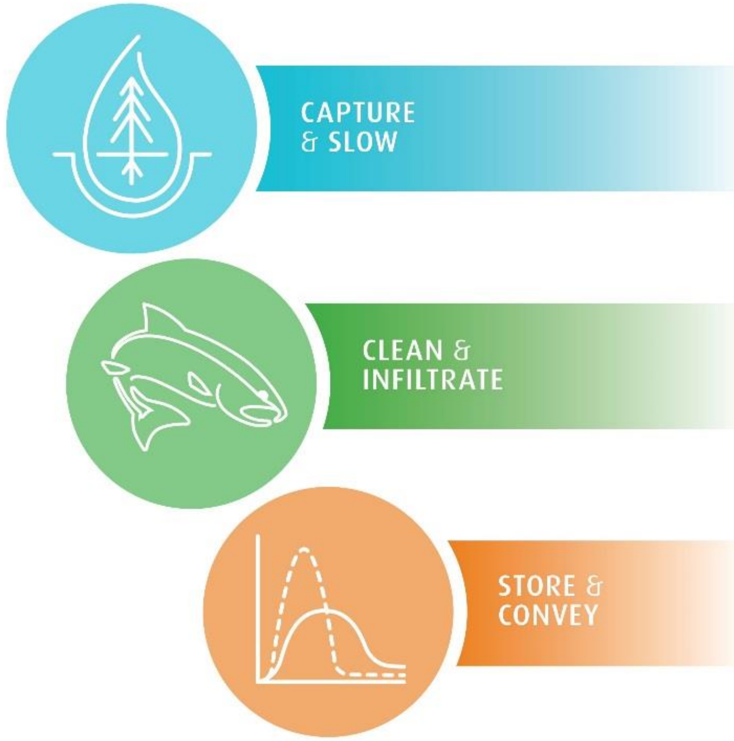


Appendix D – Rain Garden

Green Stormwater Infrastructure Design Guidelines for the Capital Region

SPRING 2019

Bioretention Rain Garden[1]

Description

The rain garden (bioretention basin or cell) is a form of bioretention that can be fully infiltrating or partial infiltrating (with underdrain). Typically, Bioretention Rain Gardens are designed as a concave landscaped area that collects, absorbs and filters stormwater runoff from roofs or paved surfaces. The stormwater is allowed to pond temporarily while infiltrating into soils below and include an adequate overflow connection to the storm drain network. Bioretention systems include the use of a specially formulated Bioretention Soil Mix (BSM) to treat the stormwater. Where infiltration is not advised or desired, flat bottomed above or below grade Flow-Through-Planters may be an option (see Appendix F Infiltration & Flow-Through Planters).

Figure 1 Rain garden on Camden Avenue, View Royal. Photo Credit: Town of View Royal

Bioretention is the process in which contaminants and sedimentation are removed from stormwater runoff. 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.

Figure 2 Rain garden on right-of-way, University of Victoria, Saanich

[1] **Adapted with permission from Metro Vancouver.**
Original document: Metro Vancouver's Stormwater Source Control Design Guidelines 2012, primary author Kerr Wood Leidal Associates Ltd. with Lanarc Consultants Ltd and Goya Ngan, http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/StormwaterSourceControlDesignGuidelines2012StormwaterSourceControlDesignGuidelines2012.pdf
Adaptations authored by: Opus International Consultants (Canada) Limited
Design guidelines drawings by: Kerr Wood Leidal Associates Ltd and/or as noted in figures.

Rain gardens generally have a drain rock reservoir and perforated drain system to collect excess water. 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.

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 (see Appendix C Grassy & Vegetated Swales). Other new designs of rain gardens include planter style flat bottomed raingardens (see Appendix F Infiltration & Flow-Through Planters or appendix E Infiltration Curb Extensions & Traffic Islands).

Figure 3 Sunken planter style, flat bottom rain garden in commercial area parking lot, Saanich

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.
- Where the native soils have low infiltration rates, underdrain systems can be installed and the facility used to filter pollutants and detain flows that exceed infiltration capacity of the surrounding soil. However, designs utilizing underdrains provide less flow control benefits and may increase nutrient loading to nearby waterbodies.
- An impervious liner can be used to limit the risk of groundwater contamination in areas with high water tables, industrial areas or ultra-urban hotspots.
- 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 of 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.

Design Guidelines

1. Detailed design requirements should be evaluated for each individual application based on site-specific constraints and objectives. Pre-treatment may be advised.
2. Follow all applicable federal, provincial and municipal regulations.
3. Geo-technical investigations are recommended with soil permeability testing being the minimum requirement for design. Advice from a qualified professional (i.e., professional engineer, landscape architect) for design is recommended.

Figure 4 Inlet type for rain garden with no dissipater

4. Site rain gardens similar to other infiltration facilities – minimum 30 m from wells, minimum 3 m downslope of building foundations, and only in areas where foundations have footing drains. See Table 1 for more details.
5. 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.
6. 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.
7. Flow may be pre-treated to remove sediment by travelling through a grassy swale prior to entering the rain garden (500 mm minimum, greater than 3,000 mm desirable swale length.)

Figure 5 Stormwater inlet to rain garden, Saanich

8. Experience has shown that grass is efficient at trapping sediment at a pavement edge and the sediment and grass matt will aggrade rapidly. In addition to the 50 mm drop (see Item 5, 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.

9. Rain garden bottom or base area: flat cross section, with a longitudinal slope of 2% maximum (or 1% by US001, or dished by GE004).

10. Rain garden base area dimensions: bottom width 600 mm minimum, 3,000 mm is desirable.

Figure 6 Rain garden with beehive grate, Saanich

11. Provide a 50 mm–75 mm layer of non-floating organic aged mulch – well-aged compost, bark mulch or similar weed-free and manure-free material. The mulch is important for both erosion control and maintaining infiltration capacity.

12. 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.

13. Maximum ponded level: 150 mm to 300 mm. 200 mm maximum pond level is common and assumed for the simplified sizing approaches here.

14. For roadside applications, rock reservoir depth should generally not exceed the depth of the surrounding utilities.

15. Drawdown time for the maximum surface ponded volume: 48 hours preferred (72 hours max).

16. A non-erodible outlet or spillway must be established to discharge overflow to the storm sewer system. Use a beehive-type grate.

17. Rain garden depth includes ponding depth (depth to overflow level), an additional surcharge allowance (100 mm is common) to prevent overflow to the roadway or surrounding area, and sediment accumulation allowance (may be 3 mm/year or more depending on loading). Rain garden depth = ponding depth + surcharge allowance + sediment accumulation allowance.

18. 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. Flat bottom planter style rain gardens may also be considered.

