4.8 Enhanced Grass Swale

4.8.1 Overview

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 to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Simple grass channels or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Enhanced grass swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel and roadside ditch designs (Figure 4.8.1). A dry swale is a design variation that incorporates an engineered soil media bed and optional perforated pipe underdrain system (see Section 4.9 – Dry Swale). Enhanced grass swales are not capable of providing the same water balance and water quality benefits as dry swales, as they lack the engineered soil media and storage capacity of that best management practice.

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 a site design, they can reduce impervious cover, accent the natural landscape, and provide aesthetic benefits.

Figure 4.8.1 Enhanced grass swales can be applied in road rights-of-way or along parking lots

Source: Seattle Public Utilities (left); Sue Donaldson (right)

Figure 4.8.2 Enhanced grass swales feature check dams that temporarily pond runoff to increase pollutant retention and infiltration and decrease flow velocity

Source: Delaware Department of Transportation (left); Center for Watershed Protection (right)

Common Concerns

If they are properly designed and maintained, enhanced grass swales can provide stormwater treatment and improved site aesthetics. However, there are some common concerns associated with their use:

- *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 (Pitt *et al.*, 1999). Chloride and sodium from de-icing salts applied to roads and parking areas during winter are not well attenuated in soil and can easily travel to shallow groundwater. Infiltration of de-icing salt constituents is also known to increase the mobility of certain heavy metals in soil (*e.g.*, lead, copper and cadmium), thereby raising the potential for elevated concentrations in underlying groundwater (Amrhein *et al.*, 1992; Bauske and Goetz, 1993). However, very few studies that have sampled groundwater below infiltration facilities or roadside ditches receiving de-icing salt laden runoff have found concentrations of heavy metals that exceed drinking water standards (*e.g.*, Howard and Beck, 1993; Granato *et al.*, 1995). To minimize risk of groundwater contamination the following management approaches are recommended (Pitt *et al.*, 1999; TRCA, 2009b):
    - stormwater 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 (*e.g.*, source areas where land uses or activities have the potential to generate highly contaminated runoff such as vehicle fuelling, servicing or demolition areas, outdoor storage or handling areas for hazardous materials and some heavy industry sites);
    - prioritize infiltration of runoff from source areas that are comparatively less contaminated such as roofs, low traffic roads and parking areas; and,
    - apply sedimentation pretreatment practices (*e.g.*, oil and grit separators) before infiltration of road or parking area runoff.

- *Risk of Soil Contamination:* Available evidence from monitoring studies indicates that small distributed stormwater infiltration practices do not contaminate underlying soils, even after more than 10 years of operation (TRCA, 2008).

- *On Private Property*: If enhanced grass swales are installed on private lots, property owners or managers will need to be educated on their routine maintenance needs, understand the long-term maintenance plan, 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 on a property that is directly connected to a storm sewer (*i.e.*, does not first drain to a pervious area or LID practice) could be used to encourage property owners or managers to maintain existing practices. Alternatively, swales 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.

- *Maintenance*: The major maintenance requirement associated with grass swales is mowing. Occasionally, sediment will need to be removed, although this can be minimized by ensuring that upstream areas are stabilized and incorporating pretreatment devices (*e.g.*, vegetated filter strips, sedimentation forebays, gravel diaphragms). If grass swales are installed on private lots, homeowners need to be educated on routine maintenance requirements.

- *Erosion:* Erosion can be prevented by limiting the allowable longitudinal slope and incorporating check dams. Additionally, designers can use permanent reinforcement matting on swales designed for high velocity flows and temporary matting during the vegetation establishment period.

- *Standing Water and Mosquitoes:* Properly designed grass swales will not pond water for longer than 24 hours following a storm event. However, poor design, installation, or maintenance can lead to nuisance conditions.

Physical Suitability and Constraints
Enhanced grass swales are suitable on sites where development density, topography and water table depth permit their implementation. Some key constraints to their application include:

- *Available Space:* Grass swales usually consume about 5 to 15 percent of their contributing drainage area. A width of at least 2 metres is needed.

- *Site Topography:* Site topography constrains the application of grass swales. Longitudinal slopes between 0.5 and 6% are allowable. This prevents ponding while providing residence time and preventing erosion. On slopes steeper than 3%, check dams should be used.

- *Water Table*: Designers should ensure that the bottom of the swale is separated from the seasonally high water table or top of bedrock elevation by at least one (1) metre.

- *Soils:* Grass swales can be applied on sites with any type of soils.

