Bioretention

Bioretention refers to vegetated stormwater practices that temporarily store roof and pavement runoff in depressed planting beds or vertical-walled structures.

Depending on native soil infiltration rate and physical constraints, the facility may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only (i.e., a stormwater planter or biofilter) design.

Bioretention can be adapted to fit into many different development contexts and provides a convenient area for snow storage and treatment.

PLANNING

Native Soil | Bioretention can be constructed over any soil type, but hydrologic soil group A and B are best for achieving water balance objectives. Facilities designed to infiltrate water should be located on portions of the site with the highest infiltration rates. For infiltration rates <15 mm/h an underdrain is recommended. Native soil infiltration rate at the proposed location and depth should be confirmed through in-situ measurements of hydraulic conductivity under field saturated conditions.

Wellhead protection | Facilities receiving road or parking lot runoff should not be located within 2 yr time-of-travel WHPA[1] (refer to drinking water source protection plan).

Available space | Reserve open space equal to roughly 10 to 20% the size of the CDA[1].

Site topography | Contributing slopes should be 1 to 5%. The filter bed surface should be flat to allow flow to spread out. A stepped, multi-cell design can also be used.

Available head | If an underdrain is used, then an elevation difference of 1 to 1.5 m is needed between the inverts of the inlet and the downstream storm sewer.

Water table | Maintaining a separation of 1 m between the elevations of the bottom of the practice and the seasonally high water table, or top of bedrock, is recommended. Lesser or greater values may be considered based on groundwater mounding analysis. See STEP LID Planning and Design Guide for further guidance and spreadsheet tool.

Pollution hot spot runoff | To prevent groundwater contamination, runoff from pollution hot spots should not be treated by bioretention facilities designed for full or partial infiltration. Filtration only facilities (with an impermeable liner) can be used.

Proximity to underground utilities | Designers should consult local utility design guidance for the horizontal and vertical clearances required between storm drains, ditches, and surface water bodies.

Karst | Infiltration designs are unsuitable in areas of known or implied karst topography.

Overhead wires | Check whether the future tree canopy height in the bioretention area will interfere with existing overhead wires.

Setback from buildings | If an impermeable liner is used, no setback is needed, although designing to maintain drainage away from the building is crucial. Where no liner is used, a setback of 4 m from the building foundations should be applied.

CONSTRUCTION

Where possible, bioretention areas should be kept offline until construction is complete, the drainage area stabilized, and vehicle mud tracking has stopped. Diverting flows around the facility offers several benefits, including: (i) less risk of erosion, clogging, and compaction, (ii) greater opportunity for establishment of seeded/planted areas, and (iii) easier access for construction, repairs or maintenance of the area.

Where diverting flows around the facility is not possible, and its location requires that it be used as a temporary runoff detention basin, protection measures can prevent fine sediment from migrating into the subgrade. During construction, the area should only be excavated to 75 cm above the final post-construction base of the facility. This layer of native soil will retain fine particles so that they will not migrate down into the subsoils. To prevent compaction during bioretention construction, heavy equipment should not enter the footprint of the bioretention area. For more detailed guidance, see the LID Construction Guide (CVC, 2012) and the ESC Guide for Urban Construction (TRCA, 2019).

