

4.8 Enhanced Swales

Best Management Practice



Description: Vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means.

LID/GI Consideration: Adaptable to many linear situations, and often a small BMP used to treat runoff close to the source.

KEY CONSIDERATIONS	STORMWATER MANAGEMENT SUITABILITY
DESIGN CRITERIA: - Longitudinal slopes must be less than 4% - Bottom width of 2 to 8 feet - Side slopes 2:1 or flatter; 4:1 recommended - Convey the 25-year storm event with a minimum of 6 inches of freeboard ADVANTAGES / BENEFITS: - Combines stormwater treatment with runoff conveyance system - Less expensive than curb and gutter - Reduces runoff velocity DISADVANTAGES / LIMITATIONS: - Higher maintenance than curb and gutter systems - Cannot be used on steep slopes - Possible resuspension of sediment - Potential for odor / mosquitoes (wet swale) MAINTENANCE REQUIREMENTS: - Maintain grass heights of approximately 4 to 6 inches (dry swale) - Remove sediment from forebay and channel	☒ Water Quality ☒ Channel Protection ☐ Overbank Flood Protection ☐ Extreme Flood Protection ✓ -suitable for this practice ☺ in certain situations may provide partial benefits. Accepts Hotspot Runoff: Yes (requires impermeable liner) ☺ in certain situations IMPLEMENTATION CONSIDERATIONS HM M L Land Requirement Capital Cost Maintenance Burden Residential Subdivision Use: Yes High Density/Ultra-Urban: No Drainage Area: 5 acres max.

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POLLUTANT REMOVAL (DRY SWALE)

80%

Total Suspended Solids

50/50%

Nutrients - Total Phosphorus / Total Nitrogen removal

40%

Metals - Cadmium, Copper, Lead, and Zinc removal

No
data

Pathogens - Coliform, Streptococci, E.Coli removal

POLLUTANT REMOVAL (WET SWALE)

80%

Total Suspended Solids

50/50%

Nutrients - Total Phosphorus / Total Nitrogen removal

40%

Metals - Cadmium, Copper, Lead, and Zinc removal

No
data

Pathogens - Coliform, Streptococci, E.Coli removal

Soils: *No restrictions*

Other Considerations:

- *Permeable soil layer (dry swale)*
- *Wetland plants (wet swale)*

L=Low M=Moderate H=High

Runoff Reduction Credit:

- Dry Swale: 100% of the runoff reduction volume provided (no underdrain)
- Dry Swale: 50% of the runoff reduction volume provided (underdrain)
- Wet Swale: 0% of the runoff reduction volume provided

3-2.4.8.1 General Description

Enhanced swales (also referred to as bioswales, vegetated open channels, or water quality swales) are conveyance channels engineered to capture and treat the water quality volume (WQ_v) for a drainage area. They differ from a normal drainage channel or swale through the incorporation of specific features that enhance stormwater pollutant removal effectiveness.

Enhanced swales are designed with limited longitudinal slopes to force the flow to be slow and shallow, thus allowing for particulates to settle and limiting the effects of erosion. Berms and/or check dams installed perpendicular to the flow path promote settling and infiltration.

There are two primary enhanced swale designs, the *dry swale* and the *wet swale* (or *wetland channel*). Below are descriptions of these two designs:

- **Dry Swale** – The dry swale is a vegetated conveyance channel designed to include a filter bed of prepared soil that may overlays an underdrain system. Dry swales are sized to allow the entire WQ_v to be filtered or infiltrated through the bottom of the swale. Because they are dry most of the time, they are often the preferred option in residential settings.
- **Wet Swale (Wetland Channel)** – The wet swale is a vegetated channel designed to retain water or marshy conditions that support wetland vegetation. A high water table or poorly drained soils are necessary to retain water. The wet swale essentially acts as a linear shallow wetland treatment system, where the WQ_v is retained.