- *Drainage Area and Runoff Volume:* The conveyance capacity should match the drainage area. Sheet flow to the grass swale is preferable. If drainage areas are greater than 2 hectares, high discharge through the swale may not allow for filtering and infiltration, and may create erosive conditions. Typical ratios of impervious drainage area to swale area range from 5:1 to 10:1.

- *Pollution Hot Spot Runoff:* To protect groundwater from possible contamination, source areas where land uses or human activities have the potential to generate highly contaminated runoff (*e.g.*, vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites) should not be treated by grass swales.

- *Setbacks from Buildings:* Enhanced grass swales should be located a minimum of four (4) metres from building foundations to prevent water damage.

- *Proximity to Underground Utilities:* Utilities running parallel to the grass swale should be offset from the centerline of the swale. Underground utilities below the bottom of the swale are not a problem.

Typical Performance

The ability of enhanced grass swales to help meet stormwater management objectives is summarized in Table 4.8.1.

Table 4.8.1 Ability of enhanced grass swales to meet SWM objectives

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Enhanced Grass Swale	Partial – depends on soil infiltration rate	Yes, if design velocity is 0.5 m/s or less for a 4 hour, 25 mm Chicago storm	Partial – depends on soil infiltration rate

Water Balance

Runoff reduction by grass swales is generally low, but is strongly influenced by soil type, slope, vegetative cover and the length of the swale. Recent research indicates that a conservative runoff reduction rate of 20 to 10% can be used depending on whether soils fall in hydrologic soil groups A/B or C/D, respectively. The runoff reduction rates can be doubled if the native soils on which the swale is located have been tilled to a depth of 300 mm and amended with compost to achieve an organic content of between 8 and 15% by weight or 30 to 40% by volume.

Table 4.8.2 Volumetric runoff reduction achieved by enhanced grass swales

LID Practice	Location	% Runoff Reduction	Reference
Grass Swale	Virginia	0%	Schueler (1983)
Grass Swale	Various	40%	Strecker *et al.*(2004)
Grass Swale	California	27 to 41%	Barrett *et al.* (2004)
Runoff Reduction Estimate[1]		**20% on HSG A or B soils; 10% on HSG C or D soils**	

Notes:
1. This estimate is provided only for the purpose of initial screening of LID practices suitable for achieving stormwater management objectives and targets. Performance of individual facilities will vary depending on site specific contexts and facility design parameters and should be estimated as part of the design process and submitted with other documentation for review by the approval authority.

Water Quality – Pollutant Removal Capacity

Research has shown the pollutant mass removal rates of grass swales are variable, depending on influent pollutant concentrations (Bäckström *et al.*, 2006), but generally moderate for most pollutants (Barrett *et al.*, 1998; Deletic and Fletcher, 2006). Median pollutant mass removal rates of swales from available performance studies are 76% for total suspended solids, 55% for total phosphorus, and 50% for total nitrogen (Deletic and Fletcher, 2006). Significant reductions in total zinc and copper event mean concentrations have been observed in performance studies with a median value of 60%, but results have varied widely (Barrett, 2008). Site specific factors such as slope, soil type, infiltration rate, swale length and vegetative cover also affect pollutant mass removal rates. In general, the dominant pollutant removal mechanism operating in grass swales is infiltration, rather than filtration, because pollutants trapped on the surface of the swale by vegetation or check dams are not permanently bound (Bäckström *et al.*, 2006). Designers should maximize the degree of infiltration achieved within a grass swale by incorporating check dams and ensuring the native soils have infiltration rates of 15 mm/hr or greater or specifying that the soils be tilled and amended with compost prior to planting.

Several of the factors that can significantly increase or decrease the pollutant removal capacity of grass channels are provided in Table 4.8.3.

Table 4.8.3 Factors that influence the pollutant removal capacity of grass swales

Factors that Reduce Removal Rates	Factors that Enhance Removal Rates
Longitudinal slope > 1%	Longitudinal slope < 1%
Measured soil infiltration rate < 15 mm/hr	Measured soil infiltration rate is 15 mm/hr or greater
Flow velocity within channel > 0.5 m/s during a 4 hour, 25 mm Chicago storm event	Flow velocity within channel is 0.5 m/s or less during a 4 hour, 25 mm Chicago storm event
No pretreatment	Pretreatment with vegetated filter strips, gravel diaphragms and/or sedimentation forebays
Side slopes steeper than 3:1 (H:V)	Side slopes 3:1 (H:V) or less