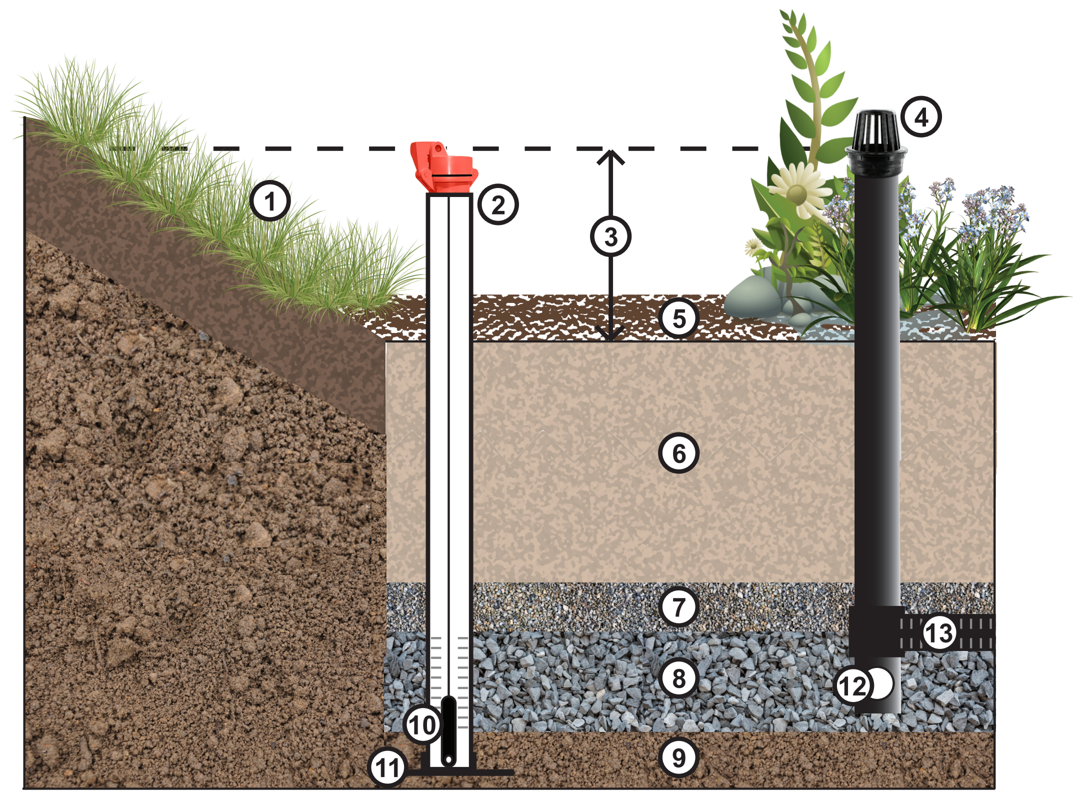
Bioretention design	Ability to meet stormwater criteria		
	Water balance	Water quality	Stream erosion control
No underdrain	Yes	Yes – size for water quality storage requirement	Partial – based on available storage volume and native soil infiltration rate
With underdrain	Partial – based on available storage, native soil infil. rate and if a flow restrictor is used	Yes – size for water quality storage requirement	Partial – based on available storage , native soil infil. rate, and if a flow restrictor is used
With underdrain & liner	Partial – some volume reduction through evapotranspiration	Yes – size for water quality storage requirement	Partial – some volume reduction through evapotranspiration

OPERATION AND MAINTENANCE

Bioretention requires regular, routine inspection and maintenance of the landscaping as well as periodic inspection of other parts of the facility. Routine maintenance should include weeding, pruning, and mulching, similar to other landscaped areas, as well as the removal of trash, debris and sediment accumulated in pretreatment areas, inlets and outlets. Watering may be needed until plant establishment (first 2 yrs.)

Inspections should occur twice annually (spring and late fall) and after major storm events. Inspect for vegetation density (≥ 80% coverage), damage by foot or vehicle traffic, erosion, debris and sediment accumulation, and damage to pretreatment devices.

Cleanouts and access points should be provided to allow clean-out of the underdrain and overflow pipe. Camera inspection of these pipes should be conducted every 5 years to ensure pipes are free of roots, sediment and debris. Hydraulic flushing or root removal may be needed to clear debris or obstructions.



1. Grass filter strip
2. Monitoring well with removable cap
3. Maximum surface ponding depth
4. Overflow outlet
5. Mulch
6. Filter media
7. 6 mm dia. clear stone choker layer
8. 20 mm dia. clear stone
9. Native soil
10. Water level logger
11. Cap stand
12. Outlet pipe
13. Perforated pipe underdrain