Enhanced Dry Swale



Enhanced Wet Swale

Figure 3-2.64.8-1 Enhanced Swale Examples



Dry and wet swales are not to be confused with a *filter strip* or *grass channel*, which are ~~Limited Application structural controls~~ and not considered acceptable for meeting the TSS removal performance goal by themselves. Ordinary *grass channels* are not engineered to provide the same treatment capability as a well-designed dry swale with filter media. *Filter strips* are designed to accommodate overland flow rather than channelized flow and can be used as stormwater credits to help reduce the total water quality treatment volume for a site. Both of these practices may be used for pretreatment or included in a “treatment train” approach where redundant treatment is provided. Please see a further discussion of these types of limited application structural controls in subsections 3-3.14.28 and 3-3.24.9, respectively.

3.2.64.8.2 Stormwater Management Suitability

Enhanced swale systems are designed primarily for stormwater quality and have only a limited ability to provide channel protection or to convey higher flows to other controls.

Water Quality

Dry swale systems rely primarily on filtration through an engineered media to provide removal of stormwater contaminants. Wet swales achieve pollutant removal both from sediment ~~accumulation-removal~~ and biological removal.

Section 3.2.64.8.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection

Generally only the WQ_v is treated by a dry or wet swale, and another structural control must be used to provide Cp_v extended detention. However, for some smaller sites, a swale may be designed to capture and detain the full Cp_v .

Overbank Flood Protection

Enhanced swales must provide flow diversion and/or be designed to safely pass overbank flood flows. Another structural control must be used in conjunction with an enhanced swale system to reduce the post-development peak flow of the 25-year storm (Q_{p25}) to pre-development levels (detention).

Extreme Flood Protection

Enhanced swales must provide flow diversion and/or be designed to safely pass extreme storm flows. Another structural control must be used in conjunction with an enhanced swale system to reduce the post-development peak flow of the 100-year storm (Q_1) if necessary.

3.2.64.8.3 Pollutant Removal Capabilities

Both the dry and wet enhanced swale are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed swales can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or "treatment train" approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – Dry Swale 50% / Wet Swale 25%**
- **Total Nitrogen – Dry Swale 50% / Wet Swale 40%**
- **Fecal Coliform – insufficient data**
- **Heavy Metals – Dry Swale 40% / Wet Swale 20%**

For additional information and data on pollutant removal capabilities for enhanced dry and wet swales, see the National Pollutant Removal Performance Database (~~2nd Edition~~[Version 3](#)) available at www.cwp.org and the National Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

3.2.64.8.4 Application and Feasibility Criteria

Enhanced swales can be used in a variety of development types; however, they are primarily applicable to residential and institutional areas of low to moderate density where the impervious cover in the contributing drainage area is relatively small, and along roads and highways. Dry swales are mainly used in moderate to large lot residential developments, small impervious areas (parking lots and rooftops), and along rural highways. Wet swales tend to be used for highway runoff applications, small parking areas, and in commercial developments as part of a landscaped area.

Because of their relatively large land requirement, enhanced swales are generally not used in higher density areas. In addition, wet swales may not be desirable for some residential applications, due to the presence of standing and stagnant water, which may create nuisance odor or mosquito problems.

The topography and soils of a site will determine the applicability of the use of one of the two enhanced swale designs. Overall, the topography should allow for the design of a swale with sufficient slope and cross-sectional area to maintain non-erosive velocities. The following criteria should be evaluated to ensure the suitability of an enhanced swale ~~stormwater pond~~ for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra Urban Areas – NO
- Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum
- Space Required – Approximately 10 to 20% of the tributary impervious area
- Site Slope – Typically no more than 4% channel slope
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 3 to 5 feet for dry swale; 1 foot for wet swale
- Minimum Depth to Water Table – 2 feet required between the bottom of a dry swale and the elevation of the seasonally high water table, if an aquifer or treating a hotspot; wet swale is below water table or placed in poorly drained soils
- Soils – Engineered media for dry swale