4.8.2 Design Template

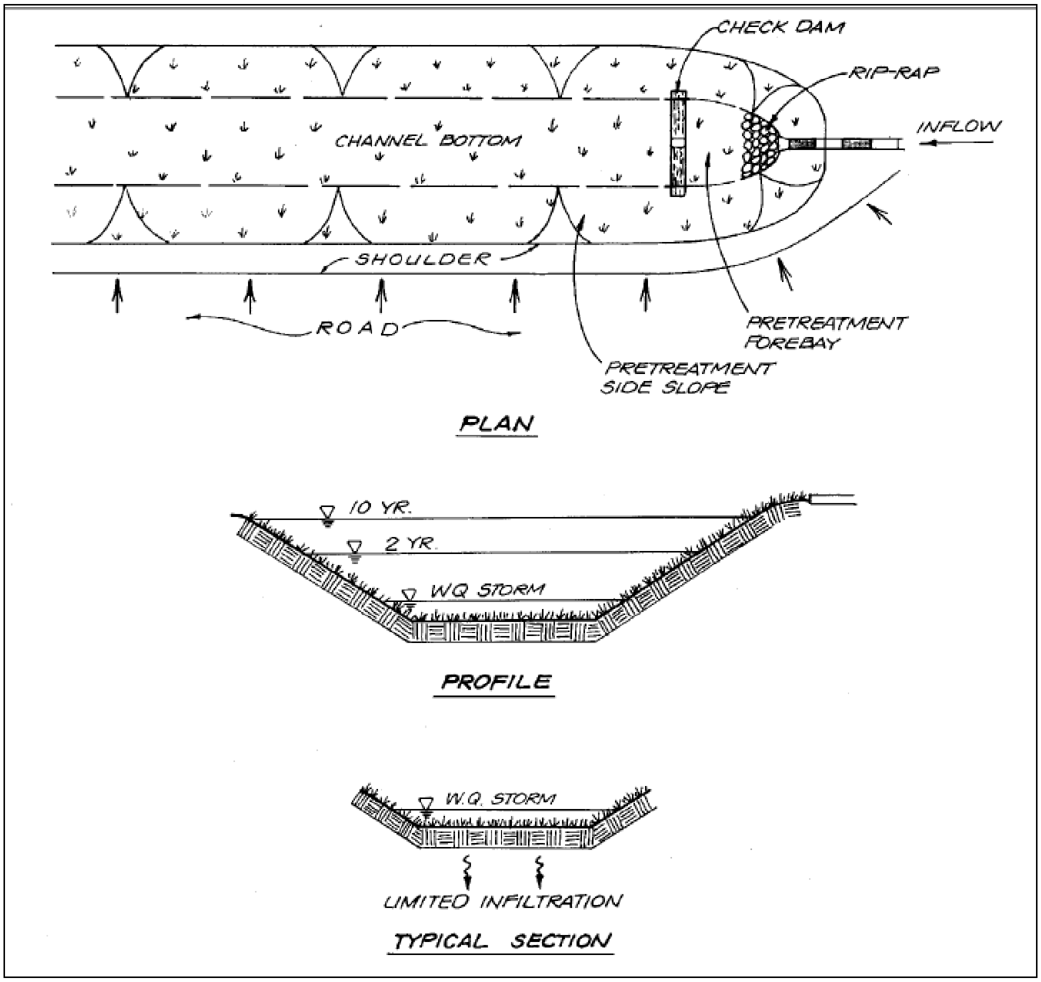
Applications

Enhanced grass swales are well suited for conveying and treating runoff from highways and other roads because they are a linear practice and easily incorporated into road rights-of-way. They are also a suitable practice for managing runoff from parking lots, roofs and pervious surfaces, such as yards, parks and landscaped areas. Grass swales can be used as snow storage areas.

Grass swales can also provide pretreatment for other stormwater best management practices, such as bioretention areas, soakaways and perforated pipe systems or be designed in series with other practices as part of a treatment train approach. They are often impractical in densely developed urban areas because they consume a large amount of space. Where development density and topograph permit, grass swales can be used in place of conventional curb and gutter and storm drain systems.

