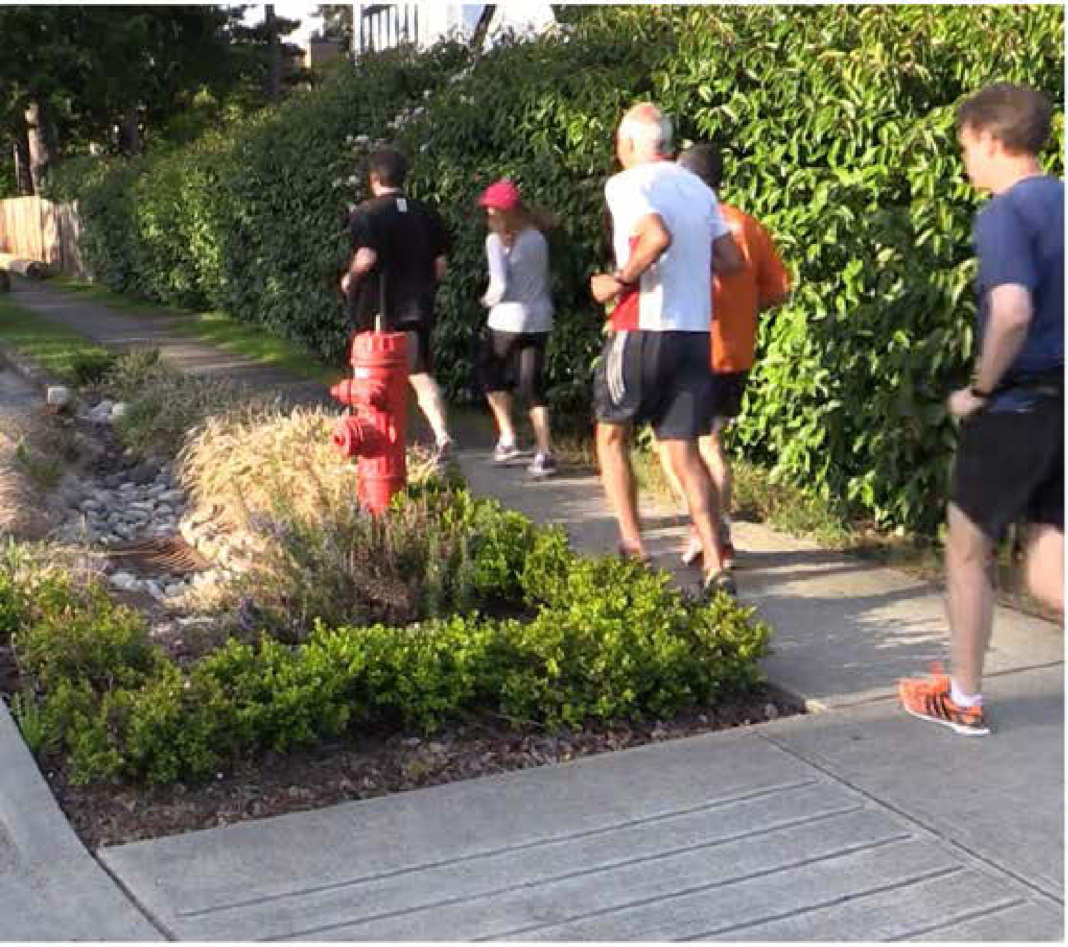


VOLUME II

Best Management Practice Toolkit

FINAL DRAFT

CITY OF VANCOUVER | GREENEST CITY

Structure of the Citywide Integrated Rainwater Management Plan

The Citywide Integrated Rainwater Management Plan (IRMP) addresses areas of Vancouver where stormwater is piped directly to either combined sewer or ocean outfalls. Outside of the IRMP study area, two watersheds in Vancouver have remaining surface streams—Still Creek and Musqueam Creek—and are guided by their own integrated stormwater (rainwater) management plans, under separate cover. Stanley Park, which has surface streams, is also excluded from this study area.

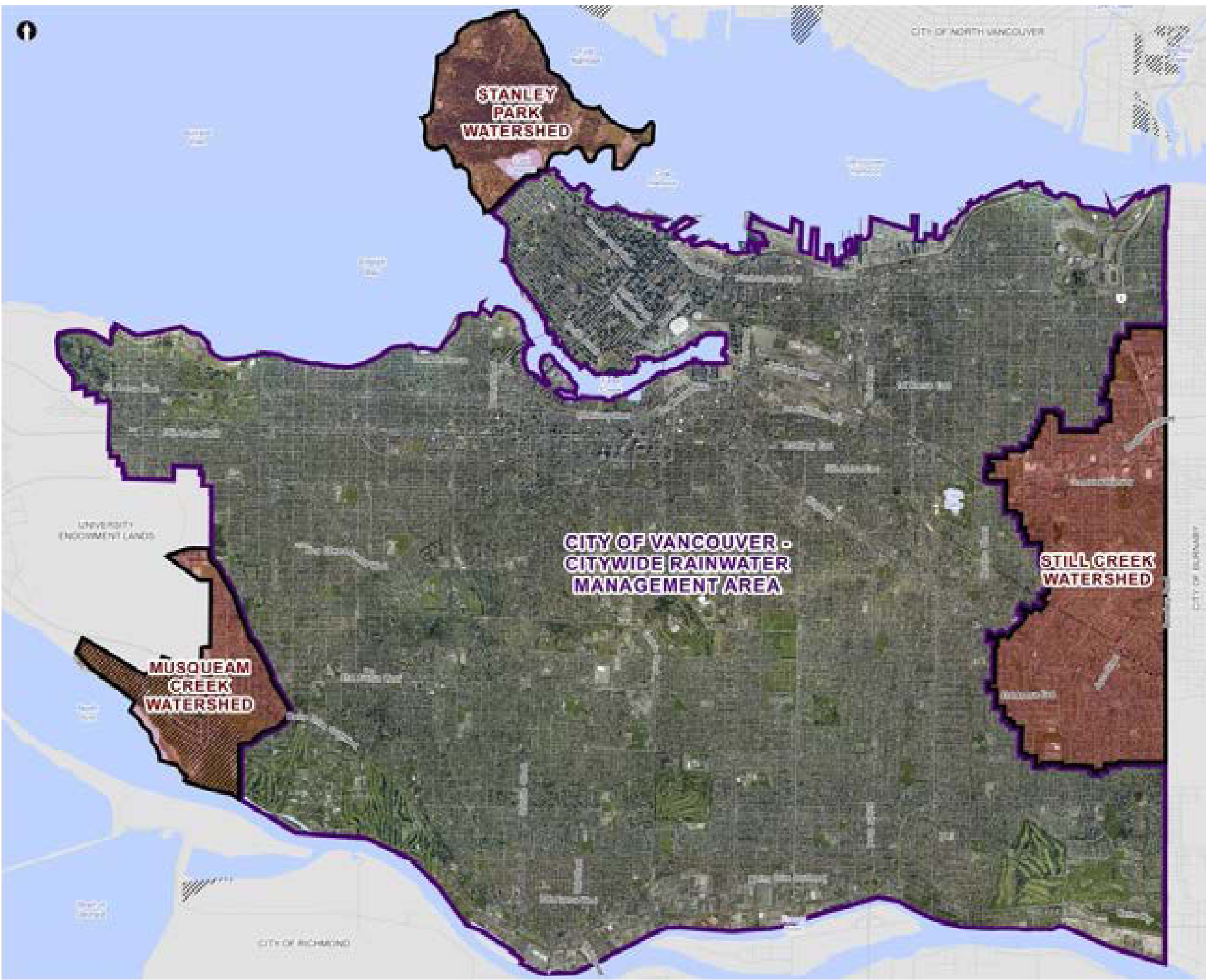
Credits

Prime Consultant/Author:
Golder Associates Ltd.

Subconsultants:
Kerr Wood Leidal Associates Ltd.
Lanarc 2015 Consultants Ltd.

March 2016

City of Vancouver - Citywide Rainwater Management Area



The Citywide Integrated Rainwater Management Plan is presented in three volumes:

I. **Vision, Principles and Actions** – a summary of why rainwater management is required, introduction to targets programs to address priorities.

II. **Best Practice Toolkit** – a guide to common tools to address rainwater management in Vancouver, highlighting their strengths and challenges. (this document)

III. **Technical Background Report** (internal) – a detailed record of process, stakeholder input, alternatives considered, technical and financial analysis, program details and action plan.

TABLE OF CONTENTS

LIST OF TABLES

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facilitate double-sided booklet printing.

1.0 BEST MANAGEMENT PRACTICE TOOLKIT

The BMP Toolkit provides an introduction to a range of common best practices to improve rainwater management. These tools are in common use in other jurisdictions around Metro Vancouver, the Pacific Northwest, and in developed areas around the world.

The Toolkit BMPs are:

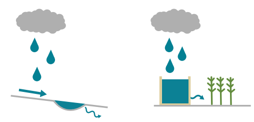
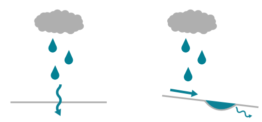
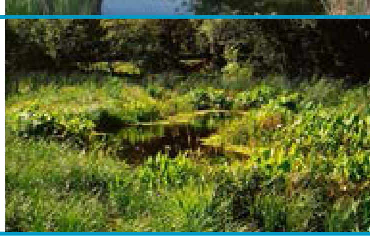
- Absorbent Landscapes
- Infiltration Swales
- Rain Gardens & Infiltration Bulges
- Pervious Paving
- Green Roof
- Tree Well Structure
- Rainwater
- Infiltration Trench
- Water Quality Structures
- Detention Tanks
- Daylighted Streams
- Constructed Wetlands

Table II - 1 summarizes the Toolkit BMPs. The Toolkit includes key description of purpose, graphics and diagrams to show scope and application, key design principles, limitations and sizing variables, and maintenance and operations considerations.

The Toolkit is introductory. Links to examples and manufacturer information is provided in the 'For More Information' Section. Readers should use the Toolkit in conjunction with more detailed technical guidance which is provided generally in the Metro Vancouver Stormwater Source Control Guidelines 2012.