19. Bioretention Soil Medium (BSM) (see details in Tables 3a and b) (i.e., treatment soil, growing media) depth: 450 mm minimum for most applications without an under-drain. BSM should have a minimum infiltration rate (lab tested) of 70 mm/hr, which is assumed in the sizing approaches in this document. BSM must be well-aged organics, weed free, preferably manure free and biosolid free.

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

21. 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.

22. 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).

23. A perforated pipe subdrain is required to drain excess water from the soil and prevent root drowning of rain garden plantings. 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.

24. 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), as measured during winter saturated soil conditions
    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).

25. Refer to Figure 12 for curbing, inlet and flow dissipator detail options.

26. See Table 1 for setbacks for rain gardens.

Table 1 Rain Garden/ Bioretention Basin/Cell Setbacks

Consideration for Setbacks From	*Distance (m)
Up-gradient of building foundations	3
Property Line	Site dependent
Drinking Water Well	30
Up-gradient of septic field	3
Seasonal High Water Table	1
Up-gradient Active of inactive landfill or contaminated site	30
Existing trees	Outside root protection zone
Up-gradient of steep (> 15%) slope	30

Note: *or as directed by a Qualified Professional

Rain Garden Sizing

In this guide, a simplified sizing approach has been developed that does not require water balance modelling or continuous simulation.

1. 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. The I/P ratio to achieve the target capture criteria will be calculated by the sizing method below.
2. The maximum allowable I/P ratio for given surface types is shown in Table 2. 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.
3. The sizing process provides the base area of the rain garden, which is the flat area at the bottom with uniform layers of mulch, topsoil and drain rock. Sizing by these methods does not account for any infiltration benefit provided by the sloped sides of the rain garden.
4. 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 Item 18 in previous section) in order to understand the actual site area required.
5. Sizing presented here is for infiltration of rainwater 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.

Table 2 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	50:1
Single Family Residential, Lot and Roof	50:1

Sizing Method Using Depth Capture Criteria: R mm in 24 hours

See Appendix A, Table 1 to determine R mm of rain in 24 hrs for area-specific GSI facility rainfall capture targets – confirm with respective municipality.

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 2,000 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), as measured during winter saturated soil conditions
   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 2). 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 Item 18 in previous section.

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.

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 subdrain.

8. 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)

9. This discharge is used to size the orifice on a flow restrictor at the downstream end of the rain garden subdrain.

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 layer (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 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 2.

11. 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:

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

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

Guideline Specifications

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

1. Infiltration Drain Rock: clean round stone or crushed rock, with a porosity of 35% to 40% such as 75 mm max., 38 mm min, 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: Bioretention Soil Media (i.e., growing media): As per Tables 3a and 3b Bioretention Soil Medium but with required minimum saturated hydraulic conductivity of 70 mm/hr.
6. Seeding: conform to Section 32 92 20 Seeding or 32 92 19 Hydraulic Seeding. (Note: seeding will be required for erosion control in most instances).
7. Sodding: conform to MMCD Section 31 92 23 Sodding. (Note: sodding will be required for erosion control in most instances).
8. Planting: see Supplemental 1, Planting Templates & Plant Lists.

Construction Practices shall meet Master Municipal Construction Document 2009 (MMCD) 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 300 mm of material over the final subgrade of the rain garden until after all sediment-producing construction in the drainage area has been completed.
2. Prevent natural or fill soils from intermixing with the infiltration drain rock. All contaminated stone aggregate must be removed and replaced.

3. Infiltration drain rock shall be installed in 300 mm lifts and compacted to eliminate voids between the geotextile and surrounding soils.
4. Maintain grass areas to mowed height between 50 mm and 150 mm, but not below the design water quality flow level. Landscape Maintenance standards shall be to the Canadian Landscape Standard, 1st Edition, Maintenance Level 4: Open Space / Play.

Bioretention Soil Medium

Composition of Bioretention Soil Medium (BSM) is an important factor in the performance of GSI facilities. Soil mixes for bioretention and vegetated infiltration facilities need to balance 3 primary design objectives for optimum performance:

- ✓ High enough infiltration rates to meet desired surface water drawdown and system dewatering.
- ✓ A growth media to support long term plant and soil health and water quality treatment capability.
- ✓ Infiltration rates that are not too high in order to optimize pollutant removal capability.

For the latest information on bioretention soil research see the Washington Stormwater Center's webpage on Bioretention http://www.wastormwatercenter.org/lid-bioretention/. Below are 2 local BSM suggested mixes.

Table 3.a Rain Garden Bioretention Soil Mediums Mix 1[2]

Rain Garden
Bioretention Soil Medium (BSM) Mix 1
Recommended depth: minimum of 450 mm
Minimum required saturated hydraulic conductivity of 70 mm/hr.

Component (partial size classes)	Percentage by Weight
Gravel (greater than 2.5 mm)	0
Sand (greater than 0.05 mm and less than 2.5 mm) • Sand to be hard, granular sharp sand well washed and free of impurities, chemicals or organic matter; and • Particle size in sand to be: a) 90-100% passing a 2.50 mm sieve, b) 0-65% passing a 0.500 mm sieve, c) 0-5% passing a 0.0500 mm sieve	70-80
Silt (greater than 0.002 mm and less than 0.05 mm)	5-15
Clay (less than 0.002 mm)	2-5
Organic Content (%dry weight) • must be well aged organics, weed free, preferably manure free and biosolid free.	10-15
Other Soil Considerations	
• **pH** of mixed materials between 6-8.5 • **Phosphorus (P) and Nitrogen (N) Management Recommendations**: In some cases, bioretention facilities have the potential to export P and N at a higher rate than contained in the storm water they are receiving. See Low Impact Development Technical Guidance Manual for Puget Sound 2012 (chapter 6.1.2 Bioretention Design) for nutrient management suggestions. http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf • **Safe Soils:** The spread and proliferation of invasive species through many regions of the province comes from the re-distribution of invasive species laden soils. In 2016, a Soils and Invasive Species Sub-Working Group was developed to explore province-wide solutions regarding the movement of soil and related materials that may contain invasive species. This Sub-Working Group involves provincial and local government representation. Learn more: Provincial Response to the Resolutions of the 2016 Union of British Columbia Municipalities Convention FEBRUARY 2017 B113 SAFE SOILS PROGRAM (page 111) http://www.ubcm.ca/assets/Resolutions~and~Policy/Resolutions/Provincial_Responses-2016_UBCM_Resolutions.pdf	

[2] Source: Rain Gardens, Stormwater Best Management Practices, District of Saanich
http://www.saanich.ca/assets/Community/Documents/Rain%20Garden.pdf

Table 3.b Rain Garden Bioretention Soil Mediums Mix 2[3]

Rain Garden

Bioretention Soil Medium (BSM) Mix 2*

Recommended depth: minimum of 450 mm

Minimum required saturated hydraulic conductivity of 70 mm/hr.

