APPENDIX A – LOW IMPACT DEVELOPMENT STORMWATER BMP FACT SHEETS
Reducing Impervious Area

Many of the strategies described previously are primarily for the purpose of reducing impervious areas on a macroscale. The following strategies provide examples of how to reduce impervious areas on a micro or lot level scale.

**STRATEGIES**

9. **Reduce building street.** Streets constitute the largest percentage of impervious area and can have the greatest effect on the urban runoff. Street widths are sized for the free flow of traffic and movements of large emergency vehicles. In many cases, such as low-density residential, these widths are oversized for the typical function of the street. Amending urban design standards to allow alternative street patterns can provide impervious area in some situations. There are a variety of ways to accommodate emergency vehicle movements and traffic flow on narrower streets, including alternative street parking configurations, vehicle pullout access on connected street systems, prohibiting parking near intersections, and reinforced turfs or gravel edges.

10. **Reduce building footprint.** Reduce the building footprint by using taller multi-story buildings and taking advantage of opportunities to consolidate services into the same space.

11. **Reduce parking footprints.** Excess parking not only results in greater stormwater and greater roadway drainage maintenance costs but also adds unnecessary construction and maintenance costs and uses space that could be used for a revenue generating purpose.

   • Keep the number of parking spaces to the minimum required. Parking requirements should be related to the typical function of the street. Amending urban design standards to prohibit parking near intersections, and reinforced turf or gravel edges.

   • Use theno parking or park and ride strategies when possible. Where avoiding development on permeable soils is not possible, stormwater impacts and greater stormwater management costs but also adds unnecessary construction and maintenance costs and uses space that could be used for a revenue generating purpose.

Avoid development on permeable soils. Highly permeable soils (e.g., hydrologic soil groups A and B) function as important groundwater recharge areas. To the greatest extent possible, avoid development in an undisturbed condition or set aside for stormwater infiltration practices. Where avoiding development on permeable soils is not possible, stormwater management should focus on mitigation of reduced groundwater recharge through application of stormwater infiltration practices.

4. **Preserve existing trees and tree clusters.** Mature stands of deciduous trees will intercept 10 to 20% of annual precipitation falling on them and a stand of evergreens will intercept 15 to 40%. Preserving mature trees will provide immediate benefits to new developments, whereas newly planted trees will take 10 years or more to provide equivalent benefits. Tree clusters can provide stormwater detention facilities, roof runoff interceptors, private lawns, open space areas, road buffers, and median strips. An uncompacted soil layer of at least 15 cm is recommended to achieve a healthy mature tree with a long lifespan.

5. **Reduce roadway setbacks and lot frontages.** Roadway setbacks and lot frontages are a determinant for the area of pavement, street, driveways, and shared parking. Clustered development also reduces the roadway setback and lot frontages.

6. **Reduce roadway networks.** Certain roadway network designs (e.g., loops, cul-de-sacs, funnel streets) provide less impervious area than other others. These layouts by themselves may not achieve the many goals of urban design. However, used in a hybrid form together with other street patterns, they can meet multiple urban design objectives and reduce the necessary pAVED area thereby reducing the amount of impervious surfaces and stormwater runoff to be managed.

7. **Use innovative street network designs.** Certain roadway network designs (e.g., loops, cul-de-sacs, funnel streets) provide less impervious area than others. These layouts by themselves may not achieve the many goals of urban design. However, used in a hybrid form together with other street patterns, they can meet multiple urban design objectives and reduce the necessary paved area thereby reducing the amount of impervious surfaces and stormwater runoff to be managed.

8. **Reduce roadway setbacks and lot frontages.** The lengths of setbacks and frontages are an important factor for the area of pavement, street, driveways, and walkways, needed to service a development. Municipal zoning regulations for setbacks and frontages have been found to be a significant influence on the production of stormwater runoff.

Soil Amendment Guidelines

Soil amendment sizing criteria:

- **Impervious area / soil area = 1**
- **Use 100 mm compost, till to 300 - 450 mm depth**
- **Soil area / paved area = 2**
- **Use 200 mm compost, till to 300 - 450 mm depth**
- **Impervious area / soil area = 3**
- **Use 300 mm compost, till to 450 - 600 mm depth**

Compact should consist of well-aged (at least one year) leaf compost. Amended soil should have an organic content of 8-15% by weight or 30-40% by volume.

Source: Soils for Roads, 2001

Oil Drainage Applied in a Medium Density Neighbourhood

Source: CWP, 1998

Using Natural Drainage Systems

Rather than creating or allowing stormwater to take advantage of undesirable vegetated areas and natural drainage patterns (e.g., small natural depressions), natural systems will extend runoff flow paths and slow down the flow of the stormwater and vegetations, and they provide more ancillary benefits.

**STRATEGIES**

14. **Disconnect impervious areas.** Road networks that have cul-de-sacs, dead ends, sidewalks, and patios should be discouraged or prohibited. Instead, direct stormwater flow to permeable areas or areas with lower infiltration potential.

15. **Preserve or create micro-topography.** Understory design strategies include the meandering of ditches, hummocks and mounds which slow and store runoff. Site grading smooths out these topographies which makes it easier to store runoff. Snowmelt can be restored in areas of ornamental landscaping or naturalization.

16. **Extend drainage flow paths.** Site grading should be extended so that runoff flow paths allow for additional opportunities for stormwater to be used for irrigation or naturalization. Extended flow travel time can also delay and lower peak flows. Where stormwater flow is conveyed using vegetated open channels (e.g., enhanced grass swales),
GENERAL DESCRIPTION
Rainwater harvesting is the process of intercepting, conveying and storing rainfall for future use. The aim is to recover the surface of which rainfall is collected. Generally, roofs are the catchment area, although rainwater from low traffic parking lots and sidewalks may be suitable for some non-potable uses (e.g., outdoor washing). The quality of the harvested water will vary according to the type of catchment area and materials from which it is constructed. Water harvested from parking lots, sidewalks, and various types of roofs (asphalt shingles, tar and gravel, and wood shingled roofs, should only be used for irrigation or toilet flushing due to potential contamination with organic compounds.

OPERATION AND MAINTENANCE
Maintenance requirements for rainwater harvesting systems vary according to use. Systems should be inspected and cleaned regularly to ensure efficient operation and optimal water quality.

MOSQUITO CONTROL
If screening is not sufficient to deter mosquitoes, vegetable oil can be used to attract larvae. Alternatively, mosquito traps or pellets containing lindane can be used.

WINTER OPERATION
Rainwater harvesting systems have a number of components that can be affected by freezing winter temperatures. For above-ground systems, winter operation may involve the use of frost protection devices. If improperly managed, tanks can create on-ground cisterns have the potential to generate highly contaminated runoff.

SITE CONSIDERATIONS

<table>
<thead>
<tr>
<th>Site Description</th>
<th>Site Impacts</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground cisterns should be placed on or in native, rather than fill soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perimeter of filtration systems should be below ground level to minimize the risk of contamination.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground cisterns should be placed adjacent to the building and within the footprint of the distribution and over-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THE STORAGE TANK
The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. The required size of storage tank is dictated by several variables: rainfall and snowfall frequency and intensities, the intended use of the harvested water, the catchment area, aesthetics, and budget. In the Greater Toronto Area, an initial target for sizing the storage tank could be the predicted rainwater usage over a 10 to 12 day period.

