditions, a or b, infiltration should not be used and alternative approaches for stormwater capture or retention should be considered, such as a tank with slow-release, or a regional source control approach to accomplish the capture target offsite. In these conditions, lined or non-infiltrating source controls can still provide critical water quality treatment for runoff.

The 3rd reason may still allow for infiltrating source control practices. Geotechnical engineers must make judgements regarding suitability of a site for infiltration based on their own experience, and may consider, for example, that a site with a tested subsurface soil saturated hydraulic conductivity of 25 mm/hr or less is unsuitable for infiltration of stormwater because it would not be considered acceptable for a septic waste treatment system. If a geotechnical report labels a site as unsuitable for infiltration or non-infiltrating, a designer or reviewer should follow-up with the geotechnical engineer to ask questions, such as:

- What are the reasons that infiltration of stormwater should not be used on this site?
- Are there any hazards that would be caused or exacerbated by infiltration of stormwater?
- Are there any adverse consequences that would be expected if infiltration did occur?
- What is the tested subsurface soil saturated hydraulic conductivity?

It is recommended that the designer consult with the geotechnical engineer in advance, discussing the appropriate locations and depths of infiltration testing to provide the best information for the source control design.

A discussion regarding how the results can be characterized should also be had, so that low subsurface soil saturated hydraulic conductivity testing results are described in the geotechnical report as "low infiltration potential" rather than "non-infiltrating", or "unsuitable for infiltration".

While low saturated hydraulic conductivity glacial till soils are common across the Metro Vancouver area, the use of infiltration source controls in these conditions has been tested and successfully implemented over the last 20 years. Any tested saturated hydraulic conductivity of 1 mm/hr and above should be considered for infiltration source controls, provided the source control design takes into account the low saturated hydraulic conductivity.

For sites with a tested saturated hydraulic conductivity below 1 mm/hr, or any of the hazards or concerns that prevent infiltration as noted in a. or b. above, some source controls may still be considered to provide benefits such as storage and evapotranspiration, and water quality treatment. Potential uses of source controls in these adverse conditions could include:

- Partial infiltration systems that rely on underdrains to convey excess flows from the system may be used, with the understanding that the infiltration benefit will be very low or negligible, depending on the volume of aggregate storage beneath the underdrain invert;
- Flow-through treatment systems, such as a rain garden or bioswale with an underdrain collection pipe for treated runoff and an impermeable liner below the growing media soil layer. These systems provide treatment of runoff for water quality improvement, as well as limited volumetric capture through storage in the soil and evapotranspiration through plants. These systems can also be designed to incorporate peak flow reduction (detention) even though they will provide only limited volume reduction; and
- Absorbent landscape where the plantings can tolerate saturated soil and there is a clear and safe flow path for excess runoff from the absorbent landscape to be collected and/or conveyed once the soil is saturated. The Metro Vancouver winter wet season climate naturally leads to such saturated conditions in areas where the native subsurface soil has low or no infiltration potential. This approach should not be used in any case where the water could pose a hazard in any way but could potentially be used where there is underlying bedrock or a shallow water table, as well as where the soil has extremely low infiltration potential. This would not be effective for grassed areas where foot traffic and play are expected as it could create poor vegetation and muddy conditions.

Table 1-5 provides general guidance on types of sources controls that may be used for different infiltration rates. Use these as guidelines, not rules.

Table 1-5: Tentative Match: Source Control Type to Soil Infiltration Rate

Subsurface Soil Saturated Hydraulic Conductivity (tested at the site of proposed infiltration)	Full Infiltration	Full Infiltration with Reservoir	Partial Infiltration with Reservoir and Subdrain	Partial Infiltration with Flow Restrictor
>30 mm/hr.	X	X		
15-30 mm/hr.	X	X	X	
1-15 mm/hr.		X	X	X
<1 mm/hr.			X	X

When saturated hydraulic conductivity rates are high – greater than 30 mm/hr, such as in sand soils – full infiltration designs should be pursued. Full infiltration provides the highest water quality treatment of all options and is the least expensive source control to construct.

In soils which have moderate saturated hydraulic conductivity rates – 15-30 mm/hr, such as in sandy loam soils – the addition of a drain rock reservoir under a soil layer provides underground storage. This system removes water from the surface and ponds it in the reservoir until it can be infiltrated by the subsoils.

In soils with low saturated hydraulic conductivity rates – 1-15 mm/hr, such as silt loams – the addition of a subdrain at the top of the drain rock reservoir diverts water to the downstream storm drainage system when the reservoir fills up. This design provides opportunities for infiltration, while minimizing surface ponding. This type of design is also advantageous for planting of non-aquatic plants in the soils above the subdrain, as the subdrain keeps roots from being saturated and deprived of oxygen for excessive periods.

In soils with very low saturated hydraulic conductivity rates rates – around and less than 1 mm/hr., such as compact till – infiltration still occurs. An infiltration rate of 1mm/hour is 24mm/day, which would absorb a significant portion of annual rainfall in undeveloped conditions, particularly in the southern portion of the Metro Vancouver region.

However, when rainfall is relatively continuous in winter months, the reservoir in a source control facility may remain full between rain events, with rainfall-runoff moving directly to drainflow through the subdrain. To provide additional storage, and a controlled release rate, a flow control structure, or flow restrictor, can be added to the subdrain. The small orifice on the flow control structure provides a gradual decanting of the storage above the drain pipe.

The orifice for this device is sized to allow drainage from the system up to the equivalent of a winter baseflow rate for the impervious catchment area. *The allowed baseflow rate is an average value that is appropriate for the whole Metro Vancouver region and allows a slow release of 0.25 L/s/ha through the orifice of the flow restrictor.* For example, for a 1 ha parking area, a flow restrictor could allow drainage at a rate of up to (1 ha x 0.25L/s/ha = 0.25 L/s). This type of system allows treatment and "capture" of more rainfall to meet higher criteria targets in poor infiltration soil conditions, however, it should be noted that these facilities will be somewhat more expensive to install and may have a higher risk of clogging and limited failure of the system due to the small orifice sizes in the flow restrictors. A minimum orifice size may be required by individual municipalities, which would over-ride the calculated orifice size if it is smaller than the minimum. Check Municipal requirements for minimum size of orifice; it may be 10, 15, 20 mm or other size. Vortex valve type flow restrictors may be preferred over orifices for small release rates.

This type of design is less appropriate for small catchment areas as the size of the orifice required for a very low flow rate would be impractically small and prone to clogging. To reduce the potential of orifice clogging, it is advisable that the water must first infiltrate through soil (as in a rain garden or swale) or pass through a filtration unit (prior to an infiltration trench) to remove particulate.

1.9 Organic Matter Maintains Soil Infiltration Rates

1.9.1 Surface Vegetation:

Plant materials work to condition the soil – providing a regular supply of organic matter through leaf drop and opening up macropores in the soil through the process of root growth, death, and decay. Soils with vegetated surfaces have higher maintained surface infiltration rates than bare soils, because macroporosity of the soil is continually regenerated by plants and animals (Ferguson, 1994). Surface vegetation is also very effective at stopping erosion from starting. Leaves of grasses and similar plants on the soil surface also act as physical filters to runoff – causing sediments and attached pollutants like metals and phosphorus to drop out of the water.

1.9.2 Organics and Compost

Addition of organic matter or compost to soils increases the infiltration and moisture holding capability of sandy, silt/clay or till soils that are not permanently saturated. Organic matter in the soil reduces the need for fertilization and can reduce the need for supplementary watering by 60% when compared to sites with un-amended topsoil (Chollak and Rosenfeld, 1999). For stormwater purposes, organic matter targets of 8% for lawn areas and 15% for shrub areas are recommended. Compost blankets and berms for erosion control have been tested and proven to be as effective as silt fence (Tyler, 2002). Bark mulch is recommended as a surface cover over the soil to protect against raindrop impact, but care should be taken to use mulch that does not have a high wood chip content as wood chips will tend to float.

1.9.3 Soil Life

Compost and soil is a living material – a mature topsoil with 5% organic matter can contain as much as 7.5 tons of organisms per hectare (Carpenter-Biggs, 2002). Together with plant roots, soil fauna such as earthworms, insects, ants, and moles form and maintain macropores in the soil. These larger organisms rely on a soil ecosystem of microscopic species sustained by organic matter. In soils or surface crusts of low conductivity, even a small amount of macroporosity can increase hydraulic conductivity by more than 10 times (Ferguson, 1994).

1.9.4 Interflow

Summer base flow in streams is maintained by 'interflow' of rainfall in shallow soils. With a typical water flow rate of 12.5mm/hr in loam, a raindrop would travel through the soil at 300mm/day, taking 100 days to travel 30 metres.

1.9.5 Deep Groundwater

Soil water also flows by gravity through soils or fractured rock to deep groundwater, which stores 98.4% of the unfrozen fresh water of the earth, as compared to 1.4% in lakes and streams (Montgomery, 1987). Protection of the quality of this groundwater through the filtration processes in surface soils is critical to drinking water supplies.

1.9.6 Water Quality Improvement

Infiltration of stormwater through healthy soil is generally agreed to be one of the most effective practices to improve water quality and remove urban pollutants.

A summary of effectiveness of the different types of source controls is shown in Table 1-6.

Table 1-6: Source Control Effectiveness for Water Quality Improvement

Source Control Type	Treatment Effectiveness (median measured % reduction)a						
	Total Suspended Solids	Total Dissolved Solids b	Bacteria	Nitrogen	Phosphorus	Hydro-carbons b	6PPD-quinone b
Absorbent Landscape	52%	-46%	-132%[c]	14%	-24%	some	some
Infiltration Swale	70-100%	-5%	70-90%	0-24%	10%	80-100%	significant
Infiltration or Treatment Rain Garden	70-100%	-256%	70-90%	0-24%	10%	80-100%	significant
Pervious Paving	70-90%	N/A	80 - 90%	0%	30-50%	some	N/A
Green or Blue-Green Roof	N/A	N/A	* Has the potential to increase concentrations of these contaminants			N/A	N/A
Infiltration Trench/ Soakaway	30 - 90%	* No/limited data available - pre-treatment recommended					

[a]1. Removal efficiencies are based on studies reported in:

International Stormwater BMP Database (2022): https://bmpdatabase.org/

Toronto and Region Conservation Authority (TRCA) (2010): Low Impact Development Stormwater Planning and Design Guide. https://sustainabletechnologies.ca/app/uploads/2013/01/LID-SWM-Guide-v1.0_2010_1_no-appendices.pdf

Toronto and Region Conservation Authority (TRCA) (2015): Performance Comparison of Surface and Underground Stormwater Infiltration Practices. https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/low-impact-development/bioretention-and-rain-gardens/performance-comparison-of-surface-and-underground-stormwater-infiltration-practices/

Drake, J.; Young, D.; McIntosh, N. Performance of an Underground Stormwater Detention Chamber and Comparison with Stormwater Management Ponds. Water 2016, 8, 211. https://doi.org/10.3390/w8050211

Sansalone J, Kuang X, Ying G, Ranieri V. Filtration and clogging of permeable pavement loaded by urban drainage. Water Res. 2012 Dec 15;46(20):6763-74. doi: 10.1016/j.watres.2011.10.018.

Ryan J. Winston, Kristi Arend, Jay D. Dorsey, William F. Hunt; Water quality performance of a permeable pavement and stormwater harvesting treatment train stormwater control measure. Blue-Green Systems 1 January 2020; 2 (1): 91–111. doi: https://doi.org/10.2166/bgs.2020.914

Pereira, B.; David, L.M.; Galvão, A. Green Infrastructures in Stormwater Control and Treatment Strategies. Proceedings 2020, 48, 7. https://doi.org/10.3390/ECWS-4-06526

Hunt, W. F.; J. T. Smith; S. J. Jadlocki; J. M. Hathaway; and P. R. Eubanks. Pollutant Removal and Peak Flow Mitigation by a Bioretention Cell in Urban Charlotte, N.C. Journal of Environmental Engineering 2008: 134(5). https://doi.org/10.1061/(ASCE)0733-9372(2008)134:5(403)

Selvakumar A, O'Connor TP. Organism Detection in Permeable Pavement Parking Lot Infiltrates at the Edison Environmental Center, New Jersey. Water Environ Res. 2018;90(1):21-29. doi:10.2175/106143017X14902968254575

[b] Note: Limited data is available for these contaminants; for 6PPD quinone, effectiveness is based on lab observations of fish survival tests with and without treatment

[c] Note: attributed to contributions from pet and bird waste

1.10 Strategies to Deal with Limited Space

Land is a significant cost in the Metro Vancouver region. A key advantage of integrating Stormwater Source Controls into the overall design of a project is to minimize or avoid requirements for additional land.

Strategies to deal with limited and constrained space for stormwater source control are listed in the Source Control Strategies for Limited Space Checklist. For high density urban conditions, see also the next sections on “Development Concepts that Integrate Stormwater Source Controls” for ways to incorporate source controls in challenging urban settings.

1.10.1 Source Control Strategies for Limited Space

- ❑ Use on-site required landscape areas as stormwater source control – make concave landscape areas at the site periphery and in parking lot islands and courtyards to receive water, rather than mounded landscape islands and features.
- ❑ Consider that even formal, rectilinear urban planters can be designed as rain gardens and if proximity to foundations or other constraints limits infiltration they can be flow-through systems. Raised planters may be particularly helpful for private rainwater management plans. municipalities will benefit from having design standards for private and public implementation. However, new asset types can be a barrier to internal municipal acceptance and working with familiar types of facilities may streamline approvals and acceptance.
- ❑ Design roadside boulevards and medians as infiltration areas (rain gardens, bioswales, or underground infiltration trenches) rather than raised landscaping. Source control systems designed for roadside boulevards and medians often have to navigate significant constraints related to utility coordination, street design standards, and maintenance. Municipalities may benefit from creating standard drawings and source control designs to smooth the process of

infrastructure integration and coordination. Source controls in boulevards and medians.

- Infiltrate into tree wells, soil cells or tree trenches, and structural soils. The use of structural soils for tree planting in paved areas is a well-established technique. Drainage of small, paved areas into these structural soils should be considered where the saturated hydraulic conductivity rate of the subsurface soils and underdrains will allow the removal of the water within 24 hours, or whatever time period is appropriate for the type of tree. Modified versions of this where structural soil is used to support tree root growth near and under pavements allows even more opportunity for utilizing the footprint of the tree growing area for infiltration. Soil cells and tree trenches are source controls that support growth of street trees and infiltration of runoff and may be used almost anywhere a street tree is proposed (see Chapter 8).
- Increase the depth and organic matter content of landscape soils in landscape areas. Good growing medium soils will be capable of storing water in up to 20% of their volume. Greater soil depth allows the storage of additional surface runoff. Sufficient organic matter maintains soil percolation rates. Look for opportunities to drain runoff to landscape areas where increased soil depth can support plant growth as well as infiltration. This approach turns ordinary landscaped edges and small spaces into absorbent landscape, which should be designed in accordance with the absorbent landscape guidance.
- Increase the vegetation height and density. Look for opportunities to add trees and larger vegetation to provide increased evapotranspiration, and shade, heat-island reduction, air quality, and visible green space benefits.
- Create hydraulic disconnects – that is, drain small, paved areas into absorbent landscape rather than to the storm drain system. A good example is draining sidewalks to boulevard rather than directly to curb and gutter. Another example is allowing small roof areas to drain from roof leaders to the surface of absorbent landscape. When the ratio of impervious area to pervious area remains small, these absorbent landscaping can absorb the runoff from disconnected areas and reduce the area of impervious surface that must be accommodated in separate source control facilities or that runs off to the storm drainage system. These small disconnects add up to reduce the total percentage of directly connected impervious area. However, highly distributed source controls can be difficult to design due to the need to create site grading that directs the right amount of drainage area to each source control. Care should be taken to delineate these drainage areas when accounting for overall site performance.
- Install pervious paving. Pervious paving of several types is highly suitable for pedestrian areas, overflow parking, and main parking areas. It can be challenging to use in dense urban areas where foundations and utilities constrain where it can be placed, but it can provide significant benefit when landscaping is not appropriate. Expected sediment loading should also be considered when

siting pervious paving. Sediment can clog these systems and lead to significant reductions in performance.

- Place infiltration trench or soakaway manhole under paved areas. For example, the drain rock reservoir under infiltration swales can extend under driveways, thus increasing the infiltration area. When used in public right-of-ways, designers should consult with any municipal engineers responsible for pavement design to ensure that the material used in the infiltration trench is acceptable for use under load-bearing paved areas.
- Allow surface storage. Temporary ponding on the surface of infiltration swales or rain gardens is approximately 3x more efficient than underground storage in a drain rock reservoir due to the volume of space taken up by the rock. Where surface storage is adjacent to traffic or pedestrian areas, a maximum ponding depth for safety should be implemented. This may vary by municipality. Surface storage should be designed to drain in 24 hours or less.
- Provide underground storage. Temporary storage of rainfall, and slow release into infiltrating soils, can greatly increase the effectiveness of limited infiltration capacity or area. Underground storage can be by concrete cistern, welded plastic pipes, or by several proprietary brands of underground infiltration structure.
- Install green roof or blue-green roof, to provide rainfall capture above buildings and parkades.
- Consider rainwater re-use, for flushing toilets, irrigation and/or laundry uses. This technique is common in Australia and Europe and is gaining traction in North America with “purple pipe” building systems for non-potable water.
- Confirm utility setback. Coordinate with utility departments to confirm vertical and horizontal setbacks from both infiltrating and non-infiltrating source control facilities and determine acceptable mitigation measures where full setbacks are not met. Non-infiltrating source controls require setbacks to protect adjacent assets during repairs and replacement.

1.11 Development Concepts that Integrate Stormwater Source Controls

1.11.1 Identify Candidate Stormwater Source Controls

Every development and site combination merits a customized solution for stormwater source controls. However, Table 1-7 illustrates the typical relationship between source controls and site or land use combinations at the parcel or street level.

Table 1–7: Typical Source Control Applications

Source Control Type	Land Use						Suitable For Retrofit	Limited Land Availability	Suitable for Difficult Sites				Allowable Water Source					Effectiveness		
	Single Family (Suburban)	Single Family (Urban)	Multifamily Strata	Civic/Institutional	Commercial/Industrial	High Density Urban			Low Infiltration Soils	Steep Slopes	High Water Table	Shallow Soils Over Bedrock	Roof Water	Parking Areas	Pedestrian Areas	Overland Flow - Ground Surface	Piped flow - Ground Surface	Volume Capture	Flow Control	Water Quality
Absorbent Landscape	●	●	●	●	●	◑	●	◑	●	○	○	◑	●	●	●	●	●	●	○	◑
Infiltration Swale	◑	○	●	●	●	◑	◑	◑	◑	○	○	○	●	●	●	●	●	●	◑	●
Infiltration Rain Garden	●	◑	●	●	●	●	◑	◑	●	○	○	○	●	●	●	●	●	●	●	●
Treatment Rain Garden	○	○	●	●	●	●	●	●	●	○	◑	◑	●	●	●	○	●	◑	◑	●
Pervious Paving	●	●	●	●	●	●	●	●	●	○	◑	◑	◑	◑	◑	◑	◑	●	◑	◑
Green Roof	○	○	●	●	●	●	○	●	●	●	●	●	●	○	○	○	○	◑	○	◑
Blue-Green Roof	○	○	◑	●	●	●	○	●	●	●	●	●	●	○	○	○	○	◑	●	◑
Infiltration Trench/Soakaway	●	●	●	●	●	◑	●	●	◑	◑	○	○	●	●	◑	○	◑	●	○	○
Soil Cell/Tree Trench	○	○	●	●	●	●	◑	●	◑	◑	○	○	◑	◑	●	●	●	●	◑	●

Effectiveness
● High
◑ Medium
○ Low

For high–density urban areas, the space pressure on both lots and right–of way areas can be extreme, and while many source control types are still possible in these settings, the source controls may need to incorporate the following design considerations:

- To be combined, either in a treatment chain (in series) or with multiple facilities or types on one site to address runoff from different areas of a single site. For example, a green roof on a portion of a building could be combined with pervious paving at walkway areas and infiltration planters for landscaping;
- Modifications to fit around constraints, so the design may not be a single shape, or may have sections with different depths or configurations;
- To be lined either in whole or in part in order to be located in close proximity to buildings and/or utilities, so that they provide treatment, evapotranspiration, and aesthetic and social benefits, but may not provide full capture benefits; and.
- To be coordinated between the property owner and the municipality such that source controls that provide benefits for a densely built urban lot may be located within or partly within the public right of way in order to take advantage of the available space at grade.

Examples of modifications for the urban context include:

- All source control systems may require additional considerations for utility coordination in dense urban areas, where high water contents in soils may impact services and utilities such as electrical, district energy, sewers, and watermains;
- Absorbent landscape: may be in small sections that receive runoff only from a walkway or adjacent small pavement area;

- Rain garden: may requires structural sides to fit in small spaces such that it resembles a recessed planter, and may need to be lined or partially lined where conflicts and setbacks limit infiltration;
- Pervious paving: may be used in small sections where there is opportunity, along with other areas of impervious paving where pervious paving does not work;
- Infiltration trench: may be narrow to fit in edge spaces, may be located close to or overlapping a property line if it can be coordinated with the municipality, may have impermeable barriers on the side to prevent migration of infiltrated water toward a foundation, or may be located under pavement;
- Green roof: may need to be coordinated and balanced with other uses of building roof space, which is at a premium in the urban context, and may need to be in multiple segments, with some deep planter-style sections for landscaping mixed with some extensive green roof, and only a portion of the area design to store water in a blue-green roof; and
- Soil cell or tree trench: may need to be fit in between areas with utility conflicts creating an uneven street scape with trees on only a portion of a lot's frontage or block.

1.12 Integrated Practices to Minimize Maintenance & Maximize Effectiveness

Design to integrate source controls into the site should consider operation and maintenance as part of the function of the system. This section summarizes common maintenance issues and recommended practices to avoid or minimize maintenance needs and costs.

1.12.1 Key Maintenance Issues & Attitudes

Common maintenance issues for source controls are introduced below (see Table 1-8).

Stormwater source controls are layered into street, site and building plans. Minimizing maintenance may be achieved by considering maintenance and operations needs in parallel with all other objectives for a project. Thinking strategically about maintenance concepts should start early at the building massing and site concept stage which will minimize costs and complexities at the detail design and operations stages.

Integrated design processes that include maintenance strategies will also maximize the effectiveness and longevity of a stormwater facility, and in many cases will minimize capital cost to construct.

Table 1-8: Key Issues Affecting Maintenance to be Considered at Planning and Design

Drainage or Erosion Issues due to:
Lack of gravity overflow to a storm drain or drainage major flow path for extreme events.*
Shape and grade of proposed swale areas that are too steep for target infiltration grades of <2%, or too narrow for maintainable side slopes.*
Standing Water or Poor Infiltration due to:
Lack of scarification of subsoils.*
Inadequate subdrainage or drain rock reservoir below growing medium.
Improper growing medium mix control.*
Compacted subgrade or compacted growing medium layers at installation.*
Surface crusting due to compaction, lack of organic mulch to keep surface open.*
Lack of growing plants/roots/stems and soil life in infiltration area to keep it open.*
Low surface elevation due to settling of or inadequate soil or mulch.*
Uncleared buildup of sediment at inlets blocking drainage into the infiltration area;
Root Conflicts:
Inadequate rooting space or incorrect tree selection leading to lifting of adjacent pavement.*
Plugged foundation or other drains due to use of nearby plant species with invasive roots (e.g., willow).*
Poor Plant Establishment and Survival due to:
Inadequate depth or area of growing medium matched to plant /tree selection.*
Long-term saturated root area at plantings not selected for such conditions.*
Lack of adequate watering during plant establishment or during periods of excessive drought.*
Excessive Weeds and Weeding due to:
Inadequate quality control to provide weed-free growing medium and mulch materials.*
Inadequate separation of highly visible / manicured areas from wind blown or water carried weed seed sources in less manicured or background areas.*
Uncertain responsibility for maintenance provision e.g., between a landowner/strata corporation and the fronting public street areas or adjacent lands.*
Excessive Pruning due to:
Sight obstructions that create potential safety issues at driveways, intersections, and pedestrian/cycle crossings.*
Conflicts with desired visibility of retail windows, pedestrian entrances, views, or signage.*
Location of proposed tree areas that are too close to buildings or overhead lines to allow canopy growth.*
Excessive Sediment due to:
Nearby construction adding sediment to the road surfaces.*
Winter grit application
Inadequate frequency of sediment cleanout in pre-treatment
Sediment build-up along road edges forming ‘dams’
Note: * items also occur outside stormwater source controls

1.13 Site Planning Practices to Minimize Maintenance

Integration of maintenance and operating considerations into a project starts in the project planning stage – it is important to not leave these considerations too late. Some issues, if not addressed in early massing and site planning, may not be resolved at the detail design and specifications stages.

1.13.1 Integrated Solutions – General Site and Landscape Planning

It is critical that early concepts anticipate space required to maintain stormwater source controls.

The process to determine the required space for stormwater source controls is iterative, with the project massing and site plan concepts providing space available, and local climate, performance targets, impervious area, and on-site infiltration rates informing sizing.

Designs may be further adjusted to incorporate combinations of in-ground, on-ground, on-building stormwater source controls at the detailed design stage.

Reduced maintenance in the long term may be achieved by incorporating maintenance into the site planning and design as a step in the process:

- Identify site constraints and opportunities.
- Collaboratively plan the site to meet density and architectural/engineering objectives.
- Identify the appropriate location, shape, sizing, and grades of stormwater source controls – integrated with architectural and site concepts.
- Create schematic maintenance level diagrams to show types of maintenance, access, and equipment needs.
- Identify and evaluate challenges for maintenance and aspects that drive increased frequency or intensity of maintenance.
- Work with client and team to confirm appropriate levels of maintenance, preferred maintenance processes, and any particular concerns for types or aspects of maintenance.
- Assess whether modifications or adjustments to the design or layout can improve the maintenance obligations in line with the client's needs, such as moving access points, providing space for equipment access, or using pre-treatment structures that are familiar to the maintenance staff.
- Wherever feasible, consider concentrating source controls to reduce the need to maintain multiple disconnected assets.
- Design source controls with staging areas that will allow maintenance staff to work and assemble necessary equipment for maintenance activities.
- Ensure source controls are protected from sediment that may be generated by upstream construction.

1.13.2 Integrated Solutions – Site and Landscape Planning Specific to Stormwater Source Controls

In order to minimize the long-term maintenance needs for a site's source controls, the design team can consider whether the following specific adjustments may help reduce maintenance for a specific site:

- On a large site, balance larger stormwater source controls in larger background landscape areas having lower levels of maintenance with smaller required area of more highly visible and high maintenance stormwater source controls.
- Early selection of locations where slopes are flatter or can be easily created through terraces will avoid excessive slopes and retaining walls and reduce complexity of access for maintenance and the potential erosion that requires repeated repairs.
- Plan schematic grading design to accommodate overflow locations for use in extreme rainfall events to minimize stormwater piping installation as well as maintenance costs and complexities.
- Plan construction phasing to install pervious paving at the end of the construction period to reduce the need for cleaning and maintenance to remove silts/muds from adjacent roads or construction areas.

1.14 Stormwater Treatment Trains and Source Control Series

It can be very effective to distribute source controls on a site such that a single source control facility treats a single impervious are or portion of impervious area. This makes for a site design that is easy to map in a stormwater management plan for construction that shows how each area is treated by each facility. Multiple source controls may be used on a single site that receive and manage runoff from different portions of the site but are still a single source control treating runoff from a single catchment area.

Designers are also encouraged to think about combinations of stormwater source controls, if needed, to improve and maximize the benefits for the site. A 'Stormwater Treatment Chain' or 'Train' is a group of source controls that are arranged in series, flowing from one facility to another. It should be noted that the term is used generically to refer to a series of facilities, and water quality treatment may or may not be part of the function of the series. A treatment train can be useful in a dense urban setting where a single type of source control may not be able to provide enough benefit to meet the stormwater management targets for a site. For example, an extensive green roof may only provide 40% of the desired capture due to the limitation of only being able to capture runoff through evapotranspiration. But the available ground surface area cannot provide enough infiltration to meet the target either. However, if the green roof captures 40% of the target, and discharges to a linear infiltration gallery that can infiltrate the remaining 60% of the target, the two combined provide enough capture to fully meet the target.

Note that when considering water quality treatment, the level of treatment is based on incoming flow of pollutants (typically characterized by sediment or TSS), so treatment in series is not additive in the same way. Rather the percent removal must be multiplied, e.g., if the first source control provides removal of 40% of incoming TSS, and the second provides 60% removal, the net removal is 40% + 60% x (100%–40%) = 76% net removal. However, each individual treatment unit or facility will have a practical limit of application where it will not be effective for removal at the design rate (% of loading) once the influent pollutant concentration is too low. Therefore lengthy chains of treatment are not recommended.

For more information see:
https://www.researchgate.net/publication/308086855_Optimal_Sizing_of_Green_Infrastructure_Treatment_Trains_for_Stormwater_Management

The diagrams in Figure 1-B illustrate alternative concepts for stormwater source controls on a development parcel.

- The Treatment Train on the left relies equally on Green Roof, Rain Gardens, and Soakaway Manhole to each capture 33% of its on-site rainfall capture target. This concept may apply to a medium density development that has a balance of rooftop and landscape area.
- The Treatment Train on the right has Green Roof take up 60% of its rainfall capture volume, and 30% in Rain Garden, with less reliance on Soakaway Manhole. This would be appropriate on a high density development with limited landscape area.

  The diagrams show these elements in concept as a series on the site. Rainfall would move from Green Roof to Rain Garden to Soakaway Manhole to Overflow.

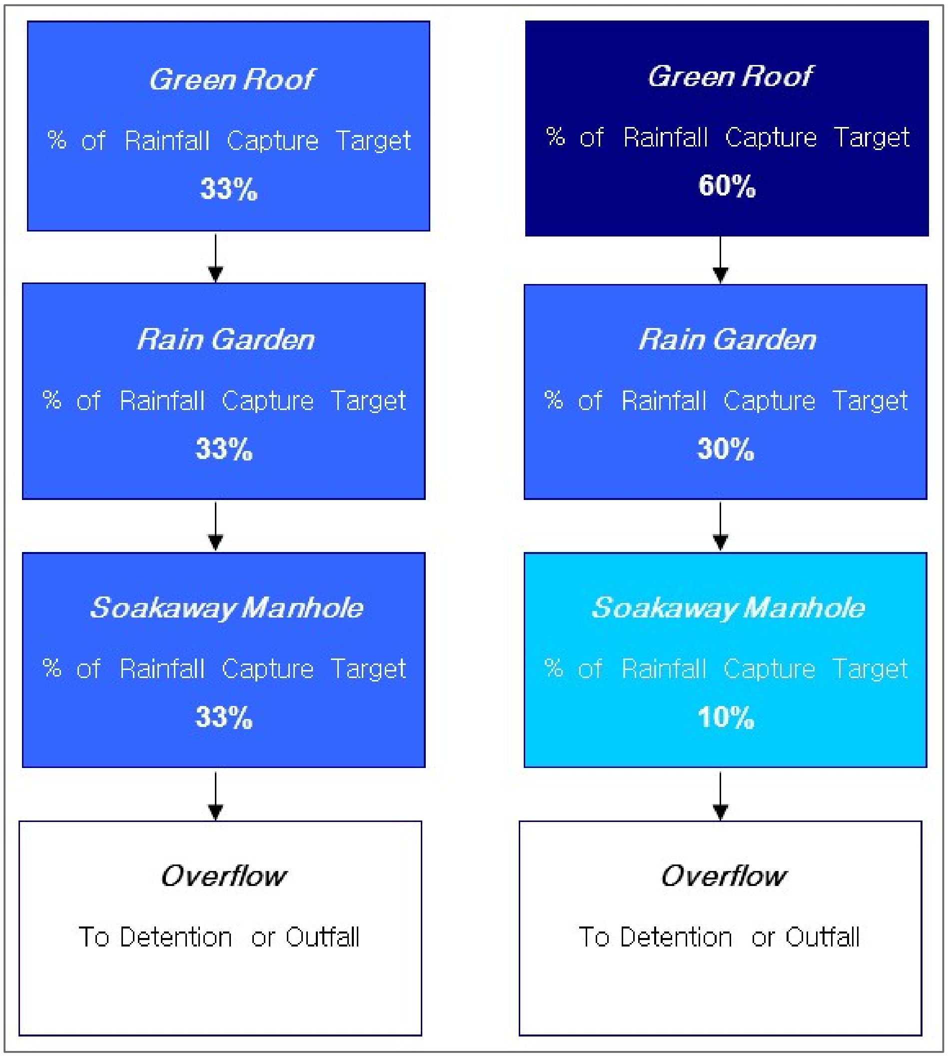


Figure 1-B: Alternative Stormwater Treatment Train for High Density Development

Parallel sequences of treatment trains are also possible.

The diagrams in Figure 1-C show one alternative for parallel stormwater source controls that is typical of Low to Medium Density development.

Two treatment trains are shown in parallel:

- On the left, an area of impervious paving such as road or travelled lane drains to pervious paving in parking areas or walkways. This pervious paving overflows to infiltration swales, which have an overflow to the major storm flow path; and
- On the right, building rooftop without green roof drains to storage devices such as cisterns or shallow surface storage area such as pools over the rain gardens. Drainage from this storage flows at a low but continuous rate into rain gardens or other infiltration system. This slow release rate of rainwater takes the most advantage of limited infiltration rates in soils, by distributing infiltration in time. The Rain Gardens have an overflow to the major storm flow path.

On-parcel stormwater source controls must be designed with an awareness of the role of neighbourhood detention ponds, and regional flow paths for major storm events.

All stormwater source controls should always be designed with an overflow to the storm system and/or major flow path.

Rainwater re-use is a technique that can also be explored to act as a part of a stormwater source control chain. Projects have used rainwater to flush toilets, for laundry purposes, or for landscape irrigation. Un-polluted roof drainage is ideal for these purposes that do not require potable water.

Designers are encouraged to describe the path of rainwater as part of the development concept stage, from rain hitting the site through stormwater source controls to outfall. Communication of this concept to all members of the design team, and to approval authorities, will allow creative synergy and integration of the source controls into overall design.

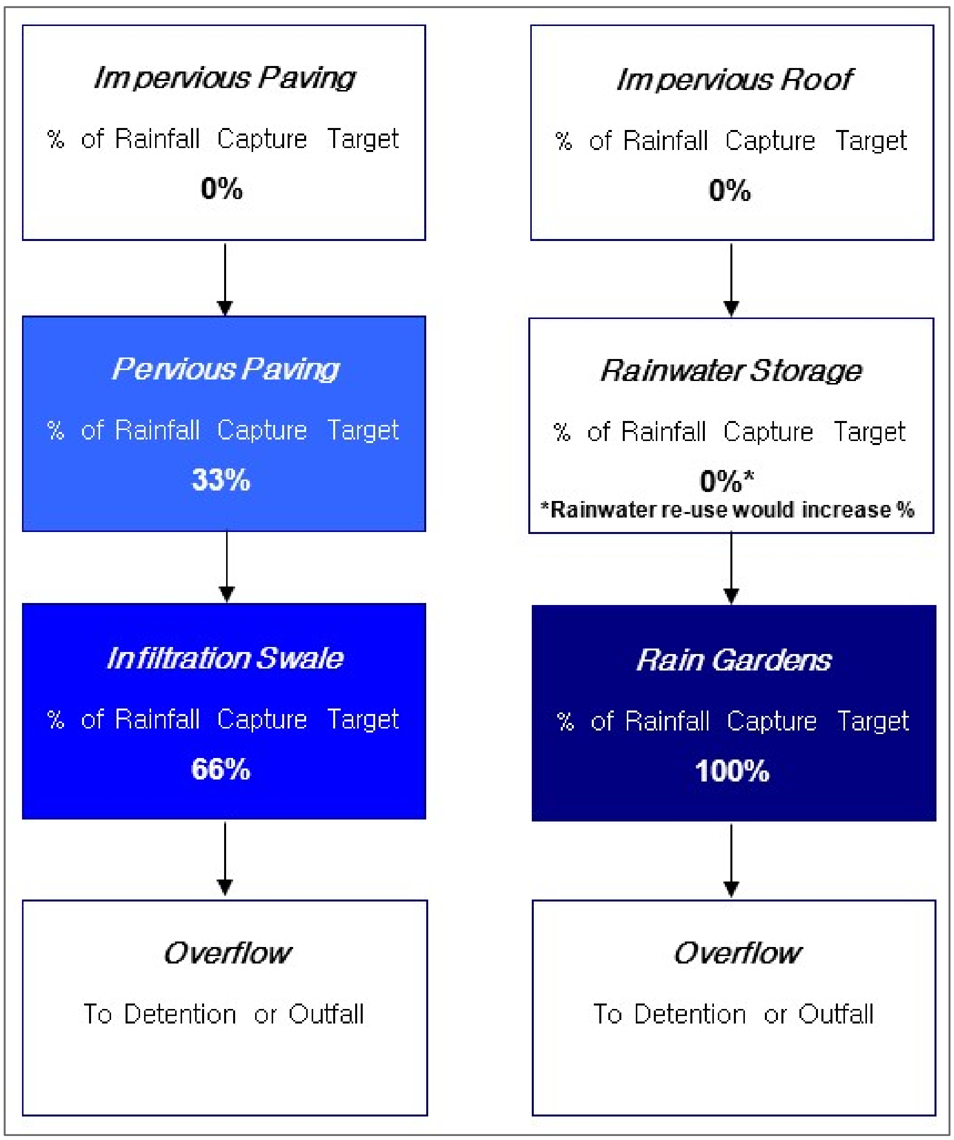


Figure 1-C: Alternative Stormwater Treatment Train for Low Density Development

1.15 Sizing for Stormwater Source Controls

1.15.1 Incorporating Climate Change in Sizing

The principal impact of climate change on design of source controls in the Metro Vancouver region is that climate change is predicted to increase the volume and intensity of rainfall in individual storms, which will impact the design volume for source controls. Typically, climate change will be accounted for by increasing the design rainfall depth used for the design capture targets for water quality and for volume reduction. Local municipal design guidance may provide either a climate change IDF curve that should be used for design for stormwater management, or a percentage increase in rainfall which should be multiplied by the design rainfall to account for climate change. The climate change adjusted rainfall value should then be used for sizing of stormwater source controls in accordance with the sizing methodologies presented in this guidance.

If a municipality does not have specific guidance for climate change, the Metro Vancouver report Climate Change Impacts on Precipitation and Stormwater for 2050 and 2100 (GHD, 2018), provides climate change IDF curves for all areas of Metro Vancouver.

Link to full report: https://metrovancouver.org/services/liquid-waste/Documents/climate-change-impacts-precipitation-stormwater-for-2050-2100-report-2018.pdf

Link to technical brief: https://metrovancouver.org/services/liquid-waste/Documents/climate-change-impacts-precipitation-stormwater-2050-2100%E2%80%93technical-brief-2018.pdf

Note that Metro Vancouver may update this guidance periodically and designers should look for the most recent information available.

1.15.2 Simplified Sizing Approaches

Source controls are usually intended to manage frequent, low intensity rainfall events and to increase infiltration and evapotranspiration throughout the year. Consequently, it is generally recommended that continuous simulation water balance modelling over an extended period of at least one year be used for design of source controls. For any series of source controls, continuous simulation modelling should be used for design. Modelling of source controls is discussed in the next section. For simple cases, in particular where a single surface type and area is treated by a single source control facility, a source control facility can be sized and designed using simplified methods based on design storm event performance. In addition, even if modelling will also be utilized, it is important to identify, early in the project at the concept level, the approximate size and location for stormwater source controls, which can be done using simplified sizing approaches. Simplified sizing approaches provide simplified sizing and design guidance to meet the specified criteria using charts and equations.

The first approach for simplified sizing, to meet design storm capture targets of the type requiring capture of “X mm” in 24-hours, is as follows:

The amount of space required for stormwater source controls is a direct function of:

- The volume and intensity of rainfall hitting the site;
- The rainfall capture target for the site;
- The amount of impervious area on the site;
- The area of infiltration footprint on the site;
- The rate of infiltration into the infiltration footprint; and
- The amount of rainfall storage that can be provided to temporarily hold water until it can infiltrate into the ground.

A calculation of the approximate space needed for a stormwater source control is described in the following steps, using a capture target in the form of mm rainfall per 24 hour period:

1. Disturbed pervious areas should be replaced with adequate soil layers to capture the rainfall target. The target is calculated by taking 72% of the 2-year, 24-hour rainfall depth from the nearest climate station IDF curve (based on DFO criteria). Determine the required soil layer depth for absorbent landscapes by assuming a reasonable field moisture capacity in the soil layer. E.g., Surrey Kwantlen Park climate station 2-year, 24-hour rainfall depth = 66.9 mm. 72% of 66.9 = 48 mm. Soil layer required with 0.2 (20%) field capacity = 240 mm;
2. Calculate the impervious area of the site. Minimize this number by providing absorbent landscape, pervious paving, or by hydraulic disconnects – where small impervious surfaces drain into large absorbent landscapes (size soil layer to accommodate impervious runoff), thereby not creating runoff;
3. Using the rainfall capture target, calculate the volume of rainfall that falls on the impervious surface and must be infiltrated or treated, in cubic metres (impervious area x rainfall capture target x unit conversions). E.g., Surrey Kwantlen Park rainfall target is 48 mm x impervious area = capture volume;
4. Determine surface area, soil layer depth, and rock reservoir depth (if needed) required for selected source controls to achieve the capture volume target. Account for infiltration into the subsurface using the on-site tested saturated hydraulic conductivity rate multiplied by 24 hours, volume storage in the source control soil layer, and rock reservoir (if used) void spaces; and
5. Investigate feasibility of selected source controls with the site plan.

Table 1-9 summarizes possible rainfall capture targets equivalent to the 6-month, 24-hour rainfall event based on DFO guidelines (approximated as 72% of the 2-year, 24-hour event) for a few regional rain gauges locations (Note – check current local gauge IDF information or municipal design criteria at time of design as values change and are updated).

Table 1-9: Typical Rainfall Capture Targets

6-Month, 24-Hour Rainfall Capture Targets	
Climate Station	Rainfall Capture Target*
North Vancouver Lynn Creek (upper elevations)	86 mm
North Vancouver Municipal Hall (lower elevations)	58 mm
West Vancouver CS (upper elevations)	85 mm
West Vancouver Municipal Hall (lower elevations)	59 mm
Maple Ridge Reservoir	65 mm
Langley Lochiel	46 mm
Surrey Kwantlen Park	48 mm
White Rock STP	41 mm
Vancouver Airport	36 mm
*Approximated at 72% of 2-year, 24-hour rainfall amount.	

The above describes a basic process of source control sizing to meet one type of design target criteria using equations. This simplified calculation approach is provided with more details and specific equations for each of the source controls in the following chapters of these guidelines.

A second type of simplified method of sizing is provided for each type of source control in the following chapters to meet criteria based on percent capture of average annual rainfall. This is similar to DFO water quality criteria which recommends treatment of 90% of the average annual rainfall volume. Sizing to meet this type of criteria is usually done using continuous simulation computer models, and for more accurate sizing with finer resolution of parameters and results, a computer model should be used. The simplified approach developed for these guidelines uses the results of hundreds of continuous simulation water balance models and collates and condenses them into simplified sizing design charts (found in Appendix B) to meet capture targets as a percent of average annual rainfall.

Both simplified sizing approaches developed for this guidance may be sufficient for simple design cases with few constraints and no series of source control facilities. These approaches are best used for cases where a single impervious surface area is to be treated with a single source control at lot scale.

1.15.3 Optimizing the Space Needs and Sizing of Stormwater Source Controls

The fine-tuning of space needs and sizing of stormwater source controls is an iterative process. Designers can use simplified sizing or computer-based modelling to test how a tentative solution will work given the location and rainfall constraints. Several scenarios can be tested, and the best scenario selected for detailed analyses and design.

Several computer modelling tools are candidates for modelling source controls in Coastal British Columbia. The Water Balance Model for BC is introduced below, and newer versions of SWMM that can model disconnected surfaces can be used.

1.15.4 Water Balance Model Powered by QUALHYMO

The Water Balance Model Powered by QUALHYMO (WBM) has been developed jointly by an Inter-Governmental Partnership that includes federal, provincial, and local government representatives, as well as consultants and industry partners. The model can be accessed on a free trial basis at www.waterbalance.ca.

The WBM is designed for larger scale land use simulations, allowing users to model the impacts of land use planning decisions and stormwater source controls at a watershed or basin scale. The WBM can also be applied at a site scale for source control facility sizing.

The WBM is not calibrated, and its results are not guaranteed to be accurate. In its disclaimer statement the WBM stresses that it is intended to be used as a planning-level decision support tool, and that the interpretation and application of scenario modeling results are the sole responsibility of individual users of the Water Balance Model for BC.

Input fields in the Water Balance Model include:

- Rainfall Data – several regional databases of hourly rainfall data are pre-installed. Custom data may be added;
- Soil Type – users select a soil type based on a soil triangle and the WBMs assumes soil characteristics based on the selected soil type;
- Land Use and Impervious Area Calculations – users input percentages or areas that characterize their site or development; and
- Proposed Stormwater Source Controls – users may select from Absorbent Landscape, Infiltration Swale, Rain Garden, Infiltration Trench, Pervious Paving and Green Roof, and input the size and general characteristics of these practices.

Output from the Water Balance Model includes:

- Proportion of Annual Rainfall that is infiltrated, evaporated, or becomes surface runoff; and
- Flow exceedance duration summary and graph.

Limitations of the Water Balance Model include:

- It is not calibrated with field test data;
- Surface flow is not modelled within the WBM. That is, infiltration swales and rain gardens are assumed to be flat, so that surface ponding will remain up to the allowable depth that is input by the user, until such time as the surface pond can infiltrate. This could result in standing surface water for an unacceptably long period in winter months in parts of the region. Users should review the water level output, and consider use of Source Controls with reservoir and subdrain if surface water ponding durations are too high; and

- Groundwater flow is also not modelled in the WBM. Site conditions where groundwater flow or interflow enter the stormwater source control from upstream are not considered. Designers should be aware that such groundwater flow may reduce the available infiltration capacity of a proposed stormwater source control.

1.15.5 SWMM

The most recent version, SWMM5, combines all the modules into one file for a single simulation. Several software packages based on the SWMM5 engine are available on the market from different software suppliers that provide more user-friendly interfaces, as well as the public domain version EPA SWMM available directly from the US EPA.

The SWMM software is capable of carrying out hydrologic and hydraulic simulation and features:

- Industry-standard SWMM analysis engine that is well-proven;
- Capability for both event (design and/or real storms) and continuous (historic rainfall record, multi-event, multi-year) modeling; and

Because the SWMM software includes a groundwater routine, it provides a complete water balance calculation allowing source control facilities to be sized for complex conditions and situations, including series of source controls (treatment chains).

The physically-based model parameters provide greater confidence in extending model results beyond those verified by a flow monitoring data set (i.e., to lower or higher return periods).

The inputs required for the model include:

- Rainfall data;
- Evaporation rate data;
- Soil parameters; and
- Catchment characteristics such as area, impervious percentage, overland flow length, and slope.

Most source controls can be modeled using the groundwater and soil parameters. Because SWMM includes a hydraulic model, additional parameters can be entered to size and test conveyance and/or detention in conjunction with source controls, however, municipal design requirements may not allow source controls to be accounted for in sizing of stormwater facilities. Additional parameters include pipe sizes or open channel cross sections, conduit inverts, roughness values, storage versus elevation relationships, weir, orifice, and pump data, and variable downstream water level boundaries (recorded stage or tidal).

Outputs from the SWMM model include:

- Catchment runoff flow rates;
- Shallow groundwater or interflow flow rates;

- Evaporation volumes;
- Water levels in conduits or detention ponds;
- Soil moisture and groundwater table elevation; and
- Statistical summaries on water balance for model run duration.

The SWMM model can be used for site, subdivision, and watershed level analysis. While parameters for SWMM are physically-based and may be assumed using literature values, it is better to use parameters from models of areas with similar watershed characteristics that have been calibrated using records of rainfall and monitored flow.

SWMM is a powerful and flexible modelling system but requires significant knowledge and experience to use. Generally, only experiences design professionals should use SWMM as a modelling tool for design of source controls. Source control options are more limited than the WBM and output of source control modelling results can be cumbersome.

1.16 Detail Design of Stormwater Source Controls

1.16.1 Detail Design and Construction Considerations to Minimize Maintenance

The detail design stage should address issues and concerns identified in the planning stage to minimize maintenance needs.

Detail Design Maintenance Issues / Solutions – see Table 1-10 – emphasizes solutions to common maintenance issues that can be addressed through the drawings and specifications of detail design.

For related information, Chapter 1: Detail Design of Stormwater Source Controls (page 1-35 to 1-39) provides examples of detail design and drawings. Also refer to the detailed guidance for sizing, design, and outline specifications for each stormwater source control in Chapters 3 through 8.

Many common best practices and specifications incorporate consideration of maintenance issues. Readers are encouraged refer to the Canadian Landscape Standard, current edition (Second Edition, July 2020, at time of writing) for detailed landscape maintenance information that may be useful in specifying maintenance for source controls.

Table 1-10: Detail Design Maintenance Issues and Solutions

Maintenance Issue	Solutions: Detail Design Drawings and Specifications
Sediment barrier at inlet	Ensure strong flow (+5%slope) through inlet and vertical drop (+50 mm) to top of cobble surface to avoid sediment dam. Or provide sediment pre-treatment sump.
Geotechnical Testing	Geotechnical testing of the subgrade is recommended to determine the saturated hydraulic conductivity rate and design according to the tested values. Geotechnical input on appropriate side slopes for sub-base, as well as material compaction and expected consolidation can

	minimize the potential for erosion and differential settlement of surfaces.
Cobble mulch maintenance	Avoid over-steepened profiles and minimize use of cobble in swales. Surface soils or bark mulches are easier to cultivate for weed removal and topdress to address subsidence.
Surface erosion / excess flow	Design swale profiles to be 1-2% between check dams or use vertical drops with rock so bark mulch/soil does not erode.
Poor surface infiltration – excess compaction or crusting	Provide detailed growing medium specs for texture and organic matter – see 'Chapter 9 – Construction and Establishment'. Specify only landscape rollers not vibratory plate compactors to compact (about 80% density). Specify subgrade scarification prior to backfill.
Poor plant survival – too wet	Choose plant species for wetness zone – see 'Chapter 10 – Landscaping and Plant List'.
Poor plant survival – too dry	Specify irrigation or supplementary watering systems during establishment period and drought for all plants, including wet zone and green roof plants.
Excessive pruning for sightlines	Specify plant species for low shrub height or high branch clearance at driveways, intersections and other locations requiring sight distance – see 'Chapter 10 –Landscaping and Plant List'.
Excessive pruning for O/H wires	Specify tree species for appropriate height at overhead wires– see 'Chapter 10 –Landscaping and Plant List' and utility company guidelines.
Excessive labour/cost of maintenance	Provide a maintenance plan and specification for the design. Consider specifying a 'natural' landscape appearance value as opposed to 'manicured' to minimize expectation of maintenance. Ensure growing medium and mulch components are weed free at installation – see 'Chapter 9 – Construction and Establishment Maintenance'.
Excessive water use	Specify low volume and weather-based irrigation systems, and design plantings to reduce irrigation use to nil after two-year establishment period except in severe drought intervals.

1.16.2 Design for Climate Change

Climate change can impact the design and operation of source control systems. While we tend to think of climate change as occurring in the future, it is a continuous process that has already begun to have impacts and will continue to have impacts over time. In the Metro Vancouver region, key climate change considerations for design include:

- Changes in the design volume due to rainfall increase or decrease – this is accounted for in the sizing process, as discussed earlier in Chapter 1;
- Changes in water balance and seasonality of dry and wet periods – this affects the plant selection. Plants may be subject to longer, drier summers, or wetter winters than previously, and must be selected for the site conditions with this in mind. In areas where there is no irrigation, the increase in duration of dry or drought periods must be considered. This concern must also be considered in determining whether or not irrigation should be installed for vegetated source controls;
- Changes in the hardiness zone – This affects plant suitability and should be considered in selection of plants for source controls. One suggestion is to consider a hardiness zone one zone warmer than the current zone and make plant selections assuming that the warmer hardiness zone will be applicable for the current lifespan of the source control facility, however, it is also thought that the levels of cold temperatures may not be reduced as volatility is increasing with climate change so plants should be selected for survival in a wider range of conditions that previously assumed;
- Changes in the atmospheric deposition of sediments and other contaminants – this may occur in areas where longer, drier summer conditions may create or exacerbate dust generation, which could affect operation and maintenance and increase the need for pre-treatment to collect sediment for removal; and
- Changing benefits – particularly in urban areas, the impacts of climate change will include increase in pavement heating and overall air temperatures. Vegetated source controls provide an opportunity to increase the vegetation in the urban environment and address these impacts by providing benefits such as:
    - Increasing interception and evapotranspiration of rainfall;
    - Carbon sequestration of CO_2 from the atmosphere;
    - Shade and cooling for pavements and people; and
    - Air quality improvement, particularly in summer when air quality in urban areas tends to be worse.

Trees, in particular, provide increased levels of these benefits, and rain gardens and soil cells or tree trenches provide opportunities to add trees to the urban environment. In the Metro Vancouver region, it should be noted that while deciduous trees provide better shade opportunities, evergreen trees provide better rain interception and evapotranspiration because they retain their leaves during the winter wet season.

1.16.3 Design Plan Details

Plan details (one or more views) for Stormwater Source Controls should show the features listed in the Plan Detail Checklist, as appropriate to the design.

Plan Detail Checklist

- ❑ Extent of impervious surface.
- ❑ Outline of Stormwater Source Control.
- ❑ Edge treatment at the Stormwater Source Control e.g., drop curb, flush curb, bollards, border, etc.
- ❑ Piping and drainage diagrams, sizes, and slopes.
- ❑ Overflow location to drainage system.
- ❑ Utility crossings and seepage cut-off details.
- ❑ Utility coordination plan to locate, protect, move, otherwise interact with, and coordinate with the utilities that will be encountered during the construction of the Stormwater Source Control.
- ❑ Spot elevations, slope arrows and/or contours to show grading design, including pipe inverts, catch basin elevations, breaks in grade.
- ❑ Proposed weir locations limiting slope to no more than 2%, other features.
- ❑ Extent of proposed growing medium installation.
- ❑ Extent of proposed drain rock reservoir installation.
- ❑ Erosion control and runoff dispersion features at steep slopes and inlet points.
- ❑ Planting plan showing trees, shrubs, ground covers, and use of grasses as applicable.
- ❑ Watering or irrigation plan showing provisions for establishment watering.

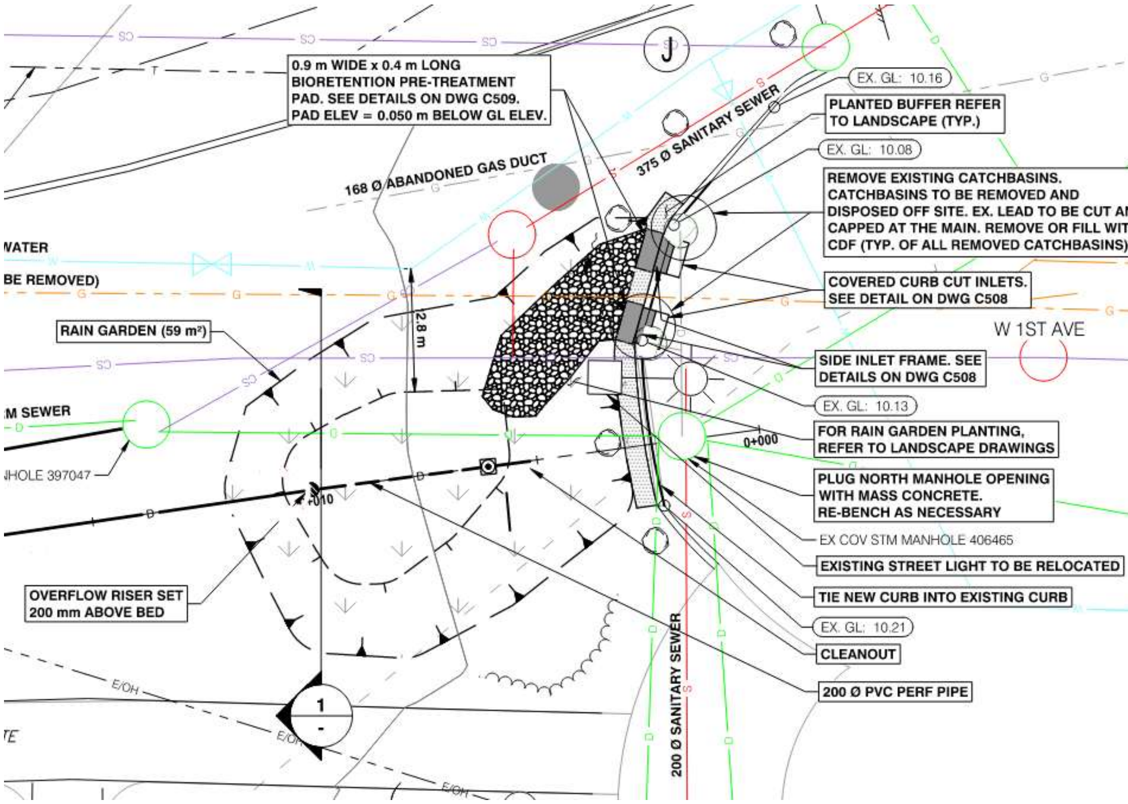


Figure 1–D: Example of Engineering Plan (Tatlow Park – KWL Associates Ltd.) Rain Garden

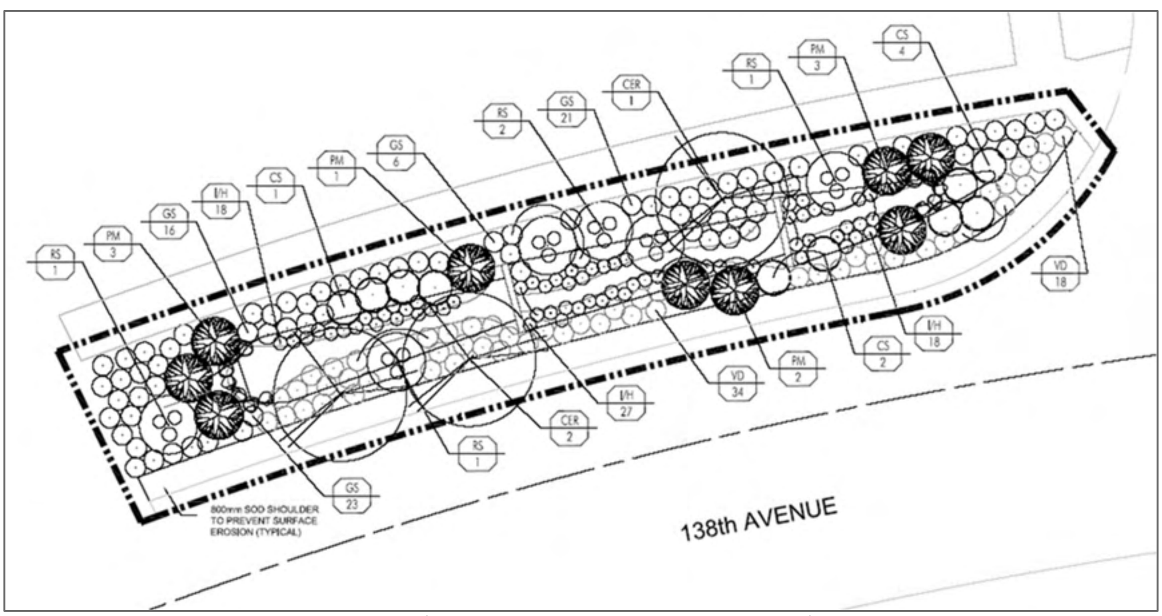


Figure 1–E: Example of Landscape Plan (Silver Ridge – Lanarc Consultants Ltd.)

1.16.4 Cross Section Details

Cross Section details (one or more views) for Stormwater Source Controls should show the features listed in the Cross Section Checklist, as appropriate to the design.

Cross Section Checklist

- ❑ Surface grades.
- ❑ Paving and base course layers, if included in design.
- ❑ Extent of proposed growing medium installation, layering of growing medium types.
- ❑ Extent of proposed drain rock reservoir installation.
- ❑ Piping and drainage locations in relation to growing medium and reservoir.
- ❑ Erosion control and runoff dispersion features at steep slopes and inlet points.
- ❑ Edge treatment at the Stormwater Source Control e.g., drop curb, flush curb, bollards, border, etc.
- ❑ Front view of proposed weirs.
- ❑ Typical cross section of planting and mulching treatment.
- ❑ Specialty materials for Green Roof, such as lightweight soils, root barrier, drainage layer.

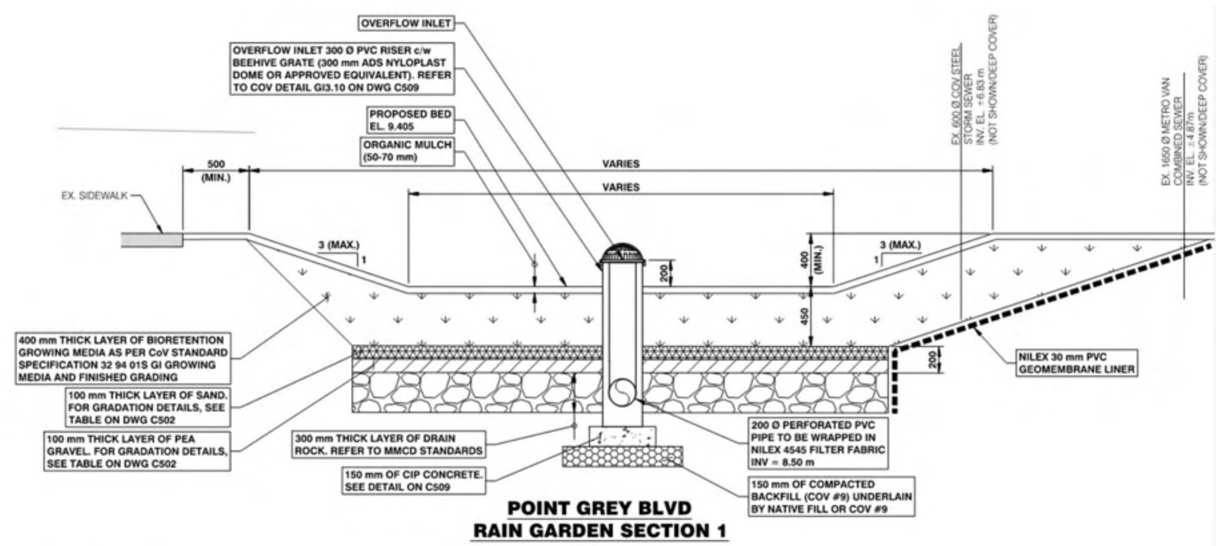


Figure 1-F: Example of Engineering Cross Section Detail (Tatlow Park – KWL Associates Ltd.) Rain Garden with Reservoir and Subdrain

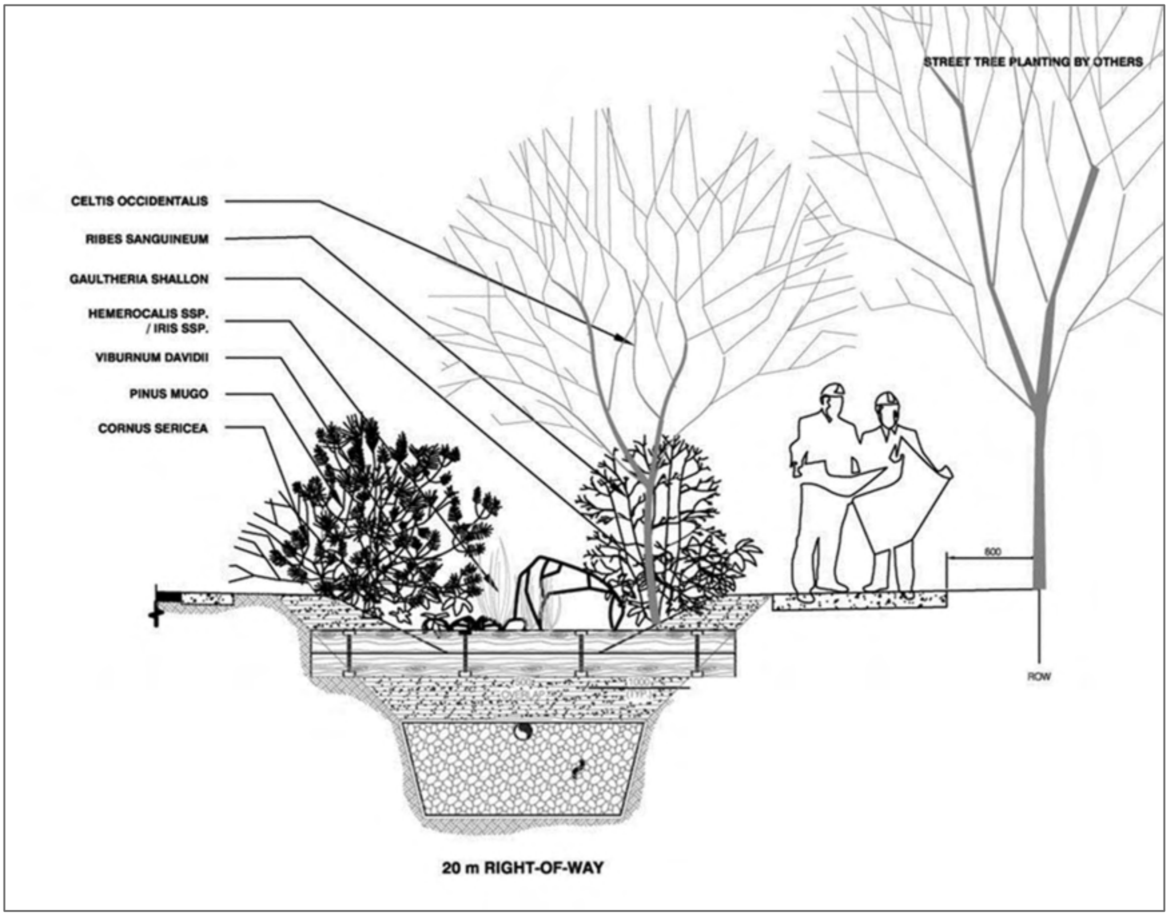


Figure 1-G: Example of Landscape Cross Section Detail (Silver Ridge – Lanarc Consultants Ltd.)

1.16.5 Profile Details

Profile details (one or more views) for Stormwater Source Controls should show the features listed in the Profile Checklist, as appropriate to the design.

Profile Checklist

- ❑ Surface grades.
- ❑ Extent of proposed growing medium installation.
- ❑ Extent of proposed drain rock reservoir or drainage layer installation (top, and level bottom).
- ❑ Undisturbed native or check dam details between discrete reservoir or infiltration trench cells.
- ❑ Piping locations in relation to soil and reservoir, pipe gradients.
- ❑ Side view of proposed weirs.

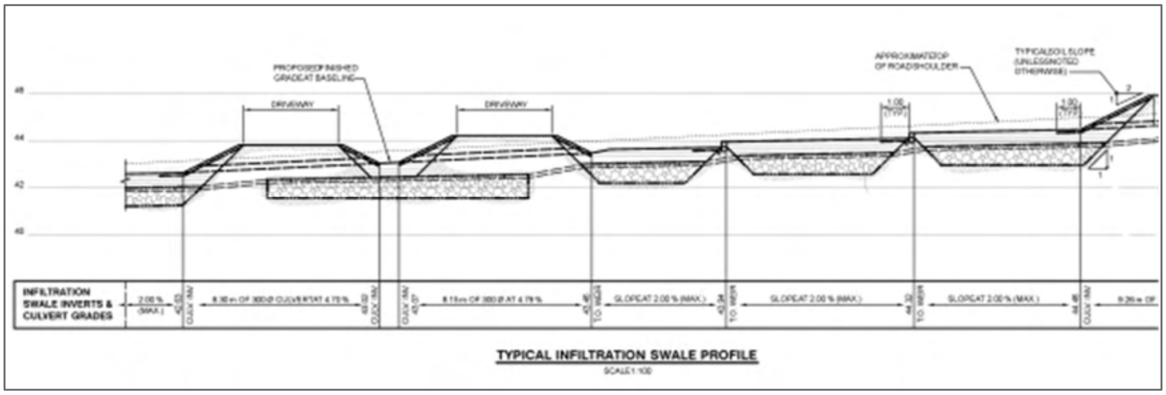


Figure 1-H: Example of Engineering Profile (Silver Ridge – KWL Associates Limited)
Roadside Infiltration Swale with Reservoir and Subdrain

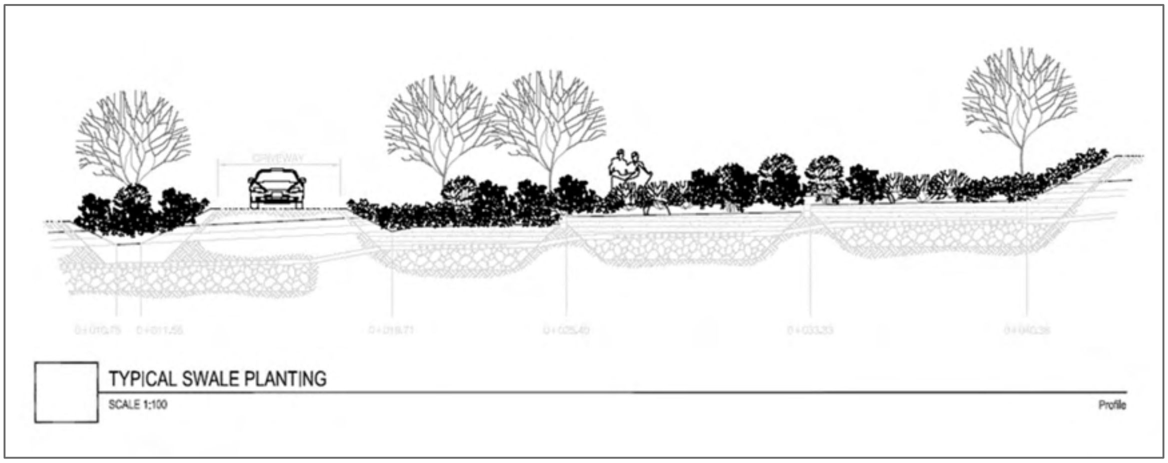


Figure 1-I: Example of Landscape Profile (Silver Ridge – Lanarc Consultants Ltd.)

ABSORBENT LANDSCAPE

2 Absorbent Landscape

Most landscape – either natural or manmade – acts like a sponge to soak up, store and slowly release rainfall. In most Metro Vancouver natural wooded conditions without paving and roof development, 90% of rainfall volume that lands on natural watersheds never becomes runoff but is either soaked into the soils or evaporates (Stephens et al., 2002). The trees, shrubs, grasses, surface organic matter, and soils all play a role in this absorbent landscape.

2.1 Stormwater Variables of Absorbent Landscape

Figure 2– shows a schematic representation of the 12 stormwater variables of absorbent landscape discussed below. Keeping these variables in balance is the key to successful stormwater source control using absorbent landscape.

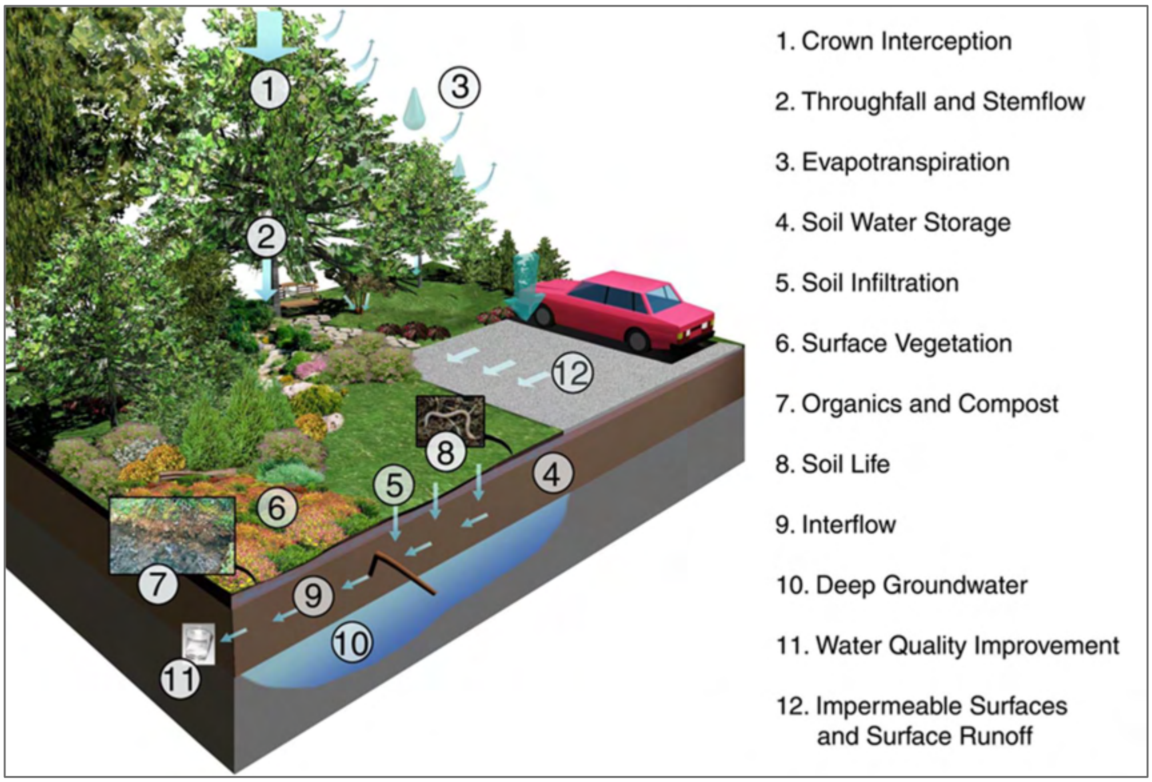


Figure 2–1: Schematic Representation of 12 Stormwater Variables of Absorbent Landscape.

2.2 Selection, Application and Limitations

- Absorbent landscape mimics the hydrologic function of undeveloped land on a development site. Its primary purpose is to absorb and infiltrate direct rainfall and has only limited capacity to accept and infiltrate runoff from impervious areas. Site plans that drain large areas of impervious area into small areas of landscape risk overwhelming the absorbent capabilities of soil.

- Absorbent landscaping can accept runoff from disconnected roof leaders, sidewalks, and limited parking areas such as driveways. It may function best to achieve stormwater capture targets when combined with an overflow to an infiltration rock trench.

Disconnected roof leader and absorbent landscape in Maple Ridge.
(Photo credit: Kerr Wood Leidal Associated Ltd.)

- Absorbent landscape essentially consists of an absorbent layer of soil with vegetation. It differs from a rain garden in having:
  - no rock reservoir or subdrain;
  - max 2:1 ratio of impervious area to absorbent landscape; and
  - no or almost no ponding.
- Where an impervious area is several times the area of absorbent landscape, a rain garden should be considered instead.
- Absorbent landscape needs to be implemented properly to avoid conditions that would cause reduced infiltration at the surface due to sedimentation, excessive compaction, or lack of vegetative cover. Quality control is necessary regarding installed soil properties, erosion and sediment control, and establishment of vegetation.
- To meet typical performance targets (e.g., infiltrating the first 25 – 60mm of rainfall), the amount of absorbent landscape area on a site or in a drainage basin must be balanced with the amount of impervious area. This will impact many aspects of urban design – e.g., by promoting building forms that minimize impervious building footprints, by placing landscape over parking or rooftops, or by designing narrower roads and larger landscape islands in parking areas.

2.3 Design Guidelines

Drainage from parking area to landscape.
(Photo credit: Lanarc Consultants Ltd.)

1. Maximize the area of absorbent landscape – either existing or constructed – on the site.
2. Conserve as much natural forest land, existing trees, and undisturbed soil as is compatible with the project. Provide temporary fencing of these protected areas during construction.
3. Minimize impervious area through such techniques as multi-storey buildings, narrower roads, minimum parking, larger landscape areas, green roof, and pervious paving.
4. Disconnect impervious areas from the storm sewer system, having them drain to absorbent landscape with only an overflow to the storm drainage system.
5. Generally, absorbent landscape is designed to infiltrate the rain that falls on it and may infiltrate runoff from limited upstream impervious area; no more than 2:1 ratio of impervious area to absorbent landscape. Maintaining this ratio ensures effective treatment can be achieved in the absorbent landscape.
6. Design absorbent landscape areas as gently sloping (2%) or slightly dished (concave) areas that temporarily store stormwater and allow it to soak in (maximum ponding time of 2 days), with overflow only occurring in large rain events.
7. Inflows from impervious area to absorbent landscape should be distributed sheet flow from pavement over a flat-panel curb, or through frequent curb cuts. A drop of 50 mm from the pavement or flat curb edge to the top of the Absorbent Landscape surface is required to accommodate sediment accumulation.
8. Where inflow is from curb cuts or point discharge (as in a disconnected roof leader), a transition area at the inflow point(s) should incorporate erosion control and flow dispersion to distribute flow to the full Absorbent Landscape area. Clean crushed rock or rounded river rock may be used.
9. All designs should calculate the projected flows and water balance and should provide for an overflow – surface or piped – to the major storm flood control system.

10. When planting, maximize the vegetation canopy cover over the site. Cover by multi-layered evergreen trees and shrubs is ideal, but deciduous tree cover also is beneficial for stormwater management.
11. Use native planting species where feasible. Non-native plantings with similar attributes to native may be suitable in conditions where natives would grow too large or not meet other urban design objectives.
12. Ensure adequate growing medium depth for both horticultural and stormwater needs – generally a minimum of 150mm depth for lawn areas, and 450mm depth for shrub/tree areas. In wetter areas of the Metro Vancouver region, near the mountains with till subsoils, a minimum growing medium depth of 300mm for lawn areas is required to store 60mm of rainfall.
13. Test growing medium for physical and chemical properties and amend it to provide approximately 8% organic matter for lawns, and 15% organic matter for planting beds, in the upper 200mm of growing medium. Growing medium for absorbent landscape should have a tested infiltration rate of 50 mm/hr, minimum.
14. Do not over-compact landscape subgrade or growing medium. Optimum compaction is firm against deep footprints (about 80% Proctor Density). Excessive compaction reduces infiltration rates. Rip or till subsoils that are excessively compacted. Aerate compacted surface soils.
15. Scarify subgrade surfaces prior to placing growing medium and rototill through layers of growing medium to create a transition in soil texture rather than discrete soil layers. Do not install soils in layers of different textures, as this can create barriers to infiltration.