Component (partial size classes)	Percentage by Weight
Coarse Gravel (particles greater than 19 mm and less than 40 mm)	0 to 1
All Gravels (particles greater than 2 mm and less than 40 mm)	10 to 25
Sand, Silt, Clay & Organic components measured from remaining non gravel portion of sample (% dry weight)	
Sand (greater than 0.05 mm and less than 2.5 mm) • Sand to be hard, granular sharp sand well washed and free of impurities, chemicals or organic matter. • Note: Growing medium/BSM to be manufactured with '2 mm minus' sand to reduce gravel content in the soil. 2 mm minus sand is available from most local quarries upon request.	60-70
Combined Silt and Clays (less than 0.05 mm)	10-20
Organics (% dry weight) • must be well aged organics, weed free, preferably manure free and biosolid free.	15-20
Other Soil Considerations	
• **pH** of mixed materials between 6-8.5 • **Phosphorus (P) and Nitrogen (N) Management Recommendations**: In some cases, bioretention facilities have the potential to export P and N at a higher rate than contained in the storm water they are receiving. See Low Impact Development Technical Guidance Manual for Puget Sound 2012 (chapter 6.1.2 Bioretention Design) for nutrient management suggestions. http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf • **Safe Soils:** The spread and proliferation of invasive species through many regions of the province comes from the re-distribution of invasive species laden soils. In 2016, a Soils and Invasive Species Sub-Working Group was developed to explore province-wide solutions regarding the movement of soil and related materials that may contain invasive species. This Sub-Working Group involves provincial and local government representation. Learn more: Provincial Response to the Resolutions of the 2016 Union of British Columbia Municipalities Convention FEBRUARY 2017, page 111 for B113 SAFE SOILS PROGRAM. http://www.ubcm.ca/assets/Resolutions~and~Policy/Resolutions/Provincial_Responses-2016_UBCM_Resolutions.pdf	

[3] Source: City of Victoria, Rainwater Management Standards – Professional Edition (June 2015) http://www.victoria.ca/assets/Departments/Engineering~Public~Works/Documents/SWVictoria_Professional_Rainwater_Mgmt_Stds_June2015.pdf

Rain Garden Design Example for Capture of R mm/24-hour Criteria

Scenario Description

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

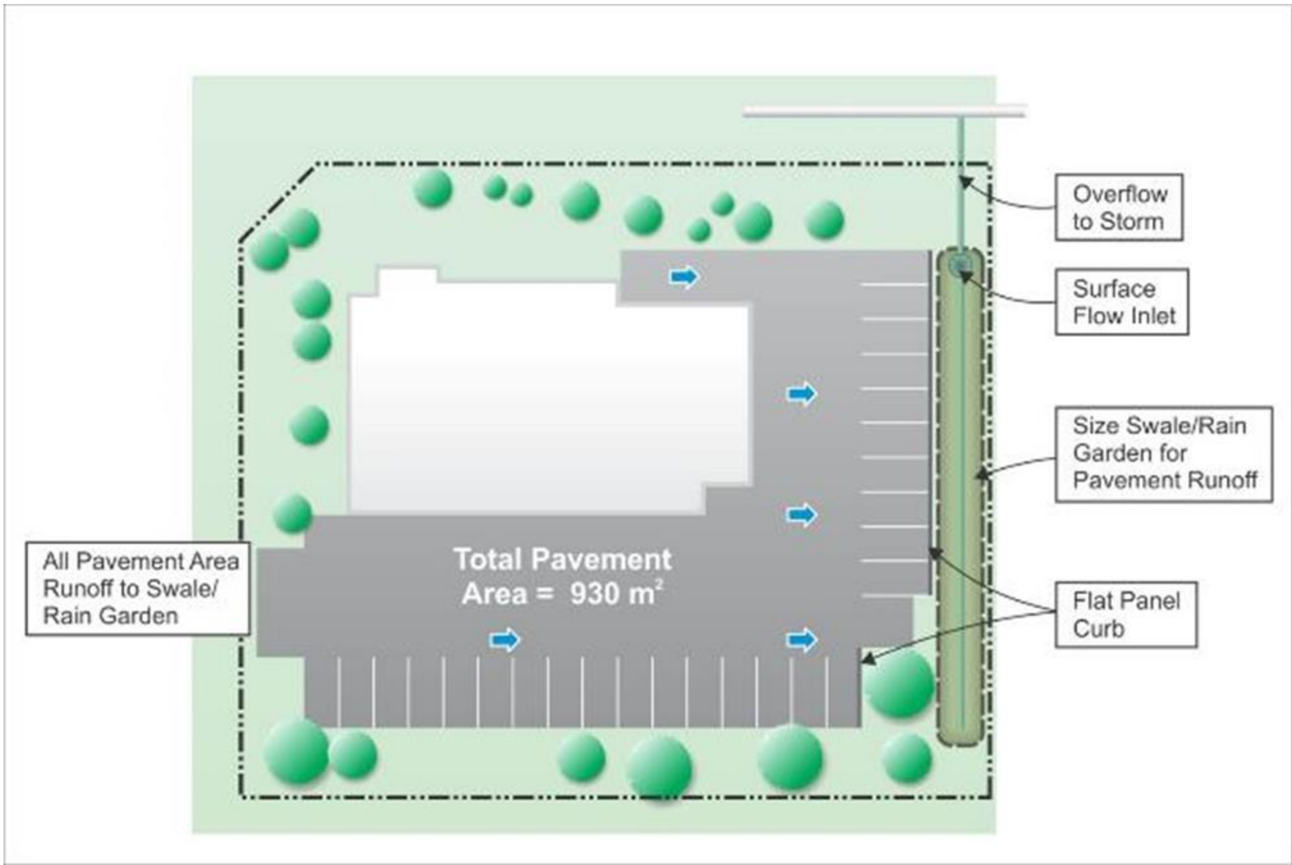


Figure 7 Example – Parking Area Draining to Rain Garden

The following parameters are known:

- Total pavement area = 930 m^2
- Annual rainfall = 1,200 mm
- 2-year 24-hour rain depth = 53 mm
- Native soil infiltration rate = 1.5 mm/hr
- Parking use is more than 1 car per day
- Capture target is 50% of 2-year 24-hour rain amount = 38 mm

Determine the rain garden footprint area and rock trench depth.

Sizing

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

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

Use 400 mm rock depth.

Determine the maximum I/P ratio (see Table 2). Parking use of more than 1 car per day yields a maximum I/P ratio of 20.