Table II - 1: BMP Toolkit Summary Table

TOOL		IMPACTS ON WATER	BENEFITS
Absorbent Landscapes		INFILTRATE	• intercept and clean rainwater through soil pores, allowing gradual infiltration into subsoils to recharge groundwater
Infiltration Swales		INFILTRATE, TREAT, DETAIN	• reduce runoff volume and increase water quality by capturing, detaining, treating, and conveying stormwater
Rain Gardens & Infiltration Bulges		INFILTRATE, TREAT, DETAIN	• reduce runoff volume and improve water quality by infiltrating, capturing, and filtering stormwater • an overflow conveys extreme rainfall volumes
Pervious Paving		INFILTRATE	• reduce runoff volume and improve water quality by infiltrating and treating stormwater while still providing a hard, drivable surface
Green Roofs		DETAIN, HABITAT, TRANSPIRE	• reduce stormwater peak flows and volume, depending on depth of growing medium • benefit buildings by providing insulation and by reducing the heat island effect • provide urban habitat
Tree Well Structures		INFILTRATE, TREAT, DETAIN, TRANSPIRE	• adequate soil volume will retain excess stormwater and help to remove pollutants from stormwater runoff • support a healthy tree canopy which intercepts rainfall

TOOL		IMPACTS ON WATER	BENEFITS
Rainwater Harvesting		 DETAIN, CAPTURE & REUSE	• runoff from roof surfaces can be captured, stored and used for non-potable uses like landscape irrigation, laundry, and toilets, subject to approval of authorities having jurisdiction.
Infiltration Trenches		 INFILTRATE, DETAIN	• reduce the volume and rate of runoff by holding and infiltrating water into subsurface soils • water quality pre-treatment is advisable
Water Quality Structures		 TREAT	• capture petroleum hydrocarbons, coarse grit and coarse sediment • provide some water quality benefits except for soluble nutrients and pollutants
Detention Tanks		 DETAIN	• reduce flooding and in-stream erosion by collecting and storing stormwater runoff during a storm event, and releasing it at controlled rates to the downstream drainage system
Daylighted Streams & Channel Improvements		 DETAIN, HABITAT, TREAT	• may provide in-stream detention, water quality improvements, and essential habitat for aquatic life • contribute to the liveability of an area and establish a sense of place if properly designed
Constructed Wetlands		 DETAIN, HABITAT, TREAT	• provide detention, storage, habitat, and treat stormwater runoff through natural processes prior to discharging it into the downstream drainage system

Absorbent Landscapes

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

Primary Purpose

- To reduce runoff from impermeable surfaces by creating more absorbent landscapes that intercept and retain rainwater.

Performance Rating

FUNCTIONAL CRITERIA

Best

- Water Quality Treatment
- Aesthetic Benefits
- Biodiversity Benefits

Good

- Volume Control (reduced CSO's)
- Public Education, Culture and Health Values

COST CRITERIA

Best

- Land Cost
- Property Value
- Longevity

Good

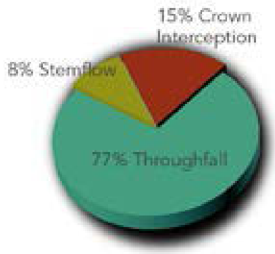
- Material and Construction Cost

Limited Benefit

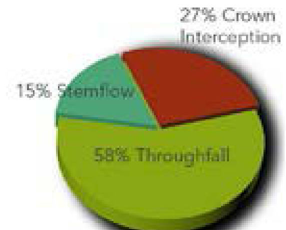
- Maintenance Cost

This tool is suitable for:

- Low Density
- Medium/High Density
- Commercial Mixed Use
- Industrial
- Institutional
- Parks & Greenspace
- Local Streets



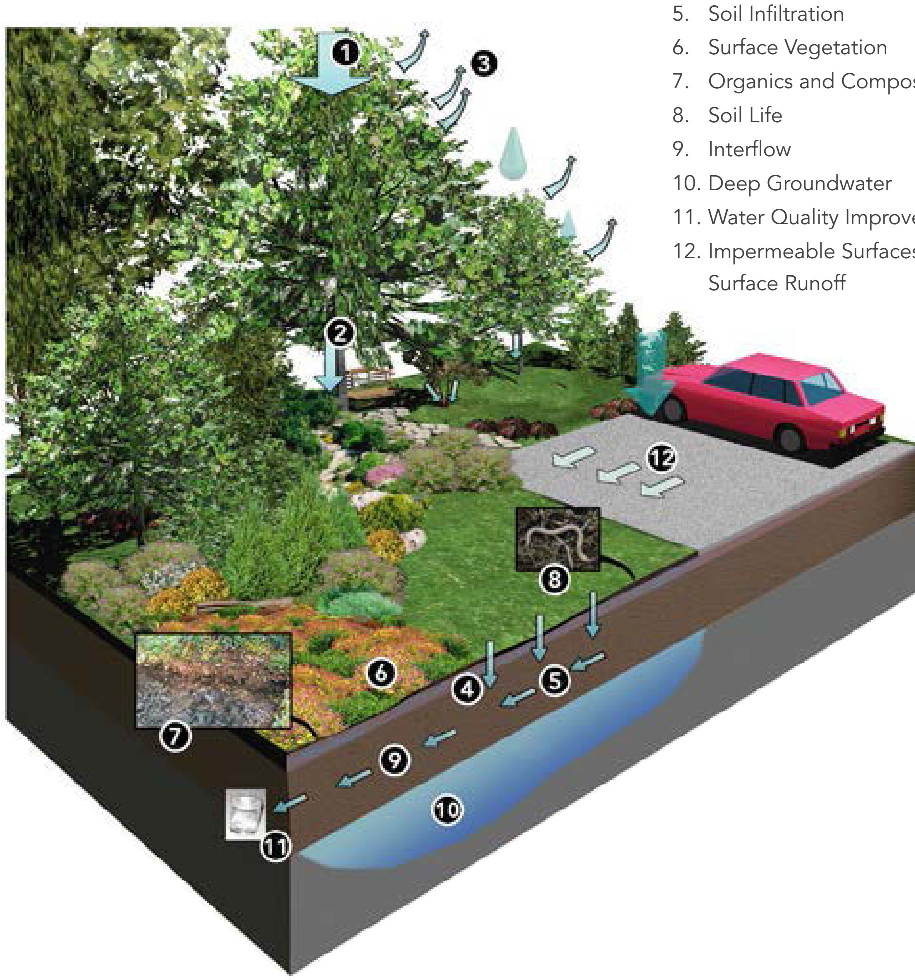
Pear Tree



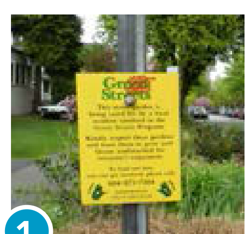
Evergreen Oak Tree

Winter tree canopies intercept 15% to 27% of rainfall

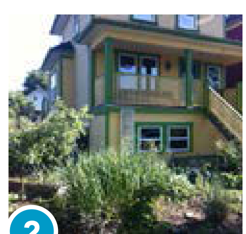
1. Crown Interception
2. Throughfall and Stemflow
3. Evapotranspiration
4. Soil Water Storage
5. Soil Infiltration
6. Surface Vegetation
7. Organics and Compost
8. Soil Life
9. Interflow
10. Deep Groundwater
11. Water Quality Improvement
12. Impermeable Surfaces and Surface Runoff



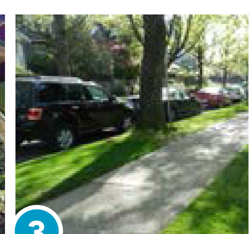
Absorbent Landscape Examples



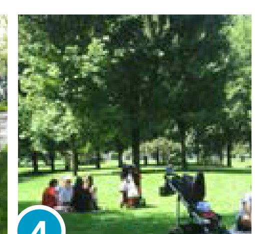
1 Vancouver's Green Street Program



2 Private residential yard



3 Residential Street



4 Parks & Open Space

Design Principles, Limitations and Sizing Variables

- 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 depth of 300 mm for lawn is required to store 60 mm 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 absorbent landscape.

Optimizing Performance

DESIGN & CONSTRUCTION

- Ensure roughening (scarification) of subgrade to reduce crusting / impermeability of the excavation surface prior to placing topsoil.
- Enforce quality control of topsoil to be free of weed seeds, and to meet specs for texture and hydraulic properties. If suitable reuse existing topsoil.
- Include compost to increase percolation and reduce need for water and fertilizer inputs.
- Greater growing medium depth equals greater storage and treatment of rainfall.
- Include an organic mulch layer to surface.

MAINTENANCE

- In planting beds, aerate or till surface 25 mm deep between plants each spring to reduce crusting.
- In lawns, core-aerate areas of surface compaction each spring.
- Ensure regular spring weeding to avoid weeds going to seed.
- Remove and replace surface mulch in ponding areas once every three years

Did you know?

- 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.

For more information:

www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/StormwaterSourceControlDesignGuidelines2012.pdf

Infiltration Swales

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.

Primary Purpose

- Water quality treatment, reduction of runoff

Performance Rating

FUNCTIONAL CRITERIA

Best

- Water Quality Treatment

Good

- Volume Control (reduced CSO's)
- Public Education, Culture and Health Values
- Aesthetic Benefits
- Biodiversity Benefits

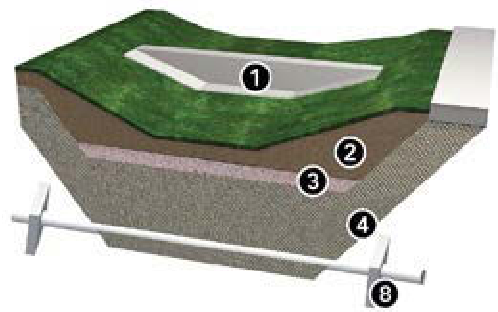
COST CRITERIA

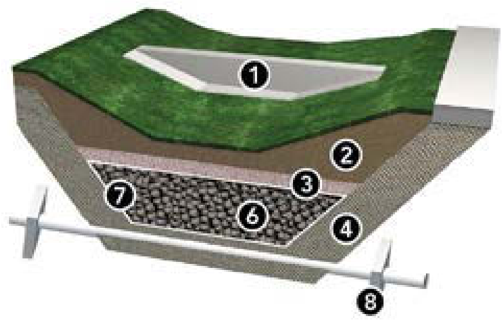
Best

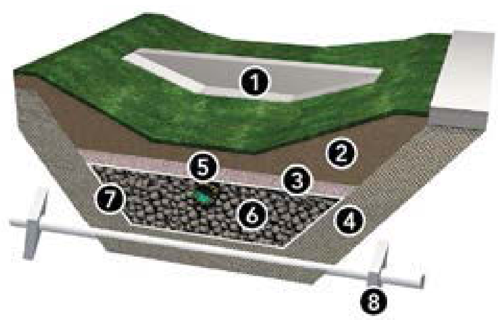
- Property Value

Good

- Longevity
- Land Cost
- Material and Construction Cost
- Maintenance Cost







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

This tool is suitable for:

- Medium/High Density
- Commercial Mixed Use
- Industrial
- Institutional
- Parks & Greenspace
- Local Streets
- Collector/ Arterial Streets

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 > 30 mm/hr.