Other Constraints / Considerations

- Aquifer Protection – Exfiltration should not be allowed ~~for in~~ hotspots areas

3.2.64.8.5 Planning and Design Criteria

*The following criteria are to be considered **minimum** standards for the design of an enhanced swale system. Consult with the local review authority to determine if there are any variations to these criteria or additional standards that must be followed.*

A. LOCATION AND SITING

- ▶ A dry or wet swale should be sited such that the topography allows for the design of a channel with sufficiently mild slope (unless small drop structures are used) and cross-sectional area to maintain non-erosive velocities.
- ▶ Enhanced swale systems should have a contributing drainage area of 5 acres or less.
- ▶ Swale siting should also take into account the location and use of other site features, such as buffers and undisturbed natural areas, and should attempt to aesthetically “fit” the facility into the landscape.

- ▶ A wet swale can be used where the water table is at or near the soil surface, or where there is a sufficient water balance in poorly drained soils to support a wetland plant community.

B. GENERAL DESIGN

- ▶ Both types of enhanced swales are designed to treat the WQ_v through a volume-based design, and to safely pass larger storm flows. Flow enters the channel through a pretreatment forebay. Runoff can also enter along the sides of the channel as sheet flow through ~~a the use of a pea gravel flow spreader, such as a pea gravel~~ trench along the top of the bank.

Dry Swale

- ▶ A dry swale system consists of an open conveyance channel with a filter bed of permeable soils that ~~may~~ overlays an underdrain system. Flow passes into and is detained in the main portion of the channel where it is filtered through the soil bed. Runoff ~~may be~~ collected and conveyed by a perforated pipe and gravel underdrain system to the outlet. Figure ~~3-2-64.8-2~~ provides a plan view and profile schematic for the design of a dry swale system.

Wet Swale

- ▶ A wet swale or wetland channel consists of an open conveyance channel which has been excavated to the water table or to poorly drained soils. Check dams are used to create multiple wetland “cells,” which act as miniature shallow marshes. Figure ~~3-2-64.8-3~~ provides a plan view and profile schematic for the design of a wet swale system.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- ▶ Channel slopes between 1% and 2% are recommended unless topography necessitates a steeper slope, in which case 6- to 12-inch drop structures can be placed to limit the energy slope to within the recommended 1 to 2% range. Energy dissipation will be required below the drops. Spacing between the drops should not be closer than 50 feet. Depth of the WQ_v at the downstream end should not exceed 18 inches.
- ▶ Dry and wet swales should have a bottom width of 2 to 8 feet to ensure adequate filtration. Wider channels can be designed, but should contain berms, walls, or a multi-level cross section to prevent channel braiding or uncontrolled sub-channel formation.
- ▶ Dry and wet swales are parabolic or trapezoidal in cross-section and are typically designed with moderate side slopes no greater than 2:1 for ease of maintenance and side inflow by sheet flow (4:1 or flatter recommended).
- ▶ Dry and wet swales should maintain a maximum WQ_v ponding depth of 18 inches at the end point of the channel. A 12-inch average depth should be maintained.
- ▶ The peak velocity for the 2-year storm must be non-erosive for the soil and vegetative cover provided.
- ▶ If the system is on-line, channels should be sized to convey runoff from the overbank flood event (Q_{p25}) safely with a minimum of 6 inches of freeboard and without damage to adjacent property.

Dry Swale

- ▶ Dry swale channels are sized to store and infiltrate the entire water quality volume (WQ_v) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. The maximum ponding time is 48 hours, though a 24-hour ponding time is more desirable.
- ▶ ~~The dry swale consists of a permeable soil layer of at least 30 inches in depth, above an underdrain. The soil media should have an infiltration rate of at least 1 foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil. Where an underdrain collection system is utilized, it should be equipped with at least a 4-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a gravel layer. bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above a 4-~~

inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a 6-inch gravel layer. The soil media should have an infiltration rate of at least 1 foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil.