Straw laid on surface to prevent erosion and crusting from raindrop impact.
(Photo Credit: Lanarc Consultants Ltd.)

16. Provide vegetative cover (grass, groundcovers, shrubs, trees) or organic cover (mulch, straw, wood fibre) to absorbent landscape as early as possible in the construction process, and prior to winter storms, to avoid surface crusting from raindrop impact and to maintain surface permeability.
17. Provide effective erosion control during construction, including erosion control on upstream sites that may flow into the absorbent landscape. Delay installation of constructed absorbent landscape until sources of potential erosion in the upstream drainage area have been permanently stabilized.

2.4 Pre-treatment Principles

1. Pre-treatment for absorbent landscapes is primarily used for erosion mitigation and sediment capture.

2. Avoid directed point source runoff onto absorbent landscapes by routing runoff through sediment control systems or by dispersing runoff onto absorbent landscapes using level spreaders or sediment traps with multiple weir notches.
3. When roof leaders are directed to absorbent landscape, provide adequate grade away from the foundation to ensure water can effectively disperse across the absorbent landscape without concentrating the flow to a single location
4. Drain rock, clear stone, or river rock can be used as pre-treatment and erosion prevention, however the maintenance needs may be greater than those for a concrete sediment pad.
5. The design of pre-treatment systems should be based on estimates of annual sediment loading. Sediment
6. Pre-treatment areas should always be 5-10cm below the height of the inlet to ensure that accumulated sediment does not prevent runoff from entering the system.

2.5 Maintenance

Maintenance for absorbent landscape focuses on maintaining the plantings, so the main considerations are access and understanding of the plant maintenance required. For grassed areas or other areas that require equipment for maintenance, access for the equipment must be planned for. Maintenance over the long term may also include re-grading of small areas, which may also require equipment access. An operation and maintenance plan should be developed as part of design to document the maintenance required and how it should be performed.

- Weeding and replacing dead plants should be conducted once in the spring and once in the fall.
- The overflow needs to be inspected monthly and maintained as needed to be kept free of debris.
- Maintenance of absorbent landscape pre-treatment requires that the dispersion of flow is maintained. For example, at the location of a disconnected downspout, ensuring that the runoff has not found a preferred flow route, short circuited towards the foundation, or eroded the landscape/grassed area it is discharging to.
- Pre-treatment areas should be regularly cleared of debris and sediment to reduce the likelihood of sediment bypass and uncontrolled discharge.
- See Chapter 11 – Maintenance Guideline for further details regarding maintenance tasks and frequency.

2.6 Sizing Absorbent Landscape

Sizing may be done using continuous simulation modeling in the WBM or SWMM or using spreadsheet design storm and water balance calculations. Where Absorbent Landscape forms part of a series of source controls, modeling of the multiple source controls should be used. Sizing for Absorbent Landscape alone is fairly straightforward and simplified sizing approaches have been developed that do not require water balance modeling or continuous simulation. Two sizing approaches are presented below for the two types of criteria used in BC.

- In general, Absorbent Landscape area is sized to infiltrate the rain that falls directly on it and may be designed to infiltrate runoff from a limited area of upstream impervious surface. The maximum ratio of impervious area to pervious area (I/P ratio) allowed will be 2:1. Pervious area refers to the Absorbent Landscape and the I/P ratio will be zero (0) where no impervious area is treated by the Absorbent Landscape.
- Sizing presented here is for infiltration of rain water for "capture" and prevention of site runoff. Sizing and design according to this guidance will generally provide water quality treatment for the volume of water infiltrated. If "water quality" criteria volumes are larger than "capture" volumes, additional sizing may be required, and a professional engineer should be consulted.
- Sizing process here assumes that the area of Absorbent Landscape is constrained by the site plan and sizing determines the depth of soil required.

2.6.1 Sizing for Depth Capture Criteria: X mm in 24 hrs.

1. Find I/P ratio for the Absorbent Landscape:

$$\text{I/P ratio} = \frac{\text{Impervious Tributary Area}}{\text{Absorbent Landscape Area}}$$

2. Determine the soil depth required:

$$D_S = \frac{R \times (I/P + 1) - Ks \times 24}{0.2}$$

Where:
D_S = Depth (thickness) of amended soil (mm)
R = Rainfall capture depth (mm)
Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
I/P = Ratio of impervious tributary area to rain garden base area (unitless)

3. Check whether the calculated soil depth is within the standard depth range of 150 to 450 mm. If calculated depth exceeds 450mm:

The soil depth may be acceptable upon consultation (i.e., 500mm soil may be acceptable if landscape designers concur);

The I/P ratio may be reduced by routing runoff from a portion of the contributing impervious area to another facility and the soil depth recalculated; or

Overflow from the absorbent landscape could be directed to an infiltration rock trench or other facility and the combined facilities should be evaluated using water balance modeling, such as the WBM, SWMM or other modeling software.

To find the absorbent landscaping area:

$$Area = \frac{\text{Impervious } TributaryArea}{I / P}$$

2.7 Alternate Absorbent Landscape Design Example For Capture of % Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

2.7.1 Sizing for % Capture of Average Annual Rainfall

1. Determine the average annual rainfall for the site. If unknown, refer to map in Appendix B of isohyetal lines showing average annual rainfall depths across the Metro Vancouver Region.
2. Consult the Absorbent Landscape Chart (Figures B-1 through B-3) in Appendix B applicable for the site's location according to average annual rainfall: 1100mm (White Rock), 1600mm (Kwantlen, Surrey, and Vancouver), or 2100mm (North shore and Coquitlam); If between these values, choose the chart for the higher amount of rainfall or interpolate the result between the two bracketing charts.
3. Find the curves on the chart matching the site's I/P ratio and select the curve that is at or above (better capture) the target capture percentage (y-axis) at the site's subsurface infiltration/saturated hydraulic conductivity rate (x-axis).
4. The soil depth required is indicated by the type of line, e.g., dashed, dotted or solid. Soil depth can be interpolated between two curves at the same I/P ratio, if desired.
5. If the target capture percentage is not achieved given the combination I/P ratio and subsurface infiltration rate, then options to improve the capture include:
   - The I/P ratio may be reduced by routing runoff from a portion of the contributing impervious area to another facility and the soil depth recalculated; or
   - Overflow from the absorbent landscape could be directed to an infiltration rock trench or other facility and the combined facilities should be evaluated using water balance modeling, such as the WBM, SWMM or other software.

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

2.8 Guideline Specifications

Materials and methods shall meet Master Municipal Construction Document 2009 requirements.

For Growing Medium Soil, see Chapter 9: Growing Medium Standards:

- ❑ The minimum infiltration rate of the growing medium should be 70 mm/hr; and
- ❑ Absorbent Topsoil Design Example For Capture of % Annual Rainfall Target.

2.9 Absorbent Landscape Alternate Sizing Approach Design Example

2.9.1 Scenario Description

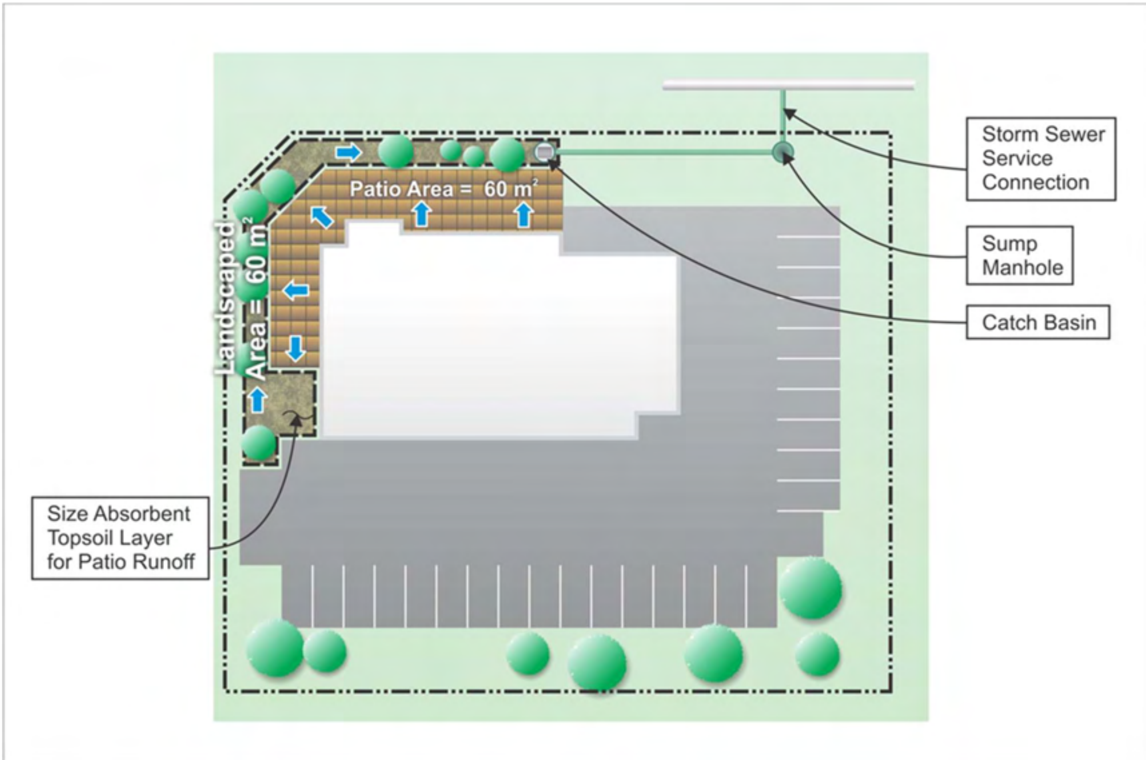


Figure 2–2: Example – Plan view of site with patio and landscape areas highlighted.

A landscaped area with Absorbent Topsoil is proposed to capture a portion of the runoff from a patio area. The following parameters are known:

- Total patio area = 60 m^2;
- Total landscaped area = 60 m^2;

- Annual rainfall = 1600 mm;
- Native soil infiltration rate = 1.5 mm/hr; and
- Capture target is 90% of annual rainfall.

1. Determine whether the landscaped area is large enough and the topsoil depth required.

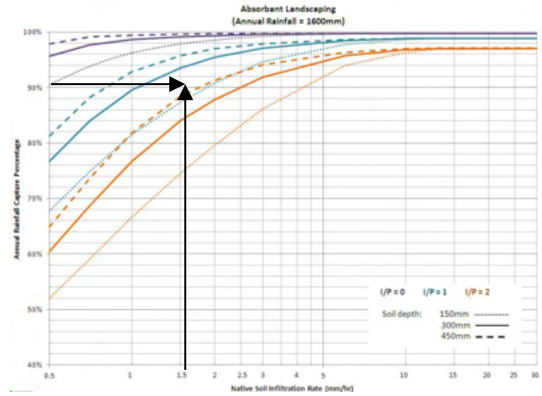


Figure 2-3: Sizing chart for 1600 mm annual rainfall.

2.9.2 Example Sizing

Determine the site I/P ratio:

$$I/P = \frac{60 sq.m}{60 sq.m} = 1.0$$

The annual rainfall at the site is 1600 mm. Using the sizing chart (Figure B-2) the 90% annual rainfall capture and 1.5 mm/hr infiltration point falls half way between the 150 mm and 300 mm curves for I/P=1.0. Therefore, the landscaped area is large enough and the topsoil depth required is 225 mm (average of the two depths).

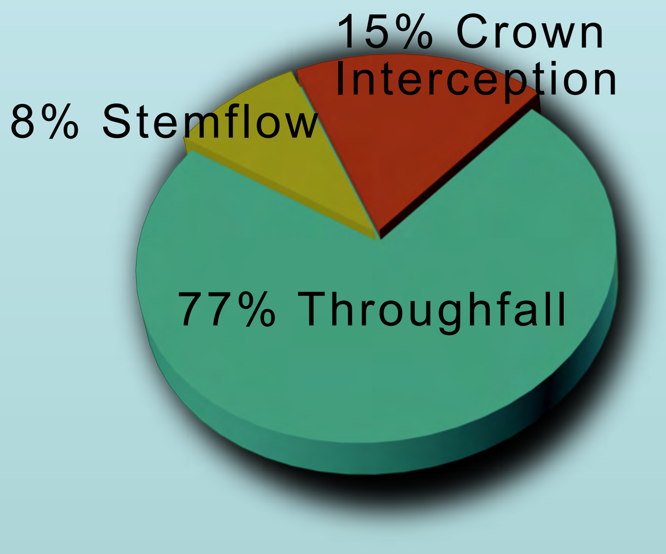
2.10 Hydraulic Components

Inlet: The impervious patio runoff sheet flows onto the landscaped area.

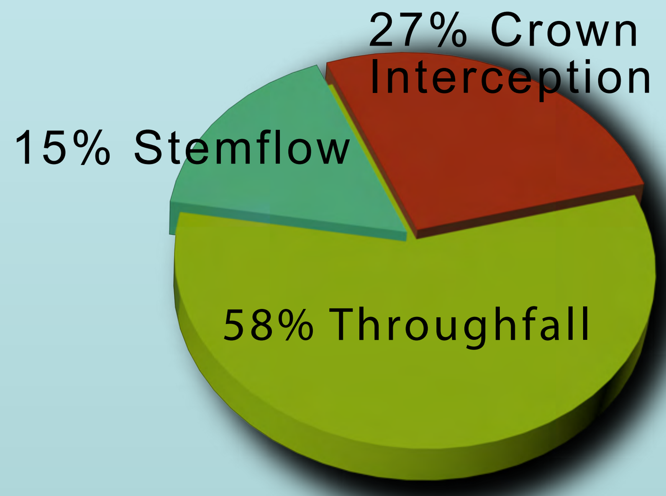
Overflow: The landscaped area grading must allow overland flow to a catch basin for minor flows and overland flow to the municipal major system (typically roadway surface) for any water that overwhelms the catch basin capacity.

DESIGN PRINCIPLES

- Maximize the area of absorbent landscape – either existing or constructed – on the site. Conserve as much existing vegetation and undisturbed soil as possible.
- Minimize impervious area by using multi-storey buildings, narrower roads, minimum parking, larger landscape areas, green roof, and pervious paving.
- Disconnect impervious areas from the storm sewer system, having them drain to absorbent landscape.
- Design absorbent landscape areas as dished areas that temporarily store stormwater and allow it to soak in, with overflow for large rain events to the storm drain system.
- Maximize the vegetation canopy cover over the site. Multi-layered evergreens are ideal, but deciduous cover is also beneficial for stormwater management.
- Ensure adequate growing medium depth for both horticultural and stormwater needs – a minimum 150mm for lawn areas, and 450mm depth for shrub/tree areas. In wetter climates with till subsoils, a minimum depth of 300mm for lawn is required to store 60mm of rainfall.
- Cultivate compost into surface soils to create minimum 8% organic matter for lawns, and 15% for planting beds.
- To avoid surface crusting and maintain surface permeability, install vegetative (grass, groundcovers, shrubs, trees) or organic cover (mulch, straw, wood fibre) as early as possible in the construction process, and prior to winter storms.
- Provide effective erosion control during construction, including erosion control on upstream sites that may flow into the absorbent landscape.



Pear Tree



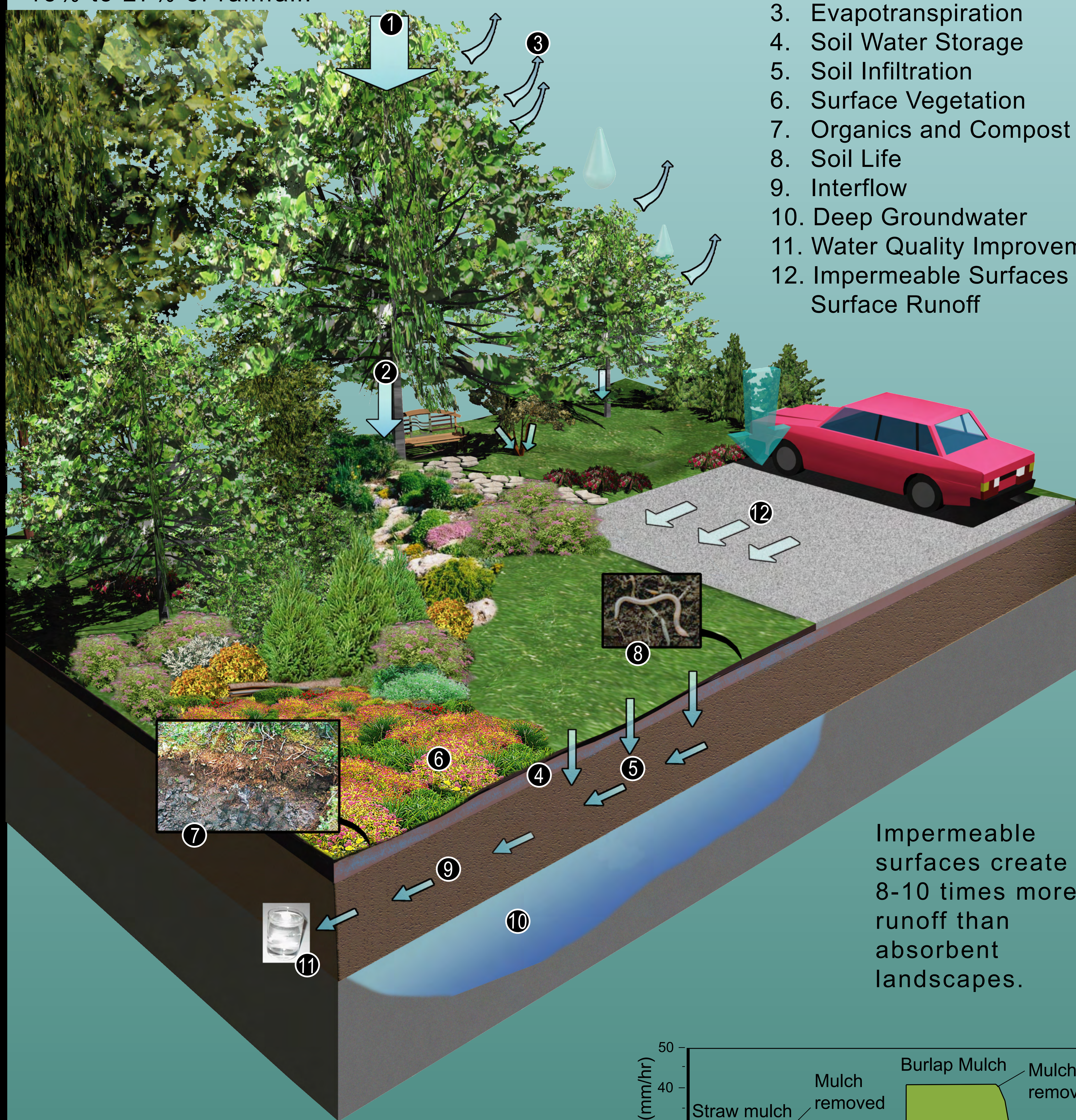
Evergreen Oak Tree

In most natural wooded conditions in the GVRD, 90% of rainfall volume never becomes runoff, but is either soaked into the soils or evaporates / transpirates. Trees, shrubs, grasses, surface organic matter, and soils all play a role.

Variables of **Absorbent Landscape**

1. Crown Interception
2. Throughfall and Stemflow
3. Evapotranspiration
4. Soil Water Storage
5. Soil Infiltration
6. Surface Vegetation
7. Organics and Compost
8. Soil Life
9. Interflow
10. Deep Groundwater
11. Water Quality Improvement
12. Impermeable Surfaces and Surface Runoff

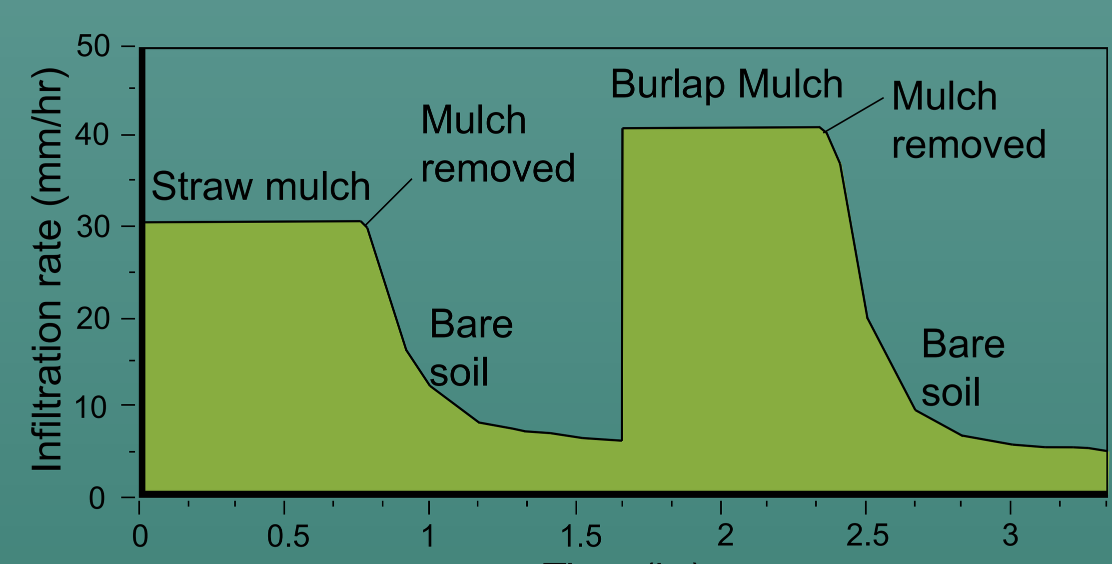
Winter tree canopies intercept 15% to 27% of rainfall.



Impermeable surfaces create 8-10 times more runoff than absorbent landscapes.

Organic matter and soil micro-organisms are vital to maintaining soil infiltration rates.

Rainfall storage in soil is 7% to 18% of soil volume.



Influence of surface cover on infiltration rate of sandy loam

Absorbent Landscapes

metrovancouver

LANARC CONSULTANTS LTD

kwl

Goya Ngan Landscape Architect

Detailed design guidelines can be found in the Design Guidelines 2012 report, available at www.metrovancouver.org

Stormwater Source Control Design Guidelines 2023

INFILTRATION SWALE SYSTEM

3 Infiltration Swale System

The Infiltration Swale System combines aspects of grass swales and infiltration trenches.

The surface component of an infiltration swale is a shallow grassed channel, accepting flows from small areas of adjacent paved surfaces such as roads and parking. The swale is designed to hold the water quality storm behind a weir, and then allow it to infiltrate slowly through a soil bed to an underlying drain rock reservoir system.

The surface soils and drain rock reservoir are sized to store the design storm event, and to allow it to infiltrate slowly into underlying soils. A perforated drain placed near the top of the drain rock reservoir provides an underground overflow, which also maintains drainage of adjacent road base courses. The surface swale and weir structures provide conveyance for larger storm events to a surface outlet.

Other common terms used are Dry Swale with Underdrain (Stephens et al., 2002), Swale/Trench Element (MUNLV-NRW, 2001) or Bioswale.

Planted and rock-lined Infiltration Swale, Rocky Point parking lot, Port Moody, BC.
(Photo Credit: Kerr Wood Leidal Associates Ltd.)

3.1 Selection, Application and Limitations

- An Infiltration Swale is designed to provide conveyance as well as infiltrate the design volumetric capture target and treat the design water quality volume (Stephens et al., 2002).
- A Rain Garden and Infiltration Swale have similar design and functions. An infiltration swale provides conveyance of non-captured flows but provides less capture of peak flows than a Rain Garden (due to ponding).
- A grassed swale is generally less expensive to install than a landscaped rain garden (per unit area) but may require a larger area to meet the same capture targets.
- When lower capture targets are used such that a higher degree of surface conveyance is required, a grassed infiltration swale is advisable due to its lower susceptibility to erosion, compared to a mulched and planted swale or rain garden.
- Suitable for most development situations – residential areas, municipal office complexes, rooftop runoff, parking and roadway runoff, parks and greenspace, golf courses (Stephens et al., 2002).
- With proper weir spacing, practical for profiles up to 10% slope.
- Maximum contributing area 2 ha (Stephens et al., 2002).

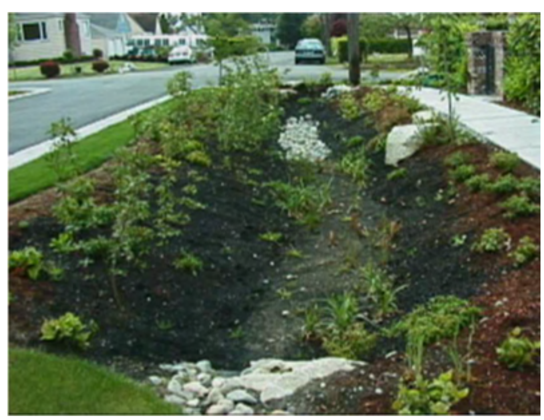
- Standard minimum separation from base of drain rock reservoir to water table 610 mm (Stephens et al., 2002).
- Identify pollutant sources, particularly in industrial/commercial hotspots, that require pre-treatment or source control upstream of this BMP. (Maryland Dept. of the Environment, 2009).
- Design should provide for drain rock reservoir to drain in 96 hours to allow aerobic conditions for water quality treatment.

Flush curb draining to terraced grassed swale at Horseshoe Bay Ferry Terminal, West Vancouver, BC

(Photo Credit: Kerr Wood Leidal Associates Ltd.)

3.2 Design Guidelines

1. An infiltration swale should be designed with a trapezoidal cross-section. Swale bottom width: 600mm minimum, 2400mm maximum (recommended), flat in cross section.
2. The infiltration swale should be sized based on infiltration area, or base area of the swale, as the effective area for infiltration occurring in the swale.
3. Flow to the swale should ideally be distributed sheet flow. Provide non-erodible material for erosion and scour protection, sediment cleanout basins, and weir flow spreaders at point-source inlets (Maryland Dept. of the Environment, 2009).
4. Provide erosion control, vegetated or otherwise, along all sides of weirs and at drainage inlets.
5. Pavement edge at the swale may be wheel stop, flush curb, or reverse curb (Figure 3-). Provide a 50 mm drop at the edge of paving to the swale soil surface, to allow for positive drainage and buildup of road sanding/organic materials at this edge.
6. Integrated mowing strip is desirable in lawn areas.
7. Swale planting is typically sodded lawn. Low volume swales can be finished with a combination of



Flush curb (left) to grass filter to vegetated (shrubs, groundcover) swale.
(Photo Credit: Lanarc Consultants)

grasses, shrub, groundcover, and tree planting to provide a 100% vegetated cover within 2 years of planting.

8. Footprint of Infiltration Swale = 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 Swale depth (m)] to each dimension of the base area to determine total footprint area. Refer to details,Figures 3-B – 3-E.
9. Swale surface side slopes – 3(horizontal):1(vertical) maximum, 4:1 preferred for maintenance.
10. Design stormwater conveyance using Manning's formula, with attention to erosion of soils and vegetation and channel stability during maximum flows.
11. Longitudinal slope of the swale should be between 1-2%.
12. For slopes of 2-10%, the swale length may be broken up by terraces (steps) or weirs of up to 300mm 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 (see Figure 3-A).
13. Where weirs are used to reduce the longitudinal slope, swale longitudinal slope should be 1-2%, or dished, between weirs.
14. Weirs to have level top to spread flows and avoid channelization, keyed in 100mm minimum.

Swale with check dams in operation.
(Photo Credit: Water Concept Kronsberg)

Swale with check dams under construction.
(Photo Credit: Water Concept Kronsberg)

15. Maximum ponded level at weirs: 150 mm (Maryland Dept. of the Environment, 2009).
16. Drawdown time for the maximum surface ponded volume – 48 hours maximum (24 hours maximum – Maryland Dept. of the Environment, 2009).
17. Minimum freeboard to adjacent paving: 100mm or in accordance with swale conveyance design.
18. Treatment soil depth: 450mm is desirable, minimum 150mm if design professional calculates adequate pollutant removal (Maryland Dept. of the

Environment, 2009), or 100 mm min. growing medium over 100mm min washed sand (MUNLV-NRW, 2001). A standard value of 300 mm soil depth is common.

19. Drain rock reservoir bottom shall be level.

20. Underground weirs (Figure 3-A) of undisturbed native material or constructed trench dams shall be provided to create underground pooling in the reservoir sufficient for infiltration performance.

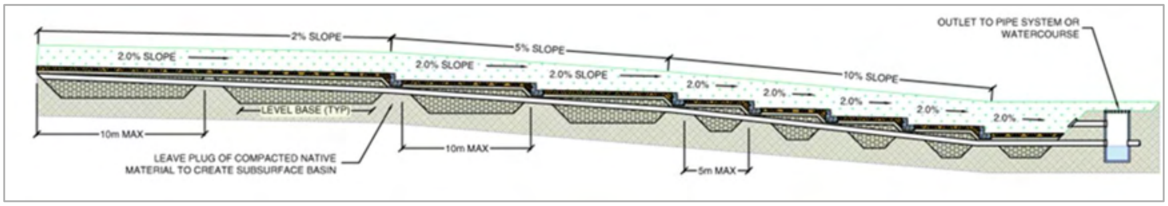


Figure 3-A: Infiltration Swale Longitudinal Section

21. A non-erodible outlet or spillway must be established to discharge overflow (Maryland Dept. of the Environment, 2009).

22. Avoid utility or other crossings of the swale. Where utility trenches must be constructed crossing below the swale, install trench dams to avoid infiltration water following the utility trench.

Curb cuts draining to naturalized, planted Infiltration Swale, Walmart parking lot, Squamish, BC.
(Photo Credit: Kerr Wood Leidal Associates Ltd.)

3.3 Design Options

Drain rock reservoir and underdrain may be deleted where infiltration tests by the design professional taken at the level of the base of the proposed construction show an infiltration rate that exceeds the maximum inflow rate for the design storm (approximately rainfall intensity x (I/P ratio + 1); I/P ratio is defined below as part of Sizing).

Figures 3-B through 3-E, and the Infiltration Swale System Summary Poster illustrate the options.

3.4 Pre-treatment Principles

Infiltration swales provide stormwater treatment through filtration and infiltration. Pre-treatment is required to ensure sediment build-up does not occur at the inlets of the systems.

Where possible, infiltration swales should aim to have dispersed inflow as the design target. The dispersal of the flow reduces the load of sediment and pollutants at any one point and distributes it across the facility, reducing the localized impact. Depending on the setting and site restrictions, inflow may require a point source. Pre-treatment guidance is provided for both settings.

The level of pre-treatment required for a system will depend on the source of the runoff. Catchments with high sediment loading (i.e., highways, arterial and collector roads) or winter de-icing and/or gritting locations will require more significant pre-treatment to maintain system longevity.

Pre-treatment principles for dispersed runoff source include:

1. Prevent scour by providing energy dissipation of stormwater input;
2. Disperse stormwater runoff into the system by incorporating flat panel curbs along the width of the system;
3. Reduce the likelihood of debris entering the system by using weirs and multiple slot inlets. Consider that trash and debris may be more widely distributed in a system receiving dispersed runoff; and
4. Pre-treatment areas should always be 5-10cm below the height of the inlet to ensure that accumulated sediment does not prevent runoff from entering the system.

Pre-treatment principles for point source inflow are as follows:

1. When point source input into the system, provide a dedicated location for sediment to settle prior to entering the infiltration swale system;
2. Refer to the recommended I/P ratios for the system to ensure impervious to pervious ratio is not exceeded, which can lead to excessive scour and sedimentation;
3. System retrofits can be completed for infiltration swale systems through installation of pre-treatment "pads" constructed with cobblestone, flagstone, or concrete; and
4. Ensure that accumulated debris is unlikely to clog essential flow paths and cause concentrated overflow into the swale.

3.4.1 Pre-treatment Maintenance

Maintenance requirements for pre-treatment zones include removal of sediment and debris. Maintaining the pre-treatment zones at a higher frequency will allow the infiltration swale system to have greater longevity and require less overall system maintenance.

Depending on the runoff source, more frequent maintenance and sediment removal may be warranted. Design guidance to include an estimated sediment removal frequency for the pre-treatment zones.

3.5 Maintenance

Maintenance for an infiltration or treatment swale includes plant care and maintenance as well as checking and clearing of pre-treatment devices and outlets. Design should include consideration of access for these activities, including for equipment, if needed, for mowing and sediment removal.

Key considerations include:

- Locate the pre-treatment device where it is easily accessible;
- Use a device design that is consistent with other devices the municipal staff maintain so that it is familiar to staff and utilizes the same equipment;
- An operation and maintenance plan should be developed as part of design to document the maintenance required and the locations for checking function and maintenance;
- If conveyance is a key consideration in infiltration swale design, operation and maintenance plans should consider the work required to maintain conveyance capacity; and
- See Chapter 11 – Maintenance Guideline for further details regarding maintenance tasks and frequency.

3.6 Infiltration Swale Sizing

Infiltration Swales may be sized in a variety of ways depending on the site needs and the design criteria. Sizing may be done using continuous simulation modeling in the WBM or SWMM or using spreadsheet design storm and water balance calculations. Simplified sizing approaches have been developed that do not require water balance modeling or continuous simulation. Two sizing approaches are presented below for the two types of criteria used in BC.

In general, the Infiltration Swale area is sized based on the upstream impervious area that it serves. This relationship can be defined by the ratio of impervious area to pervious area (e.g., I/P ratio). For the simplified sizing approaches here, this represents the ratio of upstream impervious area (also called catchment area) to Base Area of the swale. I/P ratio to achieve the target capture criteria will be calculated by the two sizing methods below.

The maximum allowable I/P ratio for given surface types is shown in the adjacent Table 3-1. This maximum is based on ability of the vegetation to handle flows and pollutants and is not related to capture. Regardless of sizing calculation below, maximum I/P ratio for a given surface type should not be exceeded. The table shows maximum allowed I/P ratios, not recommended I/P ratios. I/P ratios must be calculated in order to achieve rainfall capture targets.

The simplified sizing process provides the Base Area of the swale which is the flat area at the bottom with uniform layers of topsoil and drain rock. Sizing by these methods does not account for any infiltration benefit provided by the sloped sides of the Infiltration Swale.

The Base Area of the Infiltration Swale will always be smaller than the total footprint of the facility, so the footprint must be calculated (see Design Guideline Item 8, above) in order to understand the actual site area required.

Sizing presented here is for infiltration of rain water for "capture" and prevention of site runoff. Sizing and design according to this guidance will generally provide water quality treatment for the volume of water infiltrated. If "water quality" criteria volumes are larger than "capture" volumes, additional sizing may be required, and a professional engineer should be consulted.

Sizing the swale for conveyance is not covered here but should be done by standard methods. The simplified methods here may define the width of swale needed, but the depth and overall footprint should be based on the flow conveyance required.

3.6.1 Sizing Approach 1 – for Depth Capture Criteria: X mm in 24 hrs

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

   $$D_R = \frac{Ks \times T \times 24}{n}$$

   Where:
   D_R = Depth (thickness) of rock reservoir (mm)
   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
   T = allowable drain time (days)
   n = porosity of drain rock in reservoir (unitless, e.g. 0.35)

2. Use the following equation to determine the base (bottom) area of the swale and rock reservoir required by finding the I/P ratio for the site:

   $$I / P = \frac{24 \times Ks + D_R \times n + 0.2 \times D_S}{R} - 1$$

   Where:
   I/P = Ratio of impervious tributary area to swale base area (unitless)
   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
   D_R = Depth (thickness) of rock reservoir (mm)
   n = porosity of drain rock in reservoir (unitless, e.g. 0.35)
   D_S = Soil layer depth (thickness); standard value = 300 (mm)
   R = Rainfall capture depth (mm)

3. Check that the I/P ratio calculated is less than the maximum allowed (Table 3–). If it is not, use the maximum allowed I/P ratio. This may mean that the Infiltration Swale will exceed the % capture desired.

To find the swale base area:

$$BaseArea = \frac{\text{Impervious } TributaryArea}{I / P}$$

4. Calculate the footprint of the facility based on the Base Area and side slopes as described in step 8, above.
5. If the site cannot accommodate the I/P ratio required to provide the target capture, a partial-infiltration swale with flow restrictor design may be used (see Table 3-).
6. A 0.25 L/s/ha (or 0.09 mm/hr) unit discharge has been recommended by DFO for the flow restrictor at the downstream end of the swale underdrain (see Table 3-).
7. Calculate the allowable discharge through the orifice:

   $$Q = \frac{0.25 \times A_{SITE}}{1000}$$

   Where:
   Q = Allowable discharge through orifice (m^3/s)
   0.25 = Recommended unit discharge (L/s/ha)
   A_{SITE} = Total site area draining to the swale, including the swale area (ha)
8. Solving the orifice equation for area of the orifice (AO):

   $$A_O = \frac{Q}{K \times \sqrt{2gh}}$$

   Where:
   Q = Allowable discharge through orifice (m^3/s)
   K = Orifice Coefficient (typical value 0.6)
   g = gravitational constant (m/s^2)
   h = head on the orifice when trench is 0.3 m full of water (typical value 0.3 m)
   A_O = Area of the orifice opening (m^2) – generally assumed to be circular for calculation of orifice diameter
9. The size of the swale is then determined by the available area on the site up to the maximum I/P ratio for the surface type as shown in Table 3-.

   $$I / P = \frac{\text{Impervious } TributaryArea}{BaseArea}$$

10. The depth of the rock reservoir above the orifice outlet is calculated as:

   $$D_R = \frac{R \times (I / P + 1) - 0.09 mm / hr \times 24 hrs \times (I / P + 1) - 24 \times Ks - 0.2 \times D_S}{n}$$

   Where:
   D_R = Depth (thickness) of rock reservoir (mm)
   R = Rainfall capture depth (mm)
   I/P = Ratio of impervious tributary area to swale base area (unitless)
   0.09 = Recommended unit discharge through orifice (mm/hr)

Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
D_S = Soil layer depth (thickness); standard value = 300 (mm)
n = porosity of drain rock in reservoir (unitless, e.g. 0.35)

3.6.2 Sizing Approach 2 – for % Capture of Average Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

1. Determine the average annual rainfall for the site. If unknown, refer to map in Appendix A of isohyetal lines showing average annual rainfall depths across the Metro Vancouver Region.
2. Consult the Swale chart in Appendix B (Figures B-4 through B-6) applicable for the site's location according to average annual rainfall: 1100mm (White Rock), 1600mm (Kwantlen, Surrey, and Vancouver), or 2100mm (North shore and Coquitlam); If between these values, choose the chart for the higher amount of rainfall or interpolate the result between the two bracketing charts.
3. Find the point on the chart matching the site's subsurface soil infiltration rate and the target % Capture and select the curve that is at or above (better capture) that point. The selected curve gives the I/P ratio required to meet the given % capture for the facility.
4. Check that the I/P ratio calculated is less than the maximum allowed (Table 3-1). If it is not, use the maximum allowed I/P ratio. This may mean that the Infiltration Swale will exceed the % capture desired.

   To find the swale base area:

   $$BaseArea = \frac{\text{Tributary Impervious Area}}{\text{I/P}}$$

5. Calculate the footprint of the facility based on the base area and side slopes as described in step 12.
6. The shape of the points nearby on the selected curve indicate the depth (thickness) of the rock reservoir. The rock depth may be interpolated between two neighbouring values. Allowable rock depth range is 300 to 2000 mm.
7. If the site cannot accommodate the I/P ratio required to provide the target capture, or an I/P ratio of less than 5 would be needed (not shown on the chart) a partial-infiltration swale with flow restrictor design may be used (see Table 3-).
8. The size of the swale is then determined using the Swale with 0.25 L/s/ha Orifice charts. Read the I/P ratio required for the given infiltration rate and capture target.
9. Calculate the swale base area:

   $$BaseArea = \frac{\text{Impervious } TributaryArea}{I / P}$$

10. Check that the calculated swale base area is smaller than the available site area. If not, the capture target cannot be achieved given the site constraints using the sizing tools in this document. The site could be reconfigured to accommodate the calculated swale base area. Alternately, the rock reservoir footprint could be made larger than the swale bottom area and the capture calculated by a qualified stormwater professional.
11. The depth of the rock reservoir above the orifice outlet is given as 1.5 m for a swale with orifice for the purposes of this simplified design approach.
12. Calculate the allowable discharge through the orifice:

$$Q = \frac{0.25 \times A_{SITE}}{1000}$$

Where:
Q = Allowable discharge through orifice (m^3/s)
0.25 = Recommended unit discharge (L/s/ha)
A_{SITE} = Total site area draining to the swale, including the swale area (ha)

This discharge is used to size the orifice on a flow restrictor at the downstream end of the swale underdrain (see detail 3D).

13. Solving the orifice equation for area of the orifice (AO):

$$A_O = \frac{Q}{K \times \sqrt{2gh}}$$

Where:
Q = Allowable discharge through orifice (m^3/s)
K = Orifice Coefficient (typical value 0.6)
g = gravitational constant (m/s^2)
h = head on the orifice when trench is 0.3 m full of water (typical value 0.3 m)
A_O = Area of the orifice opening (m^2) – generally assumed to be circular for calculation of orifice diameter

An orifice of no less than 10 mm is recommended to minimize clogging. A 10 mm orifice is the size required for a 0.46 ha tributary area. If the calculated orifice size is less than 10 mm, a regional capture facility servicing at least a 0.46 ha tributary area should be considered.

3.7 Guideline Specifications

Materials shall meet Master Municipal Construction Document 2009 requirements.

1. Infiltration Drain Rock: clean round stone or crushed rock, 75mm max, 38mm min, 40% porosity (Maryland Dept. of the Environment, 2009) or MMCD Section 31-05-17 Part 2.6 – Drain Rock, Coarse.
2. Pipe: PVC, DR 35, 150 mm min. dia. with cleanouts, certified to CSA B182.1 as per MMCD.

3. Geosynthetics: as per Section 31-32-19, select for filter criteria or from approved local government product lists.
4. Sand: Pit Run Sand as per Section 31-05-17.
5. Growing Medium Soil: See Chapter 9, Growing Medium Standards.
6. Seeding: to Section 32-92-20 Seeding or 32-92-19 Hydraulic Seeding (note – sodding will be required for erosion control in most instances).
7. Sodding: to Section 31-92-23 Sodding. Construction practices shall meet Master Municipal Construction Document 2009 requirements.
8. Isolate the swale site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying the excavation of 300mm of material over the final subgrade of the swale until after all sediment-producing construction in the drainage area has been completed (Maryland Dept. of the Environment, 2009).
9. Prevent natural or fill soils from intermixing with the Infiltration Drain Rock. All contaminated stone aggregate must be removed and replaced (Maryland Dept. of the Environment, 2009).
10. Infiltration Drain Rock shall be installed in 300mm lifts and compacted to eliminate voids between the geotextile and surrounding soils (Maryland Dept. of the Environment, 2009).
11. Maintain grass areas to mowed height between 50mm and 150mm, but not below the design water level. Landscape Maintenance standards shall be to the Canadian Landscape Standard, 2nd Edition, Maintenance Level 4: Open Space / Play.

3.8 Infiltration Swale Design Example for Capture of X mm in 24-hour Criteria

3.8.1 Scenario Description

An Infiltration Swale is proposed to capture a portion of the runoff from a paved parking area (see illustration below).

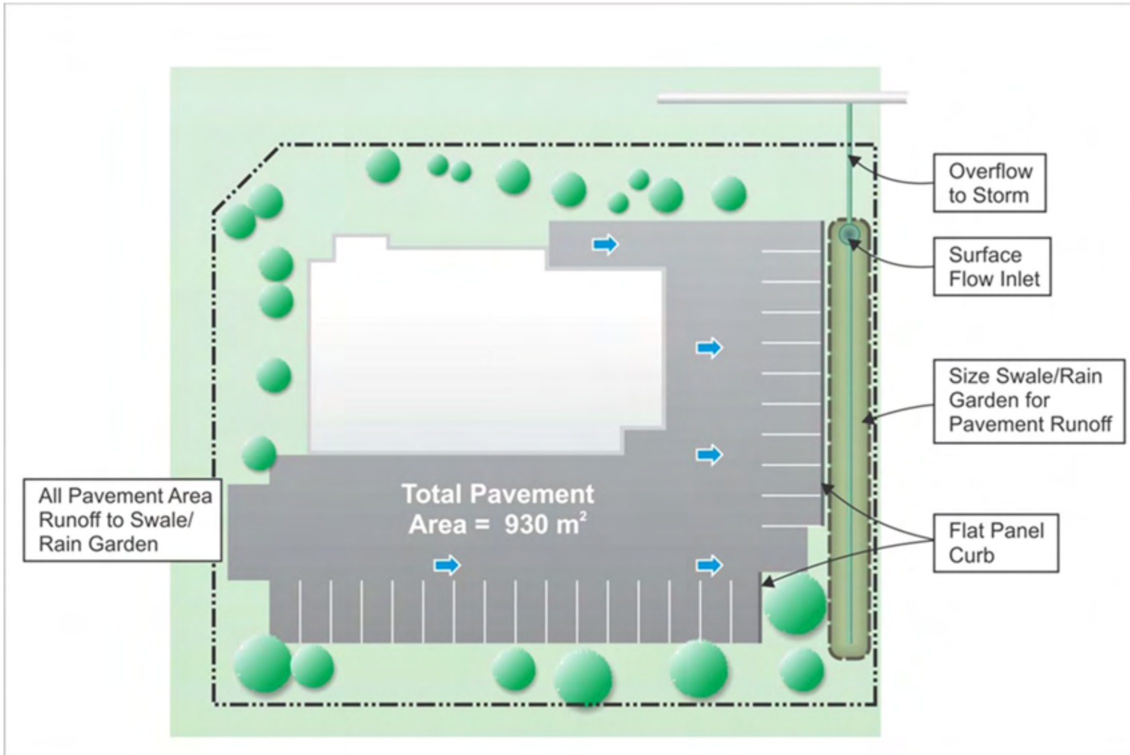


Figure 3-1: Example – Parking Area Draining to Infiltration Swale

The following parameters are known:

- Total pavement area = 930 m^2;
- Available site area for swale = 90 m^2;
- 2-year 24-hour rain depth = 92 mm;
- Native soil infiltration rate = 1.5 mm/hr;
- Parking use is more than one car per day; and
- Capture target is 50% of 2-year 24-hour rain.

1. Determine the infiltration swale footprint area and rock trench depth. Also, estimate the annual percent capture of rainfall for the calculated infiltration swale size.

3.8.2 Sizing

1. Determine the maximum rock depth based on the 4 day maximum drain time:

$$D_R = \frac{Ks \times T \times 24}{n} = \frac{1.5mm/hr \times 4days \times 24hr/day}{0.35} = 411mm$$

2. Use 400mm rock depth.
3. Determine the maximum I/P ratio (see Table 3-). Parking use of more than one car per day yields a maximum I/P ratio of 20.
4. Determine the base (bottom) area of swale and rock reservoir required by calculating the required I/P ratio:

$$I/P = \frac{24 \times Ks + D_R \times n + 0.2 \times D_S}{R} - 1$$

$$I/P = \frac{24 \times 1.5mm/hr + 400mm \times 0.35 + 0.2 \times 300mm}{50\% \times 92mm} - 1$$

$$I/P = 5.1$$

5. Check that the I/P ratio is less than the maximum (5.1 < 20, therefore OK). However, with an I/P ratio of 5.1, the swale would need to be 182 m2 in size and would not fit on the site. A partial-infiltration swale with flow restrictor is required to meet the capture target.

   The available site area for the swale is 90 m^2. The minimum I/P ratio is therefore 10.3 (930/90). Calculate the required rock trench depth with flow restrictor:

$$D_R = \frac{R \times (I/P+1) - O \times 24hrs \times (I/P+1) - 24 \times Ks - 0.2 \times D_S}{n}$$

$$D_R = \frac{50\%(92mm) \times (10.3+1) - 0.09mm/hr \times 24hrs \times (10.3+1) - 24 \times 1.5mm/hr - 0.2 \times 300mm}{0.35}$$

$$D_R = 1141\ mm$$

Table 3-1: Swale Maximum I/P Ratios by Surface Type

Surface Type	Max I/P Ratio
General/Industrial Storage/Loading Areas	20:1
Divided or Undivided Major Road (Expressway or Highway)	20:1
Collector Road	20:1
Parking >1 Car/Day/Parking Space	20:1
Local Road	30:1
Parking <1 Car/Day/Parking Space	40:1
Low Traffic Areas/No Parking	40:1
Single Family Residential/Lot and Roof	30:1

3.9 Alternate Infiltration Swale Design Example for Capture of % Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

3.9.1 Scenario Description

An Infiltration Swale is proposed to capture a portion of the runoff from a paved parking area (see Figure 3– below).

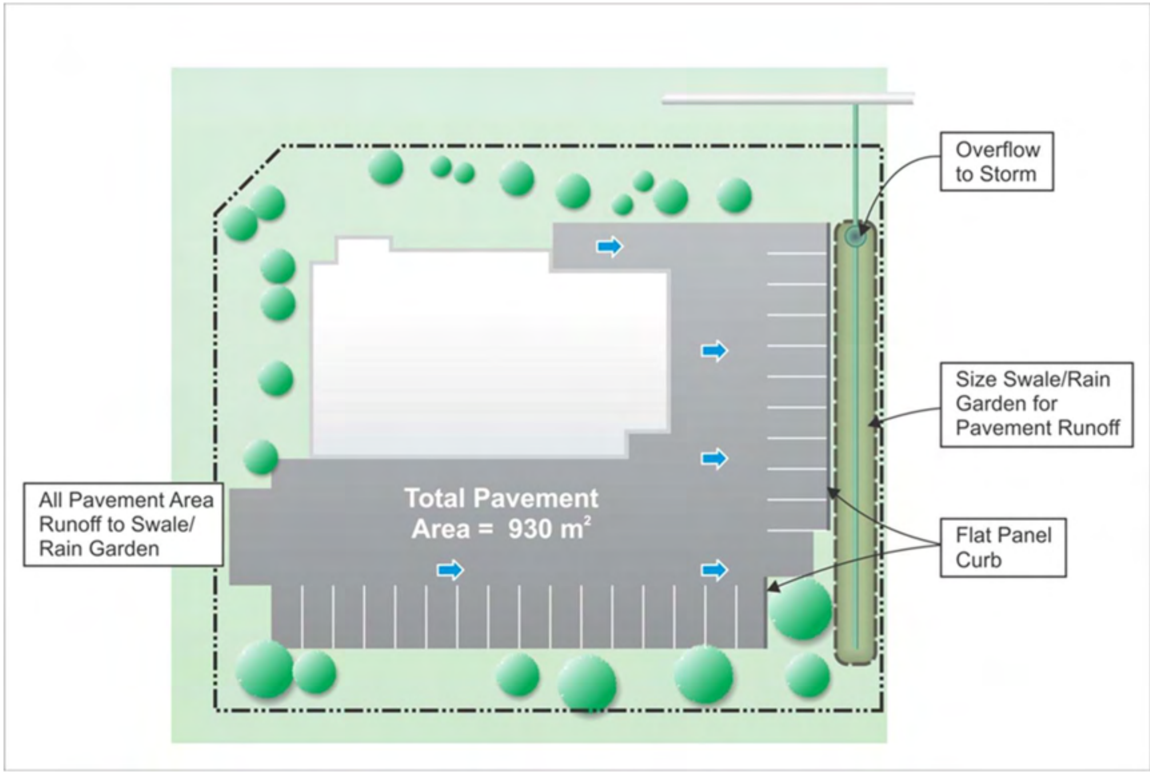


Figure 3–2: Example – Parking Area Draining to Infiltration Swale

The following parameters are known:

- Total pavement area = 930 m^2;
- Available site area for swale = 90 m^2;
- Annual rainfall = 2100 mm;
- Native soil infiltration rate = 1.5 mm/hr;
- Parking use is more than one car per day; and
- Capture target is 75% of annual rainfall.

1. Determine the swale footprint area and rock trench depth and the rock trench volume.

3.9.2 Sizing

1. Determine the maximum rock depth based on the 4 day maximum drain time:

$$D_R = \frac{Ks \times T \times 24}{n} = \frac{1.5mm/hr \times 4days \times 24hr/day}{0.35} = 411\,mm$$

2. Use 400mm rock depth.

3. Determine the maximum I/P ratio (see Table 3-1). Parking use of more than one car per day yields a maximum I/P ratio of 20.
4. Use the 2100 mm sizing chart to determine the I/P ratio needed to meet the capture target.
5. As shown in the Swale 2100 mm chart (Figure B-6), the 75% capture and 1.5 mm/hr infiltration point plots above the I/P=5 curve. At an I/P ratio of 5, the best annual capture that could be achieved is 63%. As noted on the chart, an orifice outlet is needed to meet this capture target at this site.

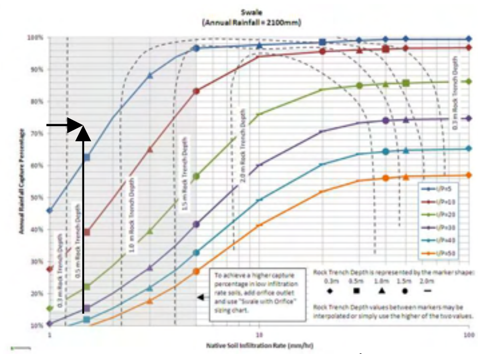


Figure 3-3: Sizing chart for Swale (without orifice) for 2100 mm annual rainfall.

6. Using the Swale with 0.25 L/s/ha Orifice 2100 mm chart (Figure B-9), the 75% capture and 1.5 mm/hr infiltration point plots between the I/P=10 and I/P=20 curves, at approximately an I/P=11 ratio. As noted on the chart, the depth of rock required is 1.5m.

   The swale footprint area equals the pavement area divided by the I/P ratio (930 m^2 / 11 = 85 m^2). Check that this is less than the available area of 90 m^2.

   The rock volume below the overflow elevation is 127 m^3 (85 m^2 x 1.5 m).

Table 3-1: Swale Maximum IP Ratios by Surface Type

Surface Type	Max I/P Ratio
General/Industrial Storage/Loading Areas	20:1
Divided or Undivided Major Road (Expressway or Highway)	20:1
Collector Road	20:1
Parking >1 Car/Day/Parking Space	20:1
Local Road	30:1
Parking <1 Car/Day/Parking Space	40:1
Low Traffic Areas/No Parking	40:1
Single Family Residential/Lot and Roof	30:1

The orifice outlet from the swale should be sized to deliver a flow of:

$$Q = \frac{0.25 \times A_{SITE}}{1000} = \frac{0.25 \times (0.0930 + 0.0085)}{1000} = 2.5 \times 10^{-5} m^3/s$$

Solving the orifice equation for area of the orifice (AO):

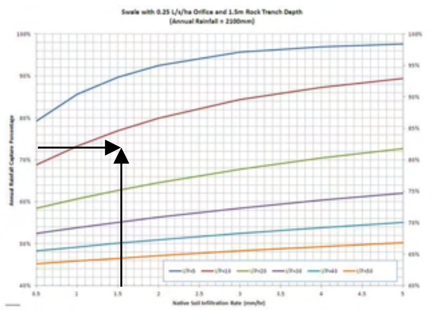
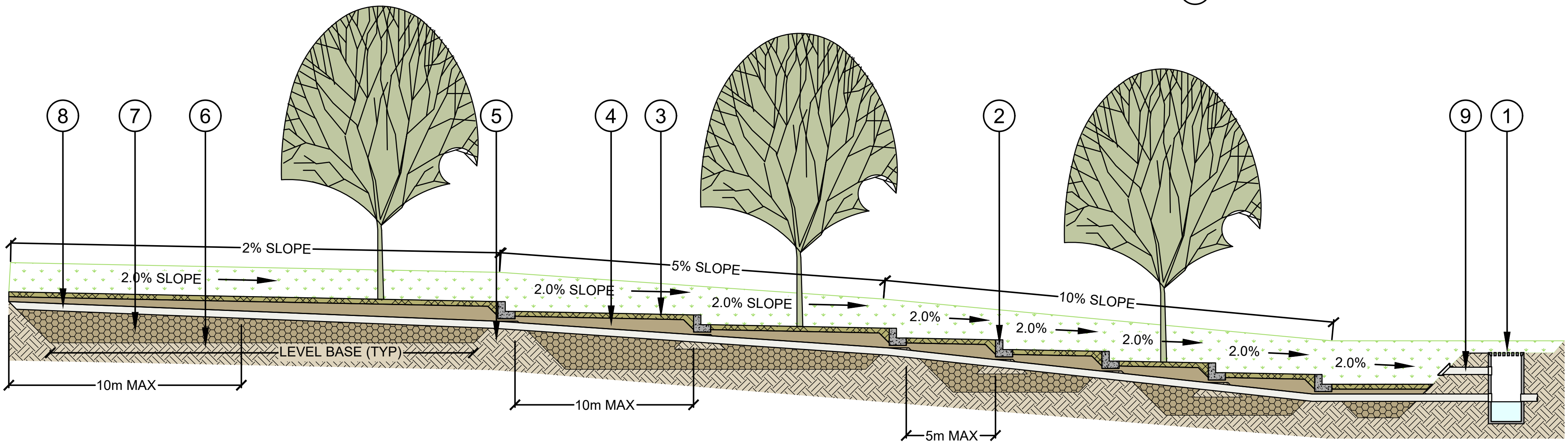


Figure 3-4: Sizing chart for Swale with 0.25 L/s/ha Orifice for 2100 mm annual rainfall.

$$A_O = \frac{Q}{K \times \sqrt{2gh}} = \frac{2.5 \times 10^{-5}}{0.6 \times \sqrt{2 \times 9.81 \times 0.3}} = 1.7 \times 10^{-5} m^2$$

The area of the orifice opening equates to a 5 mm diameter circular orifice. An orifice of no less than 10 mm is recommended to minimize clogging. A regional capture facility which would service a 0.46 ha or larger tributary area should be considered.

1 OUTLET TO PIPE SYSTEM OR WATERCOURSE
2 WEIR KEYED INTO SWALE SIDE SLOPE
3 GROWING MEDIUM
4 SAND
5 UNDERGROUND WEIR OF COMPACTED NATIVE MATERIAL OR EQUIVALENT TO CREATE SUBSURFACE BASIN
6 EXISTING SCARIFIED SUB-SOIL
7 DRAIN ROCK RESERVOIR (OPTIONAL)
8 PERFORATED DRAIN PIPE (OPTIONAL)
9 HIGH FLOW OVERFLOW

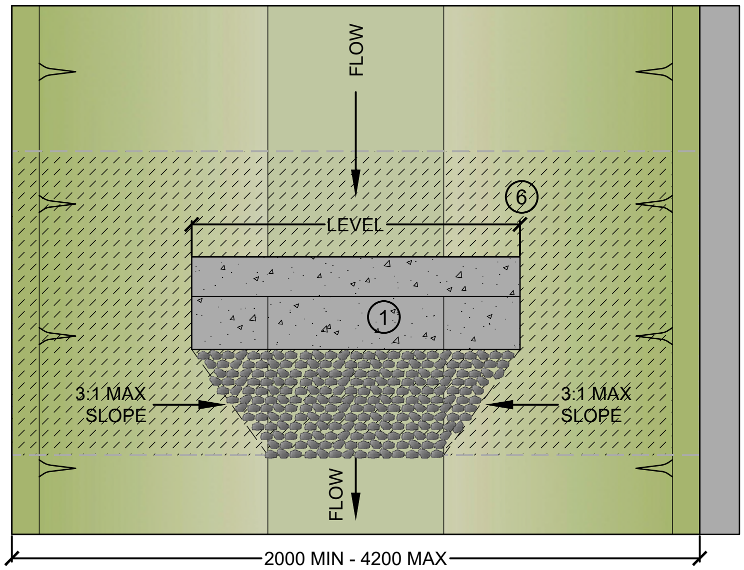


3
A

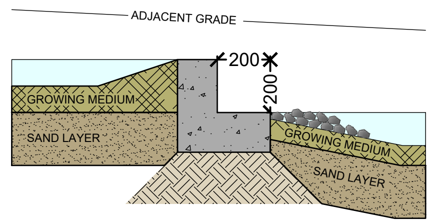
INFILTRATION SWALE

Not To Scale

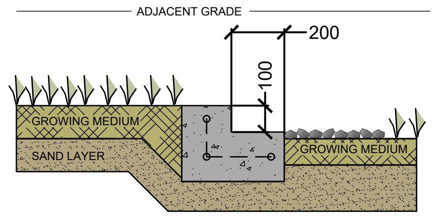
Longitudinal Profile



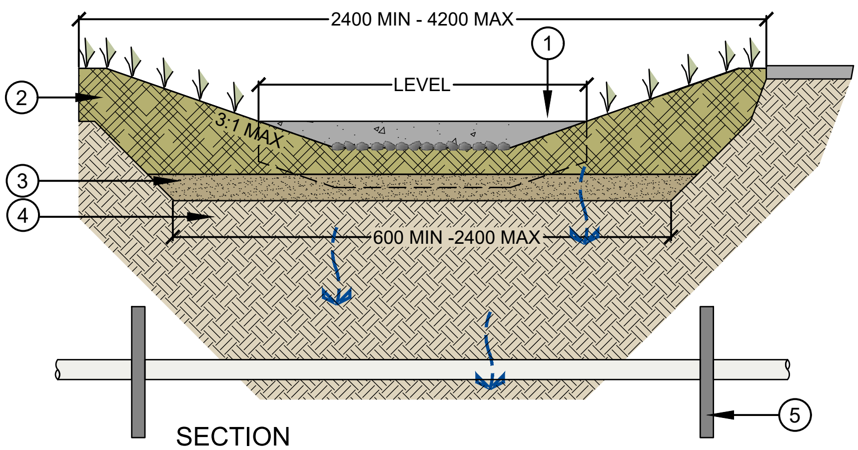
PLAN



DETAIL SECTION - WEIR WITH PONDING



DETAIL SECTION - WEIR WITHOUT PONDING



SECTION

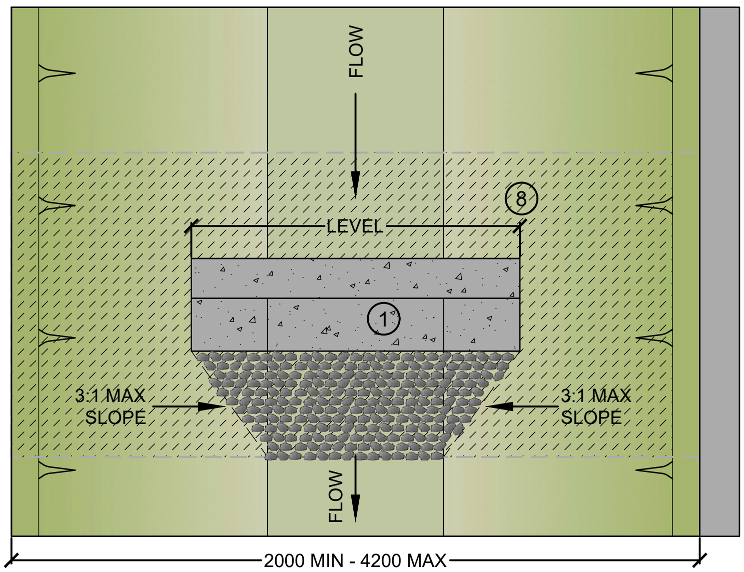
1. WEIR KEYED INTO SWALE SIDE SLOPE
2. GROWING MEDIUM
3. SAND
4. EXISTING SCARIFIED SUBSOIL
5. TRENCH DAMS AT ALL UTILITY CROSSING
6. PROVIDE EROSION CONTROL ALONG ALL SIDES OF WEIR AND AT DRAINAGE INLETS

3
B

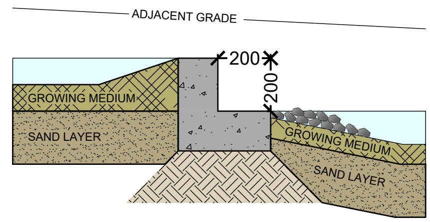
FULL INFILTRATION SWALE (NO RESERVOIR)

Not To Scale

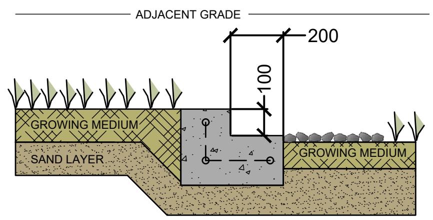
Plan / Section



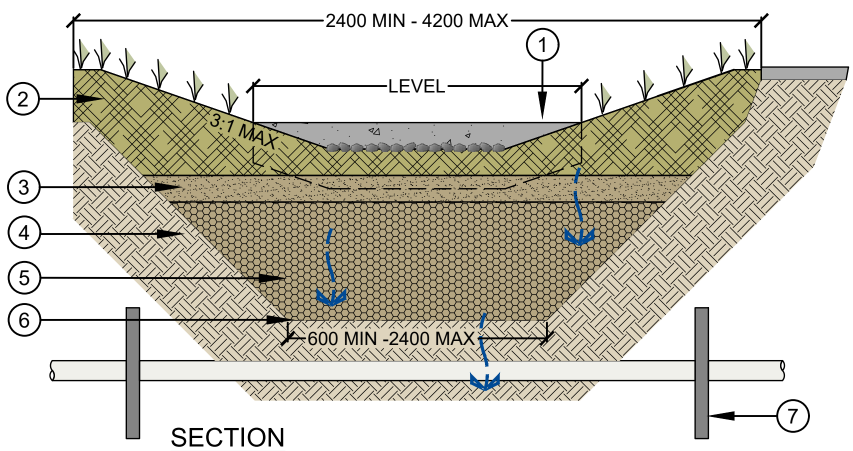
PLAN



DETAIL SECTION - WEIR WITH PONDING



DETAIL SECTION - WEIR WITHOUT PONDING



SECTION

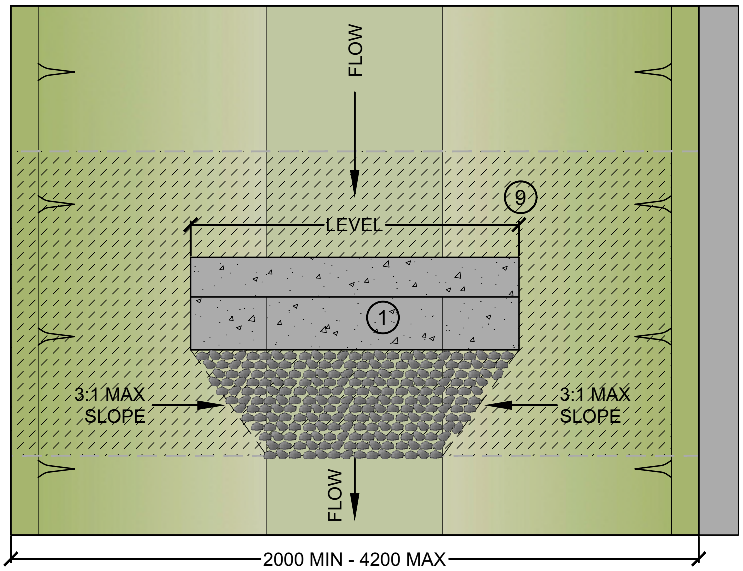
1. WEIR KEYED INTO SWALE SIDE SLOPE
2. GROWING MEDIUM
3. SAND
4. EXISTING SCARIFIED SUBSOIL
5. DRAIN ROCK RESERVOIR
6. GEOTEXTILE FILTER ALONG ALL SIDES OF RESERVOIR
7. TRENCH DAMS AT ALL UTILITY CROSSINGS
8. PROVIDE EROSION CONTROL ALONG ALL SIDES OF WEIR AND AT DRAINAGE INLETS

3 / C

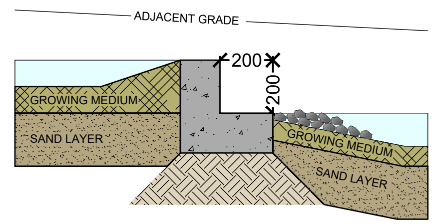
FULL INFILTRATION SWALE WITH RESERVOIR

Not To Scale

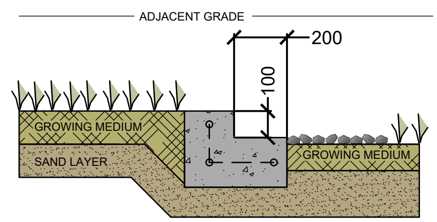
Plan / Section



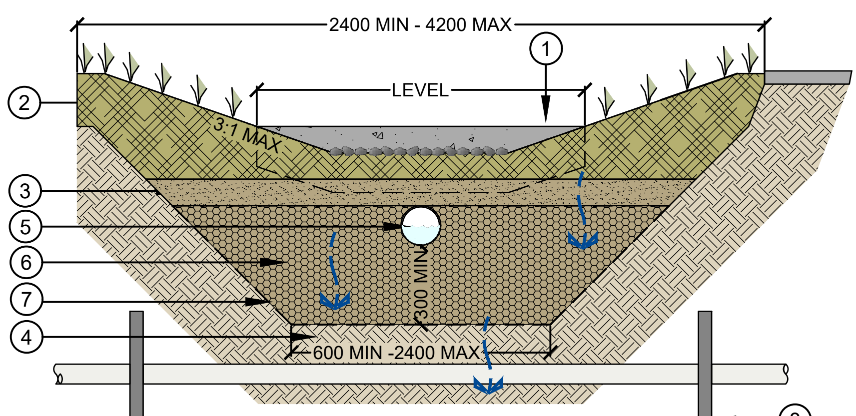
PLAN



DETAIL SECTION - WEIR WITH PONDING



DETAIL SECTION - WEIR WITHOUT PONDING



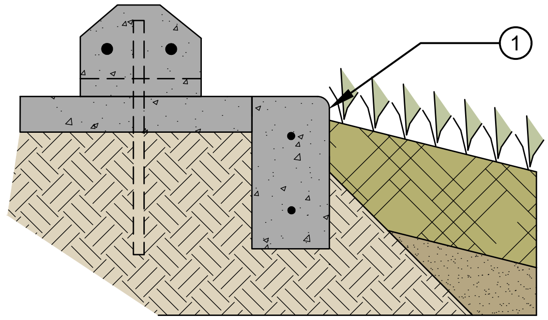
SECTION

1. WEIR KEYED INTO SWALE SIDE SLOPE
2. GROWING MEDIUM
3. SAND
4. EXISTING SCARIFIED SUBSOIL
5. PERFORATED UNDERDRAIN (150mm DIA MIN.)
6. DRAIN ROCK RESERVOIR
7. GEOTEXTILE FILTER ALONG ALL SIDES OF RESERVOIR
8. TRENCH DAMS AT ALL UTILITY CROSSING
9. PROVIDE EROSION CONTROL ALONG ALL SIDES OF WEIR AND AT DRAINAGE INLETS

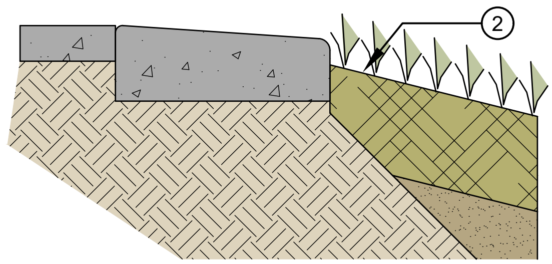
3 D PARTIAL INFILTRATION SWALE WITH RESERVOIR AND SUBDRAIN

Not To Scale

Plan / Section

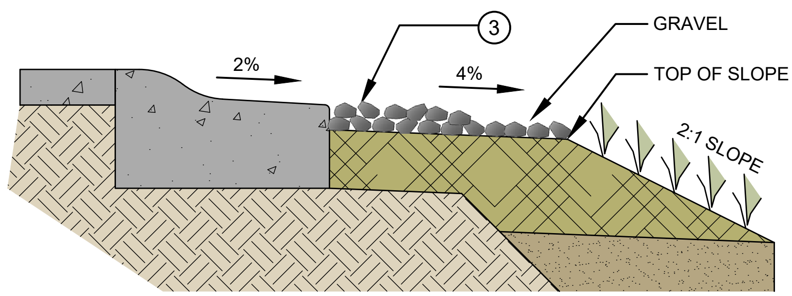


WHEEL STOP WITH GAPS



FLUSH CURB

1. 50mm VERTICAL DROP (TYP)
2. 4:1 MAX. SLOPE FOR FIRST ≥500mm
3. REINFORCED WITH EROSION CONTROL TREATMENT AND FLOW SPREADER AT POINTS OF WATER ENTRY (TYP.)

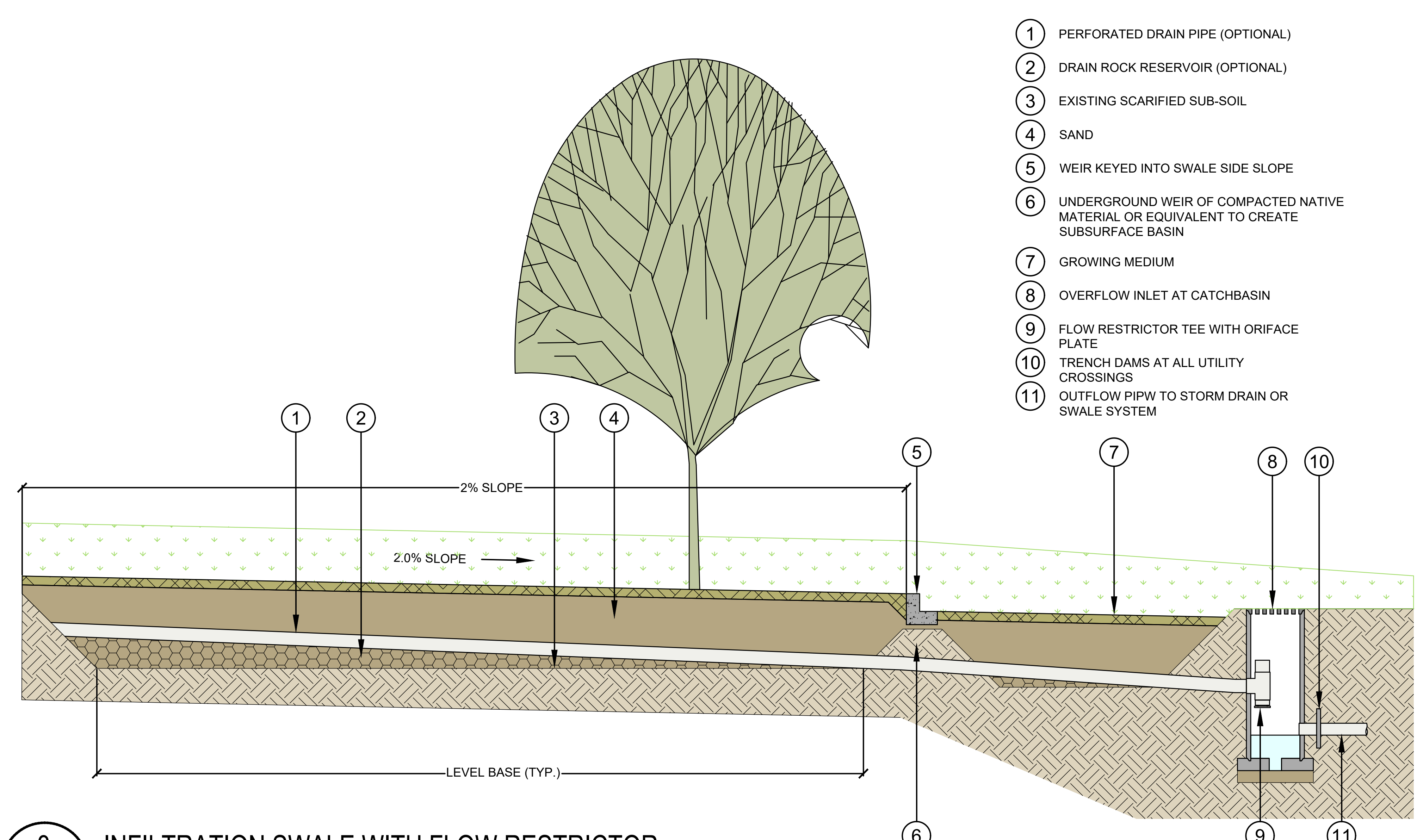


REVERSE CURB

3 / E

CURBING OPTIONS

Not To Scale | Section



3 / F

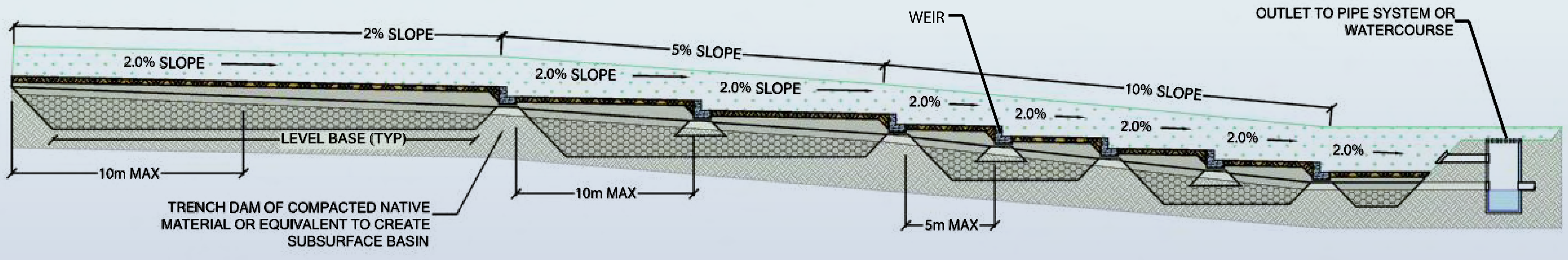
INFILTRATION SWALE WITH FLOW RESTRICTOR

Not To Scale

Longitudinal Profile

DESIGN PRINCIPLES

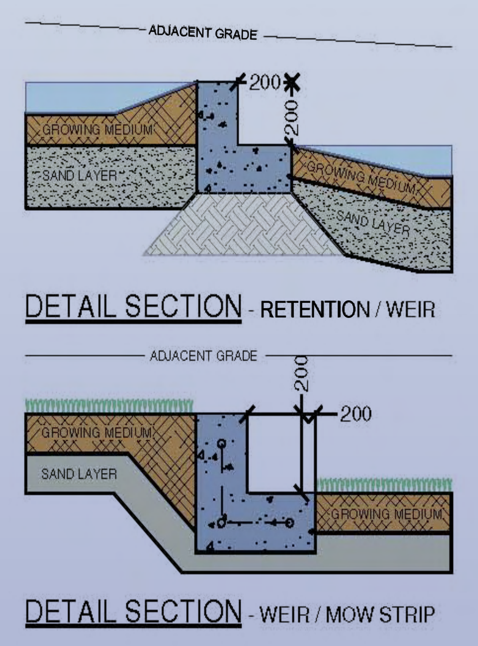
- Literature suggests swale areas of about 10-20% of upstream impervious area. Higher sediment load land uses require lower ratios of impervious area to swale area.
- Flow to the swale should be distributed sheet flow, travelling through a grassy filter area at the swale verges. Provide pre-treatment and erosion control to avoid sedimentation in the swale.
- Provide a 50mm drop at the edge of paving to the swale soil surface, to allow for positive drainage and buildup of road sanding/organic materials at this edge.
- Swale planting is typically sodded lawn. Low volume swales can be finished with a combination of grasses, shrub, groundcover and tree planting.
- Swale bottom - flat cross section, 600 to 2400mm width, 1-2% longitudinal slope or dished between weirs.
- Swale side slopes - 3(horizontal):1(vertical) maximum, 4:1 or less preferred for maintenance.
- Weirs to have level top to spread flows and avoid channelization, keyed in 100mm minimum.
- Maximum ponding level - 150mm. Drawdown time for the maximum surface ponded volume - 24 hours.
- Treatment soil depth - 300mm desirable, minimum 150mm if design professional calculates adequate pollutant removal.
- Design stormwater conveyance using Manning's formula or weir equations whichever governs with attention to channel stability during maximum flows.
- Drain rock reservoir and underdrain may be avoided where infiltration tests by a qualified professional, taken at the depth of the proposed infiltration, show an infiltration rate that exceeds the inflow rate.