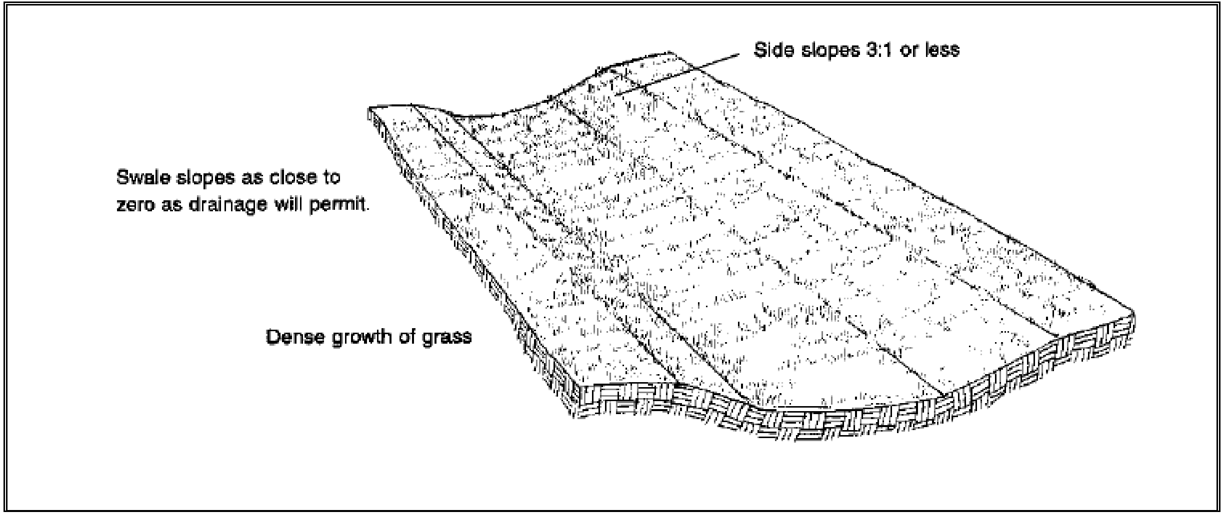
Typical Details

Figure 4.8.3 Plan, profile, and section views of a grass swale



Source: ARC, 2001

Figure 4.8.4 Plan view of a grass swale



Source: ARC, 2001

Design Guidance

Geometry and Site Layout

Design guidance regarding the geometry and layout of grass swales is provided below.

- *Shape:* Grass swales should be designed with a trapezoidal or parabolic cross section. Trapezoidal swales will generally evolve into parabolic swales over time, so the initial trapezoidal cross section design should be checked for capacity and conveyance assuming it is a parabolic cross section. Swale length between culverts should be 5 metres or greater.

- *Bottom Width:* Grass swales should be designed with a bottom width between 0.75 and 3.0 metres. The design width 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% (PDEP, 2006).

- *Length*: When used to convey and treat road runoff, the length simply parallels the road, and therefore should be equal to, or greater than the contributing roadway length.

- *Flow Depth:* The maximum flow depth should correspond to two-thirds the height of the vegetation. Vegetation in some grass swales may reach heights of 150 millimetres; therefore a maximum flow depth of 100 millimetres is recommended during a 4 hour, 25 mm Chicago storm event.

- *Side Slopes:* The side slopes should be as flat as possible to aid in providing pretreatment for lateral incoming flows and to maximize the swale filtering surface. Steeper side slopes are likely to have erosion gullying from incoming lateral flows. A maximum slope of 2.5:1 (H:V) is recommended and a 4:1 slope is preferred where space permits.

Pretreatment
A pea gravel diaphragm located along the top of each bank can be used to provide pretreatment of any stormwater runoff that may be entering the swale laterally along its length. Vegetated filter strips or mild side slopes (3:1) also provide pretreatment for any lateral sheet flow entering the swale. Sedimentation forebays at inlets to the swale are also a pretreatment option.

Conveyance and Overflow
Grass swales must be designed for a maximum velocity of 0.5 m/s or less for the 4 hour 25 mm Chicago storm. The swale should also convey the locally required design storm (usually the 10 year storm) at non-erosive velocities.

Soil Amendments
If soils along the location of the swale 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.

Landscaping
Designers should choose grasses that can withstand both wet and dry periods as well as relatively high velocity flows within the swale. For applications along roads and parking lots, where snow will be plowed and stored, non woody and salt tolerant species should be chosen. Taller and denser grasses are preferable, though the species of grass is less important than percent coverage (Barrett *et al.*, 2004). Appendix B provides further guidance regarding suitable species and planting.