Determine the base (bottom) area of rain garden and rock reservoir required by calculating the required I/P ratio:

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

$$I/P = \frac{24 \times 1.5mm/hr + 200mm + 400mm \times 0.35 + 0.2 \times 450mm}{38mm} - 1$$

$$I/P = 11.3$$

Check that the I/P ratio (Table 2) is less than the maximum (11.3 < 20, therefore OK).

Calculate the rain garden base area:

$$BaseArea = \frac{imperviousTributaryArea}{I/P} = \frac{930\,sq.m}{11.3} = 82\,sq.m$$

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 200 mm. 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 layer is full of water.

Example Operation and Maintenance

- 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.

GSI Driver Effectiveness – Runoff Reduction and Contaminant Removal

International Stormwater BMP Database http://www.bmpdatabase.org/ is a recommended resource for performance summaries of GSI facilities and latest research.

Bioretention areas function as soil and plant-based devices that can achieve both runoff reduction and pollutant removal. Runoff reduction is achieved through canopy interception, soil infiltration, and evapotranspiration. Pollutant removal is achieved through a variety of physical, biological, and chemical treatment processes. A number of pollutants including trace metals, suspended solids, nutrients, and oil and grease are removed from stormwater by filtering, adsorption, biological uptake, and denitrification within the bioretention cell's mulch and soil media. The pollutant removal efficiency can be increased or decreased based on the design components, underlying soil infiltration capabilities and what pollutants are being targeted for reduction. The following table shows the effectiveness of bioretention facilities for GSI drivers, including contaminant removal and stormwater runoff reduction.

Table 4 Runoff Reduction and Contaminant Removal

Bioretention and Vegetated Infiltration GSI Facilities (rain gardens, swales, planters, curb extensions)	
GSI Driver	***Estimated Effectiveness or typical % Reduction or Removal**
Capture & Slow – Volume Runoff Reduction	85% without underdrain 45% with underdrain low with liner and underdrain
Store & Convey- Rate Control Delay Peak	Medium to high without under drain Medium with underdrain Low with liner and underdrain
Clean & Infiltrate – Water Quality Treatment	Highly variable with design, BSM, native soil and depth, plant type. Below are typical results. Research has observed good retention and at times production and export. Export is more likely with an underdrain.
Heavy Metals (Copper, Lead, Zinc)	35 to 90
Oil and Grease	>70% (higher with mulch)
Phosphorus	-70 to >85
Nitrogen	20 to >30
Total Suspended Solids (TSS)	60 to >95
Bacteria (Fecal coliform bacteria or E. coli)	>70

Note: * Performance of individual GSI facilities will vary depending on site-specific contexts and facility design. Negative numbers indicate contaminant loading from the given GSI facility producing a higher export of a given contaminant.

Sources:
http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf
http://www.creditvalleyca.ca/wp-content/uploads/2012/02/lid-swm-guide-chapter4-4.5-bioretention.pdf
http://www.lid-stormwater.net/bio_benefits.htm
https://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
http://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/juanita-retrofit/appendix-d-removal-rates.pdf
http://www.bmpdatabase.org/
https://stormwater.pca.state.mn.us/index.php?title=Information_on_pollutant_removal_by_BMPs

Maintenance

Bioretention areas require annual plant, soil, and mulch layer maintenance to ensure optimal infiltration, storage, and pollutant removal capabilities. The successful establishment of a bioretention area requires a first year inspection and maintenance operation that includes the following tasks:

- Initial inspections after storm events of over 13 mm of rainfall
- Spot reseeding of bare or eroding areas
- Spot fertilization requirements of initial plantings
- Watering once a week during first 2 months and as needed during first growing season
- Remove and replace dead plants to ensure that vegetation is properly established (up to 10% of plant stock may die off in the first year)

After the first year, it is highly recommended that an annual spring maintenance inspection and cleanup be conducted at all bioretention facilities which would include the following:

- Check % cover of mulch plus vegetative cover
- Check for sediment buildup at entrance points
- Check for winter killed vegetation and replace
- Note presence of accumulated sediment
- Check for any erosion
- Check for signs of excessive ponding
- Check for clogged soil media and crust formation

Maintenance of bioretention areas can be divided into routine and non-routine tasks.

Routine Maintenance

Most routine maintenance procedures are typical landscape care activities performed by landowners.

Routine Maintenance for Bioretention Facilities – Rain Gardens and Planters		
ACTIVITY	**OBJECTIVE**	**SCHEDULE**
Watering (by hand or irrigation system)	Maintain a minimum 80% survival rate of plants	Once established (2-3 years), watering may be required during prolonged dry periods or as indicated by plant health.
Debris and trash removal Cleaning entrance points and basin	Maintain proper flow from impervious areas, maintain aesthetics and prevent clogging	Twice annually (October & January)
Inspect for erosion control	Maintain flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred	Twice annually (October & January)
Pruning vegetation and remove dead plants	Maintain plant coverage and health, soil health, and infiltration capability – remove all clippings and dead plant material	Once or twice annually
Weeding (by hand)	Reduce plant competition and maintain aesthetics	Twice annually preceding weed seed disbursement
Mulching – Replace mulch annually or semi-annually with 50-75 mm mulch free of weeds	Replenish organic material, reduce erosion, and maintain soil moisture in bioretention facilities where heavy metal deposition is high (e.g., contributing areas that include gas stations, ports and roads with high traffic loads). In residential settings or other areas where metals or other pollutant loads are not anticipated to be high, replace or add mulch as needed (likely 3 to 5 years) to maintain a 50-75 mm depth.	Annually
Minor sediment removal (with shovel or rake)	Reduce clogging, maintain plant survival, maintain ponding depths	Annually

Non-routine Maintenance

The most common non-routine maintenance problem involves standing water. If water remains on the surface for more than 48 hours after a storm, adjustments or repairs may be needed.

Non-Routine Maintenance for Bioretention Facilities

ACTIVITY	OBJECTIVE	SCHEDULE
Spill clean-up – block under drain temporarily	Stop flow exiting	As needed
Major sediment removal (with shovel, vactor intake structures)	Reduce clogging, maintain plant survival, maintain ponding depths	By inspection and after a major storm event (10-year, 24-hour)
Clean under drains (jet clean or rotary cut roots)	Maintain drainage, ponding depths, and dewatering rates	Determined by inspection
Clean border of pavement and vegetation (trimmer, rake, or shovel)	Maintain proper sheet flow to bioretention area	By inspection
Replace vegetation (reseed/replant)	Maintain dense vegetation to prevent erosion and exclude weeds	By inspection
Replace soil (by hand or small excavator)	Maintain infiltration, soil fertility, and pollutant removal capability	By inspection (visual and infiltration testing)
Rebuild structures (walls, intakes, weirs, etc.)	Maintain proper drainage	By inspection
Re-grade side slopes (by hand or small excavator)	Prevent erosion	By inspection
Full soil removal and replacement	Soil mixes for bioretention facilities are designed to maintain long-term fertility and pollutant processing capability. Regular replacement of mulch media in bioretention facilities where heavy metal deposition is likely provides an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.	Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioretention systems, but this will vary according to pollutant load.