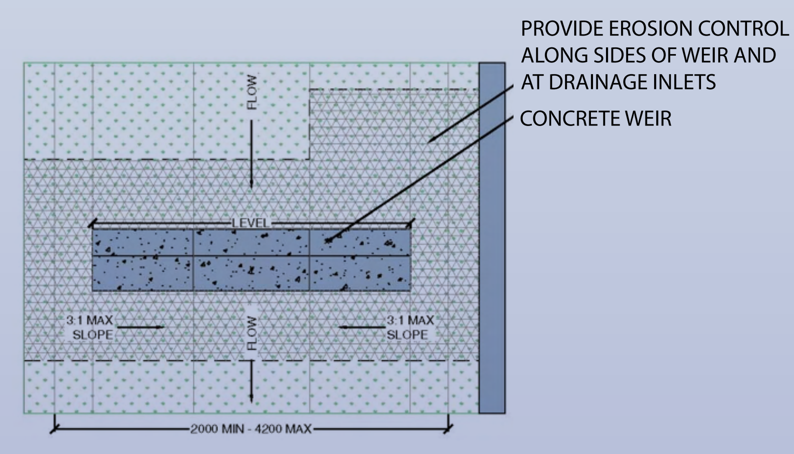


INFILTRATION SWALE

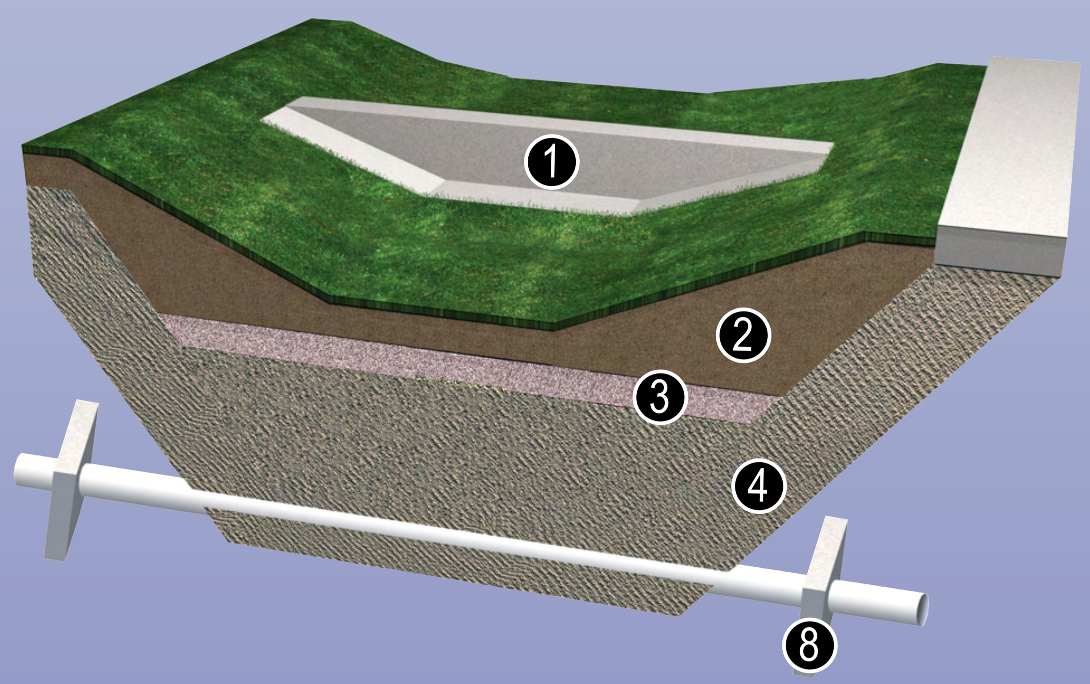
Not To Scale

Longitudinal Profile



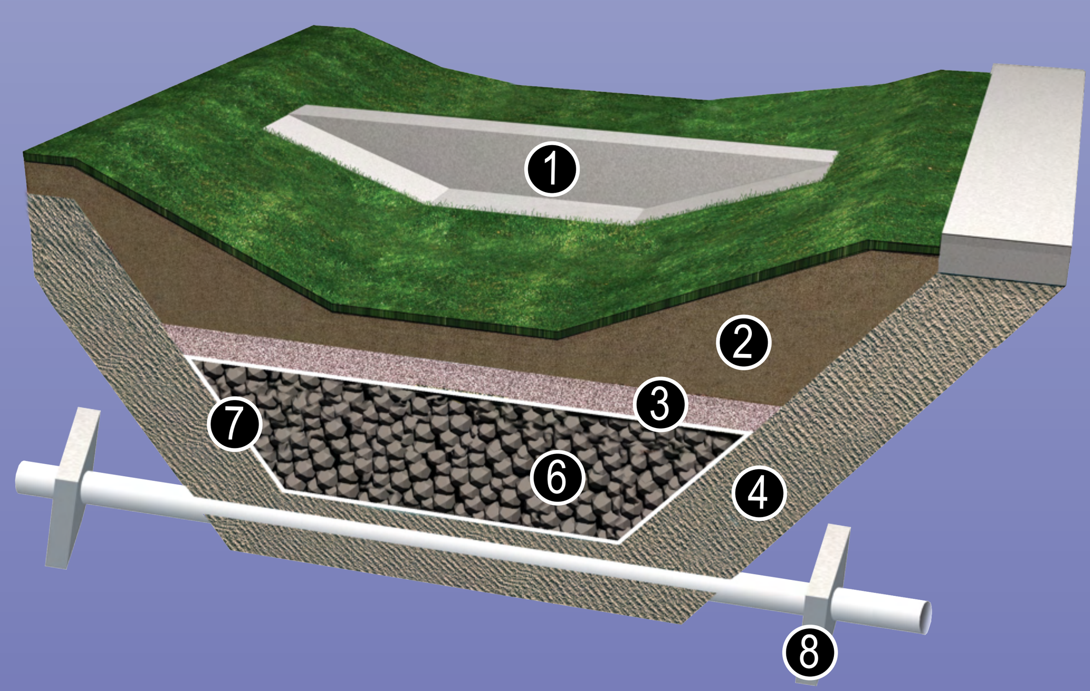


An **Infiltration Swale** is a shallow grassed or vegetated channel designed to capture, detain and treat stormwater and convey larger flows. It takes surface flows from adjacent paved surfaces, holds the water behind weirs, and allows it to infiltrate through a soil bed into underlying soils. The swale and weir structures provide conveyance for larger storm events to the storm drain system. Variations on designs include an underlying drain rock reservoir, with or without a perforated underdrain.



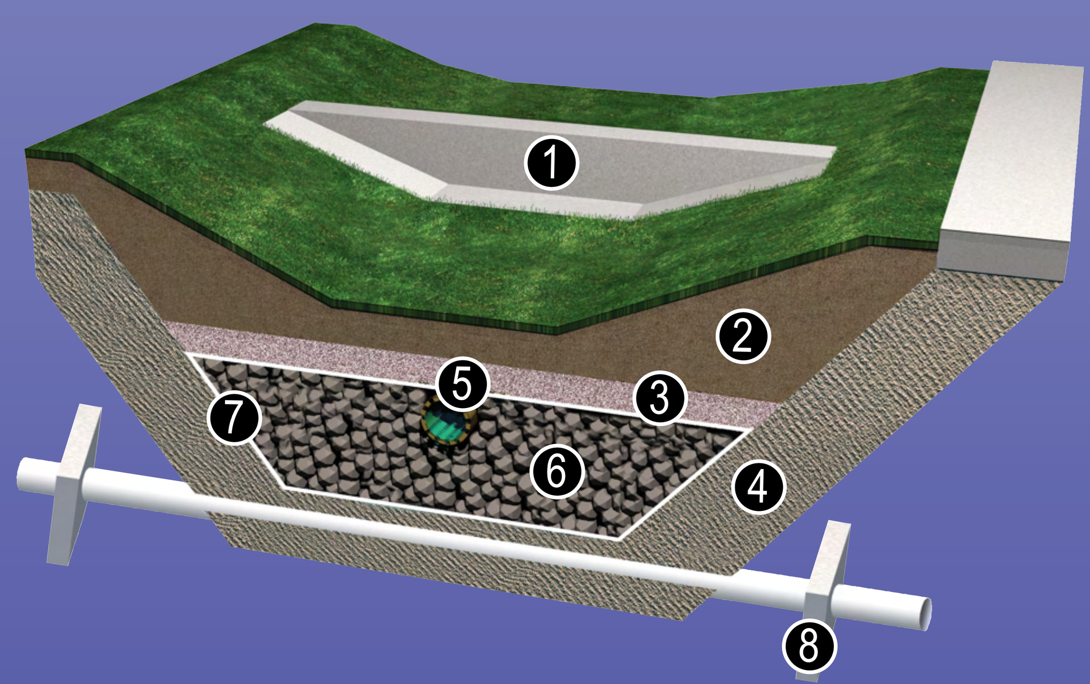
Full Infiltration

Where water entering the swale is filtered through a grass or groundcover layer, and then passes through sandy growing medium and a sand layer into underlying scarified subgrade. Suitable for sites with small catchments and subsoil permeability > 30mm/hr.



Full Infiltration with Reservoir

Designed to reduce surface ponding by providing underground storage in a drain rock reservoir. Suitable for sites with small catchments and subsoil permeability > 15mm/hr.



Partial Infiltration with Reservoir and Subdrain

Where a perforated drain pipe is installed at the top of the reservoir, providing an underground overflow that removes excess water before it backs up to the surface of the swale. Suitable for sites with larger catchments and low infiltration rates into subsoil permeability < 15mm/hr. Provides water quality treatment even if infiltration into subsoils is limited.

1. Weir Keyed into Swale Side Slope
2. Growing Medium (300mm Min.)
3. Sand
4. Existing Scarified Subsoil
5. Perforated Underdrain (150mm Dia. Min.)
6. Drain Rock Reservoir (300mm Min.)
7. Geotextile Along All Sides of Reservoir
8. Trench Dams at All Utility Crossing

Infiltration Swale System

metrovancouver

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Stormwater Source Control Design Guidelines 2023





Detailed design guidelines can be found in the Design Guidelines 2012 report, available at www.metrovancouver.org

INFILTRATION RAIN GARDEN

4 Infiltration Rain Garden

4.1 Description

The Infiltration Rain Garden is a form of bioretention facility, designed to have the aesthetic appeal of a garden, as opposed to a purely functional appearance. Rain Gardens are commonly a concave landscape area where runoff from roofs or paving is allowed to pond temporarily while infiltrating into soils below (See Figure 4–).

The surface planting of Rain Gardens is dominated by shrubs and groundcovers, with planting designs respecting the various soil moisture conditions in the garden. Plantings may also include trees, rushes, sedges, and other grass-like plants, as well as sodded lawn areas for erosion control and multiple uses. Deciduous plants, especially trees, should be used carefully as the seasonal accumulation of leaves can be a concern for maintenance and may contribute to bind-off of the soil surface.

Rain Gardens generally have a drain rock reservoir and perforated drain system to collect excess water. (See Figure 4-B and 4-C). The perforated drain system may connect to a control structure in a catch basin that provides overflow while maintaining a slow decanting of the water in the rain garden between storms (See Figure 4-D).

While usually designed as a 'standalone' facility without conveyance, new designs are evolving that put a series of Rain Gardens along linear areas like roads – with weirs and surface conveyance similar to Infiltration Swales.

Informal rain garden, Water Pollution Control Laboratory, Portland Oregon.
(Photo Credit: Lanarc Consultants Ltd.)

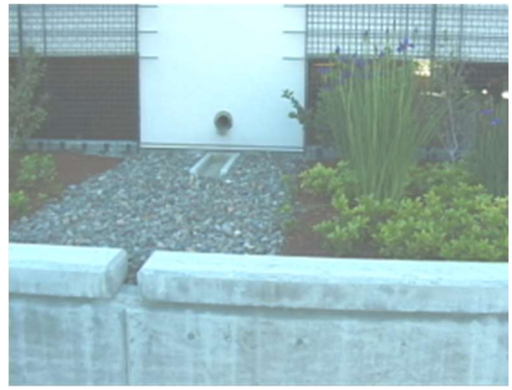
Informal rain garden, Water Pollution Control Laboratory, Portland Oregon.
(Photo Credit: Lanarc Consultants Ltd.)

Other common terms used are Bioretention and Dry Swale with Underdrain (Stephens et al., 2002) or Swale / Trench Element (MUNLV-NRW, 2001).

4.2 Selection, Application and Limitations

- 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 Infiltration Swale have similar design and functions. A Rain Garden or series of Rain Gardens provides more capture of peak flows (due to ponding) and less conveyance of non-captured flows than a swale.
- If treatment is not required (e.g., for pre-treated or roof water only), an infiltration rock trench is more economical and space efficient but does not provide the aesthetics and interactive value of the Rain Garden.
- A rain garden will provide increased volume capture over an infiltration trench due to the surface ponding and plant uptake or moisture.
- Smaller, distributed Rain Gardens are preferable to single large scale facilities.
- Infiltration Rain Gardens may take a variety of shapes, from informal, organically shaped 'bowls' to formal, rectilinear planting areas and planters.



Flow-thru planter – a formal-shaped rain garden that provides water quality treatment and limited flow attenuation – adapted to a near-building location at Buckman Terrace in Portland, Oregon.
(Photo Credit: Lanarc Consultants Ltd.)

4.3 Design Guidelines

1. Site Rain Gardens similar to other infiltration facilities – minimum 30m from wells, minimum 3m downslope of building foundations, and only in areas where foundations have footing drains.
2. Inflows should be distributed sheet flow from pavement over a flat-panel curb, or through frequent curb cuts. A minimum drop of 50 mm from the pavement or flat curb edge to the top of the Rain Garden surface is required to accommodate sediment accumulation.
3. 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. Clean crushed rock or rounded river rock may be used. The slope of the transition area should be greater than 10% to move sediment through to the rain garden.
4. Flow may be pre-treated to remove sediment by travelling through a grass

Roadside rain garden with flat panel curb and shrub and herbaceous plantings in Thunderbird subdivision, Squamish, BC.
(Photo Credit: Kerr Wood Leidal Associates)

swale prior to entering the Rain Garden (500 mm minimum, greater than 3000 mm desirable swale length; Claytor and Schueler, 1996).

5. Experience has shown that grass is efficient at trapping sediment at a pavement edge and the sediment and grass matt will agrade rapidly. In addition to the 50mm drop (see point No. 3, above) it is recommended that the transition slope or rain garden edge be covered with rock or sturdy mulch at the surface rather than grass.
6. Rain Garden bottom or Base Area (Drawing 4A): flat cross section, with a longitudinal slope of 2% maximum (or 1% by US001 or dished by GE004).
7. Provide a 50mm – 75mm layer of non-floating organic mulch – well aged compost, bark mulch or similar weed free material. The mulch is important for both erosion control and maintaining infiltration capacity.
8. Rain Garden Base Area dimensions: bottom width 600mm minimum, 3000mm desirable.
9. Rain Garden side slopes: 2 horizontal : 1 vertical maximum, 4:1 preferred for maintenance (i.e., mowing, or other equipment access, if required). Provide organic mulch on side slopes similar to bottom.
10. Maximum ponded level: 150 to 300 mm. 200 mm maximum pond level is common and assumed for the simplified sizing approaches here.
11. For roadside applications, rock reservoir depth should generally not exceed the depth of the surrounding utilities.
12. Drawdown time for the maximum surface ponded volume: 48 hours preferred (72 hours max. – Maryland Dept. of the Environment, 2009).
13. A non-erodible outlet or spillway must be established to discharge overflow to the storm sewer system (Maryland Dept. of the Environment, 2009). This often takes the form of a grated inlet raised above the Rain Garden invert to create the ponding depth.
14. 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 3mm/yr or more depending on loading). Rain Garden depth = ponding depth + surcharge allowance + sediment accumulation allowance.

15. 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.

Rain garden overflow, Buckman Terrace, Portland Oregon.
(Photo Credit: Lanarc Consultants Ltd.)

16. Treatment soil (i.e., growing medium) depth: 450mm minimum (City of Portland, 2002) for most applications. Treatment soil should have a minimum infiltration rate (lab tested) of 70 mm/hr, which is assumed in the sizing approaches in this document.

17. Slope of the drain rock reservoir bottom shall be level to maximize infiltration area.

18. Avoid utility or other crossings of the Rain Garden. Where utility trenches must be constructed crossing below the garden, install low permeability trench dams to avoid infiltration water following the utility trench.

19. Drain rock reservoir and subdrain may be omitted where infiltration tests by the design professional taken at the level of the base of the proposed construction show an infiltration rate that exceeds the inflow rate for the design storm (approximately rainfall intensity x (I/P ratio + 1); I/P ratio is the ratio of impervious to pervious area and is defined below as part of Sizing).

20. A perforated pipe subdrain is required to drain excess water from the soil and prevent root drowning of Rain Garden plantings in poorly draining soils. The subdrain should always be embedded in drain rock near the top of the rock reservoir to provide a storage volume below the subdrain unless a rain garden with flow restrictor option is used (see Figure 4-C).

21. The subdrain should have flow and inlet capacity to carry the flow infiltrated through the soil layer. Consult pipe manufacturer for perforation inflow capacity. A maximum infiltration rate through the soil can be estimated by applying Darcy's equation:

$$Q_{max} = k \times L \times W_{base} \times \frac{h_{max} + d}{d}$$

Where:
k is the hydraulic conductivity of the growing medium (soil) (m/s)
W_{base} is the average width of the ponded cross-section above the invert of the Rain Garden area (m)
L is the length of the Rain Garden base area zone (m)
h_{max} is the depth of the ponding above the growing medium (m)
d is the thickness of the growing medium layer (m)

4.4 Pre-treatment Principles

Infiltration rain gardens provide stormwater treatment through filtration and infiltration. Pre-treatment is required to ensure sediment build-up does not occur at the inlets of the systems and to maintain the health of the underlying soils. Pre-treatment is also required to maintain the infiltration capacity.

Where possible, infiltration rain gardens should aim to have dispersed inflow as the design target. The dispersal of the flow reduces the load of sediment and pollutants at any one point and distributes it across the facility, reducing the localized impact. Depending on the site restrictions, the inflow may require a point source. Pre-treatment guidance is provided for both cases.

The level of pre-treatment required for a system will depend on the source of the runoff. Catchments with high sediment loading (i.e., highways, arterial and collector roads) or winter de-icing and/or gritting locations will require more significant pre-treatment to maintain system longevity.

Pre-treatment principles for dispersed runoff source are as follows:

1. Disperse stormwater runoff into the system by incorporating flat panel curbs along the width of the system; and
2. Prevent scour by providing energy dissipation of stormwater inputs; use rock or mulch to slow flow and allow sediment to drop out.

Pre-treatment principles for point source inflow are as follows:

1. Provide dedicated sediment "forebays" (settling basins) at point source inlets;
2. Forebays are to:
   a. Be designed such that a 5-10cm depression is provided for sediment to settle prior to overtopping into the rain garden. Depression at a minimum to include a space where inflow can reduce velocity and allow sedimentation. Depressed forebays also reduce the likelihood that accumulated sediment prevents runoff from entering the system;
   b. Be physically separated from rain garden growing media. This could include a manhole/catch basin or constructed wall/weir structure. Forebay areas to include sumps where feasible or if warranted to capture more sediment prior to discharging into the rain garden;
   c. Minimum forebay depth prior to overflow into rain garden to be 50 mm. Where higher sediment loading is anticipated (i.e., collector roads), depth of depression to be calculated based on expected sediment loading;
   d. Provide a length to width ratio of ≥ 2:1;
   e. Have a total surface area of no greater than 30% of the total rain garden area; most pre-treatment requires only 10% or less of the total rain garden area; and

f. Proprietary devices utilized as pre-treatment to be sized to remove minimum 60% of total sediment load, shop drawings and sizing reports to be approved by design engineer;

3. Protect concentrated flow paths (downstream of point source inlets) with rock;
4. There can be multiple point source inflows within a single rain garden (i.e., at curb cuts), the design guidance provided can be scaled such that there are multiple sediment forebays or settling pads to provide pre-treatment, with the total area of all pre-treatment less than 30% of the rain garden area; and
5. System retrofits can be completed for infiltration swale systems through installation of pre-treatment "pads" constructed with cobblestone, flagstone, or concrete.

4.5 Pre-Treatment Maintenance

Maintenance requirements for rain garden pre-treatment zones include:

- Removal of sediment and debris from sumps and inlet pads. Maintaining the pre-treatment / forebay zones will allow for the rain garden to have greater longevity and require less overall system maintenance;
- Maintenance of inlet protection (i.e., rock or gravel flow paths) includes inspection for eroded flow paths and removal of debris where possible; and
- Depending on the runoff source, more frequent maintenance and sediment removal may be warranted. Design guidance should include an estimated sediment removal frequency for the pre-treatment zones.

4.6 Rain Garden Maintenance

Maintenance for an infiltration or treatment rain garden includes plant care and maintenance as well as checking and clearing of pre-treatment devices and outlets. Design should include consideration of access for these activities, including for equipment, if needed, for sediment removal. Key considerations include to locate the pre-treatment device where it is easily accessible, and to use a device design that is consistent with other devices the municipal staff maintain so that it is familiar to staff and utilizes the same equipment. An operation and maintenance plan should be developed as part of design to document the maintenance required and the locations for checking function and maintenance. Operation and maintenance plans should account for the needs of the vegetation used within each system. If an underdrain is present in the rain garden, ensure that a cleanout is included to enable inspection and flushing of the underdrain. Monitoring wells may also be used to assess the rate of drawdown time throughout the systems life.

Rain gardens and other bioretention systems may include hardscape components that require inspection and maintenance such as concrete sediment pads, weir walls, check dams, curb cut inlets, and concrete barriers to separate systems from pedestrian areas and facilitate ponding within the system. Rain gardens may also be connected to municipal storm sewer systems and have internal catchbasins as overflow grates which can require more frequent maintenance than roadside catchbasins due to the higher likelihood of vegetated debris clogging the service connection.

Refer to *Chapter 11 – Operation, Inspection and Maintenance*, for more detailed guidance on maintenance practices.

4.7 Rain Garden Sizing

Rain Gardens may be sized in a variety of ways depending on the site needs and the design criteria. Sizing may be done using continuous simulation modeling in the WBM or SWMM or using spreadsheet design storm and water balance calculations. Simplified sizing approaches have been developed that do not require water balance modeling or continuous simulation. Two sizing approaches are presented below for the two types of criteria used in BC.

- In general, the Rain Garden area is sized based on the upstream impervious area that it serves. This relationship can be defined by the ratio of impervious area to pervious area (e.g., I/P ratio). For the simplified sizing approaches here, this represents the ratio of upstream impervious area (also called catchment area) to Base Area of the Rain Garden. I/P ratio to achieve the target capture criteria will be calculated by the two sizing methods below.

Table 4-A: Rain Garden Maximum I/P Ratios by Surface Type

Surface Type	Max I/P Ratio
General/Industrial Storage/Loading Areas	20:1
Divided or Undivided Major Road (Expressway or Highway)	20:1
Collector Road	20:1
Parking >1 Car/Day/Parking Space	20:1
Local Road	30:1
Parking <1 Car/Day/Parking Space	40:1
Low Traffic Areas/No Parking	40:1
Single Family Residential/Lot and Roof	30:1

- The maximum allowable I/P ratio for given surface types is shown in the adjacent Table 4-A. This maximum is based on ability of the vegetation to handle flows and pollutants and is not related to capture. Regardless of sizing calculation below, maximum I/P ratio for a given surface type should not be exceeded.
- The sizing process provides the Base Area of the Rain Garden, which is the flat area at the bottom with uniform layers of mulch, topsoil and drain rock. Sizing by these methods does not account for any infiltration benefit provided by the sloped sides of the rain garden.
- The Base Area of the Rain Garden will always be smaller than the total footprint of the facility, so the footprint must be calculated (see Step 15, above) in order to understand the actual site area required.
- Sizing presented here is for infiltration of rain water for "capture" and prevention of site runoff. Sizing and design according to this guidance will generally provide water quality treatment for the volume of water infiltrated. If "water quality"

criteria volumes are larger than “capture” volumes, additional sizing may be required, and a professional engineer should be consulted.

4.7.1 Sizing Approach 1 – for Depth Capture Criteria: X mm in 24 hrs

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

   $$D_R = \frac{Ks \times T \times 24}{n}$$

   Where:
   D_R = Depth (thickness) of rock reservoir (mm).
   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr).
   T = allowable drain time (days).
   n = porosity of drain rock in reservoir (unitless, e.g., 0.35).

2. Use the following equation to determine the base (bottom) area of rain garden and rock reservoir required by finding the I/P ratio for the site:

   $$I / P = \frac{24 \times Ks + D_P + D_R \times n + 0.2 \times D_S}{R} - 1$$

   Where:
   I/P = Ratio of impervious tributary area to rain garden base area (unitless)
   R = Rainfall capture depth (mm)
   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
   D_P = Depth of ponding (mm); 200 mm standard
   D_R = Depth (thickness) of rock reservoir (mm)
   n = porosity of drain rock in reservoir (unitless, e.g., 0.35)
   D_S = Soil layer depth (thickness); standard value = 450 (mm)

3. Check that the I/P ratio calculated is less than the maximum allowed (Table 4-A). If it is not, use the maximum allowed I/P ratio. This may mean that the Rain Garden will exceed the % capture desired.

4. To find the rain garden base area:

   $$BaseArea = \frac{\text{Impervious}\,TributaryArea}{I / P}$$

5. Calculate the footprint of the facility based on the Base Area and side slopes as described in step 15.

6. If the site cannot accommodate the I/P ratio required to provide the target capture, a partial-infiltration rain garden with flow restrictor design may be used (see Figure 4-D).

7. A 0.25 L/s/ha (or 0.09 mm/hr) unit discharge has been recommended by DFO for the flow restrictor at the downstream end of the swale subdrain (see Figure 4-D).

8. Calculate the allowable discharge through the orifice:

$$Q = \frac{0.25 \times A_{SITE}}{1000}$$

Where:
Q = Allowable discharge through orifice (m3/s)
0.25 = Recommended unit discharge (L/s/ha)
A_{SITE} = Total site area draining to the swale, including the swale area (ha)

9. This discharge is used to size the orifice on a flow restrictor at the downstream end of the rain garden subdrain (see detail 4D).
10. Solving the orifice equation for area of the orifice (AO):

$$A_O = \frac{Q_{SITE}}{K \times \sqrt{2g\Delta h}}$$

Where:
Q_{SITE} = Theoretical discharge through infiltration from the impervious area (m^3/s)
K = Orifice Coefficient (typical value 0.6)
g = gravitational constant (m/s^2)
h = differential head equivalent to depth of the perforated drain pipe in the rock trench (typical value 0.3 m)
A_O = Area of the orifice opening (m^2) – generally assumed to be circular for calculation of orifice diameter

11. The size of the rain garden is then determined by the available area on the site up to the maximum I/P ratio for the surface type as shown in Table 4-A.
12. For the flow restrictor option, the subdrain should be at bottom of the rock in the rock reservoir. The depth of the rock reservoir above the orifice outlet is calculated as:

$$D_R = \frac{R \times (I/P + 1) - 0.09\,mm/hr \times 24\,hrs \times (I/P + 1) - 24 \times Ks - 0.2 \times D_S}{n}$$

Where:
D_R = Depth (thickness) of rock reservoir (mm)
R = Rainfall capture depth (mm)
I/P = Ratio of impervious tributary area to swale base area (unitless)
0.09 = Recommended unit discharge through orifice (mm/hr)
Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
D_S = Soil layer depth (thickness); standard value = 300 (mm)
n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

4.7.2 Sizing Approach 2 – for % Capture of Average Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

1. Determine the average annual rainfall for the site. If unknown, refer to map in Appendix B of isohyetal lines showing average annual rainfall depths across the Metro Vancouver Region.

2. Consult the Rain Garden chart in Appendix B applicable for the site's location according to average annual rainfall: 1100mm (White Rock), 1500mm (Kwantlen, Surrey, and Vancouver), or 2100mm (North shore and Coquitlam); If between these values, choose the chart for the higher amount of rainfall or interpolate the result between the two bracketing charts.
3. Find the point on the chart matching the site's subsurface soil infiltration rate and the target % Capture and select the curve that is at or above (better capture) that point. The selected curve gives the I/P ratio required to meet the given % capture for the facility.
4. Check that the I/P ratio calculated is less than the maximum allowed (Table 4-A). If it is not, use the maximum allowed I/P ratio. This may mean that the Rain Garden will exceed the % capture desired.
5. To find the rain garden base area:
$$BaseArea = \frac{\text{Tributary Impervious Area}}{\text{I/P}}$$
6. Calculate the footprint of the facility based on the base area and side slopes as described in Design Guidelines 4.3,Step above15.
7. The shape of the points nearby on the selected curve indicate the depth (thickness) of the rock reservoir. The rock depth may be interpolated between two neighbouring values. Allowable rock depth range is 300 to 2000 mm.
8. If the site cannot accommodate the I/P ratio required to provide the target capture, or an I/P ratio of less than 5 would be needed (not shown on the chart) a partial-infiltration rain garden with flow restrictor design may be used (see Figure 4-D).
9. The size of the rain garden is then determined using the Rain Garden with 0.25 L/s/ha Orifice charts (Appendix B). Read the I/P ratio required for the given infiltration rate and capture target.
10. Calculate the rain garden base area:
$$BaseArea = \frac{\text{Impervious } TributaryArea}{I/P}$$
11. Check that the calculated rain garden base area is smaller than the available site area. If not, the capture target cannot be achieved given the site constraints using the sizing tools in this document. The site could be reconfigured to accommodate the calculated rain garden base area. Alternately, the rock reservoir footprint could be made larger than the rain garden bottom area and the capture calculated by a qualified stormwater professional.
12. The subdrain should be located at the bottom of the rock reservoir for this option. The depth of the rock reservoir above the orifice outlet is given as 1.5 m for a rain garden with orifice, for the purposes of this simplified design approach.
13. Calculate the allowable discharge through the orifice:

$$Q = \frac{0.25 \times A_{SITE}}{1000}$$

Where:
Q = Allowable discharge through orifice (m^3/s)
0.25 = Recommended unit discharge (L/s/ha)
A_{SITE} = Total site area draining to the rain garden, including the rain garden area (ha)

14. This discharge is used to size the orifice on a flow restrictor at the downstream end of the rain garden subdrain (see Figure 4-D).

15. Solving the orifice equation for area of the orifice (AO):

$$A_O = \frac{Q_{SITE}}{K \times \sqrt{2g\Delta h}}$$

Where:
Q_{SITE} = Theoretical discharge through infiltration from the impervious area (m^3/s)
K = Orifice Coefficient (typical value 0.6)
g = gravitational constant
h = differential head equivalent to depth of the perforated drain pipe in the rock trench (minimum value 0.3 m)
A_O = Area of the orifice opening (m^2) – generally assumed to be circular for calculation of orifice diameter

An orifice of no less than 10 mm is recommended to minimize clogging. A 10 mm orifice is the size required for a 0.46 ha tributary area. If the calculated orifice size is less than 10 mm, a regional capture facility servicing at least a 0.46 ha tributary area should be considered.

4.8 Guideline Specifications

Materials shall meet Master Municipal Construction Document 2019 requirements, and:

1. Infiltration Drain Rock: clean round stone or crushed rock, with a porosity of 35 to 40 % such as 75mm max, 38mm min, (Maryland Dept. of the Environment, 2009) or MMCD Section 31-05-17 Part 2.6 – Drain Rock, Coarse.
2. Pipe: PVC, DR 35, 150 mm min. dia., with cleanouts, certified to CSA B182.1 as per MMCD.
3. Geosynthetics: as per Section 31-32-19, select for filter criteria or from approved local government product lists.
4. Sand: Pit Run Sand as per Section 31-05-17.
5. Growing Medium Soil, see Chapter 9, Growing Medium Standards Seeding, conform to Section 32-92-20 Seeding or 32-92-19 Hydraulic Seeding (note – sodding will be required for erosion control in most instances).
6. Sodding, conform to MMCD Section 31-92-23 Sodding.

Construction Practices shall meet Master Municipal Construction Document 2009 requirements, and:

1. Isolate the Rain Garden site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying the excavation of 300mm of material over the final subgrade of the Rain Garden until after all sediment-producing construction in the drainage area has been completed (Maryland Dept. of the Environment, 2009).
2. Prevent natural or fill soils from intermixing with the Infiltration Drain Rock. All contaminated stone aggregate must be removed and replaced (Maryland Dept. of the Environment, 2009).
3. Infiltration Drain Rock shall be installed in 300mm lifts and compacted to eliminate voids between the geotextile and surrounding soils (Maryland Dept. of the Environment, 2009).
4. Maintain grass areas to mowed height between 50mm and 150mm, but not below the design water quality flow level. Landscape Maintenance standards shall be to the Canadian Landscape Standard, 2nd Edition, Maintenance Level 4: Open Space / Play.

4.9 Rain Garden Design Example For Capture of Xmm/24-hour Criteria

4.9.1 Scenario Description

A Rain Garden is proposed to capture a portion of the runoff from a paved parking area (see illustration below).

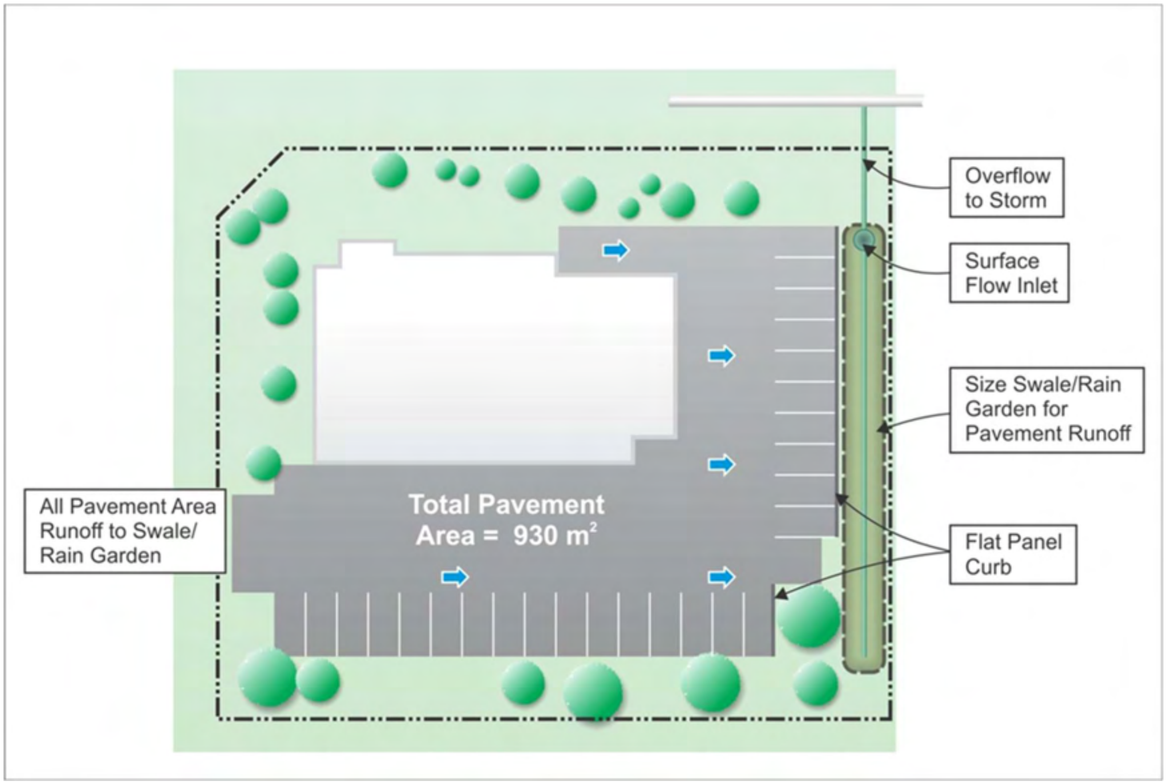


Figure 4-1: Example – Parking Area Draining to Rain Garden

The following parameters are known:

- Total pavement area = 930 m^2;
- Annual rainfall = 1200 mm;
- 2-year 24-hour rain depth = 53.2 mm;
- Native soil infiltration rate = 1.5 mm/hr;
- Parking use is more than one car per day; and
- Capture target is 50% of 2-year 24-hour rain amount.

1. Determine the rain garden footprint area and rock trench depth.

4.9.2 Sizing

1. Determine the maximum rock depth based on the 4 day maximum drain time:

$$D_R = \frac{Ks \times T \times 24}{n} = \frac{1.5mm/hr \times 4days \times 24hr/day}{0.35} = 411mm$$

2. Use 400mm rock depth.
3. Determine the maximum I/P ratio (see Table 4-A). Parking use of more than one car per day yields a maximum I/P ratio of 20.
4. Determine the base (bottom) area of rain garden and rock reservoir required by calculating the required I/P ratio:

$$I/P = \frac{24 \times Ks + D_P + D_R \times n + 0.2 \times D_S}{R} - 1$$

$$I/P = \frac{24 \times 1.5mm/hr + 200mm + 400mm \times 0.35 + 0.2 \times 450mm}{50\% \times 53.2mm} - 1$$

$$I/P = 16.5$$

5. Check that the I/P ratio is less than the maximum (16.5 < 20, therefore OK).
6. Calculate the rain garden base area:

$$BaseArea = \frac{imperviousTributaryArea}{I/P} = \frac{930sq.m}{16.5} = 56sq.m$$

Table 4-A: Rain Garden Maximum I/P Ratios by Surface Type

Surface Type	Max I/P Ratio
General/Industrial Storage/Loading Areas	20:1
Divided or Undivided Major Road (Expressway or Highway)	20:1
Collector Road	20:1
Parking >1 Car/Day/Parking Space	20:1
Local Road	30:1
Parking <1 Car/Day/Parking Space	40:1
Low Traffic Areas/No Parking	40:1
Single Family Residential/Lot and Roof	30:1

4.10 Rain Garden Design Example for Capture of % Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

4.10.1 Scenario Description

A Rain Garden is proposed to capture a portion of the runoff from a paved parking area (see illustration below).

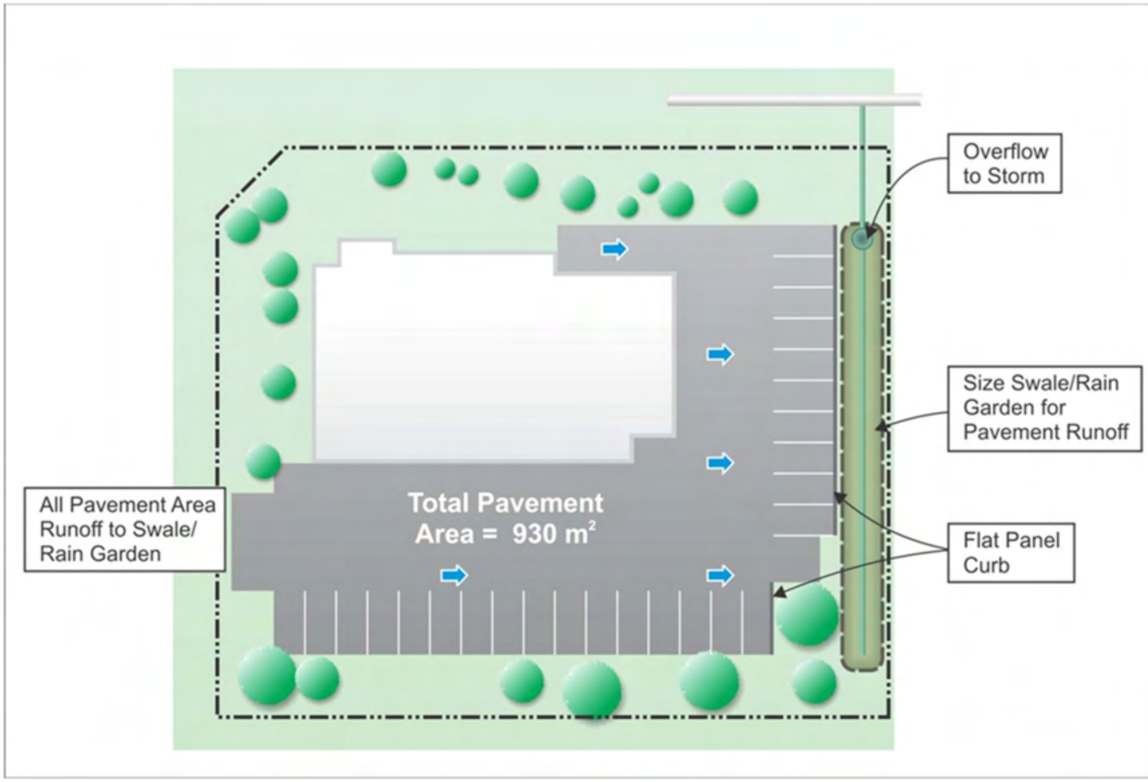


Figure 4-2: Example – Parking Area Draining to Rain Garden

The following parameters are known:

- Total pavement area = 930 m^2;
- Annual rainfall = 1200 mm;
- Native soil infiltration rate = 1.0 mm/hr;
- Parking use is more than one car per day; and
- Capture target is 90% of annual rainfall.

1. Determine the rain garden footprint area and rock trench depth and the rock trench volume.

4.10.2 Sizing

1. Determine the maximum rock depth based on the 4 day maximum drain time:

$$D_R = \frac{Ks \times T \times 24}{n} = \frac{1.0mm / hr \times 4days \times 24hr / day}{0.35} = 274mm$$

2. Use 300mm rock depth.

Table 4-1: Rain Garden Maximum I/P Ratios by Surface Type

Surface Type	Max I/P Ratio
General/Industrial Storage/Loading Areas	20:1
Divided or Undivided Major Road (Expressway or Highway)	20:1
Collector Road	20:1
Parking >1 Car/Day/Parking Space	20:1
Local Road	30:1
Parking <1 Car/Day/Parking Space	40:1
Low Traffic Areas/No Parking	40:1
Single Family Residential/Lot and Roof	30:1

3. Determine the maximum I/P ratio (see Table 4-A1). Parking use of more than one car per day yields a maximum I/P ratio of 20.

   Because the annual rainfall at the site falls between two sizing charts, the 1100 mm and 1600 mm, both will need to be used to interpolate the I/P ratio needed to meet the capture target.

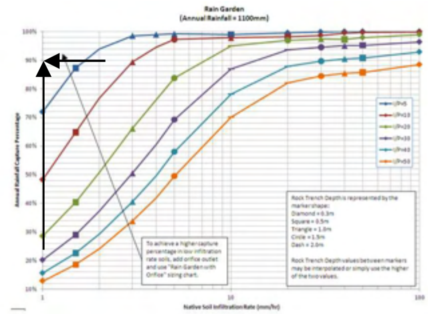


Figure 4-3: Sizing chart for Rain Garden (without orifice) for 1100 mm annual rainfall.

   As shown in the Rain Garden 1100 mm chart (Figure 4-3), the 90% capture and 1.0 mm/hr infiltration point plots above the I/P=5 curve. As noted on the chart, an orifice outlet is needed to meet this capture target at this site.

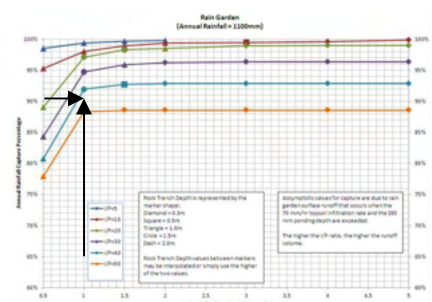


Figure 4-4: Sizing chart for Rain Garden with Orifice for 1100 mm annual rainfall.

   Using the Rain Garden with Orifice 1100 mm chart (Figure 4-4), the 90% capture and 1.0 mm/hr infiltration point plots between the I/P=40 and I/P=50 curves. Similarly, the Rain Garden with Orifice 1600 mm chart shows this point between the I/P=30 and I/P=40 curves.

   Because both charts show required I/P ratios larger than the maximum allowed (determined above to be I/P=20), the design I/P ratio should be 20. In both the Rain Garden with Orifice 1100mm and 1600mm charts, the circular marker on the I/P=20 curve indicates a 1.5 m rock trench depth. This is the depth of rock required above the subdrain for storage, so the total depth of rock for this facility is 1.8m (1.5 m + 0.3 m).

   The rain garden footprint area equals the pavement area divided by the I/P ratio (930 m2 / 20 = 47 m2).

   The rock volume below the overflow elevation is 70 m3 (47 m2 x 1.5 m).

4. The orifice outlet from the rain garden should be sized to deliver a maximum flow of:

$$Qo = \frac{Ks \times I}{360} = \frac{1.0mm/hr \times 0.093ha}{360} = 0.00026m3/s = 0.26L/s$$

Where:
Qo = Orifice flow at full rock trench conditions (m^3/s)
Ks = Saturated hydraulic conductivity of native soil (mm/hr)
I = Impervious area tributary to rain garden (ha)

4.11 Example Hydraulic Components

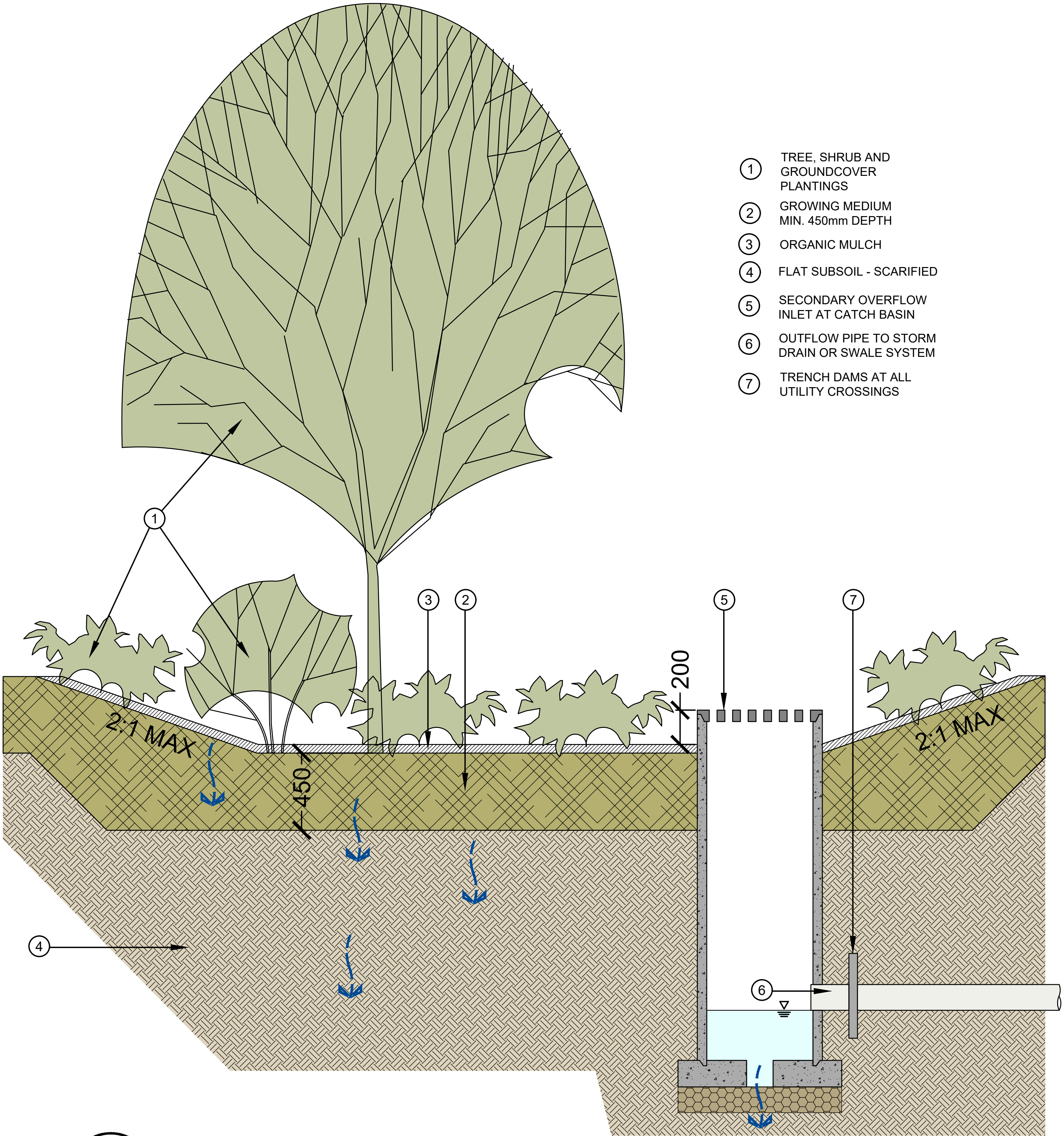
Inlet: Pavement runoff sheet flows over a panel curb into the rain garden.

Overflow: A surface inlet in the rain garden decants water that cannot infiltrate into the soil once the ponding reaches a depth of 200mm. The surface inlet is connected to the municipal storm sewer connection.

Subdrain: A perforated pipe located along the top of the rock layer decants excess water into the municipal storm sewer connection when the rock trench is full of water.

4.12 Example Operation and Maintenance Considerations

- Correct erosion problems as necessary. Ensure distributed sheet flow into the rain garden.
- Mow to keep grass in the active growth phase, remove clippings to prevent clogging of outlets, and remove trash and debris.
- Remove leaves each fall, inspect overflow, hydraulic and structural facilities annually.
- Replace dead plants as required.
- Surface inlet sump should be inspected annually and cleaned as required. Sediment should be removed from the sump bottom and floatables removed from the water surface.

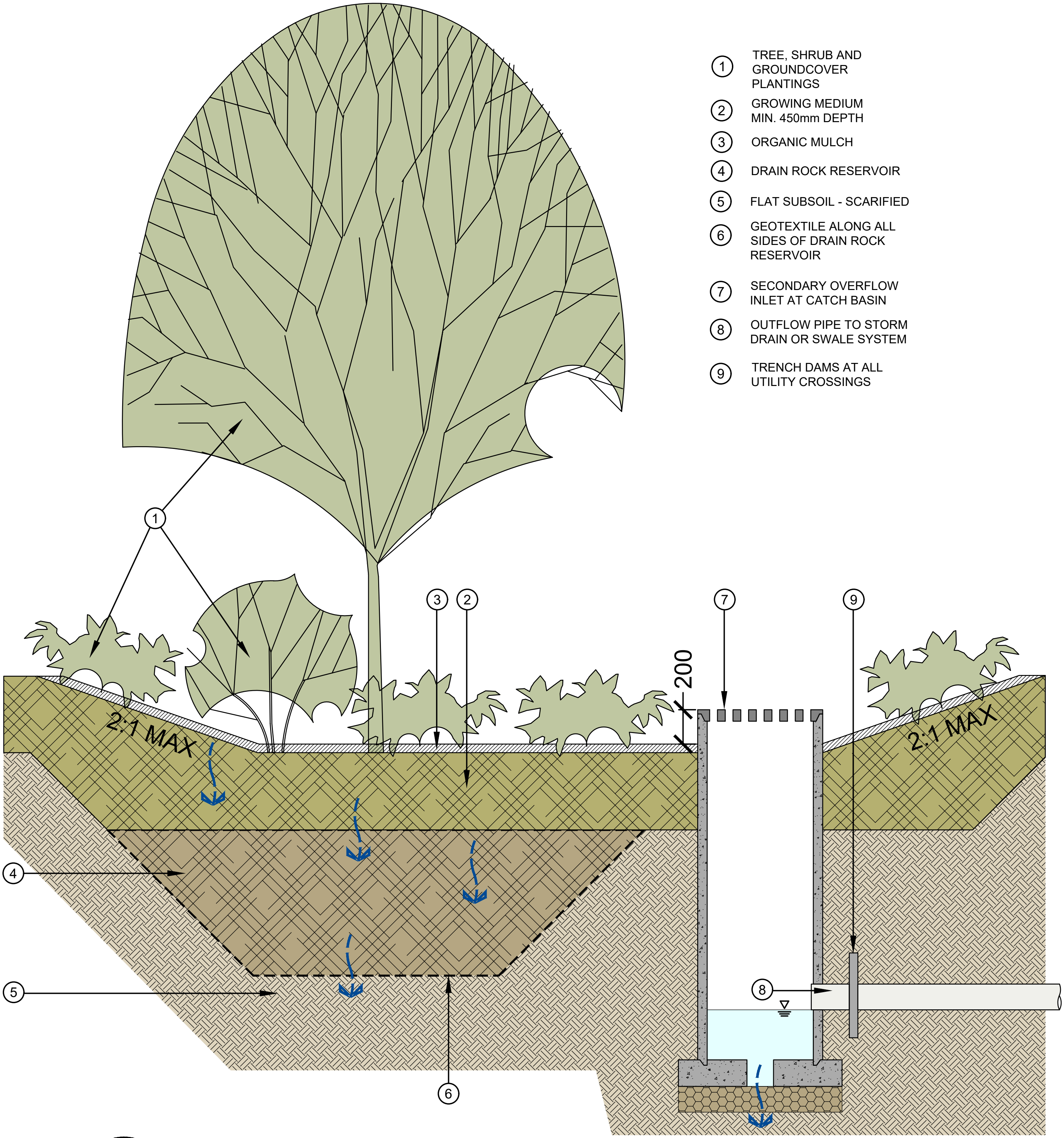


4
A

RAIN GARDEN - FULL INFILTRATION (NO RESERVOIR)

Not To Scale

Section

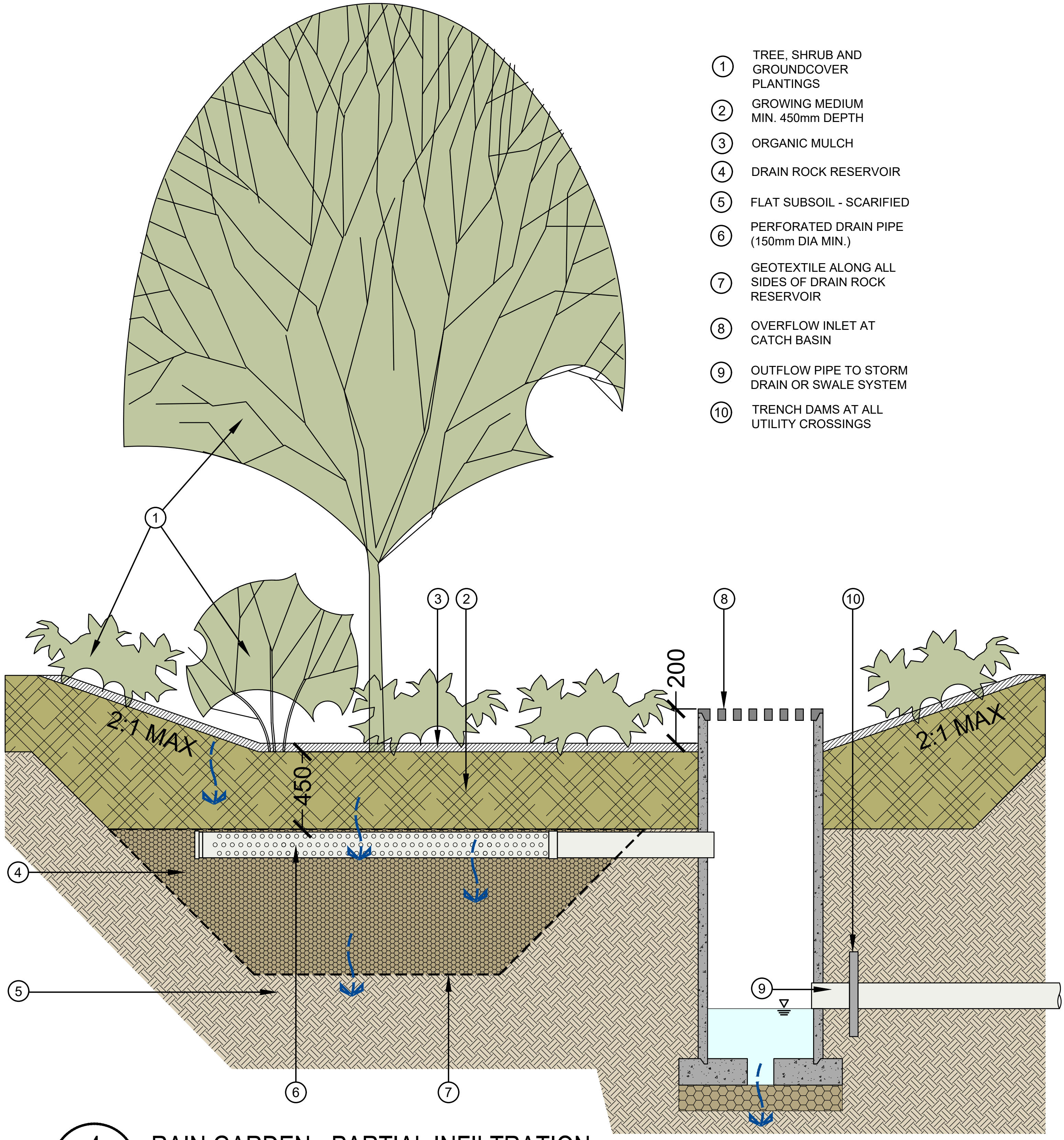


4
B

RAIN GARDEN - FULL INFILTRATION WITH RESERVOIR

Not To Scale

Section

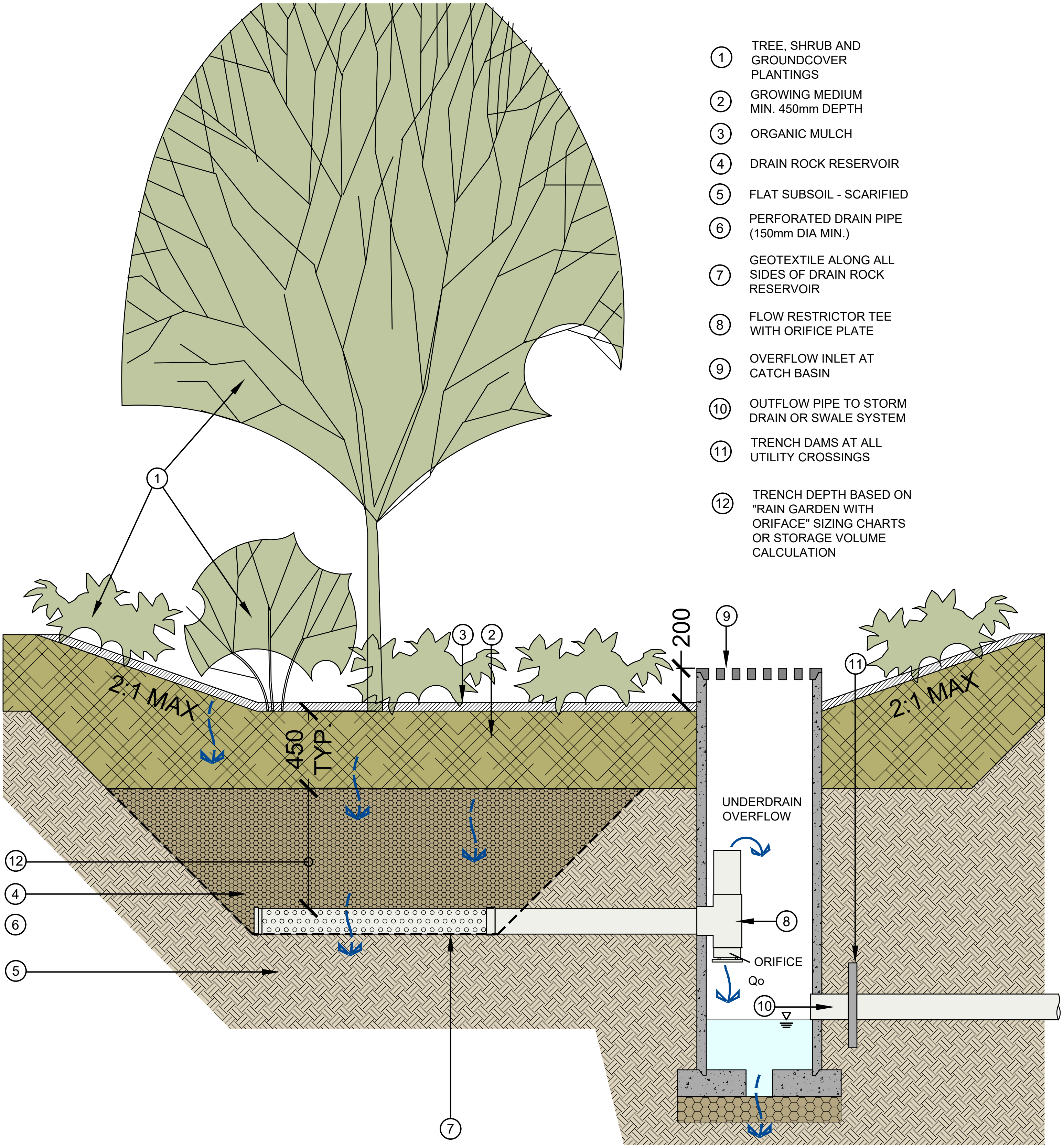


4 / C

RAIN GARDEN - PARTIAL INFILTRATION

Not To Scale

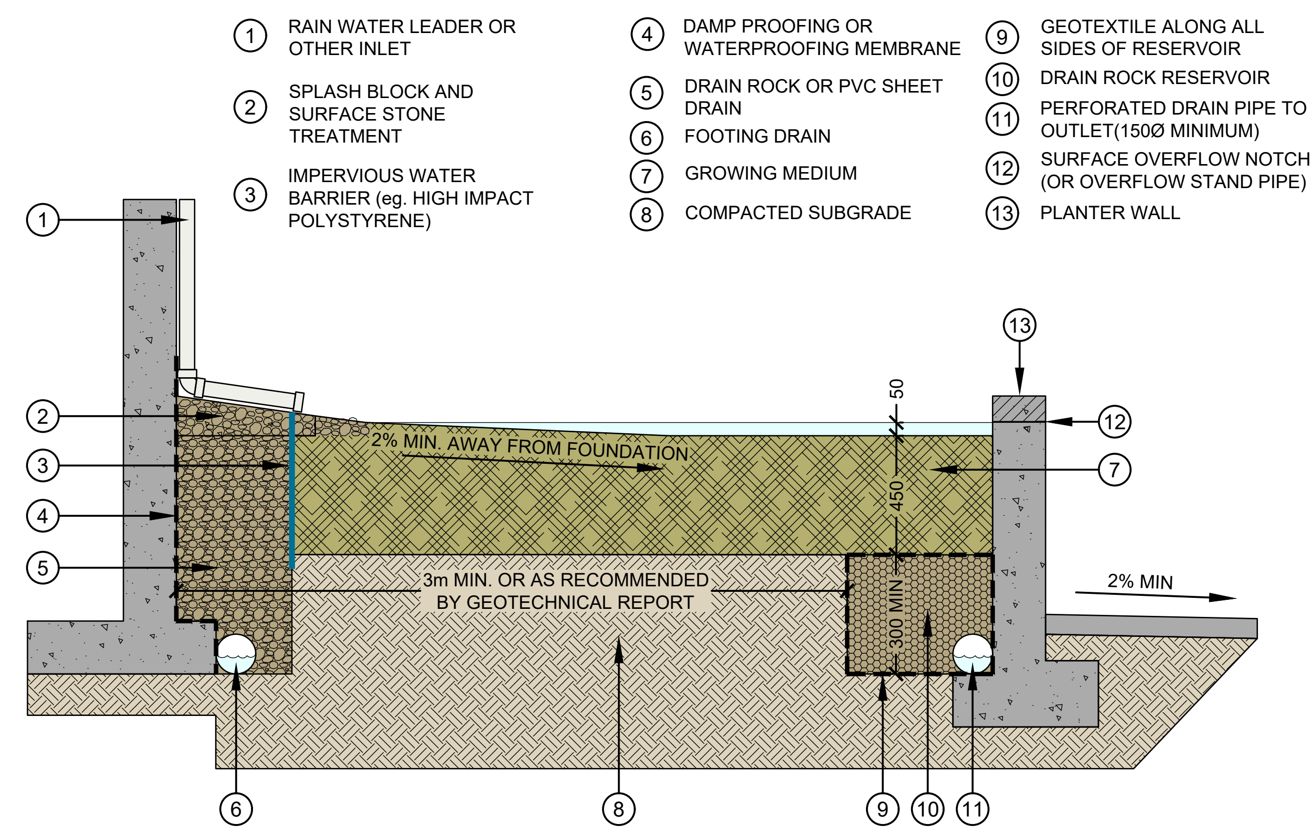
Section



4
D
RAIN GARDEN - PARTIAL INFILTRATION WITH FLOW RESTRICTOR

Not To Scale

Section



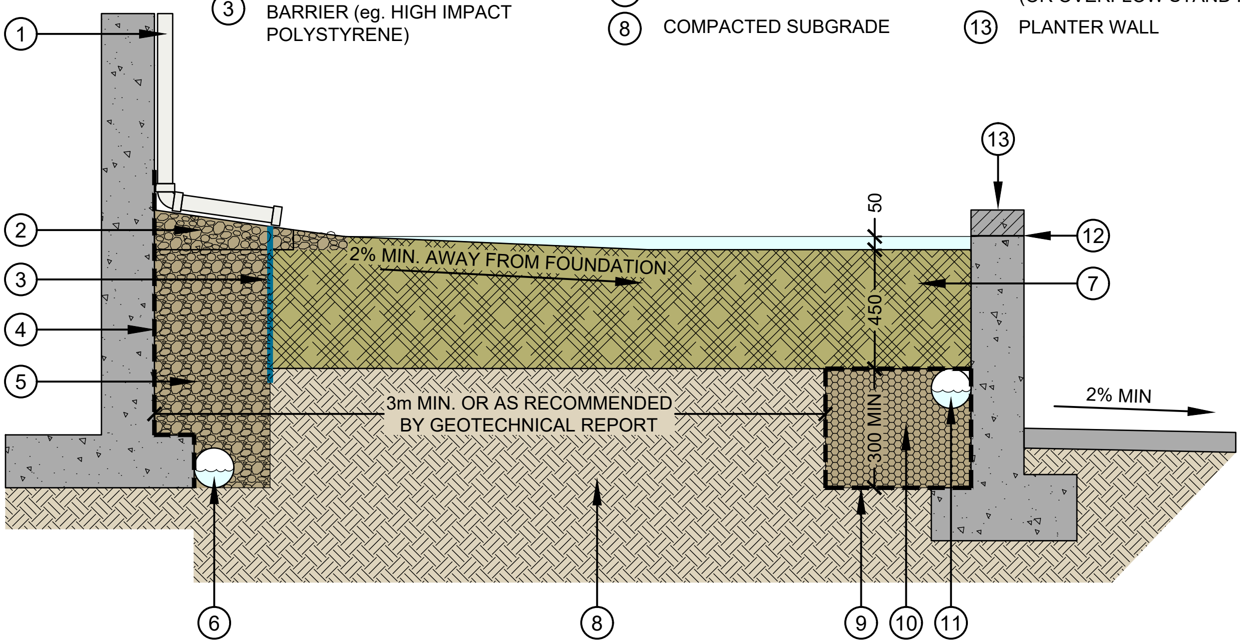
4
E

FLOW THROUGH PLANTER

Not To Scale

Section

1. RAIN WATER LEADER OR OTHER INLET
2. SPLASH BLOCK AND SURFACE STONE TREATMENT
3. IMPERVIOUS WATER BARRIER (eg. HIGH IMPACT POLYSTYRENE)
4. DAMP PROOFING OR WATERPROOFING MEMBRANE
5. DRAIN ROCK OR PVC SHEET DRAIN
6. FOOTING DRAIN
7. GROWING MEDIUM
8. COMPACTED SUBGRADE
9. GEOTEXTILE ALONG ALL SIDES OF RESERVOIR
10. DRAIN ROCK RESERVOIR
11. PERFORATED DRAIN PIPE TO OUTLET(150Ø MINIMUM)
12. SURFACE OVERFLOW NOTCH (OR OVERFLOW STAND PIPE)
13. PLANTER WALL



4 / F

INFILTRATION PLANTER

Not To Scale

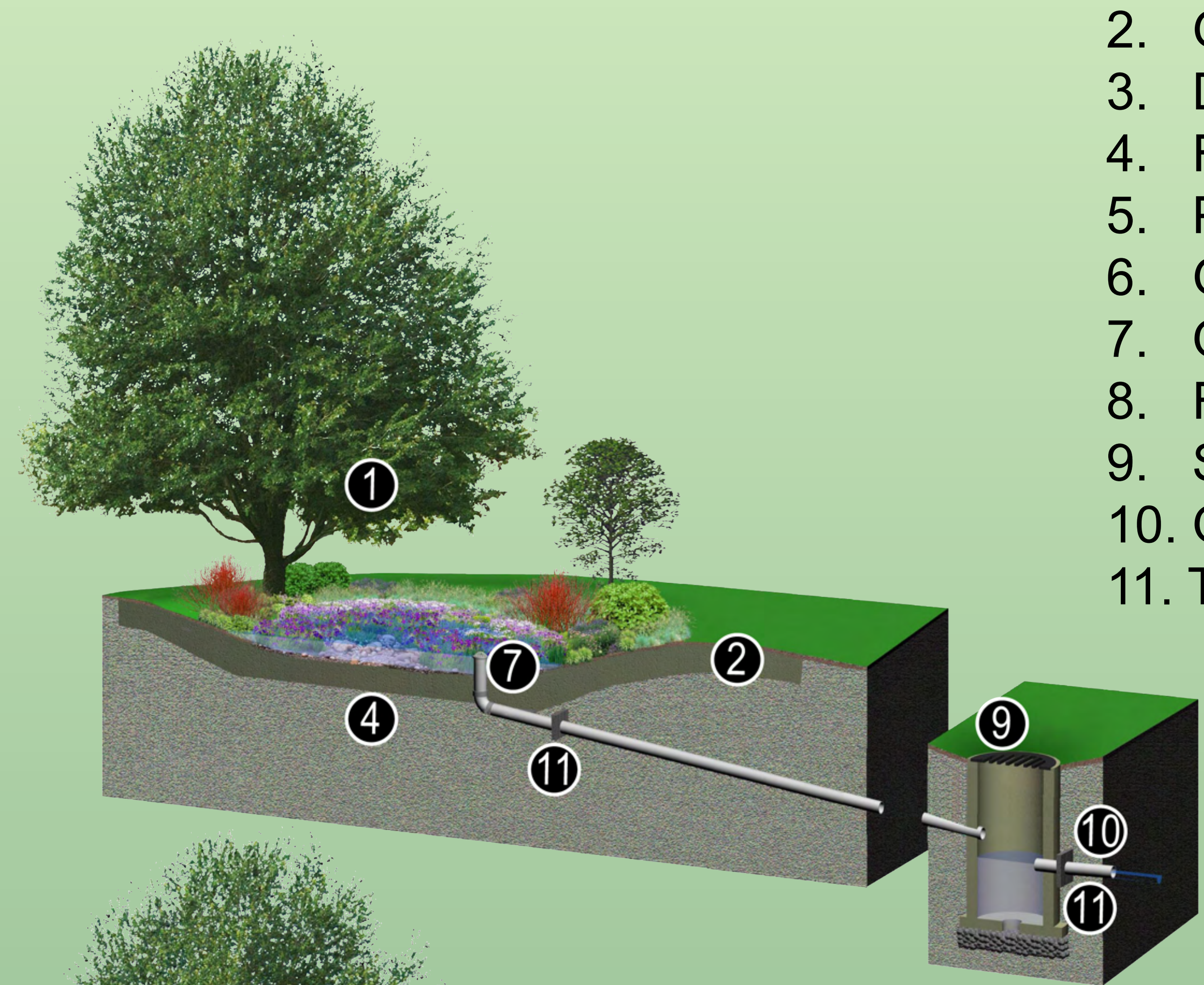
Section

DESIGN PRINCIPLES

- Literature suggests rain garden areas of about 10-20% of upstream impervious area. Higher sediment load land uses require lower ratios of impervious area to rain garden area.
- Smaller, distributed rain gardens are better than single large scale facilities.
- Locate rain gardens a minimum 30.5m from wells, 3m downslope of building foundations, and only in areas where foundations have footing drains and are not above steep slopes.
- Provide pretreatment and erosion control i.e. grass filter strip to avoid introducing sediment into the garden.
- At point-source inlets, install non-erodable material, sediment cleanout basins, and weir flow spreaders.
- Bottom width - 600mm (Min.) to 3000mm and length-width ratio of 2:1 desirable.
- Side slopes - 2:1 maximum, 4:1 preferred for maintenance. Ponding depth - 150 - 300mm.
- Draw-down time for maximum ponded volume - 72 hours.
- Treatment soil depth - 300mm (Min.) to 1200mm (desirable); use soils with minimum infiltration rate of 50mm/hr.
- Surface planting should be primarily trees, shrubs, and groundcovers, with planting designs respecting the various soil moisture conditions in the garden. Plantings may include rushes, sedges and grasses as well as lawn areas for erosion control and multiple uses.
- Apply a 50-75mm layer of organic mulch for both erosion control and to maintain infiltration capacity.
- Install a non-erodible outlet or spillway to discharge overflow.
- Avoid utility or other crossings of the rain garden. Where utility trenches must be constructed below the garden, install trench dams to avoid infiltration water following the utility trench.
- Drain rock reservoir and perforated drain pipe may be avoided where infiltration tests by a design professional show a subsoil infiltration rate that exceeds the inflow rate.

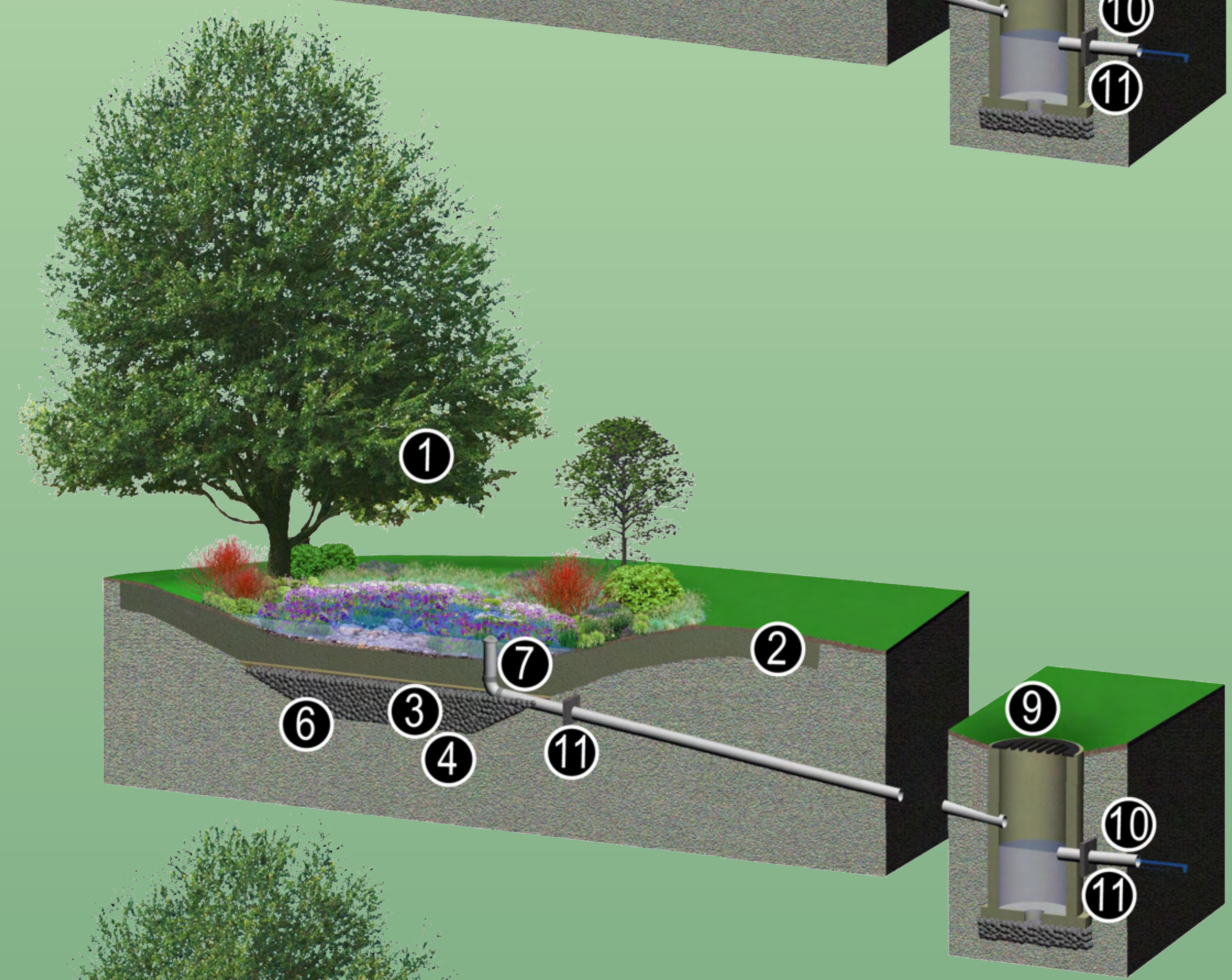
An **Infiltration Rain Garden** is a form of bioretention facility designed to have aesthetic appeal as well as a stormwater function. Rain gardens are commonly a concave landscaped area where runoff from roofs or paving infiltrates into deep constructed soils and subsoils below. On subsoils with low infiltration rates, Rain Gardens often have a drain rock reservoir and perforated drain system to convey away excess water.