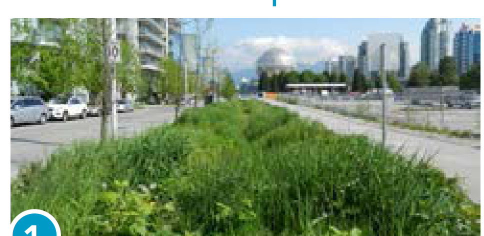
FULL INFILTRATION WITH RESERVOIR

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

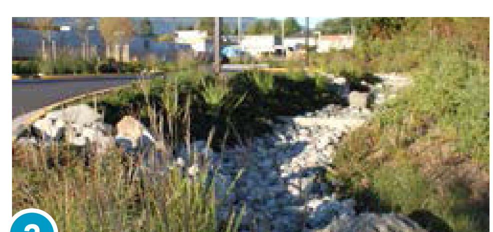
PARTIAL INFILTRATION WITH RESERVOIR & SUBDRAIN

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 < 15 mm/hr. Provides water quality treatment even if infiltration into subsoils is limited.

Precedent examples



1 **Bioswale -** Olympic Village



2 **Infiltration Swale -** Nanaimo Regional General Hospital

Design Principles, Limitations and Sizing Variables

- See the reference document for sizing guidelines. Higher sediment load land uses require lower ratios of impervious area to swale area.
- Flow to the swale should be distributed sheet flow, traveling through a filter area at the swale verges. Provide pre-treatment and erosion control to avoid sedimentation in the swale.
- 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.
- 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 2400 mm 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 100 mm minimum.
- Maximum ponding level - 150 mm for minimum hazard. Drawdown time for the maximum surface ponded volume - 48 hrs
- Treatment soil depth—300 mm desirable, minimum 150 mm if design professional calculates adequate pollutant removal - varies depending on planting design.
- 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 rate required by the design.

Optimizing Performance

DESIGN & CONSTRUCTION

- Undertake site-specific infiltration testing and, based on results, design the system infiltration area, surface and underground storage volume, and overflow subdrain. Be careful to not exceed impervious / pervious (I/P) guidelines in design, exercising great caution in Vancouver if exceeding a 5:1 I/P ratio.
- Provide a minimum 50 mm drop in gutter profiles and further 50 mm drop into the infiltration surface to avoid runoff bypassing the facility.
- Enforce quality control of topsoil to be free of weed seeds, and to meet specs for texture and hydraulic properties. Use of non-angular sand (e.g. Fraser River pump sand) is encouraged for the sand component. Native topsoil will rarely be suitable, having too low an infiltration rate.
- Include compost to increase percolation and reduce need for water and fertilizer inputs. Greater growing medium depth equals greater storage and treatment of rainfall. Include an organic mulch layer to surface.

MAINTENANCE

- Inspect and clean the inlet twice per year minimum (spring and fall).
- In lawns, core-aerate areas of surface compaction each spring.
- In planting beds, cultivate surface 25 mm deep between plants each spring to reduce crusting. Ensure regular spring weeding to avoid weeds going to seed.
- Remove and replace surface mulch between plants in ponding areas once every three years.

For more information:

www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/04StormwaterSourceControlDesignGuidelinesInfiltrationSwales.pdf

Rain Gardens & Infiltration Bulges

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.

Primary Purpose

- Capture and filter runoff from adjacent impervious surfaces such as roads, roofs, parking lots and driveways.

Performance Rating

FUNCTIONAL CRITERIA

Best

- Water Quality Treatment
- Aesthetic Benefits
- Biodiversity Benefits

Good

- Volume Control (reduced CSO's)
- Public Education, Culture and Health Values

COST CRITERIA

Best

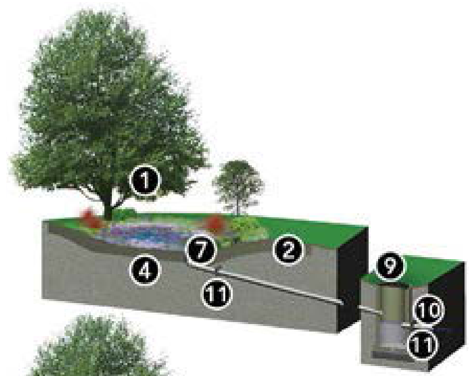
- Land Cost
- Property Value

Good

- Longevity
- Material and Construction Cost
- Maintenance Cost

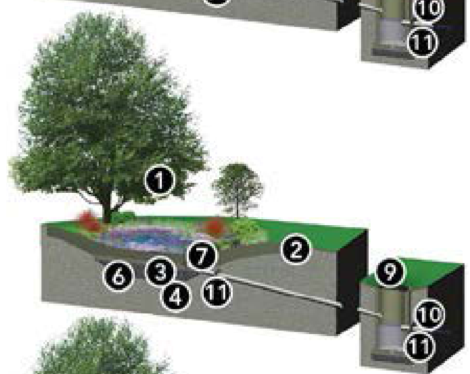
This tool is suitable for:

- Low Density
- Medium/High Density
- Commercial Mixed Use
- Industrial
- Institutional
- Parks & Greenspace
- Local Streets



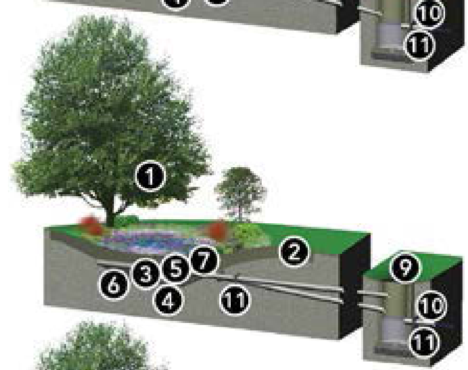
FULL INFILTRATION

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



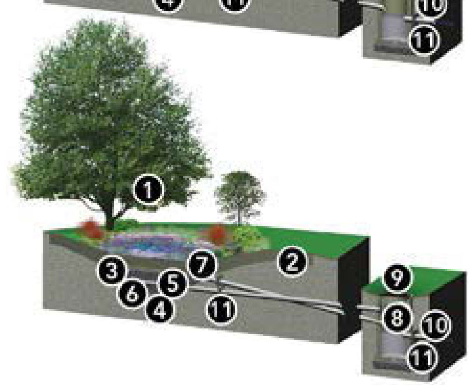
FULL INFILTRATION WITH RESERVOIR

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 > 15 mm/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 < 15 mm/hr.

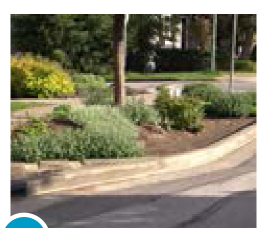


PARTIAL INFILTRATION WITH FLOW RESTRICTOR

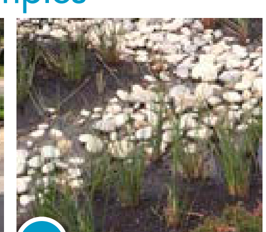
For sites with subsoil permeability < 5 mm/hr, the addition of a flow restrictor assembly with a small orifice slowly decants the top portion of the reservoir and rain garden. Provides water quality treatment and some infiltration, while acting like a small detention facility.

1. Tree, Shrub and Groundcover Plantings
2. Growing Medium Minimum 450 mm Depth
3. Drain Rock Reservoir
4. Flat Subsoil - scarified
5. Perforated Drain Pipe 150 mm 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

Precedent examples



1 **Infiltration Bulge -** Ontario St.



2 **Rain garden infiltration area -** East Fraserlands

Design Principles, Limitations and Sizing Variables

- See the references for sizing guidelines. 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 30.5 m 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 - 600 mm (Min.) to 3000 mm and length-width ratio of 2:1 desirable.
- Side slopes – 2:1 maximum, 4:1 preferred for maintenance. Ponding depth - 150 – 300 mm.
- Draw-down time for maximum ponded volume - 72 hours.
- Treatment soil depth - 300 mm (Min.) to 1200 mm (desirable); use soils with minimum infiltration rate of 50 mm/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 50–75 mm 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..

Optimizing Performance

DESIGN & CONSTRUCTION

- Undertake site-specific infiltration testing and, based on results, design the system infiltration area, surface and underground storage volume, and overflow subdrain. Be careful to not exceed impervious / pervious (I/P) guidelines in design, exercising great caution in Vancouver if exceeding a 5:1 I/P ratio.
- Provide a minimum 50 mm drop in gutter profiles and further 50 mm drop into the infiltration surface to avoid runoff bypassing the facility.
- Enforce quality control of topsoil to be free of weed seeds, and to meet specs for texture and hydraulic properties. Use of non-angular sand (e.g. Fraser River pump sand) is encouraged for the sand component. Native topsoil will rarely be suitable, having too low an infiltration rate.
- Include compost to increase percolation and reduce need for water and fertilizer inputs. Greater growing medium depth equals greater storage and treatment of rainfall. Include an organic mulch layer to surface.

MAINTENANCE

- Inspect and clean the inlet twice per year minimum (spring and fall).
- In planting beds, cultivate surface 25 mm deep between plants each spring to reduce crusting. Ensure regular spring weeding to avoid weeds going to seed.
- Remove and replace surface mulch between plants in ponding areas once every three years.

For more information:

www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/05StormwaterSourceControlDesignGuidelinesRainGarden.pdf

Pervious Paving

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.

Primary Purpose

- Infiltrate and treat stormwater while still providing a hard surface.