Guidance and specifications for bioretention components	
Geometry & site layout	• Min. filter bed area is based on the design storm runoff volume and effective surface ponding depth. Recommended I:P[1] ratios range from 5:1 on low permeability soils (HSG[1] C & D) to 20:1 on high permeability soils (HSG A & B). • Typical CDAs[1] are 100 m^2 to 0.5 ha, and max. recommended is 0.8 ha • Shapes and locations can vary, but linear trench or swale geometries will drain faster than round or square shapes due to larger perimeters. • Min. width of 0.6 m is recommended for plant health, and max. width should not exceed reach of excavator.
Inlets	• Configurations: overland sheet flow, concentrated overland flow, concentrated underground flow (i.e. piped flow) • Distribute concentrated inflows between multiple inlets or facilities to avoid erosion • For concentrated overland flow: (i) draining roads should be located at all sag points in the gutter grade and immediately upgrade of median breaks, crosswalks and street intersections, (ii) types include curb openings, side inlet catchbasins, trench drains, pre-fabricated inlet structures, (iii) spillways aid in turning flow 30, 45 or 90 degrees into the practice, (iv) incorporate concrete aprons at curb opening or spillway locations to increase inflow effectiveness, and (v) Provide a 50 to 100 mm drop in elevation between inlet invert and mulch surface or concrete apron. • For concentrated underground flow: May include pipes from roof drains, catch basins, storm sewers, oil and grit separators (OGS) or outlet leader from an upstream best management practice.
Pre-treatment	Pretreatment prevents clogging by capturing sediment before it reaches the filter bed. It is typically necessary unless runoff sediment loads are very low (e.g. roof drainage). Pretreatment options include: • Level spreader: A shallow trench structure (with concrete, metal or wood lip), graded to be level and installed parallel to the pavement edge or flush curb. Recommended sizing: (i) 1.4 m of length for every 0.01 m^3/s of inflow during the design storm event, (ii) width of 300 mm or 3 times inflow pipe diameter, (iii) depth of 200 mm or half the inflow pipe diameter. Used with any overland flow inlets. • Gravel diaphragm: A shallow, geotextile-lined depression, filled with clean aggregate, graded level and installed parallel to pavement edge (for sheet inflows) or perpendicular to concentrated inflows. Elevation change of 75 to 100 mm from pavement to top of diaphragm. Typically 600 mm wide by 300 mm deep. Stone: 5 to 20 mm (sheet flow inlets) or rip rap for concentrated inflows. Used with overland flow inlets. • Vegetated filter strip: Use where CDA[1] flow path length is ≤ 25 m and slopes are <3%. Min. flow path length of 3 m, with 5 m preferred, and slope between 1 and 3%. Must be graded to provide a 75 to 150 mm elevation drop between the pavement and the filter strip surface. Used with overland sheet flow inlets. • Catchbasin, manhole, or other inlet structure sump: Consider using shield, baffle, trap or filter insert device to increase removal of sediment and debris. Used with overland or underground concentrated inflows. • Forebay: Constructed with 2:1 length to width ratio and sized to accommodate ponding volume of 25% of the surface ponding storage requirement. Used with concentrated overland flow inlets. • Oil and grit (hydrodynamic) separator. Used with concentrated underground flow inlets.
Filter media bed	COMPOSITION: Should come pre-mixed from an approved vendor, be free of stones or debris greater than 50 mm diameter, and meet the following specifications: • Blend A - Use when drainage rate is the priority (when I:P[1] ratio ≥15:1). Consists of 3 parts sand to 1 part organic material/additives. • Blend B – Use when water quality treatment (phosphorus, metals) is the priority and more diverse planting options are desired. Consists of 3 parts sand to 2 parts topsoil to 1 part organic material/additives. REQUIRED PERFORMANCE CRITERIA: (i) saturated hydraulic conductivity (ASTM D2434) at 85% maximum dry density (ASTM D698) of 75 - 300 mm/hr for Blend A or 25 - 300 mm/hr for Blend B, (ii) phosphorus concentration (plant available or extractable) of 10 - 40 ppm, (iii) cation exchange capacity (ASTM D7503) >10 meq/100 g, and (iv) organic matter content of 3 - 10% of filter media by dry weight. COMPONENT GUIDELINES (superseded by required performance criteria where applicable): • Organic material: Should be low in available phosphorus such as leaf and yard waste compost, untreated wood chips, shredded paper, coir. • Sand: Should be coarse and have a fineness modulus index between 2.8 and 3.1 according to ASTM C33/C33M. • Topsoil: Should contain 9 - 39% clay-sized particles, have a sodium absorption ratio < 15, and meet soil quality standards defined in the applicable tables from the Soil, Ground Water and Sediment Standards of Ontario Regulation 153/04. • Additives: Typically 5 to 10% by volume of the filter media blend (follow product manufacturer instructions where applicable). • Particle-size distribution (ASTM D7928): Should be <25% silt and clay combined (smaller than 0.05 mm) and 3 to 12% clay (0.002 mm or smaller). DEPTH: 0.5 to 1.0 m recommended, but in constrained applications pollutant removal benefits may be achieved by beds as shallow as 0.3 m. Plant-specific depths recommended are: 0.3 m for grasses and perennials, 0.6 m for shrubs and 1.0 metre for trees. MULCH: A 75 to 100 