1. Tree, Shrub and Groundcover Plantings
2. Growing Medium Minimum 450mm Depth
3. Drain Rock Reservoir
4. Flat Subsoil - scarified
5. Perforated Drain Pipe 150mm Dia. Min.
6. Geotextile Along All Sides of Drain Rock Reservoir
7. Overflow (standpipe or swale)
8. Flow Restrictor Assembly
9. Secondary Overflow Inlet at Catch Basin
10. Outflow Pipe to Storm Drain or Swale System
11. Trench Dams at All Utility Crossings



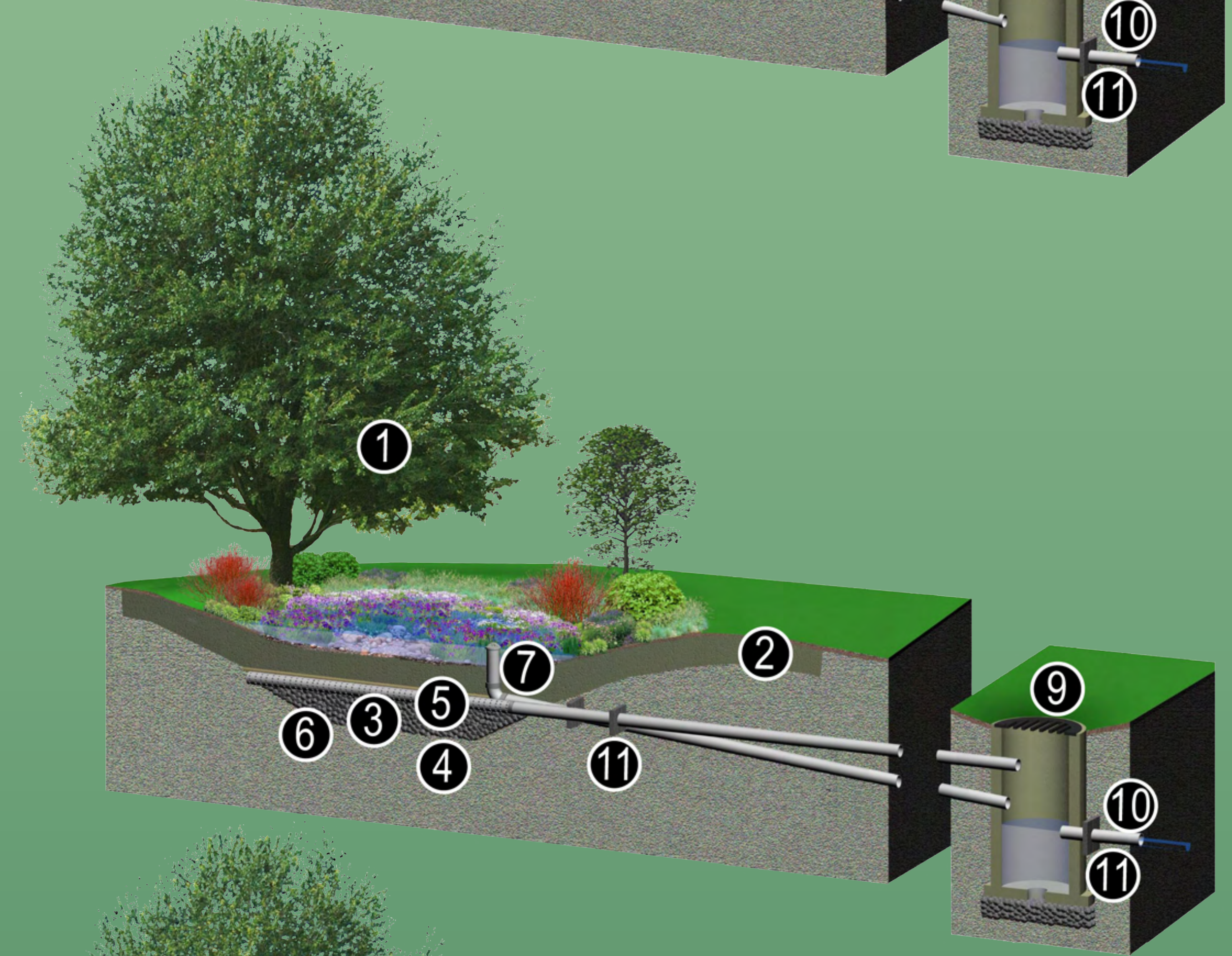
Full Infiltration

Where all inflow is intended to infiltrate into the underlying subsoil. Candidate in sites with subsoil permeability > 30mm/hr. An overflow for large events is provided by pipe or swale to the storm drain system.



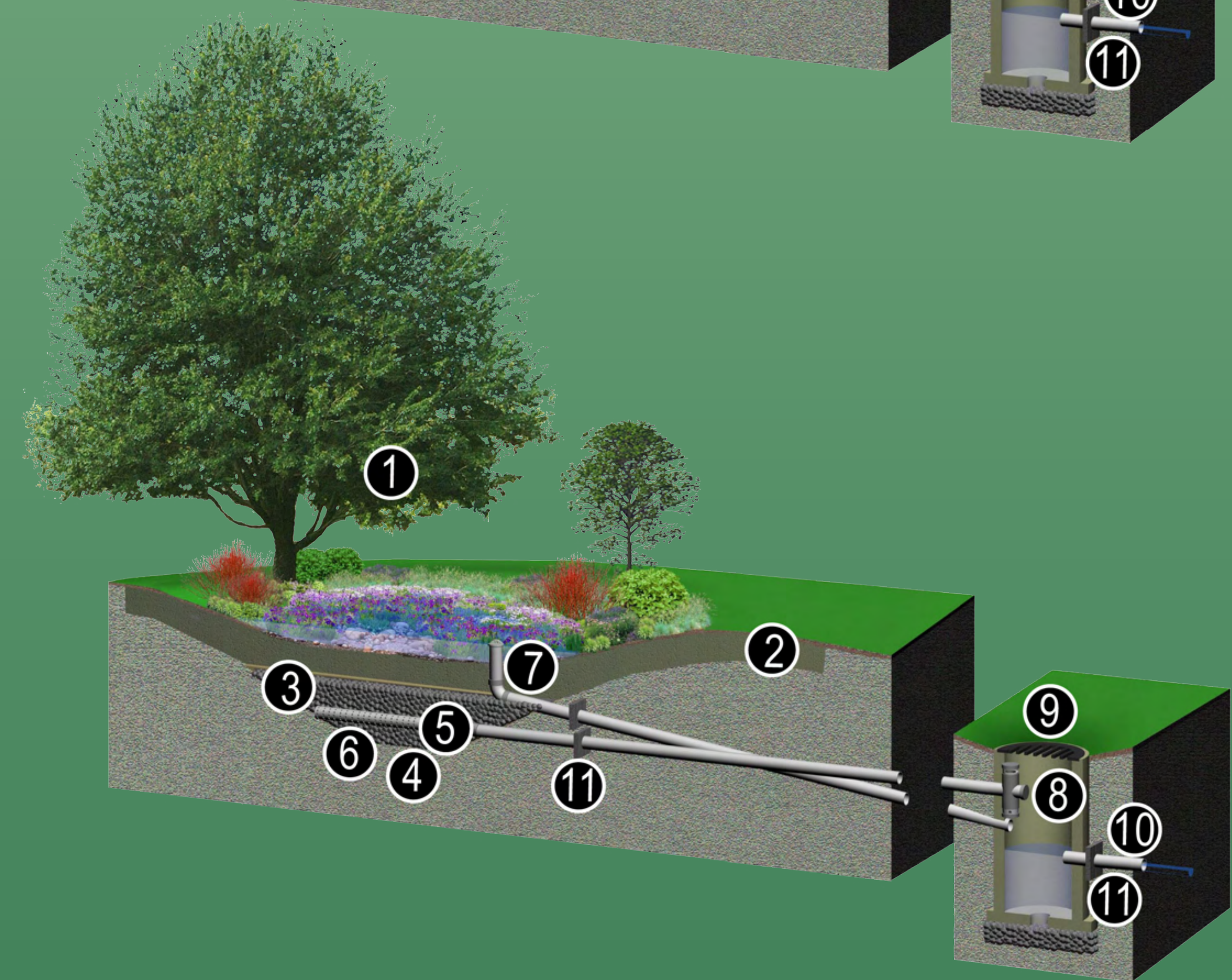
Full Infiltration with Reservoir

Adding a drain rock reservoir so that surface water can move quickly through the installed growing medium and infiltrate slowly into subsoils from the reservoir below. Candidate in sites with subsoil permeability > 15mm/hr.



Partial Infiltration

Designed so that most water may infiltrate into the underlying soil while the surplus overflow is drained by perforated pipes that are placed near the top of the drain rock reservoir. Suitable for sites with subsoil permeability > 1 and < 15mm/hr.



Partial Infiltration with Flow Restrictor

For sites with subsoil permeability < 5mm/hr, the addition of a flow restrictor assembly with a small orifice slowly decants the top portion of the reservoir and rain garden. Provides water quality treatment and some infiltration, while acting like a small detention facility.

Rain Garden

metrovancouver

LANARC CONSULTANTS LTD

kwl

Goya Ngan Landscape Architect

Stormwater Source Control Design Guidelines 2023

Detailed design guidelines can be found in the Design Guidelines 2012 report, available at www.metrovancouver.org

PERVIOUS PAVING

5 Pervious Paving

5.1 Description

Pervious paving is a surface layer of paving systems which allows rainfall to percolate into an underlying reservoir base, where rainfall is stored and either exfiltrated to underlying subgrade or discharged via a subdrain.

The surface component of pervious 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. There have been problems with surface clogging of this type of pavement;
- Concrete or plastic grid pavers, where a structural load bearing matrix has large voids that are filled with permeable material – usually gravel or soil – and may have grass growing in the void spaces; and

Plastic grid pavers in parking, White Rock Operations Centre.

(Photo Credit: Lanarc Consultants Ltd.)

- Permeable unit pavers, made up of impervious concrete modular pavers with gapped joints that allow water to percolate between the pavers.

The focus of this section is on the permeable unit pavers, as they have been used with consistent success and appear more resilient to clogging than porous paving alternatives. (James et al, 2003).

5.2 Selection and Application

- Pervious paving does not have a soil layer that treats runoff and is subject to clogging from surface pollutants. Pervious paving should not be used to infiltrate runoff from moderate- to high-traffic roads and parking areas that receive more than 1 vehicle per day per space. For pollutant-laden runoff, Absorbent Landscaping, Infiltration Swale or Rain Garden should be considered.
- It is suitable for low traffic areas – e.g., driveways, commuter parking areas,

Permeable unit paver parking lot at Mountain Equipment Co-Op, Surrey, BC.
(Photo Credit: Kerr Wood Leidal Associates Ltd.)

storage yards, bike paths, walkways, recreational vehicle pads, service roads, and fire lanes (GVSDD, 1999).

- Can receive runoff from other areas, if the tributary areas have low sediment loads or protection from sediment loads is provided (GVSDD, 1999). If the contributing impervious area is greater than 2 x the area of pervious paving (Formpave, 2003), alternative solutions such as Rain Gardens and Infiltration Trench should be considered.
- Grid pavers with soil and grass should be restricted to areas with evening parking (i.e., residential) or periodic day parking to allow sunshine to reach the grass during the daylight hours.
- Suitable for reduction in peak flows and runoff volumes, contaminant removal, and groundwater recharge (GVSDD, 1999).
- May be used to retrofit existing developments and redeveloping areas as well as in new developments (GVSDD, 1999).
- A greater design and construction control effort is required when compared with impermeable pavements (Smith, 2001).
- Types of permeable interlocking concrete pavements that have wide joints (some manufacturers) should not be used for disabled persons parking stalls or pedestrian ramps at street crossings (Smith, 2001).

Concrete grid paving parking lot, Netherlands
(Photo Credit: Lanarc Consultants Ltd.)

5.3 Design Guidelines for Permeable Interlocking Concrete Paving

Pervious pavement designs may be one of three types (Smith, 2001):

1. Full Infiltration – where all inflow is intended to infiltrate into the underlying subsoil (See Figure 5-A);
2. Partial Infiltration – designed so that some water may infiltrate into the underlying soil while the remainder is drained by perforated pipes (See Figure 5-B); and
3. Partial Infiltration with Flow Restrictor – designed with a perforated pipe and flow restrictor located at the bottom of the drain rock reservoir. A small orifice in the flow restrictor allows the gradual decanting of water above the perforated pipe, with infiltration occurring as much as possible. These systems are essentially underground detention systems and are used in cases where the underlying soil has low permeability or there is high water table (See Figure 5-C).

   This type of design is generally not needed if only upstream paved area is discharged to pervious paving at a ratio of 2:1 or less but could be used if roof water is discharged to permeable paving at more than 2:1 I/P ratio.

Permeable unit paving streetside parking in the Netherlands.
(Photo Credit: Lanarc Consultants Ltd.)

Pervious paving reservoir base.
(Photo Credit: Lanarc Consultants Ltd.)

5.3.1 Design Guidelines for all three types include the following:

1. Soil subgrade sampling and analysis should be provided by a professional engineer knowledgeable in the local soils. Testing of soil cores taken at the proposed area to be paved should include soil texture classification, sampled moisture content, 96-hour soaked California Bearing Ratio (CBR) with a target of at least 5% for light vehicular traffic, 15% for heavy vehicles, and on-site infiltration tests using a Double-Ring Infiltrometer taken at the elevation of the proposed base of the reservoir;

2. Minimum recommended tested infiltration rate for a full infiltration pavement design is 13 mm/hr. Sites with lower rates will require partial infiltration solutions with drain pipes, and care must be taken that the subbase will remain stable while saturated. (Smith, 2001);
3. At least 30m should be maintained between permeable pavements and water supply wells (Smith, 2001);
4. The pavement should be downslope from building foundations, and the foundations should have piped drainage at the footing (Smith, 2001);
5. To avoid surface plugging, it is critical to protect this BMP from sedimentation both during and after construction. In addition, identify pollutant sources, particularly in industrial/commercial hotspots, that require pre-treatment or source control upstream of this BMP (Maryland Dept. of the Environment, 2009);

Permeable paver walkway, Mountain Equipment Co-op, Surrey, BC.

(Photo Credit: Kerr Wood Leidal Associates Ltd.)

6. Where it is proposed to drain impermeable surfaces onto pervious pavement surfaces, it is recommended that a maximum ratio of 2:1 impermeable to permeable is used (Formpave, 2003). This may vary by rainfall and soil characteristics as determined by modelling;
7. For draining roof water to pervious pavers, much higher ratios of upstream impervious surface to pervious pavers, such as 50:1, may be used. Sediment loading potential of the upstream surface will determine allowable ratio;
8. Permeable Unit Pavers should be selected and designed based on a manufacturer's tests that the installed unit paving system can maintain a minimum 28mm/hr infiltration rate over the pavement life (usually 20 years). This rate includes a factor of safety of 10 – the initial infiltration rate should be >280mm/hr (Smith, 2001);
9. Permeable unit pavers are usually 80mm depth. Provide edge restraint to contain the pavers, similar to standard unit paving. Edge restraints that use spikes are not recommended (Smith 2001);
10. Permeable unit paving surface slope should be 1% minimum to avoid ponding on the surface, and related settlement of clay sized particles (Smith, 2001);
11. Provision of vegetated joints, and overhanging trees which drop needles onto the pavement have, in research studies, helped to maintain high infiltration capabilities of pervious unit paving (James et al., 2003). Vegetated joints are not suitable in heavily shaded areas such as under long-term parking;

12. Paver bedding material shall be wrapped with geotextile filter cloth on bottom and all sides (see Figure 5– – 5–C). 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;
13. Minimum depth from base of drain rock reservoir to water table or solid bedrock 600 mm (Smith, 2001);
14. Bottom of reservoir: flat in full infiltration designs, minimum 0.1% slope to drain in piped systems (Formpave, 2003);
15. If the pavement is being designed for heavy loads, optional reinforcing grids (geogrid) may be included in the pavement subbase;
16. With infiltration designs, the bottom and sides of all reservoir base and subbase courses shall be contained by a geotextile filter cloth. Geotextile shall be adhered to the drains (Formpave 2003);
17. Design reservoir water levels and stormwater detention using a continuous modelling program. Drawdown time for the reservoir: 96 hours maximum, 72–hours desirable;
18. If the design is for partial infiltration with a flow restrictor assembly, size the orifice for a design flow that meets local requirements or replicates base flow from the drainage area;
19. Provide a secondary overflow inlet and inspection chamber (catch basin or manhole) at the flow control assembly. If no secondary overflow inlet is installed, provide a non–erodible outlet or spillway to the major storm flow path. (Smith, 2001);
20. Underground weirs of undisturbed native material or constructed ditch blocks shall be provided to create underground pooling in the reservoir sufficient for infiltration performance; and
21. Avoid utility or other crossings of the pervious pavement area. Where utility trenches must be constructed crossing below the reservoir, install trench dams at exits to avoid infiltration water following the utility trench.

5.4 Pre–treatment Principles

In general, pervious pavers capture and treat only the rainfall which falls directly onto them, or a limited additional amount from adjacent areas (see above design I/P ratio) and do not require pre–treatment.

In the case where adjacent impervious area is directed onto pervious pavements, general pre–treatment principles are as follows:

1. Disperse stormwater runoff from adjacent surfaces by sheet flow onto permeable paving area;

2. Ensure there are no localized low points in adjacent surfaces that could concentrate run-on directed to the pervious paving area;
3. Pervious paving is particularly vulnerable to high sediment loading, which can occur when there is construction in the contributing drainage area or if a large portion of the contributing drainage area is vegetated. Pre-treatment should always be provided for runoff with high sediment loading. If pre-treatment cannot be provided, areas with high sediment loading should be prevented from draining onto pervious paving; and
4. Construction site runoff can contain high sediment loads that should be held onsite through Erosion and Sediment Control (ESC) measures. Onsite ESC should prevent all sediment laden runoff from flowing onto permeable pavements.

5.5 Pre-treatment Maintenance

Maintenance requirements include inspection of the pervious pavement to ensure surface infiltration capacity is maintained. When pervious paving is providing treatment for adjacent impervious areas, the zone which receives adjacent runoff may require more frequent maintenance and removal of sediment from the surface pavers.

Any sediment traps or erosion or upstream erosion sediment control measures should be regularly maintained and cleared of excess sediment to minimize the likelihood of high sediment loading onto the pervious paving area.

5.6 Maintenance

Pervious paving maintenance is often cited as a significant impediment to implementation. Successful maintenance programs for permeable pavement are essential to ensuring long-term performance and should be integrated into the design process. Maintenance is complicated by the variety of products available for pervious paving, which may have unique maintenance needs. Maintenance needs and strategies may also vary significantly between the two primary pervious paving technologies; porous asphalt and permeable pavers.

- Maintenance should be conducted on a semi-regular basis to prevent sediment from becoming deeply embedded within the pavement structure. If maintenance is neglected for a significant period of time, there is a high likelihood that sediments cannot be removed without replacing the pavers entirely.
- When conducted consistently, vacuum sweeping can effectively remove sediment from pervious paving but may be ineffective if maintenance is neglected for many years.
- Power washing pervious pavers can be highly effective at restoring performance but can be expensive and intrusive, requiring replacement of the filler material used between pavers. Power washing porous asphalt should be avoided as this can force sediment into the paver sub-base and accelerate clogging.

- See Chapter 11 – Maintenance Guideline for further details regarding maintenance tasks and frequency.

5.7 Sizing Pervious Paving

Sizing may be done using continuous simulation modeling in the WBM or SWMM or using spreadsheet design storm and water balance calculations. Where Pervious Paving forms part of a series of source controls, modeling of the multiple source controls should be used. Sizing for Pervious Paving alone is fairly straightforward and simplified sizing approaches have been developed that do not require water balance modeling or continuous simulation. Two sizing approaches are presented below for the two types of criteria used in BC.

In general, Pervious Paving is sized to infiltrate the rain that falls directly on it and runoff from a limited area of upstream impervious surface. The maximum ratio of impervious paved area to pervious paving area (I/P ratio) allowed will be 2:1. Pervious area refers to the Pervious Paving area and the I/P ratio will be zero (0) where no impervious area is directed to the Pervious Paving.

These sizing approaches do not apply to a partial infiltration reservoir and drain with flow restrictor under Pervious Paving.

Sizing presented here is for infiltration of rain water for "capture" and prevention of site runoff. Sizing and design according to this guidance will not provide adequate water quality treatment for runoff from high-vehicle-volume and other polluted surfaces. Sizing of treatment, when needed, must be performed separately.

5.7.1 Sizing Approach 1 – for Depth Capture Criteria: X mm in 24 hrs

1. Determine the maximum rock depth according to the drain time (4 days max.) and round down to the nearest 50 mm increment for constructability; allowable depth range is 300 to 1000 mm:

$$D_R = \frac{Ks \times T \times 24}{n}$$

   Where:
   D_R = Depth (thickness) of rock reservoir (mm)
   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
   T = allowable drain time (days)
   n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

2. Use the following equation to determine the base (bottom) area of Pervious Paving and rock reservoir required by finding the I/P ratio for the site:

$$I/P = \frac{24 \times Ks + D_R \times n}{R} - 1$$

   Where:
   I/P = Ratio of impervious tributary area to rain garden base area (unitless)
   R = Rainfall capture depth (mm)
   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)

D_R = Depth (thickness) of rock reservoir (mm)
n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

3. Check that the I/P ratio calculated is less than the maximum allowed (2:1). If it is not, the I/P ratio may be reduced by routing runoff from a portion of the contributing impervious area to another facility and the I/P ratio recalculated.

   To find the Pervious Paving area:

$$PerviousArea = \frac{\text{Impervious TributaryA rea}}{I / P}$$

5.7.2 Sizing Approach 2 – for % Capture of Average Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

1. Determine the average annual rainfall for the site. If unknown, refer to map in Appendix B of isohyetal lines showing average annual rainfall depths across the Metro Vancouver Region.
2. Consult the Pervious Paving chart (Figures B-10 through B-12) in Appendix B applicable for the site's location according to average annual rainfall: 1100mm (White Rock), 1600mm (Kwantlen, Surrey, and Vancouver), or 2100mm (North shore and Coquitlam); If between these values, choose the chart for the higher amount of rainfall or interpolate the result between the two bracketing charts.
3. Find the point on the chart matching the site's subsurface soil infiltration rate and the target % Capture and select the curve that is at or above (better capture) that point. The selected curve gives the I/P ratio required to meet the given % capture for the facility.
4. Check that the I/P ratio calculated is less than the maximum allowed (2:1). If it is not, the I/P ratio may be reduced by routing runoff from a portion of the contributing impervious area to another facility and the I/P ratio recalculated.

   To find the Pervious Paving area:

$$PerviousArea = \frac{\text{Tributary Impervious Area}}{\text{I/P}}$$

5. The shape of the points nearby on the selected curve indicate the depth (thickness) of the rock reservoir. The rock depth may be interpolated between two neighbouring values. Allowable rock depth range is 300 to 1000 mm.

5.8 Guideline Specifications

Materials shall meet Master Municipal Construction Document (MMCD) 2009 requirements, and:

1. Pavers: 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 an initial infiltration rate >280mm/hr. and a maintained >28mm/hr infiltration rate over the pavement life (usually 20 years) (Smith, 2001);

2. Paver bedding course (50mm thick) and joint filling material shall be open-graded crush 5mm aggregate (or ASTM No.8 – no sand). A surface finish of 3mm clean crush aggregate (or ASTM No 89) should be applied to the finish surface and brushed in (Formpave, 2003; Smith, 2001);
3. 3. Reservoir Base course shall be clean crushed stone graded from 5mm to 20mm (approximately 100mm deep or greater – varies with design) (Formpave, 2003). In cases where this finer base is not required for water quality treatment, the Reservoir Base may be the same material as the Reservoir Subbase;
4. Reservoir Subbase shall be clean crushed stone graded from 10mm to 63mm, with void space ratio >35% (or ASTM No. 57 – approximately 250mm deep or greater – varies with design) (Formpave, 2003; Smith 2001);
5. Pipe: PVC, DR 35, 150 mm min. diameter, with cleanouts. Practical depth of cover over the pipe may be a determinant in depth of base courses; and
6. Geosynthetics: as per Section 31-32-19, select for filter criteria or from approved local government product lists.

Construction Practices shall meet Master Municipal Construction Document 2009 requirements, and:

1. Isolate the permeable paving site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying the excavation of 300mm of material over the final subgrade of the pavement until after all sediment-producing construction in the drainage area has been completed (Maryland Dept. of the Environment, 2009);
2. The subgrade should be compacted to 95% standard proctor for walk/bike areas, and 95% modified proctor for vehicular areas. Remove and replace soft areas (Smith, 2001);
3. Scarify subgrade (native) soil prior to placement of filter cloth and aggregate to ensure the subsurface has sealed due to equipment or raindrops;
4. Prevent natural or fill soils from intermixing with the reservoir base, sub-base, or bedding courses and filter cloths. All contaminated stone aggregate and cloth must be removed and replaced (Smith, 2001);
5. Reservoir drain rock sub base and base courses shall be installed in 100 to 150mm lifts and compacted with at least 4 passes with a minimum 9 T steel drum roller (Smith, 2001);
6. When all base courses are compacted the surface should be topped with filter cloth and a layer of bedding aggregate, and the surface graded carefully to final slopes, as the bedding aggregate will compact down much less than sand. Unit pavers shall be placed tightly butt jointed according to manufacturers specifications. Blocks should be vibrated with a vibrating plated compactor.

Following a first pass, a light dressing of 3mm single size clean stone should be applied to the surface and brushed in, approximately 2 kg/m^2. Blocks should again be vibrated, and any debris brushed off (Formpave, 2003); and

7. For maintenance, the surface should be brushed at least twice a year with a mechanical suction brush (vacuum sweeper) – in the spring and in autumn after leaf fall (Formpave, 2003).

Pervious unit paving with aggregate joints at bike rack.
(Photo Credit: Lanarc Consultants)

5.9 Pervious Paving Design Example

5.9.1 Scenario Description

Pervious Paving is proposed to capture a portion of the runoff from a paved parking area (see illustration below).

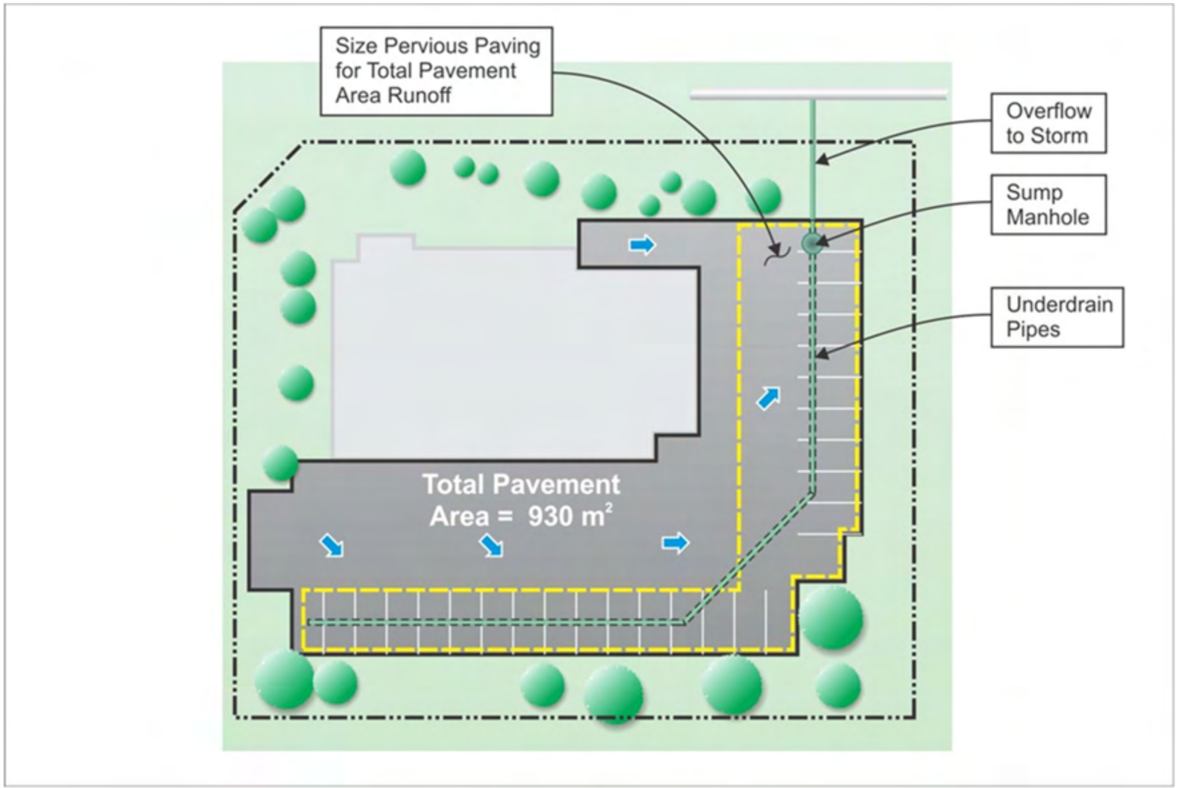


Figure 5–1: Example – Parking Area Draining to Pervious Paving

The following parameters are known:

- Total pavement area = 930 m^2;
- Annual rainfall = 2100 mm;
- Native soil infiltration rate = 2.0 mm/hr; and
- Capture target is 90% of annual rainfall.

Determine the pervious paving area and rock trench depth.

5.9.2 Sizing

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

1. Determine the maximum rock depth based on the 4 day maximum drain time:

$$D_R = \frac{Ks \times T \times 24}{n} = \frac{2.0mm/hr \times 4days \times 24hr/day}{0.35} = 548\,mm$$

The annual rainfall at the site is 2100 mm. Using the sizing chart from Appendix B the 90% annual rainfall capture and 2.0 mm/hr infiltration point falls near the I/P=1.2 ratio curve. At this point on the I/P=1.2 curve, the rock trench depth is indicated by the square marker shape as 0.5m.

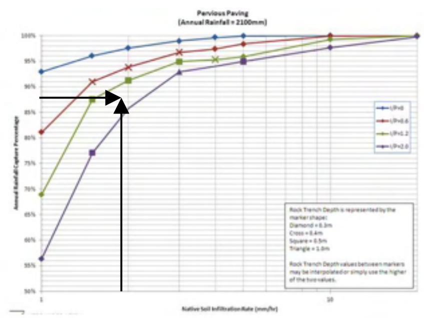


Figure 5-2: Sizing chart for 2100 mm annual rainfall.

2. Check that the rock trench depth is less than the maximum calculated above (0.5 m < 548 mm, therefore OK).

3. Calculate the pervious paving area:

$$PerviousArea = \frac{imperviousTributaryArea}{I/P}$$

$$PerviousArea = \frac{930sq.m. - PerviousArea}{1.2}$$

$$1.2 \times PerviousArea = 930\,sq.m. - PerviousArea$$

$$PerviousArea = \frac{930sq.m.}{2.2} = 423sq.m$$

5.9.3 Hydraulic Components

Inlet: The impervious pavement runoff sheet flows onto the pervious paving.

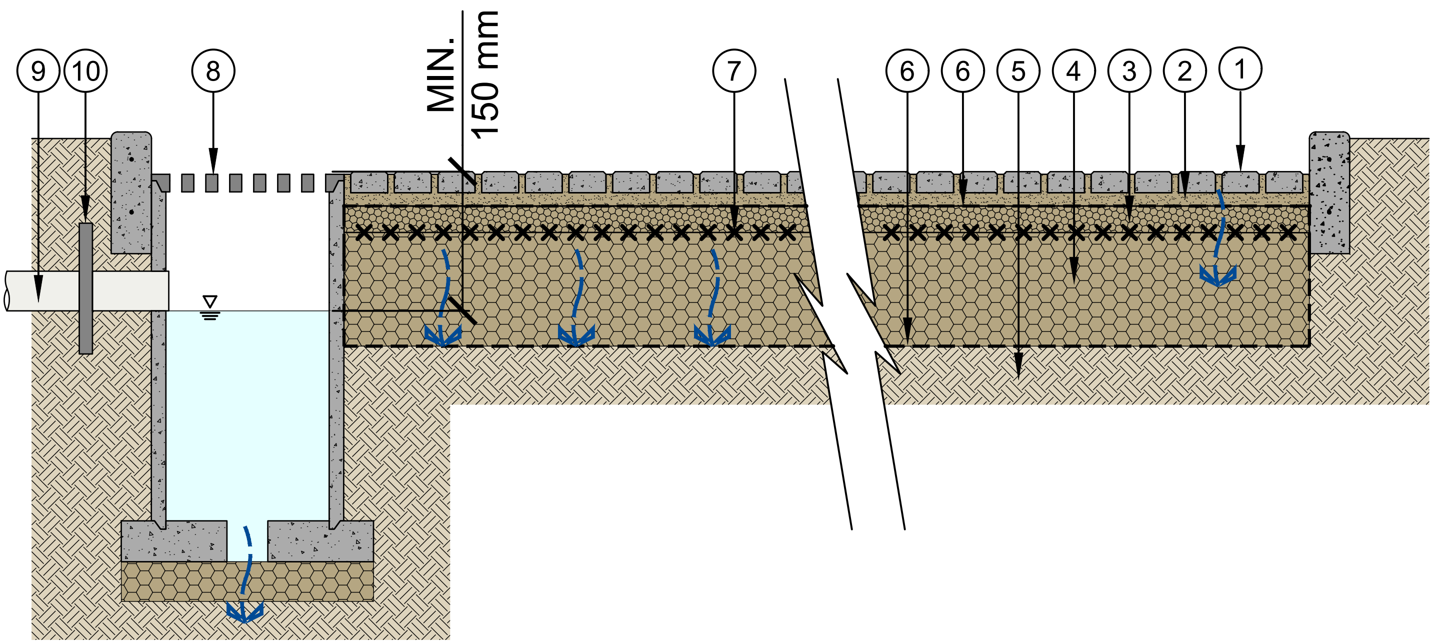
Overflow: The site grading and pavement grading must allow overland flow to the municipal major system (typically roadway surface) for any water that overwhelms the infiltration capacity of the pervious paving.

Underdrain: A perforated pipe located along the top of the rock layer decants excess water into a sump manhole when the rock trench is full of water. The sump is connected to the municipal storm sewer connection.

5.9.4 Maintenance

- Vacuum sweep the pervious paving annually to remove built up fines on the surface.
- Underdrain sump should be inspected annually and cleaned as required. Sediment should be removed from the sump bottom.

1. PERMEABLE PAVERS (MIN. 80mm THICKNESS)
2. AGGREGATE BEDDING COURSE -NOT SAND (50mm DEPTH)
3. OPEN GRADED BASE (DEPTH VARIES BY DESIGN APPLICATION)
4. OPEN GRADED SUB-BASE (DEPTH VARIES BY DESIGN APPLICATION)
5. SUBSOIL - FLAT AND SCARIFIED IN INFILTRATION DESIGNS
6. GEOTEXTILE ON ALL SIDES OF RESERVOIR
7. OPTIONAL REINFORCING GRID FOR HEAVY LOADS
8. OVERFLOW INLET AT CATCH BASIN
9. OUTLET PIPE TO STORM DRAIN OR SWALE SYSTEM. LOCATE CROWN OF PIPE BELOW OPEN GRADED BASE (NO. 3) TO PREVENT HEAVING DURING FREEZE/THAW CYCLE
10. TRENCH DAMS AT ALL UTILITY CROSSINGS



5 / A

PERVIOUS PAVING - FULL INFILTRATION

Not To Scale

Section

1 PERMEABLE PAVERS (MIN. 80mm THICKNESS)

2 AGGREGATE BEDDING COURSE -NOT SAND (50mm DEPTH)

3 OPEN GRADED BASE (DEPTH VARIES BY DESIGN APPLICATION)

4 OPEN GRADED SUB-BASE (DEPTH VARIES BY DESIGN APPLICATION)

5 SUBSOIL - FLAT AND SCARIFIED IN INFILTRATION DESIGNS

6 GEOTEXTILE ON ALL SIDES OF RESERVOIR

7 OPTIONAL REINFORCING GRID FOR HEAVY LOADS

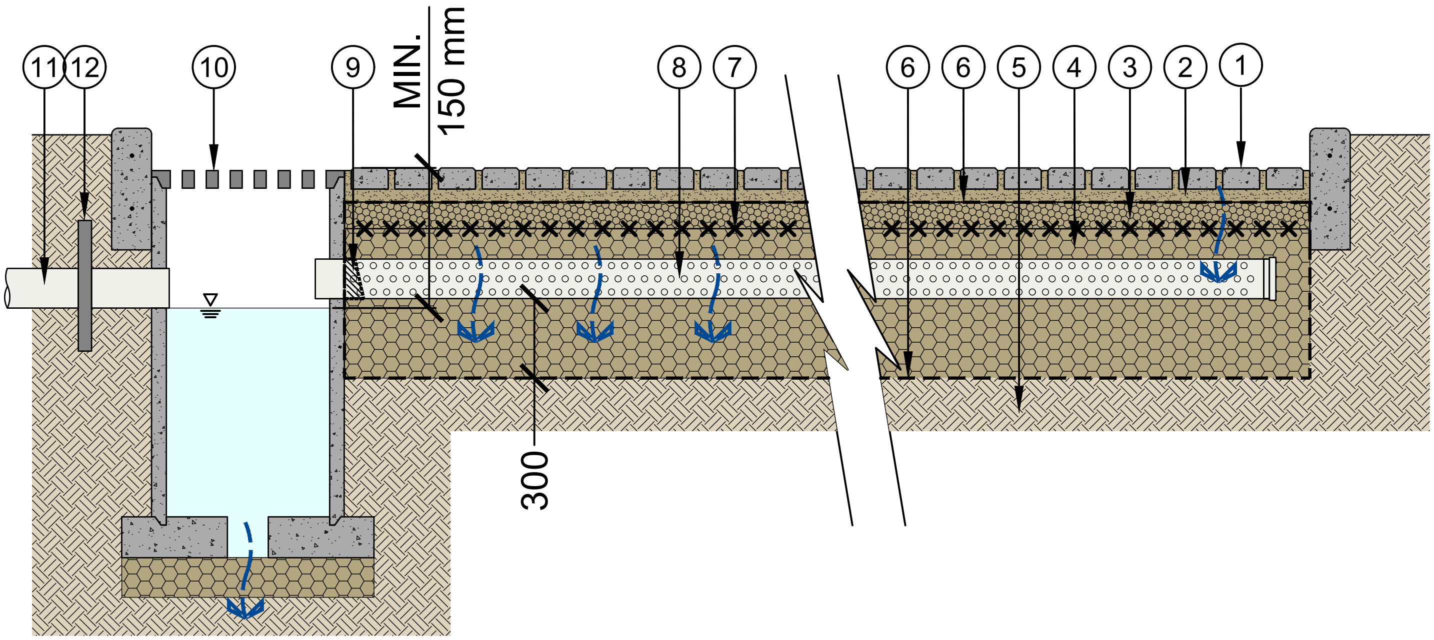
8 PERFORATED DRAIN PIPE 150mm DIA MIN.

9 GEOTEXTILE ADHERED TO DRAIN AT OPENING

10 OVERFLOW INLET AT CATCH BASIN

11 OUTLET PIPE TO STORM DRAIN OR SWALE SYSTEM. LOCATE CROWN OF PIPE BELOW OPEN GRADED BASE (NO. 3) TO PREVENT HEAVING DURING FREEZE/THAW CYCLE

12 TRENCH DAMS AT ALL UTILITY CROSSINGS



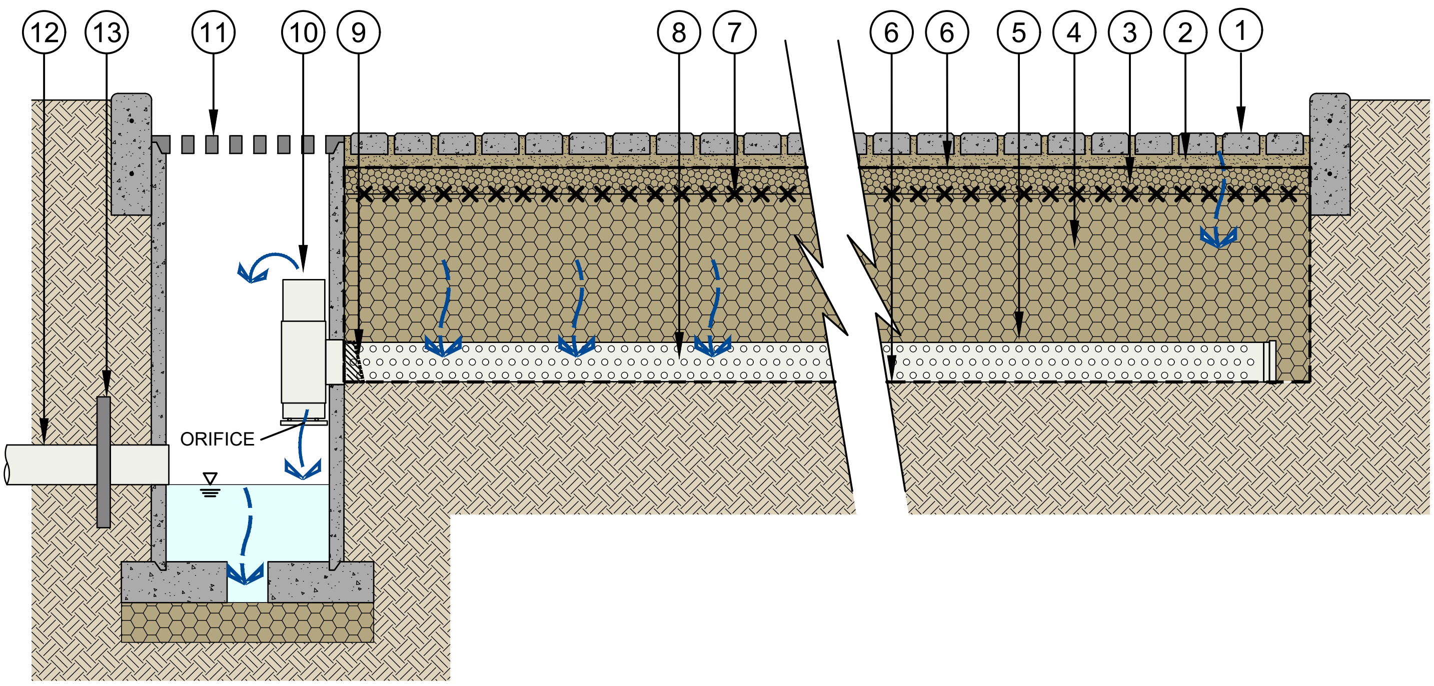
5 / B

PERVIOUS PAVING - PARTIAL INFILTRATION

Not To Scale

Section

1. PERMEABLE PAVERS (MIN. 80mm THICKNESS)
2. AGGREGATE BEDDING COURSE -NOT SAND (50mm DEPTH)
3. OPEN GRADED BASE (DEPTH VARIES BY DESIGN APPLICATION)
4. OPEN GRADED SUB-BASE (DEPTH VARIES BY DESIGN APPLICATION)
5. SUBSOIL - FLAT AND SCARIFIED IN INFILTRATION DESIGNS
6. GEOTEXTILE ON ALL SIDES OF RESERVOIR
7. OPTIONAL REINFORCING GRID FOR HEAVY LOADS
8. PERFORATED DRAIN PIPE 150mm DIA MIN.
9. GEOTEXTILE ADHERED TO DRAIN AT OPENING
10. FLOW RESTRICTOR ASSEMBLY
11. OVERFLOW INLET AT CATCH BASIN
12. OUTLET PIPE TO STORM DRAIN OR SWALE SYSTEM. LOCATE CROWN OF PIPE BELOW OPEN GRADED BASE (NO. 3) TO PREVENT HEAVING DURING FREEZE/THAW CYCLE
13. TRENCH DAMS AT ALL UTILITY CROSSINGS



5 / C

PERVIOUS PAVING - PARTIAL INFILTRATION WITH FLOW RESTRICTOR

Not To Scale

Section

DESIGN PRINCIPLES

- Pervious paving is most suitable for low traffic areas – driveways, parking areas(maximum 1 - 2 vehicles per day per parking space), walkways, recreational vehicle pads, service roads, fire lanes.
- The ratio of impermeable surface area draining onto pervious pavement area should be ratio 2:1 maximum.
- To avoid surface plugging, it is critical to protect pervious paving from sedimentation during and after construction.
- Identify pollutant sources, particularly in industrial/ commercial hotspots, that require pre-treatment or source control upstream.
- For designs which rely entirely on infiltration into underlying soils, the infiltration rate should be 15mm/hr minimum.
- Soil subgrade analysis should include soil texture class, moisture content, 96 hour soaked California Bearing Ratio (CBR) and on-site infiltration tests at the elevation of the base of the reservoir.
- Surface slope should be 1% minimum to avoid ponding and related sediment accumulation.
- Wrap paver bedding material with geotextile filter cloth on bottom and sides to maintain water quality performance and keep out intrusion of fines.
- Provide edge restraint to contain pavers, similar to standard unit paving.
- Design reservoir water levels using continuous flow modelling. Drawdown time - 96 hrs max., 72 hrs desirable.
- Bottom of reservoir: flat in full infiltration designs, minimum 0.1% slope to drain in piped systems.
- Where utility trenches must be constructed below the reservoir, install trench dams at exits to avoid infiltration water following the utility trench.
- Pavers with wide joints should not be used for disabled persons parking or pedestrian ramps at street crossings.
- If being designed for heavy loads, optional reinforcing grids may be included in the pavement subbase.

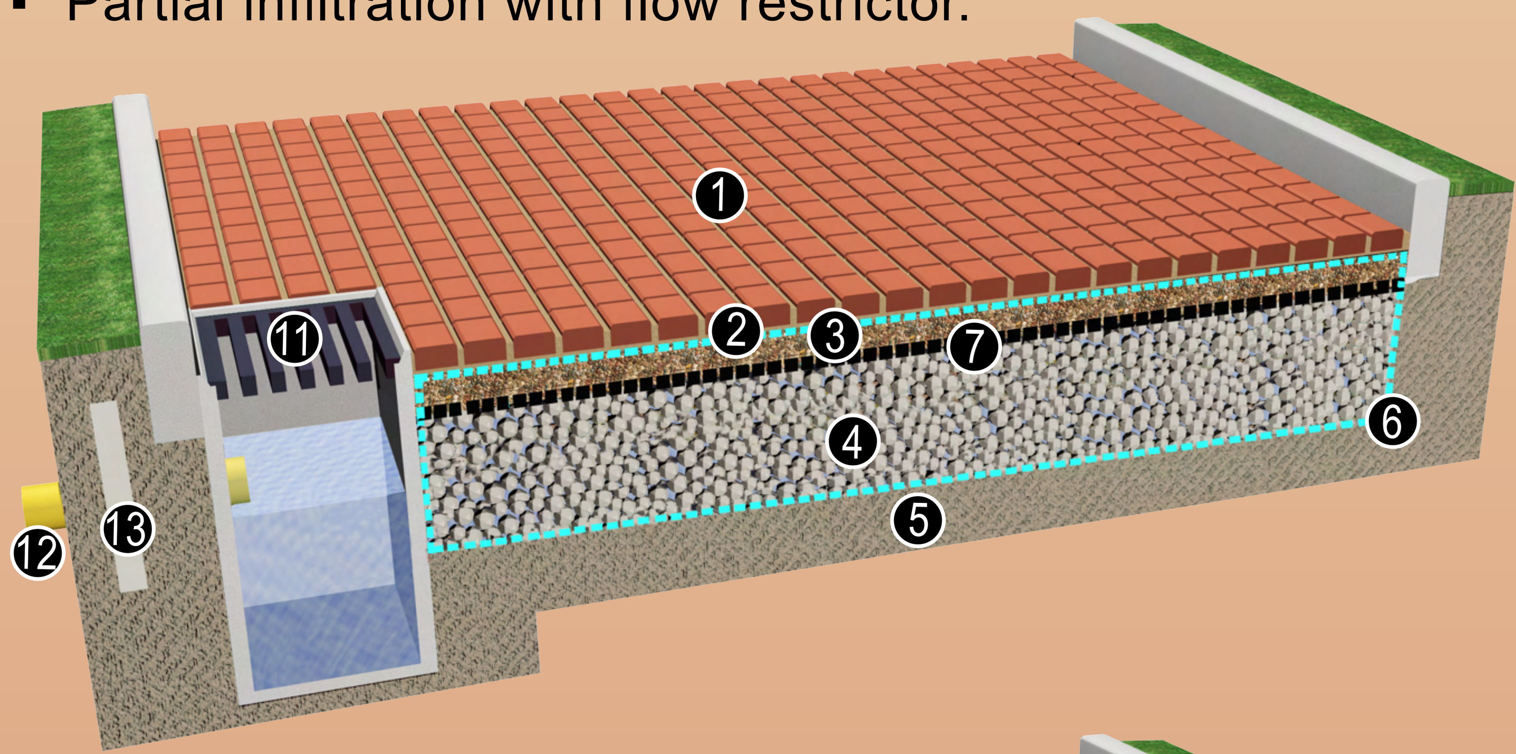



Pervious paving is a surface layer that allows rainfall to percolate into an underlying reservoir base where rainfall is either infiltrated to underlying soils or removed by a subsurface drain. The surface component of pervious paving can be:

- Porous asphalt or porous concrete.
- Concrete or plastic grid structures filled with unvegetated gravel or vegetated soil,
- Concrete modular pavers with gapped joints that allow water to percolate through.

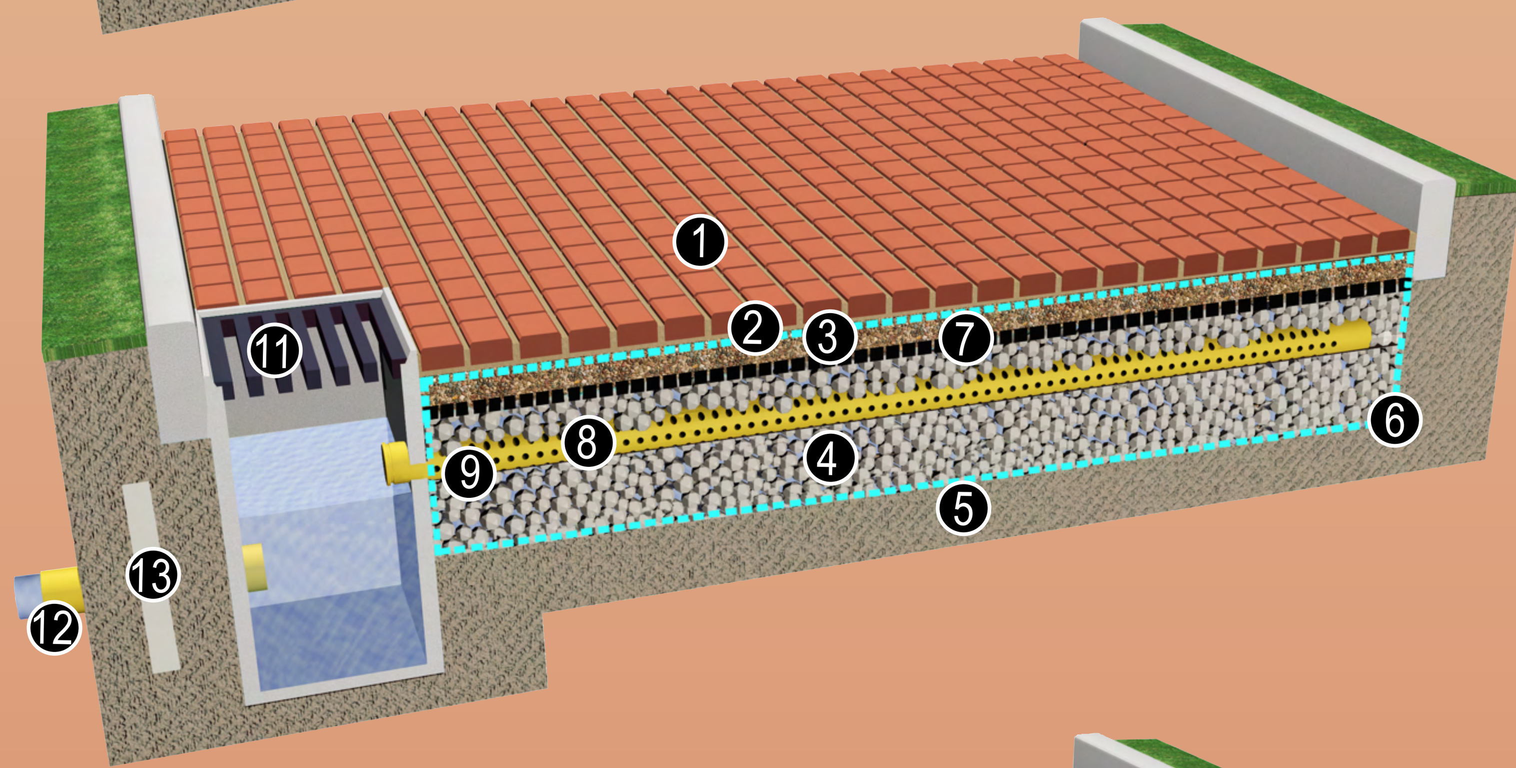
Pervious pavement designs may be one of three types:

- Full infiltration.
- Partial infiltration.
- Partial infiltration with flow restrictor.



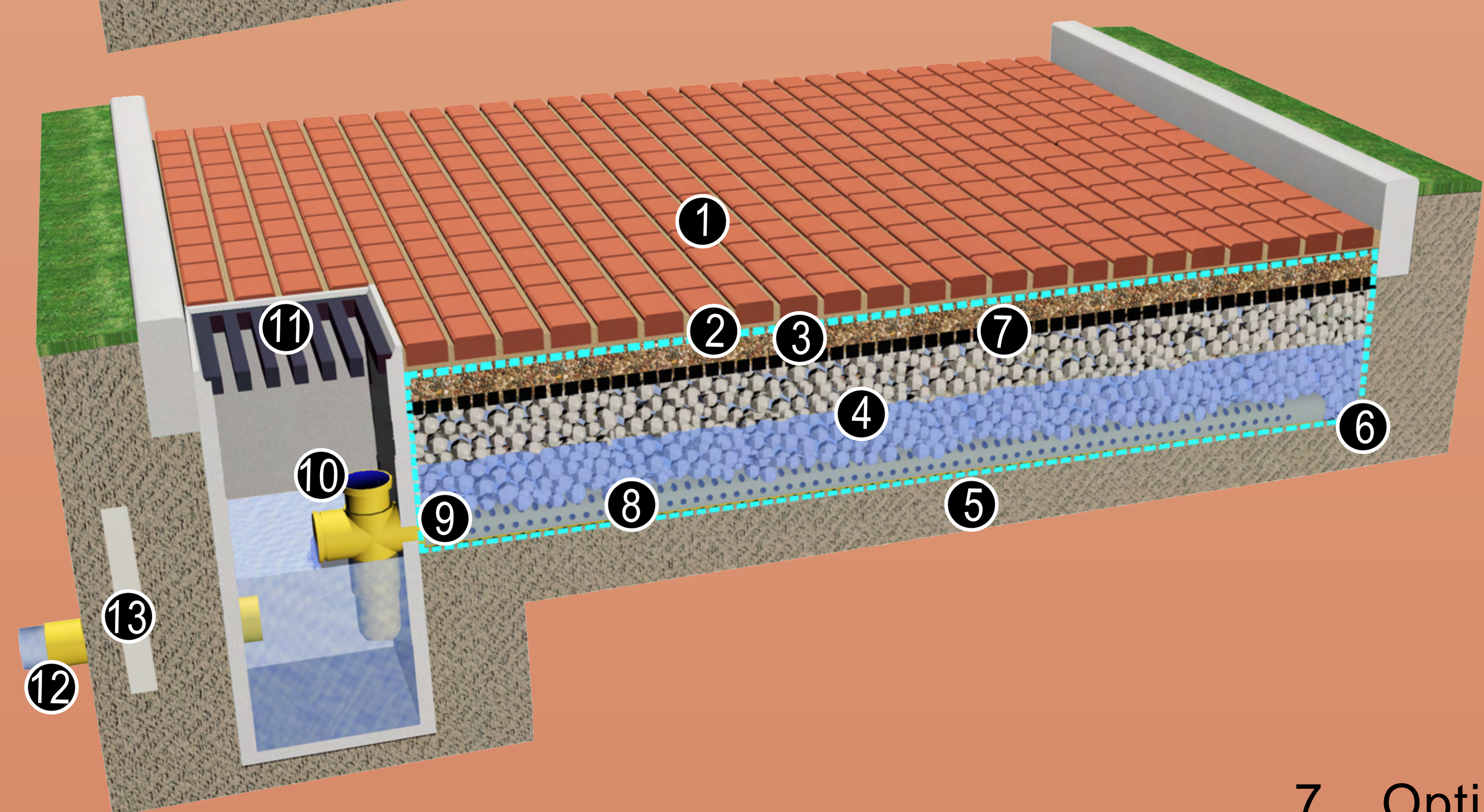
Full Infiltration

Where rainfall is intended to infiltrate into the underlying subsoil. Candidate in sites with subsoil permeability > 15mm/hr.



Partial Infiltration

Designed so that most water may infiltrate into the underlying soil while the surplus overflow is drained by perforated pipes that are placed near the top of the drain rock reservoir. Suitable for subsoil permeability >1 and < 15mm/hr.



Partial Infiltration with Flow Restrictor

Where subsoil permeability is < 1mm/hr, water is removed at a controlled rate through a bottom pipe system and flow restrictor assembly. Systems are essentially underground detention systems, used where the underlying soil has very low permeability or in areas with high water table. Also provides water quality benefits. However this should not be needed if I/P≤ 2.

1. Permeable Pavers (Min. 80mm thickness)
2. Aggregate Bedding Course - not sand (50mm depth)
3. Open Graded Base (depth varies by design application)
4. Open Graded Sub-base (depth varies by design application)
5. Subsoil - flat and scarified in infiltration designs
6. Geotextile on All Sides of Reservoir
7. Optional Reinforcing Grid for Heavy Loads
8. Perforated Drain Pipe 150mm Dia. Min.
9. Geotextile Adhered to Drain at Opening
10. Flow Restrictor Assembly
11. Secondary Overflow Inlet at Catch Basin
12. Outlet Pipe to Storm Drain or Swale System. Locate Crown of Pipe Below Open Graded Base (no. 3) to Prevent Heaving During Freeze/Thaw Cycle
13. Trench Dams at All Utility Crossings

Pervious Paving

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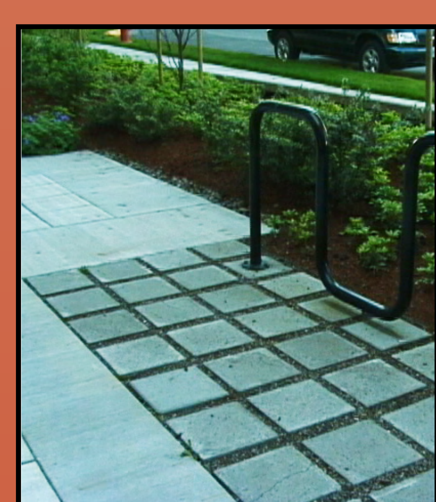
Stormwater Source Control Design Guidelines 2023



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Goya Ngan Landscape Architect

Detailed design guidelines can be found in the Design Guidelines 2012 report, available at www.metrovancouver.org

GREEN ROOF AND BLUE-GREEN ROOF

6 Green Roof and Blue-Green Roof

6.1 Description

Green roofs and blue-green roofs provide management of rainwater that falls on a building roof before it leaves the roof, reducing the need for source controls in the ground space outside of a building footprint. This makes them particularly useful for high density urban areas where space is at a premium.

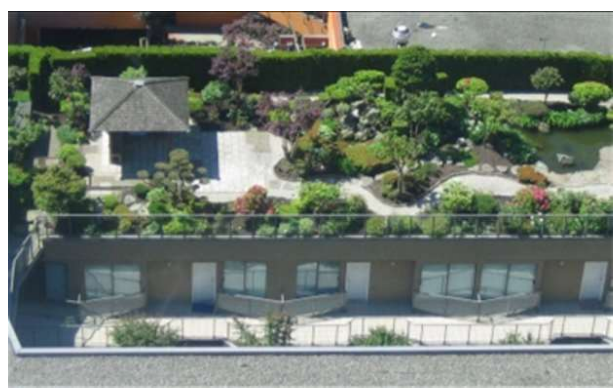
A green roof consists of a waterproof membrane and layers of drainage and growing medium that support living vegetation. They can cover all or part of a building roof and can include variations such as roof-top gardens that are focussed on growing food or ornamental plants.

Green roofs with a relatively shallow growing medium thickness (less than 300 mm) are generally called 'Extensive Green Roofs'. They may be designed for stormwater management, insulation, and climate amelioration functions, and usually have no public access. Vegetation is selected for its ability to withstand harsh conditions and its ability to maintain itself over the long-term.

'Intensive Green Roofs' are usually designed with public access and use in mind and have deeper growing medium depths (greater than 300 mm) to support larger plants and trees. Intensive green roofs also provide stormwater benefits but are heavier and more expensive to develop and maintain.

Extensive green roofs are far more common world-wide, and this section is focused on the stormwater aspects of Extensive Green Roofs.

A blue-green roof is a variety of green roof where there is a storage layer with a controlled outlet incorporated in the design to provide attenuation of flow, i.e., detention, on the roof itself for the rain that falls on the roof. A blue-green roof provides all the benefits of a green roof, with the addition of storage and rate control of roof runoff.



Intensive Green Roof in downtown Vancouver.

(Photo Credit: Kerr Wood Leidal Associates Ltd.)

6.2 Applications

- Suitable for many rooftop situations – industrial and warehousing, commercial buildings, municipal office complexes, hospitals, schools, institutional/ administrative buildings and offices, residential developments, and garages.

Extensive Green Roof on the Vancouver Public Library.
(Photo Credit: Kerr Wood Leidal Associates Ltd.)

- Suitable for flat roofs and, with specialized design, roofs of up to 20º slope (Peck & Kuhn, 2001). Roofs may be inverted or traditional flat roofing systems, but shingle and tile roofs are not suitable for greening (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V (FLL), 2002).
- Green roofs and blue-green roofs provide multiple benefits, including:
  - Reduction in stormwater peak flows; smaller winter event peak flows were attenuated 30% in monitoring of the Vancouver Public Library green roof (Johnston, 2004). Blue-green roofs can provide even greater peak flow attenuation, incorporating enough storage to meet municipal detention requirements if the structural design can accommodate the weight of the water.
  - Reduction in rainfall volume leaving the roof due to evaporation and evapo-transpiration. A typical extensive green roof of about 75mm in growing media can be designed to reduce annual runoff by more than 50% (Miller, 2001b; FLL, 2002). The seasonal rainfall patterns in Metro Vancouver mean that green roofs have less effect in the wet winter season, retaining 13-18% of rainfall, versus 86-94% in the summer (Connelly, 2006).
  - Mitigation of the urban heat island effect, which is raising the temperatures of cities and increasing energy use as well as increasing the effects of air pollution (Peck & Kuhn, 2001).
  - Air filtration, removing fine particulates from the air (Peck & Kuhn, 2001).
  - Reduction in heat gain and the need for air conditioning in the summer – peak sensible cooling needs can be reduced by about 25% (Christian, 1996).
  - Reduced heat loss in the winter; heat loss in Toronto was reduced 10-30% (Liu, 2003 & 2005). Research at BCIT found heat transfer through the roof was reduced 80% in summer and 40% in winter (Connelly, 2006)

- Roof membrane protection and life extension. European studies have revealed that green roof installation can double the life span of a conventional roof, by helping to protect the membrane from extreme temperature fluctuations, ultraviolet radiation, and mechanical damage (Peck & Kuhn, 2001).
- Sound insulation – tests at BCIT found that typical extensive green roof can reduce sound by 2 to 13 dB (Connelly and Hodgeson, 2008).
- Increasing biodiversity in urban areas by providing habitat for birds, insects, native plants, and rare or endangered species.
- Aesthetic value and increased urban green space.

6.3 Limitations

- Green roofs and blue-green roofs must be designed with an awareness of the loading of the roof and water on the underlying structure. Use of lightweight growing media for a green roof has created solutions where saturated growing media can be installed without structural upgrading beyond the standard requirements, especially in concrete buildings or new construction. (Peck & Kuhn, 2001). A blue-green roof will always require increased structural support relative to a traditional roof and thus are only suitable for new construction.
- Canada does not have official green roof standards. Until such standards are published, the German FLL guidelines and test procedures represent the only comprehensive standards for green roof design, installation, and maintenance. Green roofs, as extensions of the roofing system, should comply with the BC Building Code.

6.4 Extensive Green and Blue-Green Roof Types

Extensive green roofs can be one of following designs:

- Multiple layer construction (Drawing 6A and 6B) – consists of either: i) a three-layer system including separate drainage course, filter layer and growing medium or; ii) a two layer system where the growing medium is sized to not require a filter between it and the underlying drainage layer. Extensive Green Roof may be installed over either a conventional or an inverted roof system.
- Single layer construction (Drawing 6C) – consists of a growing medium which includes the filter and drainage functions.

Extensive blue-green roofs are typically:

- Multiple layer construction (Drawing 6D) – consists of a four-layer system including separate drainage course, storage layer, filter layer and growing medium. Installed over a conventional or inverted roof system.

6.5 Design Guidelines

1. Start the design of the green roof or blue-green roof at the same time as the design of the building or retrofit project, so that the structural load of the green roof components and stored water can be balanced with the structural design of the building. From the outset, involve all design disciplines – structural, mechanical, and electrical engineers, architects, and landscape architects – and include roofing design professionals in a collaborative and optimization effort (Oberlander et al., 2002).

Extensive green roof – Halle Zoo, Germany.
(Photo Credit: Goya Ngan)

2. Provide construction and maintenance access to extensive green roofs. Access through a 'man door' is preferable to access through a small roof hatch (Peck & Kuhn, 2001). Provide areas of storage for maintenance equipment. Review Workers Compensation Board requirements for safety of maintenance workers. Provide a hose bib for manual watering during establishment if no automatic irrigation system is planned.

3. Roofs with less that 2% slope require special drainage construction so that no part of the growing medium is continuously saturated. As the slope increases, so does the rate of rainfall leaving the roof. This can be compensated for by using a medium with high water storage capacity. Roofs with over 20º angle surfaces require special precautions against sliding and shearing (FLL. 2002). If inverted roof systems are used with exterior insulation, good drainage needs to be provided to prevent continuous saturation of the insulation, and subsequent damage (Peck & Kuhn, 2001). With inverted roofs, the green roof components must allow moisture to move upwards from the insulation and to eventually evaporate (Krupka, 1992).

Extensive green roof – Amsterdam.
(Photo Credit: Lanarc Consultants)

Newly planted extensive green roof showing plant-free zones at drain and edges – White Rock Operations Building.
(Photo Credit: Lanarc Consultants Ltd.)

4. Provide plant free zones to facilitate access for inspections and maintenance and prevent plants from spreading moisture onto exposed structural components. They can also function as a measure against fire and wind-uplift. They should be at least 50 cm wide and located along the perimeter, all adjacent facades and covered expansion joints, and around each roof penetration.
5. Fire breaks of non-combustible material, such as gravel or concrete pavers, 50 cm wide, should be located every 40 m in all directions, and at all roof perimeter and roof penetrations (FLL, 2002). Other fire control options include use of sedums or other succulent plants that have a high water content, or a sprinkler irrigation system connected to the fire alarm (Peck & Kuhn, 2001).
6. There are several choices of waterproof membranes. Thermoplastic membranes, such as PVC (polyvinyl chloride) or TPO (thermal polyolefin) using hot air fusion methods are commonly used for green and blue-green roof applications. Elastomeric membranes like EPDM (ethylene-propylene rubber materials) have high tensile strength and are well-suited to large roof surfaces with fewer roof penetrations for both green and blue-green roofs. For a blue-green roof, a thicker membrane may be needed to support the weight of stored water over the long term and should be selected based on manufacturer's specifications of performance. For a green roof only, options include modified bitumen sheets that are applied in two layers and are commonly available, and liquid-applied membranes that are generally applied in two liquid layers with reinforcement in between. The quality is variable for both. A factor in choosing a waterproofing system is resistance to root penetration (see point 7 below).
7. Provide protection against root penetration of the waterproof membrane by either adding a root barrier or using a membrane that is itself resistant to root penetration (more cost efficient). Resistance to root penetration is not being tested in Canada at time of writing. Thermoplastic and elastomeric membranes in suitable thicknesses are usually resistant to root penetration. Roofing membranes, existing or new, which contain bitumen or other organic materials are susceptible to root penetration and micro-organic activity. These types of roofing membranes need to be separated from the growing medium by a continuous root barrier unless they contain an adequate root repelling chemical or copper foil (Ngan, 2003).

8. Chemically incompatible materials such as bitumen and PVC require a separation layer (FLL, 2002).
9. When the roofing membrane installation is complete, but prior to installing layers above the waterproof membrane, it should be tested by flooding and thorough inspection. Any leaks should be repaired prior to installing materials above the membrane (Ngan, 2003).
10. Install a protection layer to protect the waterproof membrane/root barrier from physical damage caused by construction activities, sharp drainage materials such as lava rock or broken expanded clay, and subsequent levels of stress placed on the roof (Ngan, 2003).
11. For a green roof the drainage layer may be drain rock, but is often a lightweight composite such as lava, expanded clay pellets, expanded slate or crushed brick. If weight is a concern, rigid plastic materials that allow rapid lateral drainage may be used. The drainage layer may also function to store water and make it available to the vegetation during dry periods. The top of the drainage layer is normally separated from the growing medium by non-woven filter cloth. For a blue-green roof, the drainage layer becomes the storage layer, and is typically a rigid structure with a high void ratio that provides storage volume and supports the above layers.
12. Light weight growing medium is often a combination of pumice, lava rock, expanded clay or other lightweight absorbent filler, with a small amount of organic matter. The FLL recommends between 6 and 8% organic matter. When properly sized (see Figure 6-), a mineral-based growing medium is able to retain stormwater as effectively as soil high in organic matter without the disadvantage of compacting and breaking down over time. For additional detailed information on the properties of green roof growing media, refer to the FLL guidelines(2002).

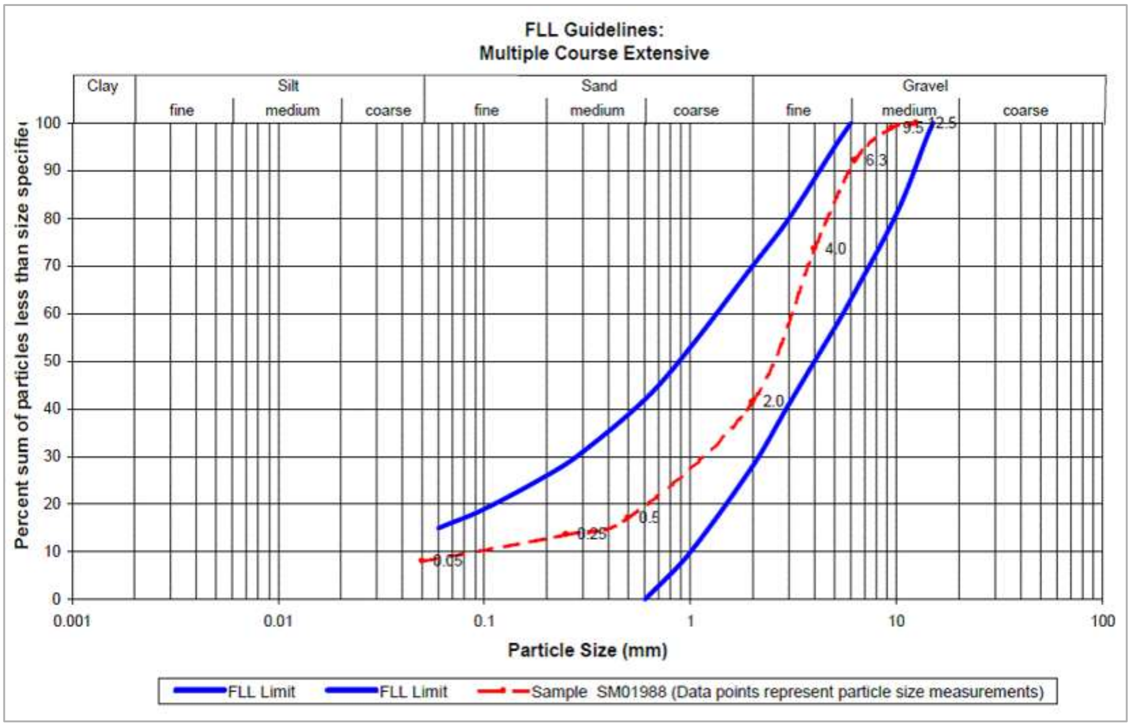


Figure 6-1: Particle (grain) size distribution range for substrates used in multiple layer extensive green roofs (FLL, 2008, Guidelines for the Planning, Execution and Upkeep of Green-Roof Sites).
(Image Credit: Agricultural Analytical Services Laboratory, The Pennsylvania State University)

13. Some proprietary green roof systems may instead use an inorganic fibrous mat for the growing medium rather than a soil material. These systems often provide more water storage volume in a smaller thickness of material compared to soil and granular growing medium. The system manufacturer should be able to provide tested storage and flow through rates. Fibrous mat systems are suited to low maintenance extensive green and blue-green roofs, and are particularly common planted with sedums, but do not support intensive roofs for ornamental plants or gardening.
14. For blue-green roofs a scaffold system is used to keep the vegetation rooting layer out of the ponded water.
15. In calculating structural loads, always design for the saturated weight of each material (Oberlander et al., 2002).
16. Light weight growing medium can be subject to wind erosion when dry. If planting is delayed through a dry weather season, provide a wind erosion control blanket over the growing medium.
17. Plant choices for extensive green roofs are limited to plants that can withstand the extremes of temperature, wind, and moisture condition on a roof. Typically, extensive green roofs use a variety of mosses, sedums, sempervivums, alliums, other bulbs and herbs, and grasses. Blue-green roofs use similar plantings as the water storage is typically not available for plant uptake and so the plant conditions are similar.

18. Avoid specifying or allowing volunteer plant materials with aggressive root systems (e.g., bamboo, couch grass, tree seedlings). Supply and install growing medium that is free of weeds (Ngan, 2003).

19. Design planting to respect microclimate and sun/aspect conditions. Collaborate with mechanical engineers on placement of exhaust vents, and design plantings accordingly (Oberlander et al., 2002).

20. Avoid swaths of one species. The chances of creating a self-maintaining plant community are increased when a wide mix of species is used.

Green roof test plots – Saskatoon.
(Photo Credit: Goya Ngan)

21. Planting methods include seeding, hydroseeding, spreading of sedum sprigs, planting of plugs or container plants, and installing pre-cultivated vegetation mats.

22. If automatic irrigation is required, low volume and rainwater reuse systems are preferred.

23. Provide intensive maintenance for the first two years after the plant installation – including watering in dry periods, removal of weeds, light fertilization with slow release complete fertilizers, and replacement of dead plants. It is recommended that the maintenance contract for the first 3-5 years be awarded to the same company that installed the green roof and that the service be included in the original bid price (Peck & Kuhn, 2001). Once established, a typical extensive green should require only one or two annual visits for weeding of undesired plants, clearing of plant-free zones, and inspecting of drains and the membrane.

24. Installers should have experience with green roof systems. It may be preferable to have one company handle the entire project from roofing to planting to avoid scheduling conflicts and damage claims (Peck & Kuhn, 2001). If it is not possible, make a clear separation between the responsibilities of the roofing contractor and those of the green roof contractor (Krupka, 1992).

25. Although green roof membranes will last longer than others, leaks can still occur at flashings or through faulty workmanship. Some companies are recommending an electronic leak detection system to pinpoint the exact location of water leaks, for easier repair (Peck & Kuhn, 2001). An example of such a system is Detec Systems, of Sidney, BC.

26. Consider the water quality impacts of green and blue-green roof materials: avoid galvanized steel components that will contact the rainwater and leach zinc and ensure that growing medium materials have no excess nutrients that will leach over time.

Extensive Green Roof on a warehouse in Port Coquitlam, BC.
(Photo Credit: Kerr Wood Leidal Associated Ltd.)

27. Several companies provide the Metro Vancouver region with complete green roof service and offer a range of long-term guarantees on the entire assembly. This type of comprehensive installation may be more expensive than comparable 'off the shelf' products not specifically designed for green roof use. The decision on risk management is with the owner (Peck & Kuhn, 2001).

28. In general, green roofs capture and treat only the rainfall which falls directly onto them and do not require pre-treatment. If there is runoff from other roof areas that drains onto a green roof the runoff should pass through a settling sump prior to discharge to settle any entrained particles.

29. If there is additional runoff from adjacent or taller roof areas that discharge to a green roof, the catchment area draining to the green roof should be no more than the area of the receiving green roof, a 1:1 ration of additional catchment to green roof.

6.6 Maintenance

- Weeding and replacing dead plants should be conducted once in the spring and once in the fall.
- The overflow needs inspected monthly and maintained as needed to be kept free of debris.
- The orifice-controlled outlet should be checked monthly and maintained as needed to ensure that the orifice is free of debris and not clogged.
- See *Chapter 11 – Operation, Inspection and Maintenance* for further details regarding maintenance tasks and frequency.