Other Design Resources
Section 4.9.8 of the OMOE *Stormwater Management Planning and Design Manual* (2003) provides further guidance regarding design and modelling performance of enhanced grass swales. Several other stormwater manuals that provide useful design guidance for grass swales include:

Minnesota Stormwater Manual
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

Virginia Stormwater Management Handbook
http://www.dcr.virginia.gov/soil_&_water/stormwat.shtml

Georgia Stormwater Management Manual
http://www.georgiastormwater.com/

BMP Sizing

Enhanced grass swale designs are flow rate based. The swale should be designed for a maximum flow velocity of 0.5 m/s and flow depth of 100 mm during a 4 hour 25 mm Chicago storm event. The suggested Manning's n for use in Manning's equation is 0.027 (grass swale) to 0.050 (shrub vegetated or cobble lined swale). Given typical urban swale dimensions (0.75 m bottom width, 2.5:1 side slopes and 0.5 m depth), the contributing drainage area is generally limited to ≤ 2 hectares to maintain flow ≤ 0.15 m^3/s and velocity ≤ 0.5 m/s. Table 4.8.4 describes the relationship between imperviousness of the development and maximum drainage area that can be treated by a grass swale.

Table 4.8.4 Grassed swale drainage area guidelines

Percent Imperviousness	Maximum Drainage Area (hectares)
35	2.0
75	1.5
90	1.0

Source: OMOE, 2003.

For further guidance regarding BMP sizing, refer to the OMOE *Stormwater Management Planning and Design Manual* (OMOE, 2003).

Design Specifications

Recommended design specifications for enhanced grass swales are provided in Table 4.8.5

Table 4.8.5 Design specifications for enhanced grass swales

Component	Specification	Quantity
Check Dams	Check dams should be constructed of a non-erosive material such as suitably sized aggregate, wood, gabions, riprap, or concrete. All check dams should be underlain with filter fabric conforming to local design standards. Wood used for check dams should consist of pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.	Spacing should be based on the longitudinal slope and desired ponding volume
Pea Gravel Diaphragm	Washed stone between 3 and 10 mm in diameter.	Minimum of 300 mm wide and 600 mm deep

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 banks are stabilized.

Preferably, the swale should be planted in the spring so that the vegetation can become established with minimal irrigation. Installation of erosion control matting or blanketing 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.

4.8.3 Maintenance and Construction Costs

Inspection and Maintenance

Maintenance requirements for enhanced grass swales is similar to vegetated filter strips and typically involve a low level of activity after vegetation becomes established. Grass channel maintenance procedures are already in place at many municipal public works and transportation departments. These procedures should be compared to the recommendations below (Table 4.8.6) to assure that the infiltration and water quality benefits of enhanced grass swales are preserved. Routine roadside ditch maintenance practices such as scraping and re-grading should be avoided at swale locations. Vehicles should not be parked or driven on grass swales. For routine mowing, the lightest possible mowing equipment should be used to prevent soil compaction.

For swales located on private property, the property owner or manager is responsible for maintenance as outlined in a legally binding maintenance agreement. Roadside swales in residential areas generally receive routine maintenance from homeowners who should be advised regarding recommended maintenance activities.

Table 4.8.6 Typical inspection and maintenance activities for enhanced grass swales

Activity	Schedule
▪ 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.	After every major storm event (>25 mm), quarterly for the first two years, and twice annually thereafter.
▪ Regular watering may be required during the first two years while vegetation is becoming established; ▪ Mow grass to maintain height between 75 to 150 mm; ▪ Remove trash and debris from pretreatment devices, the swale surface and inlet and outlets.	At least twice annually. More frequently if desired for aesthetic reasons.
▪ Remove accumulated sediment from pretreatment devices, inlets and outlets; ▪ Replace dead vegetation, remove invasive growth, dethatch, remove thatching and aerate (PDEP, 2006; ▪ Repair eroded or sparsely vegetated areas; ▪ Remove accumulated sediment on the swale surface when dry and exceeds 25 mm depth (PDEP, 2006); ▪ If gullies are observed along the swale, regrading and revegetating may be required.	Annually or as needed

Installation and Operation Costs

In study by the Center for Watershed Protection to estimate and compare construction costs for various stormwater BMPs, the median base construction cost for grass swales was estimated to be $44,850 (2006 USD) per impervious hectare treated with estimates ranging from $26,935 to $89,700 (CWP, 2007b). These estimates do not include design and engineering costs, which could range from 5 to 40% of the base construction cost, nor land acquisition costs (CWP, 2007b). However, since grass swales serve as a conveyance measure, their cost is offset by the savings in curb and gutter, inlets, and storm sewer pipe as well as the reduction in other stormwater best management practices needed.

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