DISTRIBUTION SYSTEM
Most distribution systems are gravity-fed or operated using pumps to convey harvested rainwater from the storage tank to its final destination. Typical outdoor systems use gravity to feed hoses via a tap and spigot. For underground systems, a water pump is needed. Indoor systems usually require a pump, whereas door systems use gravity feed via a tap and spigot. For underground systems, all connections between eavestroughs, conveyance pipes, and the storage tank must prevent entry of small animals or other debris into the storage tank.

CATCHMENT AREA
The catchment area is the surface from which rainfall is collected. Generally, roofs are the catchment area, although rainwater from low traffic parking lots and sidewalks may be suitable for some non-potable uses (e.g., outdoor washing). The quality of the harvested water will vary according to the type of catchment area and materials from which it is constructed. Water harvested from parking lots, sidewalks, and various types of roofs (asphalt shingles, tar and gravel, and wood shingled roofs, should only be used for irrigation or toilet flushing due to potential contamination with organic compounds.

COLLECTION AND CONVEYANCE SYSTEM
The collection and conveyance system consists of the eavestroughs, downspouts, and pipe that channel rainwater into the storage tank. Eavestroughs and downspouts should be designed with screens to prevent large debris from entering the storage tank. For dual-use eavestroughs (used for both outdoor and indoor uses), the conveyance pipe leading to the catchment should be buried at a depth of at least 1.5 m to protect it from freezing. Pipes leading to gutters should have a minimum 1% slope. If this is not possible, pipes should be located in a heated interior environment (e.g., garage, basement) or be insulated with heat tracing to prevent freezing. All connections between downspouts, conveyance pipes, and the storage tank must prevent entry of small animals or other debris into the storage tank.

PRE-TREATMENT
Pre-treatment is required to remove debris, dust, leaves, and other debris that accumulate on catchment surfaces. The treatment system can include first-flush diverters, screening, and filtration. The treatment system should be designed to protect the downstream water quality from contamination with organic compounds.

GENERAL SPECIFICATIONS
- **Component**: Storage Tanks
  - **Specification**: Materials used for construction
  - **Quantity**: Stated in cubic meters
- **Component**: Storage Tanks
  - **Specification**: Storage tanks should be fit for potable use
  - **Quantity**: Stated in cubic meters
- **Component**: Storage Tanks
  - **Specification**: Storage tanks should be lockable
  - **Quantity**: Stated in cubic meters

ABLE TO MEET SWM BENEFITS
- **BMP**: Rainwater Harvesting
  - **Water Balance**: Magnitude depends on water usage
  - **Water Quality Improvement**: Stated in terms of the water quality storage requirement
  - **Stream Channel Erosion Control**: Stated in terms of the water quality storage requirement

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainwater Harvesting</td>
<td>Magnitude depends on water usage</td>
<td>-</td>
</tr>
<tr>
<td>Water Quality Improvement</td>
<td>Stated in terms of the water quality storage requirement</td>
<td>-</td>
</tr>
<tr>
<td>Stream Channel Erosion Control</td>
<td>Stated in terms of the water quality storage requirement</td>
<td>-</td>
</tr>
</tbody>
</table>
GENERAL DESCRIPTION

Green roofs, also known as "living roofs" or "roofs gardens", consist of a thin layer of vegetation and growing medium installed on top of a conventional flat or sloped roof. Green roofs are rooted for their benefits to cities, as they improve energy efficiency, reduce urban heat island effects, and create private spaces for passive recreation or aesthetic enjoyment. They are also attractive for their water quality, water balance, and peak flow control benefits. The green roofs catch the rainwater and use it for irrigation or release it slowly to the surrounding areas.

There are two types of green roofs: intensive and extensive. Intensive green roofs contain plants, their depth of growing medium, can be planted with deeply rooted plants and are designed to handle pedestrian traffic. Extensive green roofs contain plants that self-saturate the growing medium, as well as permeable vegetation cover. Guidance here focuses on extensive green roofs.

DESIGN GUIDANCE

ROOF STRUCTURE

The load bearing capacity of the roof structure must be sufficient to support the soil and plants of the green roof assembly, as well as the live load associated with maintenance staff accessing the roof. A green roof assembly weighing more than 80 kg per square metre, when saturated, requires consultation with a structural engineer. Green roofs may be installed on roofs with slopes up to 19%. As a fire resistance measure, non-vegetative materials, such as stones or pebbles, should be installed around all roof openings and at the base of all walls that contain openings.

WATERPROOFING SYSTEM

The first layer above the roof surface is a waterproofing membrane. Two common waterproofing techniques are monolithic and thermoplastic sheet membranes. The monolithic layer is a waterproof membrane assembly system in which the insulation is placed on the waterproofing, which adheres to the roof structure. The additional protective layer is generally placed on top of the membrane followed by a physical or chemical roof barrier. Once the waterproofing system has been installed, it should be fully tested prior to connecting the drainage or conveyance system. Electronic leak detection systems should also be installed as a first line of defense.

DRAINAGE LAYER

The drainage system includes a porous drainage layer and a geosynthetic filter fabric to prevent fine growing medium particles from clogging the porous media. The drainage layer can be made up of gravel or recycled polyethylene material that acts as capillary rise and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The density of the drainage layer should be greater than or equal to 25%.

CONVEYANCE AND OVERFLOW

Once the porous media is saturated, all runoff (infiltrate or overland flow) should be directed to a traditional roof storm drain system. Landscaping style catch basins should be installed with the elevation raised to the desired ponding elevation. Alternatively, roof drain flow restrictions can be used. Excess runoff can be directed through roof headers to another stormwater BMP such as a rain barrel, swaleway, biofiltration area, open or simply drain to a pervious area.

GROWING MEDIUM

The growing medium is usually a mixture of sand, gravel, crushed brick, compost, or organic matter. The soil ranges between 40 and 150 mm in depth and increases the roof load by 80 to 170 kg per square metre. The growing medium is typically made up of sand, gravel, crushed brick, or recycled-polyethylene materials that are capable of water retention and efficient drainage. The depth of the growing medium depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The density of the growing medium should be greater than or equal to 25%.

COMMON CONCERNS

VEGETATION

Vegetation must be able to withstand the conditions of the roof where it is installed. Extreme weather conditions can have an impact on plant survival. Appropriately selected vegetation can absorb plant damage and keep the roof cool and protected from other damage. Maintenance works to keep the roof in good condition and prevent damage can reduce energy demand by as much as 75%.

ABILITY TO MEET SWM OBJECTIVES

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Storm Channel Erosion Control Benefit</th>
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</thead>
<tbody>
<tr>
<td>Green Roofs</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

GENERAL SPECIFICATIONS

ASTM International released the following Green Roof standards in 2005:

- E2397-05 Standard Determination of Dead Loads and Live Loads Associated with Green Roof Systems
- E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems
- E2400-05 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems

ALTERNATIVE SYSTEMS

Conventional standing seam metal or EPDM rubber membranes are the most common waterproofing materials. Another option is a liquid-applied inverted roofing system, which has a warranty that can ensure that any damage to the waterproofing system will be covered. While failure of waterproofing elements may present a risk of water damage, this risk can be minimized through proper maintenance and regular inspection of the system. Electronic leak detection systemsmy also be installed as a first line of defense.

CONSTRUCTION CONSIDERATIONS

An experienced professional green roof installer is needed to ensure that the installation of a green roof is successful. The installer must work with the construction contractor to ensure that the waterproofing assembly is installed correctly. The waterproofing assembly should be constructed in sections for ease of inspection and maintenance access to the membrane on the roof. Green roofs can be maintained per approved maintenance specifications. Suppliers who distribute all the assembly components, including the waterproofing membrane, should be evaluated. Alternatively, a green roof designer can design a custom green roof and specify suppliers for each component of the system.