6.7 Sizing Green Roofs

Sizing may be done using continuous simulation modeling in the WBM or SWMM or using spreadsheet design storm and water balance calculations. Where a Green Roof forms part of a series of source controls, modeling of the multiple source controls should be used. Sizing for a Green Roof alone is fairly straightforward and simplified sizing approaches have been developed that do not require water balance modeling or continuous simulation. Two sizing approaches are presented below for the two types of criteria used in BC.

- In general, a Green Roof is sized to capture a portion of the rain that falls on it through retention of water in the soil and on the vegetation, and evaporation and evapotranspiration.
- Sizing presented here is for evaporation/ evapotranspiration of rain water for "capture" and prevention of site runoff.
- Sizing process here assumes that the entire roof area will be covered by a Green Roof and sizing determines the depth of soil required.

6.7.1 Sizing Approach 1 – for Depth Capture Criteria: R mm in 24 hrs

1. Determine the soil depth required:

$$D_S = \frac{R}{0.2}$$

Where:
D_S = Depth (thickness) of Green Roof soil (mm)
R = Rainfall capture depth (mm)
0.2 = Water holding capacity of the soil calculated as field capacity minus wilting point (unitless)

2. Check whether the calculated soil depth is within the standard depth range of 150 to 600 mm. If the calculated depth is less than 150 mm, use 150 mm as a minimum soil depth, unless the planting plan includes only shallow-rooted plants (e.g., sedums) that can survive with a shorter root depth. If the calculated depth exceeds 600 mm, the overflow from the Green Roof could be directed to an infiltration rock trench or other facility and the combined facilities should be evaluated using water balance calculations.

6.7.2 Sizing Approach 2 – for % Capture of Average Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

1. Determine the average annual rainfall for the site. If unknown, refer to map in Appendix B of isohyetal lines showing average annual rainfall depths across the Metro Vancouver Region.
2. Consult the Green Roof chart (Figure B-19) in Appendix B.

3. Find the curve on the chart matching the site's average annual rainfall. If between these values, choose the curve for the higher amount of rainfall or interpolate the result between the two bracketing curves.
4. Using the target capture percentage (y-axis) read off the corresponding required soil depth (x-axis).

   If the target capture percentage does not intersect the site rainfall curve, then the overflow from the Green Roof could be directed to an infiltration rock trench or other facility to improve the capture. The combined facilities should be evaluated using water balance calculations.

6.8 Sizing Blue-Green Roofs

Sizing for blue-green roofs is the same as for green roofs, in terms of sizing for capture of an amount of rainfall that does not leave the roof but is retained and evapo-transpired to the atmosphere. Sizing for the storage to provide detention in a blue-green roof system is an additional step to determine the depth of storage required in the reservoir storage layer.

1. Assuming the roof is intended to meet a municipal requirement for on-lot detention, the volume of detention must be determined. Typically, that requires understanding the design storm of interest, and the design outflow rate that needs to be met.

   A simplified approach for determining the storage depth required assumes that the full design event that must be detained is stored at one time:

   $$D_{ST} = \frac{R_{ST}}{n}$$

   Where:
   D_S = Depth (thickness) of Storage layer (mm)
   R_{ST} = Rainfall depth requiring storage (mm) for the design event for detention (e.g., depth of 5-year, 2-hour storm event)
   n = porosity of storage layer (unitless, e.g., 0.95)

   A better approach for determining the depth of storage required would be to calculate with a spreadsheet or model the storage required to detain the design storm event and release at the desired outflow rate. The maximum volume required using one of these tools can be distributed over the blue-green roof by dividing the volume by the roof area. A typical max ponding depth is 150 mm; however, more may be able to be accommodated if and specifically accounted for in the structural design.
2. The design depth of water in the storage reservoir layer must be calculated in advance of and accounted for in the structural design of the building.

6.9 Green Roof Design Example for Capture of 25 mm Rain in 24 hours

6.9.1 Scenario Description

A Green Roof is proposed to capture a portion of the runoff from a building roof (see illustration below).

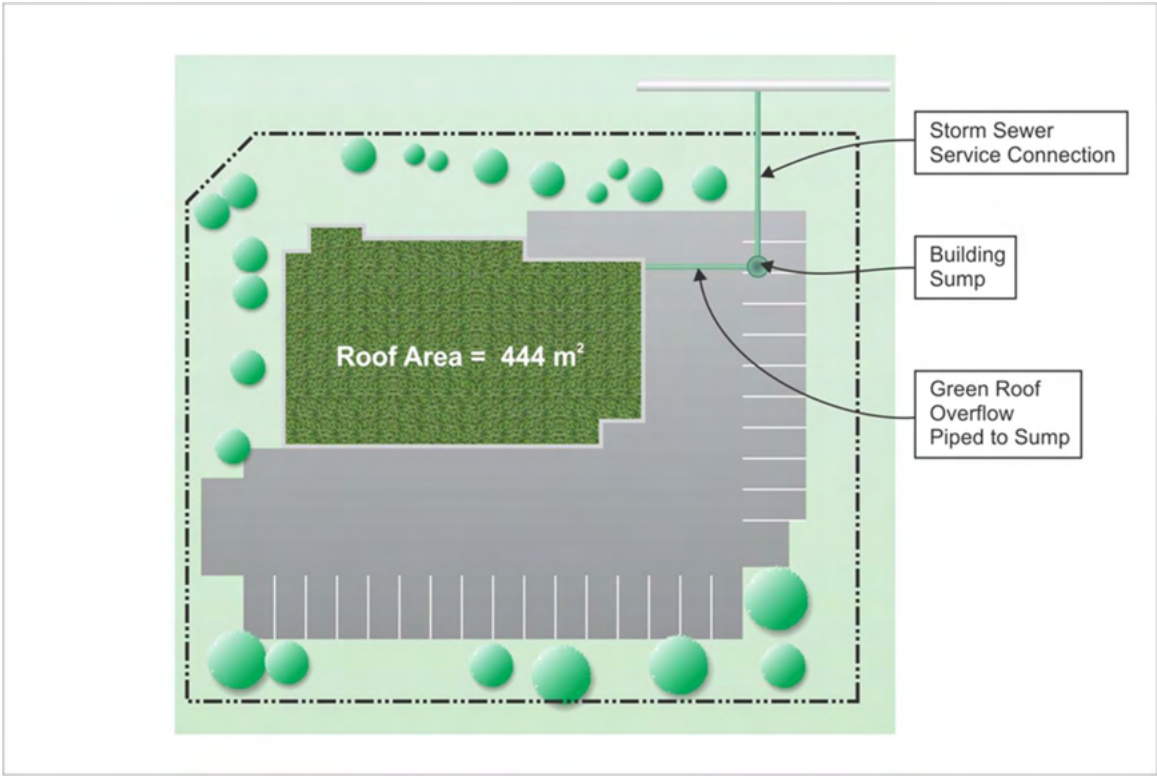


Figure 6-2: Example – Roof Area Covered with Green Roof.

The following parameters are known:

- Roof area = 444 m2;
- Rainfall capture target = 25 mm;
- Water holding capacity of the green roof soil = 0.2; and
- Determine the required green roof topsoil thickness.

6.9.2 Sizing

1. The rainfall capture target is 25 mm. Using the equation, calculate the depth of soil required to achieve the capture target:

   $$D_S = \frac{R}{0.2}$$

   Where:
   D_S = Depth (thickness) of Green Roof soil (mm)
   R = Rainfall capture depth (mm)
   0.2 = Water holding capacity of the soil calculated as field capacity minus wilting point (unitless)

2. Using the target capture depth of 25 mm:

$$D_S = \frac{25\,mm}{0.2} = 125\,mm$$

A minimum soil depth of 125 mm is needed to achieve the 25 mm capture goal for the green roof. If only sedums are planted on the roof, 125 mm of soil is adequate. If a more diverse plant group is desired the soil depth should be increased to 150 mm to accommodate plant roots.

6.10 Alternate Green Roof Design Example For Capture of % Annual Rainfall

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

6.10.1 Scenario Description

A Green Roof is proposed to capture a portion of the runoff from a building roof (see illustration below).

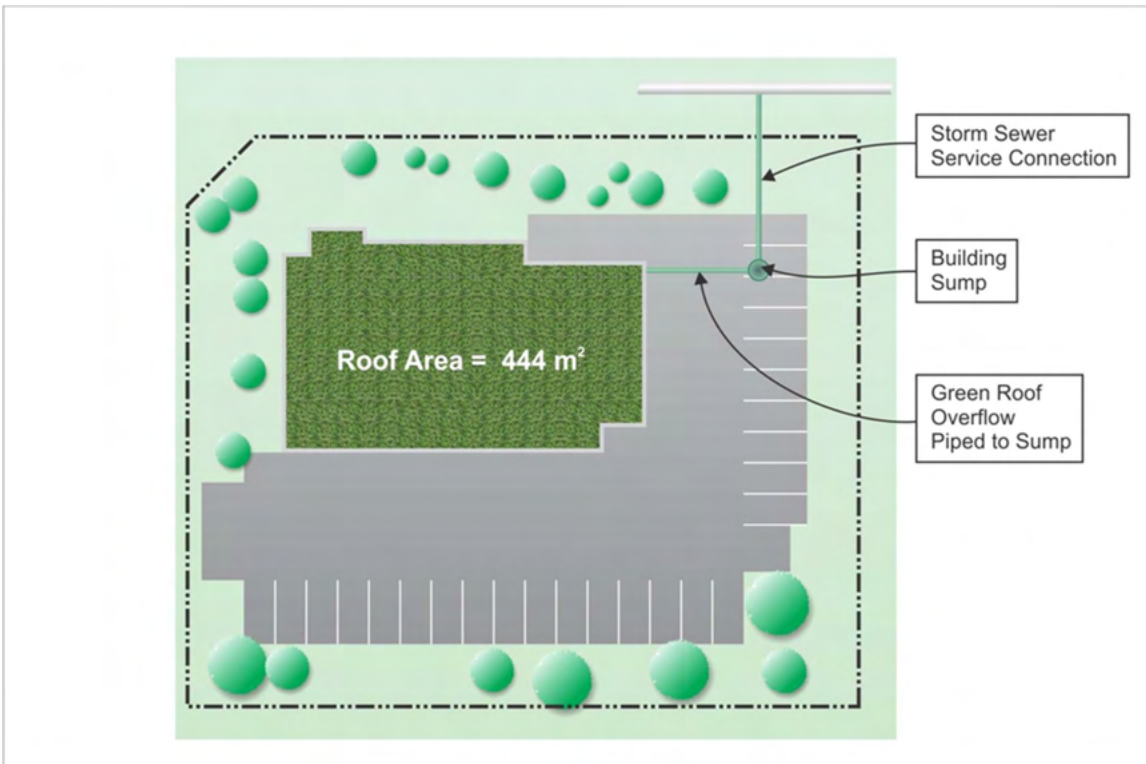


Figure 6-2: Example – Roof Area Covered with Green Roof.

The following parameters are known:

- Roof area = 444 m2
- Annual rainfall = 1100 mm
- Annual rainfall capture target = 50%

1. Determine the required green roof topsoil thickness.

6.10.2 Sizing

The annual rainfall at the site is 1100 mm. Using the sizing chart (Figure 6-3) from Appendix B look up the 50% annual rainfall capture point along the 1100 mm rainfall curve and read off the corresponding topsoil depth.

The sizing chart shows that 450 mm of topsoil depth is required to meet the capture target.

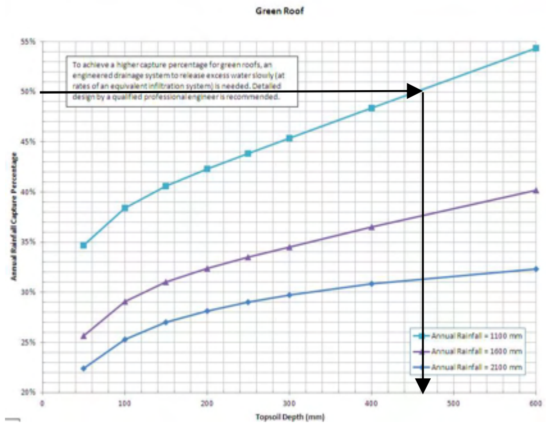


Figure 6-3: Sizing chart for green roofs.

Note: the above calculation assumes a "typical" green roof construction; there is significant room for improvement in performance with modifications to the underdrain or drainage layer to improve capture.

6.11 Hydraulic Components

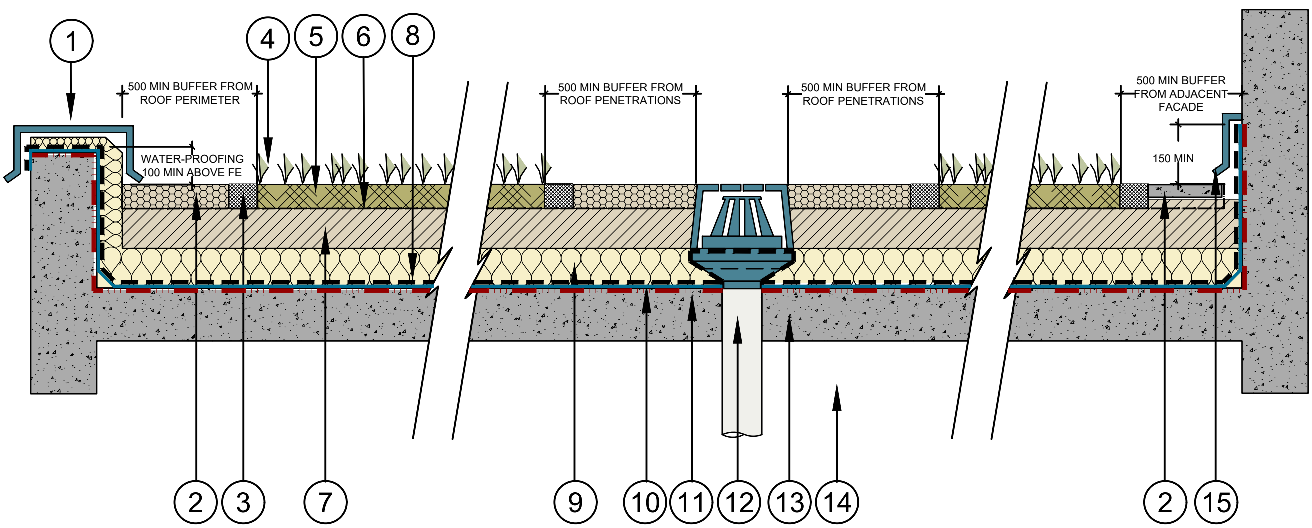
Underdrain: To prevent the green roof topsoil from becoming saturated and negatively impacting the plan roots, an underdrain layer is standard practice for green roofs. The underdrain layer also reduces the likelihood of roof membrane leakage by relieving water pressure on the membrane.

Overflow: During extreme rainfall, the topsoil infiltration capacity may be overwhelmed resulting in ponding of water on the soil surface and runoff. This excess water is collected by an overflow designed to limit the water level on the roof. For a blue-green roof the overflow should be set at the maximum ponding depth, e.g., 150 mm.

Discharge: The green roof topsoil underdrain and the overflow are connected to roof water leaders or downspouts to convey excess water to the municipal storm sewer.

Orifice Controlled Outlet: This outlet controls the rate of flow that discharges from the storage reservoir layer. An orifice should be sized for the detention outflow rate required, and the orifice and outlet should be located at the bottom of the reservoir storage area. To reduce the risk of clogging or for a large roof area, a modular approach with multiple outlets is recommended. A typical minimum orifice size is 10 mm diameter.

1. WALL CAP FLASHING
2. DRAIN ROCK, PAVING SLAB, OR OTHER BUFFER EQUIVALENT
3. WOOD, STEEL OR CONCRETE CURB/EDGING (OPTIONAL)
4. PLANTING
5. GROWING MEDIUM
6. FILTER LAYER
7. DRAINAGE LAYER
8. PROTECTION LAYER AND ROOT BARRIER
9. THERMAL INSULATION
10. WATERPROOF MEMBRANE
11. VAPOUR BARRIER
12. AREA DRAIN
13. STRUCTURAL SLAB
14. BUILDING INTERIOR
15. WALL FLASHING



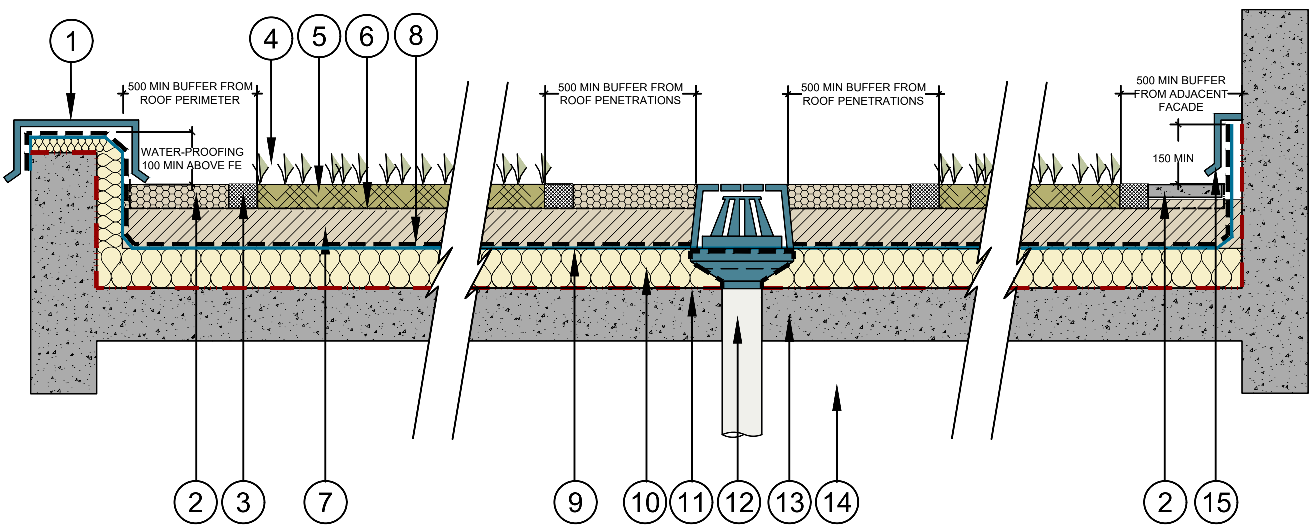
NOTE: UNLESS THE WATERPROOF MEMBRANE IS RESISTANT TO ROOT PENETRATION, A ROOT BARRIER IS REQUIRED BETWEEN THE PROTECTION LAYER AND WATERPROOF MEMBRANE. A SEPARATION LAYER MAY BE REQUIRED BETWEEN CHEMICALLY INCOMPATIBLE MATERIALS.

6 / A MULTIPLE LAYER EXTENSIVE GREEN ROOF

Not To Scale

Section

1. WALL CAP FLASHING
2. DRAIN ROCK, PAVING SLAB, OR OTHER BUFFER EQUIVALENT
3. WOOD, STEEL OR CONCRETE CURB/EDGING (OPTIONAL)
4. PLANTING
5. GROWING MEDIUM
6. FILTER LAYER
7. DRAINAGE LAYER
8. PROTECTION LAYER AND ROOT BARRIER
9. WATERPROOF MEMBRANE
10. THERMAL INSULATION
11. VAPOUR BARRIER
12. AREA DRAIN
13. STRUCTURAL SLAB
14. BUILDING INTERIOR
15. WALL FLASHING



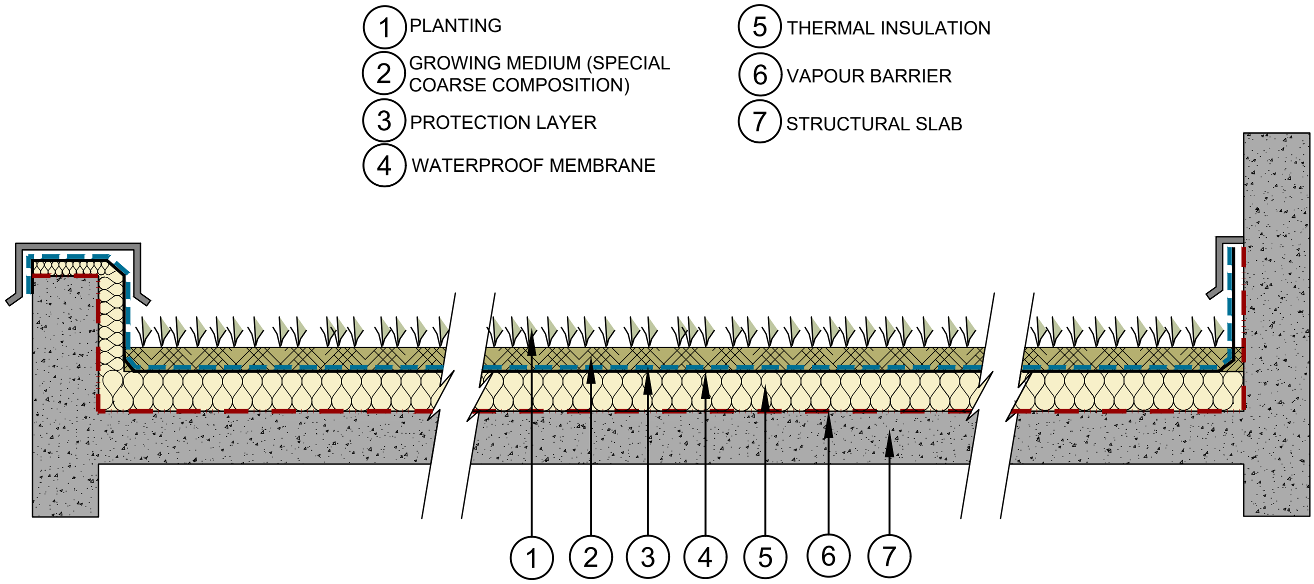
NOTE: UNLESS THE WATERPROOF MEMBRANE IS RESISTANT TO ROOT PENETRATION, A ROOT BARRIER IS REQUIRED BETWEEN THE PROTECTION LAYER AND WATERPROOF MEMBRANE. A SEPARATION LAYER MAY BE REQUIRED BETWEEN CHEMICALLY INCOMPATIBLE MATERIALS.

6 / B MULTIPLE LAYER EXTENSIVE GREEN "INVERTED" ROOF

Not To Scale

Section

metrovancouver



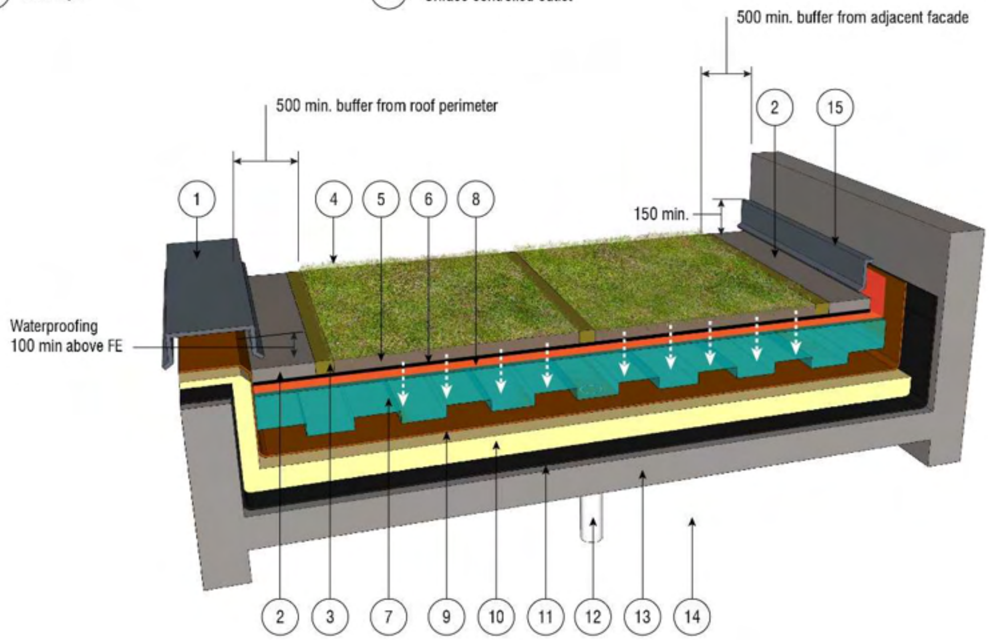
6 / C SINGLE LAYER EXTENSIVE GREEN ROOF (NO DRAINAGE LAYER)

Not To Scale

Section

1. Wall cap flashing
2. Drain rock, paving slab, or other buffer equivalent
3. Wood, steel or concrete curb/edging (optional)
4. Planting
5. Growing medium
6. Filter layer
7. Reservoir storage layer
8. Protection layer and root barrier
9. Waterproof membrane
10. Thermal insulation
11. Vapour barrier
12. Oriface controlled outlet
13. Structural slab
14. Building interior
15. Wall flashing

Note:
Unless the waterproof membrane is resistant to root penetration, a root barrier is required between the protection layer and waterproof membrane. a separation layer may be required between chemically incompatible materials.



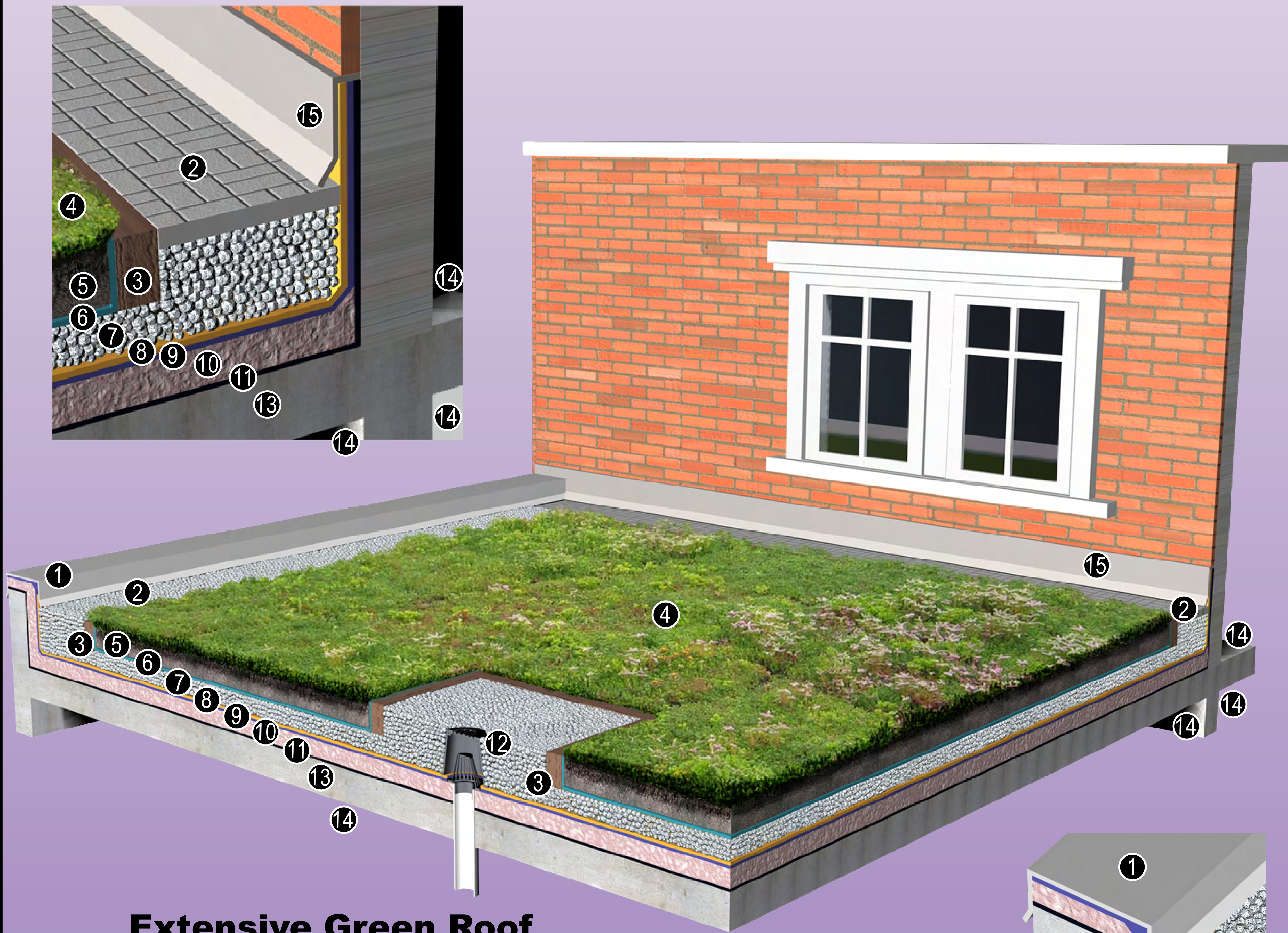
6
D
BLUE-GREEN ROOF
Not to Scale

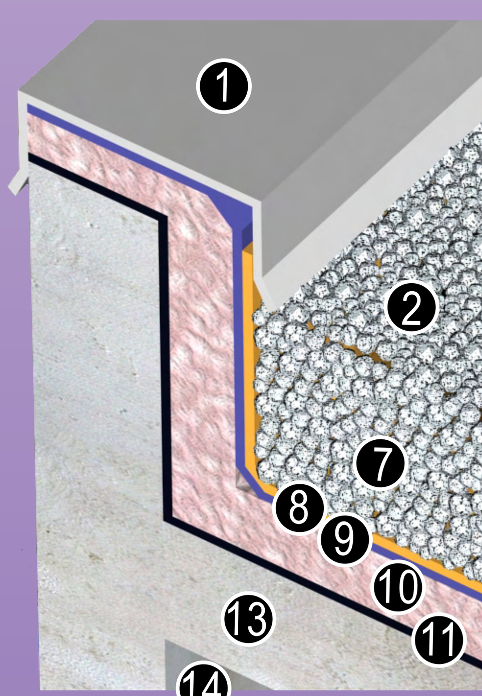
DESIGN PRINCIPLES

- Suitable for flat roofs and, with proper design, roofs of 20º (4:12 roof pitch) or less.
- Suitable for many rooftop situations – industrial, warehousing, commercial buildings, office complexes, hospitals, schools, institutional/ administrative buildings, residential and garages.
- Design a green roof at the same time as designing the building or retrofit, so that the structural load can be balanced with the design of the building.
- In calculating structural loads, always design for the saturated weight of each material.
- Provide construction and maintenance access to extensive green roofs. Access through a 'man door' is preferable to a roof hatch.
- Roofs with less than 2% slope require special drainage construction so that no part of the growing medium is continuously saturated.
- Avoid monocultures when planting a green roof; the success of establishing a self-maintaining plant community is increased when a mix of species is used.
- Provide intensive maintenance for the first 2 years after plant installation – irrigation in dry periods, weed removal, light fertilization with slow release complete fertilizers, and replacement of dead plants.
- To facilitate access and prevent moisture on exposed structural components, provide plant free zones along the perimeter, adjacent facades, expansion joints, and around each roof penetration.
- Fire breaks of non-combustible material, 50cm wide, should be located every 40m in all directions and at roof penetrations.
- Provide protection against root penetration of the waterproof membrane by either adding a root barrier or using a membrane that is itself resistant to root penetration.

A **Green Roof** is a roof with a veneer of drainage and growing media that supports living vegetation. Green roofs provide a wide range of benefits – from reduction in peak flows and volumes to building heat gain reductions. There are two basic types:

- Intensive – deeper growing medium to support larger plants and trees; designed for public use as well as stormwater and insulation functions.
- Extensive - shallow, lightweight growing medium; designed for stormwater, insulation and environmental functions; vegetation is low and hardy; usually no public access.





Extensive Green Roof

1. Wall Cap Flashing, waterproof membrane extends to 100mm above finished grade
2. Drain Rock, Paving Slab, or Other Buffer Equivalent
3. Wood, Steel or Concrete Curb/Edging (Optional)
4. Planting
5. Growing Medium
6. Filter Layer
7. Drainage Layer
8. Protection Layer and Root Barrier
9. Waterproof Membrane
10. Thermal Insulation
11. Vapour Barrier
12. Area Drain
13. Structural Slab
14. Building Interior
15. Wall Flashing, waterproof membrane extends to 150mm above finished grade

Green Roof

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Stormwater Source Control Design Guidelines 2023

Detailed design guidelines can be found in the Design Guidelines 2012 report, available at www.metrovancouver.org

INFILTRATION TRENCH AND SOAKAWAY MANHOLE

7 Infiltration Trench and Soakaway Manhole

7.1 Description

An **Infiltration Trench** System includes an inlet pipe or water source, catch basin sump, perforated distribution pipe, infiltration trench and overflow to the storm drainage system. Although commonly in a linear trench shape, the same principles apply to underground drain rock infiltration devices of any shape (See Drawing 7D). Other common terms used are Rock Trench or Rock Pit.

A **Soakaway Manhole** System includes an inlet pipe, a sedimentation manhole, and one or more Soakaway Manholes with connecting pipes (See Drawings 7A, 7B, 7C).

Other common terms used are *Infiltration Sump, Dry Well, or Infiltration Shaft*.

Photo Credit: Kerr Wood Leidal Associates

Single family lot infiltration trench being installed in East Clayton development, Surrey, BC.

Photo Credit: Kerr Wood Leidal Associates

Single family lot infiltration trench being installed in East Clayton development, Surrey, BC.

Completed single family lot infiltration trench completed; lawn basin is the only visible indication that it is there.

7.2 Selection and Application

- Infiltration Trenches are often used to allow roof runoff to soak away into the ground. With water quality pre-treatment, they can be used for infiltration of other surface waters. Although ideally located under surface soils that will allow some evaporation, there are applications where an infiltration trench can be installed under pavement, provided that the structural design of the pavement is appropriate for this use.
- Suitable for clean, unpolluted runoff from many development situations – residential areas, municipal office complexes, rooftop runoff, parks and greenspace, golf courses (Stephens et al., 2002).
- Not suited for parking and heavy traffic roadway runoff unless installed in conjunction with water quality pre-treatment designed to remove hydrocarbons and heavy metals.

Infiltration facilities near urban structures should only be installed in neighbourhoods that have footing drains or other methods to protect basements from flooding.
(Photo Credit: Lanarc Consultants Ltd.)

- An Infiltration Trench does not itself provide treatment; for any situation where treatment is necessary, such as runoff from vehicle-accessible surfaces, an infiltration Rain Garden should be considered.
- Provision of underground overflow allows use of the technique in most soils, including clay with infiltration rates as low as 0.6mm/hr.
- Due to the low infiltration rates and high rainfall common across the Metro Vancouver region, an Infiltration Trench will generally be more space-efficient for meeting volume capture targets for development. For small impervious areas, a Soakaway Manhole may be more appropriate.
- Use Infiltration Trench or Soakaway Manhole only in areas with footing drains. If steep slopes or drinking water wells exist within 200m horizontally from the proposed Infiltration Trench or Soakaway Manhole, provide a hydro-geotechnical report to analyze site-specific risks and determine setbacks. Guidelines for setbacks to steep slopes are 60m from the tops of slopes more than 3m high and steeper than 2h:1v. Setbacks to drinking water wells should at least equal the BC Ministry of Health minimum setback from well to septic field (30.5 m at time of writing).

7.3 Design Guidelines

7.3.1 Infiltration Trench System:

1. Locate Infiltration Trench at least 3m from any building, 1.5m from property lines, and 6m from adjacent infiltration facilities (or as recommended by local bylaws or a geotechnical engineer).
2. If any surface water is to enter the system, provide pre-treatment and upstream erosion control to avoid sedimentation in the Infiltration Trench. Provide non-erodible material and sediment cleanout basins at point-source inlets (Maryland Dept. of the Environment, 2009).

3. To avoid groundwater pollution, do not direct un-treated polluted runoff to Infiltration Trench or Soakaway Manhole:
   - Direct clean runoff (roof, non-vehicle paving) to Infiltration Trench or Soakaway Manhole.
   - For polluted runoff (roads, parking areas, other pollution sources), provide upstream source control (Rain Garden or Infiltration Swale) for pollutant reduction prior to release to Infiltration Trench or Soakaway Manhole.

Infiltration trench being installed at Mountain Equipment Co-Op in North Vancouver, BC.
(Photo Credit: Kerr Wood Leidal Associates Ltd.)

4. Identify pollutant sources other than vehicles, particularly in industrial/ commercial hotspots, that require pre-treatment or source control upstream of this BMP. (Maryland Dept. of the Environment, 2009).
5. Sump (see Detail 7D): A concrete, plastic, or other non-degradable box with strength suitable to withstand surface loads. Provide a lid for periodic inspection and cleanout. Include a T-inlet pipe to trap oils, sediments, and debris. Weep holes may be included to dewater the sump, for mosquito management.
6. Infiltration Trench: perforated distribution pipe and bottom of drain rock to be installed level. If more than one section of infiltration trench is required, design so that underground water is temporarily ‘ponded’ in each infiltration section, using underground weirs of undisturbed native material or constructed ditch blocks designed to create underground pooling in the reservoir sufficient for infiltration performance.
7. Separation from base of drain rock reservoir to water table should be a minimum of 600 mm.
8. Infiltration Trench bottom width is not restricted to but is generally between 600mm and 2400mm.

Infiltration trench can be in any plan shape – the photo shows a rectangular infiltration trench under construction at a single-family subdivision in BC.

(Photo Credit: Lanarc Consultants Ltd.)

9. Design should provide for drain rock reservoir to drain in 96 hours to allow aerobic conditions for water quality.
10. Install the Infiltration Trench in native ground, and avoid over-compaction of the trench sides and bottom, which reduces infiltration. Base of trench

should be scarified to a minimum of 150 mm prior to installation of the rock reservoir material.

11. Observation well for each Infiltration Trench (optional but recommended to allow monitoring of water depth in the reservoir): vertical standpipe, with perforated sides, and locking lid.
12. A bypass or overflow must be included in the facility design to accommodate flows in excess of the design infiltration volume.
13. Avoid utility or other crossings of the Infiltration Trench. Where utility trenches must be constructed crossing below the Infiltration Trench, install trench dams to avoid infiltration water following the utility trench.
14. A typical infiltration trench has a simple overflow to the storm system. In areas where native soil infiltration is poor, a partial-infiltration rock trench may be used to achieve increased capture of runoff. This design will separate the perforated inflow pipe and perforated outflow pipe such that a layer of storage is rock is provided between the inflow and outflow elevations. The outflow pipe will connect to a control structure in a catch basin that provides overflow while maintaining a slow decanting of the water in the rock trench between storms (See Detail 7E).

Perforated pipe over drain rock reservoir at infiltration trench under construction in Maple Ridge.
(Photo Credit: Lanarc Consultants Ltd.)

7.4 Soakaway Manhole System:

1. Provide a report from a geotechnical engineer including on-site test data of infiltration rates at the depth of the proposed infiltration. The bottom of the Soakaway Manhole shall be at least 600mm above the seasonal high water table or bedrock, or as recommended by the engineer.
2. Provide a sedimentation manhole, and a maximum of two Soakaway Manholes in series, unless otherwise approved. Minimum distance between Soakaway Manholes shall be 8m.
3. Provide an overflow from Soakaway Manhole to the storm drainage system or major storm flow path.
4. Size the Soakaway Manhole system by continuous flow modelling.

7.5 Pre-treatment Principles

Infiltration trenches require pre-treatment to remove prevent sediment and debris from entering the system and to ensure that the system and underlying soils maintain their infiltration and water holding capacity.

Pre-treatment for Infiltration Trench and Soakaway Manhole can take a wide variety of forms, from a simple depression in the grass to slow and settle inflow to proprietary treatment devices to remove sediment or other potential contaminants from the inflow.

Pre-treatment principles are as follows:

1. At minimum, include installation of sump at inlet location;
2. Application of a "treatment train" approach can utilize other green infrastructure practices (i.e., vegetated filter strips) to pre-treat runoff;
3. Proprietary devices may be used and should be sized to remove sediment prior to stormwater entering the infiltration trench; and
4. Proprietary devices utilized as pre-treatment to be sized to remove minimum 60% of total sediment load; shop drawings and sizing reports to be approved by design engineer.

7.6 Pre-treatment Maintenance

Maintenance requirements for infiltration trench pre-treatment zones include:

- Inspection and removal of sediment and debris from sumps. Maintaining the sumps will reduce sediment loading in the infiltration facility and increase the life span of the infiltration trench;
- Depending on the runoff source, more frequent maintenance and sediment removal may be warranted; and
- Design guidance to include an estimated sediment removal frequency for the pre-treatment zones.

7.7 Maintenance

A pre-treatment facility to collect sediment from runoff prior to the flow entering the infiltration facility should always be incorporated into the design. It should be easy to clean out to minimize the effort needed for ongoing maintenance. Key considerations include:

- Locate the pre-treatment device where it is easily accessible;
- Use a device design that is consistent with other devices the municipal staff maintain so that it is familiar to staff and utilizes the same equipment;

- Infiltration trenches should also incorporate monitoring wells to assess system drawdown rates;
- An operation and maintenance plan should be developed as part of the system design to document the maintenance required and the locations for checking function and maintenance; and
- See *Chapter 11 – Operation, Inspection and Maintenance* for further details regarding maintenance tasks and frequency.

7.8 Infiltration Trench Sizing

Sizing methods are presented here for the Infiltration Trench but not the Soakaway Manhole.

Infiltration trenches may be sized using continuous simulation modeling in the WBM or SWMM or using spreadsheet design storm and water balance calculations. Simplified sizing approaches have been developed that do not require water balance modeling or continuous simulation. Two sizing approaches are presented below for the two types of criteria used in BC.

- For these sizing approaches, the Infiltration Trench 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. Depth of cover over the rock trench is not considered or accounted for.
- In general, the Infiltration Trench 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 impervious area to pervious area (e.g., I/P ratio). For the simplified sizing approaches here, this represents the ratio of upstream impervious area (also called catchment area) to Base Area (bottom area) of the Infiltration Trench. I/P ratio to achieve the target capture criteria will be calculated by the two sizing methods below.
- Sizing presented here is for infiltration of rain water for “capture” and prevention of site runoff. No sizing and design is provided for any required pre-treatment facility.

7.8.1 Sizing Approach 1 – for depth capture criteria: X mm in 24 hrs

1. Determine the maximum rock depth according to the drain time (4 days max.) and round down to the nearest 50 mm increment for constructability; standard depth range used in this sizing guidance is 300 to 2000 mm:

$$D_R = \frac{Ks \times T \times 24}{n}$$

Where:
D_R = Depth (thickness) of rock in trench (mm)
Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
T = allowable drain time (days)
n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

2. Use the following equation to determine the base (bottom) area of rock trench required by finding the I/P ratio for the site:

$$I/P = \frac{24 \times Ks + D_R \times n}{R} - 1$$

Where:
I/P = Ratio of impervious tributary area to rock trench base area (unitless)
R = Rainfall capture depth (mm)
Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
D_R = Depth (thickness) of rock reservoir (mm)
n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

To find the rock trench base area:

$$BaseArea = \frac{\text{Impervious Tributary Area}}{I/P}$$

If the site cannot accommodate the I/P ratio required to provide the target capture, a partial-infiltration rock trench with flow restrictor design may be used.

A 0.25 L/s/ha (or 0.09 mm/hr) unit discharge has been recommended by DFO for the flow restrictor at the downstream end of the swale underdrain (see detail 7E).

3. Calculate the allowable discharge through the orifice:

$$Q = \frac{0.25 \times A_{SITE}}{1000}$$

Where:
Q = Allowable discharge through orifice (m^3/s)
0.25 = Recommended unit discharge (L/s/ha)
A_{SITE} = Total site area draining to the swale, including the swale area (ha)
Solving the orifice equation for area of the orifice (AO):

$$A_O = \frac{Q_O}{K \times \sqrt{2g\Delta h}}$$

Where:
Q_O = Theoretical discharge through infiltration from the impervious area that will be discharged via orifice (m^3/s)
K = Orifice Coefficient (typical value 0.6)
g = gravitational constant
h = differential head equivalent to depth of the perforated drain pipe in the rock trench (typical value 0.3 m)
A_O = Area of the orifice opening (m^2) – generally assumed to be circular for calculation of orifice diameter.
The size of the swale is then determined by the available area on the site.

$$I/P = \frac{\text{Impervious } TributaryArea}{BaseArea}$$

The depth of the rock reservoir above the orifice outlet is calculated as:

$$D_R = \frac{R \times (I/P+1) - 0.09\,mm/hr \times 24\,hrs \times (I/P+1) - 24 \times Ks - 0.2 \times D_S}{n}$$

Where:
D_R = Depth (thickness) of rock reservoir (mm)
R = Rainfall capture depth (mm)
I/P = Ratio of impervious tributary area to swale base area (unitless)
0.09 = Recommended unit discharge through orifice (mm/hr)
Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
D_S = Soil layer depth (thickness); standard value = 300 (mm)
n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

7.8.2 Sizing Approach 2 – for % Capture of Average Annual Rainfall

1. Determine the average annual rainfall for the site. If unknown, refer to map in Appendix B of isohyetal lines showing average annual rainfall depths across the Metro Vancouver Region.
2. Consult the Rock Trench chart in Appendix B (B-20 through B-22) applicable for the site's location according to average annual rainfall: 1100mm (White Rock), 1500mm (Kwantlen, Surrey, and Vancouver), or 2100mm (North shore and Coquitlam); If between these values, choose the chart for the higher amount of rainfall or interpolate the result between the two bracketing charts.
3. Find the point on the chart matching the site's subsurface soil infiltration rate and the target % Capture and select the curve that is at or above (better capture) that point. The selected curve gives the I/P ratio required to meet the given % capture for the facility.
4. To find the infiltration trench base area:

   $$BaseArea = \frac{\text{Tributary Impervious Area}}{\text{I/P}}$$

   The shape of the points nearby on the selected curve indicate the depth (thickness) of the rock reservoir. The rock depth may be interpolated between two neighbouring values. Allowable rock depth range is 300 to 2000 mm.

   If the site cannot accommodate the I/P ratio required to provide the target capture, or an I/P ratio of less than 5 would be needed (not shown on the chart) a partial-infiltration rock trench with flow restrictor design may be used.

   The size of the infiltration trench is then determined using the "Rock Trench with 0.25 L/s/ha Orifice" charts in Appendix B (B-23 through B-25). Read the I/P ratio required for the given infiltration rate and capture target.
5. Calculate the infiltration trench base area:

   $$BaseArea = \frac{\text{Impervious } TributaryArea}{I/P}$$

6. Check that the calculated infiltration trench base area is smaller than the available site area. If not, the capture target cannot be achieved given the site

constraints using the sizing tools in this document. The site may be able to be reconfigured to accommodate the calculated infiltration trench base area.

The depth of the rock reservoir above the orifice outlet is given as 1.5 m for an infiltration trench with orifice for the purposes of this simplified design approach.

7. Calculate the allowable discharge through the orifice:

$$Q = \frac{0.25 \times A_{SITE}}{1000}$$

Where:
Q = Allowable discharge through orifice (m^3/s)
0.25 = Recommended unit discharge (L/s/ha)
A_{SITE} = Total site area draining to the swale, including the swale area (ha)
This discharge is used to size the orifice on a flow restrictor at the downstream end of the infiltration trench underdrain (see detail 7E).

Solving the orifice equation for area of the orifice (AO):

$$A_O = \frac{Q_O}{K \times \sqrt{2g\Delta h}}$$

Where:
Q_O = Theoretical discharge through infiltration from the impervious area that will be discharged via orifice (m^3/s)
K = Orifice Coefficient (typical value 0.6)
g = gravitational constant
h = differential head equivalent to depth of the perforated drain pipe in the rock trench (minimum value 0.3 m)
A_O = Area of the orifice opening (m^2) – generally assumed to be circular for calculation of orifice diameter.

An orifice of no less than 10 mm is recommended to minimize clogging. A 10 mm orifice is the size required for a 0.46 ha tributary area. If the calculated orifice size is less than 10 mm, a regional capture facility servicing at least a 0.46 ha tributary area should be considered.

7.9 Guideline Specifications

Materials shall meet Master Municipal Construction Document 2009 requirements, and:

1. Infiltration Drain Rock: clean round stone or crushed rock, with a porosity of 35 to 40 % such as 75mm max, 38mm min, (Maryland Dept. of the Environment, 2009) or MMCD Section 31-05-17 Part 2.6 – Drain Rock, Coarse;
2. Pipe: PVC, DR 35, 100 mm min. dia. with cleanouts certified to CSA B182.1 as per MMCD;
3. Geosynthetics: as per Section 31-32-19, select for filter criteria or from approved local government product lists;
4. Sand: Pit Run Sand as per Section 31-05-17;

5. Growing Medium over trench: As per Section 32-91-21 Topsoil and Finish Grading, Table 2;
6. Seeding: conform to Section 32-92-20 Seeding or 32-92-19 Hydraulic Seeding (note – sodding will be required for erosion control in most instances);
7. Sodding: to MMCD Section 31-92-23 Sodding;
8. All precast sections shall conform to the requirements of ASTM C 478;
9. Invert shall be level and smooth; and
10. Soakaway Manhole barrel shall not be perforated within 1200mm of the cone (top section).

Construction Practices shall meet Master Municipal Construction Document 2009 requirements, and:

1. Isolate the infiltration site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying the excavation of 300mm of material over the final subgrade until after all sediment-producing construction in the drainage area has been completed (Maryland Dept. of the Environment, 2009);
2. Prevent natural or fill soils from intermixing with the Infiltration Drain Rock. All contaminated stone aggregate must be removed and replaced (Maryland Dept. of the Environment, 2009);
3. Infiltration Drain Rock shall be installed in 300mm lifts and compacted to eliminate voids between the geotextile and surrounding soils (Maryland Dept. of the Environment, 2009); and
4. Provide a min. of 150mm of 25mm or 19mm clean crushed rock under all pipes.

7.10 Infiltration Trench Design Example

7.10.1 Scenario Description

A Partial Infiltration Trench is proposed to capture a portion of the runoff from a building roof (see illustration below).

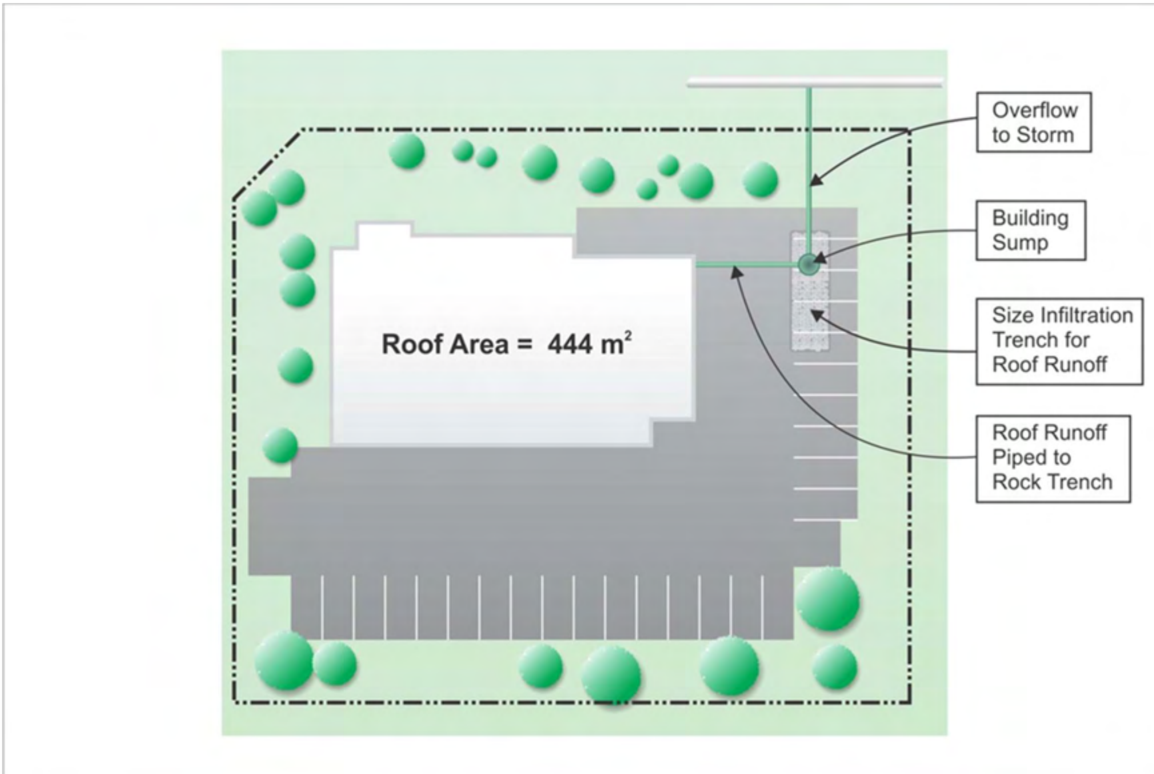


Figure 7-1: Example – Roof Area Draining to Infiltration Trench

The following parameters are known:

- Roof area = 444 m^2;
- Annual rainfall = 1300 mm;
- 2-year 24-hour rain depth = 56 mm;
- Native soil infiltration rate = 5 mm/hr; and
- Annual rainfall capture target = 70%.

1. Determine the infiltration trench footprint area, and rock depth and volume below the overflow level.

7.10.2 Sizing

Note: this sizing approach is only used when the rainfall capture target is a % of average annual rainfall.

Because the annual rainfall at the site falls between two sizing charts, the 1100 mm and 1500 mm, both will need to be used to interpolate the I/P ratio needed to meet the capture target.

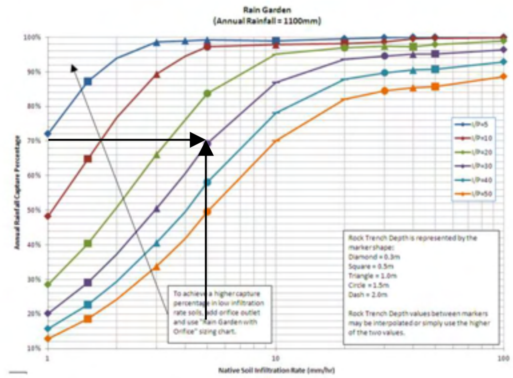


Figure 7-2: Sizing chart for Infiltration Trench for 1100 mm annual rainfall.

As shown in the 1100 mm chart (Figure 7-2), the 70% capture and 5 mm/hr infiltration point plots on the I/P=30 curve. The circular marker indicates a 1.5 m rock trench depth requirement. Similarly, the 1600 mm chart shows that an I/P=20 and 1.5 m deep trench are required to meet the capture target.

Interpolating between the two curves to estimate the requirements for a 1300 mm annual rainfall location yields an I/P=24 ratio and 1.5 m deep rock trench.

The infiltration trench footprint area equals the roof area divided by the I/P ratio ($444\ m^2 / 24 = 19\ m^2$).

The rock volume below the overflow elevation is 28 m3 (19 m2 x 1.5 m).

7.10.3 Hydraulic Components

Inlet: Roof runoff is piped into the building sump. A perforated pipe or series of pipes convey the flow from the sump and distribute it throughout the infiltration trench.

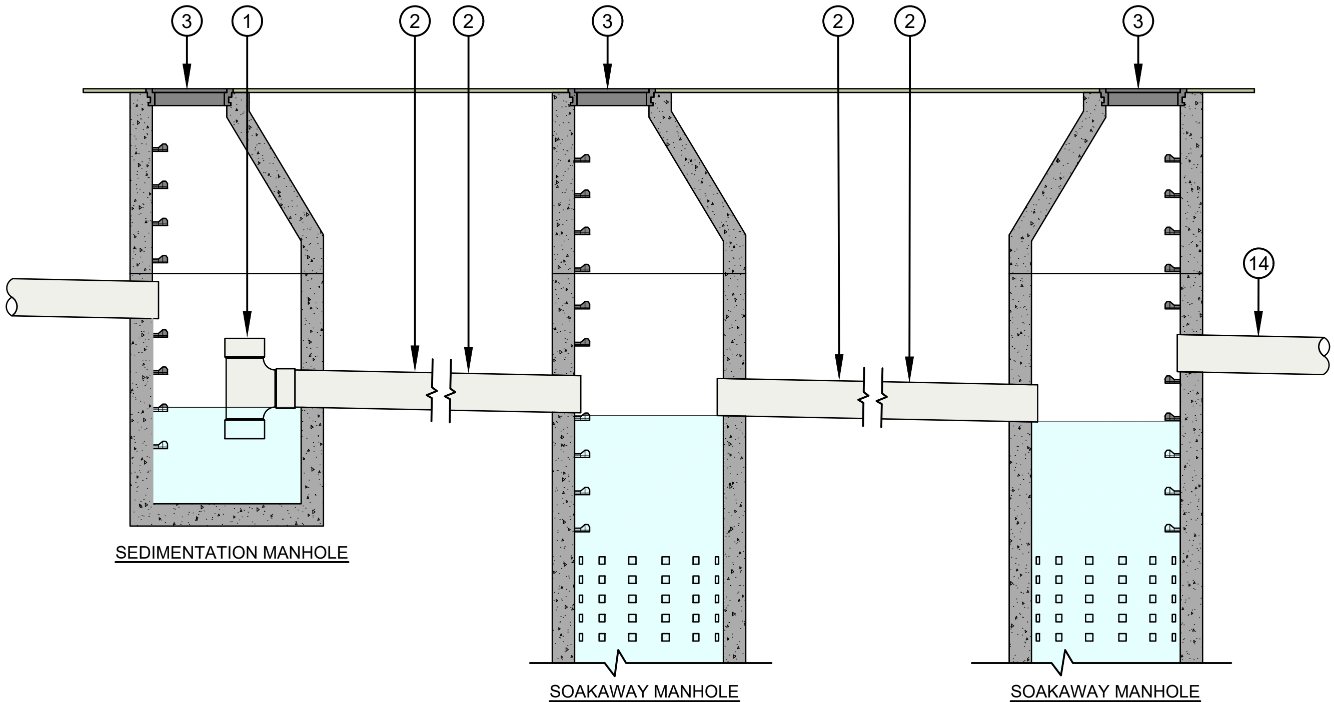
Overflow: The perforated pipes are located along the top of the infiltration trench rock layer. When the trench is full of water, the water level in the building sump reaches the invert of an overflow pipe which conveys excess water to the municipal storm sewer.

7.10.4 Maintenance

- Building sump should be inspected annually and cleaned as required. Sediment should be removed from the sump bottom and floatables removed from the water surface.

7.10.5 Operation and Maintenance Considerations

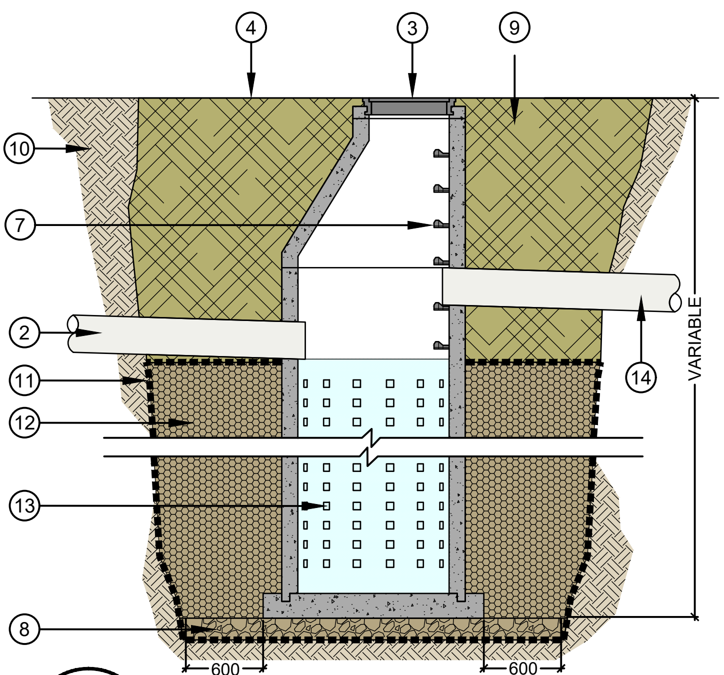
Infiltration trenches used for vehicle or pedestrian traveled areas require that a pre-treatment system be installed ahead of the infiltration trench to remove sediment and gross pollutants. This will maximize the longevity of the infiltration trench performance.



7 A **SEDIMENTATION MANHOLE AND SOAKAWAY MANHOLES**

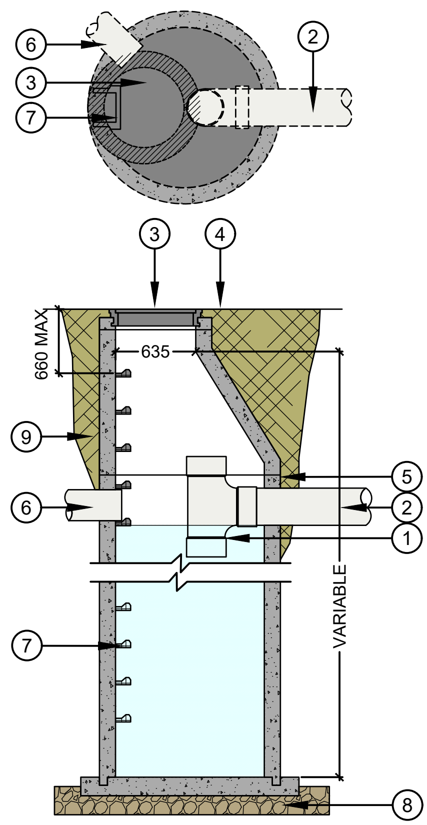
Not To Scale — Section

NOTES:
ALL PRECAST SECTIONS SHALL CONFORM TO THE REQUIREMENTS OF ASTM C 478.
PROVIDE A MIN. OF 150mm OF 25mm OR 19mm CLEAN CRUSHED ROCK UNDER ALL PIPES.
INVERT SHALL BE LEVEL AND SMOOTH.
SUMP BARREL SHALL NOT BE PERFORATED WITHIN 1200mm OF THE CONE.



7 B **SOAKAWAY MANHOLE**

Not To Scale — Section

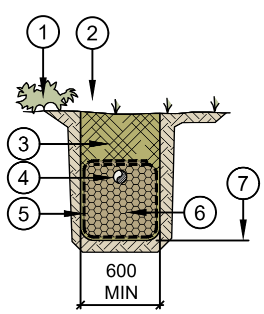


7 C **SEDIMENTATION MANHOLE**

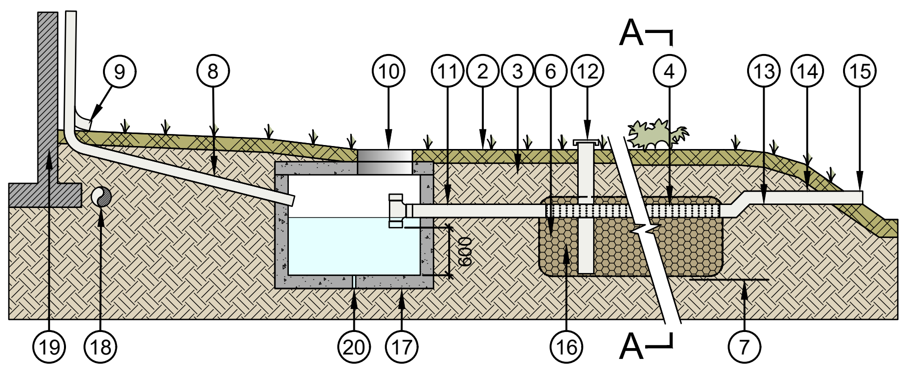
Not To Scale — Section

1. PVC SOLID PIPE C/W INLET TEE
2. INTERCONNECTING PVC SOLID PIPE
3. STANDARD MANHOLE FRAME AND COVER
4. FINISH GRADE
5. SEAL JOINTS WITH CEMENT GROUT OR APPROVED MASTIC
6. STREET INLET CONNECTION
7. LADDER RUNG
8. 25mm CRUSH GRAVEL OR DRAIN ROCK BASE
9. NATIVE SOIL BACK FILL
10. UNDISTURBED GROUND
11. GEOTEXTILE BETWEEN DRAIN ROCK AND NATIVE SOIL
12. 50mm DRAIN ROCK
13. 1200mm PERFORATED BARREL (LANGLEY CONCRETE OR EQUAL)
14. OVERFLOW TO STORM DRAINAGE SYSTEM

1. GRASS OR OTHER PLANTING
2. FINISH GRADE
3. GROWING MEDIUM BACKFILL
4. 100mm DIA PVC DR28 PERFORATED PIPE
5. LIGHT NON-WOVEN GEOTEXTILE C/W MIN. 400mm LAPS
6. 50mm DRAIN ROCK OR ROCK OF EQUAL POROSITY
7. MAXIMUM GROUNDWATER ELEVATION
8. NON-POLLUTED DRAINAGE FROM BUILDING OR TERRACE
9. ALTERNATE SURFACE ROUTE - WITH SPLASH PAD AND VEGETATED SWALE TO CB
10. CB LID / ACCESS HATCH FOR CLEANOUT, INSPECTION AND INFLOW / OVERFLOW FROM SUMP
11. 100mm DIA PVC SOLID PIPE C/W INLET TEE
12. OBSERVATION WELL (OPTIONAL)
13. INVERT TO TOP OF INFILTRATION PIPE (APPROX.)
14. 100mm DIA PVC SOLID PIPE
15. DISCHARGE TO STORM DRAINAGE SYSTEM. ENSURE DRAINAGE DOES NOT IMPACT NEIGHBOURING USES. DIRECT DISCHARGE TO ROAD RIGHT-OF-WAY IF NECESSARY
16. INFILTRATION TRENCH WITH LEVEL BOTTOM
17. CATCH BASIN
18. BUILDING FOOTING DRAIN (NOT CONNECTED TO INFILTRATION FACILITY)
19. BUILDING
20. 50mm DIA MIN. DRAIN HOLE



SECTION A-A



SECTION FROM WATER SOURCE TO INFILTRATION TRENCH

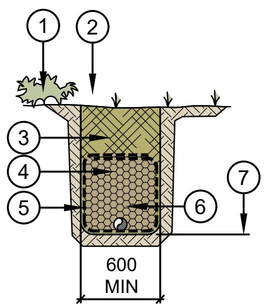
7
D

INFILTRATION TRENCH

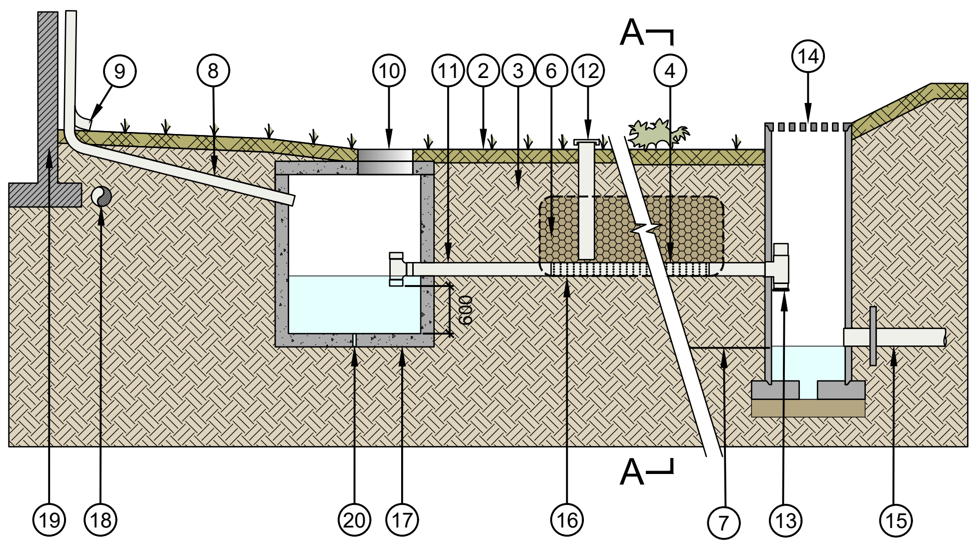
Not To Scale

Section

1 GRASS OR OTHER PLANTING
2 FINISH GRADE
3 GROWING MEDIUM BACKFILL
4 100mm DIA PVC DR28 PERFORATED PIPE
5 LIGHT NON-WOVEN GEOTEXTILE C/W MIN. 400mm LAPS
6 50mm DRAIN ROCK OR ROCK OF EQUAL POROSITY
7 MAXIMUM GROUNDWATER ELEVATION
8 NON-POLLUTED DRAINAGE FROM BUILDING OR TERRACE
9 ALTERNATE SURFACE ROUTE - WITH SPLASH PAD AND VEGETATED SWALE TO CB
10 CB LID / ACCESS HATCH FOR CLEANOUT, INSPECTION AND INFLOW / OVERFLOW FROM SUMP
11 100mm DIA PVC SOLID PIPE C/W INLET TEE
12 OBSERVATION WELL (OPTIONAL)
13 INFLOW RESTRICTOR TEE WITH ORIFICE TEE
14 OVERFLOW INLET AT CATCHBASIN
15 DISCHARGE TO STORM DRAINAGE SYSTEM. ENSURE DRAINAGE DOES NOT IMPACT NEIGHBOURING USES. DIRECT DISCHARGE TO ROAD RIGHT-OF-WAY IF NECESSARY
16 INFILTRATION TRENCH WITH LEVEL BOTTOM
17 CATCH BASIN
18 BUILDING FOOTING DRAIN (NOT CONNECTED TO INFILTRATION FACILITY)
19 BUILDING
20 50mm DIA MIN. DRAIN HOLE



SECTION A-A



SECTION FROM WATER SOURCE TO INFILTRATION TRENCH

7 E INFILTRATION TRENCH WITH FLOW RESTRICTOR

Not To Scale

Section

DESIGN PRINCIPLES

- Infiltration Trench System:

a) Locate infiltration trench at least 3m from any building, 1.5m from property lines, and 6m from adjacent infiltration facilities (or as recommended by a geotechnical engineer).

b) Sump: Provide a lid for periodic inspection and cleanout. Include a T-inlet pipe to trap oils, sediments and debris.

c) Infiltration Trench: installation of distribution pipe and bottom of drainrock to be level. If more than one section of infiltration trench is required, design so that underground water is temporarily 'ponded' in each infiltration section.

d) Install the Infiltration Trench in native ground, and avoid over-compaction of the trench sides and bottom, which reduces infiltration.

e) Observation well for each infiltration trench (optional): vertical standpipe, with perforated sides, and locking lid, to allow the monitoring of water depth.

- Soakaway Manholes System:

a) Provide a report from an engineer with experience in geotechnical engineering including on-site test data of infiltration rates at the depth of the proposed infiltration. The bottom of the shaft shall be at least 600mm above the seasonal high water table or bedrock, or as recommended by the engineer.

b) If steep slopes or drinking water wells exist within 200m horizontally from the proposed Soakaway Manhole, provide a hydro-geotechnical report to analyze site-specific risks and determine setbacks.

c) Provide a sedimentation manhole, and a maximum of two Soakaway Manholes in series, unless otherwise approved.

d) Provide an overflow from the Soakaway Manhole to the storm drainage system or major storm flow path.

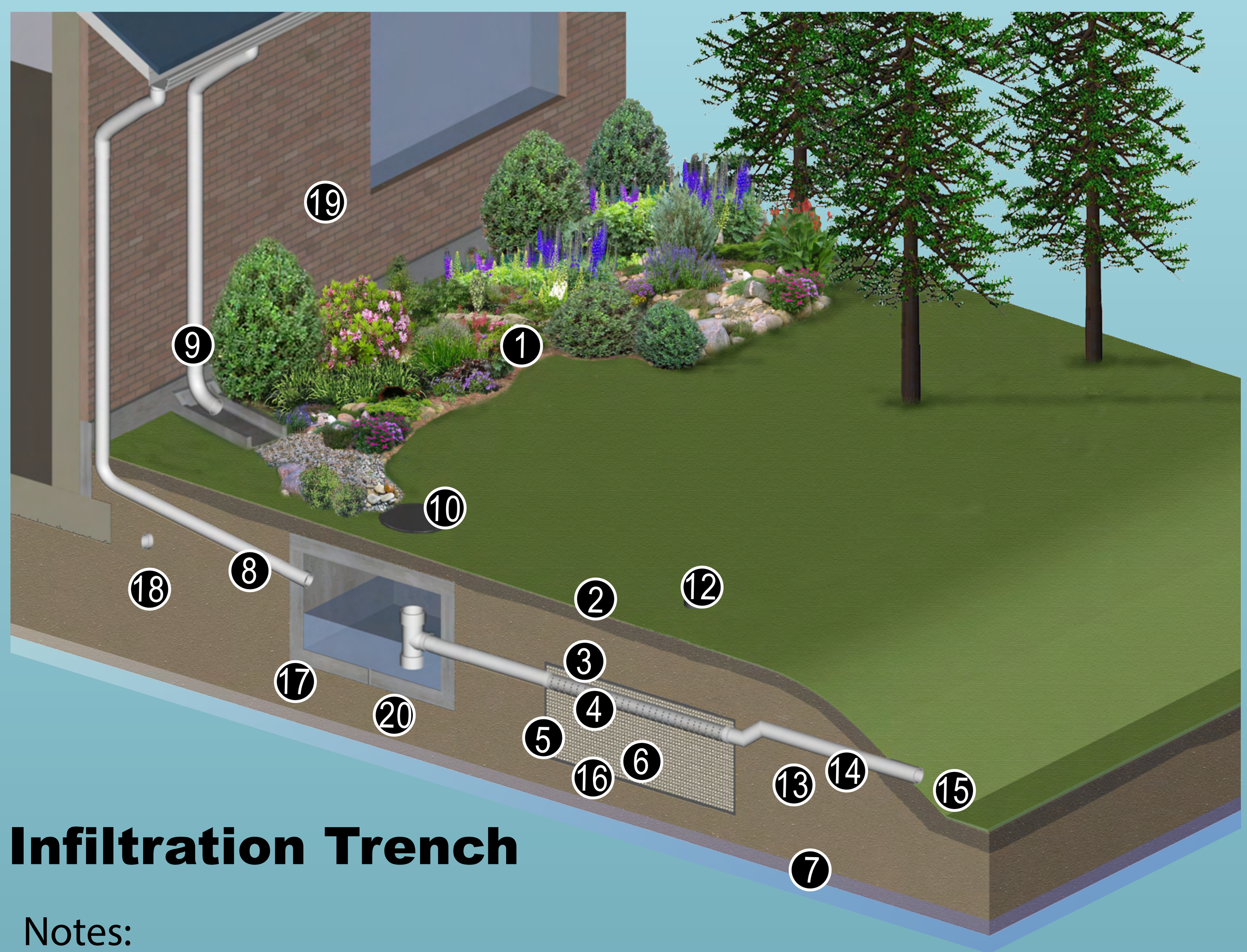
An **Infiltration Trench** System includes an inlet pipe or water source, catch basin sump, perforated distribution pipe, infiltration trench and overflow to the storm drainage system.

A Soakaway Manhole (Sump, or Dry Well) System includes an inlet pipe, a sedimentation manhole, and one or more infiltration shafts with connecting pipes. Use of Infiltration Shaft will be limited by hydro-geotechnical conditions in much of GVRD.

Limitations of Infiltration Trench or Soakaway Manholes:

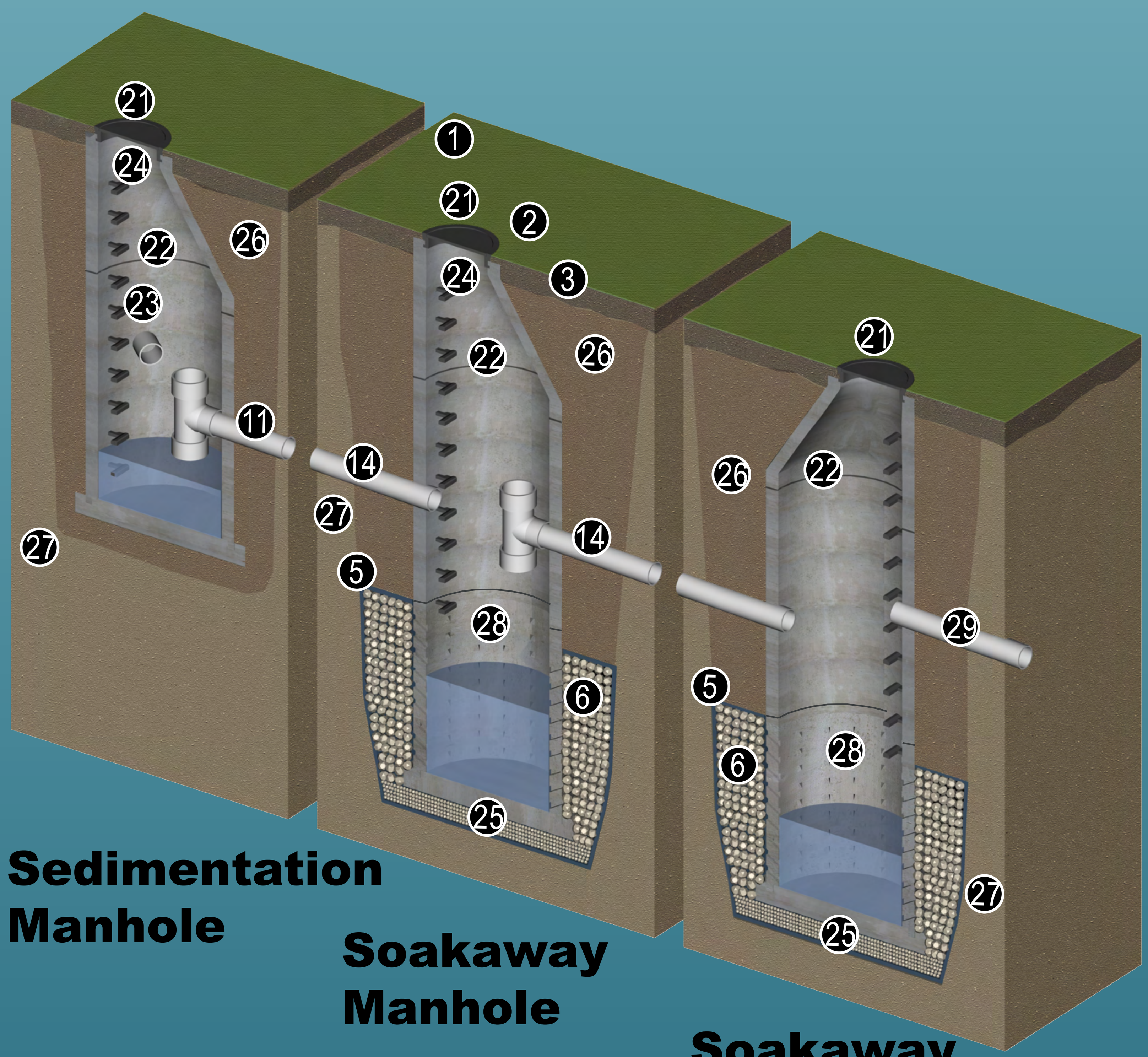
a) To avoid groundwater pollution, do not direct un-treated polluted runoff to Infiltration Trench or Shaft:
   - Direct clean runoff (roof, non-automobile paving) to Infiltration Trench or Shaft.
   - For polluted runoff (roads > 1000 vehicles / day, parking areas, other pollution sources), provide upstream source control for pollutant reduction prior to release to Infiltration Trench or Shaft.

b) Use infiltration trench or shaft only in areas with footing drains.