Adapted from: Western Washington manual
http://www.ecy.wa.gov/programs/wq/stormwater/manual/2014SWMMWWinteractive/Content/Topics/VolumeV2014/VolV%20Ch7%202014/VolV%20BMPt730%202014.htm

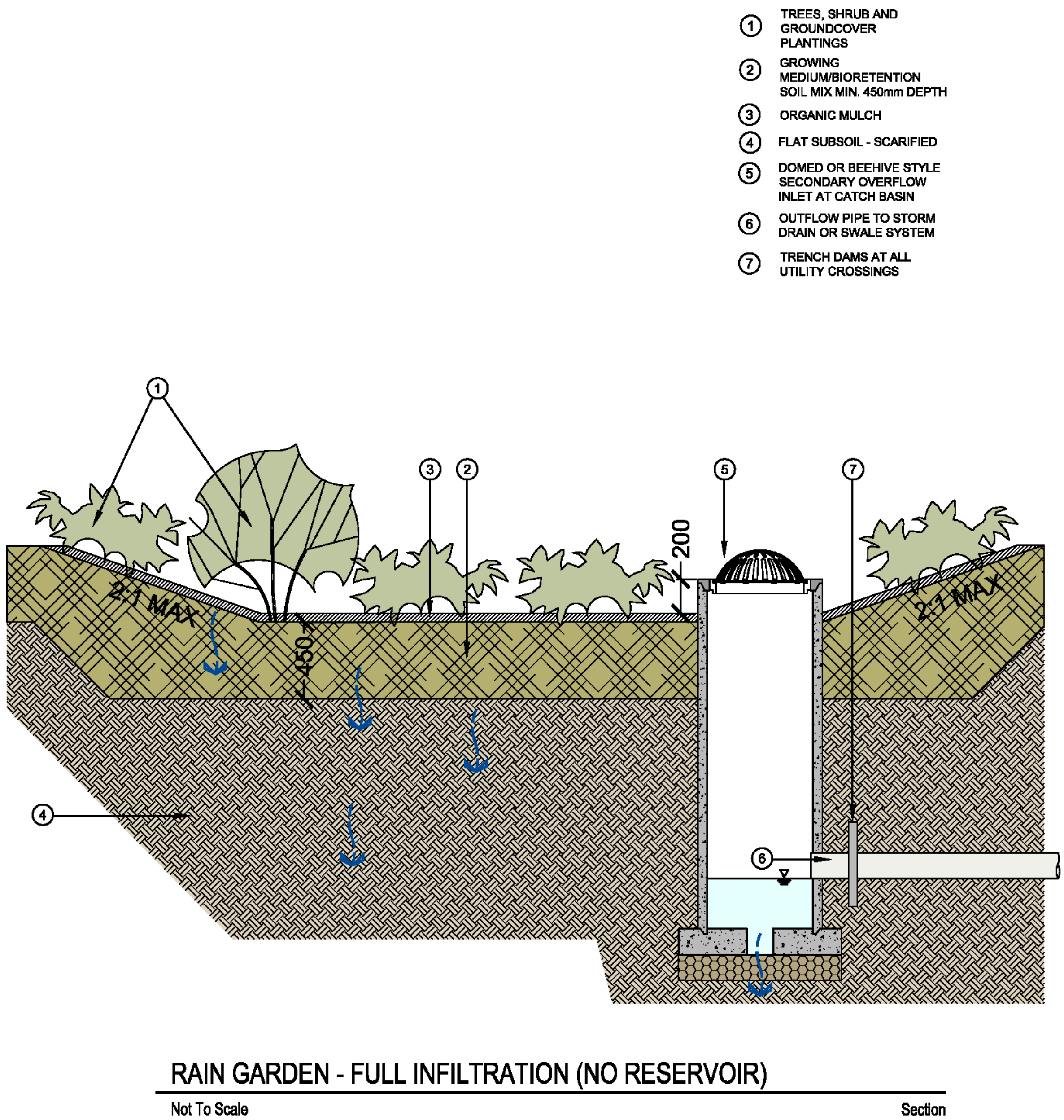


Figure 8 Rain Garden – Full Infiltration (No Reservoir) (Not to scale, Section)