Performance Rating

FUNCTIONAL CRITERIA

Best

- Water Quality Treatment

Good

- Volume Control (reduced CSO's)
- Public Education, Culture and Health Values

Limited Benefit

- Aesthetic Benefits
- Biodiversity Benefits

COST CRITERIA

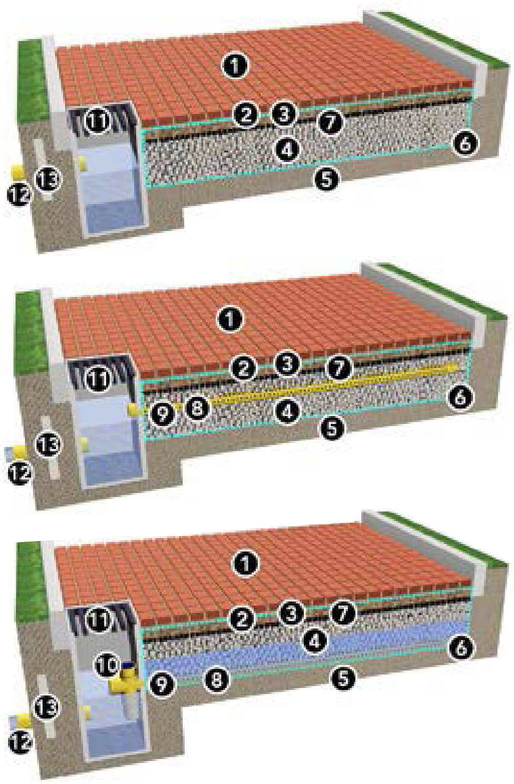
Best

- Land Cost

Good

- Property Value
- Material and Construction Cost
- Maintenance Cost
- Longevity

PERVIOUS PAVEMENT DESIGNS MAY BE ONE OF THREE TYPES:



1. Permeable Pavers (Min. 80 mm thickness)
2. Aggregate Bedding Course - not sand (50 mm 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 150 mm 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

FULL INFILTRATION

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

PARTIAL INFILTRATION WITH FLOW RESTRICTOR

Where subsoil permeability is < 1 mm/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.

This tool is suitable for:

- Low Density
- Medium/High Density
- Commercial Mixed Use
- Institutional
- Parks & Greenspace
- Local Streets

Precedent examples

1 Olympic Village

2 Reid Residence, Nanaimo, BC

Design Principles, Limitations and Sizing Variables

- 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 15 mm/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 modeling. 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 sub-base.

Optimizing Performance

DESIGN & CONSTRUCTION

- Undertake site-specific infiltration testing and, based on results, design the system infiltration area, underground storage volume, and overflow subdrain. Be careful to not exceed impervious / pervious (I/P) guidelines in design, exercising great caution if exceeding a 2:1 I/P ratio.
- Isolate the pervious pavement from sources of sediment – consider a gutter to separate traveled lane drainage from pervious pavement parking area. Although this would reduce the I/P area efficiency, it also reduces the risk of surface plugging. Install pervious paving after adjacent construction is complete.
- Enforce quality control of materials, in particular bedding and crack aggregate sizing and fractured face qualities. These pavements have no sands, no fines.
- Greater reservoir depth equals greater storage and treatment of rainfall. Hydrocarbons soaking into the aggregate undergo aerobic digestion.

MAINTENANCE

- Provide vacuum sweeping at least twice/year, spring, and fall after leaf drop.
- Surface weeding may be similar to that required of standard interlocking pavers (some weed/ moss growth). Ensure regular spring weeding to avoid weeds going to seed.
- In interlocking pervious pavements, remove and replace top one-third of crack aggregate once every three years. Localized plugged areas, if found, may be repaired by lifting the pavers, replacing bedding aggregate and upper filter cloth, and returning the pavers—a shallow repair.

For more information:

www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/06StormwaterSourceControlDesignGuidelinesPerviousPaving.pdf

www.pavingstones.com/document/pdfviewer/printer-friendly-brochure/160/aquapave_web.pdf

Green Roof

CITY OF VANCOUVER | GREENEST CITY

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.

Primary Purpose

- To reduce peak flows and stormwater volume;
- To provide additional benefits to the building, such as insulation, air filtration and reduced heat island effect.

Performance Rating

FUNCTIONAL CRITERIA

Best

- Aesthetic Benefits
- Biodiversity Benefits

Good

- Public Education, Culture and Health Values
- Volume Control (reduced CSO's)

Limited Benefit

- Water Quality Treatment

COST CRITERIA

Best

- Land Cost
- Property Value

Good

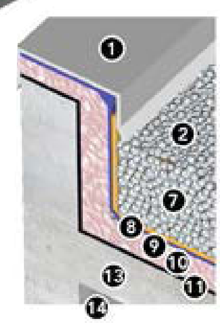
- Longevity

Limited Benefit

- Maintenance Cost
- Material and Construction Cost

This tool is suitable for:

- Commercial Mixed Use
- Institutional
- Parks & Greenspace



There are two basic types of Green Roofs:

***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 100 mm 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

Precedent examples

1 Vancouver Convention Centre

2 Vancouver Central Library

3 Private Residence, Vancouver

4 Creekside Community Centre

Design Principles, Limitations and Sizing Variables

- Suitable for flat roofs and, with proper design, roofs of 20° (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, 50 cm wide, should be located every 40 m 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.

Optimizing Performance

DESIGN & CONSTRUCTION

- Intensive green roof (>100 depth) provides greater rainwater storage and stormwater benefits than an Extensive Green Roof (<100 depth)
- Growing medium mixes for Extensive Green roof may be primarily fine aggregate with limited rainwater storage potential.
- Greater growing medium depth and higher fines/organic content of Intensive Green Roof equals greater storage and treatment of rainfall.

MAINTENANCE

- In planting beds, cultivate surface 25mm deep between plants each spring to reduce crusting.
- In Extensive Green Roof lawns, core-aerate areas of surface compaction each spring.
- Ensure regular spring weeding to avoid weeds going to seed.

Green Roof Benefits

- Reduced peak flows & stormwater volume
- Mitigation of urban heat island effect
- Insulation against heat loss and gain
- Extended roof membrane life
- Sound insulation & air filtration
- Urban habitat & biodiversity
- Aesthetics

For more information:

www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/07StormwaterSourceControlDesignGuidelinesGreenRoof.pdf

Tree Well Structures

Trees play a vital role in reducing stormwater runoff in urban settings. Trees within tree wells are generally healthier and reach mature height faster, which leads to more water being intercepted by the tree canopy. Tree wells contain a large volume of soil which retains excess stormwater and helps to remove pollutants from stormwater runoff.

Primary Purpose

- To optimize tree growth and manage stormwater from adjacent hard surfaces.

Performance Rating

FUNCTIONAL CRITERIA

Good

- Water Quality Treatment
- Volume Control (reduced CSO's)
- Aesthetic Benefits
- Public Education, Culture and Health Values

Limited Benefit

- Biodiversity Benefits

COST CRITERIA

Best

- Land Cost
- Longevity

Good

- Maintenance Cost
- Property Value

Limited Benefit

- Material and Construction Cost

This tool is suitable for:

- Medium/High Density
- Commercial Mixed Use
- Institutional
- Collector/Arterial Streets

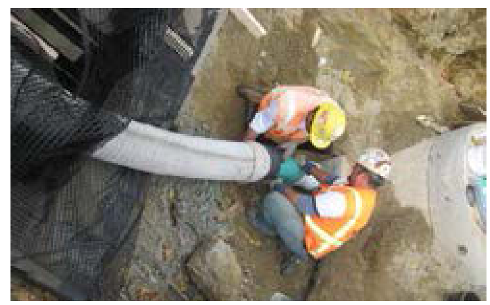
Tree wells (also called soil cells) are rigid frame structures which are typically installed under a hard surface such as a sidewalk, parking lot or road. Tree wells allow a large amount of soil to be installed under hard surfaces without compromising surface loading.

Street tree in Silva Cell - 2009

Street tree in Silva Cell - 2013

Winter tree canopies intercept 15% to 27% of rainfall. The bigger the canopy, the more water it intercepts.

Perforated drain line is installed at the bottom of the 1st layer of Silva Cells and connected to the catch basin.



Did you know?

- Tree wells can be fed by curb grates, permeable pavement, natural surface infiltration and collected roof water.
- Tree wells can be used in a number of areas including streetscapes, plazas, and parking lots.

Tree Well Examples

Installation of Strata Cell - Rossland, BC

Installation of Silva Cell - Queensway, Toronto, ON

Design Principles, Limitations and Sizing Variables

- Verify location of all existing underground utilities and conditions prior to excavation.
- Excavate the trench according to the dimensions necessary to install the desired tree well system. Allow 12" (30 cm) additional space along all edges.
- Compact subgrade to 95% density or as recommended by the geotechnical engineer.
- Prepare the sub-base as per product specifications.
- Do not install when subgrades or planting soils are wet, muddy or frozen.
- Review installation layout and procedures with the general contractor, landscape architect and product representative prior to installation.
- Refer to product supplier specifications for information on sizing, material type, preparation and system installation.
- Refer to product specifications for installation instructions.

Optimizing Performance

DESIGN & CONSTRUCTION

- If including infiltration in the design, undertake site-specific infiltration testing and, based on results, design the system infiltration area, surface and underground storage volume, and overflow subdrain. Be careful to not exceed impervious/pervious (I/P) guidelines in design, exercising great caution in Vancouver if exceeding a 5:1 I/P ratio. If using a 'flow-through' design, do not exceed the infiltration capacity of the design soil.
- Ensure the design provides root barriers and/or air gap to separate tree roots from paving. Note that root barriers must break to the air surface – roots will grow over buried root barriers.
- Enforce quality control of topsoil to be free of weed seeds, and to meet specs for texture and hydraulic properties. Use of non-angular sand (e.g. Fraser River pump sand) is encouraged for the sand component. Native topsoil will rarely be suitable, having too low an infiltration rate.
- Include compost to increase percolation and reduce need for water and fertilizer inputs. Greater growing medium depth equals greater storage and treatment of rainfall.
- Include an organic mulch layer to surface.

MAINTENANCE

- Inspect and clean the inlet twice per year minimum (spring and fall).
- Surface areas exposed to air/moisture will require weeding. Ensure regular spring weeding to avoid weeds going to seed.
- Adjust the tree well grate opening to allow for tree growth, and remove/replace organic mulch to exposed areas, as required but at least once every three years.

For more information:

www.deeproot.com/silvapdfs/resources/supporting/silva_cell_brochure.pdf
www.citygreen.com/products/structural-cells/stratacell/

Rainwater Harvesting

Rainwater harvesting involves collecting rainwater from roofs and storing it for non-potable uses.

Primary Purpose

- To reduce domestic water demands and runoff from impermeable surfaces.

Performance Rating

FUNCTIONAL CRITERIA

Good

- Volume Control (reduced CSO's)
- Aesthetic Benefits
- Public Education, Culture and Health Values

Limited Benefit

- Water Quality Treatment
- Biodiversity Benefits

COST CRITERIA

Best

- Land Cost
- Property Value

Good

- Longevity

Limited Benefit

- Maintenance Cost
- Material and Construction Cost

This tool is suitable for:

- Commercial Mixed Use
- Institutional

The primary components of a rainwater harvesting system for non-potable water applications include the following:

- Roofing materials;
- Gutters, gutter covers and downspouts;
- Leaf screens and roof washers;
- First-flush diverter;
- Storage Tank (Cistern);
- Pump and pressure tank.
- Filter; and
- Backflow preventer.