Infiltration Trench

Notes:
All precast sections shall conform to the requirements of ASTM C 478.
Provide a min. of 150mm of 25mm or 19mm clean crushed rock under all pipes.
Invert shall be level and smooth.
Soakaway Manhole barrel shall not be perforated within 1200mm of the cone.



Sedimentation Manhole

Soakaway Manhole

Soakaway Manhole

1. Grass or Other Planting
2. Finish Grade
3. Growing Medium Backfill
4. 100mm Dia PVC DR28 Perforated Pipe
5. Light Non-woven Polyester Geotextile c/w Min. 400mm Laps
6. 50mm Drain Rock or Rock of Equal Porosity
7. Maximum Groundwater Elevation
8. Non-polluted Drainage From Building or Terrace
9. Alternate Surface Route - With Splash Pad and Vegetated Swale to CB
10. CB Lid / Access Hatch for Cleanout, Inspection and Inflow / Overflow from Sump
11. Solid Pipe c/w Inlet Tee
12. Observation Well (Optional)
13. Provide pipe elbows to have outlet pipe invert at top of infiltration pipe
14. PVC Solid Pipe
15. Discharge to Storm Drainage System. Ensure Drainage Does Not Impact Neighbouring Uses. Direct Discharge to Road Right-of-way if Necessary
16. Infiltration Trench with Level Bottom
17. Catch Basin
18. Building Footing Drain (Not Connected to Infiltration Facility)
19. Building
20. 50mm Dia Drain Hole
21. Standard Manhole Frame and Cover
22. Seal Joints with Cement Grout or Approved Mastic
23. Street Inlet Connection
24. Ladder Rung
25. 25mm Crush Gravel or Drain Rock Base
26. Native Soil Back Fill
27. Undisturbed Ground
28. 1200mm Perforated Barrel (Langley Concrete or Equal)
29. Overflow to storm drainage system.

Infiltration Trench & Soakaways

metrovancouver

Stormwater Source Control Design Guidelines 2023

LANARC CONSULTANTS LTD

kwl

Goya Ngan Landscape Architect

Detailed design guidelines can be found in the Design Guidelines 2012 report, available at www.metrovancouver.org

Detailed design guidelines can be found in the Preliminary Design Guidelines report available at www.gvrd.bc.ca

SOIL CELL AND TREE TRENCH

8 Soil Cell and Tree Trench

8.1 Description

A **Soil Cell** System is a system that provides loading support for adjacent or overlying hard surfaces while allowing large volumes of uncompacted soil media to be placed below and adjacent to the pavement. They are most often used to support the inclusion and health of trees, even large trees, in an urban environment. Soil cells may be called by the names of some proprietary tree and soil systems.

A **Tree Trench** System is similar to a soil cell, but it is constructed in a linear manner to provide a 'trench' of uncompacted soils, with reinforced sides and top sections rather than internal supports.

A common variation of soil cells and tree trenches utilizes structural soil – a mix of crushed stone and loam soil – to provide structural support for overlying and adjacent pavement rather than separate support structures around the soil. It provides a suitable base for pavement while still allowing roots to penetrate.

Installed tree in soil cell, Richards St., Vancouver. (Photo Credit: City of Vancouver)

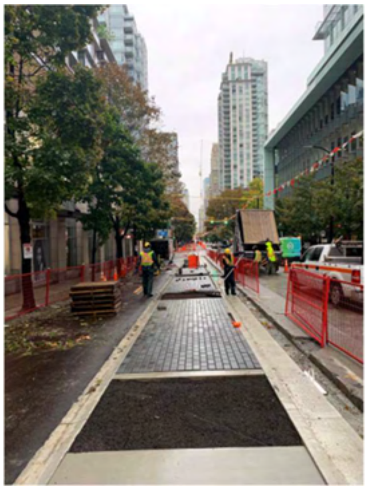
8.2 Selection and Application

- Soil cells and tree trenches are used for growing trees, supporting root growth in the uncompacted soil, and providing rainwater filtering, detention, and retention within the system.
- Because they contain soil media, they are suitable for treating runoff from adjacent roads or other pollutant-generating surfaces.
- The structural system can be designed to support loads up to and including AASHTO H-20 and sidewalk standards.
- If using a proprietary system, the system must be designed and installed in accordance with the manufacturer's instructions and requirements.
- Structural soil is used in urban areas where trees can share a volume of continuous soil. It is also used for "root bridging" or "breakout zones" to connect tree roots to adjacent areas of soil (e.g., a trench of structural soil that connects tree roots to a lawn area on the opposite side of the sidewalk).
- Structural Soil can be used under sidewalks, parking lots, and low-use roads.
- Structural Soil is typically less expensive than soil cells and/or tree trenches. However, the volume of soil (and therefore the volume of stormwater detention/retention) at about 20% is significantly less with Structural Soil.

8.3 Design Guidelines

8.3.1 Soil Cell:

1. Inflow to the soil cell may be surface distribution, i.e., flow onto the soil surface, or sub-surface distribution, i.e., flow into the soil in a perforated pipe surrounded by drain rock.
2. For surface distribution, the inflow may be point source or distributed. For point source runoff in inflow may be through pipes or curb cuts from nearby surfaces. Distributed inflow may consist of surface overland flow to the soil cell from adjacent surfaces. It is possible for a soil cell to have both point source and distributed inflows.
3. Separation from base of soil cell/trench to water table should be a minimum of 600 mm.
4. Soil cells may be any size accommodated in the space available. Municipalities may provide minimum targets for soils volume for street trees.



Tree pit and pavers over soil cells.
(Photo Credit: City of Vancouver.)

5. Each soil cell or stack of soil cells must be structurally independent of adjacent soil cell stacks such that a single stack or group of stacks can be removed to facilitate future utility installation and repair.
6. Each soil cell should facilitate movement of roots and water between the cells and into surrounding cells, i.e., there should not be flow barriers between cells.
7. Soil cells are typically designed to infiltrate water into the subsurface, but if required the outer faces of the cell may be lined with impermeable membrane in order to prevent infiltration and provide treatment only. If this is required, a provision for providing irrigation for the trees in dry periods must also be included.
8. An observation well is recommended for each group of soil cells to allow monitoring of water depth in the reservoir, consisting of a vertical standpipe, with perforated sides, and locking lid.
9. A bypass or overflow must be included in the facility design to accommodate flows in excess of the design infiltration volume. This may include overflow onto the roadway for conveyance to downstream catchbasins.
10. Unless the native soil infiltration rate is very high, an underdrain/subdrain should be provided at the base of the soil layer to ensure that the soil column does not remain saturated and suffocate the tree roots. A root barrier should be used to prevent tree roots from growing into perforated pipe underdrains, either as a layer above the underdrain or a wrap around the underdrain pipe.

11. Avoid utility or other crossings through the soil cell where possible. Where utility trenches must be constructed crossing through or below the cell, install infiltration barriers or trench dams to avoid infiltration water following the utility trench. Coordinate with utility providers to ensure that protective measures are acceptable to all parties.
12. The structural support for the overlying and adjacent pavements must be checked as part of the design. Structural soil (see below) may be used to support adjacent loads

Trench installation, showing filter cloth wrap, and showing trench dam of native material between infiltration trench 'cells'.
(Photo Credit: Lanarc Consultants Ltd.)

8.3.2 Tree Trench:

1. Design of a tree trench is very similar to that of a soil cell, but there are a few key differences. The principal difference is that the tree trench resists the load of the adjacent soil and pavement through the reinforced structure of the trench walls and top; therefore, the structural design of the trench must account for the loading of the adjacent soil and pavement on the trench structure. Typically, the trench has an open surface where soil is visible and additional vegetation may be installed between the trees.
2. A tree trench can also be designed as a linear trench with structural soil providing the structure around the tree pits rather than a soil cell support system. Structural soil may also be used for growing trees beneath a sidewalk, bike lane or boulevard surface.
3. The tree trench may be overlaid by permeable pavers or porous asphalt surrounding the trees to provide a hard permeable surface over the trench rather than an open top trench with exposed soil or mulch. It may also be overlaid by grass.
4. Structural soil should be designed and mixed in accordance with a specification such as that used by the City of Vancouver in their Engineering Construction Specifications. Typical applications using structural soil are between 600mm and 1000mm deep.

Silva Cell (proprietary) and structural soil installed adjacent to one another, Vancouver.
(Photo Credit: City of Vancouver.)

8.4 Pre-Treatment Principles

A sump or pre-treatment system should be installed to remove sediment and gross pollutants prior to discharge into the soil cell or tree trench through a pipe distribution system, whether at the surface or subsurface in the growing media soil. This will maximize the longevity of the soil cell performance.

1. For surface runoff that requires treatment, e.g., road runoff, a pre-treatment sump or other settling or sediment removal device is recommended to reduce the sediment load to the soil cell. However, surface overland flow to the soil cell is acceptable if planned maintenance, potentially including periodic removal and replacement of the surface few centimetres of soil accounts for sediment deposition and removal.
2. Where inflow is through a distribution pipe, a sump should be part of the inlet piping, such as aa concrete, plastic, or other non-degradable box with strength suitable to withstand surface loads. Provide a removable lid for periodic inspection and cleanout. Include a T-inlet pipe to trap oils, sediments, and debris. Weep holes may be included to dewater the sump, for mosquito management.
3. Identify pollutant sources other than vehicles, particularly in industrial/commercial hotspots, that require pre-treatment or source control upstream of this BMP.
4. If the discharge is by overland sheet flow into the surface of the soil cell it may not be possible to provide pre-treatment. Then the inflow sediment should distribute over the surface of the soil cell and the top few centimetres of soil can be removed and replaced periodically as needed. If the surface inflow occurs at discharge points, sediment pads or basins may be used for pre-treatment and removal of sediment.

8.5 Maintenance Considerations

Particularly when the runoff inflow to the source control comes from road surfaces, including a pre-treatment facility to collect sediment from runoff that can be easily cleaned out minimizes the effort needed for ongoing maintenance for soil cells and tree trenches. Accessible inspection ports for perforated distribution ports and underdrains are recommended.

If monitoring of the installed system is desired, a monitoring well should be designed as part of the system.

- ❑ Locate the pre-treatment device where it is easily accessible.
- ❑ Use a device design that is consistent with other devices the municipal staff maintain so that it is familiar to staff and utilizes the same equipment.
- ❑ Pre-treatment device or sump should be inspected and cleaned seasonally, (spring and fall) as a minimum, and as required. Sediment should be removed from the sump/device bottom and floatables removed from the water surface.
- ❑ See Chapter 11 – Maintenance Guideline for further details regarding maintenance tasks and frequency.

8.6 Soil Cell Sizing

Sizing methods are presented here for a generic soil cell; sizing is similar for a tree trench. Providers of proprietary soil cell products often provide sizing services to municipalities for their products.

Soil cells may be sized using continuous simulation modeling in the WBM or SWMM or using spreadsheet design storm and water balance calculations. Simplified sizing approaches have been developed that do not require water balance modeling or continuous simulation.

1. For these sizing approaches, a soil cell is assumed to be a rectilinear underground facility defined by a Base Area which is the same as the footprint, and a depth of soil in the cell. Depth of cover and surfacing over the soil is not considered or accounted for.
2. In general, the soil cell 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 impervious area to pervious area (e.g., I/P ratio). For the simplified sizing approaches here, this represents the ratio of upstream impervious area (also called catchment area) to Base Area (bottom area) of the Infiltration Trench. I/P ratio to achieve the target capture criteria will be calculated.
3. Sizing presented here is for infiltration of rain water for “capture” and prevention of site runoff. No sizing and design is provided for any pre-treatment facility.

8.6.1 Sizing for depth capture criteria: R mm in 24 hrs

1. Determine the maximum soil depth needed according to the drain time (4 days max.) and round down to the nearest 100 mm increment for constructability; standard depth range used in this sizing guidance is 1000 to 2000 mm:

   $$D_{Soil} = \frac{Ks \times T \times 24}{n}$$

   Where:

   D_{Soil} = Depth (thickness) of soil (mm)
   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
   T = allowable drain time (days)
   n = field capacity of soil in cell (unitless, e.g., 0.2)

   Note: if treatment is the performance goal rather than capture and an underdrain is used at the base of the trench, the soil depth does not need to be sized but may be selected based on tree root soil depth needs.

2. Use the following equation to determine the base (bottom) area of soil cell required by finding the I/P ratio for the site:

$$I/P = \frac{24 \times Ks + D_{Soil} \times n}{R} - 1$$

Where:

I/P = Ratio of impervious tributary area to rock trench base area (unitless)
R = Rainfall capture depth (mm)
Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr)
D_{Soil} = Depth (thickness) of soil cell (mm)
n = field capacity of soil in cell (unitless, e.g., 0.2)

To find the minimum soil cell base area:

$$BaseArea = \frac{\text{ImperviousTributaryArea}}{I/P}$$

If the site cannot accommodate the calculated I/P ratio, the designer may consider whether a smaller area is acceptable, with the understanding that the capture may not meet the desired target. A SWMM model of the catchment and soil cell will likely provide a less conservative estimate of the area required in order to meet the target.

If inflow is discharged to the soil through a subsurface distribution pipe, then the infiltration rate of the soil media should also be adjusted to reflect the different surface infiltration area compared to a surface distribution approach. The soil conductivity adjustment factor is calculated using:

$$K_{saf} = \frac{BaseArea}{P_r \times L}$$

Where:

K_{saf} = is the soil conductivity adjustment factor (unitless)
BaseArea = Base area or surface area of the soil cell (m^2)
P_r = outside perimeter of the rock surrounding the distribution pipe (m)
L = length of the perforated portion of the distribution pipe (m)

Therefore, the soil conductivity to use in calculating the soil depth and I/P ratio when subsurface distribution is used should be:

$$K_{s(adjusted)} = \frac{K_s \times K_{saf}}{3}$$

3. Check the maximum inflow that can be discharged to the soil through a subsurface distribution pipe. The maximum pipe discharge must greater than the design inflow for the infiltration system. If the pipe manufacturer provides a flow per metre length for the pipe, use that to calculate the max flow. If that is not available, the maximum flow can be calculated using:

   $$Q_{max,pipe} = L \times B \times C_d \times A_o \sqrt{2 \times g \times h_{max}}$$

   Where:
   L = the length of perforated pipe (m)
   B = the clogging factor (between 0.5 for matured installation and 1 for new installation)
   C_d = the coefficient of discharge (usually 0.61)
   A_o = the total open area per unit length of pipe (m^2/m)
   g = acceleration due to gravity (m/s^2)
   h_{max} = total head of water over the perforated pipe (m)

8.7 Guideline Specifications

Materials shall meet Master Municipal Construction Document 2019 requirements, and:

1. Pipe: PVC, DR 35, 100 mm min. dia. with cleanouts certified to CSA B182.1 as per MMCD;
2. Geosynthetics: as per Section 31-32-19, select for filter criteria or from approved local government product lists;
3. Sand: Pit Run Sand as per Section 31-05-17;
4. Growing Medium Soil: See Chapter 9, Growing Medium Standards;
5. Structural Soil: Example specification may be found in Section 32 91 22S Engineered Soil in the City of Vancouver's Engineering Construction Specifications;
6. All precast sections shall conform to the requirements of ASTM C 478; and
7. Invert shall be level and even but scarified.

Construction Practices shall meet Master Municipal Construction Document 2019 requirements, and:

1. Isolate the soil cell or tree trench site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying the excavation of 300mm of material over the final subgrade until after all sediment-producing construction in the drainage area has been completed (Maryland Dept. of the Environment, 2009);
2. Prevent natural or fill soils from intermixing with the Growing Media Soil and/or Structural Soil; and
3. Construction of trench for soil cell or tree trench must include stabilization of the trench sides and/or shoring as required for all trench construction work.

8.8 Soil Cell Design Example

8.8.1 Scenario Description

A Soil Cell is proposed to capture a portion of the runoff from a section of road.

The following parameters are known:

- Catchment area = 600 m2
- Annual rainfall = 1300 mm
- Target capture depth = 40 mm
- Native soil infiltration rate = 5 mm/hr

1. Determine the soil cell footprint area, and growing media soil depth.

8.8.2 Sizing

1. Determine the maximum soil depth needed according to the drain time (4 days max.) and round down to the nearest 100 mm increment for constructability; standard depth range used in this sizing guidance is 1000 to 3000 mm:

   $$D_{Soil} = \frac{5\times4\times24}{0.2} = 2400\,mm$$

   Max Soil depth needed is 2400 mm.

2. Find the I/P ratio needed to meet the capture target for the site:

   $$\frac{I}{P} = \frac{24\times 5 + 2400 \times 0.2}{40} - 1 = 14$$

   To find the minimum soil cell base area:

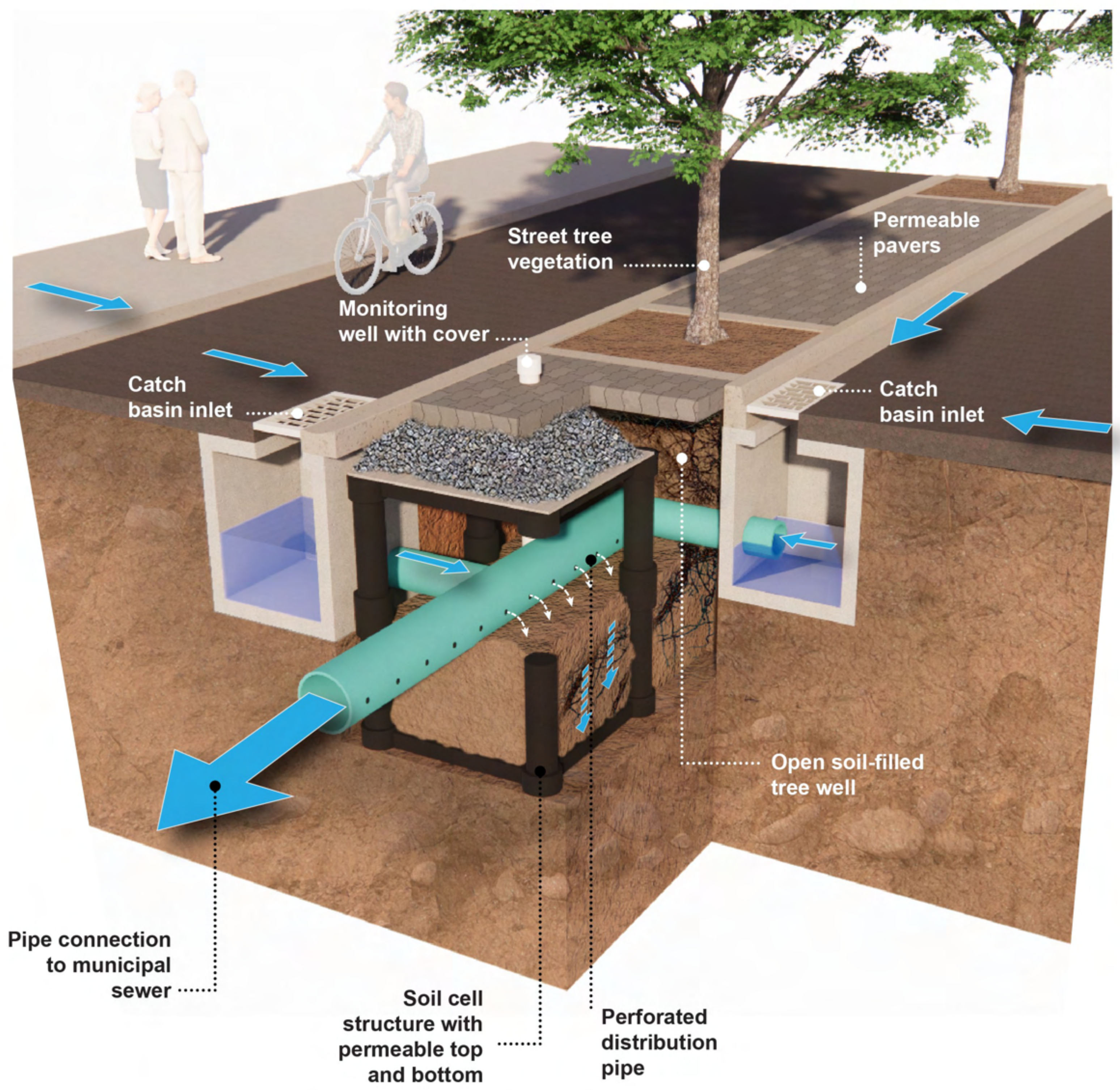
   $$aseArea = \frac{600}{14} = 43\,m^2$$

   A minimum of 43 m^2 should be used for the base area of the soil cell to treat the runoff from 600 m^2 of road (approximately half the road along one city block). This amounts to a soil cell base area approximately 21 m long by 2 m wide.

8.8.3 Hydraulic Components

Inlet: inflow runoff flows in at the surface either via overland flow through curb cuts or surface drains that discharge at the surface of the soil. Alternatively, for a subsurface inflow a perforated pipe or series of pipes convey the flow from the sump or pre-treatment device and distributes it throughout the soil in the cell or trench. A subsurface inflow should include a layer of filter cloth and drain rock around the perforated distribution pipe.

Underdrain/subdrain: The perforated pipes are located along the base of the growing media soil layer. When the trench is full of water, the water level in the building sump reaches the invert of an overflow pipe which conveys excess water to the municipal storm sewer.



8 / A SOIL CELL STRUCTURE WITH STREET TREE

Not to Scale

CONSTRUCTION AND ESTABLISHMENT PROCESS

9 Construction and Establishment Process

9.1 Existing Vegetation Cover on the Development Site

Where possible, leaving existing vegetation in place on a development site provides both interception of rainfall to reduce on-site surface runoff and reduction in surface erosion due to exposed soils.

Trees and vegetation have been shown to intercept significant amounts of annual rainfall:

1. 15% interception by leafless deciduous trees (Xiao et al, 2000), relative to a typical year.
2. 27-28% interception by evergreen trees (Xiao et al, 2000) (Johnston, 1990).

In addition to their canopy interception, trees and vegetation provide significant evapo-transpiration – removing water from the soils, and thereby freeing up soil pore space to accept and store infiltrated rainwater.

Erosion control is also provided in a most effective way by surface vegetation. Leaving surface vegetation in place until development proceeds at UniverCity in Burnaby provided 100% erosion control on individual parcels (Reid, 2004).

Initial site investigations for development projects should map the existing vegetation, and consider its role prior, during and after construction. Development strategies that have been successful in maintaining, or delaying removal of, vegetation are listed in the Vegetation Management Strategies on the facing page.

A site analysis drawing should summarize the opportunities and constraints presented by existing vegetation. Make this information available to all members of the design and approvals team.

9.2 Vegetation Management Strategies

- ❑ Leave existing vegetation in place during the planning and approvals stages. Pre-clearing vegetation results in increased costs for temporary re-vegetation and erosion control, at the same time as increasing runoff and sedimentation unnecessarily.
- ❑ Clear the site in stages as development proceeds. For instance, for larger developments, clear only road and utility corridors during each phase of subdivision, leaving the development parcels vegetated until they are sold, designed, approved and ready for construction.
- ❑ Identify areas where vegetation can permanently remain in the development. These may be areas of steep slope, stream riparian or wetland areas, wildlife or greenway corridors, specimen trees or other site areas with site constraints.

- ❑ Protect the soils under vegetation to be retained during construction. It is critical to their stormwater performance that these areas are not disturbed or compacted by equipment or storage during construction. Temporary fencing is likely required.
- ❑ In stormwater calculations, consider the contribution from existing vegetation and soils make to stormwater capture targets. These areas will count as pervious area.

Consider the possibility for some stormwater management techniques to make use of vegetated areas for stormwater capture. For example, parking areas may be graded toward areas of existing vegetation, encouraging both filtration and infiltration of surface water. Roof drainage could also be directed towards forested areas, provided the drainage is dispersed before entering the existing vegetated area. Only where the vegetated area is owned by the subject site owner and is not the property of others may this be considered. The target “capture” runoff volume should be calculated, and the capacity of the receiving area estimated to check that capture can be achieved. As a guideline, the ratio of impervious area to pervious area (I/P) for discharge to existing vegetated areas should be limited to 1:1, perhaps increasing to 2:1 if testing of the existing soil infiltration and the types of existing vegetation indicate to the designer that the area would be capable of thriving with that level of inflow. Infiltration trenches or swales can encourage infiltration just uphill from vegetated areas, so that shallow groundwater interflow occurs through the area. Although root zones should not be disturbed, development schemes have included the addition of check dams composed of drain rock, compost, or soil to create vernal infiltration pools in existing vegetated areas.

9.3 Construction Staging for Stormwater Source Controls

Natural soils generally have infiltration capabilities. Most infiltration problems are created during construction – commonly associated with disturbance, compaction, and sedimentation of proposed infiltration areas. Operations of grading and building construction are highly disruptive, with much competition for space on a construction site, leading to most of the site being compacted. Rainfall during the construction period can also readily erode exposed soils, and transport fine sediment to proposed infiltration areas, creating a surface crust that impedes infiltration.

Successful strategies that have been used to avoid disturbance, compaction and sedimentation of infiltration areas are listed in the Construction Staging Considerations.

9.4 Construction Staging Considerations

- Provide temporary fencing during construction if proposed infiltration areas are in areas of natural vegetation and require that vegetation remain in place.
- Ensure effective erosion control practices are in place during the construction period. If fine sediments are deposited on infiltration areas by accident, remove the surface crust prior to opening the infiltration facility.
- If possible, have stormwater outfalls bypass the proposed infiltration area during construction.
- Do not place erosion control sediment traps in infiltration areas. Only if absolutely necessary, build erosion control sediment traps above infiltration areas, protecting the infiltration soils with temporary cover of plastic, sand, or other mechanism that will capture all surface sediments without compacting the infiltration area, and that can be removed prior to opening the infiltration facility.
- When infiltration facilities involve the excavation of native soil material, consider staging infiltration area excavation until after all adjacent construction is complete. Then the surface soils may be disturbed and compacted during construction, but when they are removed for the final infiltration facility construction, the compacted layers will also be removed.
- For infiltration facilities that involve excavation, ensure that the bottom and sides of infiltration excavations are scarified to remove glazing and improve infiltration.
- When infiltration facilities involve installation of growing medium, ensure that layers of growing medium are tilled so that a transition of soil texture occurs. Do not compact between layers. Layers of different soil texture or compaction can create perched water tables.
- Unvegetated infiltration areas that are subjected to heavy rainfall will set up a surface crust – even in sand. Although only a few millimetres thick, the surface crust will impede infiltration. Any infiltration area, or growing medium, that is left open to heavy rainfall, must be scarified prior to adding additional layers, opening the area for infiltration, or planting.
- Cultivate in organic matter to the surface of growing medium infiltration areas. The organic matter and associated soil life will increase soil infiltration.
- Avoid the intrusion of road sands and construction traffic sediment into infiltration facilities, and pervious paving in particular. Provide regular street sweeping of roads as a part of the erosion control system. After construction, pervious paving should also be maintained by dry sweeping at least twice annually.

9.5 Field Review of Stormwater Source Controls

9.5.1 Required Field Reviews

Critical field reviews during construction include those in the Field Review Items list.

9.5.2 Field Review Items

- Protection of proposed infiltration areas from disturbance, compaction, and sedimentation.
- Scarification of subgrade.
- Filter cloth and rock reservoir installation, including rejection of contaminated drain rock and inspection of filter cloth overlap.
- Pipe, drainage utilities, structures, and bedding.
- Laboratory testing of growing medium components, for texture, fertility, and amendment requirements.
- Growing medium installation and depth. Scarification of growing medium surfaces after heavy rainfall and prior to installation of subsequent layers.
- Plant material review at the nursery or assembly point prior to planting.
- Irrigation piping and bedding, hydrostatic testing, operational performance.
- Plant material and surface mulch installation.
- Substantial and Final Performance.
- Periodic review of Establishment Maintenance.
- Review condition of facility and survival and establishment of plantings at end of Establishment Maintenance Period and/or Warranty Period.
- Record drawings.

9.5.3 Post-Construction Environmental Monitoring Strategies

The objective of post-construction monitoring is to measure the performance of the source controls. The results can help determine if the stormwater capture targets were met and can provide real data of performance and effectiveness to municipalities, practitioners, and developers for the adaptive management process. The results can be used both locally and regionally to refine source control designs and/or recommend additional environmental protection measures if needed.

Post-construction monitoring can consist of rainfall, groundwater levels, and flow downstream of the constructed source control. Flow can be compared with the identified stormwater target.

In large, multi-phase developments, post construction monitoring can provide data for adaptive management for later phases. In some cases, requirements for stormwater source controls may be reduced because monitoring indicates targets are being exceeded.

9.6 Construction and Establishment Maintenance

The foundations of a low maintenance landscape include quality control during the sourcing of materials and field reviews of proper installation techniques throughout construction. This section discusses the details of the checking and maintenance needed during and after construction to promote successful source control facilities, as well as links in the establishment maintenance period, which immediately follows construction.

To support the long-term health and function of living soils and plant materials in source controls a one year minimum (two years optimum) establishment period of higher maintenance should be planned, which if properly performed, will lead to reduced levels of maintenance in the longer term.

Projects need to include establishment and/or ongoing maintenance plans and specifications to define scope and responsibilities – and to allocate appropriate funding and qualified personnel for performance of this more intensive maintenance period. See Chapter 11 for additional guidance on post-establishment long term maintenance.

Table 9-1 and 9-2 emphasize the connections between maintenance issues that may arise during the construction, field review and establishment maintenance phases. These link to concerns that were identified in the planning stages of the design (see Chapter 2 – Source Control Design Process).

Thorough quality control and field reviews throughout the construction process are essential to developing successful low-maintenance landscape systems.

Living soils and plant materials require a one year minimum (two years optimum) establishment period of higher maintenance, which if properly performed, will lead to reduced levels of maintenance in the longer term.

Projects need to include establishment and ongoing maintenance plans to define scope and responsibilities, with appropriate funding and qualified personnel allocated for the different maintenance phases. Ideally, this is done as part of the design process, and it is understood by all parties before the construction is underway who is responsible for establishment maintenance and for how long. While the establishment maintenance is often part of the construction contract, that may not always be the case. For post-establishment maintenance see Operation, Inspection and Maintenance Guideline, Chapter 11.

Table 9-1: Construction Maintenance Issues and Solutions

Maintenance Issue	Solutions
Sediment barrier at inlet	Coordinate among trades (concrete / civil / landscape) to ensure inlet slopes and drops. Replace inlets not constructed to design.
Excess standing water duration	If standing water is visible more than 24 hours post rainfall, review infiltration surface. Ensure subgrade scarification prior to backfill. Test and field review proper depths of growing medium /drain rock and perforated underdrain as specified.
Excessive weeding in plantings and grass areas	Ensure growing medium and mulch components are weed free at installation – see 'Avoid Importing Weeds' in this Chapter.

Table 9-A: Establishment Maintenance Issues and Solutions

Maintenance Issue	Solutions
Cobble mulch maintenance	Cobble maintenance involves hand rock lifting and weeding. Cobble areas that have sediment and weed accumulations should be removed and replaced without cobble or with clean materials.
Surface erosion / excess flow	Regrade swale profiles or install additional check dams to reduce surface slopes to 1% to 2%. Cultivate/replace surface mulch.
Poor surface infiltration – excess compaction or crusting	Test and field review growing medium quality and installation, including infiltration capacity – see 'Guideline Specification for Growing Medium' in this Chapter. Check for construction compaction. Re-cultivate if excess compaction.
Poor plant survival – too wet	Consider change order to plant species based on as-built wetness zone – see Chapter 10 – Landscaping and Plant List.
Poor plant survival – too dry	Based on specifications, supply irrigation or supplementary watering systems during establishment period. Adjust to seasonal conditions. Winterize and commission/check in spring.
Excessive weeding in plantings and grass areas	Organize maintenance continuity at end of establishment maintenance period to transition to long-term maintenance program.
Sediment / weeds in pervious pavers	Avoid tracking mud onto pervious pavers during construction. Avoid allowing nearby weeds to seed onto pervious paving areas. Contractor to vacuum remove and replace joint aggregate if required in establishment maintenance period, and owner to do so periodically (once every 3-5 years).
Excessive pruning for sightlines	Prune if required for low shrub height or high branch clearance at driveways, intersections and other locations requiring sight distance.
Excessive pruning for O/H wires	Ideally trees should be selected to grow to mature heights and shapes compatible with nearby wires and overhead utilities rather than be pruned aggressively for overhead wires. Owner may choose to replace trees if required.
Excessive labour/cost of maintenance	If level of on-going labour appears excessive, long-term maintenance could consider transitioning planting areas such that future area of mown lawn/trees with weed tolerance increases with area of hand-weeded shrub/groundcover decreasing over time to acceptable maintenance level.
Excessive water use	Manage plant establishment maintenance to reduce irrigation use to nil after two-year establishment period except in severe drought intervals associated with climate change.
Cobble mulch maintenance	Cobble maintenance involves hand rock lifting and weeding. Cobble areas that have sediment and weed accumulations should be removed and replaced without cobble or with clean materials. Consider concrete pads in pre-treatment areas to reduce long-term maintenance effort.
Surface erosion / excess flow	Regrade swale profiles or install additional check dams to reduce surface slopes to 1% to 2%. Cultivate/replace surface mulch.

9.7 Construction and Establishment Maintenance Specifications

Specifications for Construction should include either references to accepted standards or customized clauses on the topics listed in the Specifications Checklist. These topics are suggested as a place to start, but for individual projects the specifications needed will vary.

9.7.1 Specifications Checklist

- ❑ Construction staging guidelines, and request for Contractor's Construction Plan to avoid disturbance, compaction, or sedimentation of infiltration areas.
- ❑ Growing medium materials, amendments mixing, installation and maintenance for the establishment period. See next section on growing medium.
- ❑ Reservoir and drainage materials, installation, and maintenance during construction.
- ❑ Geotextile materials, installation, and maintenance during construction.
- ❑ Erosion control materials, installation, and maintenance during construction.
- ❑ Plants and planting materials, installation, and establishment maintenance.
- ❑ Seeding and sodding materials, installation, and establishment maintenance.
- ❑ Watering or Irrigation materials, installation, and establishment maintenance.
- ❑ Specialty materials for Green Roof, such as lightweight soils, root barrier, drainage layer.

9.7.2 Growing Medium Standards

This section discusses quality control standards for Growing Medium. The guidelines in this section are specific to Stormwater Source Control applications, but also apply generally to most urban or suburban landscape areas including Absorbent Landscape.

In Stormwater Source Control applications, growing medium texture, organic matter content, installation technique and ability to absorb and drain water (hydraulic conductivity) are critical to success of the installation. Other physical and chemical properties such as fertility, salinity, carbon to nitrogen ratio etc. are important at installation but also change over time requiring regular sampling and laboratory testing and supplementary maintenance practices to maintain healthy landscapes.

Providing appropriate growing medium specifications and ensuring they are met during construction is a foundation of successful projects.

Adequate soil testing of growing medium, both before placement and once in place, is critical to ensure specifications are met.

Two options are presented below to provide guidance for a general specification for a typical growing medium. The options are based on common references, which should be familiar to most suppliers. For designers, engineers are likely to be more familiar with using the Master Municipal Construction Document (MMCD) as a reference, and landscape architects are likely to be more familiar with using the Canadian Landscape Standard (CLS). In both cases, suggested wording as shown is needed to modify the reference for source control applications. The below specifications are suitable for most stormwater source control applications; custom specifications will be warranted for some conditions such as green roof, or for Restoration, Naturalization or Background areas where urban/suburban standards may not apply.

9.8 Guideline Specifications for Growing Medium

9.8.1 Growing Medium (Specification Option A)

Growing Medium shall be as per the Master Municipal Construction Document 2009 requirements, as per Section 32-91.21 Topsoil and Finish Grading, Table 2 but with required minimum saturated hydraulic conductivity of 7 cm / hr (70 mm / hr), requiring texture gradation similar to High Traffic Lawn Areas in Table 2, but with organic matter amendments amended as follows:

a. For lawn areas – minimum 5% maximum 8%; and
b. For planting areas – minimum 15% maximum 25%.

9.8.2 Growing Medium (Specification Option B)

Growing Medium shall be as per the Canadian Landscape Standard (CLS) Second Edition July 2020 Table T-5.3.5.3 Properties of Growing Media for Level 2 “Groomed” and Level 3 “Moderate” Areas, column 2H for High Traffic Lawn Areas and column 2P for Planting Areas. For both columns, replace the Drainage Row with the requirement that minimum saturated hydraulic conductivity of 7 cm/hr. shall be maintained, measured in place after compaction to approximately 80% proctor (firm against deep footprints).

9.8.3 Growing Medium Testing and Submittals

Typically, the Contractor will source and supply all topsoil and growing medium components for the project. All growing medium supplied should be tested prior to placement. Oversight of the installation should ensure that the growing medium tested and the growing medium applied on site are from the same stockpile. Changes in source shall require new testing. Any soil amendments made on site after delivery of the growing medium should be on the basis of recommendations from the soil testing laboratory.

Testing should be completed only by an experienced Soil Science Laboratory agreed to by both the Contractor and the designer and is typically part of the Contractor's supply and installation work. If possible, the designer should supervise or approve the selection of growing medium samples. The project schedule should recognize that a minimum period of one (1) week is required for such testing beginning from the time that the laboratory receives the soil sample(s). In the event that the Contractor initiates application of soil on site prior to completion of the soil analysis, it is possible that the soil will be rejected and require removal at the Contractor's expense.

The Contractor shall submit the soil analysis report to the designer for review a minimum of 48 hours prior to commencement of work.

Each submission to the testing laboratory shall include the following:

- Minimum 4 Litre sample of growing medium intended for each use.
- Indication of landscape application type:

a. High traffic lawn;
b. Low traffic lawn;
c. Trees and large shrubs;
d. Planting bed;
e. Raised planter; and
f. Natural area – including the planting plug backfill mix specified.

The planned watering/irrigation method:

a. Permanent automatic irrigation;
b. Temporary irrigation for establishment;
c. Manual watering; and
d. No irrigation.

The soil analytical requirements shall include:

a. pH;
b. Lime requirement to achieve a pH of 6.5;
c. Soluble salts or electrical conductivity (E.C.);
d. % sands + % fines (silt and clay) + % organic matter = 100%;
e. % total nitrogen.
f. Available levels of phosphorous, potassium, calcium, and magnesium.

The laboratory analysis shall include recommendations for:

a. Soil amendments to bring soil attributes to acceptable levels as outlined in this specification; and

b. Fertilizer applications, by category of plant type, to bring growing medium fertility to levels outlined in this specification.

9.8.4 Growing Medium Post-Installation Testing

A sample of installed soils should be obtained and submitted to the approved Soil Science Laboratory for testing to confirm that installed soil(s) satisfies the properties and requirements of this and that required amendments have been completed.

Non-conforming soils, at the direction of the Contract Administrator, may require amendment in-place or removal and replacement at the Contractor's expense.

9.9 Avoid Importing Weeds

Although most weeds do not inhibit the core functions of stormwater source controls, weeds may out-compete the desired plantings and impact the survival of the vegetation through the wet and dry seasons. Excessive weeds may be a source of public or neighbourhood complaints which is frustrating for maintenance staff or agencies.

It must be noted that weeding issues and solutions are not specific to stormwater source controls. For any intensively landscaped area, weeding will be an important part of maintenance in source controls as well as the rest of the landscape. For parks, roadsides, or other areas where a manicured look is not necessary, the need for weeding will be reduced and may be zero.

In the interest of preventing weed establishment and future weed maintenance, a key requirement during the project construction stage is to ensure that weed seeds and viable plant parts are not problems that are imported in growing media or mulch components. Project specifications and construction / establishment maintenance practices must be specific in creating projects that meet low tolerances for imported weeds. Although some weeds will always arrive via air or water transport, proper management of weeds during construction and establishment maintenance will greatly reduce long term maintenance demands.

See 'Guideline Specifications for Growing Medium Weed Management' below in this Chapter for an example specification suitable for most stormwater source control applications. Custom specifications will be warranted for some conditions such as green roof, or for restoration, naturalization, or background areas where urban/suburban standards may not apply.

9.9.1 Guideline Specifications for Growing Medium Weed Management

Best practices to avoid weed infestation in growing media is a key required addition to growing medium specifications. The section below is intended to provide guidance for developing a supplementary specification to either MMCD or Canadian Landscape Standard forms of specifications. Sample specification wording is given in two options following the section below.

9.9.2 Control Of Weeds In Source And Combined Materials

Identify the source of supply for all growing medium and mulch components and final mixes for approval and repeat approval process for any proposed change in the source of supply. Table 9-B below, should be filled out for each topsoil, growing medium, and mulch source of supply.

Table 9-B: Weed Control Practices for Growing Medium and Mulch Components and Mixes

Date:		Material:	Supplier:
Check Yes or No		Best Practice	Comments
Yes	No		
		Weed germination test plots of finish materials at least once per growing season (give last test date).	
		Covered stockpiles of finished materials between delivery events to minimize wind-blown weed seeds.	
		Regular turning / windrowing of compost operations to reach seed-killing temperatures for all material.	
		Source inspection and/or weed seed germination testing for all source materials.	
		Washing / cleaning of material mixing and handling equipment to remove potential weed seeds.	
		Weed and weed seed control of environs of stockpile and production sites.	

The Owner's representative should reserve the right to reject topsoil, growing medium and bark or stone mulch sources of supply that do not substantially comply with the best practices in Table 9-B. The designer may review source locations and take samples for sieve analysis prior to approval, but testing or approval by the designer does not in any way relieve the Contractor of responsibility for providing materials that meet the specifications, including weed free status.

9.9.3 Growing Medium Weed Management Standards

9.9.3.1 (Option A – Amending the MMCD)

Replace the Master Municipal Construction Document 2009 requirements for weed control Section 32-91.21 Topsoil and Finish Grading, Clause 1.4.1, 'To be free from crabgrass, couchgrass, equisetum or noxious weeds or seeds or parts thereof' with the requirements:

"Topsoil, bark mulch or stone mulch and related growing medium components and planting mixes shall be free of crabgrass, couchgrass, equisetum, bindweed/morning glory, himilayan blackberry, broom, weeds, invasive plants, noxious weeds and viable weed roots, parts or weed seeds. Weeds shall be defined as any plant not specified in the project plant list or amendments to the plant list. Volunteer germination of additional plants that are the same as those in the project plant list shall be accepted, whereas volunteer germination of any other plant species shall be defined as weeds and are not permitted to be present in growing medium or mulches and are subject to removal as defined in the maintenance specifications."

Replace the Master Municipal Construction Document 2009 requirements for weed control in Section 32.92.19 Hydraulic Seeding, Section 32 92 20 Seeding, 32 92 23 Sodding and Section 32 93 01 Planting of Trees, Shrubs and Groundcovers with Landscape Maintenance Specifications (level of maintenance objective) based on Section 9 Landscape Maintenance from the Canadian Landscape Standard (CLS) Second Edition July 2020.

Additional wording should include that the contractor understands the requirements and commits to providing materials as specified, including replacement of any materials that are not in compliance with requirements.

9.9.3.2 (Option B – Amending the CLS)

Growing Medium Weed Management Standards shall be as per the Canadian Landscape Standard (CLS) Second Edition July 2020 Growing Medium Section 5.1 General Requirements and to Table T-5.3.5.3 Properties of Growing Media for Level 2 "Groomed" and Level 3 "Moderate" Areas, column 2H for High Traffic Lawn Areas and column 2P for Planting Areas). For both columns, replace the Drainage row with the requirement that minimum saturated hydraulic conductivity of 7 cm/hr. shall be maintained, measured in place after compaction to approximately 80% proctor (firm against deep footprints).

Establishment maintenance including weed management shall comply with (level of maintenance objective) based on Section 9 Landscape Maintenance from the Canadian Landscape Standard (CLS) Second Edition July 2020.

Amend CLS Section 5.1.5. Testing Clause .7 to add additional wording that the contractor understands the requirements and commits to providing materials as specified, including replacement of any materials that are not in compliance with requirements. Topsoil, bark mulch or stone mulch and related growing medium components and planting mixes shall be free of crabgrass, couchgrass, equisetum, bindweed/morning glory, himilayan blackberry, broom, weeds, invasive plants, noxious weeds and viable weed roots, parts or weed seeds.

Weeds shall be defined as any plant not specified in the project plant list or amendments to the plant list. Volunteer germination of additional plants that are the same as those in the project plant list shall be accepted, whereas volunteer germination of any other plant species shall be defined as weeds and are not permitted to be present in growing medium or mulches and are subject to removal as defined in the maintenance specifications.

9.10 Guideline Specifications for Establishment Maintenance

All landscape areas shall be maintained as per the Operation and Maintenance Guideline. Recommended Maintenance Procedures & Frequencies. This table provides a recommended schedule for the minimum 1-year establishment maintenance period and beyond. This schedule has been adapted from and is generally consistent with the Canadian Landscape Standard Section 9 Landscape Maintenance.

9.10.1 Landscape Establishment Maintenance Standards (Specification Option A)

Establishment Landscape Maintenance shall be provided for one year from the date of substantial performance of the landscape components of the project. Replace the Master Municipal Construction Document 2009 requirements for landscape maintenance in Section 32.92.19 Hydraulic Seeding, Section 32 92 20 Seeding, 32 92 23 Sodding and Section 32 93 01 Planting of Trees, Shrubs and Groundcovers with the requirements of Section 9 Landscape Maintenance from the Canadian Landscape Standard (CLS) Second Edition July 2020 for a Level 2 'Groomed' standard in accordance with Section 9 and Table T-9.2.

Replace CLS Table T-9.8 Recommended Maintenance Procedures and Frequencies Level 2 'Groomed' with Table 4 LANDSCAPE MAINTENANCE FREQUENCY.

Weed control standards during the maintenance period shall comply with CLS Table-9.18 Weed Control Standards for 3. Moderate requirements (as opposed to 2. Groomed requirements).

9.10.2 Landscape Establishment Maintenance Standards (Specification Option B)

Establishment Landscape Maintenance shall be provided for one year from the date of substantial performance of the landscape components of the project to meet the requirements of Section 9 Landscape Maintenance from the Canadian Landscape Standard (CLS) Second Edition July 2020 for a Level 2 'Groomed' standard in accordance with Section 9 and Table T-9.2.

Replace CLS Table T-9.8 Recommended Maintenance Procedures and Frequencies Level 2 'Groomed' with Table 4 LANDSCAPE MAINTENANCE FREQUENCY.

Weed control standards during the maintenance period shall comply with CLS Table-9.18 Weed Control Standards for 3. Moderate requirements (as opposed to 2. Groomed clause).

LANDSCAPING CONSIDERATIONS AND PLANT LISTS

10 Landscaping Considerations and Plant Lists

Landscaping considerations cover a wide range of aspects that affect the selection and survival of plants in stormwater source control facilities, including the value of the plants, and trees in particular, in the stormwater management context.

10.1 Crown Interception

Scientific studies have shown that a significant amount of gross precipitation is intercepted (i.e., never reaches the ground) by tree crowns. A 50-year-old evergreen forest in Scotland had canopy interception of 28% of annual rainfall (Johnston, 1990). Studies of open grown urban trees in Davis, California (average annual rainfall of 446 mm) have shown significant crown interception even in winter – about 15% by a leafless pear tree, and about 27% by a broadleaf evergreen oak (Figure 10– – Xiao et al., 2000).

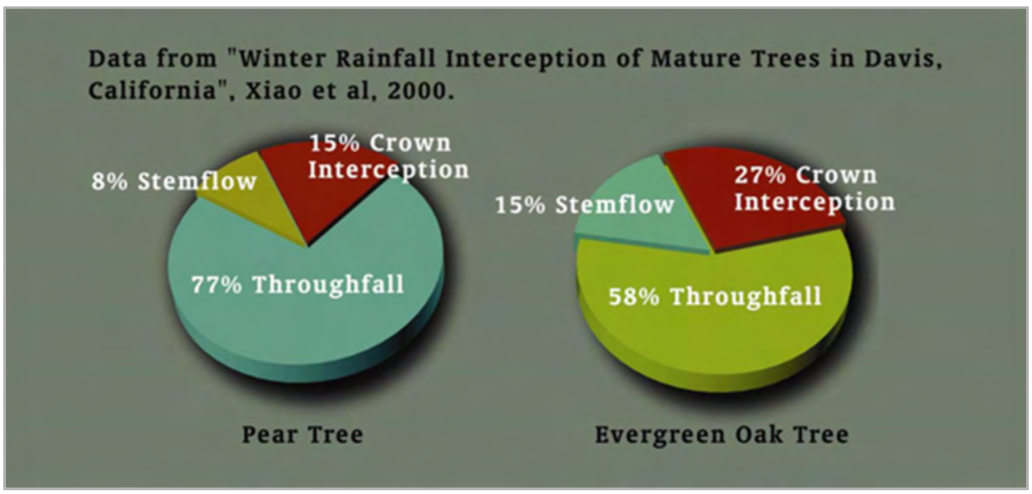


Figure 10-1: Interception, stemflow and throughfall data from California (Xiao et al., 2000)

10.2 Throughfall and Stemflow

Plants provide a stormwater detention function, slowing down rain before it hits the ground surface. Although some rain falls through the canopy as free throughfall, a significant portion lands on either leaf or twigs, where it is delayed prior to creating canopy drip. Some of this rainfall flows down twigs and branches to become stemflow at the tree trunk. The twigs, branches and rough bark of leafless deciduous trees play a significant role in stormwater detention.

10.3 Evapotranspiration

Trees, shrubs, grasses, and other plants draw water up from the soil to the leaves, where the stomata (openings) in the leaves allow for evapo-transpiration. Evaporation also occurs from surface water (puddles, lakes, streams, rooftops) and from surface soils, snow, and tree/plant surfaces. The combination of tree canopy interception and evapotranspiration in a natural rainforest can approach 40% of annual rainfall (Stephens et al., 2002).

10.4 Soil Water Storage

Soils are the most significant landscape storage mechanism for stormwater. Landscape soils typically store from 7% (sand) to 20% (loam) of their volume as water before becoming saturated to field capacity and generating flow-through or runoff. Loamy soils store more water than sandy soils (Ferguson, 1994).

10.5 Soil Infiltration

The rate at which water soaks into soils (the infiltration rate or saturated hydraulic conductivity) varies depending on the texture and amount of organic matter in the soil. Fine textured soils with silt and clay exceeding 35% by volume tend to have low infiltration rates (0.6 to 6 mm/hr), whereas sand surface soils are very open to infiltration (210 mm/hr), with loam soils having moderate infiltration rates (13 mm/hr).

Surface crusting and compaction of the top 2 mm of soil can be an important limitation. Thin crusts can be formed on all bare soil surfaces , including fine sand, due to raindrop impact. Surface crusting risks can be addressed by avoiding erosion and sedimentation that carries fines onto the soil surface, and by providing surface mulching, vegetation, organic matter, and related soil life in the surface soil (Figure 10- – Ferguson, 1994).

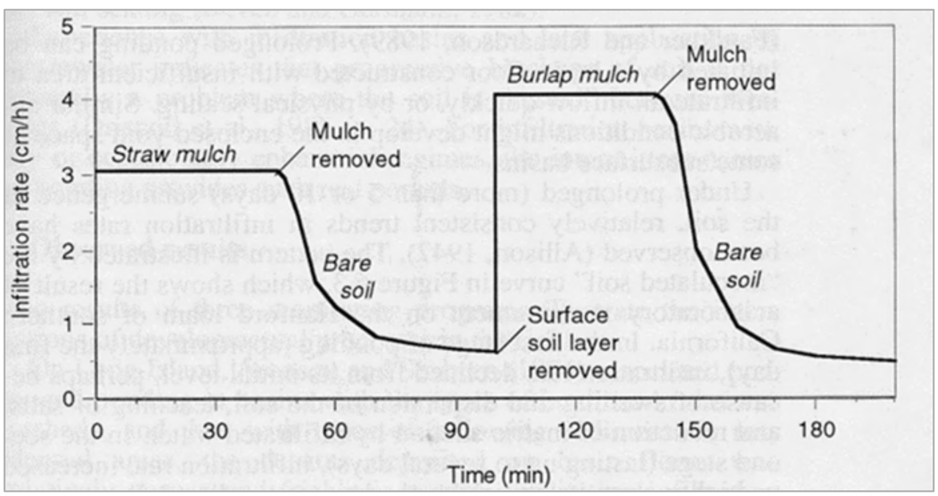


Figure 10-2: Infiltration rate of a sandy loam under continuous water sprinkling at a rate in excess of intake with a series of 4 surface conditions (Ferguson, 1994: 191).

10.6 Plant Choice Guide

Right Plant Right Place

Planting designs succeed by choosing the right plant for the right place. Key considerations in all urban landscapes include:

- Climate hardiness;
- Sun/Shade conditions;
- Established height and spread;
- Suitability for site constraints such as sight distance triangles or overhead utilities;
- Foliage texture, colour;
- Flower and fruit features and seasons;
- Environmental value;
- Susceptibility to disease; and
- Risk of breakage.

In stormwater source control applications, additional considerations include:

- Tolerance to soil water conditions; and
- Resilience to repeated wetting and drying cycles.

Stormwater source control designs may have a wide range of Impervious: Pervious (I/P) ratios that will influence how wet the planting area tends to be.

Absorbent Landscapes are often designed with a 2:1 target I/P ratio, which with appropriate growing medium depth will store most roof and site runoff water from a low to moderate density development in a design rainfall event. Growing medium in this situation will be temporarily wet near stormwater inlets, moist further away, but may become dry to very dry in summer seasons. Landscape plantings in these cases usually rely on supplementary watering for establishment and to support plant growth and vigour through the dry season. If the landscape maintenance intent is to only provide rare watering during droughts after establishment, specific plant choices would need to be made.

Some street or commercial landscapes that are higher density may have I/P ratios of 20:1 or 30:1 or greater. These high I/P ratios will lead to greater concentration and duration of stormwater runoff into a smaller landscape area. During rainfall, infiltration areas will tend to be wet to very wet, including periods of saturated soil conditions and standing water in some cases. If the duration of saturation is beyond 24 to 48 hours, only specific adapted plant materials may survive that condition. These wetland plants also must be able to survive the dry summer periods with minimal supplementary watering.

Plant Hydrozone/ Moisture Zone wetness, shown in Table 10-1, introduces the concept of choosing plants based on their adaptability to typical wetness conditions in their root zone. Designers are encouraged to assess the relative wetness of various planting zones specific to the site. Plant Lists (end of this chapter) indicates plant adaptability to Planting Hydrozones, however landscape designers are encouraged to undertake their own assessments and research.

Plant choice should also be influenced by:

- Adaptability to increased wet periods and longer drought periods associated with climate change;
- Although planting designs need to respect todays' plant hardiness zones based on today's climate, species which have a broader range of hardiness zone are likely to be more resilient than those at the 'edge' of their climate comfort. However, specifying plants from warmer hardiness zones may be premature and subject to cold weather failure;
- Planting with respect to watering and/or irrigation plans. Like other landscape areas, infiltration areas, although wet in winter months, will require supplementary watering during the dry season from approximately mid-May through mid-October. Watering needs will vary, and amount of water supplied should be adjusted to apply the minimum supplementary water required for plant growth to conserve water. Given the relatively rapid drainage requirements of stormwater source control growing media, use of well-designed low volume weather-based irrigation systems is recommended for most urban and suburban situations;
- Planting choices and assessment of Planting Hydrozone should be done in full coordination with choices of full or partial infiltration designs. Full infiltration designs may be feasible in some situations but would need to be proven viable by extensive subsoil infiltration testing to avoid creation of over-saturated growing medium. Partial infiltration designs will be more resilient to a wide range of plant materials, I/P ratios, and maintenance regimes; and
- Grass surfacing may be suitable and relatively low maintenance cost for some lower I/P ratios in partial infiltration designs. Very Wet and Wet hydrozones are not suitable for turf grass but would need to use sedges (Carex spp) or rushes (Juncus spp) or similar.

Table 10-1: Plant Hydrozone/ Moisture Zone Wetness Description

Planting Hydrozone	Typical Conditions **Note:** Site-specific assessments are required.
Zone 1 – Wet	Planting soils are often saturated after rainfall, with common standing water. Dries up in dry periods. Plant species prefer soil saturation and can accommodate shallow inundation for long durations (e.g., 72 hours or more). These conditions are found in the flat bottom or lowest parts of rain gardens and bioswales.
Zone 2 – Moist	Planting soils are occasionally saturated after rainfall, without standing water. Soils remain moist in dry periods. Plant species can accommodate short-term saturation (e.g., 24 -72 hours) as well as dry periods but cannot sustain continued inundation.
Zone 3 – Average	Planting soils are moist but not saturated after rainfall without standing water. Soils become dry in dry periods. Plant species should be suited to well-drained slopes or average moisture conditions. Supplemental watering should generally be provided.
Zone 4 – Dry	Planting soils have moist areas near inlets after rainfall but are not saturated. Soils become dry in dry periods, Plant species are drought tolerant once established, cannot tolerate inundation, and are suited only to high, dry areas. Many plants will decline or die unless chosen specifically for these conditions.

10.7 Plant Lists

The candidate plant list has been reviewed and updated for the 2023 update of the guideline.

There are three lists. There are two **Short Lists** consisting of plants that are considered hardy, durable, and typically readily available at local nurseries in the region. One short list is geared toward urban areas and constrained, small sites, and the other is geared toward larger sites where a more natural character is desired. The **Master List** includes all plants from the short lists and includes additional plants that are considered suitable for source control facilities, but may be less available, or more finicky in their care requirements.

Metro Vancouver SSCDG Plant List (URBAN / SMALL SITES Short List*)

* The short list consists of plants suitable for an urban evironment or smaller site. These species are hardy, durable, and typically readily available at local nurseries.

GENERAL NOTES:

- This is a list of plants suitable for use in stormwater source control facilities within the Metro Vancouver region. It is not an exhaustive list. Other plants may be suitable for various conditions.
- It is recommended that a BCSLA registered landscape architect prepare detailed planting plans that consider the full range of site conditions including, but not limited to: anticipated moisture, plant height, light levels, sightline needs, site context, and suitability for anticipated maintenance.
- All plants on this list require establishment maintenance for 2-3 years that includes regular watering, weeding, top dressing, and bed cultivation.
- For drought tolerant plants, review items that are identified as Moisture Zone 4 (DRY conditions).
- Plant height is a key consideration for shrub plantings within close proximity to roadways, crossings, and intersections. The shrub height information noted is provided for reference only as it is the average height under urban conditions, not the maximum height possible. Pruning may be required to maintain 60cm or 90cm maximum height in the right-of-way as per local and/or provincial regulations.

MOISTURE ZONES

Zone 1 (WET Conditions)	Designation for species that prefer soil saturation and can accomodate shallow inundation for long durations (e.g. 72 hours or more). These conditions are typically found in the flat bottom or lowest parts of rain gardens and bioswales.
Zone 2 (MOIST Conditions)	Designation for species that can accomodate short-term saturation (e.g. 24-72 hours) as well as dry periods, but cannot sustain continued inundation.
Zone 3 (AVERAGE Conditions)	Designation for plants best suited to well-drained slopes or average moisture conditions.
Zone 4 (DRY Conditions)	Designation for plants that are drought toltertant once established, cannot tolerate inundation, and are suited only to high, dry areas.

Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Trees								
Acer x freemanii ('Jeffersred' or others)	Freeman Maple	3	12-18m	Full Sun			●	Med/large shade tree, great fall colour
Ginkgo biloba	Maidenhair Tree	3, 4	10-15m	Full Sun			●	Slow growing, yellow fall colour, interesting leaf shape, urban and drought tolerant, avoid female trees (fruit)
Nyssa sylvatica ('Wildfire' or others)	Black Gum or Tupelo	1, 2	10-15m	Full Sun / Part Shade			●	Tough urban tolerant tree, fall colour, modest spread, tolerates soggy soils
Pinus contorta var. contorta	Shore Pine	2, 3	10-15m	Full Sun	●	●	●	Native tree, sculpted form
Quercus rubra	Red Oak	3	15-20m	Full Sun			●	Large tree, needs space, fall colour, nuts
Taxodium distichum (varieties)	Bald Cypress	1, 2, 3	10-18m	Full Sun / Part Shade			●	Deciduous conifer, turns russet orange in fall, tolerates diverse soil conditions, excellent for rain gardens
Small Trees								
Amelanchier x grandiflora 'Autumn Brilliance'	Autumn Brilliance Serviceberry	3	4-8m	Full Sun / Part Shade			●	Good for narrow areas, often multi-stem, white blooms, reliable fall colour
Carpinus japonica	Japanese Hornbeam	3	4-8m	Full Sun / Part Shade			●	Wide spreading, slow growing, muted fall colour
Cercis canadensis	Redbud	2, 3	4-8m	Full Sun / Part Shade			●	Small but showy early pink blooms, attractive form, can suffer from canker and environmental stresses
Styrax japonica	Japanese Snowbell	3	4-8m	Part Shade			●	Ornate form, white blooms
Shrubs								
Abelia x grandiflora 'Rose Creek'	Rose Creek Glossy Abelia	3	0.6-1.2m	Full Sun / Part Shade		●*	●	Mounding, crimson stems, white flowers
Cornus sericea 'Kelseyi'	Kelsey Dwarf Dogwood	2, 3	0.9m	Full Sun			●	Compact form for sightlines, winter interest red stems
Berberis thunbergii	Japanese Barberry	3	0.9-1.8m	Full Sun			●	Multi-coloured foliage, arching form
Cistus x lenis 'Grayswood Pink'	Grayswood Pink Rock Rose	3, 4	0.6-0.9m	Full Sun		●	●	Grey-green foliage, pink flowers, drought-tolerant

Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Euonymus alatas 'Little Moses'	Little Moses Dwarf Burning Bush	3	0.9m	Full Sun / Part Shade			●	More compact form, brilliant red fall colour
Lonicera pileata	Box Leaf Honeysuckle	3	0.6-0.9m	Full Sun / Part Shade		●	●	Dependable evergreen structure, fine evergreen leaves
Mahonia aquifolium 'Compacta'	Compact Oregon Grape	3, 4	0.6-0.9m	Full Sun / Part Shade	●	●	●	Native, evergreen, yellow flowers, small bitter fruit
Mahonia repens	Creeping Oregon Grape	3, 4	0.3-0.6m	Full Sun / Part Shade	●	●	●	Native, evergreen, drought tolerant
Pinus mugo 'Mugo/Mops'	Dwarf Mountain Pine	3	0.6-1.2m	Full Sun		●	●	Coniferous evergreen, slow growing
Ribes sanguineum	Red Flowering Currant	3	1.2-3m	Full Sun / Part Shade	●		●	Upright, pink flowers
Rosa gymnocarpa	Baldhip Rose	2, 3	0.9-1.5m	Full Sun	●		●	Pink flowers, small hips in fall
Salix purpurea 'Nana'	Dwarf Arctic Willow	2, 3	0.6-1.5m	Full Sun / Part Shade			●	Compact, slender leaves, great movement in wind
Spiraea japonica (varieties)	Japanese Spirea	3	0.6-0.9m	Full Sun			●	Mound form, pink flower clusters
Symphoricarpos albus	Snowberry	2, 3	0.6-1.5m	Full Sun / Part Shade	●		●	Loose structure, fine foliage, notable foamy white berries
Vaccinium ovatum	Evergreen Huckleberry	3	0.9-3m	Full Sun / Part Shade	●		●	Native, evergreen, fine-textured glossy leaves, small edible fruits, wildlife value
Viburnum davidii	David Viburnum	3	0.6-1.2m	Full Sun / Part Shade		●	●	Dependable, white flowers, blue fruits with red stems
Herbaceous Perennials, Grasses & Ferns								
Achillea millefolium	Yarrow	3, 4	0.6-0.9m	Full Sun / Part Shade	●		●	Spreading, long flowering period
Calamagrostis x acutiflora 'Karl Foerster'	Karl Foerster Reed Grass	3	0.9-1.5m	Full Sun / Part Shade			●	Striking upright form, summer and fall interest
Carex morrowii 'Ice Dance'	Ice Dance Japanese Sedge	2, 3	0.3m	Full Sun / Part Shade		●*	●	Variegated, fine-textured, semi-evergreen foliage
Echinacea purpurea ('Magnus' or others)	Purple Coneflower	3, 4	0.6-0.9m	Full Sun / Part Shade			●	Purple flowers, fall interest
Erica x darleyensis 'Kramer's Red'	Kramer Red Winter Heath	3, 4	0.45m	Full Sun		●	●	Early flower winter interest, fine needle-like foliage
Iris sibirica	Siberian Iris	3	0.6-1.2m	Full Sun / Part Shade		●	●	Upright foliage, purple-blue flowers
Polystichum munitum	Sword Fern	3	0.6-0.9m	Part Shade / Shade	●	●*	●	Coarse-textured fronds, semi-evergreen
Rudbeckia (varieties)	Black-eyed Susan	3, 4	0.6-0.9m	Full Sun / Part Shade			●	Deep yellow flowers for summer through fall
Wetland Plants								
Carex obnupta	Slough Sedge	1, 2	0.6-1.5m	Part Shade	●		●	Not drought-tolerant, spreading, stiff stems
Carex stipata	Sawbeak Sedge	1, 2	0.25-1m	Part Shade	●			Not drought-tolerant, shorter stems, clump forming
Juncus acuminatus	Taper-tipped Rush	1, 2	0.3-1m	Full Sun	●	●	●	Not drought-tolerant, round stems, rhizome spreading
Juncus effusus	Common Rush	1, 2	0.6-1.2m	Full Sun	●		●	Not drought-tolerant, round stems, rhizome spreading
Juncus ensifolius	Dagger-leaf Rush	1, 2	0.3-0.45m	Full Sun	●		●	Not drought-tolerant, dagger-shape stems, compact
Groundcovers								
Arctostaphylos uva-ursi	Kinnikinnick	3, 4	0.15m	Full Sun / Part Shade	●	●	●	Low-growing, evergreen, native, branches trap debris (maintenance consideration)
Cotoneaster dammeri 'Lowfast'	Lowfast Cotoneaster	3	0.15m	Full Sun / Part Shade		●	●	Hardy and very low growing, small leaves
Fragaria chiloensis	Beach Strawberry	3	0.3m	Full Sun / Part Shade	●	●*	●	Coarse leaves, white flowers, small fruits, spreads by runners, sometimes difficult to establish

Metro Vancouver SSCDG Plant List (NATURAL / LARGE SITES Short List*)

* The short list consists of plants suitable for natural environments or large natural character sites. These plants are hardy, durable, and typically readily available at local nurseries.

GENERAL NOTES:

- This is a list of plants suitable for use in stormwater source control facilities within the Metro Vancouver region. It is not an exhaustive list. Other plants may be suitable for various conditions.
- It is recommended that a BCSLA registered landscape architect prepare detailed planting plans that consider the full range of site conditions including, but not limited to: anticipated moisture, plant height, light levels, sightline needs, site context, and suitability for anticipated maintenance.
- All plants on this list require establishment maintenance for 2-3 years that includes regular watering, weeding, top dressing, and bed cultivation.
- For drought tolerant plants, review items that are identified as Moisture Zone 4 (DRY conditions).
- Plant height is a key consideration for shrub plantings within close proximity to roadways, crossings, and intersections. The shrub height information noted is provided for reference only as it is the average height under urban conditions, not the maximum height possible. Pruning may be required to maintain 60cm or 90cm maximum height in the right-of-way as per local and/or provincial regulations.

MOISTURE ZONES

Zone 1 (WET Conditions)	Designation for species that prefer soil saturation and can accomodate shallow inundation for long durations (e.g. 72 hours or more). These conditions are typically found in the flat bottom or lowest parts of rain gardens and bioswales.
Zone 2 (MOIST Conditions)	Designation for species that can accomodate short-term saturation (e.g. 24-72 hours) as well as dry periods, but cannot sustain continued inundation.
Zone 3 (AVERAGE Conditions)	Designation for plants best suited to well-drained slopes or average moisture conditions.
Zone 4 (DRY Conditions)	Designation for plants that are drought toleratnt once established, cannot tolerate inundation, and are suited only to high, dry areas.

Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Trees								
Pinus contorta var. contorta	Shore Pine	2, 3	10-15m	Full Sun	●	●	●	Native tree, sculpted form
Pseudotsuga menziesii	Douglas Fir	3	18-30m	Full Sun	●	●		Native tree, needs space in maturity
Quercus garryana	Garry Oak	3, 4	12-18m	Full Sun				Not a street tree - twisted form, slow to establish, noteworthy in maturity, wildlife value
Small Trees								
Amelanchier alnifolia	Western Serviceberry	3	4-8m	Full Sun / Part Shade	●		●	Natural form, large shrub or small tree, blooms, fruit, wildlife value
Acer circinatum (varieties)	Vine Maple	3	5-10m	Part Shade	●		●	Attractive form and leaves, often multi-stemmed, sensitive to extreme heat or southwestern exposure
Corylus cornuta	Beaked Hazelnut	3	4-8m	Full Sun / Part Shade	●			Often multi-stem, large shrub or small tree, spring catkins, attractive nuts, wildlife species
Malus fusca	Pacific Crab Apple	3	4-8m	Full Sun / Part Shade	●			Natural shrubby tree, white blossoms, small fruit, subject to powdery mildew and leaf defoliating scab
Shrubs								
Cornus sericea	Redtwig Dogwood	2, 3	1.8-3m	Full Sun	●		●	Natural form, winter interest red stems
Gaultheria shallon	Salal	3	0.6-1.2m	Part Shade / Shade	●	●		Native, can be finicky in uban settings, fruit, wildlife value
Holodiscus discolor	Oceanspray	3, 4	2.4-4m	Full Sun / Part Shade	●			Upright form, with cascading white flower clusters
Mahonia aquifolium 'Compacta'	Compact Oregon Grape	3, 4	0.6-0.9m	Full Sun / Part Shade	●	●	●	Native, evergreen, yellow flowers, small bitter fruit
Mahonia repens	Creeping Oregon Grape	3, 4	0.3-0.6m	Full Sun / Part Shade	●	●	●	Native, evergreen, drought tolerant
Oemleria cerasiformis	Osoberry/ Indian Plum	2, 3	1.8-5m	Full Sun / Part Shade	●			Large shrub or tree-like form, early leaves in spring
Ribes sanguineum	Red Flowering Currant	3	1.2-3m	Full Sun / Part Shade	●		●	Upright, pink flowers

Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Rosa gymnocarpa	Baldhip Rose	2, 3	0.9-1.5m	Full Sun	●		●	Pink flowers, small hips in fall
Rosa nutkana	Nootka Rose	2, 3	0.9-2.4m	Full Sun	●			Thicket forming, large fragrant pink flowers, hips in fall
Rubus spectabilis	Salmonberry	2, 3	1.5-3m	Full Sun / Part Shade	●			Thicket forming, edible berries
Salix scouleriana	Scouler's Willow	1, 2, 3	2-12m	Full Sun / Part Shade	●			Large shrub or small tree, natural habit, aggressive roots
Salix sitchensis	Sitka Willow	1, 2, 3	1-8m	Full Sun / Part Shade	●			Large shrub, natural character, aggressive roots
Spiraea douglasii	Hardhack	1, 2, 3	0.9-1.8m	Full Sun / Part Shade	●			Native, upright, freely suckering, pink flower clusters
Symphoricarpos albus	Snowberry	2, 3	0.6-1.5m	Full Sun / Part Shade	●		●	Loose structure, fine foliage, notable foamy white berries
Herbaceous Perennials, Grasses & Ferns								
Achillea millefolium	Yarrow	3, 4	0.6-0.9m	Full Sun / Part Shade	●		●	Spreading, long flowering period
Lupinus polyphyllus	Large-Leaf Lupine	3	0.9-1.2m	Full Sun	●		●	Architectural foliage, flowers, and seed pods
Polystichum munitum	Sword Fern	3	0.6-0.9m	Part Shade / Shade	●	●*	●	Coarse-textured fronds, semi-evergreen
Wetland Plants								
Carex obnupta	Slough Sedge	1, 2	0.6-1.5m	Part Shade	●		●	Not drought-tolerant, spreading, stiff stems
Carex stipata	Sawbeak Sedge	1, 2	0.25-1m	Part Shade	●			Not drought-tolerant, shorter stems, clump forming
Juncus acuminatus	Taper-tipped Rush	1, 2	0.3-1m	Full Sun	●	●	●	Not drought-tolerant, round stems, rhizome spreading
Juncus effusus	Common Rush	1, 2	0.6-1.2m	Full Sun	●		●	Not drought-tolerant, round stems, rhizome spreading
Juncus ensifolius	Dagger-leaf Rush	1, 2	0.3-0.45m	Full Sun	●		●	Not drought-tolerant, dagger-shape stems, compact
Groundcovers								
Arctostaphylos uva-ursi	Kinnikinnick	3, 4	0.15m	Full Sun / Part Shade	●	●	●	Low-growing, evergreen, native, branches trap debris (maintenance consideration)

Metro Vancouver SSCDG Plant List (MASTER LIST)

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Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Trees								
Acer x freemanii ('Jeffersred' or others)	Freeman Maple	3	12-18m	Full Sun			●	Med/large shade tree, great fall colour
Carpinus betulus (varieties)	European Hornbeam	3	10-15m	Full Sun			●	Moderately slow-growing, dense form, smooth bark, very adaptable to urban environments.
Ginkgo biloba	Maidenhair Tree	3, 4	10-15m	Full Sun			●	Slow growing, yellow fall colour, interesting leaf shape, urban and drought tolerant, avoid female trees (fruit)
Liquidambar styraciflua ('Worplesdon' or others)	Sweetgum	3	10-15m	Full Sun / Part Shade			●	Pyramidal form, yellow/orange fall colour, spiny seed balls, prone to large shallow roots
Liriodendron tulipifera	Tulip Tree	3	15-20m	Full Sun			●	Large shade tree, street tree - yellow fall colour, needs ample space, can be prone to aphids
Nyssa sylvatica ('Wildfire' or others)	Black Gum or Tupelo	1,2	10-15m	Full Sun / Part Shade			●	Tough urban tolerant tree, fall colour, modest spread, tolerates soggy soils
Ostrya virginiana	American Hop Hornbeam/Ironwood	3	10-12m	Full Sun / Part Shade			●	Medium growth-rate, shaggy bark, yellow fall colour. Drought tolerant, and tolerant of wet sites.
Pinus contorta var. contorta	Shore Pine	2, 3	10-15m	Full Sun	●	●	●	Native tree, sculpted form
Pseudotsuga menziesii	Douglas Fir	3	18-30m	Full Sun	●	●		Native tree, needs space in maturity
Quercus garryana	Garry Oak	3, 4	12-18m	Full Sun				Not a street tree - twisted form, slow to establish, noteworthy in maturity, wildlife value
Quercus palustris	Pin Oak	3	15-20m	Full Sun			●	Shade tree, fall colour, susceptible to leaf skeletonizer
Quercus rubra	Red Oak	3	15-20m	Full Sun			●	Large tree, needs space, fall colour, nuts
Taxodium distichum (varieties)	Bald Cypress	1, 2, 3	10-18m	Full Sun / Part Shade			●	Deciduous conifer, turns russet orange in fall, tolerates diverse soil conditions, excellent for rain gardens
Small Trees								
Amelanchier alnifolia	Western Serviceberry	3	4-8m	Full Sun / Part Shade	●		●	Natural form, large shrub or small tree, blooms, fruit, wildlife value
Amelanchier x grandiflora 'Autumn Brilliance'	Autumn Brilliance Serviceberry	3	4-8m	Full Sun / Part Shade			●	Good for narrow areas, often multi-stem, white blooms, reliable fall colour
Acer circinatum (varieties)	Vine Maple	3	5-10m	Part Shade	●		●	Attractive form and leaves, often multi-stemmed, sensitive to extreme heat or southwestern exposure

Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Acer palmatum (varieties)	Japanese Maple	3	4-8m	Part Shade			●	Architectural form, attractive leaves and habit, many varieties, sensitive to extreme heat
Carpinus japonica	Japanese Hornbeam	3	4-8m	Full Sun / Part Shade			●	Wide spreading, slow growing, muted fall colour
Cercis canadensis	Redbud	2, 3	4-8m	Full Sun / Part Shade			●	Small but showy early pink blooms, attractive form, can suffer from canker and environmental stresses
Corylus cornuta	Beaked Hazelnut	3	4-8m	Full Sun / Part Shade	●			Often multi-stem, large shrub or small tree, spring catkins, attractive nuts. wildlife species
Malus fusca	Pacific Crab Apple	2	4-8m	Full Sun / Part Shade	●			Natural shrubby tree, white blossoms, small fruit, subject to powdery mildew and leaf defoliating scab
Magnolia 'Galaxy'	Galaxy Magnolia	3	4-8m	Full Sun / Part Shade				Moderately fast-growing, showy purple flowes in spring, prefers moist soil and shade from afternoon sun
Styrax japonica	Japanese Snowbell	3	4-8m	Part Shade			●	Ornate form, white blooms
Taxus brevifolia	Pacific Yew	3	5-12m	Shade	●			Sparse, natural form & very slow growing

Shrubs								
Abelia x grandiflora 'Rose Creek'	Rose Creek Glossy Abelia	3	0.6-1.2m	Full Sun / Part Shade		●*	●	Mounding, crimson stems, white flowers
Cornus sericea	Redtwig Dogwood	2, 3	1.8-3m	Full Sun	●		●	Natural form, winter interest red stems
Cornus sericea 'Kelseyi'	Kelsey Dwarf Dogwood	2, 3	0.9m	Full Sun			●	Compact form for sightlines, winter interest red stems
Berberis thunbergii	Japanese Barberry	3	0.9-1.8m	Full Sun			●	Multi-coloured foliage, arching form
Choisya ternata	Mexican Orange Blossom	3	0.9-2.4m	Full Sun / Part Sun / Shade		●	●	Fragrant, white flowers, glossy evergreen leaves
Cistus x lenis 'Grayswood Pink'	Grayswood Pink Rock Rose	3, 4	0.6-0.9m	Full Sun		●	●	Grey-green foliage, pink flowers, drought-tolerant
Euonymus alatas	Burning Bush	3	1.2-2.4m	Full Sun / Part Shade			●	Dense shrub, brillant red fall colour
Euonymus alatas 'Little Moses'	Little Moses Dwarf Burning Bush	3	0.9m	Full Sun / Part Shade			●	More compact form, brilliant red fall colour
Gaultheria shallon	Salal	3	0.6-1.2m	Part Shade / Shade	●	●		Native, can be finicky in uban settings, fruit, wildlife value
Holodiscus discolor	Oceanspray	3, 4	2.4-4m	Full Sun / Part Shade	●			Upright form, with cascading white flower clusters
Ilex crenata 'Compacta'	Compact Japanese Holly	3	0.9-1.5m	Full Sun / Part Shade		●	●	Durable, woody structure with fine glossy evergreen leaves
Lavandula (varieties)	Lavender	3, 4	0.6-0.9m	Full Sun		●*	●	Silver foliage, fragrant, purple flowers, does not tolerate soggy conditions, drought tolerant once established
Lonicera pileata	Box Leaf Honeysuckle	3	0.6-0.9m	Full Sun / Part Shade		●	●	Dependable evergreen structure, fine evergreen leaves
Mahonia aquifolium 'Compacta'	Compact Oregon Grape	3, 4	0.6-0.9m	Full Sun / Part Shade	●	●	●	Native, evergreen, yellow flowers, small bitter fruit
Mahonia repens	Creeping Oregon Grape	3, 4	0.3-0.6m	Full Sun / Part Shade	●	●	●	Native, evergreen, drought tolerant
Nandina domestica 'Gulf Stream'	Dwarf Heavenly Bamboo	3	0.6-0.9m	Full Sun / Light Shade		●	●	Multi-colour foliage interest, not a true bamboo
Oemleria cerasiformis	Osoberry/ Indian Plum	2, 3	1.8-5m	Full Sun / Part Shade	●			Large shrub or tree-like form, early leaves in spring
Physocarpus capitatus	Pacific Ninebark	1, 2, 3	1.5-3m	Shade	●			Large arching shrub, hardy, native to streambanks
Pinus mugo 'Mugo/Mops'	Dwarf Mountain Pine	3	0.6-1.2m	Full Sun		●	●	Coniferous evergreen, slow growing
Potentilla fruticosa	Shrubby Cinquefoil	3, 4	0.6-1.2m	Full Sun			●	Mounding hardy flowering shrub
Ribes sanguineum	Red Flowering Currant	3	1.2-3m	Full Sun / Part Shade	●		●	Upright, pink flowers

Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Rosa gymnocarpa	Baldhip Rose	2, 3	0.9-1.5m	Full Sun	●		●	Pink flowers, small hips in fall
Rosa nutkana	Nootka Rose	2, 3	0.9-2.4m	Full Sun	●			Thicket forming, large fragrant pink flowers, hips in fall
Rubus parviflorus	Thimbleberry	3	0.6-1.8m	Part Shade	●			Thicket forming, edible berries
Rubus spectabilis	Salmonberry	2, 3	1.5-3m	Full Sun / Part Shade	●			Thicket forming, edible berries
Salix purpurea 'Nana'	Dwarf Arctic Willow	2, 3	0.6-1.5m	Full Sun / Part Shade			●	Compact, slender leaves, great movement in wind
Salix scouleriana	Scouler's Willow	1, 2, 3	2-12m	Full Sun / Part Shade	●			Large shrub or small tree, natural habit, aggressive roots
Salix sitchensis	Sitka Willow	1, 2, 3	1-8m	Full Sun / Part Shade	●			Large shrub, natural character, aggressive roots
Sambucus racemosa	Red Elderberry	2, 3	2-4m	Part Shade	●			Multi-stemmed, tree-like, striking clusters of red berries
Spiraea japonica (varieties)	Japanese Spirea	3	0.6-0.9m	Full Sun			●	Mound form, pink flower clusters
Spiraea douglasii	Hardhack	1, 2, 3	0.9-1.8m	Full Sun / Part Shade	●			Native, upright, freely suckering, pink flower clusters
Symphoricarpos albus	Snowberry	2, 3	0.6-1.5m	Full Sun / Part Shade	●		●	Loose structure, fine foliage, notable foamy white berries
Vaccinium ovatum	Evergreen Huckleberry	3	0.9-3m	Full Sun / Part Shade	●		●	Native, evergreen, fine-textured glossy leaves, small edible fruits, wildlife value
Viburnum davidii	David Viburnum	3	0.6-1.2m	Full Sun / Part Shade		●	●	Dependable, white flowers, blue fruits with red stems
Herbaceous Perennials, Grasses & Ferns								
Achillea millefolium	Yarrow	3, 4	0.6-0.9m	Full Sun / Part Shade	●		●	Spreading, long flowering period
Athyrium filix-femina	Lady Fern	3	0.3-0.9m	Part Shade / Shade	●			Delicate texture fronds
Calamagrostis x acutiflora 'Karl Foerster'	Karl Foerster Reed Grass	3	0.9-1.5m	Full Sun / Part Shade			●	Striking upright form, summer and fall interest
Camassia quamash	Camas	2, 3	0.3-0.9m	Part Shade	●		●	Native bulb, flowers for spring interest
Carex elata 'Aurea'	Bowles Golden Sedge	2, 3	0.3-0.6m	Part Shade / Shade			●	Glowing golden-green foliage, clump-forming
Carex morrowii 'Ice Dance'	Ice Dance Japanese Sedge	2, 3	0.3m	Full Sun / Part Shade		●*	●	Variegated, fine-textured, semi-evergreen foliage
Deschampsia cespitosa	Tufted Hair Grass	3	0.6-0.9m	Full Sun / Part Shade			●	Clump forming with airy seed tops
Echinacea purpurea ('Magnus' or others)	Purple Coneflower	3, 4	0.6-0.9m	Full Sun / Part Shade			●	Purple flowers, fall interest
Erica x darleyensis 'Kramer's Red'	Kramer Red Winter Heath	3, 4	0.45m	Full Sun		●	●	Early flower winter interest, fine needle-like foliage
Gaura lindheimeri (varieties)	Gaura cultivars	3	0.6-1.2m	Full Sun		●*	●	Great movement in wind, long flowering season
Hemerocallis ('Stella D'Oro' or others)	Autumn Red Daylilly	3	0.3-0.9m	Full Sun / Part Shade			●	Proflific flowers, coarse grass-like foliage, vigorous, blooms from spring through fall
Heuchera micrantha	Small-flower Alumroot	3	0.3-0.6m	Shade	●	●*	●	Foliage texture interest with raised flowers in spring
Iris sibirica	Siberian Iris	3	0.6-1.2m	Full Sun / Part Shade		●	●	Upright foliage, purple-blue flowers
Lupinus polyphyllus	Large-Leaf Lupine	3	0.9-1.2m	Full Sun	●		●	Architectural foliage, flowers, and seed pods
Panicum virgatum 'Heavy Metal'	Blue Switchgrass	3	0.9-1.2m	Full Sun			●	Fine-textured, best en-masse
Polystichum munitum	Sword Fern	3	0.6-0.9m	Part Shade / Shade	●	●*	●	Coarse-textured fronds, semi-evergreen
Rudbeckia (varieties)	Black-eyed Susan	3, 4	0.6-0.9m	Full Sun / Part Shade			●	Deep yellow flowers for summer through fall

Latin Name / Botanical name	Common Name	Moisture Zone	Height (average ht. under urban conditions)	Light Condition	Native	Evergreen *=Semi-evergreen)	Urban Suitability	Notes
Wetland Plants								
Carex obnupta	Slough Sedge	1, 2	0.6-1.5m	Part Shade	●		●	Not drought-tolerant, spreading, stiff stems
Carex stipata	Sawbeak Sedge	1, 2	0.25-1m	Part Shade	●			Not drought-tolerant, shorter stems, clump forming
Juncus acuminatus	Taper-tipped Rush	1, 2	0.3-1m	Full Sun	●	●	●	Not drought-tolerant, round stems, rhizome spreading
Juncus effusus	Common Rush	1, 2	0.6-1.2m	Full Sun	●		●	Not drought-tolerant, round stems, rhizome spreading
Juncus ensifolius	Dagger-leaf Rush	1, 2	0.3-0.45m	Full Sun	●		●	Not drought-tolerant, dagger-shape stems, compact
Scirpus microcarpus	Small-fruited Bullrush	1	1.5m	Full Sun / Part Shade	●			Not drought-tolerant, broader leaf blades
Groundcovers								
Arctostaphylos uva-ursi	Kinnikinnick	3, 4	0.15m	Full Sun / Part Shade	●	●	●	Low-growing, evergreen, native, branches trap debris (maintenance consideration)
Ceanothus gloriosus	Point Reyes Creeper	3, 4	0.3m	Full Sun		●	●	Blue flower clusters, pollinator interest, spreading
Cerastium tomentosum	Snow-in-summer	3,4	0.3m	Full Sun		●*	●	Silver foliage, white flowers, low growing
Cotoneaster dammeri 'Lowfast'	Lowfast Cotoneaster	3	0.15m	Full Sun / Part Shade		●	●	Hardy and very low growing, small leaves
Fragaria chiloensis	Beach Strawberry	3	0.3m	Full Sun / Part Shade	●	●*	●	Coarse leaves, white flowers, small fruits, spreads by runners, sometimes difficult to establish
Iberis sempervirens	Evergreen Candytuft	3, 4	0.3m	Full Sun		●	●	Low, spreading green mat with showy white flowers
Lithodora diffusa 'Grace Ward'	Grace Ward Lithodora	3,4	0.15m	Full Sun		●	●	Low, spreading, dark green mat with bright blue flowers

OPERATION, INSPECTION AND MAINTENANCE

11 Operation, Inspection and Maintenance

Maintenance of stormwater source controls is a critical part of operating source control facilities and systems. The goal of maintenance activities is to maintain the function of the source control for the long term to promote and protect the lifespan of the system. Without maintenance a source control will not function as intended for the design lifespan of the facility but may fail or require replacement before its design lifespan is ended. Additional benefits of maintenance include prevention of flooding and negative effects on nearby infrastructure, decreasing long-term costs to the municipality, as well as maintaining the aesthetics of the system and community acceptance.

Maintenance can range from removal of litter or debris, to dredging or hydrovac removal of sediment, to partial reconstruction of a damaged or impaired facility.

The first part of this guide includes descriptions of essential maintenance tasks that apply to many source control systems.

The second part of this guide includes recommendations for specific maintenance and operational activities for each type of source control, including recommended frequency for maintenance work, and what aspects of facilities should be observed or checked to ensure the facility is operating within normal expectations. If desired, the checklists in this guideline could be used as a starting point for development of operation and maintenance manuals for individual sites or installations. Municipalities may have additional resources for recommended or required maintenance within municipal maintenance guidelines, checklists, or bylaws.

11.1 Timely and Continuous Plant Maintenance

Most maintenance considerations apply equally to all site and landscape areas, not just stormwater source controls. Many landscape maintenance issues get much worse quickly if maintenance is not provided consistently or in a timely manner. Many examples exist of weeds growing to the point of going to seed, which can increase weed populations exponentially and create untenable maintenance challenges. Similarly, irrigation breakdown, improper scheduling, or lack of proper watering during drought can challenge plant survival, growth, or vigour. Lack of sedimentation removal in sumps or inlets can block runoff from accessing stormwater source controls.

Clear maintenance responsibility and consistent application of preventative maintenance will avoid issues getting out of control. Projects require specifications and arrangements to support:

- Establishment maintenance, from the time of planting until at least one year from the date of substantial performance. Two years establishment maintenance is optimum; see Chapter 9 – Construction and Establishment; and
- On-going landscape and site maintenance, including transfer of responsibility to the Owner.

If Construction quality control and establishment maintenance are effective, the demands of on-going landscape maintenance, monitoring and watering may be reduced, but still require ongoing vigilance, in particular on timely weed management.

The Canadian Landscape Standard (CLS) Section 9 Landscape Maintenance is an excellent introduction to recommended maintenance practices. It describes 6 levels of maintenance objectives, appearance standards and maintenance practices appropriate to various parts of sites:

- Level 1 "Well Groomed";
- Level 2 "Groomed";
- Level 3 "Moderate";
- Level 4 "Open Space / Play";
- Level 5 "Background & Natural"; and
- Level 6 "Service and Industrial".

The cost of maintenance may be directly related to the maintenance objective and level chosen. Generally, the effort and cost of maintenance will be lowest for Levels 5 and 6, moderate for Levels 3 and 4, and higher for Levels 1 and 2. Site planning (see Site Planning Practices to Minimize Maintenance) that organizes larger areas of stormwater source controls location to locations where lower levels of maintenance are warranted is one of the best ways to minimize maintenance costs.

In urban and suburban environments, for most visible stormwater source controls during the construction/establishment maintenance period, a Level 2 "Groomed" maintenance standard is recommended. If that level of maintenance is performed, it may be possible to drop to Level 3 "Moderate" or in some cases Level 4 "Open Space / Play" for long term maintenance in some areas.

Design and Construction Documentation needs to include maintenance area designations and maintenance specifications to make clear the responsibilities of the contractor or owner. Guideline maintenance specs are introduced below.

11.2 Landscape Maintenance Frequency

Defining maintenance objectives, and how much and how often maintenance is required is a key to both landscape performance and maintenance cost. The Recommended Maintenance Procedures and Frequencies below, or an equivalent custom schedule, could be added to either MMCD or Canadian Landscape Standard forms of specifications. Customized versions of this table may be required for different landscape maintenance levels in different areas or sites. Sample specification wording is given in two options following the section below.

All landscape areas shall be maintained as per Table 11-1: Recommended Maintenance Procedures & Frequencies. This table provides a recommended schedule for the 1-year establishment maintenance period. This schedule has been adapted from and is generally consistent with the Canadian Landscape Standard Section 9 Landscape Maintenance.

***This schedule is provided for information only and provides guidance for minimum effort but not the maximum required to meet performance specifications. Changes with weather and site conditions will dictate increased effort or tasks that are the responsibility of the Contractor to determine and carry out in order to ensure plant material is healthy and thriving and weed management status is maintained.**

Table 11-1: Recommended Maintenance Procedures & Frequencies

Recommended Maintenance Procedures & Frequencies													
Procedure	Recommended Monthly Schedule												Frequency
	J	F	M	A	M	J	J	A	S	O	N	D	
General:	✓ Recommended Procedure • As Necessary												
Inspection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Seasonally, and after large events
Litter removal			•	•	✓	•	✓	•	✓	•	•		Monthly (and as necessary)
Reporting	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Annually
Lawns:													
Aerate & de-thatch			•	•	•				•				As required, or conditions allow
Edge			•		✓			✓					1-3 times/growing season
Fertilize				✓			✓		✓				Up to 1-2 times/year (based on soil test)
Lime				•					•				Based on soil test
Mow				•	✓	✓	✓	✓	✓	•			7-10 day intervals during growing season
Pest control				•	•	•	•	•	•	•			As required
Repair				•	•	•	•	•	•	•			As required, within 2 weeks
Reseed/ overseed				•	•			•	•				As required
Trim				•	✓	✓	✓	✓	✓	•			Each time lawn is mown
Water				•	✓	✓	✓	✓	✓	•			2-3 times weekly (per local bylaws)
Weed control	•	•	✓	✓	✓	✓	✓	✓	✓	•	•	•	Bi-weekly, if required
Trees/Shrubs:													
Fertilize				✓		✓			✓				3 times/year (based on soil test)
Mulch / cultivate			✓										Spring start-up
Pest control				•	•	•	•	•	•				As required for healthy appearance
Plant replacements			•	•	•				•				As required
Prune		•							•	•			As required
Transplant				•	•				•				As required
Repair	•	•	•	•	•	•	•	•	•	•	•	•	As required, within 2 weeks
Water				•	✓	✓	✓	✓	✓	•			2-3 times weekly (per local bylaws)
Weed control			✓	✓	✓	✓	✓	✓	✓	•	•		Bi-weekly, if required
Herbaceous Plants:													
Cut back grasses		•							•	•			Annually, before spring re-growth
Bulb planting			•						•	•			Fall or spring (as required by type of bulb)
Dead heading					•	•	•	•	•				As needed
Water				•	✓	✓	✓	✓	✓	•			2-4 times weekly (per local bylaws)

11.3 Costs of Operation and Maintenance

Operation and maintenance of source controls have costs associated with the work. A large part of the cost is incurred in the time for labour required for work to be completed. Resources needed may include:

Labour:

- Inspections
- Trash or debris removal
- Weeding
- Pruning or trimming
- Re-planting
- Mulch addition or re-distribution
- Hand sediment removal

Equipment:

- Hand tools
- Truck or Gator for carrying materials and/or sediment or trash removal
- Vac truck or hydrovac for sediment removal
- Mowing equipment
- Cherry picker or other lift equipment for street tree maintenance
- Saws/pruning equipment

Other key components of cost for operation and maintenance may include:

- Disposal of removed sediments from pre-treatment
- Replacement of materials including growing media, mulch and plants
- Watering during establishment periods

In estimating the costs for operation and maintenance for source control facilities, the duration of labour for individual tasks must be multiplied by the frequency of the task to account for the total hours needed for that task over a period of time, e.g., a year. The other costs then need to be accounted for on the same basis. For the equipment, the up-front and on-going costs should be calculated for the lifespan of the equipment and then divided over that lifespan to provide a yearly cost. For the materials, the total expected usage per year should be added together. When all these costs are accumulated together, an estimate of the annual cost of operation and maintenance is generated. If the costs have significant uncertainty a contingency allowance of a small percentage may be added, usually 10 to 20 %. That annual amount can then be budgeted for in annual operating budgets.

In general, vegetative source control practices incur more total maintenance time than non-vegetative practices, however, as the environmental and social benefits of green vegetative practices are higher, the maintenance costs should be considered in the context of the multiple benefits provided by those practices, and not as an equivalent comparison with non-vegetative source controls.

11.4 Challenges for Operation and Maintenance

Some common challenges for operation and maintenance of source controls are noted below, for consideration for source control implementation:

- Ease of public access – public assess presents risks of both intentional and unintentional damage by individuals;
- High traffic areas – increased wear, damage and litter, and makes access difficult for maintenance;
- Adjacent construction sites – equipment and work on nearby construction sites can generate sediment that may cause sedimentation in source controls, and the construction process may create vibration and cause compaction of the surface and subsurface soils;
- Scheduling and weather – where road closures or traffic management needs to be scheduled in advance or good weather is needed to perform maintenance the scheduling of work must be done in advance, but not too far in advance;
- Climate change – changing climate can cause seasonal droughts and floods that damage source controls;
- Training for staff – there is a lack of training programs available for maintenance staff so it is very difficult to find skilled staff;
- Municipal maintenance priorities – due to funding and staffing limitations, municipalities may prioritize low maintenance solutions, or opt to reduce maintenance, or maintenance frequency or source controls. Some municipalities have partnered with volunteer organizations in order to reduce labour costs for maintenance, however, volunteer maintenance is untrained and will likely not be able to meet the desired level of service for the system; and
- Ownership and jurisdiction of different source control assets – the maintenance of source controls can be complicated by ownership of the site or the infrastructure, such as sits on private vs. public land, and the intersection of storm sewer infrastructure, streets components, landscaping, and parks.

11.5 Operation and Maintenance Programs

The sections below provide recommended operation and maintenance programs for each of the types of source controls in the Stormwater Source Control Design Guidelines.

11.5.1 Absorbent Landscape Operation and Maintenance Program

Maintenance for absorbent landscaping is similar to any other landscaping and may include regular mowing, weeding, irrigation, and pruning. Minor re-grading of the landscape may be necessary as sediments collect or pools form as settling occurs. Observation of the health and function of the landscape is an important part of the maintenance process to make planting, erosion protection, and grading adjustments as needed.

Table 11-2: Absorbent Landscape Operation and Maintenance Program

Activity	Indicators	Frequency
Absorbent Landscape Operations		
Check landscape area performance.	Ensure stormwater is flowing to and over the absorbent landscaping areas from inlets to outlets or as expected across the landscape. Prevent or fix any channelization, riling, settlement, scour, and erosion of the soils.	3 to 4 times a year, after large storm events
Absorbent Landscape Maintenance		
Ensure plant establishment.	Regular watering, weed removal, sediment removal, and replanting. Hand-dig weeds and start over where weed clusters have taken hold.	As needed for first 2 years
Maintain vegetation.	Remove weeds and invasive species, replace dead plants, remove any accumulated sediment, garbage, or debris. Synthetic fertilizers and herbicides are strongly discouraged.	Spring, mid-summer, fall
Ensure aeration of the soil profile.	Aerate by coring and dethatching.	Annually

11.5.2 Infiltration Swale System Operation and Maintenance Program

Swale conveyance capacity and functionality must be maintained through frequent monitoring and maintenance of vegetation, infiltration capacity, and structures. Regular inspection is necessary to identify signs of erosion, as well as sediment and debris accumulation.

Table 11-3: Infiltration Swale System Operation and Maintenance Program

Activity	Indicators	Frequency
Infiltration Swale Operations		
Conduct monitoring or observation of vegetation, infiltration capacity, and structures to maintain functional integrity.	Identify signs of erosion, debris accumulation (particularly around structures), and signs of sedimentation or settlement. Inspect for damage from foot/vehicular traffic. Checking sediment depth Photo credit:: City of Vancouver 	Regularly and as needed; after major storm events.
Inspect swale for debris and blockage.	Inspect swale inlet (curb cuts, pipes, etc.) and outlet, remove debris and blockage as needed. Removal of trash, debris, and sediment from pre-treatment devices, inlets, check dams, and outlets.	Semi-annually (spring and late fall).
Monitoring of storage reservoir water level (optional).	Ensure drainage time meets requirements. Use monitoring well to monitor drainage before/after natural or simulated storm event. Photo: Monitoring well with minimal sediment (Photo credit:: City of Vancouver) 	Following construction, major rehabilitation, and every 5 to 15 years, (depending on criticality of system, and available monitoring resources).
Test soil infiltration capacity.	Check for potential soil clogging by identifying pools of standing water. Remediate soil if testing indicates reduced infiltration capacity below design.	Test if/when poor infiltration/standing water is observed.
Infiltration Swale Maintenance		
Ensure proper establishment of vegetation.	Identify areas where vegetation did not survive and plant alternative species to achieve appropriate density in all areas.	As required during establishment period, typically 2-years min.

Activity	Indicators	Frequency
Watering of vegetation.	Water vegetation during establishment and extended dry periods.	Regularly during establishment and as needed.
Trimming and general landscape maintenance, including mowing, weeding, pruning, and mulching of vegetation.	Inspect for litter and remove prior to mowing. Remove any invasive species. Maintain grass height between approximately 75 mm – 150 mm by mowing – smaller, lighter, more maneuverable mowing equipment should be used (e.g., large tractor to be avoided). Mow only when dry to avoid rutting and compaction. Dispose of cuttings at a local facility.	Seasonal/quarterly.
Inspect swale for debris and blockage.	Inspect swale inlet (curb cuts, pipes, etc.) and outlet, correct as needed. Inspect for standing water and dewater, as necessary. Removal of trash, debris, and sediment from pre-treatment devices, inlets, check dams, and outlets. Hydro-vac truck for sediment removal where appropriate; may be required if sump is full and sediment is difficult to remove manually.	Routine/semi-annually (spring and late fall).

11.5.3 Infiltration Rain Garden Operation and Maintenance Program

Infiltration rain gardens use a vegetated soil medium to infiltrate runoff and therefore the vegetation health and infiltration capacity of the growing media and subsurface soil are critical to maintain. The plantings are often designed to require minimal maintenance, but they must be monitored during establishment and in periods of drought. Regular watering of the vegetation through the growing season in the first year is essential to successful establishment.

Table 11-4: Infiltration Rain Garden Operation and Maintenance Program

Activity	Indicators	Frequency
Infiltration Rain Garden Operations		
Evaluate drain down time.	Ensure drain down time is in accordance with design.	Ongoing, as needed.
Inspect inlet and outlet control structures.	Ensure structures are functioning properly after storms; Identify damage or settlement for repair.  Flow draining to outlet structure Photo credit:: City of Vancouver	Annually or as needed.
Monitor sediment accumulation.	Inspect and removed sediment from inflow areas and pre-treatment systems to prevent clogging. If rate of sediment accumulation is high, identify and control sources of sediment.	Semi-annually in the fall and spring, before and after the wet season.
Infiltration Rain Garden Maintenance		
Establish vegetation.	Water by either hand-watering or irrigation during establishment period. Inspect vegetation biweekly for first year after installation. Look for signs of disease or distress. Replace unsuccessful plantings with alternate for the conditions, if needed to achieve appropriate density in all areas..	Biweekly, as needed during first two growing seasons.
Monitor general rain garden conditions to determine maintenance frequency.	Identify void areas, diseased trees and shrubs, or blocked overflow. Replenish mulch in void or eroded areas. Treat/replace diseased trees and shrubs. Remove leaves and debris blocking overflow, grates, orifices. Clear clogged underdrains.	Monthly for first year after installation

Activity	Indicators	Frequency
Remove debris and sediment	 Accumulating leaves and sediment at inlet. Photo credit:: City of Vancouver Removal of trash, debris, and sediment from pre-treatment devices, inlets, check dams, and outlets. Hydro-vac truck for sediment removal where appropriate.	Monthly to quarterly, depending on site conditions
Inspect underdrain cleanouts.	Remove sediment or debris if necessary.	Annually
Replenish mulch and/or growing medium.	Add mulch throughout garden as needed to restore cover and design depth. Add/adjust growing medium if needed.  Sediment accumulation and erosion needing repair Photo credit:: City of Vancouver	Annually
Maintain vegetation.	Remove weeds, trim shrubs, prune trees, cut back dead or excess vegetation. Remove any invasive species. If any plantings have died or are otherwise unsuccessful, replace with alternates suited to the observed conditions.	Monthly in growing season to Annually, depending on site conditions

11.5.4 Pervious Paving Operation and Maintenance Program

Pervious paving requires regular maintenance to function as intended for the surface's design life. Annual inspections and evaluation of conditions are essential to determine ongoing maintenance practices and frequencies for the individual system.

Table 11-5: Pervious Paving Operation and Maintenance Program

Activity	Indicators	Frequency
Pervious Paving Operations		
Observe infiltration performance.	Review flow over surface for settlement or damage that should be repaired to maintain operation. Check contributing drainage area for controllable sediment and erosion sources. Remove trash, natural debris, and clippings.	Annually, in the spring, and following large storm events.
Monitor storage and tracking of material atop of paving.	Prevent construction vehicle access to prevent tracking sediment on surface. Avoid storing soil, compost, sand, salt, or unwashed gravel directly on paved surface and instead use tarps or geotextile if temporary storage of materials is required. Avoid spreading sand or piling snow on surface during winter maintenance as the pores will become clogged, inhibiting drainage.	Ongoing.
Maintenance – Standard Pavers and Permeable Pavements		
Inspect pavement surface for sediment deposition, organic debris, ponding, or staining that may be indicative of surface ponding.	Test pavement infiltration to identify clogging. If pavement is clogged, schedule vacuum sweeper to regenerate surface infiltration. Sweeping of impervious areas draining to pervious paving. Clear any debris.	As needed.
Inspect structural integrity of pavement surface.	Note signs of deterioration such as slumping, cracking, spalling, or broken pavers and replace/repair pavers or sections as necessary.	As needed.
Remove trash, natural debris, and clippings	Inspect and remove from contributing drainage area, overflow outlets, and pavement surface.	Semi-annually.
Remove undesired vegetation at pavement surface.	If sediment has accumulated enough to grow weed on and between pavers, remove the weeds as well as the sediment.	Annually.
Remove accumulated sediment.	Surface sweeping using commercial vacuum unit to remove sediment Replace joint fill aggregate that may be removed from vacuuming. Avoid use of high pressure or compression units as fines will be imbedded in pavement. Replace vegetation and seed bare areas in contributing drainage area Remove accumulated sediment in overflow outlets.	Annually or Bi-annually.
Inspect underdrain.	Clear debris and clean, as necessary.	Every 5 years, or as required.

Activity	Indicators	Frequency
Maintenance – Grass-filled Pavers Only		
Mowing of grid pavers planted with grass.	Remove clippings and periodically water/fertilize vegetation. Maintain grass height between 5 to 10 cm.	Monthly, or as needed during the growing season
Maintain grass-filled pavers.	Smooth or replace soil that has been displaced. Replant if vegetation has been removed or did not survive.	Annually or Bi-annually

11.5.5 Blue-green Roof / Green Roof Operation and Maintenance Program

The most critical period for a new green roof is the establishment period, which for green and blue-green roofs is approximately 24 to 26 months. The roof should be closely monitored during the establishment period to adjust the ongoing maintenance plan accordingly.

In general, sharp tools should be avoided during maintenance and repair work to prevent damage to the drainage layer.

Maintenance tasks should be performed in dry weather, as foot traffic on saturated growing medium soil has a higher risk of damage or compaction.

Maintenance and operations for proprietary green roof or blue-green roof systems should be in accordance with the manufacturer's recommendations.

Table 11-6: Blue-green Roof / Green Roof Operation and Maintenance Program

Activity	Indicators	Frequency
Blue-green Roof Operations		
Inspect inlets and drain time.	Check drainage inlets for blockage or debris and remove, as necessary. Inspect roof to ensure water depth and drain time are consistent with design. If standing water is observed, check roof drain inlets for clogging and clear as needed.	Quarterly, and after large rain events.
Blue-green Roof Maintenance		
Establish Vegetation	Hand water or irrigate using automatic sprinkler system.	Biweekly, as needed during first two growing seasons.
Inspect roof drain inlets for damage.	Check roof drain inlets for snow or ice buildup, deterioration, or displacement.	After snow or freezing conditions.
Inspect condition of roof components under dry conditions.	Inspect condition of roof drain inlets and inlet screens, as well as roof membrane for signs of deterioration.	Annually or Bi-annually, or as required for insurance purposes.

Activity	Indicators	Frequency
Green Roof Operations		
Inspect inlets and drain time.	Check drainage inlets for blockage by soil substrate, vegetation, or debris and remove as necessary. Identify and control sources of sediment and debris. Inspect roof to ensure water depth and drain time are in.	After large rain events.
Irrigation system preservation and winterization.	Disconnect system in winter and reconnect in spring to prevent freezing or damage to components. Inspect and test system regularly.	Ongoing.
Green Roof Maintenance		
Establish vegetation.	Hand water or irrigate using automatic sprinkler system.	Biweekly, as needed during first two growing seasons.
Water vegetation.	During summer or periods of drought, consistent with the needs of the types of plantings. For extensive roofs with shallow growing media layer, regular summer watering may be required.	As needed.
Inspect roof drain inlets.	Check roof drain inlets for snow or ice buildup.	After snow or freezing conditions.
Inspect vegetation.	Identify and remove weeds (manual weeding) and invasive species. Maintain 90% plant cover. Re-vegetate bare patches. Check if footprints are present and post signs to prevent future foot traffic. Check vegetation in extended dry periods for signs of drought.	Monthly or quarterly, or as needed during growing season.
Inspect growing medium.	Check for signs of wind or water erosion. Add additional growth medium to noted erosion channels.	Quarterly.
Inspect condition of roof components under dry conditions.	Inspect condition of roof drain inlets and inlet screens, overflow outlets, as well as exposed waterproofing for signs of deterioration. Inspect drains during irrigation, as there should be no dry-weather flow. Dry-weather flow is indicative of over-watering. Remove trash and debris from filter bed.	Bi-annually.
Remove accumulated sediment.	Flush sediment from overflow outlets using hose or pressure washer. Remove sediment accumulation and debris from assembly filter.	Bi-annually.
Inspect soil conditions.	Sample soil to evaluate nutritional requirements.	Annually
Prune and maintain vegetation.	Prune shrubs and trees, cut back spent plants, replace deceased plants.	Annually

11.5.6 Infiltration Trench and Soakaway Manholes Operation and Maintenance Program

Infiltration trench and soakaway manholes are subsurface structures that typically require minimal inspection and maintenance.

Table 11-7: Infiltration Trench and Soakaway Manholes Operation and Maintenance Program

Activity	Indicators	Frequency
Infiltration Trench and Soakaway Manholes Operations		
Ensure adequate drainage.	Check for surface ponding that may be indicative of clogging (after design drain-down time, e.g., 24-hours, has elapsed). Check for surface subsidence that may indicate a failure in the structure below.	Annually, and after large storms.
Infiltration Trench and Soakaway Manholes Maintenance		
Inspect catch basins and inlets.	Clear debris from catch basins and inlets. Remove sediment when more than 10% of available capacity, either manually or by a vacuum truck.	Bi-annually.
Inspect vegetation at surface.	Check for bare patches and revegetate, as necessary. Mow grass a minimum of twice a year or as required but avoid unnecessary compaction from mower. Collect clippings and dispose outside of trench area.	Bi-annually.

11.5.7 Soil Cells and Tree Trenches Operation and Maintenance Program

Street trees including soil cells and tree trenches manage stormwater and manage root growth using a modular support system, improving the tree health by providing water storage. Street tree maintenance should be directed by a certified arborist, to ensure it is consistent with the needs of the specific tree species. Watering and pruning will vary based on tree species planted. Removal of sediment and debris from pre-treatment areas is critical to the success of the infrastructure.

Table 11-8: Soil Cells and Tree Trenches Operation and Maintenance Program

Activity	Indicators	Frequency
Soil Cell and Tree Trenches Operations		
Ensure adequate drainage in soil cells.	Check drainage is occurring as intended. Look for any ponding or algae along surface or edges.	Annually.
Soil Cell and Tree Trenches		
Establish trees.	Inspect and monitor pre-treatment areas and develop appropriate maintenance plan. Water and control weeds regularly until trees are fully established. Watering bags are recommended for efficient use of water and labour for first three growing seasons.	As needed during first two growing seasons.
Watering of street trees and weed removal.	Water approximately monthly during dry season. Remove weeds 2-3 times during the active growing season to reduce competition with tree roots.	Monthly or as needed.
Soil cells.	Observe soil cell operation; if filter media at surface become clogged remove and replace media as needed.	Quarterly.
Tree pruning.	Prune as necessary so trees are not obstructing street signs, traffic signs, streetlights, and sidewalks.	Bi-Annually or as needed.
Sediment Removal.	Inspect pre-treatment devices for sediment accumulation and clear by vacuum removal, as necessary.	Annually.
Mulching.	Restore and replenish mulch to retain soil moisture and protect tree from potential damage inflicted by maintenance equipment.	Annually.

12. GLOSSARY

12 Glossary

Absorbent landscape – a combination of surface soil structure, surface plants and/or organic matter that is highly permeable and supports high infiltration and evapotranspiration capacity. Absorbent landscapes help to store, infiltrate, evaporate and cleanse surface runoff. "To optimize infiltration, the surface soil layer should have high organic content (10–25%)… A range of soil and vegetation characteristics is acceptable depending on whether the area is to be covered by lawn, shrubs, or trees" (B.C. MWLAP, 2002: 7–9). To establish absorbent landscapes, recommended minimum depths of growing medium range from 150 mm (6") for lawn areas, 300 mm (12") for ground covers, 450 mm (18") for shrubs respectively, and 600 mm (24") for tree planting areas. These depths are modified according to the depth and drainage capacity of the subgrade.

Blue-green roof – a blue-green roof is a variety of green roof where there is a storage layer with a controlled outlet incorporated in the design to provide attenuation of flow, i.e., detention, on the roof itself for the rain that falls on the roof. A blue-green roof provides all the benefits of a green roof, with the addition of storage and rate control of roof runoff.

Dry wells – sub-surface reservoirs made from graded rock or large diameter pipes set on end over a base of washed rock, typically used to receive runoff from roof downspouts (GVRD, 1999: 4-73).

Evapotranspiration – the combination of water transpired (or breathed) from vegetation and evaporated from the soil and plant surfaces (Ward and Trimble, 2003).

Exfiltration – the movement (usually downward) of water out of one soil layer and into another soil layer or into a drainage structure.

French drain – a small, underground trench filled with a layer of open-graded gravel, designed to accept surface and shallow groundwater and to drain it away from a building or area that is prone to surface water build up and/or flooding. It may include a perforated drain pipe at the bottom of the gravel layer to convey overflow waters to a drainage system.

Filter drain – similar to a french drain, a small, underground trench filled with a layer of open-graded gravel, designed to accept surface and shallow groundwater. However, a filter drain is commonly used as a water quality treatment, placed at roadside or in roadway medians. Runoff passing through the rock is detained and has coarse sediments removed. Filter drains also commonly include a perforated drain pipe at the bottom of the gravel layer to convey of overflow waters to a drainage system.

Filter strips – (also known as vegetated filter strips or biofilters) broad vegetated areas along the edges of impervious surfaces (such as roadways) that intercept, and direct stormwater flows over the vegetated surface before the flows can become substantially concentrated. The vegetated surface can range from turf to forest. Filter strips are intended to promote even sheet flow over a gently sloped vegetated ground surface, thereby directing stormwater broadly into a swale or similar conveyance structure. Some infiltration may occur, as well as some attenuation of peak runoff rates for flood control and streambank erosion protection. Contaminant removal mechanisms are similar to those for grassed channels. (GVRD, 1999: 4-60).

Green roof – a vegetation-supporting roof cover aimed at reducing the volume and rate of runoff from a rooftop. Additional benefits include improved thermal efficiency (enhanced building heating in winter and cooling in summer), sound attenuation, extended service life of the underlying waterproofing system, improved air quality and urban 'greening'. Green roofs can be:

- Extensive – soil depths are shallow, typically 20-200 mm, and support mosses, grasses, and sedums. They are characterized by their low weight, low per unit capital cost and lower maintenance; and
- Intensive – soil depths are greater than 200 mm and able to support larger vegetation (shrubs, small trees, etc.) that have higher maintenance requirements.

Green roof designs are a functional enhancement to a "roof garden" where the latter may be largely a series of freestanding planters and paving installed primarily for aesthetic or 'living space' purposes with little emphasis on source control.

Hydraulic conductivity – the ability of soil to transmit water under a unit hydraulic gradient. Hydraulic conductivity is often equated to permeability and is a function of soil suction and soil water content. Fine-grained soils tend to have lower hydraulic conductivity than coarse grained soils (Ward and Trimble, 2003).

Infiltration – the downward entry of water through a soil surface and into the soil (Ward and Trimble, 2003).

Interflow – water that infiltrates into the soil and moves laterally through the upper soil layers until it returns to the surface, often as a stream (Ward and Trimble, 2003).

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

Permeability – the ease with which a liquid penetrates or passes through a layer of soil or porous medium; can also be referred to as perviousness.

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 underlying sub-base soils, or to a reservoir where water is stored and either exfiltrated to the underlying subgrade or removed by a subdrain. 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 or plastic with large voids that are filled with a permeable material – usually gravel or soil; the latter often have grass; and
- 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".

Qualified professional – an applied scientist or technologist specializing in a relevant science or technology, including but not limited to agrology, forestry, biology, engineering, geomorphology, geology, hydrology, hydrogeology, or landscape architecture. Qualified professionals should be registered with their applicable professional organization and acting under that association's code of ethics and subject to disciplinary action by that association. Qualified professionals should demonstrate suitable education, experience, accreditation, and knowledge relevant to the particular matter, such that they can be reasonably relied on to provide sound advice within their area of expertise.

Rain garden (bioretention) – a concave landscape area where runoff from roofs or paving is retained temporarily to allow infiltration into deep constructed soils below; designed to have the aesthetic appeal of a garden, as opposed to a purely functional appearance. Plantings may include trees, shrubs, groundcovers, rushes, sedges, grasses, and turf. On subsoils with low infiltration rates, rain gardens usually have an underlying drain rock reservoir and perforated drain. Typically designed as a 'standalone' facility to serve a small area, new designs are putting rain gardens in series along linear areas like roads with weirs and surface conveyance similar to infiltration swales (dry swale with underdrain).

Soakaway – a hole in the ground filled with rubble and coarse stone to which a small-scale drainage pipe (such as a roof downspout) conveys rainwater. To allow rainwater to "soak away", the soil in which the soakaway is placed must have good drainage properties.

Soil cell – a system that provides loading support for adjacent or overlying hard surfaces while allowing large volumes of uncompacted soil media to be placed below and adjacent to the pavement. They are most often used to support the inclusion and health of trees, even large trees, in an urban environment. Other common terms used are Street Tree and the names of some proprietary tree and soil systems.

Structural soil – a mix of crushed stone and loam soil – used to provide structural support for overlying and adjacent pavement rather than separate support structures around the soil. It provides a suitable base for pavement while still allowing roots to penetrate.

Subsurface infiltration structure – any type of underground structure designed to receive water from the surface by infiltration (e.g., through porous paving) or conveyance (e.g., via a swale with drain outlet) and temporarily retain it to allow gradual exfiltration of the water into the underlying structural or native subsoil. They may be individual, isolated structures (e.g., rock pit, soakaway, dry well, sump, plastic void structures, perforated or “leaky” tank or catch basin, drain rock blanket) or linear (french drains, underdrains, plastic void chambers, underground infiltration trenches). They are frequently combined with surface structures such as swales, rain gardens or porous paving.

Swale – a linear depression or wide, shallow channel used to collect, infiltrate, treat and convey stormwater. A variety of types of swales and related terms are identified in the literature:

- Grassed swale – lined with grass, named presumably to differentiate from a rock or concrete lined swale; considered as typically dry between storms. The grass acts to decrease stormwater flow velocities; reduce peak flow rates, reduce flooding and erosion, and promote infiltration, thereby reducing the overall runoff volume. Removal of contaminants can be accomplished through filtration of suspended solids by plant stems, adsorption to soil particles and plants, infiltration, and some biological action. (GVRD, 1999: 4–52);
- Vegetated swale – a variant on the grassed swale that is more densely vegetated or landscaped with plants other than grass. The same attenuating, infiltration and contaminant removal characteristics apply;
- Wet swale – grassed or vegetation swale with standing water between storms, due to high groundwater levels or high base flow; alternatively, may be purposely designed with check dams that store water in shallow ponding areas. Check dams help to reduce flow velocity, promote infiltration and evapotranspiration, enhance settling of particulates and contaminant removal. Wet swales are planted with water tolerant or wetland plant species, with turf on the side slopes;
- Bioswale – a term to collectively refer to grassed, vegetated, or wet swales; and
- Dry Swale with Underdrain, Bioretention swale, Infiltration swale – a shallow grassed channel designed to enhance infiltration by containing check dams or weirs to create shallow ponds of stormwater and promote infiltration through an augmented soil bed to an underground drain rock reservoir and ultimately into underlying soils. A perforated drain placed near the top of the drain rock reservoir provides an underground overflow. The surface swale and weir structures also convey larger storms (overflows) to a surface outlet. German literature refers to a Swale/Trench Element and adds an outlet control structure to detain stormwater in the drain rock reservoir and soils, releasing the water either through infiltration or through small outlet orifices at the control structure.

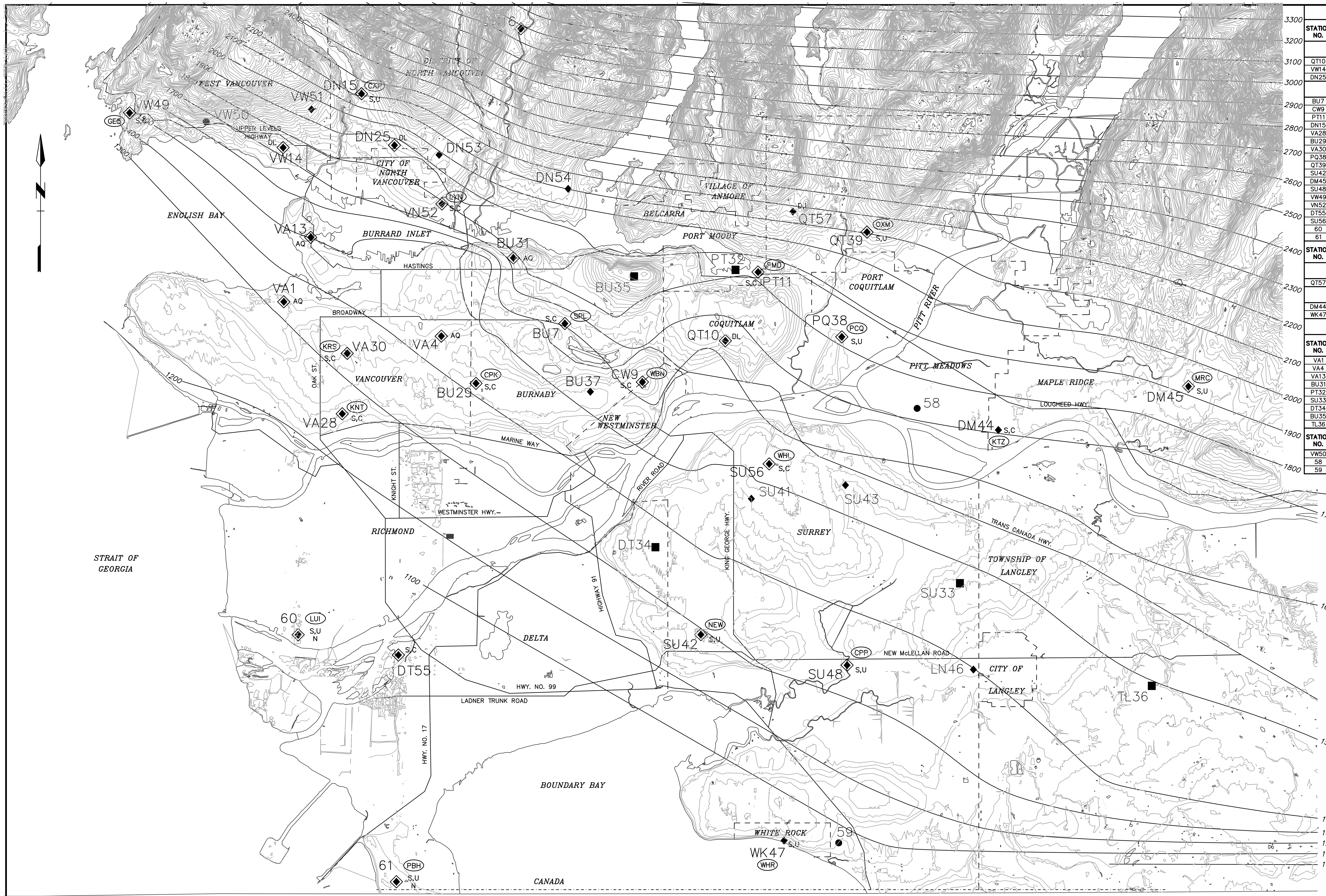
Treatment train – the application of a series of physical stormwater best management practices to achieve managed hydrology and water quality . Often used to treat contaminated runoff, the chain (or train) may incorporate chambers or units that first slow water and remove large particulates, followed by a unit to allow settling out of finer particulates, and a third "finishing" unit to remove dissolved compounds. (See GVRD, 1999: 4–108, Western Australia Water and Rivers Commission, 1998: 3 or Argue, 2002 for further details and examples.)

Tree trench – a system is similar to a soil cell, but it is constructed in a linear manner to provide a 'trench' of uncompacted soils, with reinforced sides and top sections rather than internal supports.

APPENDIX A

Average Annual Rainfall

Regional Rainfall Isohyet Map



G.V.S. & D.D. RAIN GAUGES

STATION NO.	PERMANENT GAUGE LOCATION
	DATA LOGGERS
QT10	Coquitlam City Hall – 1111 Brunette St., Coquitlam
VW14	West Vancouver Municipal Hall – 750 17th. St., West Vancouver
DN25	District of North Vancouver Municipal Hall – 355 W. Queens Rd., North Vancouver
	SCADA GAUGES
BU7	Sperling Ave. P.S. – Sperling Ave. between Laurel St. & Sprott St., Burnaby
CW9	Westburnco Reservoir – Massey St. & Churchill Ave., New Westminister
PT11	Port Moody Pumping Station – Guilford Dr. West of Ioco Rd., Port Moody
DN15	Cleveland Dam Caretaker's House – Top of Capilano Road, North Vancouver
VA28	Kent Ave. P.S. – Kent Ave. & Yukon St., Vancouver
BU29	Central Park – Kingsway and Patterson St., Burnaby
VA30	Kersland Reservoir – W. 37th. Ave., Vancouver
PQ38	Port Coquitlam Pump Station – McLean Ave. and Taylor St., Port Coquitlam
QT39	Burke Mountain Firehall – 1424 Coast Meridian Rd., Coquitlam
SU42	Newton Reservoir – 62A Ave. and 128th. St., Surrey
DM45	Maple Ridge Reservoir – Dewney Trunk Rd, Between 244th.St. & 248th,St.,Langley
SU48	Cloverdale P.S. – 164th. St. & Highway No. 10, Surrey
VW49	Gleneagles Lift Station No.5 – Marine Dr. & Kensington Crescent, West Vancouver
VN52	Lynn P.S. – 4th. St. & Kenneth Ave., North Vancouver
DT55	Ferry Road Pump Station – Delta Ferry Road West of Highway 99
SU56	Whalley Reservoir – Surrey, 104a Avenue and 146 Street.
60	Lulu Island W.W.T.P. – 13500 Gilbert Rd., Richmond
61	Pebble Hill Reservoir – 2nd Ave. and 52nd St., Delta
STATION NO.	**TEMPORARY GAUGE LOCATION**
	DATA LOGGERS
QT57	Westwood Plateau – BC Hydro Transformer Station
	SCADA GAUGES
DM44	Katzie P.S. – South end of Maple–Meadows Way, Maple Ridge
WK47	White Rock P.S. – Marine Dr. & 48th. St., White Rock
	OTHERS
STATION NO.	**AIR QUALITY GAUGES (GVRD)**
VA1	Kitsilano High School – 2550 W. 10th. Ave., Vancouver
VA4	Renfrew Elementary School – 3315 E. 22nd. Ave., Vancouver
VA13	Stanley Park Yard Office
BU31	Confederation Park – Pandora St. and Alpha Ave., Burnaby
PT32	AES Rocky Point Park – foot of Murray Street, Port Moody
SU33	AES Surrey East – 19000 block 72nd Ave., Surrey (Clayton Reservoir)
DT34	AES North Delta – 8544 – 116th Street, Delta (Hellings Tank)
BU35	AES Burnaby Mountain – Ring Road, Simon Fraser University
TL36	AES Langley Central – 23752–52nd Avenue, AES Langley
STATION NO.	**ATMOSPHERIC ENVIRONMENT SERVICE AUTOSTATIONS**
VW50	AES Climate Station – Cypress Bowl Interchange – Trans Canada Hwy., W. Vanc.
58	Pitt Meadows Airport
59	White Rock

LEGEND:

- MAJOR HIGHWAY
- MUNICIPAL BOUNDARY
- COASTLINE
- 58 — A.E.S. AUTOSTATION
- SU33 — AIR QUALITY RAIN GAUGE
- SU33 DL, AQ or S, C or U, R,N — G.V.S. & D.D. RAIN GAUGE (PERMANENT) DL=DATA LOGGER, AQ=AIR QUALITY S=SCADA, C=ALREADY CUT OVER, U=UNCONNECTED, R=RELOCATED GAUGE, N=NEW LOCATION
- LN46 DL or S, C or U — G.V.S. & D.D. RAIN GAUGE (TEMPORARY) DL=DATA LOGGER, S=SCADA, C=ALREADY CUT OVER, U=UNCONNECTED
- WHR — GVRD RTU LOCATION
- 1100 — AVERAGE YEARLY PRECIPITATION BANDS (ISOHYETES) AND TOTALS (mm)
- GROUND CONTOURS AT 20m INTERVALS
- GROUND CONTOURS AT 100m INTERVALS

0 1 2 3 4 5 10km

SCALE 1:100,000

NOTES:

1. ISOHYETS DRAWN FROM G.V.S.& D.D. AND A.E.S. RAINFALL GAUGES THAT HAD AT LEAST 20 YEARS OF RECORDS DURING THE PERIOD BETWEEN 1961–1990.
2. 20m CONTOURS FROM PROVINCIAL TRIM MAPS

Professional Engineer's Seal

Issue	Date	Des'n	Dr'n	Chkd	App'd	Description

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

Design R.B.
Drawn B.L.
Checked
Submitted
Engineer

G.V.S. & D.D.
RAIN GAUGE
RECOMMENDED NETWORK

FIGURE 3

SCALE AS SHOWN
DATE MAY 1997
DISTRICT FILE SF–1981
SHEET 3C
DRAWING SF–1981

SUPERSEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO ➡ A

APPENDIX B
Sizing Charts for
Percent Annual Rainfall Criteria

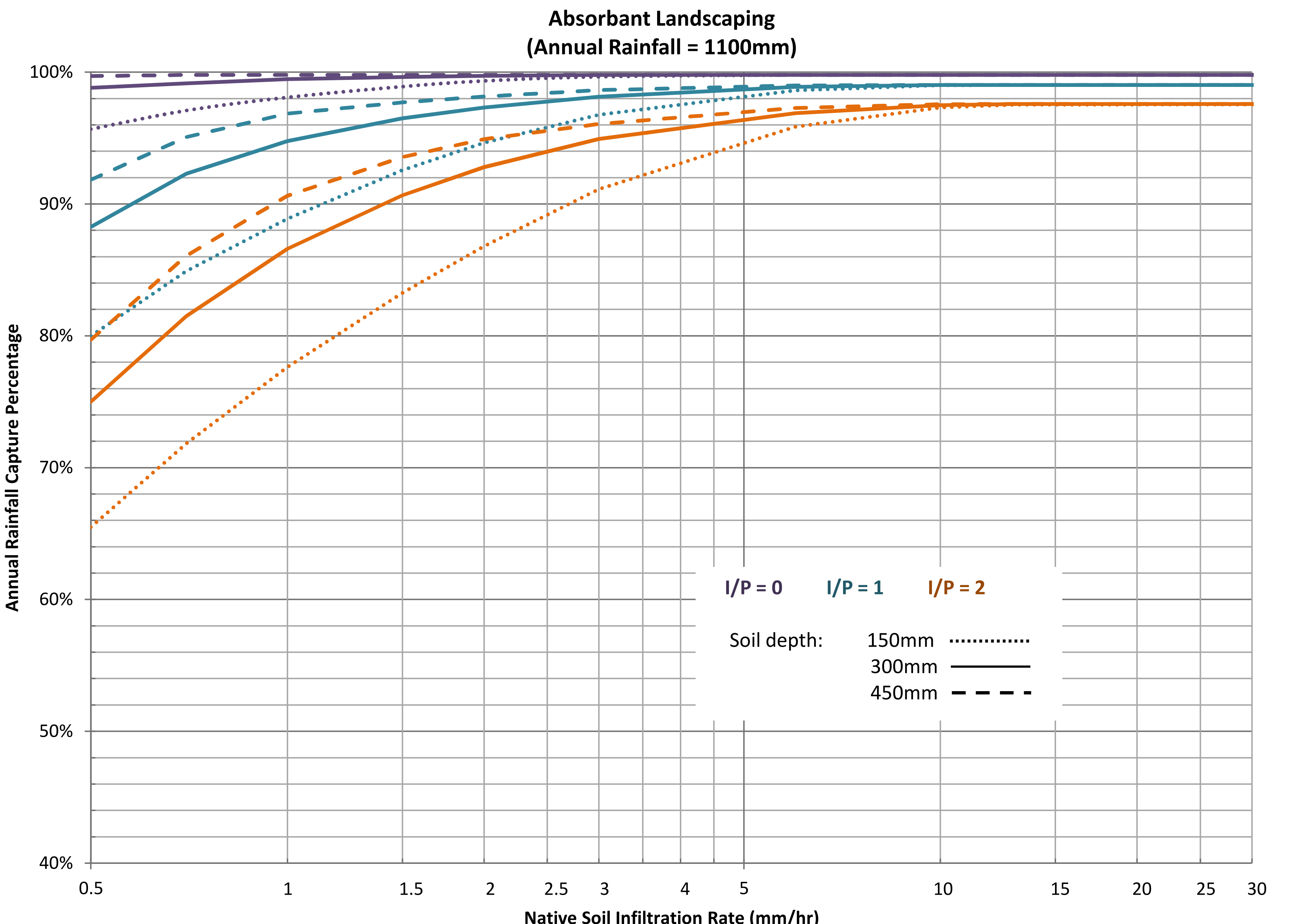


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FIGURE B-1

\\libra25.burnaby.kerrwoodleidal.org\0000-0999\0200-0299\251-261\400-Work\Results\ALSummaryGraphs.xlsx1100mm

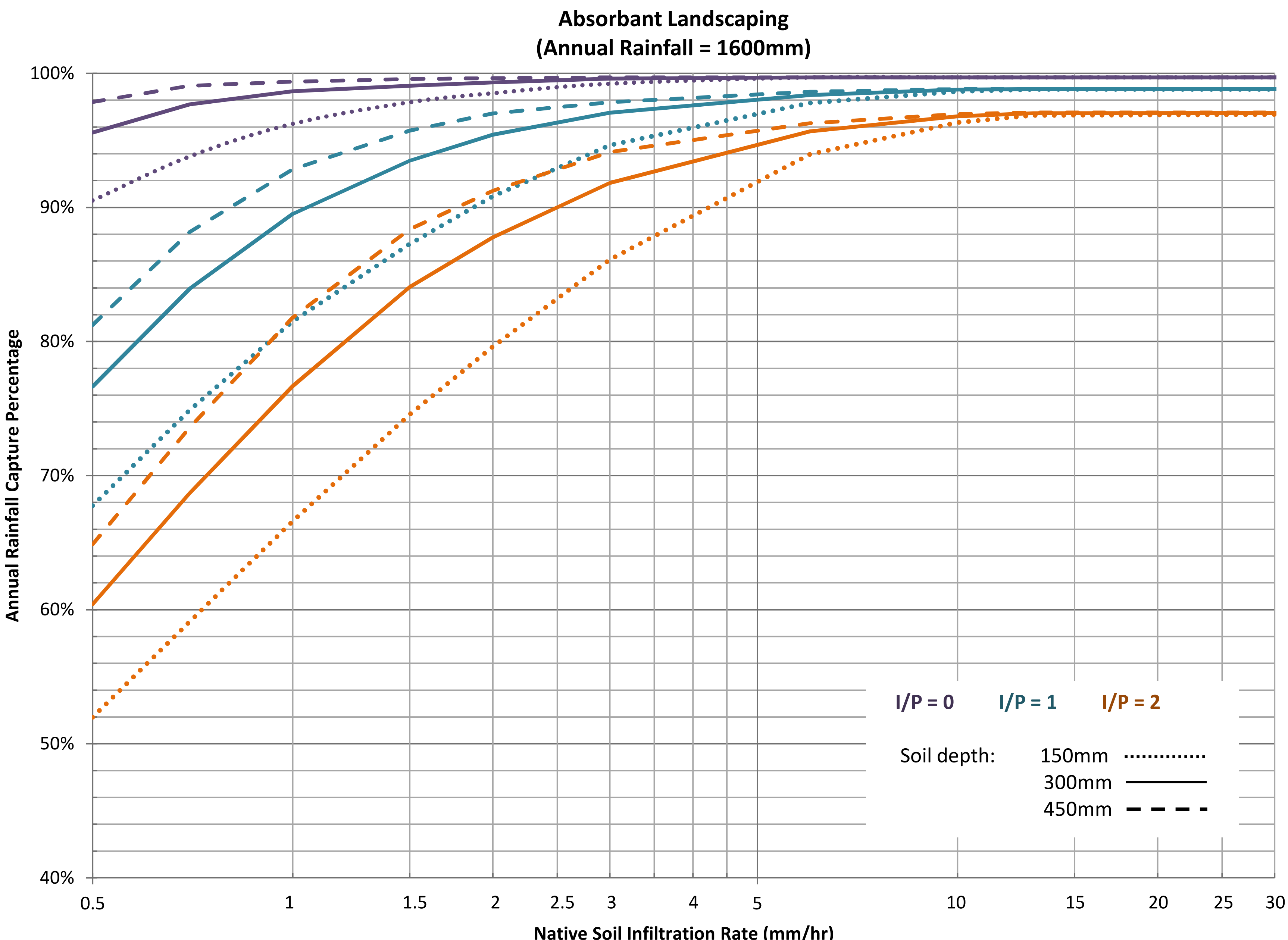

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FIGURE B-2

\\libra25.burnaby.kerrwoodleidal.org\0000-0999\0200-0299\251-261\400-Work\Results\ALSummaryGraphs.xlsx1600mm

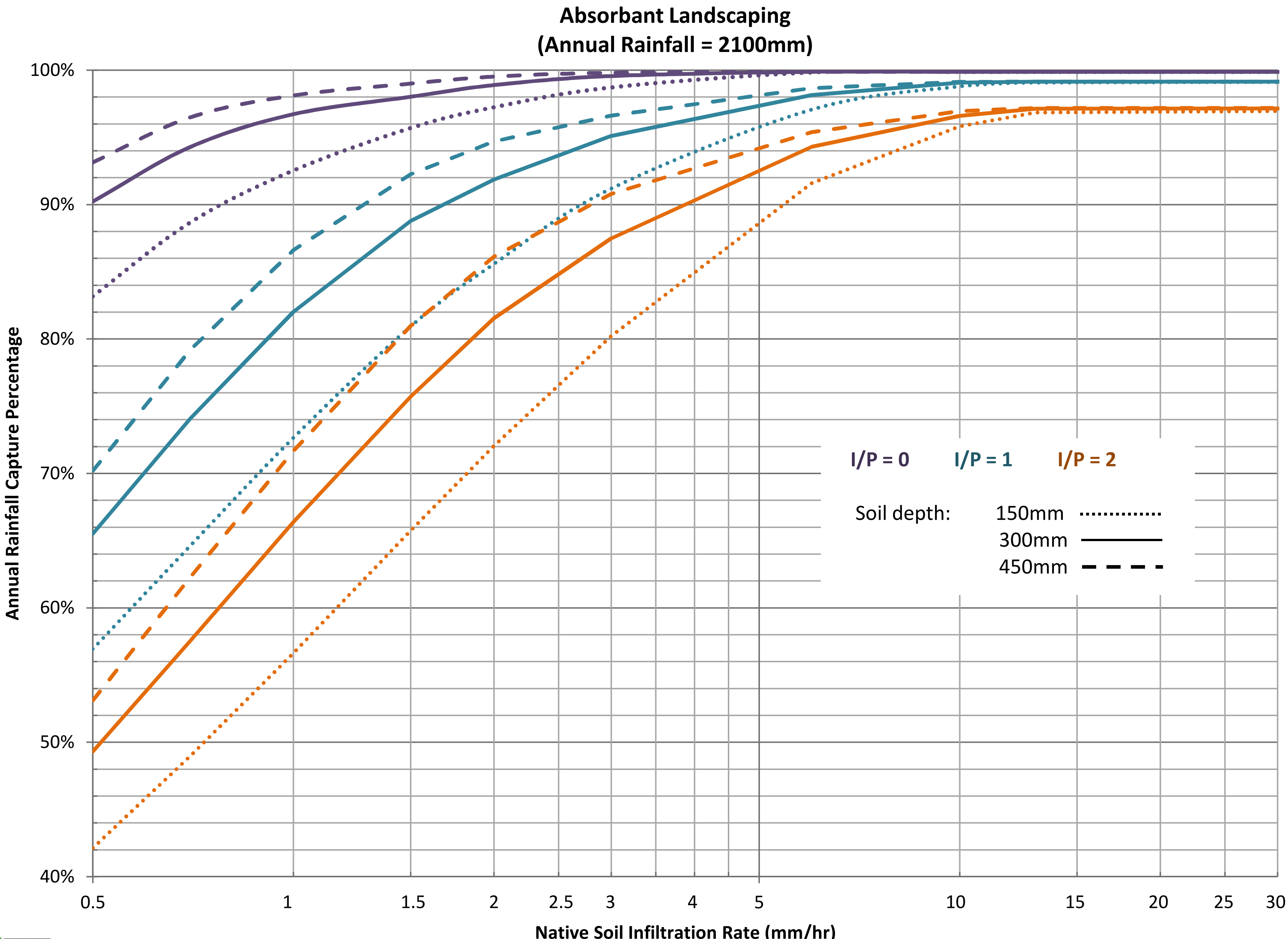

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FIGURE B-3

\\libra25.burnaby.kerrwoodleidal.org\0000-0999\0200-0299\251-261\400-Work\Results\ALSummaryGraphs.xlsx2100mm

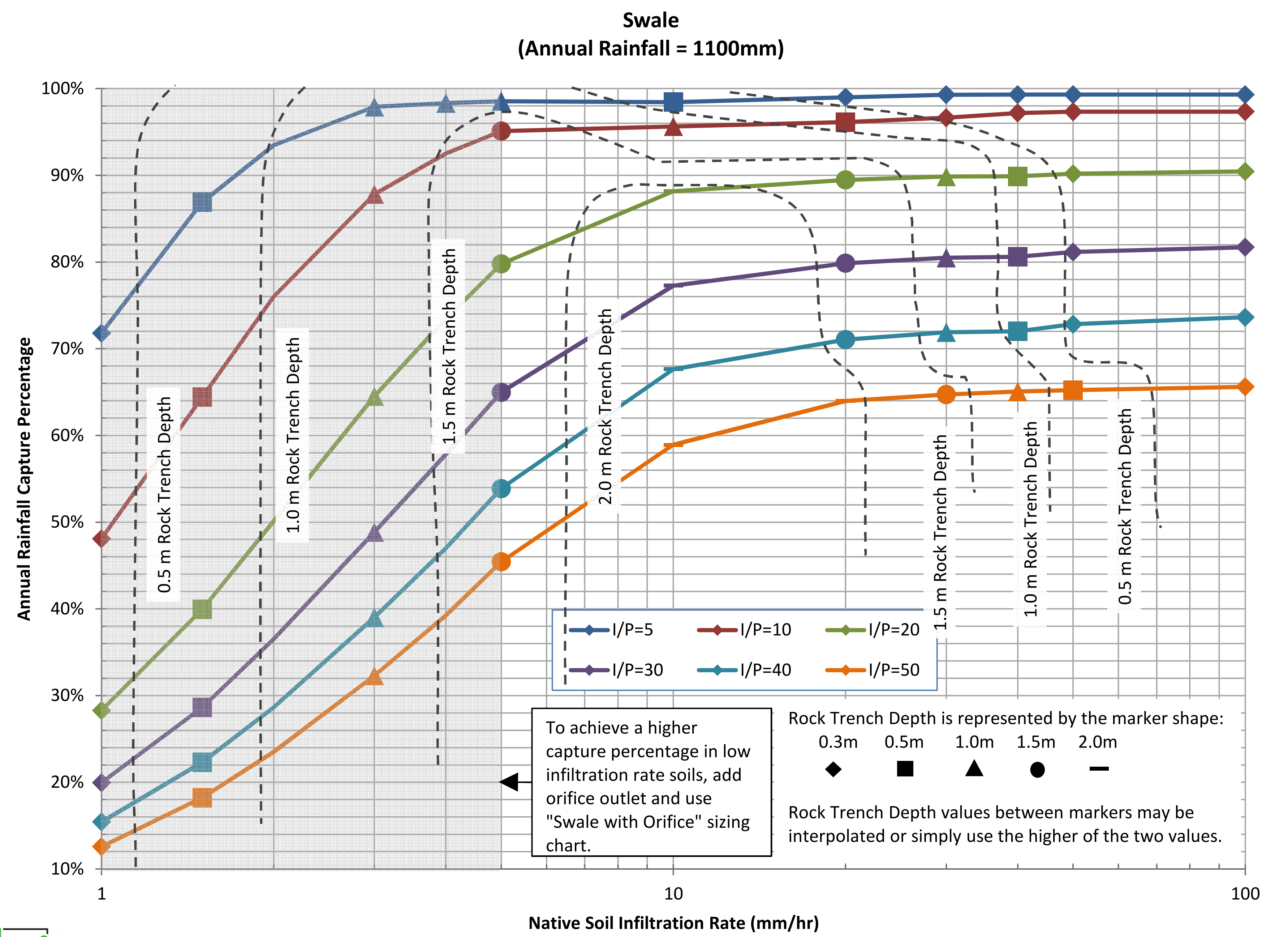

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FIGURE B-4

C:\Users\LMorgan\Desktop\BCWWA2012\252-261_copies\400-Work\Results\SwaleSummaryGraphs-WhiteRock.xlsx1100-proposed

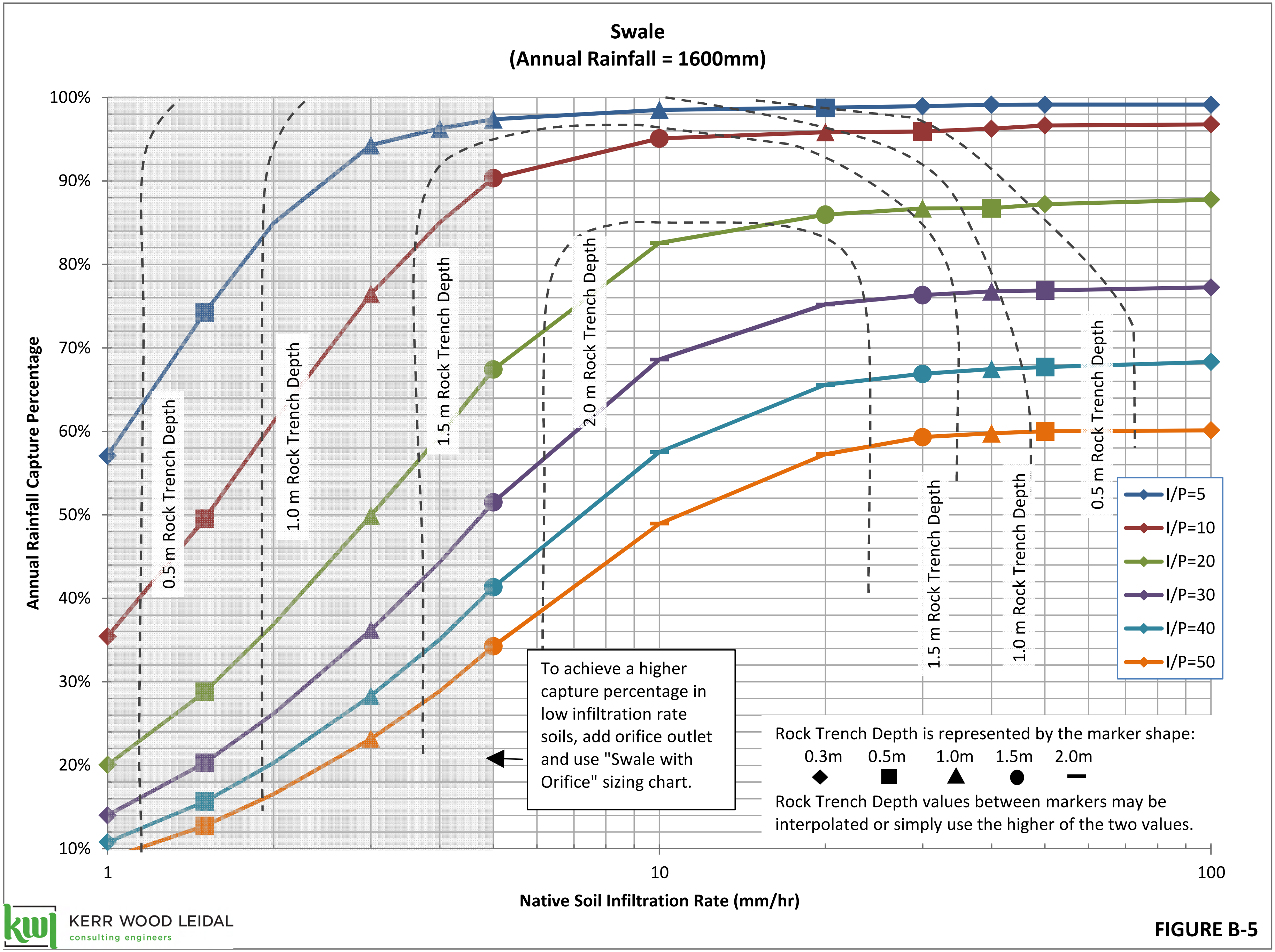
Swale
(Annual Rainfall = 1600mm)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
Annual Rainfall Capture Percentage
1
10
100
Native Soil Infiltration Rate (mm/hr)
0.5 m Rock Trench Depth
1.0 m Rock Trench Depth
1.5 m Rock Trench Depth
2.0 m Rock Trench Depth
1.5 m Rock Trench Depth
1.0 m Rock Trench Depth
0.5 m Rock Trench Depth
I/P=5
I/P=10
I/P=20
I/P=30
I/P=40
I/P=50
To achieve a higher capture percentage in low infiltration rate soils, add orifice outlet and use "Swale with Orifice" sizing chart.
Rock Trench Depth is represented by the marker shape:
0.3m 0.5m 1.0m 1.5m 2.0m
Rock Trench Depth values between markers may be interpolated or simply use the higher of the two values.
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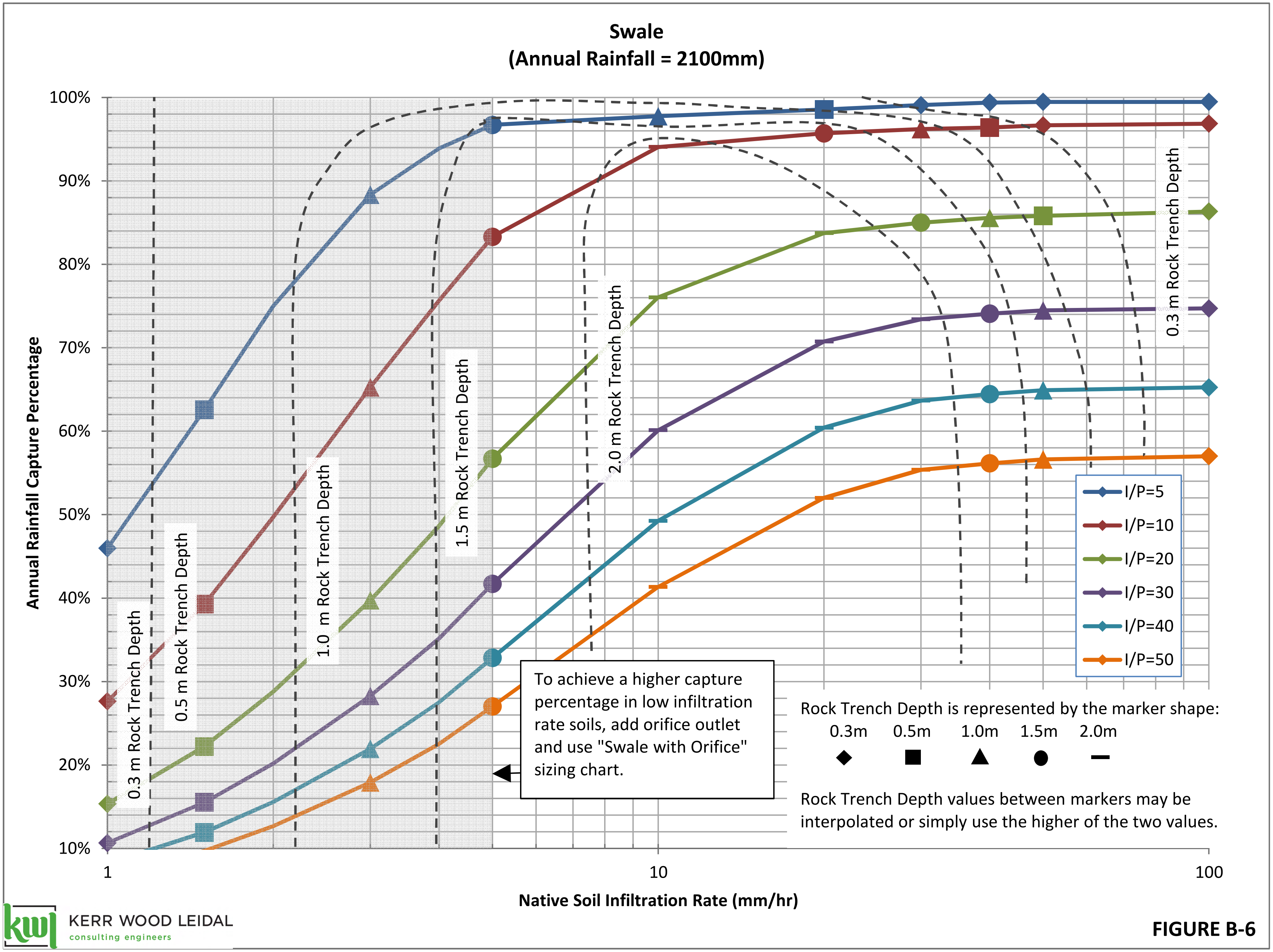
FIGURE B-5



C:\Users\LMorgan\Desktop\BCWWA2012\252-261_copies\400-Work\Results\SwaleSummaryGraphs-Burke.xlsx2100-proposed