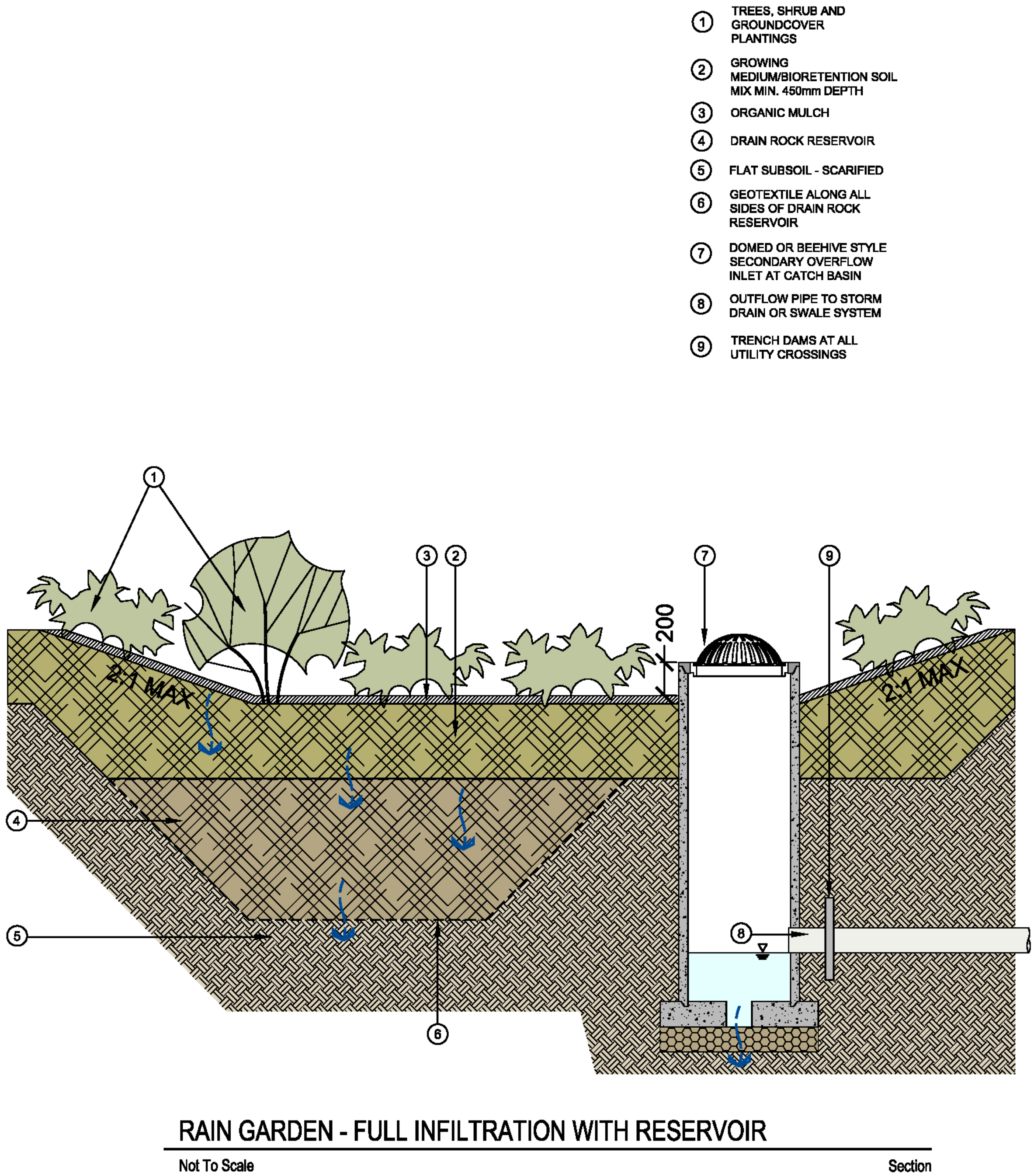


Figure 9 Rain Garden – Full Infiltration with Reservoir (Not to scale, Section)

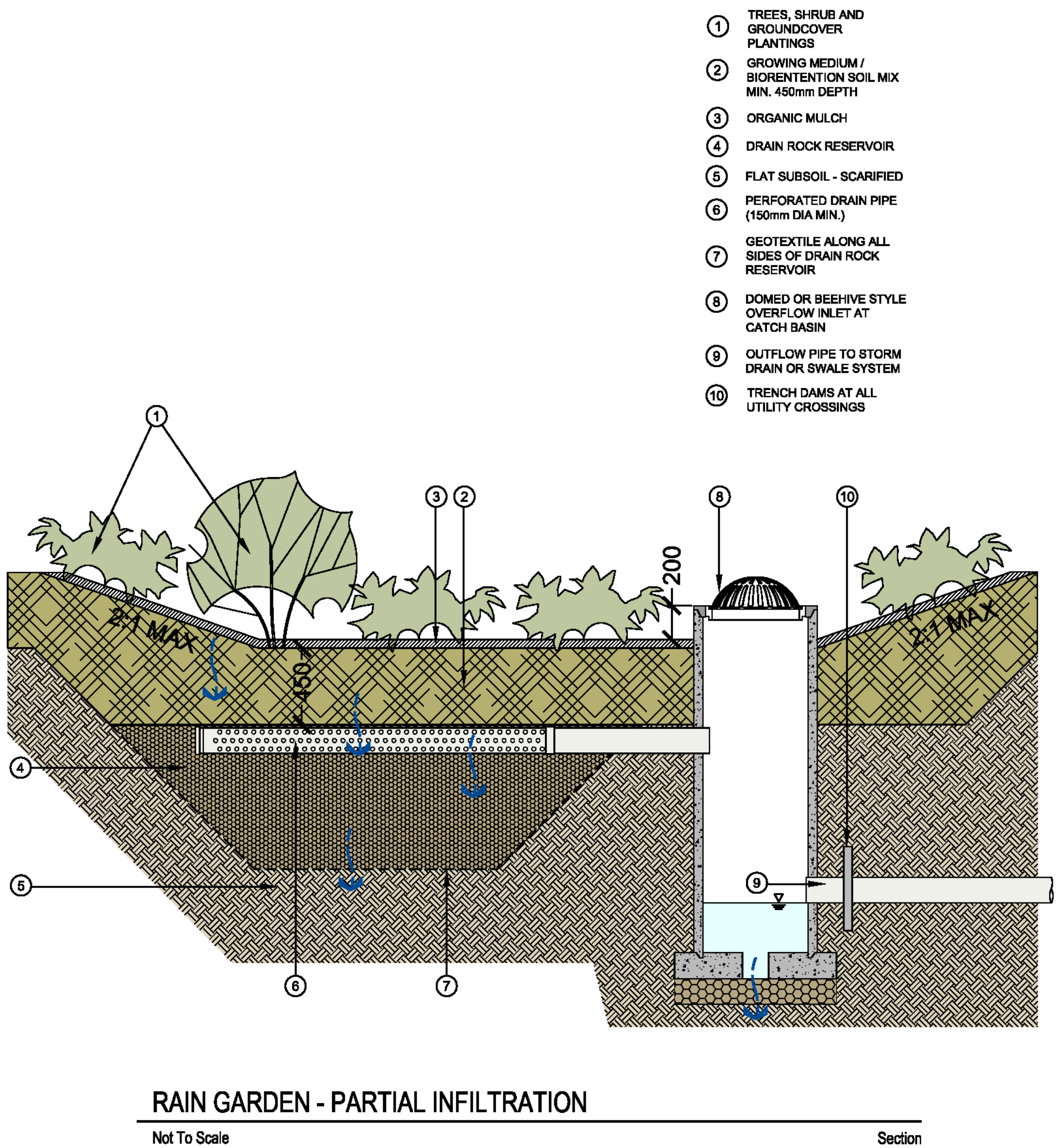


Figure 10 Rain Garden – Partial Infiltration (Not to scale, Section)