OPERATION AND MAINTENANCE

- Green roof maintenance is typically great, as the first two years as plants are being established, they should be monitored to ensure dense coverage. A warranty on the vegetation should be included in the construction contract.
- Regular operation of a green roof includes irrigation and leak detection. Watering should be based on the water requirements of the plants, and conditions as plants are designed to be drought tolerant. Electronic leak detection systems should be installed as a first line of defense.
- Ongoing maintenance should occur at least twice per year and should include removing weeds to maintain the system and clear channels to allow water to drain.

SITE CONSIDERATIONS

- Roof Slope: Green roofs may be installed on roofs with slopes up to 10%.
- Drains: Area & Runoff Volatiles: Green roofs are designed to manage the amount of water precipitation falling directly on the roof surface. They are not designed to receive runoff diverted from other source areas.
- Structural Requirements: The roof structure and building must be designed to support the weight of the soil, vegetation and accumulated water. Support may be needed to support pedestrians, concrete pavers, etc.

COST

An analysis to determine cost effectiveness for a given site should include the roof lifespan, energy savings, stormwater management requirements, aesthetics, market value, tax and other municipal incentives. It is estimated that green roofs can extend the life of a roof structure by as long as 25 years, by reducing the amount of material in sun and precipitation. They can also reduce energy demand by as much as 70%.

ON PRIVATE PROPERTY

Properties containing green roofs will need to be educated on their routine operation and maintenance needs, understand the long-term maintenance plan, and may be subject to a legally binding maintenance agreement. Additionally, it is estimated that green roofs can extend the life of a roof structure by as long as 25 years, by reducing the amount of material in sun and precipitation. They can also reduce energy demand by as much as 70%.
**GENERAL DESCRIPTION**

Simple downspout disconnection involves directing flow from roof downspouts to a pervious area that drains away from the building. This prevents stormwater from directly entering the storm sewer system or flowing across a “connected” impervious surface, such as a driveway, that drains to a storm sewer. Simple downspout disconnection requires a minimum flow path length across the pervious area of 5 metres.

**DESIGN GUIDANCE**

Roof downspout disconnections should meet the following criteria:

- Pervious areas used for downspout disconnection should be graded to have a slope of between 1 to 5%.
- Pervious areas should slope away from the building.
- The flow path length across the pervious area should be 5 metres or greater.
- The infiltration rate of soils in the pervious area should be 1.5 m/hr or greater (i.e., hydraulic conductivity of 1x10⁻⁶ cm/s or greater).
- If infiltration rate of the soil in the pervious area is less than 1.5 m/hr, it should be treated to a depth of 300 mm and amended with compost to achieve a ratio of 8 to 15% organic content by weight or 30 to 40% by volume.
- If the flow path length across the pervious area is less than 5 metres and the soils have hydrologic soil group C or D, roof runoff should be directed to another LID practice (e.g., rainwater harvesting system, bioretention area, swale, soakaway, permeable pavement system).
- The total roof area contributing drainage to any single downspout discharge location should not exceed 100 square metres, and:
  - A level spreading device (e.g., pea gravel diaphragm) or energy dissipating device (e.g., splash pad) should be placed at the downspout discharge location to distribute runoff as evenly as possible over the pervious area.

**APPLICATIONS**

There are many options for keeping roof runoff out of the storm sewer system. Some of the options are as follows:

- Simple roof downspout disconnection to a pervious area or vegetated filter strip, where sufficient flow path length across the pervious area and suitable soil conditions exist;
- Roof downspout disconnection to a pervious area or vegetated filter strip that has been filled and amended with compost to improve soil infiltration rate and moisture storage capacity;
- Directing roof runoff to an enhanced grass swale, dry swale, compost to improve soil infiltration rate and moisture storage capacity;
- Directing roof runoff to a rainwater harvesting system (e.g., rain barrel or cistern) with overflow to a pervious area, vegetated filter strip, swale, bioretention area, soakaway or perforated pipe system;
- Directing roof runoff to a rainfall harvesting system (e.g., rain barrel or cistern) with overflow to a pervious area, vegetated filter strip, swale, bioretention area, soakaway or permeable pavement.

**CONSTRUCTION CONSIDERATIONS**

**SOIL DISTURBANCE AND COMPACTION**

Only vehicular traffic necessary for construction should be allowed on the pervious areas to which roof downspouts will be discharged. If vehicle traffic is unavoidable, then the pervious area should be filled to a depth of 300 mm to loosen the compacted soil.

**EROSION AND SEDIMENT CONTROL**

If possible, construction runoff should be directed away from the proposed downspout discharge location. After the contributing drainage area and the downspout discharge location are stabilized and vegetated, erosion and sediment control structures can be removed.

**ABILITY TO MEET SWM OBJECTIVES**

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downspout Disconnection</td>
<td>Partial - depends on soil infiltration rate and length of flow path over the pervious area</td>
<td>Partial - depends on soil infiltration rate and length of flow path over the pervious area</td>
<td>Partial depends on combination with other practices</td>
</tr>
</tbody>
</table>

Downspout disconnection is primarily a practice used to help achieve water balance benefits, although it can also contribute to water quality improvement. Very limited research has been conducted on the runoff reduction benefits of downspout disconnection, so initial estimates are drawn from research on filter strips, which operate in a similar manner. The research indicates that runoff reduction is a function of soil type, slope, vegetative cover and filtering distance. A conservative runoff reduction rate is 25% for hydrologic soil group C and D soils and 50% for HSG A and B soils. These values apply to disconnections that meet the feasibility criteria outlined in this section, and do not include any further runoff reduction due to the use of compost amendments along the filter path.

**SOIL DISTURBANCE AND COMPACTION**

Disconnection of least one (1) metre below the surface. Hydrologic soil group (HSG) classifications are based on the ability of the soil to transmit water. Soil groups are ranked from A to D. Group A soils are sandy, loamy sand, or sandy loam types. Group B soils are alluvial fan or terrace types. Group C soils are sandy clay loam types. Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay types. These values apply to disconnections that meet the feasibility criteria outlined in this section, and do not include any further runoff reduction due to the use of compost amendments along the filter path.

**SITE CONSIDERATIONS**

**COMMON CONCERNS**

- **ON PRIVATE PROPERTY**
  - Property owners or managers will need to be educated on its function and maintenance needs, and may be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer user fee based on the area of impervious cover or a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain existing practices.

- **STANDING WATER AND POLLEN CONCERNS**
  - Downspout disconnection is not intended to pooled water, so any standing water should be infiltrated or removed within 48 hours of the event. If pooling for longer than 24 hours occurs, mitigation actions should be undertaken under Operation and Maintenance. Maintenance of disconnected downspouts will generally be no different than for lawns or landscaped areas. Maintenance agreements with property owners or managers may be required to ensure that downspouts remain disconnected and the connection of other practices. For long-term efficiency, the pervious area should be protected from compaction. One method is to plant shrubs or trees along the perimeter of the pervious area to prevent traffic. On commercial sites, the pervious area should be an area with high foot traffic. If pooling of water for longer than 24 hours occurs, the pervious area should be dethatched and aerated. If pooling persists, regrading or tilling to reverse compaction and/or use of compost amendments along the filter path.