- The installed cost for an in-ground rainwater harvesting system capable of meeting two-thirds of residential water needs Is about $10,000
- Good practice involves diverting the initial portion of a rainfall event to prevent contaminants from entering the water storage

Rainwater Harvesting Example

1 Above Ground Rainwater Harvesting System (www.completeenergyuk.co.uk)

Design Principles, Limitations and Sizing Variables

- The amount of rainfall that can be potentially captured depends on the catchment area (area of the roof used to capture rainfall) and the precipitation.
- In Vancouver average precipitation is 1170–1600 mm per year depending on location.
- The total amount of rainfall in Litres that can be captured is calculated by multiplying the roof area (m^2) by a percent of average rainfall.
- In South Vancouver, a roof area of 100 m^2 would require a 19 m^3 of storage to maximize the amount of captured water
- To avoid contaminating the rainwater, careful selection of building materials is required as well as incorporating screens and making provision for diverting the first 0.5 mm of each rainfall event.
- A pumping and pressure control system needs to meet minimum pressure requirements under conditions of maximum demand and system head-losses.
- Backflow prevention, either air gap or reduced pressure principle, is required to avoid direct connection between the rainwater system and the municipal potable water system.
- The cost of a rainwater harvesting system is approximately $10,000 for 15 m^3 (4,000 gallon) capacity below ground tank, and less for above ground storage, and could supply about 2/3 of the domestic water demands for an average family.
- By diverting roof runoff from the storm sewer, rainwater capture and reuse that includes toilet flushing to draw down the tank year round provides stormwater benefits.
- Combined with toilet flushing, summer outdoor water use from rainwater tank provides major water conservation benefits.

Optimizing Performance

DESIGN & CONSTRUCTION

- To maximize stormwater benefits, a regular, slow decanting of the tank is desired year round. Toilets (and laundry) provide this regular demand. If they are not connected, the tank needs to have a winter 'seep' facility to slowly decant to absorbent landscape or infiltration trench.
- Roof surfaces that are not under trees, and of relatively clean materials (metal or asphalt) are preferred. Green roof is not a desirable source of rainwater harvesting.
- Careful plumbing installation/inspection to avoid cross connection between rainwater and potable water is warranted.
- Minor rainwater treatment to reduce colouration of rainwater will increase user acceptance, in particular for indoor non-potable uses.

Key Eight Rainwater Harvesting System Design Considerations (Exall, K., and T.D. Vassos, 2012)

MAINTENANCE

- Inspect and clean gutters, first flush diverter regularly (spring and fall or more often).
- Maintain non-light conditions in tanks and pipes—this will reduce algae growth.
- Drain and clean tanks and fixtures at least once every three years.

For more information:

www.rdn.bc.ca/cms/wpattachments/wpID2430atID5059.pdf

Infiltration Trench

An Infiltration Trench system is a sub-surface infiltration facility. These systems are often rock retention trenches or 'milk crate' type facilities that hold and infiltrate water into the subsurface soils. The system includes an inlet pipe or water source, catch basin sump, perforated distribution pipe, infiltration trench and overflow to the storm sewer.

Primary Purpose

- Volumetric Reduction and Rate Reduction

Performance Rating

FUNCTIONAL CRITERIA

Best

- Water Quality Treatment

Good

- Volume Control (reduced CSO's)
- Aesthetic Benefits
- Public Education, Culture and Health Values

Limited Benefit

- Biodiversity Benefits

COST CRITERIA

Best

- Land Cost

Good

- Material and Construction Cost
- Maintenance Cost
- Property Value
- Longevity

This tool is suitable for:

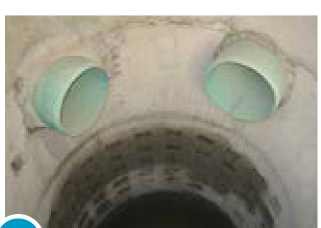
- Commercial Mixed Use
- Industrial
- Institutional
- Local Streets

A properly designed retention trench differs from a rock pit in a number of ways. To prevent the retention trench from clogging over time, the trench is encapsulated in filter fabric to prevent entry of any fine material around and on top of the trench and the stormwater entering the trench via perforated pipes is first treated to remove fines in a sump or through grass filter strips. No pavement/walkway runoff, which may contain pollutants and grit, is allowed to flow directly into the trench. Instead it is also first filtered by a grass area, a filter strip, or a planted swale. The retention trench is sized based on measured infiltration rates of the native soils below the trench and the trench depth is limited to allow it to fully drain between storm events. The retention trench is only used where the seasonal high water table and/or bedrock is well below the bottom of the trench. An overflow pipe is incorporated into the retention trench design to prevent the lawn overtop of the trench from becoming saturated and unusable.

Infiltration Chamber Installation, MEC North Vancouver

Rock Trench Installation with Perforated Pipe, MEC North Vancouver

Precedent examples



1 Whistler Athletes Village Drywell

2 Rock Pit Installation, Squamish Thunderbird Subdivision

3 Atlantis Style Infiltration Chamber, Turtle Mountain

Design Principles, Limitations and Sizing Variables

- Sized to drain completely between storms.
- Rock Trench depth vary from 0.3 m to 2 m deep depending on infiltration capacity of native soils
- Trench must be located 5 m from any building, 1.5 m from property lines and 6 m from adjacent infiltration systems
- Suitable for clean runoff from surfaces such as roofs
- Does not provide water quality, dirty runoff (parking, roads) must be treated prior to being directed to infiltration trench.
- Can be placed under pervious or impervious surfaces (lawns or parking lots)
- Conduct on an on-site infiltration test at the proposed infiltration depth and design the trench based on the design flow and infiltration rate.
- Separation between base of drain rock reservoir and water table should be a minimum of 600 mm
- Trench bottom width is not restricted but is generally between 600 mm and 2400 mm
- Install infiltration trench over native ground and avoid over compaction of the trench sides and bottom to protect the infiltration capacity.
- Scarify infiltration trench base to a depth of 150 mm prior to installation of the rock reservoir.
- Infiltration trench shall include a sump with lid to allow for inspection and cleanout.
- Install infiltration trench with overflow to storm sewer to allow flows in excess of the design flow to pass.
- Avoid utilities and other crossings of the trench. Where utilities cross the trench install trench dams to avid infiltration water following the utility trench.
- More detailed design information can be found at www.metrovancouver.org/about/publications/Publications/01StormwaterSourceControlDesignGuidelinesCover-Intro.pdf

Optimizing Performance

DESIGN & CONSTRUCTION

- Infiltration trenches used for vehicle or pedestrian traveled areas require a water quality pre-treatment system installed ahead of the trench to remove sediment and gross pollutants.
- Preform site-specific infiltration testing and design infiltration basin based on the results of such.
- Site the infiltration trench at least 5 meters from any building footings or foundations

MAINTENANCE

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

For more information: (not to imply a recommendation on suppliers)

www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/08StormwaterSourceControlDesignGuidelinesInfiltrationTrenchSoakawayManhole.pdf

Infiltration Chambers

StormTrap: www.stormtrap.com

Brentwood Industries Storm Tank: www.BrentwoodProcess.com

Hancor LandMax system: www.hancor.com

Triton Stormwater: www.tritonsws.com

Stormtech: www.stormtech.com

Contech: www.conteches.com/products/applications/stormwater-infiltration.aspx

Water Quality Structures

Water quality structures are manufactured BMPs that treat for a variety of pollutants. There are several different kinds of water quality structures including: Oil separators, grit/sediment separators, and filter structures.

Primary Purpose

- Water Quality Treatment

Performance Rating

FUNCTIONAL CRITERIA

Good

- Water Quality Treatment
- Aesthetic Benefits
- Public Education, Culture and Health Values

Limited Benefit

- Volume Control (reduced CSO's)
- Biodiversity Benefits

COST CRITERIA

Best

- Land Cost

Good

- Material and Construction Cost
- Property Value
- Longevity

Limited Benefit

- Maintenance Cost

This tool is suitable for:

- Local Streets
- Collector/Arterial Streets

Oil separators are typically precast tanks with buffer walls or coalescing plates to encourage oil to float to the top of the structure and become trapped behind the buffer or plate. The oil remains floating on the top of the tank until removed by routine maintenance. Oil separators may also collect floating trash.

Grit / sediment separators can take several forms including precast cylindrical tanks which replace manholes in pipe systems or precast tanks. Most separators rely on gravity separation or hydrodynamic separation and settlement of particles. Several of the hydrodynamic separators also collect oil and floating trash. Particles are settled and collect until removed by routine maintenance.

Filter structures can be used to remove the most challenging pollutants from stormwater including nutrients such as phosphorus. Similar to sediment separators, filter structures come in either a precast cylindrical tank or a more traditional shaped precast tank. The filter structures require filter media that must be maintained or replaced regularly.

Installation of a Oil Water Separator - Coast Mountain Bus Company

Copper Valley Oil Interceptor installation (Photo Credit: Langley Concrete)

Precedent examples

1 Oil & Grit Separator, ICBC Salvage Facility, New Westminster

2 MEC Head Office Interceptor, Vancouver

3 Deltaport Multiple Unit Stormceptor

Design Principles, Limitations and Sizing Variables

- They are available in a variety of sizes and are sized based on maximum treatment flow.
- Any flow above the designed treatment flow is bypassed either by an upstream bypass or an in structure bypass.
- Work with product manufacture to ensure product is properly sized and selected for site and runoff composition.

Optimizing Performance

DESIGN & CONSTRUCTION

- Ensure proper design flow and move unit off line if peak flows are expected to exceed desired treatment flow to prevent wash though and other problems

MAINTENANCE

- Inspect annually and clean as required. Sediment should be removed from the structure bottom and floatables removed from the water surface. Vacuum truck should be used to dispose of any oil/hydro carbons within the unit.
- Change any filter media / cartridges as needed or as recommended by manufacture

For more information: (not to imply a recommendation on suppliers)

Proceptor by Green Turtle: www.greenturtletech.com/introduction-to-proceptor.php
Imbrium: Stormceptor, Jellyfish, Sorbtive media: www.imbriumsystems.com/
Contech: Vortech, Vortsentry, Jellyfish, VortClarex: www.conteches.com/products/stormwater-management/treatment.aspx
Armtec: www.armtec.com/products/stormwater-management/

Detention Tanks

Detention tanks collect and store stormwater runoff during a storm event, then release it at controlled rates to the downstream drainage system, thereby attenuating peak discharge rates from the site. With such systems in place, a drainage system can cater for high intensity rainfall events. Detention tanks may be located above or below ground. Detention systems can address a number of stormwater related issues such as: flood protection, erosion and aquatic habitat.