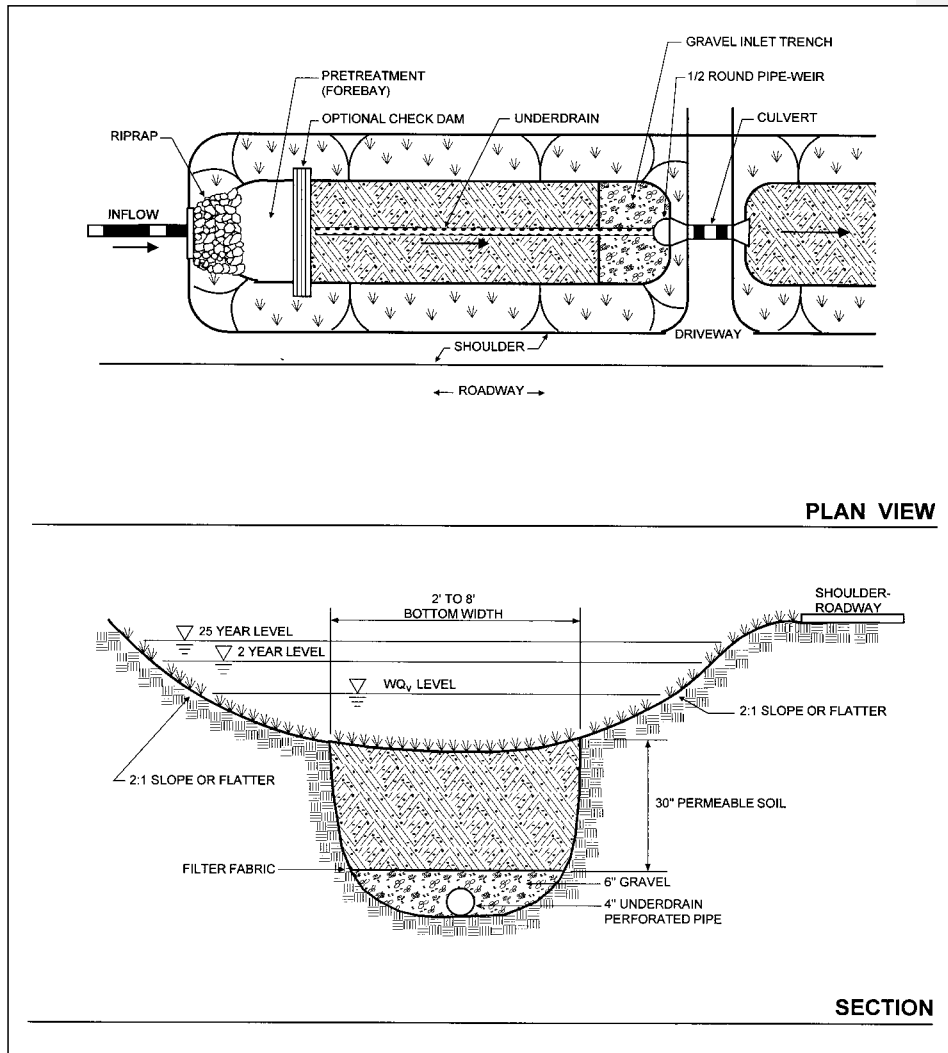


Figure 4.8-2 Schematic of Dry Swale

(Source: Center for Watershed Protection)