- **OPERATION AND MAINTENANCE**
  - Maintenance of disconnected downspouts will generally be no different than for lawns or landscaped areas. Maintenance agreements with property owners or managers may be required to ensure that downspouts remain disconnected and the connection of other practices. For long-term efficiency, the pervious area should be protected from compaction. One method is to plant shrubs or trees along the perimeter of the pervious area to prevent traffic. On commercial sites, the pervious area should be an area with high foot traffic. If pooling of water for longer than 24 hours occurs, the pervious area should be dethatched and aerated. If pooling persists, regrading or tilling to reverse compaction and/or addition of compost to improve soil moisture retention may be required.

- **FOR FURTHER DETAILS SEE SECTION 7 OF THE CVC/TRCA LID SWM GUIDE**
GENERAL DESCRIPTION

Soakaways are rectangular excavations lined with geotextile fabric and filled with clean granular stone or other void forming material that receive runoff from a perforated pipe inlet and allow it to infiltrate into the native soil. Structures typically have open bottoms, perforated side walls and optional underlying granular stone reservoirs. They can be installed individually or in series in trench or bed configurations. They can also be referred to as infiltration galleries or linear soakaways.

Infiltration chambers are another design variation on soakaways. They include a range of proprietary manufactured modular structures installed underground, typically under parking or landscaped areas that creates large voids for temporary storage of stormwater, allowing it to infiltrate into the underlying native soil. Structures typically have open bottoms, perforated side walls and optional underlying granular stone reservoirs. They can be installed individually or in series in trench or bed configurations. They can also be referred to as infiltration galleries or linear soakaways. Infiltration trenches are rectangular trenched lined with geotextile fabric and filled with clean granular stone or other void forming material. Like soakaways, they typically service an individual lot and receive only roof and walkway runoff. This design variation on soakaways is well suited to sites where available space for other facilities is limited to narrow strips of land between buildings or properties, or along road rights-of-way. They can also be referred to as infiltration galleries or linear soakaways.

Infiltration chambers are another design variation on soakaways. They include a range of proprietary manufactured modular structures installed underground, typically under parking or landscaped areas that creates large voids for temporary storage of stormwater, allowing it to infiltrate into the underlying native soil. Structures typically have open bottoms, perforated side walls and optional underlying granular stone reservoirs. They can be installed individually or in series in trench or bed configurations. They can also be referred to as infiltration galleries or linear soakaways. Infiltration trenches are rectangular trenched lined with geotextile fabric and filled with clean granular stone or other void forming material. Like soakaways, they typically service an individual lot and receive only roof and walkway runoff. This design variation on soakaways is well suited to sites where available space for other facilities is limited to narrow strips of land between buildings or properties, or along road rights-of-way. They can also be referred to as infiltration galleries or linear soakaways.

DESIGN GUIDANCE

MOONLIING WELLS

Capped vertical non-perforated pipes connected to the inlet and outlet of the facility are recommended to provide a means of inspecting and troubleshooting their performance as part of routine maintenance. A capped vertical standpipe consisting of an anchored 100 to 150 mm diameter perforated pipe with a turbine cap installed to the top of the facility is also recommended for monitoring the length of time required to fully drain the facility between maintenance activities. Manholes and inspection ports should be installed in infiltration chambers to provide access for monitoring and maintenance activities.

PRE-TREATMENT

It is important to prevent sediment and debris from entering infiltration facilities because they could contribute to clogging and failure of the system. The following pretreatment devices are options:

- Leaf screens: Leaf screens are mesh screens installed either on the building eaves or roof downspouts and are used to remove leaves and other large debris from roof runoff.
- In-ground devices: Devices placed between a conveyance pipe and the facility (e.g., oil and grit separators, sedimentation chamber or gas traps) that can be designed to remove both large and fine particulates from runoff. A number of proprietary stormwater filter designs are available.
- Vegetated filter strips or grass swales: Road and parking lot runoff can be pretreated with vegetated filter strips or grass swales prior to entering the infiltration practice.
- FILTER MEDIA

- Stone reservoir: Soakaways and infiltration trenches should be filled with uniformly graded, washed stone that provides 30 to 40% void space. Granular material should be 50 mm clear stone.
- Geotextile: A non-woven needle punched or woven monofilament geotextile fabric should be installed around the stone reservoir of soakaways and infiltration trenches to limit movement of the filter media. A minimum depth of 100 mm of non-woven fabric, or percent open area (POA) for woven fabrics, which typically are designed for surface flow, is recommended. Other factors that need consideration include maximum forces to be exerted on the fabric, and the load bearing ratio, texture (e.g., grain size distribution) and permeability of the native soil in which they will be installed.

ABILITY TO MEET SWO OBJECTIVES

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soakaways, Infiltration Trenches and Chambers</td>
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<td>Yes</td>
<td>Partial, depends on soil infiltration rate</td>
</tr>
</tbody>
</table>

CONSTRUCTION CONSIDERATIONS

SITE DISTURBANCE AND COMPACTION: Before site work begins, locations of facilities should be clearly marked. Only vehicular traffic used for construction of the infiltration facility should be allowed close to the facility location.

EROSION AND SEDIMENT CONTROL: Infiltration practices should never serve as a sediment control device during construction. Construction runoff should be directed away from the proposed facility location. After the site is vegetated, erosion and sediment control structures can be removed.

COMMON CONCERNS

RISK OF GROUNDWATER CONTAMINATION

Most pollutants in urban runoff are well retained by infiltration practices and soils and therefore, have a low to moderate potential for groundwater contamination. To minimize risk of groundwater contamination the following management approaches are recommended:

- Infiltration practices should not receive runoff from high traffic areas where large amounts of deicing salts are applied (e.g., busy highways), nor from pollution hot spots.
- Prioritize infiltration of runoff from source areas that are comparatively less contaminated, such as residential and commercial uses and detached garages.
- Sedimentation or pre-treatment devices (e.g., oil and grit separators) before infiltration of road or parking runoff.

RISK OF SOIL CONTAMINATION

Available evidence from monitoring studies indicates that small distributed stormwater infiltration facilities do not contaminate underlying soils, even after 10 years of operation.

ON PRIVATE PROPERTY

Property owners or managers will need to be educated on their routine maintenance needs, understand the long-term maintenance plan, and be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer use fee based on the area of impervious cover on a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain their stormwater facilities. Alternatively, infiltration facilities could be located in an expanded road right-of-way or “stormwater easement” so that municipal staff can access the facility in the event it fails to function properly.

WINTER OPERATION

Soakaways and infiltration trenches and chambers will continue to function during winter months if the inlet pipe and top of the facility is located below the seasonal high water table. The bottom of the facility should be located higher than the facility drains within the maximum acceptable length of time (typically 72 hours) at least 20:1, even in wet weather. Minimum ratio of 10:1 is recommended for sites located near wellhead protection areas.

Operation and Maintenance

Maintenance typically consists of clearing out leaves, debris and accumula-
tions from the retrieval outlet and from upstream devices, inlet and outlet connections as needed. Inspection via monitoring well should be performed to ensure the facility drains within the maximum acceptable length of time (typically 72 hours) at least 20:1, even in wet weather. Minimum ratio of 10:1 is recommended for sites located near wellhead protection areas.

SITE CONSIDERATIONS

Wellhead Protection

Facilities receiving road or parking lot runoff within two (2) years of travel time from natural upland protection areas.

DIVERSION TRENCHES

The bottom of the facility should be located higher than the facility drains within the maximum acceptable length of time (typically 72 hours) at least 20:1, even in wet weather. Minimum ratio of 10:1 is recommended for sites located near wellhead protection areas.

SOIL AWARENESS

Soakaways, infiltration trenches and chambers can be constructed over any soil type, but hydrophilic soil groups A & B soils are best for achieving water balance, channel erosion control objectives. If possible, facilities should be located in the portions of the site with the highest native soil infiltration rates. Designers should verify the soil in the areas of interest for infiltration and the fill material and its potential for erosion and sediment control structures can be removed.