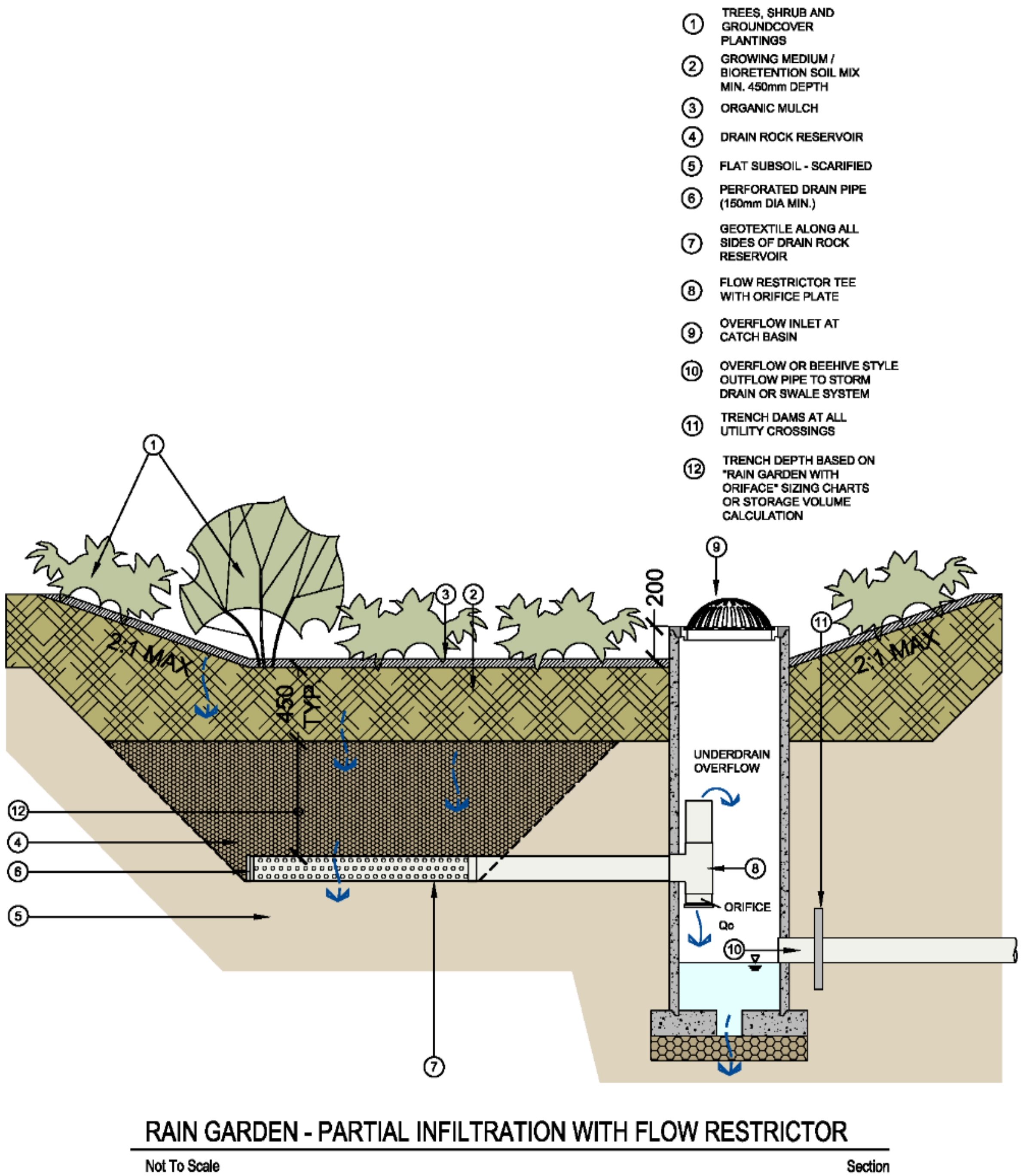


Figure 11 Rain Garden – Partial Infiltration with Flow Restrictor (Not to scale, Section)

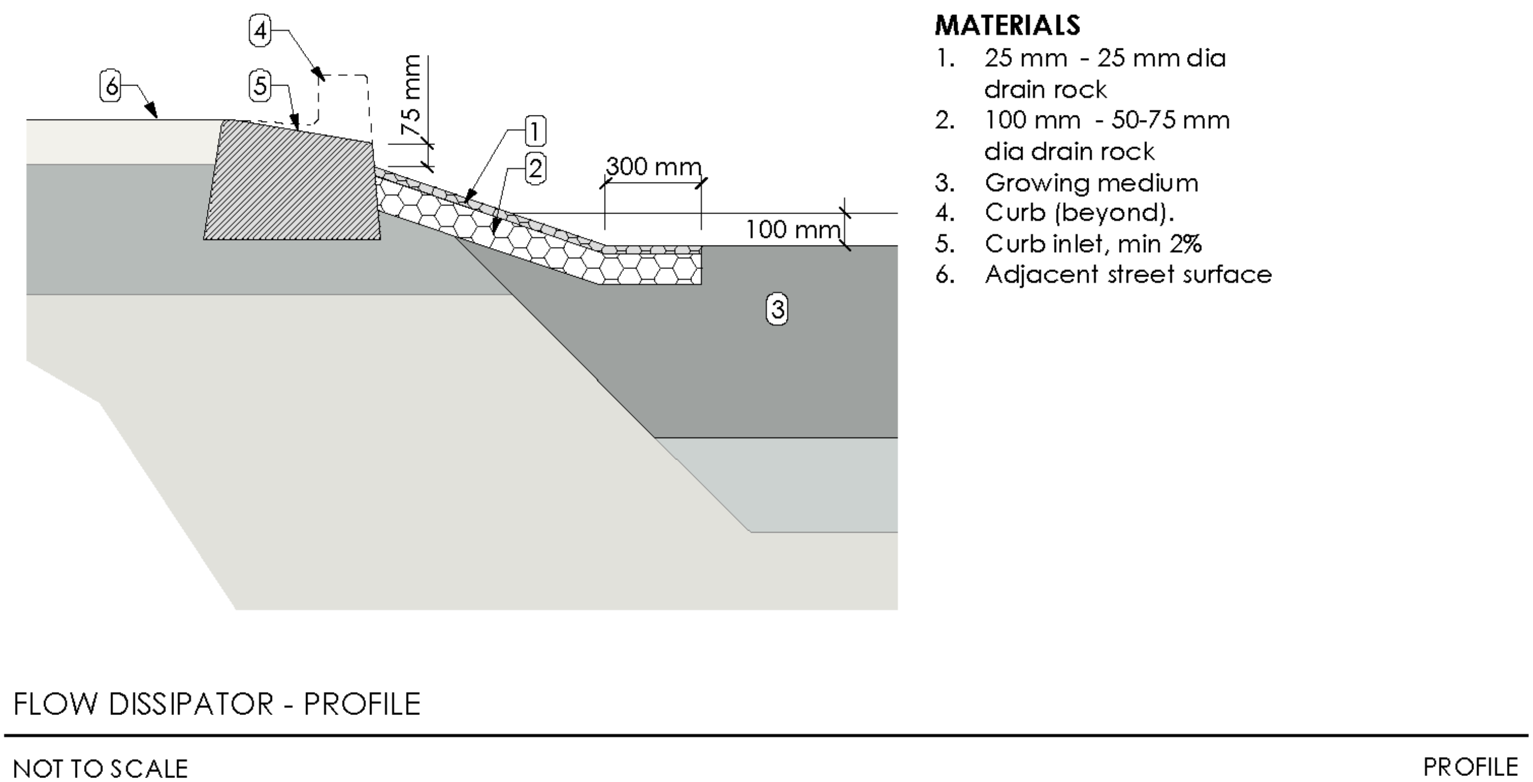
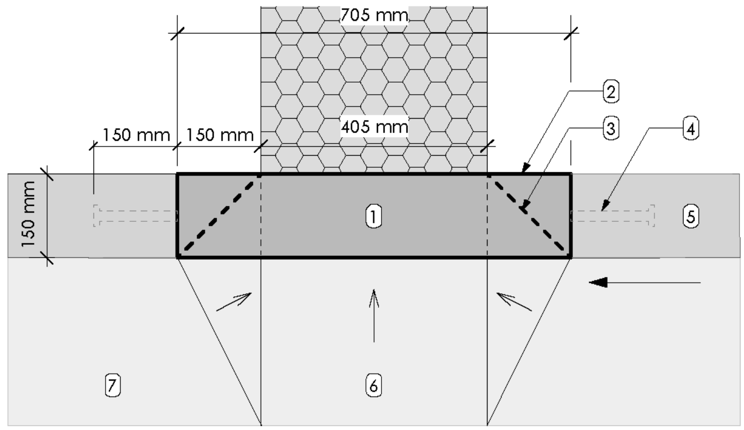