Primary Purpose

- Reduce the risk of flooding and erosion downstream of the detention tanks for major storm events

Performance Rating

FUNCTIONAL CRITERIA

Good

- Aesthetic Benefits

Limited Benefit

- Volume Control (reduced CSO's)
- Water Quality Treatment
- Biodiversity Benefits
- Public Education, Culture and Health Values

COST CRITERIA

Best

- Land Cost

Good

- Maintenance Cost
- Longevity

Limited Benefit

- Material and Construction Cost
- Property Value

Detention Tank Installation, MEC Head Office

This tool is suitable for:

- Commercial Mixed Use
- Industrial
- Institutional

Precedent examples

1 UBC Detention Tank Installation

2 StormTrap Detention Installation
(Photo credit: Sustainable Technologies Evaluation Program)

Design Principles, Limitations and Sizing Variables

- To determine if detention tank systems are required for a site by looking at municipal or LEED requirements.
- Determine the pre-development flow pattern and volume for the site.
- The tank should be designed based on the size of the development, degree of detention required and specific criteria for post development flows.
- Design tank to meet criteria for post-development flows.
- Typical Peak Discharge Criteria
  - » **Flood/Erosion Protection:** Control the post-development to pre-development levels for the 5-year return period.
  - » **Aquatic Habitat Protection (DFO) :** 6-MONTH Volume Reduction and Water Quality treatment and flow control 6-month, 2-year, and 5-year 24-hour post-development flows to pre-development levels.
- Detention requirements can be estimated by various methods including: the rational method, SCS (U.S. Soil Conservation Service) unit hydrograph and level pool routing as examples.
- The selection of the method of analysis depends on the size of the development and the intended application of the results.
- Most analysis should be done or reviewed by a Professional Engineer.
- Underground detention can be provided by tanks or pipes or culverts that are designed to be oversized.
- Discharge either by gravity or through pumping. In order to ensure that detention volume is available for the next storm event.
- A pre-treatment sump is required to remove sediments in the runoff.
- Provide an overflow to allow larger storms to overflow the tank.
- Tank should be designed to allow for access for maintenance or cleaning.
- All underground tanks should have an air space equal to 20% of the maximum depth, connected to the atmosphere by a vent.
- The maximum depth is a function of safety and convenience of users. A depth of over 2 meters is not recommended.
- Undertone tanks must have a minimum of 0.5 meters of cover and must be capable of handing the loads from the surface above.
- More detailed information can be found at: Metro Vancouver Best Management Practices Guide: www.metrovancouver.org/about/publications/Publications/BMPVol1a.pdf

Optimizing Performance

DESIGN & CONSTRUCTION

- To maximize stormwater benefits, detention to pre-development conditions is preferred.
- Many pre-cast concrete vaults exist that can be utilized for detention tanks.

MAINTENANCE

- Inspect manhole/tank annually and clean as required. Sediment should be removed from the tank bottom and floatables removed from the water surface.
- Maintain any sumps or upstream pre-treatment regularly to ensure proper operation.

For more information: (not to imply a recommendation on suppliers)

ZCL: www.zcl.com/products/water-products.html

Langley Concrete: www.langleyconcretegroup.com/

Barr: www.barrplastics.com

Armtech: www.armtec.com

StormTech: www.stormtech.com/

Cultech: www.cultec.com/stormwater-systems.html

Storm Chamber: https://www.layfieldgroup.com/Geosynthetics/Storm-Water-Control-Products/StormChamber-Arch-System.aspx

Contech: www.conteches.com

StormTrap: www.stormtrap.com

Hancor: www.hancor.com

Daylighted Streams

In the City of Vancouver, all but two of the historic streams flow through storm sewers before discharging into the Fraser River, Burrard inlet, False Creek or English Bay. Daylighting of historical streams creates essential habitat for aquatic life, contributes to the liveability of a neighbourhood and provides a sense of place.

Primary Purpose

- To contribute to the liveability, sense of place, and environmental education of residents and providing needed habitat for birds, small mammals, amphibians and other wildlife within the urban environment

Performance Rating

FUNCTIONAL CRITERIA

Best

- Habitat Creation
- Biodiversity Benefits
- Increased Liveability

Good

- Flood Control

Limited Benefit

- Water Quality Treatment

COST CRITERIA

Best

- Property Values
- Longevity

Good

- Material & Construction Costs

Limited Benefit

- Land Acquisition Cost
- Stream Maintenance

Daylighting of streams should be undertaken in areas where maximum benefit (i.e. maximized habitat creation) can be achieved.

This tool is suitable for:

- Parks and Green Space
- Commercial Mixed Use
- Industrial
- Institutional

Design Principles, Limitations and Sizing Variables

- Determine flow patterns.
- Design the channel to convey the 100 year event as well as maintaining adequate depths and flows for aquatic species during summer
- Create complexity within the channel (use large woody debris, boulder clusters, weirs and vegetation to mimic the natural environment)
- Provide a riparian margin planted with woody vegetation to provide shade to the stream as well as creating further habitat for birds and other wildlife
- Provide appropriate armouring at storm outfalls into the daylighted creek
- Have a geotechnical assessment done.
- Is there soil contaminant issues?
- Is stability an issue?
- Utilize catchment metrics to determine the suitability of daylighting
  - » Total impervious area
  - » Catchment flow characteristics
  - » Available stream corridor width

Optimizing Performance

- Undertake public consultation to give a sense of ownership to the community and to understand what is driving the project
- Utilize landscape architecture and fish biology principles early. Determine the correct species to plant given design objectives, site conditions, and desired maintenance levels. Incorporate habitat features into the design and plantings
- Plan for follow-up and repair to stream features as the daylighted reach evolves throughout the first few seasons. Prepare an operation and maintenance manual to manage and maintain the stream and riparian buffers after construction.

For more information:

www.americanrivers.org/newsroom/resources/daylighting-streams-breathing-life-into-urban-streams-and-communities/

Constructed Wetlands

Engineered stormwater treatment wetlands are a series of shallow ponds connected by an engineered marsh system designed to treat contaminated stormwater through the biological processes associated with emergent aquatic plants and via sedimentation. Treatment wetlands typically are not designed to provide stormwater detention as the area required for both treatment and detention is usually in excess of what is available (approximately 3–5% of the catchment area).

Primary Purpose

- Treat stormwater runoff through natural processes prior to discharge into the receiving waters

Performance Rating

FUNCTIONAL CRITERIA

Best

- Water Quality Treatment
- Habitat Creation
- Biodiversity Benefits

Good

- Aesthetic Benefits
- Peak Flow Reduction for Frequent Events

Limited Benefit

- Volume Control (reduced CSO's)

COST CRITERIA

Best

- Longevity

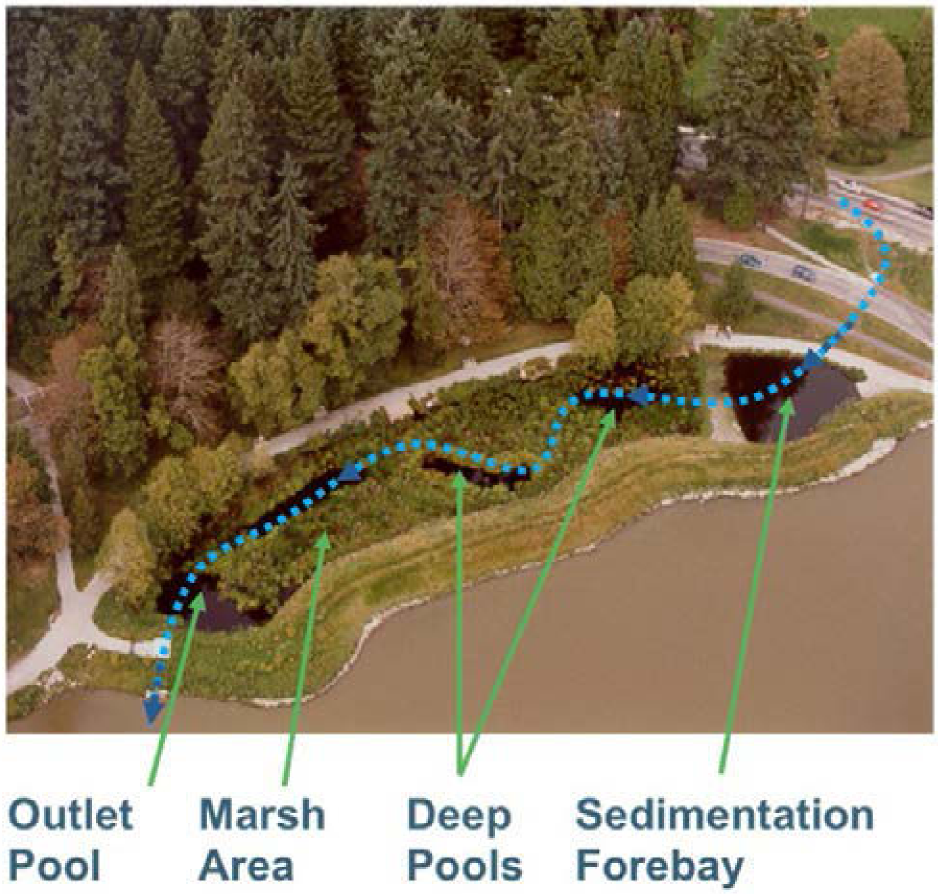
Good

- Construction Costs

Limited Benefit

- Land Cost
- Maintenance Cost

Wetlands collect, detain and treat stormwater runoff during storm events and release it into the receiving environment. Properly constructed wetland systems provide a high level of contaminant removal through sedimentation and biological uptake. Wetlands can also benefit issues such as flood protection, stream erosion, habitat creation and protection.