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDELINES - FACT SHEET - TRENCHES AND CHAMBERS

INTEGRAL TRENCH BELOW A LANEWAY

INTEGRATION CHAMBER SYSTEM UNDER A PARKING LOT
GENERAL DESCRIPTION

As a stormwater filter and infiltration practice, bioretention temporarily stores, treats, and infiltrates runoff. Designing on rainfall and infiltration rate and physical characteristics, the system may be designed without a underdrain for infiltration, with an underdrain for partial infiltration, or with an impermeable layer under and underlying the filter material (i.e., a biobarrier). The primary component of the practice is the filter bed which is a mixture of soil, rocks, and organic materials. Other filter elements include mobile ground covers and plants adapted to the conditions of a stormwater practice. Bioretention is designed to handle minor storm events in the same quality storm management. An overland flow by-pass is necessary to pass large storm event flows. Bioretention can be adapted to fit many different development contexts and provide a convenient area for snow storage and treatment.

DESIGN GUIDANCE

Soil Characteristics

Bioretention can be constructed on any soil type, but hydric soil group A and B soils are best for achieving infiltration goals. Soils should be in the areas of the development with the highest native soil infiltration rates. Bioretention can be located over any soil type, but hydrologic soil group A and B soils are best for achieving water balance benefits. If possible, bioretention should be situated in the areas of the development with the highest native soil infiltration rates. Soils

Geometry & Site Layout

Key Elements of Stormwater Bioretention Design
- The minimum footprint of the filter bed area is based on the drainage area. Typical drainage areas to bioretention are between 300 m2 to 5,000 m2.
- The minimum required drainage area is 1.3 times the surface area of impervious drainage area to treatment facility area range from 3:1 to 5:1.
- Bioretention can be configured to fit roads, buildings, or other features. However, cells that are narrow may concentrate flow as it spreads throughout the cell and result in erosion.
- The filter bed surface should be level to encourage stormwater to spread out evenly over the surface.

Preliminary Design

Preliminary design precedes capturing of coarse sediment particles before reaching the filter bed. Where the runoff source area produces little sediment, such as roofs, bioretention can function effectively without pre-treatment. To treat parking areas or road run out areas, a pre-treatment that incorporates a filtering layer is recommended. Preliminary practices that may be feasible, depending on the need for conveyance and conveyance in the system.

- Two-cell design (channel flow): Filtered ponding volume should account for 25% of the site's water quality storage requirement and be designed with a depth to width ratio.
GENERAL DESCRIPTION
Vegetated filter strips (a.k.a. buffer strips and grassed filter strips) are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They allow runoff velocity and filter out sediment and associated pollutants, and provide some infiltration into underlying soils. Originally used as an agricultural treatment practice, filter strips have evolved into an urban SWM practice. Vegetation may be comprised of a variety of trees, shrubs and native plants to add aesthetic value as well as water quality benefits. With proper design and maintenance, filter strips can provide relatively high pollutant removal benefits. Maintaining sheet flow into the filter strip through the use of a level spreading device (e.g., pea gravel diaphragm) is essential. Using vegetated filter strips as pretreatment practices to other best management practices is highly recommended. They also provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for snowmelt infiltration.

DESIGN GUIDANCE

GEOMETRY AND SITE LAYOUT
The maximum contributing flow path length across adjacent impervious surfaces should not exceed 25 metres. The impervious areas draining to a filter strip should not have slopes greater than 3%. The filter strip should have a flow path length of at least five (5) metres to provide substantial water quality benefits; however, some pollutant removal benefits are realized with three (3) metres of flow path length.

PRETREATMENT
A pea gravel diaphragm at the top of the slope is recommended to act as a pretreatment device and level spreader to maintain sheet flow into the filter strip.

CONVEYANCE AND OVERFLOW
Level spreaders are recommended to ensure runoff draining into the filter strip does so as sheet flow (e.g., pea gravel diaphragms, concrete curbs with curbing). Whenever filter strips are greater than 3%, a series of level spreaders should be used to help maintain sheet flow.

When designed as a stand alone water quality BMP (i.e., not pretreatment to another BMP) the vegetated filter strip should be designed with a pervious berm at the toe of the slope for shallow ponding of runoff. The berm should be 150 to 300 millimetres in height above the bottom of the depression and should contain a perforated pipe and drain connected to the storm sewer. The volume ponded behind the berm should be equal to the water quality storage requirements. During larger storms, runoff overtops the berm and flows directly into a storm sewer inlet.

SOIL AMENDMENTS
If soils on the filter strip site are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8% to 15% by weight or 30 to 40% by volume. If soils on the filter strip site are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8% to 15% by weight or 30 to 40% by volume.

OPERATION AND MAINTENANCE
Generally, routine maintenance will be the same as for any other landscaped area; weeding, pruning, and filter removal. Regular watering may be required during the first two years until vegetation is established. Routine inspection is very important to ensure that dense vegetation cover is maintained and inflowing runoff does not become concentrated and short circuit the practice. Vegetables should not be parked or driven on filter strips. For routine mowing of grassed filter strips, the lightest possible mowing equipment should be used to prevent soil compaction.

For the first two years following construction the filter strip should be inspected at least quarterly and after every major storm event (> 25 mm). Subsequently, inspections should be conducted in the spring and fall of each year and after major storm events. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, channelization, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices and the filter strip surface at least twice annually. Other maintenance activities include weeding, replacing dead vegetation, removing eroded areas, dethatching and aerating as needed. Regularly removed sediment on the filter strip surface when dry and exceeding 25 mm depth.

ABILITY TO MEET SWM OBJECTIVES

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetated Filter Strips</td>
<td>Partial depends on soil infiltration rate</td>
<td>Partial depends on soil infiltration rate and flow path length</td>
<td>Partial - depends on soil infiltration rate</td>
</tr>
</tbody>
</table>

GENERAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel/Diaphragm</td>
<td>Washed 3 to 10 mm diameter stone</td>
<td>N/A</td>
</tr>
<tr>
<td>Gravel/Berm</td>
<td>Berm should be composed of sand (35 to 60%), soil (30 to 55%), and gravel (15 to 25%)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

SITE CONSIDERATIONS

<table>
<thead>
<tr>
<th>Resource</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water table</td>
<td>Filter strips should only be used where depth is the seasonal high water table is at least one (1) metre below the ground surface.</td>
</tr>
<tr>
<td>Available Space</td>
<td>The maximum flow path length across the contributing impervious areas should be less than 25 metres.</td>
</tr>
<tr>
<td>Site Topography</td>
<td>Filter strips are a suitable practice on all soil types. If soils are clay, if used for sediment control, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8% to 15% by weight or 30 to 40% by volume.</td>
</tr>
<tr>
<td>Pollution Hot Spot Runoff</td>
<td>To protect groundwater from possible contamination, runoff from possible contamination, runoff should be directed away from the proposed filter strip site. The recommended filter strip slope is between 1 to 5%.</td>
</tr>
</tbody>
</table>

CONSTRUCTION CONSIDERATIONS

<table>
<thead>
<tr>
<th>.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Disturbance and Compaction</td>
<td>The limits of disturbance should be clearly shown on all construction drawings. Before site work begins, areas for filter strips should be clearly marked and protected by acceptable signage and site fencing. Only vehicular traffic for construction should be allowed within three metres of the filter strip.</td>
</tr>
<tr>
<td>Erosion and Sediment Control</td>
<td>Construction runoff should be directed away from the proposed filter strip site. The recommended filter strip slope is between 1 to 5%.</td>
</tr>
</tbody>
</table>

Vegetated Filter Strips
**GENERAL DESCRIPTION**

Permeable pavement, an alternative to impervious pavement, allows stormwater to drain through it and enter a storm drain system where it is infiltrated into the underlying native soil or tempered with sediment and treated in a wetland, traffic courts, parking lots, driveways, pedestrian plazas and walkways. Permeable pavement is ideal for sites with limited space for underground stormwater BMPs. Examples of permeable pavement types include:

- slot installed concrete (also known as "pave panels")
- poro-porous or pervious asphalt

Depending on the native soils and physical constraints, the system may be designed with or no infiltration for detention, with an impermeable liner and underdrain for no infiltration or detention and filtration only, or partial systems or compressed air units.