Figure 12 Flow Dissipator Option

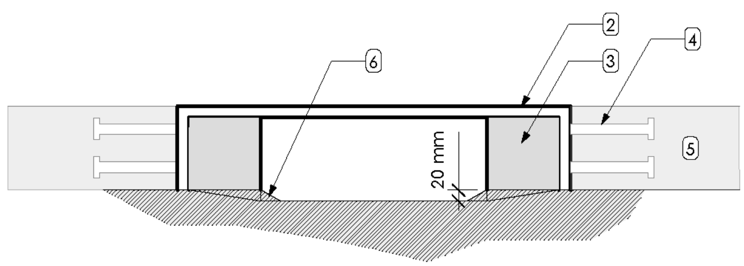
Modified from: District of Saanich Stormwater Management Guidebook (2011, Unpublished Draft), written by Kerr Wood Leidal Associates Ltd. and Murdoch de Greeff Inc.



MATERIALS
1. Steel inlet structure
2. Steel rear wall
3. Steel baffle, angled 45 degrees towards rear wall.
4. Steel anchor, welded to inlet structure (2 each side)
5. Cast in place concrete curb
6. Hand trowel gutter to meet inlet base. Ensure positive drainage towards inlet.
7. Concrete gutter

STEEL CURB INLET

NOT TO SCALE — PLAN



STEEL CURB INLET

NOT TO SCALE — FRONT SECTION/ELEVATION DETAIL

Figure 13 Steel Curb Inlet Option

Modified from: District of Saanich Stormwater Management Guidebook (2011, Unpublished Draft), written by Kerr Wood Leidal Associates Ltd. and Murdoch de Greeff Inc.

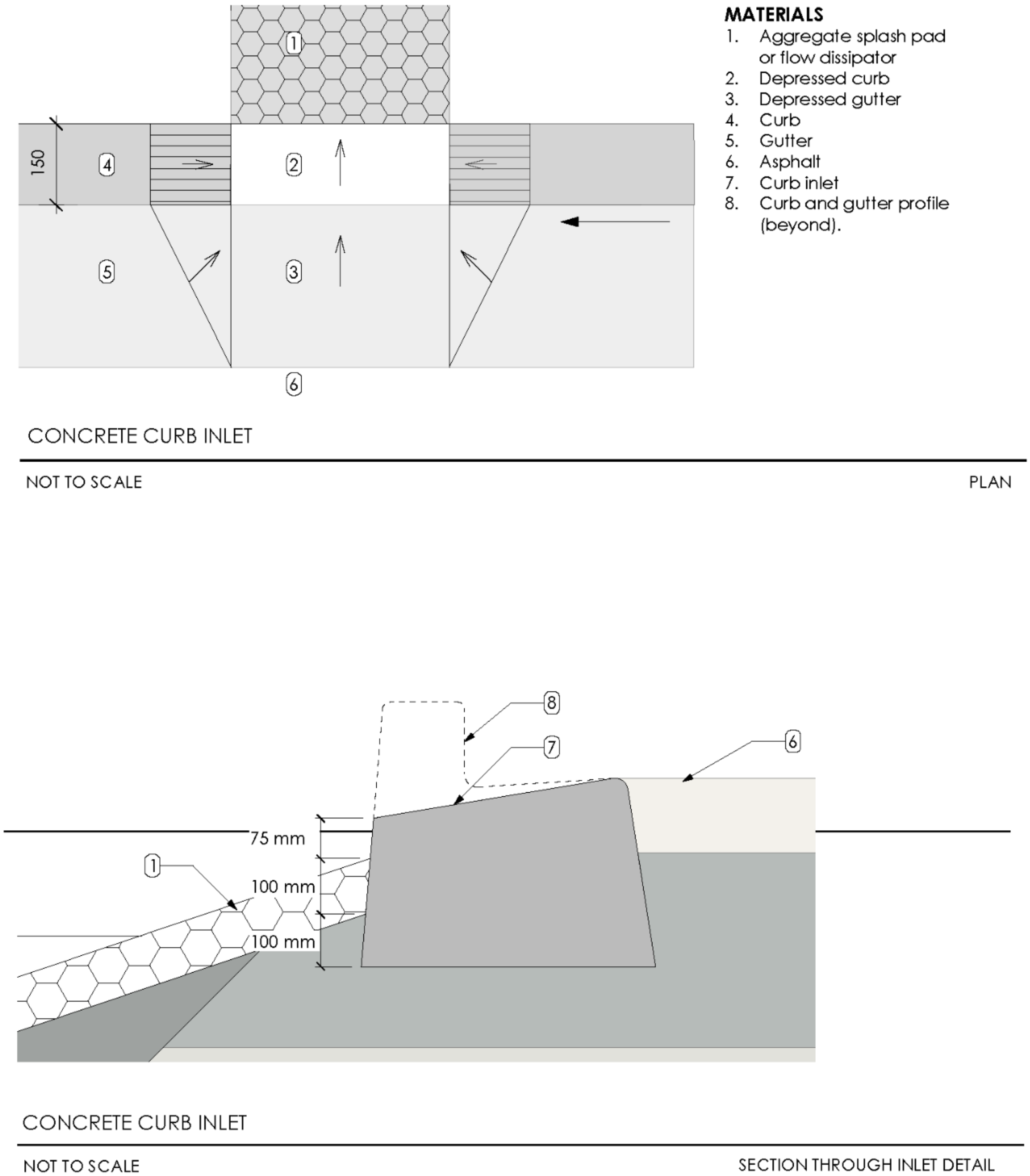


Figure 14 Concrete Curb Inlet Option

Modified from: District of Saanich Stormwater Management Guidebook (2011, Unpublished Draft), written by Kerr Wood Leidal Associates Ltd. and Murdoch de Greeff Inc.