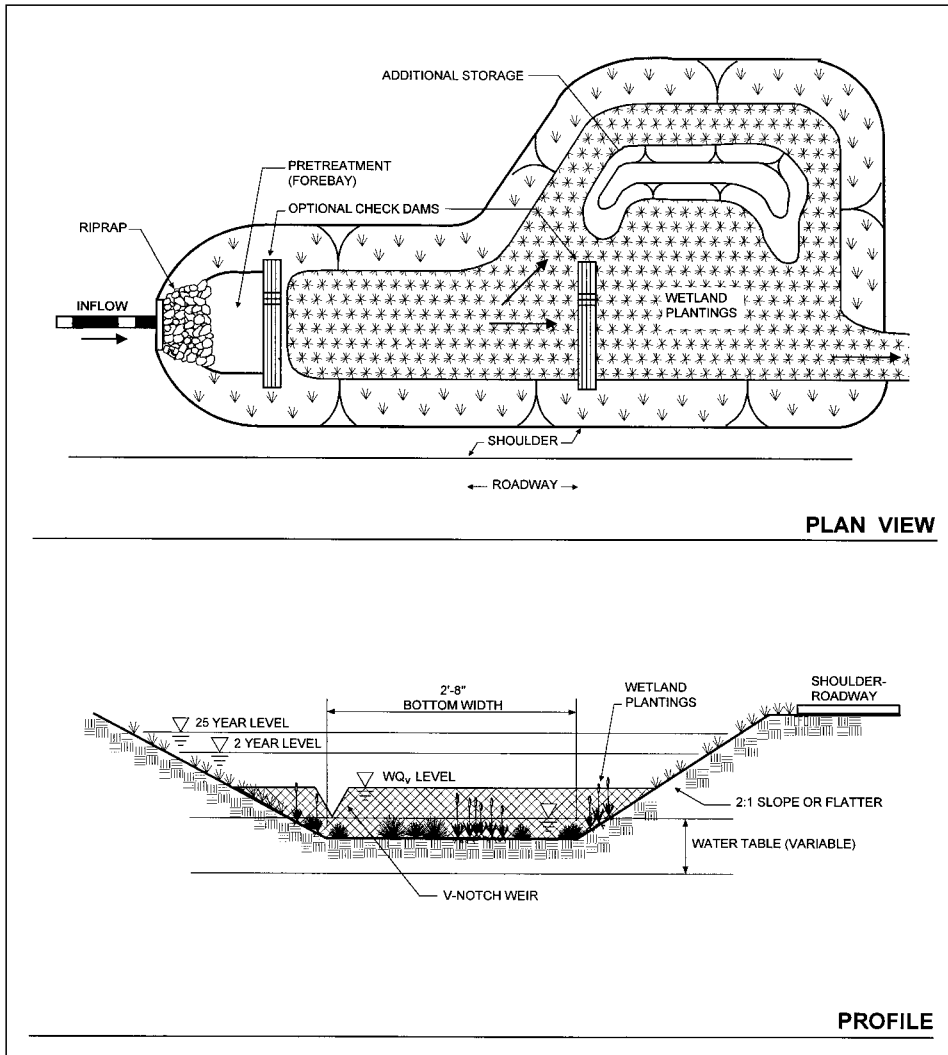


Figure 4.8-3 Schematic of Wet Swale
 (Source: Center for Watershed Protection)

- ▶ The channel and underdrain excavation should be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and shall be scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

Wet Swale

- ▶ Wet swale channels are sized to retain the entire water quality volume (WQ_v) with less than 18 inches of ponding at the maximum depth point.
- ▶ Check dams can be used to achieve multiple wetland cells. V-notch weirs in the check dams can be utilized to direct low flow volumes.

D. PRETREATMENT / INLETS

- ▶ Inlets to enhanced swales must be provided with energy dissipators such as riprap.
- ▶ Pretreatment of runoff in both a dry and wet swale system is typically provided by a sediment forebay located at the inlet. The pretreatment volume should be equal to 0.1 inches per impervious acre. This storage is usually obtained by providing check dams at pipe inlets and/or driveway crossings.
- ▶ Enhanced swale systems that receive direct concentrated runoff may have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control.
- ▶ ~~A pea gravel diaphragm~~ Vegetated filter strips and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.

E. OUTLET STRUCTURES

Dry Swale

- ▶ The underdrain system should discharge to the storm drainage infrastructure or a stable outfall.