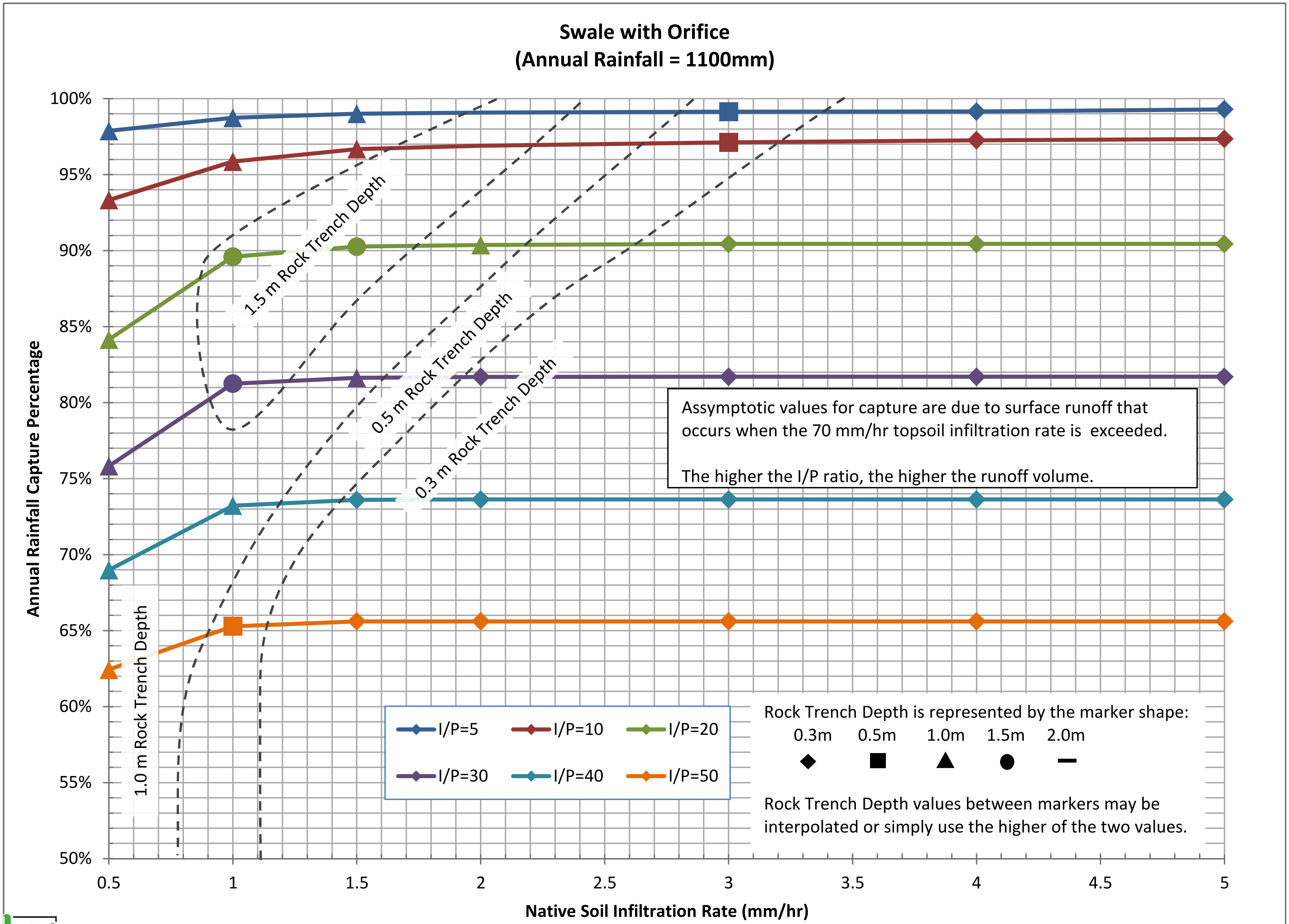


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FIGURE B-7

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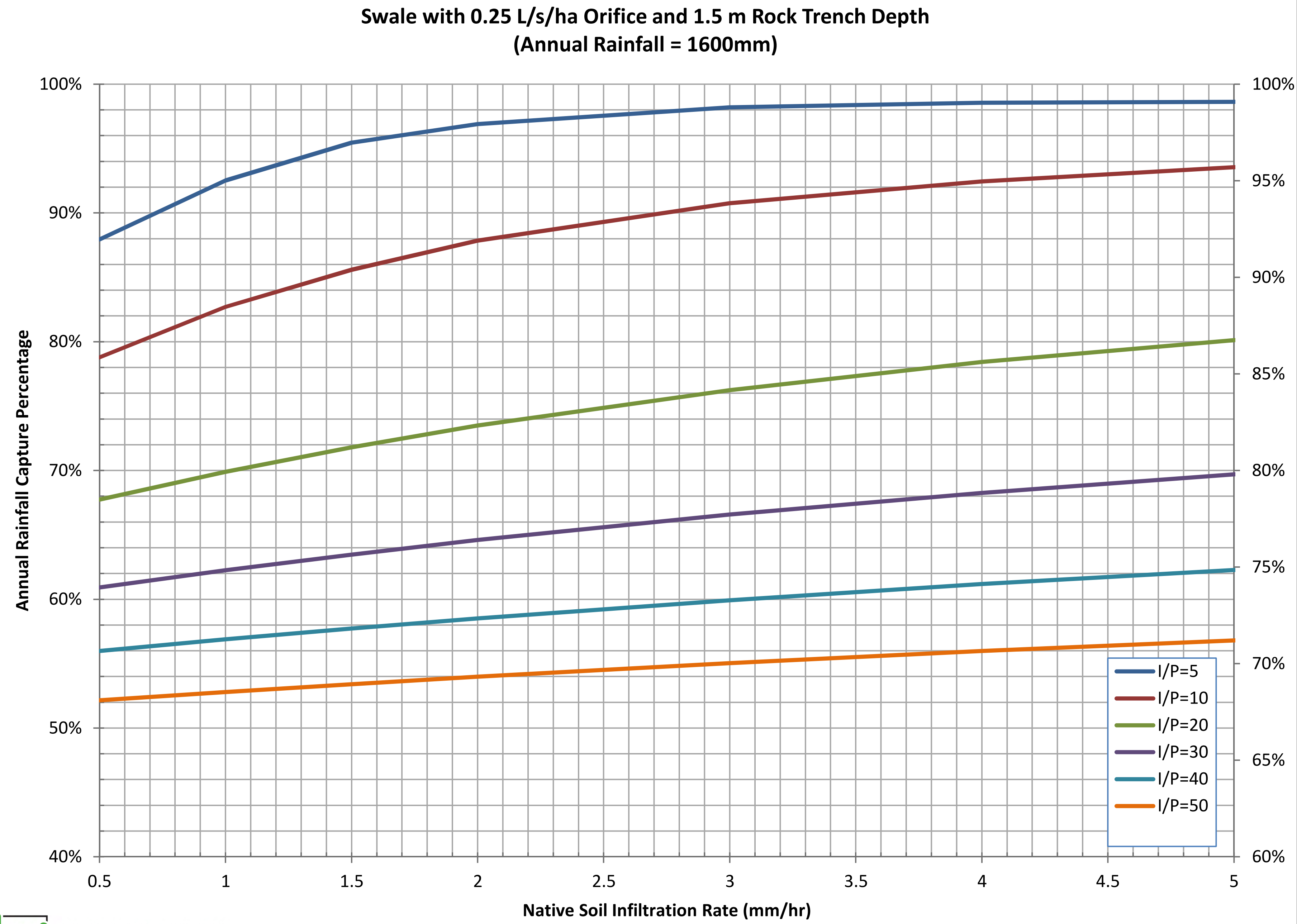

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FIGURE B-8

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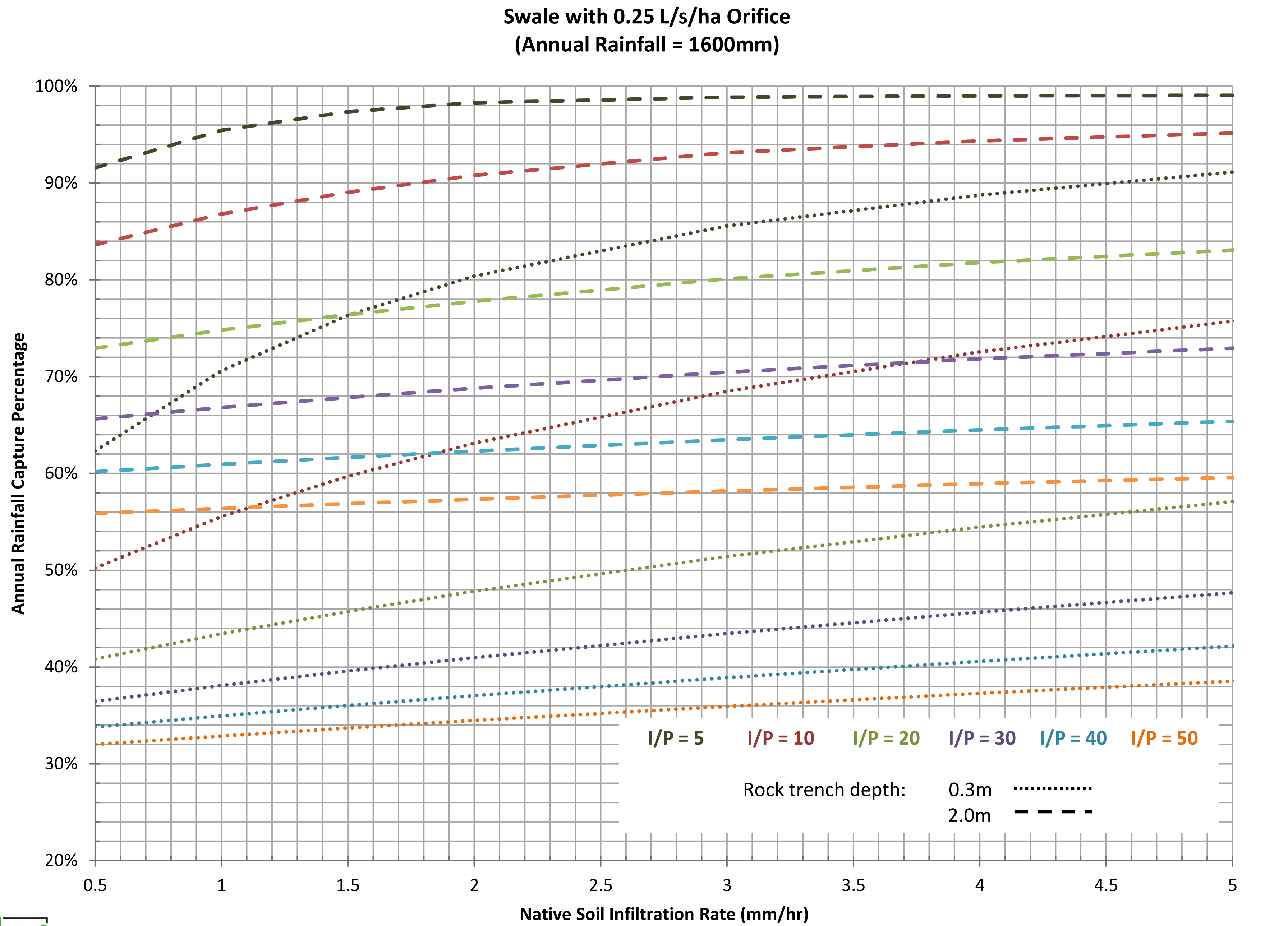

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ALT FIGURE B-8

C:\Users\LMorgan\Desktop\BCWWA2012\252-261_copies\400-Work\Results\SwaleOrifice0.25LshaSummaryGraphs-Kwantlen.xlsx1600-band

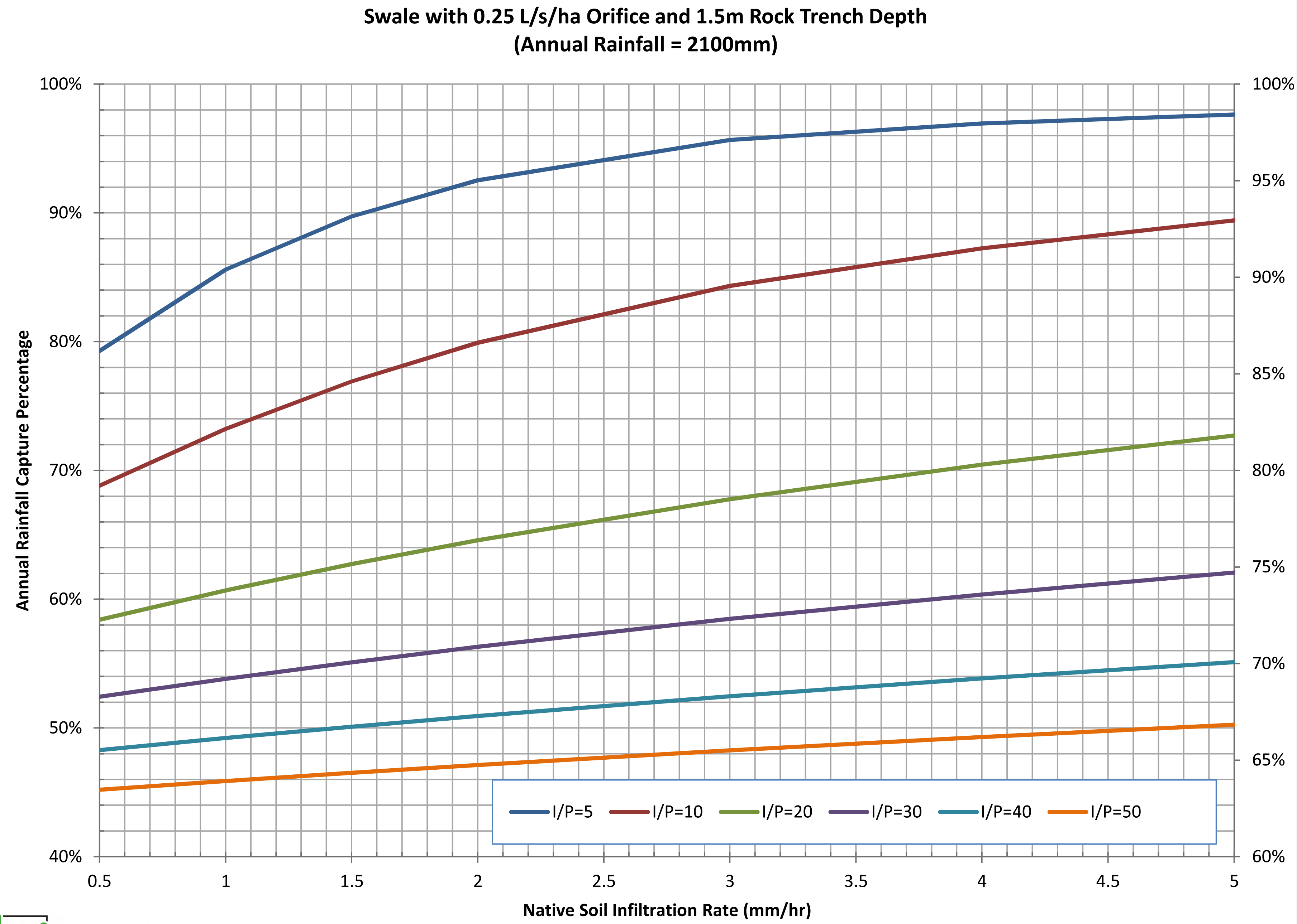

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FIGURE B-9

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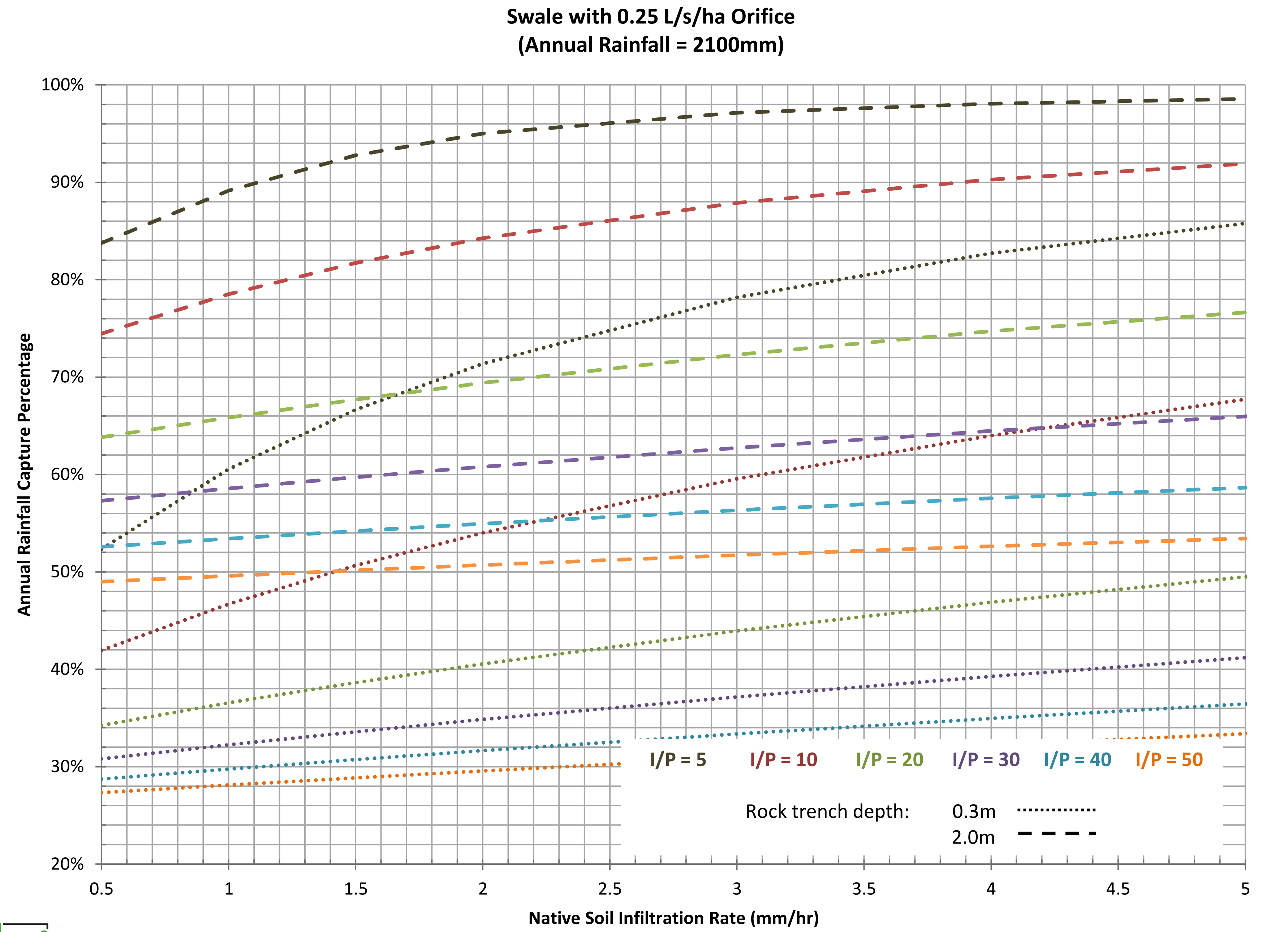

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ALT FIGURE B-9

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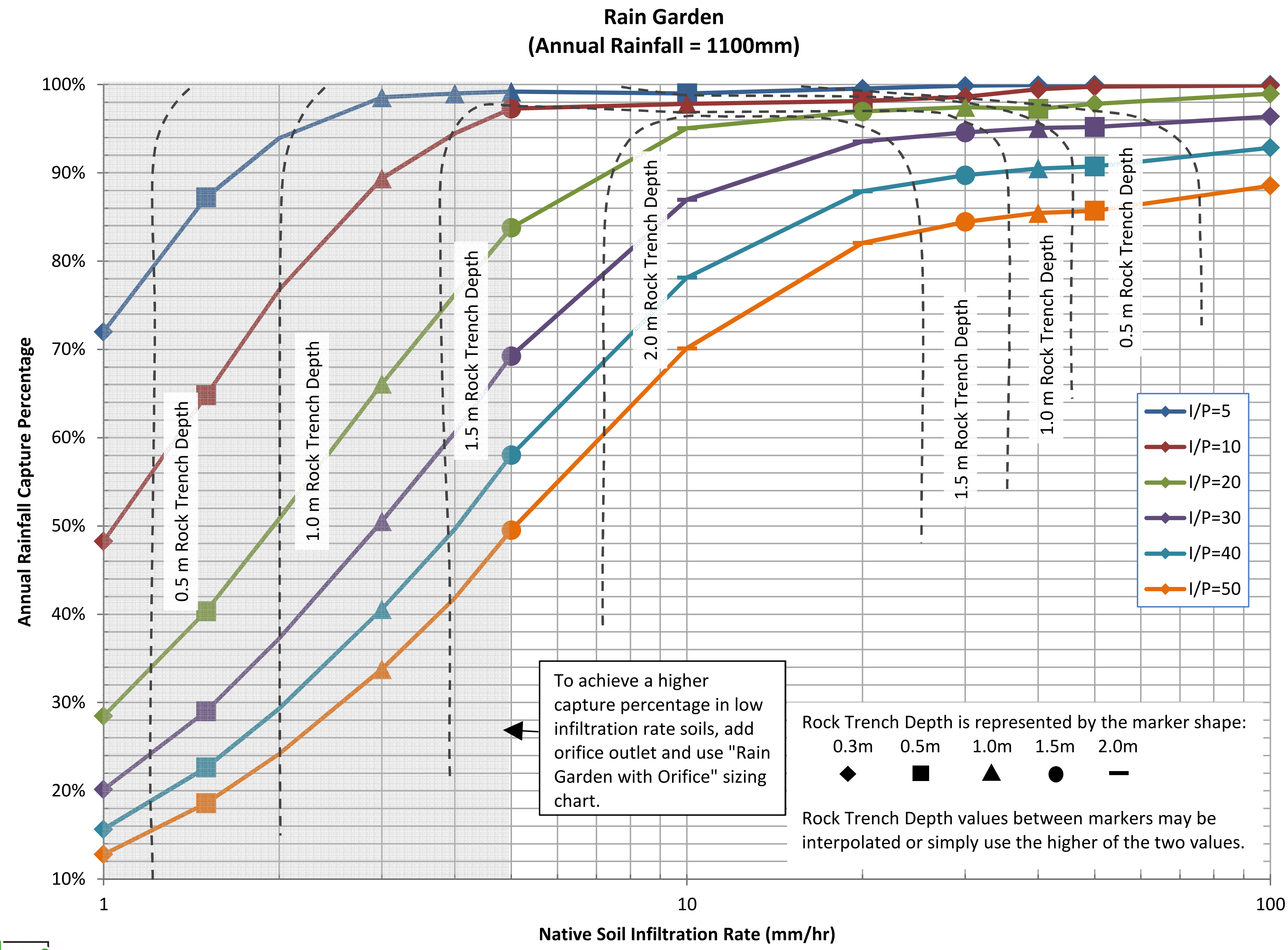

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FIGURE B-10

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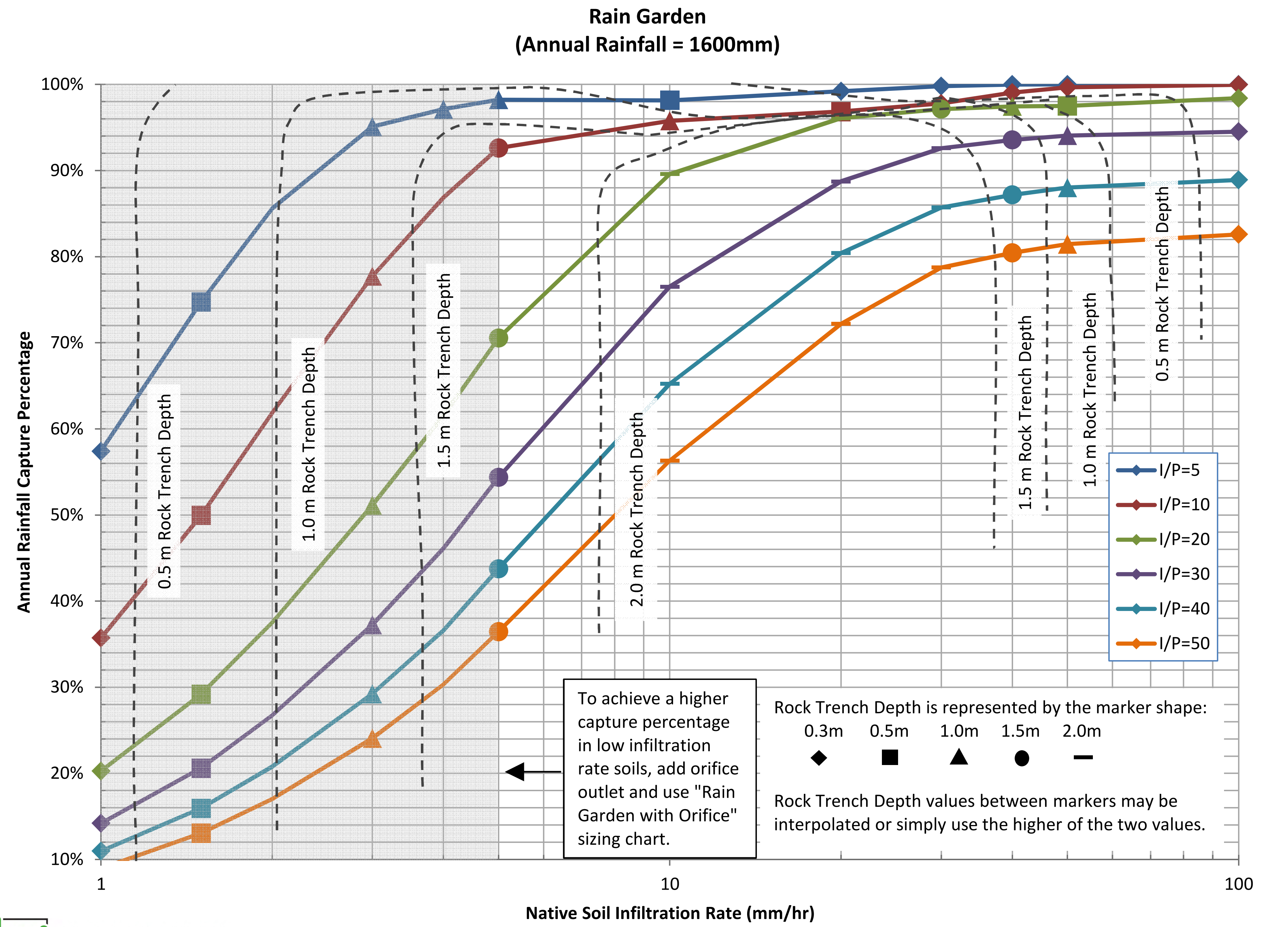

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FIGURE B-11

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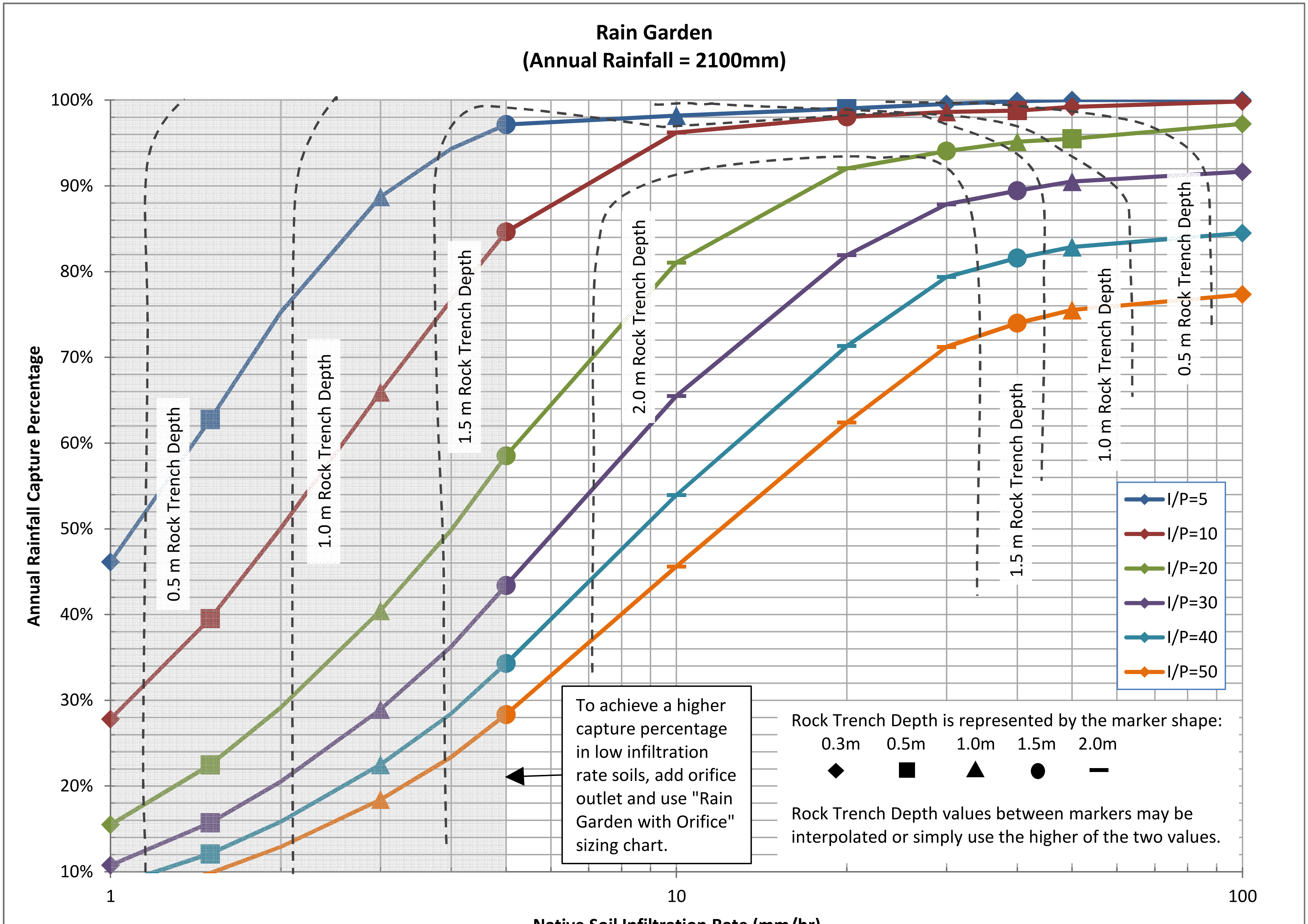

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FIGURE B-12

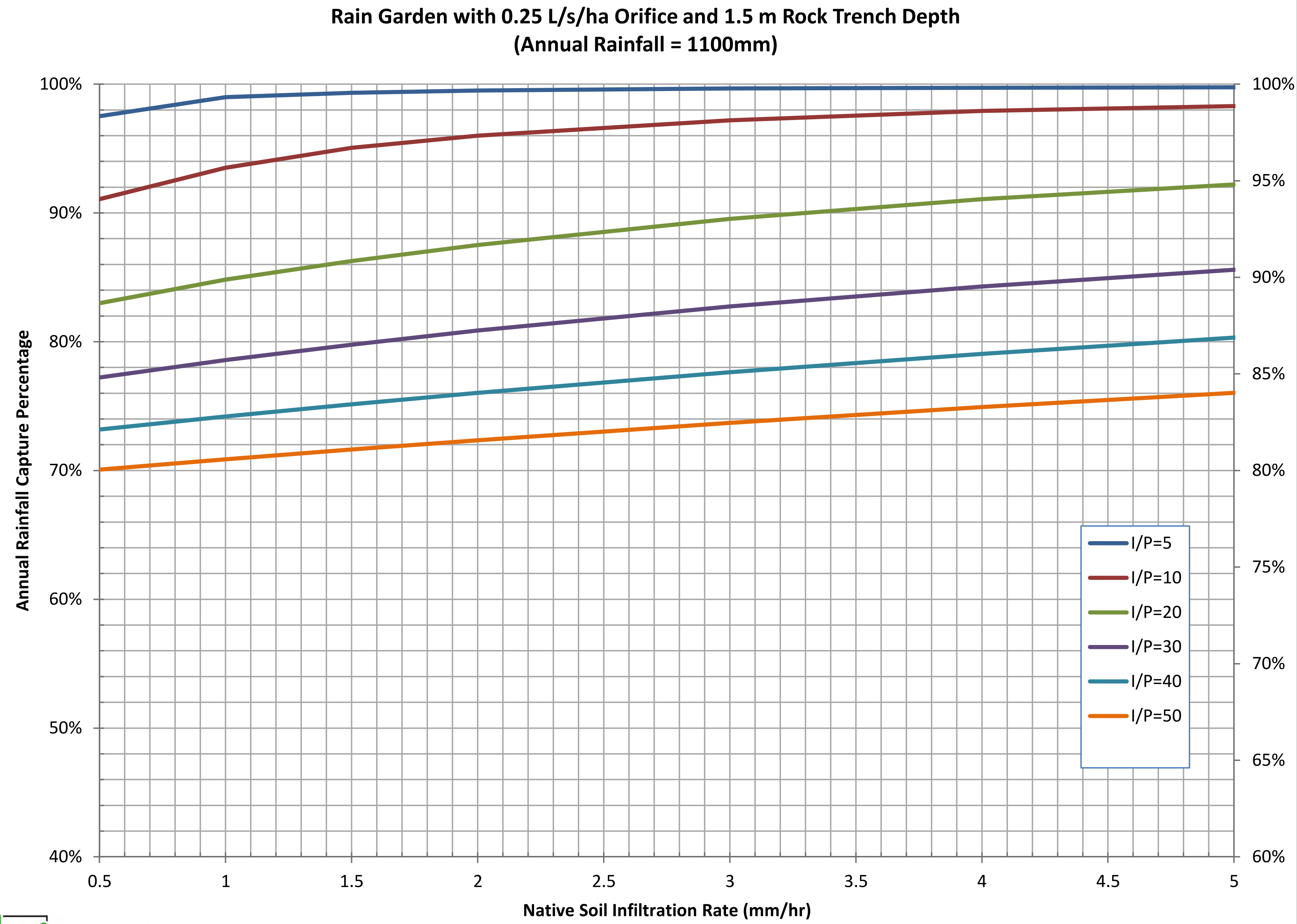

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FIGURE B-13

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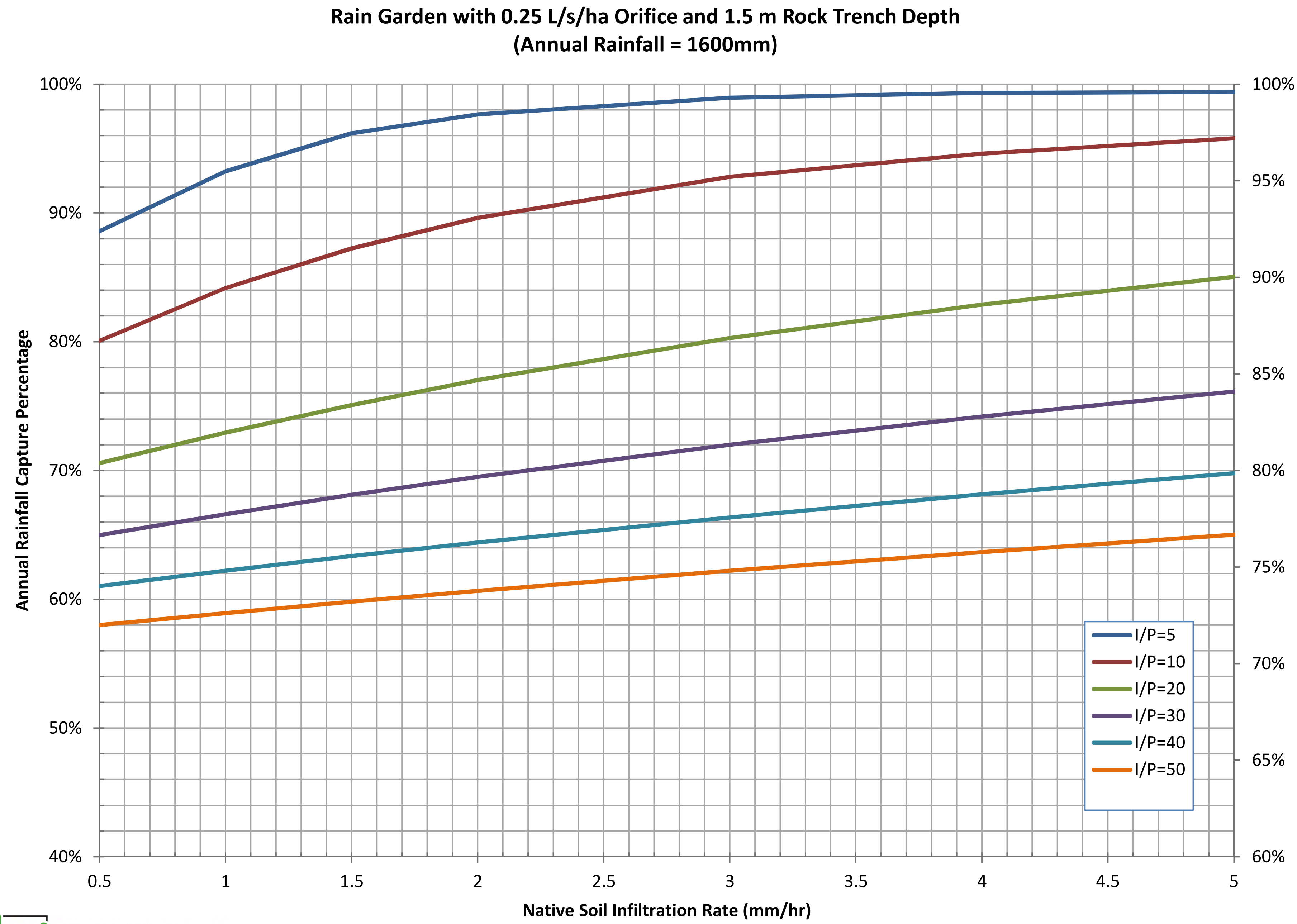

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FIGURE B-14

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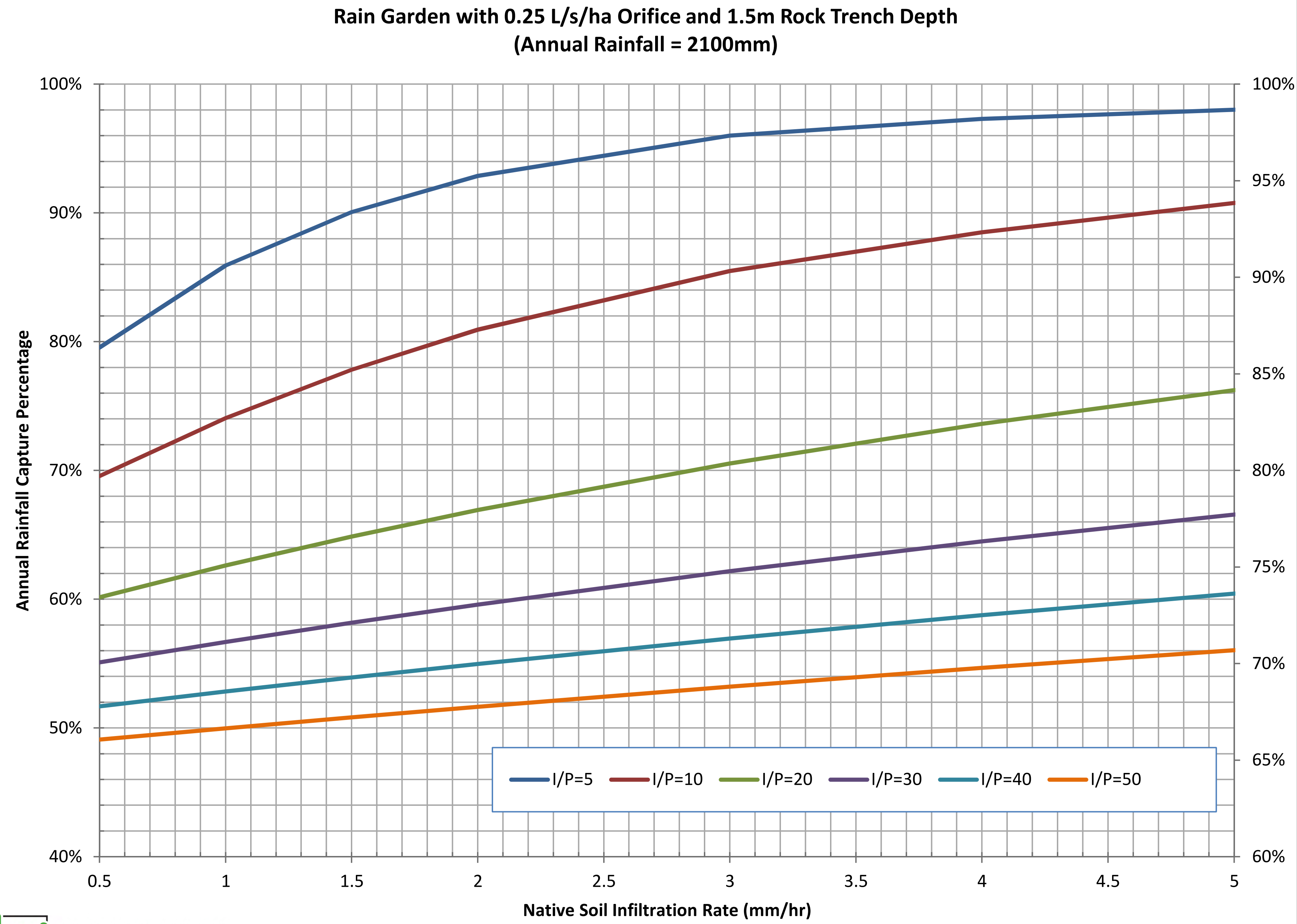

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FIGURE B-15

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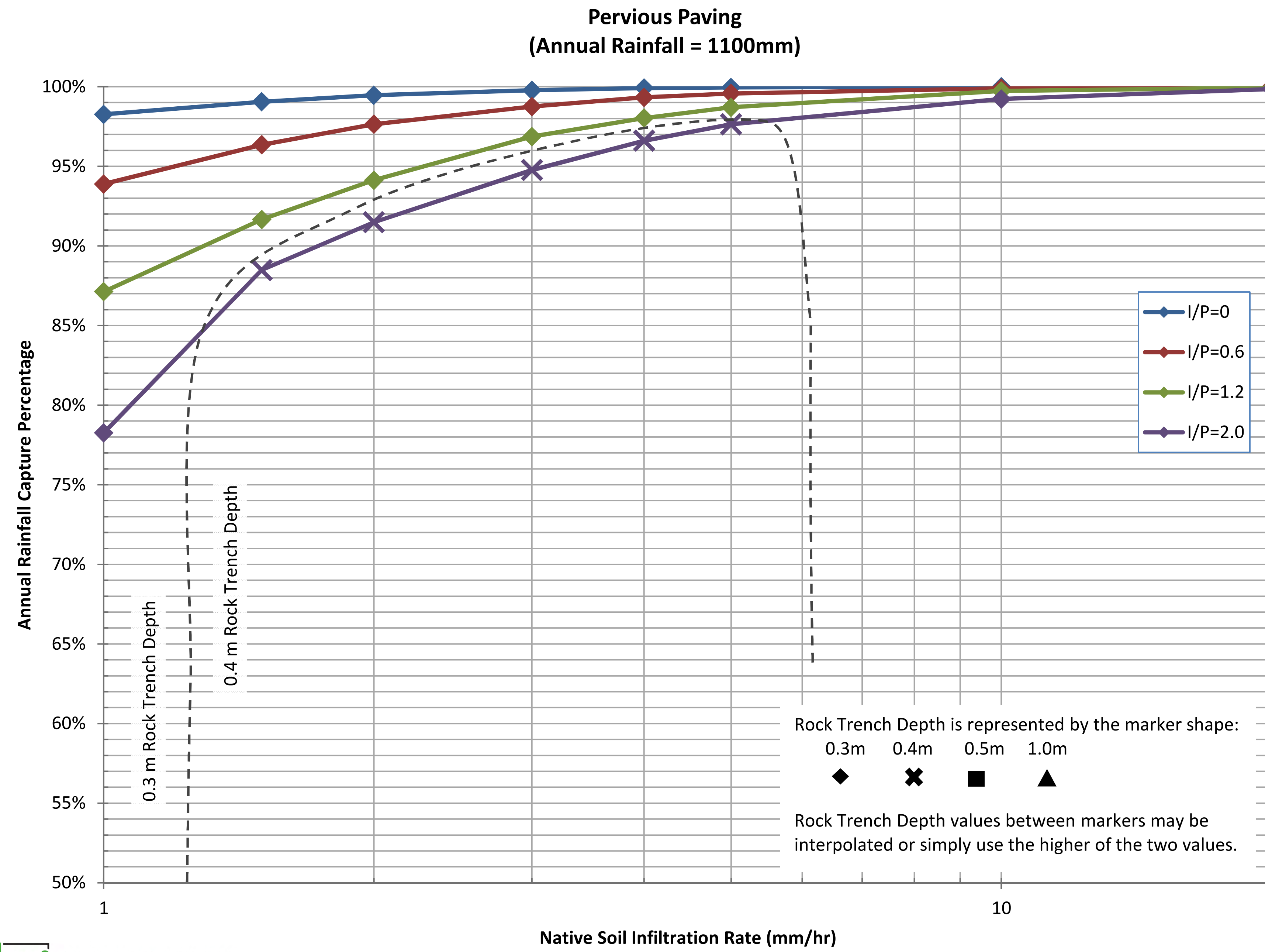

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FIGURE B-16

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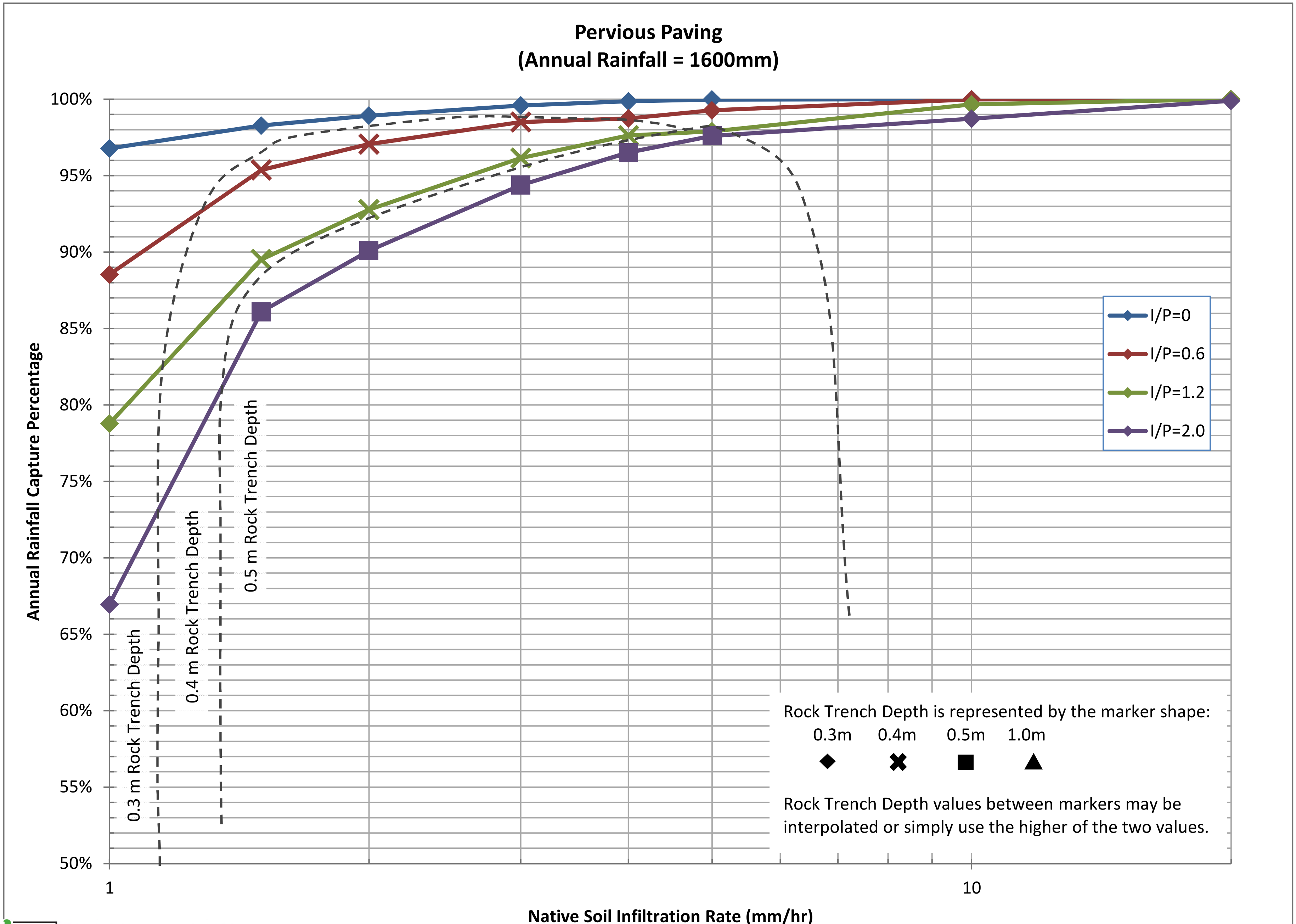

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FIGURE B-17

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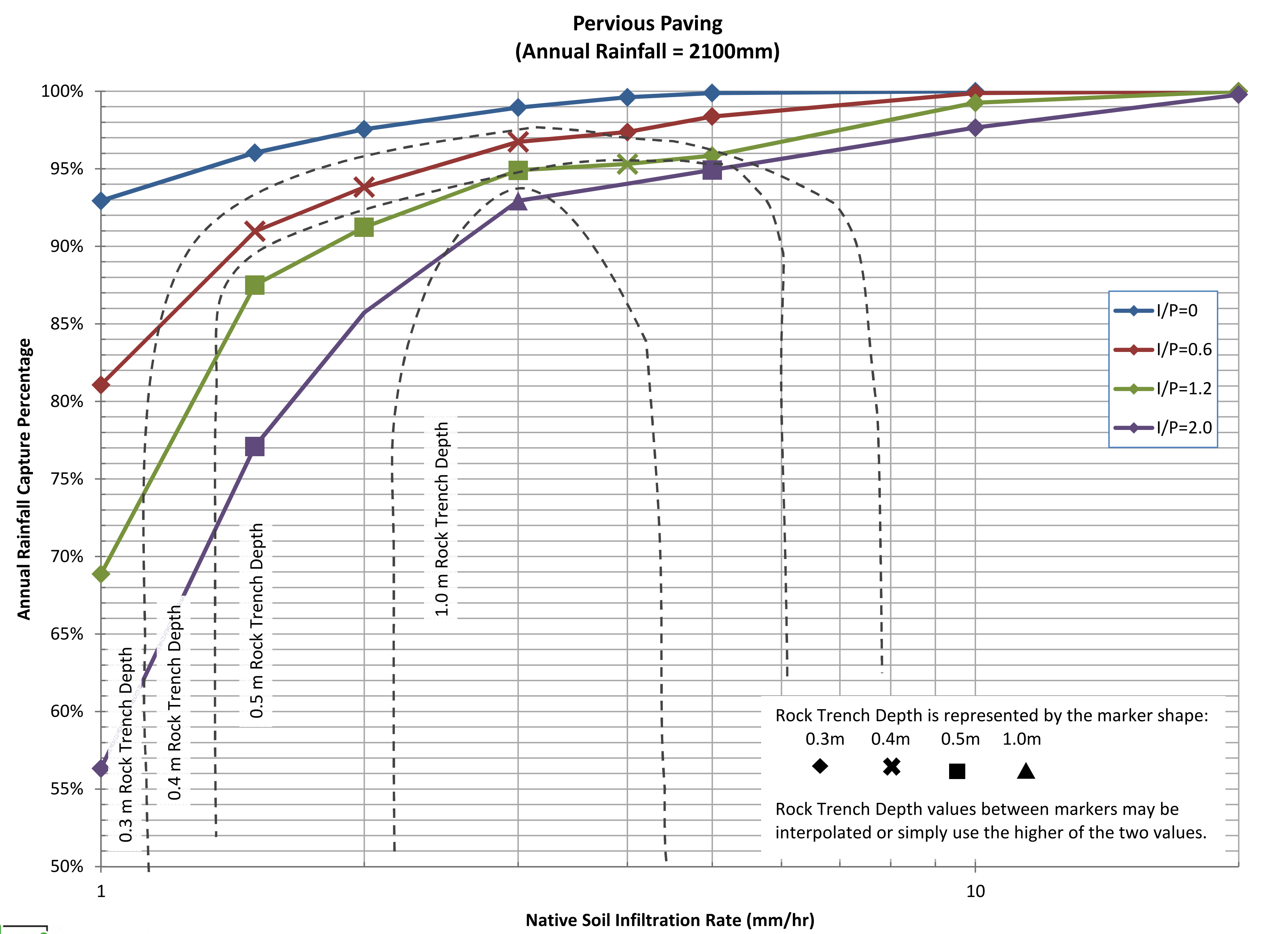

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FIGURE B-18

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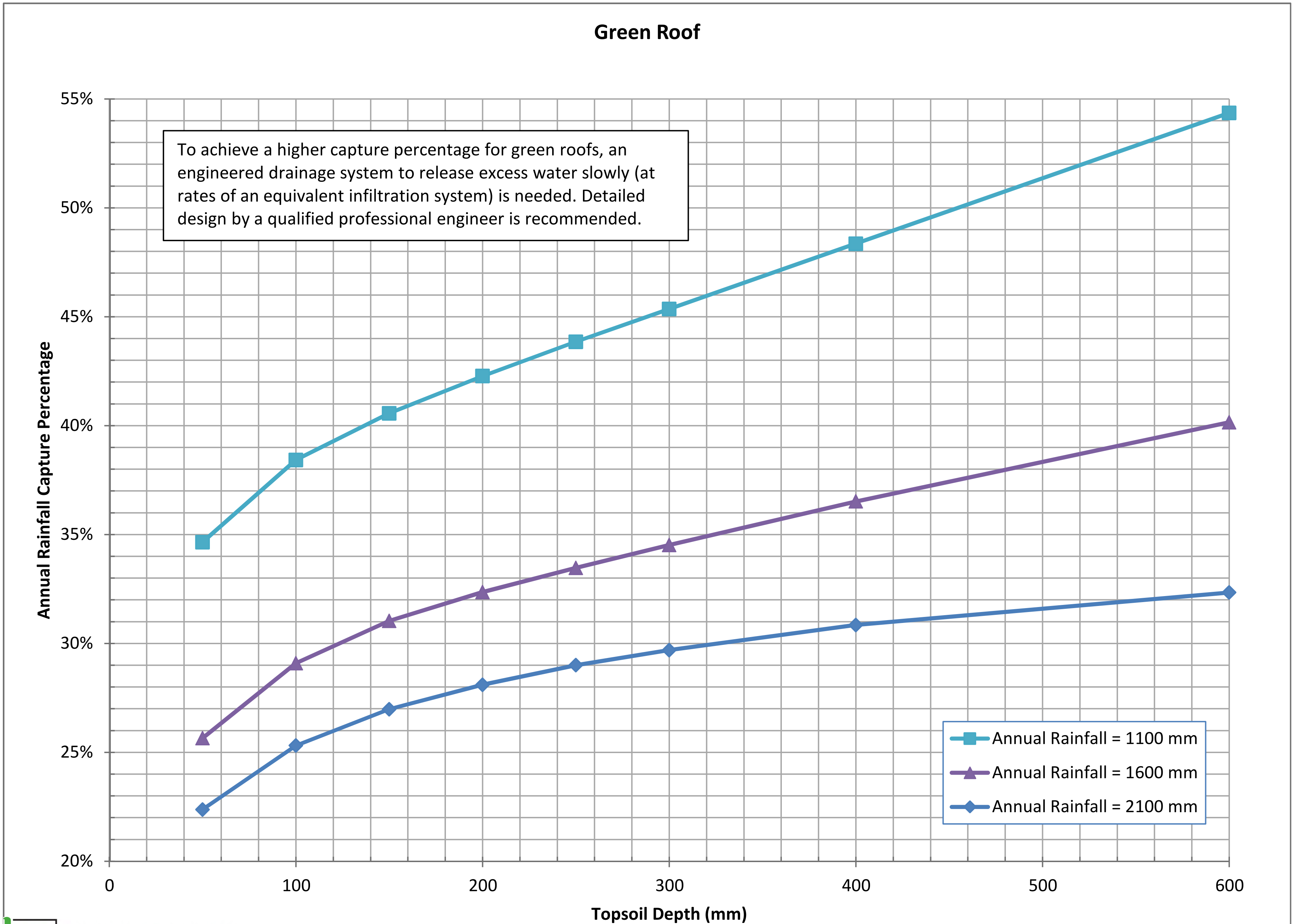

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FIGURE B-19

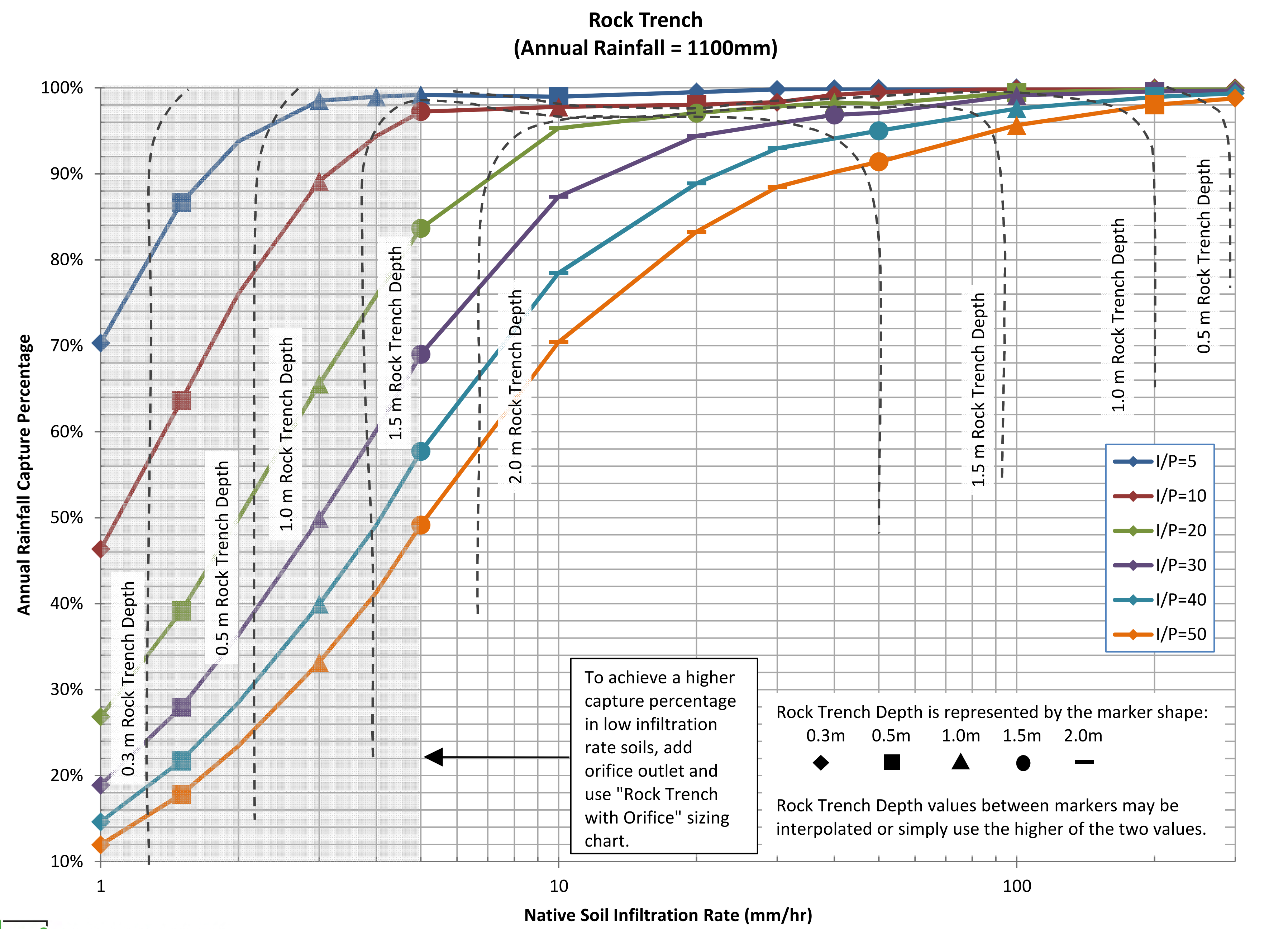

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FIGURE B-20

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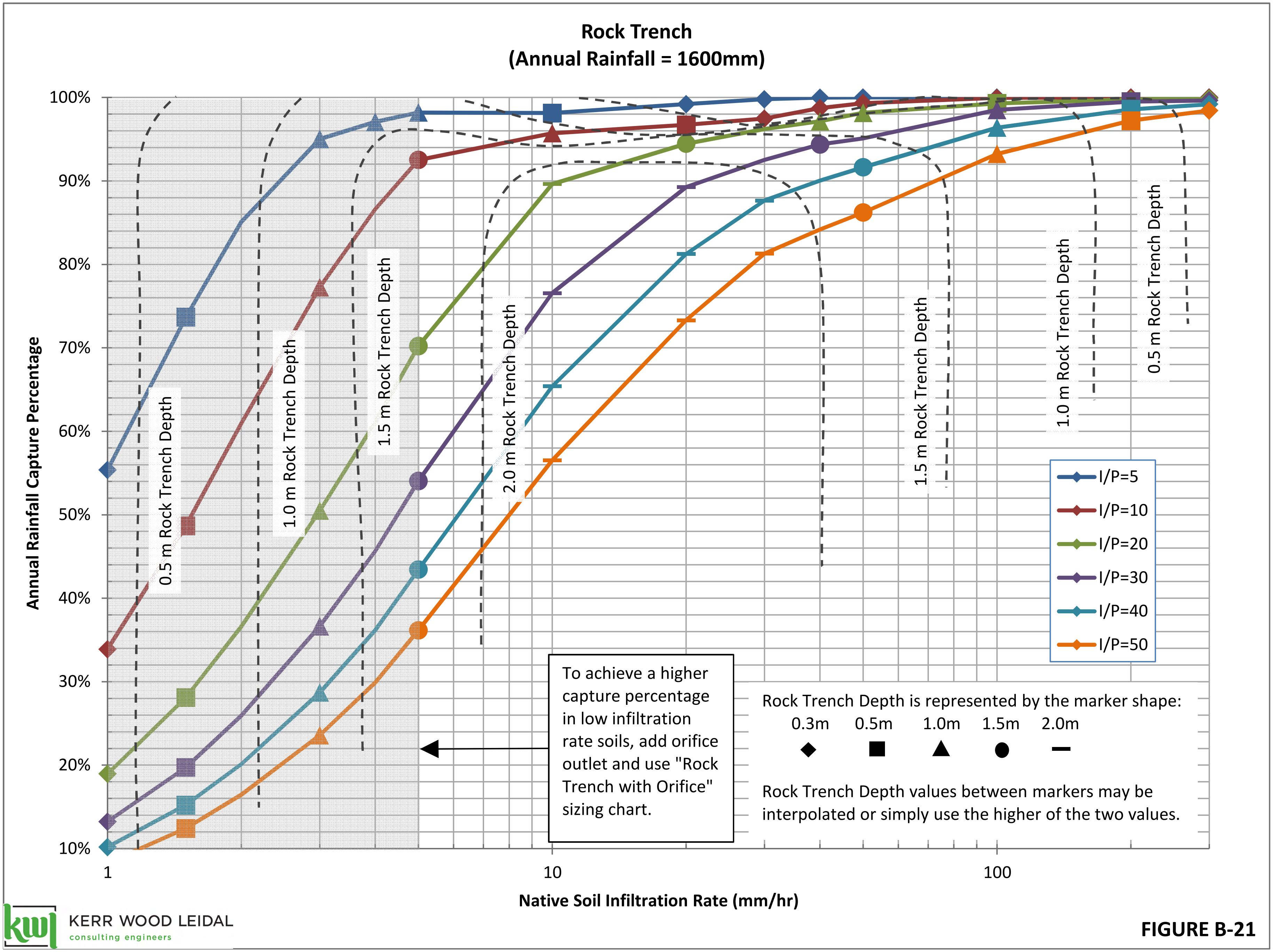

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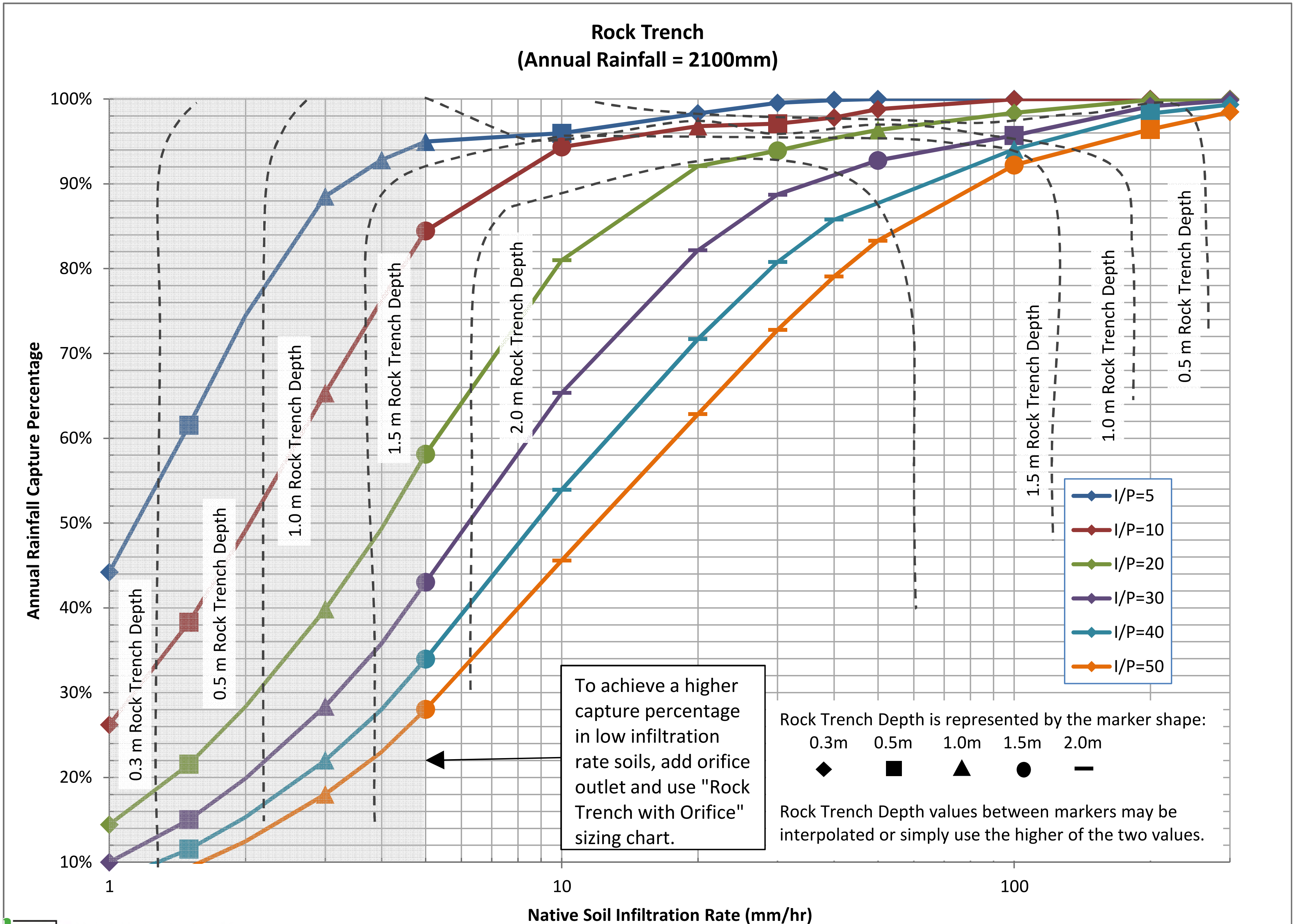

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FIGURE B-22

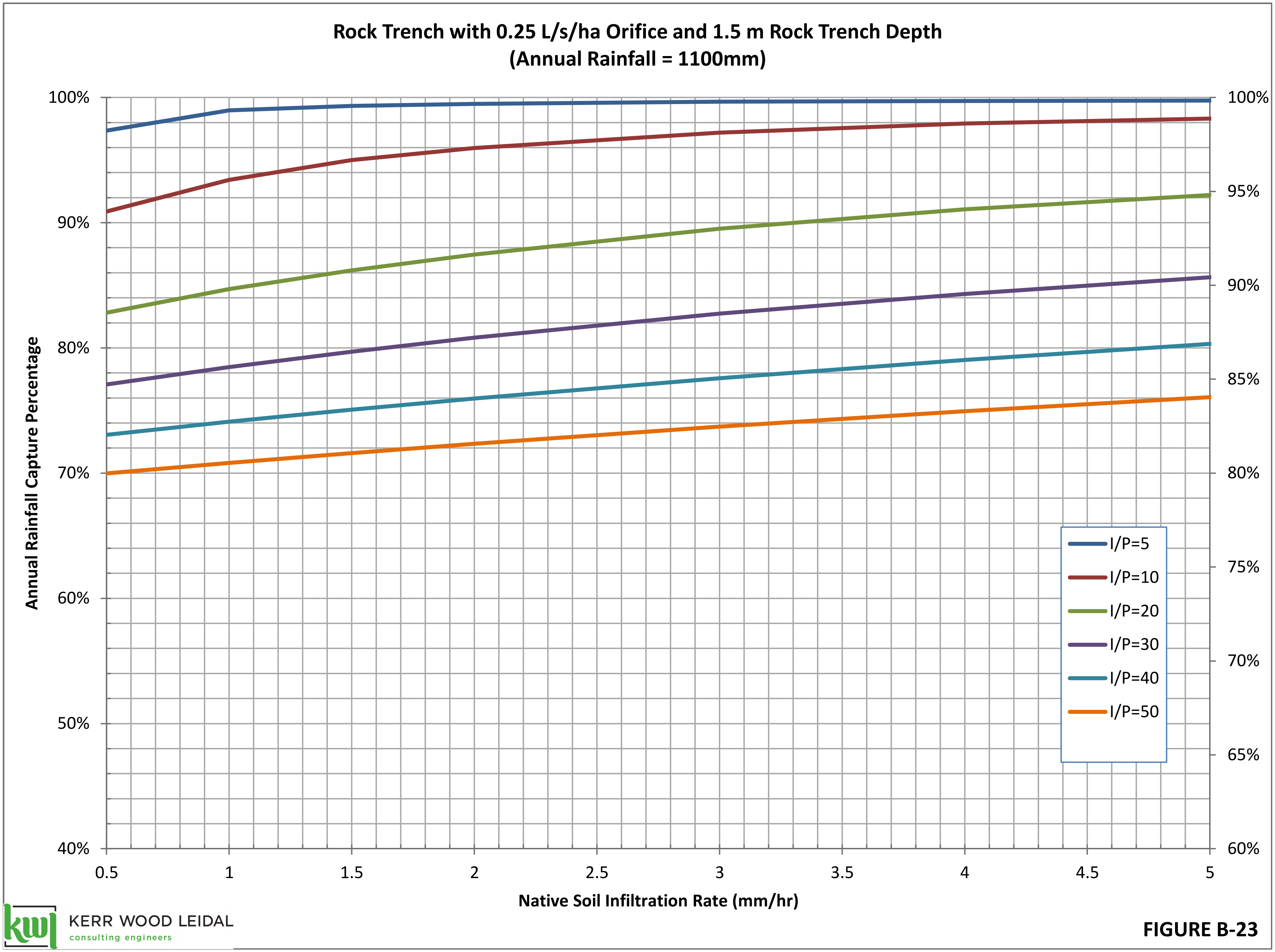

FIGURE B-23

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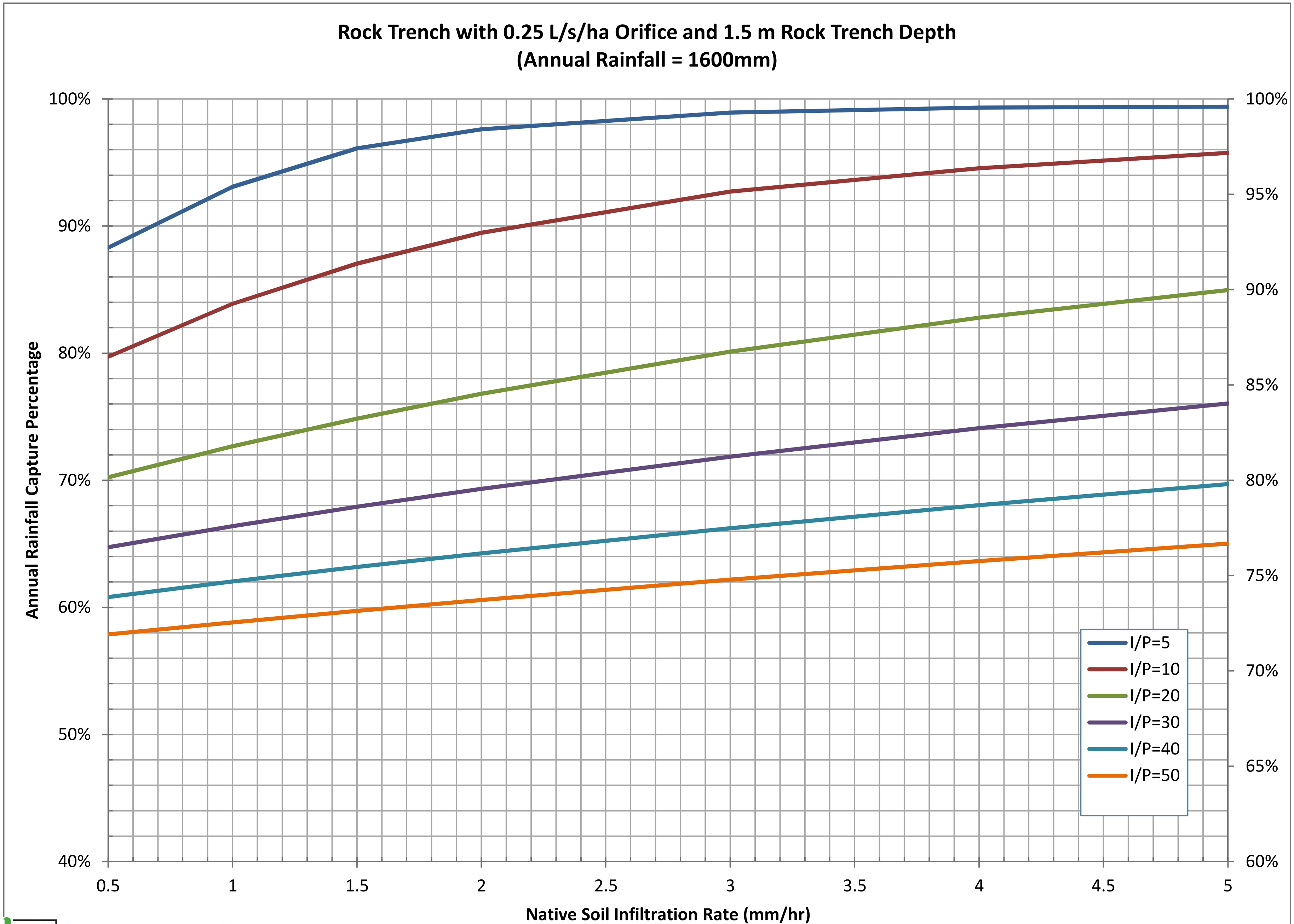

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FIGURE B-24

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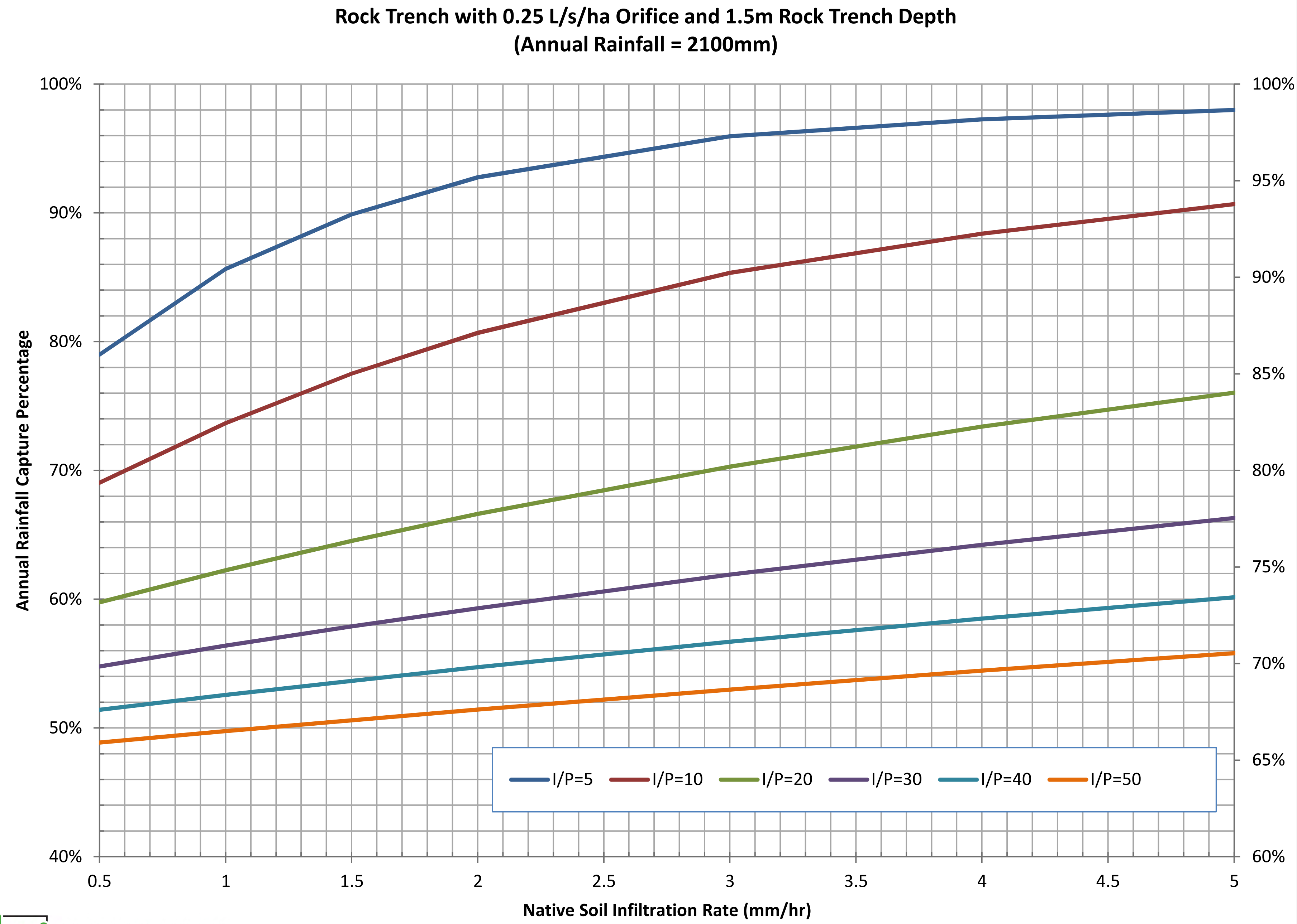

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FIGURE B-25

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