This tool is suitable for:

- Parks & Greenspace
- Industrial
- Institutional

Design Principles, Limitations and Sizing Variables

- The wetland location should be chosen to provide continual flow throughout the year so as not to allow stagnation.
- Typical Design Criteria
  - » Water Quality Treatment Size forebay to allow sediment to settle out (~80% TSS removal) Size wetland to hold 90% of average annual rainfall runoff
- Wetlands can be land intensive because they are shallow facilities
  - » Minimum 65% of the pond should be less than 450 mm deep allowing for vegetation growth and contaminant uptake
  - » Depths should vary (25% > 1.2 m deep, 65% < 450 mm deep, 35% < 150 mm deep)
- A sediment forebay of 10% of the total wetland area

- Length to width ratio of 3:1 to 5:1
- Recommended side slopes 5:1 (H:V) or flatter
- Permanently wetted area should be approximately 72% of the runoff from a 2-year 24-hour rainfall event
- Analysis should be done or reviewed by a professional engineer
- Select plant species for survival rather than contaminant uptake
- Use a professional to determine the correct plants for each of the zones (wet to dry)

Optimizing Performance

- Location should be chosen to ensure a large enough catchment for continual flow though the dry season (June – September)
- Design wetland to mimic natural systems (varying depths, islands, high marsh peninsulas)
- Minimize flow velocities to minimize sediment re-entrainment and erosion
- Intersperse open water with marsh
- Limit extended detention depth (live storage) to 1m or less to protect plants

For more information:

www.saskatoon.ca/sites/default/files/wetlands_design_guidelines.pdf

www.env.gov.bc.ca/wld/documents/bmp/wetlandways2009/Wetland%20Ways%20Ch%2010%20Development.pdf

www.env.gov.bc.ca/wld/documents/bmp/wetlandways2009/Wetland%20Ways%20Ch%2011%20Enhancement.pdf

2.0 TOOL PERFORMANCE AND SUITABILITY

Performance Rating

A Performance Rating is provided as a summary of how each tool compares with others in the Toolkit.

The general Performance Rating is a summary of 10 criteria, which are organized in two groups: Function and Cost. The 'Considerations in Evaluating Performance' section provides a detailed description of how the criteria apply to the specific conditions of the City of Vancouver Citywide study area.

Considerations in Evaluating Performance

Vancouver's Citywide IRMP is different than many other watershed-based stormwater management plans, in that the Vancouver study area is entirely serviced with piped stormwater systems. Whereas most IRMPs would aim to protect the water quality and hydrological flow systems of streams, the Citywide IRMP is focused on managing piped systems that discharge to tidal or estrarine receiving waters.

In this context, there is a need for the Citywide IRMP to revisit common criteria for evaluating performance of stormwater best management practices (BMPs) or alternative combinations of BMPs.

The primary criteria relevant to the Citywide IRMP are discussed below in two groups: functional criteria and cost criteria.

Functional Criteria

- Maximize Water Quality Treatment
- Maximize Volume Control (reduced CSOs)
- Maximize Aesthetic Benefits
- Maximize Biodiversity Benefits
- Maximize Public Education, Culture, and Health Values

Cost Criteria

- Minimize Land or Space Cost
- Minimize Material and Construction Cost
- Minimize Maintenance Cost
- Maximize Property Value
- Maximize Longetivity

Functional Criteria

The functional Criteria compare how well the proposed Best Management Practice would provide a functional benefit. These objectives may be set out at the federal, provincial or local level, or be encouraged by non-government stakeholders and the general public in engagement events.

MAXIMIZE WATER QUALITY TREATMENT

A primary driver in rainwater management in Vancouver's Citywide area is to maintain the water quality of receiving waters. This is particularly important where receiving waters are sensitive, including:

- Areas with reduced dilution or dispersion of pollutants, such as False Creek
- Areas with high habitat values, such as shorelines of the Fraser River;
- Areas with sensitive recreational use, such as beaches along Kitsilano, West End and Jericho.

The City also needs to meet Water Quality Guidelines that are established under senior levels of government, and in particular under the Metro Vancouver Liquid Waste Management Plan. A Monitoring and Adaptive Management Framework under consideration between Metro Vancouver and the Province of BC will call for regular monitoring and corresponding

False Creek is the receiving body for several stormwater outfalls

action to meet prescribed targets for quality of water at outfalls to receiving waters. Specific water quality parameters of concern for piped stormwater include:

- Turbidity, which results from erosion of sediments, often from construction activities or materials tracked on to paved surfaces. These suspended solids impact the gills and food visibility for fish, and can settle in and smother the life on the bed receiving waters.
- Nitrate (Nitrogen), often from fertilizers or animal feces.
- Indicator bacteria (e.g. Enterococci and E. coli) that may indicate the stormwater is contaminated by sanitary waste (e.g. from cross-connections at houses) but can also be due to feces from animals (e.g. dogs, geese, and ducks) or bacteria growing on decaying vegetation (e.g. organic material accumulation in catch basins).
- Metals, including iron, copper, lead, zinc and cadmium, which commonly in urban are associated with metal corrosion, vehicle exhaust and brakes/rotors, as well as roof and drainage metal components.
- Hydrocarbons from oil drips in parking areas and atmospheric fall-out of exhaust and other emissions.
- Secondary concerns in tidal receiving waters are high pH (e.g. concrete wash water), elevated water temperature, and low dissolved oxygen concentrations.

In practical terms in the Citywide study area, these water quality objectives create a need to:

1. Provide full sediment and erosion control during construction, and control of wash water.
2. Avoid surface runoff from fertilized landscape areas into the storm sewer system.
3. Proceed with the separation of stormwater from combined sewers, eliminate combined sewer overflows, and find/repair sewer cross-connections.
4. Intercept rainwater that comes into contact with trafficked areas (vehicle parking in particular) and treat runoff from these areas to remove hydrocarbons and heavy metals.
5. Provide regular catch basin maintenance in sewer-separated areas to reduce downstream microbiological contamination.
6. Educate and enforce pollution control standards from point source pollution sources like industrial operations or fueling stations.
7. Give priority to water quality actions in areas where sewer separation is leading to outfalls to surface receiving waters (e.g. Trout Lake, recovered streams, or sensitive tidal waters).

MAXIMIZE VOLUME CONTROL (REDUCED CSOS)

In less urbanized watersheds outside the Citywide study area, Integrated Stormwater Management Plans would pay special attention to the volume of stormwater in order to reduce impacts on receiving streams, flood plains and wetlands. However, at present the Citywide study area, does not have these types of receiving waters that are sensitive to the rate and volume of runoff.

The City has an established program to separate combined sewers into separated systems of sanitary and storm sewers. As this program is implemented over the next 35-50 years, there will be new outfalls for stormwater that will fall directly into tidal and estuarine receiving waters around the City. When these stormwater outfalls become active, the Water Quality criteria listed above will become paramount in importance. The volume of stormwater entering tidal receiving waters is, however, not considered a criterion of concern among senior government agencies.
However, until such time as separated sewers are completed, there will be continuing combined sewer overflows (CSOs). Reductions in stormwater volume in this interim period will reduce the frequency and size of these CSO events.

There is therefore a benefit to actions that reduce impervious area, or redirect stormwater to areas where it can soak in or be stored. Modelling (Effectiveness of Stormwater Source Control, GVSDD, CH2M Hill, December 2002) shows that these 'stormwater source controls' can play a significant role in reducing the peak flows from summer cloudbursts, and in reducing the load on the piped stormwater system - having the effect of providing additional capacity to allow for climate-related changes in rainfall patterns.

In summary for the Citywide study area, rainwater volume objectives are:

1. Continue with the separation of combined sewers into separate sanitary and stormwater sewer systems.
2. Although stormwater source controls may be driven ultimately by water quality considerations, recognize the benefits in reducing CSOs in the short term, and providing resilience against climate change in the long term.

MAXIMIZE AESTHETIC BENEFITS

The recognition of Vancouver as one of the most desirable places to live on earth is the result of many factors, but the aesthetics of the City is a major component.

Stormwater Best Management Practices that add to the beauty of the city provide an important function. Examples of aesthetic objectives include:

1. Maintaining or enhancing the urban forest and tree cover of the City.
2. Choosing other surface plantings that provide visual interest, including shrubs, groundcovers and flowers.
3. Providing lawn areas and open spaces.
4. Including attractive pavement texture, colour and articulation that provide a comfortable pedestrian or cycling environment.
5. Celebrating the presence of rainfall and surface water, and its reflective, movement and ephemeral qualities.
6. Preventing the eutrofication of streams and receiving waters.

MAXIMIZE BIODIVERSITY BENEFITS

Stormwater elements that support a variety of habitats also add to the value of the City. Examples of biodiversity objectives include:

1. Increasing the presence of surface water streams, wetlands, and sylvan or intermittent ponds and pools.
2. Providing a variety of water and riparian habitats for birds, bees, dragonflies, butterflies and other compatible urban wildlife.
3. Restoring, where possible, fish habitat in the City.

MAXIMIZE PUBLIC EDUCATION, CULTURE AND HEALTH VALUES

The citizens of Vancouver are highly educated and involved in their City. Many community groups and individuals are actively pursuing:

1. School and public education programs and events that reconnect Vancouver citizens with nature and natural systems. Often these programs include a public art component.
2. Cultural programs and events that bring people outdoors and build neighbourhood community. Green Streets is a good example of volunteer-based community involvement that often involves a stormwater component.
3. Additional amenity along Greenways and Streets to encourage active and healthy transportation like walking, running, cycling.

Cost Criteria

Cost considerations of a stormwater Best Management Practice is not limited to its capital and maintenance costs. With very high land values in the City of Vancouver, and the trend towards increasing density, BMPs need to be effective with minimal land area, and in locations (e.g. street edges or front/side yards) where transportation or building area is not impacted. BMPs also need to consider the potential impact on property value (positive or negative). Property and land value impacts of these BMPS may in many cases be the most significant financial consideration, in particular on private property.

MINIMIZE LAND OR SPACE COST

With extraordinarily high land values, anything in Vancouver that requires dedicated land that would displace economic uses is a significant cost. The space objectives for stormwater source controls in the Citywide area include:

1. Creating multiple benefits of a given space by layering other uses (e.g. parking, building, circulation or open space uses, traffic calming) under or over stormwater functions.

2. Incorporating stormwater into buildings, either on rooftops or in tanks, minimizing the structural costs of accommodating the stormwater.

3. Integrating stormwater functions into landscape setback and amenity areas, and biodiversity areas as much as possible, so that there is minimal reduction in 'buildable area' that is an essential measure of land value.

MINIMIZE MATERIAL AND CONSTRUCTION COST

The lowest cost BMP is not always the best performing BMP. Cost objectives include:

1. Giving priority to BMPs that provide efficient benefits for the cost.

2. Considering the 'incremental cost' of the stormwater benefit, as opposed to costs which may be incurred for other reasons. For example the costs of street tree wells may be largely driven by the need to provide adequate soil volumes for tree growth and to avoid root sidewalk damage, as opposed to being driven by stormwater objectives. Similarly, the cost of a green roof may be aesthetically driven, or for energy and heat island reasons, rather than purely for stormwater benefits.

3. Considering the waste management aspects of a practice – how much deconstruction is required and corresponding solid waste? Are there opportunities to reuse materials like topsoil, organics and compost?