Wet Swale

- ▶ Outlet protection must be used at any discharge point from a wet swale to prevent scour and downstream erosion.

F. EMERGENCY SPILLWAY

- ▶ Enhanced swales must be adequately designed to safely pass flows that exceed the design storm flows.

G. MAINTENANCE ACCESS

- ▶ Adequate access should be provided for all dry and wet swale systems for inspection and maintenance.

H. SAFETY FEATURES

- ▶ Ponding depths should be limited to a maximum of 18 inches.

I. LANDSCAPING

Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel. Table 4.8-1 below provides a number of grass species that perform well in the stressful environment of an open channel BMP. In addition, wet swales may include other wetland species (see plant list in Section 5 of Appendix D). Select plant material capable of salt tolerance in areas that may include high salt levels.

Table 4.8-1: Common Grass Species for Dry and Wet Enhanced Swales

Common Name	Scientific Name	Notes
Bermuda Grass	<i>Cynodon dactylon</i>	
Big Bluestem	<i>Andropogon gerardii</i>	Not for wet swales
Creeping Bentgrass	<i>Agrostis palustris</i>	
Red Fescue	<i>Festuca rubra</i>	Not for wet swales
Reed Canary Grass	<i>Phalaris arundinacea</i>	Wet swales
Redtop	<i>Agrostis alba</i>	
Smooth Brome	<i>Bromus inermis</i>	Not for wet swales
Switch Grass	<i>Panicum virgatum</i>	
Note 1: These grasses are sod-forming and can withstand frequent inundation, and are thus ideal for swale or channel environments. Most are salt-tolerant as well.		
Note 2: Where possible, one or more of these grasses should be in the seed mixes.		

The following information ~~Below~~ is some specific guidance for ~~dry and~~ wet swales:

Wet Swale

- ▶ Emergent vegetation should be planted, or wetland soils may be spread on the swale bottom for seed stock.
- ~~Information on establishing wetland vegetation and appropriate wetland species for Georgia can be found in Appendix D, Planting and Soil Guidance~~ Appendix F (Landscaping and Aesthetics Guidance).
- ▶ Where wet swales do not intercept the groundwater table, a water balance calculation should be performed to ensure an adequate water budget to support the specified wetland species. See subsection 23.1.8 for guidance on water balance calculations.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Reduced need for use of check dams
- High Relief – Often infeasible if slopes are greater than 4%
- Karst – No exfiltration of hotspot runoff from dry swales; use impermeable liner

Soils

No additional criteria

Special Downstream Watershed Considerations

- Aquifer Protection – No exfiltration of hotspot runoff from dry swales; use impermeable liner 3

K. CONSTRUCTION CONSIDERATIONS

- ▶ Construction equipment should be restricted from the enhanced swale area to prevent compaction of the native soils.
- ▶ A dense and vigorous vegetative cover should be established over the contributing pervious drainage areas before runoff can be accepted into the facility. Otherwise the sediment from the stormwater runoff will clog the pores in the planting media and native soils

3.2.64.8.6 Design Procedures

Step 1. Determine the goals and primary function of the enhanced swale and if a dry or wet swale is desired.

Consider whether the enhanced swale is intended to:

- Meet a runoff reduction* target or water quality (treatment) target. *Note that minimum infiltration rates of the surrounding native soils must be acceptable and suitable when used in runoff reduction applications.
- Be "oversized" to include partial credit for storage capacity for other stormwater requirements (Channel Protection Volume (Cp_v))
- Provide a possible solution to a drainage problem
- Enhance landscape and provide aesthetic qualities

Check with local officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply. In addition, consider if the enhanced swale has any special site-specific design conditions or criteria. List any restrictions or other requirements that may apply or affect the design.