**DESIGN GUIDANCE**

- **GEOMETRY & SITE LAYOUT**
  Permeable pavement systems can be used for entire parking lot aisles or drive lanes. Permeable pavement can be limited to the surface areas designated between two buildings. For example, the parking spaces of a parking lot or road can be permeable pavement while the drive lanes are impervious asphalt. In general, the permeable area should not exceed 1.2 times the area of the permeable pavement which receives the runoff. (GVPD, 2010)

- **PRE-TREATMENT**
  In most permeable pavement designs, the pre-treatment bedding layer acts as a pre-treatment layer. In some permeable pavement systems, pre-treatment measures such as not starting or other materials on the pavement are critical to preventing clogging of the permeable pavement. The pre-treatment layer can be a gravel crush blanket layer above the coarse gravel storage reservoir.

- **CONVEYANCE AND OVERFLOW**
  All designs require an impermeable blanket to a storm sewer with capacity to convey larger storms. One option is to set storm drain manholes above the ground level. Stormdrain manholes are normally lowered by 300 mm to provide a gravel bedding layer above the surface. Another design option is an overflow apron, which is a gravel apron that can be a gravel bedding layer above the coarse gravel storage reservoir.

- **MONITORING WELLS**
  A gravel or slotted stone well consisting of an anchored 100 to 150 mm diameter perforated pipe with a backfill cap installed to the bottom of the facility is recommended for monitoring the time required to fully drain the existing between storms.

- **STONE RESERVOIR**
  The stone reservoir must be designed to meet both runoff storage and structural support requirements. Clear crushed stone is recommended as this is the aggregative material that will not degrade to release fines into the permeable pavement. The bottom of the reservoir should be flat so that runoff can be infiltrated through the entire surface. Any consequent spreading of joints. The restraints must be able to withstand the load. Pavers must abut tightly against the restraints to prevent rotation under load and reduction in cover thickness.

- **STABILITY**
  A non-woven needle punched, or woven monofilament geotextile fabric should be inserted between the stone reservoir and native soil to prevent separation.

- **EDGE RESTRAINTS**
  Pavers must be tightly restrained to the restraint to prevent movement. Concrete edge restraints should be supported on a minimum base of 100 mm to 150 mm. The top of the standpipe should be covered with a clear crushed stone (5 mm dia.) with a minimum inside diameter of 100 mm.

- **LANDSCAPING**
  Additional permeable areas should drain away from permeable pavement to prevent runoff from entering the surface. Urban trees also benefit from being surrounded by permeable pavement rather than impervious cover, because their roots receive more air and water surrounded by permeable pavement rather than impervious cover, because their roots receive more air and water.

**OPERATION AND MAINTENANCE**

Annual inspections of permeable pavement should be conducted in the spring to ensure continued infiltration performance. The maximum frequency of cleaning is a function of the depth of the permeable layer or of the media separating the soils.

- **Surface Sweeping**
  Sweeping should occur once or twice a year with a commercial vacuum that can handle the amount of solids. Permeable pavement should not be washed with high pressure water systems or compressed air units. Inter Stuctures: Drainage pipes and structures within or draining to the subsurface bed beneath permeable pavement should be cleaned out regularly. The depth of the crown point at the bottom of the trench along the downgradient edge of the pavement surface that drains to the granular stone reservoir. Partial infiltration designs can also include a flow redirector. Permeable pavement is ideal for sites with limited space for underground stormwater BMPs. Examples of permeable pavement types include:

- slot installed concrete (also known as "pave panels")
- poro-porous or pervious asphalt

Depending on the native soils and physical constraints, the system may be designed with or no infiltration for detention, with an impermeable liner and underdrain for no infiltration or detention and filtration only, or partial systems or compressed air units.
GENERAL DESCRIPTION
Enhanced grass swales are vegetated open channels designed to convey, treat and attenuate stormwater runoff (also referred to as enhanced vegetated swales). Check dams and vegetation in the swale slows the water, allows sedimentation, filtration through the root zone and soil matrix, and reduces the potential for erosion. Water quality, stormwater management, and aesthetic benefits are important considerations when designing and constructing enhanced grass swales. These swales are often used when traditional hard solutions are not cost-effective or practical. Enhanced grass swales are a preferred alternative to both curb and gutter grass channel and roadside ditch designs.

Where development density, topography and depth to water table permit, enhanced grass swales are a preferred alternative to both curb and gutter and storm drains as a stormwater conveyance system. When incorporated into site design, they can reduce impervious cover, accent the natural landscape, and provide aesthetic benefits.

DESIGN GUIDANCE

GEOMETRY AND SITE LAYOUT
- **Shape**: Should be designed with a trapezoidal or parabolic cross section. Trapezoidal swales will generally evolve into parabolic cross sections over time. All trapezoidal cross-section designs should be designed to need a minimum 5 metres of grass swale.
- **Bottom Width**: Should be designed with a bottom width between 0.75 and 3.0 metres. Should allow for shallow flows and adequate water quality treatment, while preventing flows from concentrating and creating gullies.
- **Longitudinal Slope**: Slopes should be between 0.5% and 4%. Check dams should be incorporated on slopes greater than 3%.
- **Length**: When used to convey and treat road runoff, the length simply extends parallel to the road. Should be equal to, or greater than, the contributing roadway length.
- **Flow Depth**: A maximum flow depth of 100 mm is recommended during a 4 hour, 25 mm Chicago storm event.
- **Side Slopes**: Should be as flat as possible to aid in providing pre-treatment for lateral incoming flows and to maximize the swale filtering surface. Steeper side slopes are likely to have erosion concentrating and creating gullies.

PRE-TREATMENT
- A pea gravel diaphragm located along the top of each bank can be used to provide pre-treatment of any runoff entering the swale laterally. Use washed stone between 3 and 10 mm in diameter. Wood used for check dams should be underlain with geotextile filter fabric.

SOIL AMENDMENTS
- It is recommended that at least 90% of the topsoil be retained and inlets and pretreatment devices are free of debris.

PLAN VIEW OF A GRASS SWALE

**GENERAL SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check Dams</td>
<td>Constructed of a non-erodible material such as wood, gabions, riprap, or concrete. All check dams should be underlain with geotextile filter fabric.</td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td>Washed stone between 3 and 10 mm in diameter.</td>
<td></td>
</tr>
</tbody>
</table>

**CONSTRUCTION CONSIDERATIONS**

Grass swales should be clearly marked before site work begins to avoid disturbance during construction. No vehicular traffic, except that specifically used to construct the facility, should be allowed within the swale site. Any accumulation of sediment that does occur within the swale must be removed during the final stages of grading to achieve the design cross-section. Final grading and planting should not occur until the adjoining areas draining into the swale are stabilized. Flow should not be diverted into the swale until the soil is stabilized.