mm layer of double shredded wood mulch is recommended on bed surface. Benefits include soil moisture preservation, suppression of weed growth and enhanced water treatment. Erosion-prone inlets may require stone instead of mulch. GRADING: Filter bed must be installed level, with side slopes at max. of 1:3 or 33%. PLANTS: Planting should be dense to help maintain surface infiltration and improve sediment settling and retention of dissolved contaminants. It is recommended that perennial forbs and grasses are planted 0.5 m on center, and no more than 0.6 m on center. Planting plans should feature a mixture of deeply rooting perennials adapted to both wet and dry conditions and local climate. Road salt tolerance should be considered if facility will receive pavement runoff. Native plants are often the most hearty, adaptable, salt tolerant and deeply rooted options for bioretention planting. Invasive plants should not be planted in bioretention areas. See LID Planning and Design Guide (wiki.sustainabletechnologies.ca) for detailed planting guidance.
Geotex-tile	To avoid clogging, the use of geotextile should be avoided exept for a strip over the perforated pipe or on the sides of the bioretention if necessary. For pipes with 360° perforations place a strip of geotextile over the pipe to reduce the migration of fines from overlying media. Geotextile used for weed control (i.e. landscape fabric) in filter bed media or under mulch should be avoided. Geotextile that is used should have material specifications that conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. Should be woven monofilament or non-woven needle punched fabrics.
Choker layer	A minimum 100 mm deep layer of clean 5 to 20 mm diameter angular or rounded stone (e.g. High Performance Bedding, HL-6, pea gravel) should be placed on top of the coarser storage reservoir aggregate to prevent downward migration of filter media into the reservoir and pipe.
Storage reser-voir	Should be a minimum of 300 mm deep, and filled with granular material of washed 25 or 50 mm diameter crushed angular stone (max. wash loss of 0.5%). Include organic material derived from untreated wood (e.g. chips, mulch or shavings) to enhance nitrogen removal. See STEP LID Planning and Design Guide (wiki.sustainabletechnologies.ca) for reservoir sizing guidance, including depth and area of surface ponding and reservoir volume needed to capture and store the design storm.
Underdrain perforated pipe	• Continuously perforated, smooth interior HDPE or PVC pipe with diameter ≥ 200 mm to reduce freezing risk and facilitate access by camera and cleaning equip. Perforated pipe extends length of facility and solid pipe is used to connect to storm drain system. • Caps and couplings: Recommended where native soil infiltration rate is less than 15 mm/h (hydraulic conductivity < $1x10^{-6}$ cm/s) and needed for non-infiltrating designs. Comprised of a length of perforated pipe embedded near the top of the storage reservoir, with an overlying choker layer of medium-sized aggregate, and structures to provide inspection and maintenance access. Alternatively the perforated pipe could be installed on the reservoir bottom and connected to an upturned pipe assembly or riser. Another option is to include a flow restrictor (e.g., orifice cap or valve) on the underdrain outlet pipe, to optimize infiltration while meeting the required drainage time.
Convey-ance & overflow	Bioretention can be designed to be inline (accepts all flow from the drainage area and conveys large event flows through an overflow outlet) or offline (allows only the design storm runoff storage volume to enter the facility). Overflow structures must be sized to safely convey large event flows out of the facility. The invert of the overflow should be placed at the max. water surface elevation of the bioretention cell (typically 150 to 350 mm above mulch surface). In offline bioretention, excess flows are conveyed to a downstream storm sewer or other best management practice by a flow splitting manhole containing a weir and/or overflow outlet pipe, or by by-passing the curb opening and flowing into a downstream catch basin.
Monitor-ing wells & access	• Monitoring well should be a vertical standpipe consisting of an anchored 100 to 150 mm diameter pipe with perforations along the length within the reservoir, installed to the bottom of the facility, with a lockable cap. The well allows monitoring of post-event drainage times. • Access structures, used for inspection and flushing, may be a maintenance hole or vertical standpipe connected to the perforated pipe. Couplings used for standpipe connections should be 45° to facilitate pipe access by camera or cleaning equipment.

Acronyms used:

[1]CDA - Contributing Drainage Area ; OGS - Oil and Grit Separator; WHPA - Wellhead Protection Area; I:P ratio - Impervious area to pervious area ratio; HSG - Hydrologic Soil Group

For more information:

Visit the online Low Impact Development Stormwater Management Planning and Design Guide for more information including links to all sources cited: wiki.sustainabletechnologies.ca.
LID Stormwater Inspection and Maintenance Guide (TRCA, 2016): sustainabletechnologies.ca.
LID Construction Guide (CVC, 2012): sustainabletechnologies.ca.

The water component of the Sustainable Technologies Evaluation Program (STEP) is a collaboration of:

Toronto and Region Conservation Authority,

Credit Valley Conservation, and

Lake Simcoe Region Conservation Authority