MINIMIZE MAINTENANCE COST

The cost of maintenance and operations is of great concern. Objectives include:

1. Isolating the 'incremental cost of maintenance' related to stormwater functions. What maintenance would be required even without the stormwater aspects of the best management practice? How often is maintenance required?
2. Considering the traffic management impacts of maintenance. Is machine access needed?
3. Determining what maintenance activities could be combined with other routine maintenance to increase efficiency.
4. Determining if the City has the equipment needed to undertake the maintenance?
5. Determining if there is specialized expertise needed to provide maintenance, or is it well-known practices.
6. Determining the current role of volunteers, fronting property owners and/or contract labour. What is the future role?

Infiltration bulges throughout Vancouver enhance the aesthetic quality of city streets.

MAXIMIZE PROPERTY VALUE

Whereas taxes and fees are commonly a concern, in the case of Vancouver's Citywide area a minor percent effect on property value can be a very large sum. Objectives in considering the relationship of stormwater BMPs to property value include:

1. Maintaining the high visual and functional quality of streetscapes, street trees and visible areas
2. Avoiding urban decay, or areas of unsightly, weedy or unkempt areas where they front highly maintained private settings (naturalized areas are more acceptable when backed by natural settings).
3. Treating 'utilities' as part of the urban fabric, and integrating them into architecture, street furniture and public art
4. Avoid flooding outside infiltration areas, in vehicle and pedestrian traffic areas, and around buildings.

MAXIMIZE LONGEVITY

If a stormwater BMP has a long service life, it may be worth more initial investment than otherwise. Life-cycle considerations include:

1. Selecting BMPs that have a service life that matches or exceeds the street or development in which they are situated.
2. Considering the consequences of inadequate maintenance or operational errors – is the practice resilient?

Summary of Tool Advantages and Disadvantages

The 10 criteria above are shown on each Toolkit factsheet and are split into three categories based on how they perform in relation to the BMP:

- Best: The criterion provides a high functional benefit in meeting public objectives and/or reducing costs.
- Good: The criterion provides a moderate functional benefit in meeting public objectives and/or reducing cost.
- Limited Benefit: The criterion has limited benefit to the overall performance of the BMP.

The Performance Rating provides an overall summary of how each tool compares with other tools in isolation. Table II-2 summarizes how BMPs are suitable for land uses. Note that exceptions to these ratings will occur on specific site and land use situations.

Most important is how the tools work together as a system at the City-wide and drainage basin scales (i.e., what is the optimum combination of tools for each land use typology?). Refer to the Technical Background Report for related scenarios and analysis of tool combinations.

Table II - 2: Summary of BMP Suitability for Land Uses

LEGEND

- Green: BEST SUITABILITY
- Yellow: GOOD SUITABILITY, BUT WITH CONSTRAINTS
- Red: LIMITED BENEFIT, OR NOT APPLICABLE

TOOL	PERFORMANCE RATING (varies by site)	LOW DENSITY (one/two family & lane housing)	MEDIUM / HIGH DENSITY	COMMERCIAL MIXED USE	INDUSTRIAL
Absorbent Landscapes	4.4	Best suitability	Best suitability	Best suitability	Best suitability
Infiltration Swales	3.7	Best suitability: Infiltration swale along narrow linear strips (i.e. along the side of the house) to capture roof drainage, etc.	Best suitability: Infiltration swale along boulevards & along parking lots	Best suitability: Infiltration swale along boulevards & along parking lots	Best suitability: Infiltration swale along parking lots
Rain Gardens & Infiltration Bulges	4.3	Best suitability: Install rain gardens at natural low points of property in place of regular shrub beds	Best suitability: Install rain gardens at natural low points of property in place of regular shrub beds	Best suitability: Install rain gardens at natural low points of property in place of regular shrub beds	Best suitability: Install rain gardens at natural low points of property in place of regular shrub beds
Pervious Paving	3.3	Best suitability: Driveways, walkways, patios	Best suitability: Parking, walkways, patios	Best suitability: Parking, walkways, patios	Limited benefit, or not applicable: Staff parking areas (away from sediment sources)
Green Roofs	3.6	Good suitability, but with constraints: Desirable, but cost of adequate soil depth for rainwater management may be prohibitive in many cases	Best suitability: Intensive Green Roof recommended for rainwater management over parking garages	Best suitability: Intensive Green Roof recommended for rainwater management over parking garages	Best suitability: Intensive Green Roof recommended for rainwater management over parking garages
Tree Well Structures	3.7	Limited benefit, or not applicable: Not applicable	Best suitability: Along boulevard where space restrictions prevent adequate tree soil volume to be achieved	Best suitability: Along boulevard where space restrictions prevent adequate tree soil volume to be achieved	Good suitability, but with constraints: Cost and available space may promote tree planting without tree wells

INSTITUTIONAL	PARKS & GREENSPACE	LANES	LOCAL STREETS	COLLECTOR / ARTERIAL STREETS
		Potential 'country lanes' approach		
Infiltration swale along boulevards & along parking lots	Infiltration swale along parking edges	Not applicable	Infiltration swale along boulevards & medians at time of tree replacement	Infiltration swale along boulevards & medians at time of tree replacement
Install rain gardens along buildings and/or in open space. Bulges within internal streets	Install rain gardens in open space at natural low points and within parking lots	Not applicable	Install rain gardens at natural low points of streets or above intersections	Likely limited by available space
Parking, walkways, patios	Parking, walkways	Potential 'country lanes' approach	On-street parking bays	Not applicable
Showcase green roofs on University campus buildings, hospitals, & other institutions	Community Centres, Interpretive Centres	Not applicable	Not applicable	Not applicable
Along pedestrian corridors & internal roads where space restrictions / paving prevent adequate tree soil volume to be achieved	Cost and available space may promote tree planting without tree wells	Cost and space would prohibit using this tool in laneways	Generally the boulevard on a local street has adequate soil volume for tree planting	Along boulevards & paved medians where space restrictions / paving prevent adequate tree soil volume from being achieved

Table II - 2: Summary of BMP Suitability for Land Uses (continued)

LEGEND: BEST SUITABILITY (green) | GOOD SUITABILITY, BUT WITH CONSTRAINTS (yellow) | LIMITED BENEFIT, OR NOT APPLICABLE (red)

TOOL	PERFORMANCE RATING (varies by site)	LOW DENSITY (one/two family & lane housing)	MEDIUM / HIGH DENSITY	COMMERCIAL MIXED USE	INDUSTRIAL
Detention Tanks	2.3	LIMITED BENEFIT, OR NOT APPLICABLE	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Used when there is not adequate surface area for ponding infiltration	BEST SUITABILITY: Used when there is not adequate surface area for ponding infiltration	BEST SUITABILITY: Used when there is not adequate surface area for ponding infiltration
Water Quality Structure	2.8	LIMITED BENEFIT, OR NOT APPLICABLE	LIMITED BENEFIT, OR NOT APPLICABLE: Soil and plant-based BMPs are preferred. Use WQ structural only as last resort	LIMITED BENEFIT, OR NOT APPLICABLE: Soil and plant-based BMPs are preferred. Use WQ structural only as last resort	LIMITED BENEFIT, OR NOT APPLICABLE: Soil and plant-based BMPs are preferred. Use WQ structural only as last resort
Infiltration Trench Engineered underground structures suitable for large-scale developments	3.6	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Use only for roof drainage or after pre-treatment of parking runoff	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Use only for roof drainage or after pre-treatment of parking runoff	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Use only for roof drainage or after pre-treatment of parking runoff	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Use only for roof drainage or after pre-treatment of parking runoff
Rainwater Harvesting	3.0	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Gain advice on plumbing and treatment for toilet aesthetic considerations	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Gain advice on plumbing and treatment for toilet aesthetic considerations	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Gain advice on plumbing and treatment for toilet aesthetic considerations	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Gain advice on plumbing and treatment for toilet aesthetic considerations
Daylighted Watercourses / Constructed Wetlands	3.0	LIMITED BENEFIT, OR NOT APPLICABLE: Inadequate space	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Ensure sufficient drainage area for summer base flow, or design to be seasonally dry	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Ensure sufficient drainage area for summer base flow, or design to be seasonally dry	GOOD SUITABILITY, BUT WITH CONSTRAINTS: Ensure sufficient drainage area for summer base flow, or design to be seasonally dry

INSTITUTIONAL	PARKS & GREENSPACE	LANES	LOCAL STREETS	COLLECTOR / ARTERIAL STREETS
Used when there is not adequate surface area for ponding infiltration	Cost and available space may promote tree planting without tree wells	Cost and space would prohibit using this tool in laneways	Generally the boulevard on a local street has adequate soil volume for tree planting	Along boulevards & paved medians where space restrictions / paving prevent adequate tree soil volume from being achieved
Soil and plant-based BMPs are preferred. Use WQ structural only as last resort	Use soil and plant-based BMPs		Installed on local streets only where space for other treatments is not available	Installed on collector / arterial streets where space is an issue and / or parking cannot be compromised
Use only for roof drainage or after pre-treatment of parking runoff	Use only for roof drainage or after pre-treatment of parking runoff			
Gain advice on plumbing and treatment for toilet aesthetic considerations				
Ensure sufficient drainage area for summer base flow, or design to be seasonally dry	Ensure sufficient drainage area for summer base flow, or design to be seasonally dry	Cost and space would prohibit using this tool in laneways	May be considered on extemely low volume streets or unused rights of way	Cost and space would prohibit using this tool in collector/arterial streets, unless there are large medians or boulevards

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facilitate double-sided booklet printing.

Assumptions and Limitations

The analysis and recommended actions in this document are based on review of currently available information, and are in accordance with current planning and engineering practice.

Readers should note the following limitations:

1. Maps and quantities shown are based on 'sample areas' that are representative of the pattern of conditions across the study area. Actual total quantities may vary.
2. Where unit costs or quantities are shown, these are approximate 2014 dollars CDN suitable for comparison of options, and based on little or no site information, and therefore only accurate within a range of plus or minus 30% (Class D). No warranty is implied or given on accuracy of quantities or unit costs for any given project.
3. Mapping is based on data and polygons from a variety of sources, and is schematic in nature. No warranty is made as to accuracy of map information.
4. Infiltration rates discussed are theoretical based on typical rates in assumed soil conditions, sufficient for general option comparison and policy guidance. Users are advised to gain site-specific hydrotechnical advice as a basis for detail design.
5. Where design detail guidelines are provided, the information is intended as an introduction. Readers are guided to the technical reference documents listed as References in IRMP Volume II and III for more information. In all cases, it is required that professional site-specific design and construction management advice should be sought to customize application of these best practices to a specific site and land use situation.

Notes:

Notes:

CITY OF VANCOUVER

GREENEST CITY

Golder Associates

Sustainable Communities