Preferably, the swale should be planted in the spring so that the vegetation can become established with minimal irrigation. Installation of erosion control blanket matting or troweling to stabilize soil during establishment of vegetation is highly recommended. If sod is used, it should be placed with staggered ends and secured by rolling the sod. This helps to prevent gullies.

For the first two years following construction the swale should be inspected at least quarterly and after every major storm event (>25 mm). Subsequently, inspections should be conducted in the spring and fall of each year and after major storm events. Inspect for vegetation density (at least 80% coverage) and any potential contamination of stormwater quality. Vegetation should be maintained and keep inlets and pre-treatment devices free of debris.

OPERATION AND MAINTENANCE

Generally, routine maintenance will be the same as for any other landscaped area; weeding, mowing, and litter removal. Grassed swales should be mowed at least twice yearly to maintain grass height between 75 and 150 mm. The most efficient mowing equipment should be used to prevent soil contamination. Routine roadside ditch maintenance practices such as scraping and re-grading should be avoided. Regular watering may be required during the first two years until vegetation is established. Routine inspection is very important to ensure that dense vegetation cover is maintained and inlets and pre-treatment devices are free of debris.

PLACE AND PROFILE VIEWS

For further details see Section 4.8 of the CVC/TRCA LID SWM Guide.
A dry swale can be thought of as an enhanced grass swale that incorporates an engineered filter bed and an engineered pavement. It consists of a pervious pavement cell configured as a linear open channel. They can also be referred to as infiltration basins or dry swales. Dry swales are similar to enhanced grass swales in terms of the design of their surface geometry, slope, check dams and pretreatment devices. They are used to manage stormwater runoff and are similar to constructed wetlands as they have a soil filter bed and storage volume.

**GENERAL DESCRIPTION**

A dry swale can be thought of as an enhanced grass swale that incorporates an engineered filter bed and an engineered pavement. It consists of a pervious pavement cell configured as a linear open channel. They can also be referred to as infiltration basins or dry swales. Dry swales are similar to enhanced grass swales in terms of the design of their surface geometry, slope, check dams and pretreatment devices. They are used to manage stormwater runoff and are similar to constructed wetlands as they have a soil filter bed and storage volume.

**DESIGN GUIDANCE**

- **SHAPE**: A parabolic shape is preferable for aesthetic and maintenance purposes. It is defined by a parabolic cross-section along the length of the swale.
- **BREACH WIDTH**: The trapezoidal cross section, the bottom width should be between 0.7 and 2.0 metres, while greater widths are desired. An alternate trapezoidal cross-section design should be used.
- **SITE ASPECT**: Should be no steeper than 3:1 for maintenance considerations (moving). Flutter slopes are encouraged where adequate space is available to provide permanent plantings for the softening of the treatment wall.
- **LONGITUDINAL SLOPE**: Should be as gradual as possible to permit the permanent control of vegetation. A slope of 0.2% is recommended with longitudinal slopes generally ranging from 0.5 to 4%, and no greater than 6%. Or slopes steeper than 3%, check dams should be used. Check dams should be spaced far enough to allow for access to maintenance equipment.

**PRE-TREATMENT**

Pretreatment systems are designed to separate and remove certain pollutants before they reach the filter bed. Runoff source areas produce little sediment, such as roads, dry swales can function effectively without pretreatment. To treat parking area or roof runoff, a combined system of sump drainage and storage is recommended. Pretreatment practices that may be feasible, depending on conveyance method and availability of facilities.

**BEDDING MATERIAL**

- **Soil**: Where applicable and provided above the required design storm water level.
- **Gravel**: Filter media should come pre-mixed from an approved vendor.
- **Sand**: Should be used in dry swales where the required soil infiltration rate is less than 15 mm/hr (hydraulic conductivity of less than 1 x 10^-6 cm/s). Should consist of a pervious pavement embedded in the coarse gravel filter bed layer at least 100 mm deep. A strip of geotextile filter fabric placed between the filter media and pea gravel check dam layer is optional to help prevent fine soil particle from entering the underdrain. A vertical standpipe connected to the underdrain at the furthest downstream and of the swale can be used as a cleanup and monitoring well.

**ABILITY TO MEET SWOM OBJECTIVES**

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance</th>
<th>Water Quality Improvement</th>
<th>Stream Channel</th>
<th>Erosion Control</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry swale with no underdrain or full infiltration</td>
<td>Yes</td>
<td>Yes</td>
<td>Partial</td>
<td>Based on available storage volume and soil infiltration rate</td>
<td>Partial</td>
</tr>
</tbody>
</table>

**OPERATION AND MAINTENANCE**

- **Siting**: Dry swales require routine inspection and maintenance of the landscape as well as periodic inspection for less frequent maintenance needs or remedial maintenance. Generally, routine maintenance will be the same for any other landscaped area, weeding, pruning, and filter removal. Regular watering may be required during the first two years until vegetation is established.
- **Filter Media**: Dry swales should be designed for a maximum velocity of 0.5 m/s or less for a 4-hour 25 mm Chicago storm event. The swale should also convey the locally required design stormwater volume. While the filter bed and storage volume should be sized to provide high-quality water for beneficial uses, the underdrain should be sized to provide appropriate storage volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume.
- **Check Dams**: Check dams should be constructed of a non-erosive material such as wood, galvanized, riprap, or concrete and underdrain with filter fabric. Underdrain should consist of pressure treated logs or timbers, or water-resistant free species such as cedar, hemlock, swamp cypress, or locust.
- **Mulch or Matting**: Mulch or matting should be used to provide permanent plantings for the softening of the treatment wall. Mulch is placed on the surface of the filter bed. Matting may be used on the surface of the filter bed.
- **Conveyance and Overflow**: Conveyance and overflow should be designed for a maximum velocity of 0.5 m/s or less for a 4-hour 25 mm Chicago storm event. The swale should also convey the locally required design stormwater volume. While the filter bed and storage volume should be sized to provide high-quality water for beneficial uses, the underdrain should be sized to provide appropriate storage volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume.
- **Monitoring Wells**: Monitoring wells should be designed for a maximum velocity of 0.5 m/s or less for a 4-hour 25 mm Chicago storm event. The swale should also convey the locally required design stormwater volume. While the filter bed and storage volume should be sized to provide high-quality water for beneficial uses, the underdrain should be sized to provide appropriate storage volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume.

**GENERAL SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Media</td>
<td>Filter Media Soil Mixture to contain</td>
<td>85% to 88% sand + 8% to 12% silt fines + 3% to 5% organic matter (leaf compost)</td>
</tr>
</tbody>
</table>

**VOLUMETRIC COMPOSITION**

- **Crop Amelioration (if present)**: Apply compost to the filter media to improve soil structure and physical properties.
- **Surface Water Quality (if present)**: Surface water quality should be designed to provide the required stormwater volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume.

**SITE CONSIDERATIONS**

- **Available Space**: From each design to the contributing drainage area, the swale design should be sized to provide the required stormwater volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume.
- **Topography**: Topography should be taken into account. The design should be modified to avoid stormwater runoff into the designated drainage area. The design should be modified to accommodate stormwater runoff.
- **Drainage Design**: Drainage design should be performed to determine the appropriate size and shape of the swale. The design should be modified to accommodate stormwater runoff.
- **Vegetation**: Vegetation should be selected to provide the required stormwater volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume.

**CONSTRUCTION CONSIDERATIONS**

- **Irrigation**: Irrigation should be provided to the filter media to improve soil structure and physical properties. The design should be modified to accommodate stormwater runoff.
- **Vegetation**: Vegetation should be selected to provide the required stormwater volume and soil infiltration rate. The dry swale design should be sized to provide the required stormwater volume.
GENERAL DESCRIPTION
Perforated pipe systems can be thought of as long infiltration trenches or linear soakaways that are designed for both conveyance and infiltration of stormwater runoff. They are composed of perforated pipes installed in gently sloping granular stone beds that are lined with geosynthetic fabrics that allow infiltration of runoff into the gravel bed and underlying native soil while it is being conveyed from source areas or other BMPs to an end-of-pipe facility or receiving water body. Perforated pipe systems can be used in place of conventional storm sewer pipes, where topography, water table depth, and underlying native soil provide an opportunity to breed. Complete drawdown should occur within 72 hours after a storm event, before mosquitoes can develop.

SITE CONSIDERATIONS
Perforated pipe systems can also be referred to as porous pipe systems, infiltration systems, clean water collector systems and percolation drainage systems.

DESIGN GUIDANCE

- MATERIAL SPECIFICATIONS

  - Perforated pipe should be continuously perforated, smooth outside diameter must be a minimum inside diameter of 200 millimetres.
  - Stone should be washed 50 mm clear stone with a 40% void ratio.
  - Geotextile: Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they prone to clogging.
  - Perforated pipe should run length wise through the facility at least 100 mm above the bottom of the gravel filled trench. Non-perforated pipe should be used for conveyance in the gravel bed.
  - Volume is based on trench dimensions and a void ratio of 40%.

- GEOMETRY AND SITE LAYOUT

  - Perforated pipe systems can be constructed over any soil type, but hydromorphic soil groups A and B are best for achieving water balance objectives. If possible, facilities should be located in portions of the site with the highest native soil infiltration area. Designers should work with the native soil infiltration rates at the proposed location and depth through measurement of hydraulic conductivity under field saturated conditions.

- CONVEYANCE AND OVERFLOW

  - Collection and conveyance of runoff into the perforated pipe system can be accomplished through conventional catchbasin and non-perforated pipes leading from foundation drains and roof downspouts. Perforated pipes should be smooth walled to reduce the potential for stagnation and facilitate clean out. The gravel filled trench should be at least 100 mm deep above the perforated pipe. On fine-grained soils, clay or plastic trench builder pipes cannot be installed across the gravel filled trench to reduce flow along the system, thereby increasing the possibility of overflows. Infiltration from the gravel filled trench should either back up into manholes that are adjacent to conventional storm sewers or be conveyed to a storm sewer or receiving water body.

- FILTER MEDIA

  - Gravel filled trench should be filled with uniformly graded, washed, 50 mm clear stone that provides 40% void space.
  - Geotextile: Non-woven needle punched or woven monofilament geotextile fabric should be installed around the stone reservoir of perforated pipe systems with a minimum overlap at the top of 300 mm.

- COMMON CONCERNS

  - Risk of Groundwater Contamination
    - Most collectors in urban runoff are well retained by infiltration practices and soils and therefore, have a low potential for groundwater contamination. To minimize risk of groundwater contamination the following management practices are recommended:
      - Infiltration practices should not receive runoff from high traffic areas where large amounts of de-icing salts are applied (e.g., busy highways), nor from pollution hot spots.
      - Permeable infiltration of runoff from source areas that are comparatively less contaminated such as roads, low traffic roads and parking areas, and.
      - Apply sedimentation pre-treatment practices (e.g., oil and grit separation) before infiltration or road and parking area runoff.

  - Standing Water and Mosquitoes
    - Complete drydown should occur within 72 hours after a storm event, before mosquitoes have an opportunity to breed.

  - Foundations and Seepage
    - Should be setback at least four (4) metres from building foundations to prevent base ment flooding and damage during freeze/thaw cycles.

  - Winter Operation
    - Perforated pipe systems will continue to function during winter months if the inlet pipe and top of the gravel bed is located below the lowest possible freeze depth.

CONSTRUCTION CONSIDERATIONS

- Soil Disturbance and Compaction

  - Before site work begins, locations of facilities should be clearly marked. Only vehicular traffic used for construction of the infiltration facility should be allowed close to the facility location.

- Erosion and Sediment Control

  - Infiltration practices should never serve as a sediment control device during construction. Construction stockpiles should be isolated away from the proposed facility location. After the site is vegetated, erosion and sediment control structures can be removed.

GENERAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforated pipe</td>
<td>Should be continuously perforated, smooth outside diameter must be a minimum inside diameter of 200 millimetres.</td>
<td></td>
</tr>
<tr>
<td>Stone</td>
<td>The trench in which perforated pipes are installed should be filled with washed 50 mm clear stone with a 40% void ratio.</td>
<td>Around the gravel filled trench (stone reservoir).</td>
</tr>
<tr>
<td>Geotextile</td>
<td>Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1880 for Class 1 geotextile fabrics.</td>
<td></td>
</tr>
<tr>
<td>Pipe systems</td>
<td>Perforated pipe should run length wise through the facility at least 100 mm above the bottom of the gravel filled trench. Non-perforated pipe should be used for conveyance in the gravel bed.</td>
<td></td>
</tr>
</tbody>
</table>

SITE CONSIDERATIONS

- Topography

  - Stormwater systems cannot be located on natural slopes greater than 15%. The gravel bed should be designed with grades between 0.5 to 1.5%.

- Drainage Area

  - Typically designed with an impervious drainage area to total drainage area ratio of between 5.1 to 10.1.

- Soil

  - Perforated pipe systems can be located over any soil type, but hydromorphic soil groups A and B are best for achieving water balance objectives. The gravel bed should be designed in portions of the site with the highest native soil infiltration rates.

- Wellhead Protection

  - Facilities receiving road or parking area runoff should be located within two (2) years time-frame of travel toward protection areas.

- Water Table

  - The bottom of the gravel bed should be at least 300 mm below any high groundwater table or top of bedrock elevation to a maximum of one (1) metre to prevent groundwater contamination.

- Pollution Hot Spot Runoff

  - To protect groundwater from potentially contaminated soils, concentrated stormwater runoff from areas identified as pollution hot spots should be treated by perforated pipe systems.

- Setback from Buildings

  - Facilities should be setback a minimum of at least 20.0 metres from building foundations.

- Proximity to Underground Utilities

  - Facilities should be located at least 20.0 metres from underground services to be consulted to define the horizontal and vertical offsets. Contact local utility design guidance to define the horizontal and vertical offsets.

- Ordinance Requirements

  - Requirements for underground utilities are site specific and should be consulted to define the horizontal and vertical offsets. Contact the local city or regional government to define appropriate setback distances.

ABILITY TO MEET SWM OBJECTIVES

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforated Pipe Systems</td>
<td>Yes</td>
<td>Yes</td>
<td>Partial, depends on soil infiltration rate</td>
</tr>
</tbody>
</table>

OPERATION AND MAINTENANCE

- Maintenance typically consists of cleaning out leaves, debris and accumulated sediments. This can be done by regular inspection or needed as required. A maintenance program should be established to ensure the facility drains within the maximum acceptable length of time (typically 72 hours) at least annually and following major storm events (up to 25 mm). If the time required to clean out the gravel bed is determined to be more than 72 hours, clean out the perforated pipe by flushing. If slow drainage persists, the system may need removal or replacement of geotextile liners. Perforated pipe systems should be located below shoulders of roadways, previous boulevards or grass swales where they can be readily excavated for servicing.