The design of the enhanced swale should be centered on the restrictions/requirements, goals, targets, and primary function(s) of an enhanced swale. By considering the primary function, as well as, topographic and soil conditions, the design elements of the enhanced swale can be determined (i.e. planting media, underdrain, inlet/outlet, overflow, etc.)

Step 2. Determine if the development site and conditions are appropriate for the use of an enhanced swale

Consider the application and site feasibility criteria in this chapter. In addition, determine if site conditions are suitable for an enhanced swale. Create a rough layout of the enhanced swale dimensions taking into consideration existing trees, utility lines, and other obstructions.

Complete Steps 3A & 3B for a runoff reduction approach, or skip 'Step 3' and complete Steps 4A & 4B for a water quality (treatment) approach. Refer to your local community's guidelines for any additional information or specific requirements regarding either method. In cases where RR_v can be partially met, the remaining amount of WQ_v must be traditionally treated, refer to 'Step 5' for an additional discussion.

Step 3A. Calculate the Stormwater Runoff Reduction Target Volume

Calculate the Runoff Reduction Volume using the following formula:

$$RR_v = (P) (R_v) (A) / 12$$

Where:

RR_v = Runoff Reduction Target Volume (acre-feet)

P = Target runoff reduction rainfall (inches)

R_v = Volumetric runoff coefficient which can be found by:

$$R_v = 0.05 + 0.009(I)$$

Where:

I = new impervious area of the contributing drainage area (%)

A = Site area (acres)

12 = Unit conversion factor (in/ft)

Using Table 4.1.3-2 - BMP Runoff Reduction Credits, lookup the appropriate runoff reduction percentage (or credit) provided by the practice:

Calculate the Runoff Reduction Volume provided by the selected practice

$$RR_v (\text{provided}) = (RR\%) (RR_v)$$

Where:

RRv (provided) = Runoff Reduction Volume provided (acre-feet) by a specific BMP
 RR% = Runoff Reduction percentage, or credit, assigned to the specific practice
 RRv = Runoff Reduction Target Volume (acre-feet), as calculated at the beginning of Step 3A

When RRv(provided) = Target RRv, Water Quality requirements are met. If RRv (provided) is less than the Target RRv, then continue to Step 5.

To size the BMP based on RRv(provided), proceed to step 3B to calculate VP.

Step 3B. If using the practice for Runoff Reduction, determine the storage volume of the practice and the Pretreatment Volume

To determine the actual volume provided in the enhanced swale, use the following equation:

$$VP = (PV + VES (N))$$

Where:

VP = Volume provided (temporary storage)
 PV = Ponding Volume
 VES = Volume of Engineered Soils
 N = Porosity

To determine the porosity, a qualified licensed Professional should be consulted to determine the proper porosity based on the engineered soils used. Most soil media has a porosity of 0.25 and gravel a value of 0.40.

Provide pretreatment by using a grass filter strip or pea gravel diaphragm, as needed, (sheet flow), or a grass channel or forebay (concentrated flow). Where filter strips are used, 100% of the runoff should flow across the filter strip. Pretreatment may also be desired to reduce flow velocities or assist in sediment removal and maintenance. Pretreatment can include a forebay, weir, or check dam. Splash blocks or level spreaders should be considered to dissipate concentrated stormwater runoff at the inlet and prevent scour. Forebays should be sized to contain 0.1 inches per impervious acre of contributing drainagehold 10% of the WQ_v (or RRv). Refer to subsection 4.9 for design criteria for a grass channel and subsection 4.29 for vegetated filter strips.

Step 4A. Calculate the Target Water Quality Volume

Calculate the Water Quality Volume using the following formula:

$$WQ_v = (1.2) (R_v) (A) / 12$$

Where:

WQ_v = Water Quality Volume (acre-feet)

1.2 = Target rainfall amount to be treated (inches)

R_v = Volumetric runoff coefficient which can be found by:

$$R_v = 0.05 + 0.009(I)$$

Where:

I = new impervious area of the contributing drainage area (%)

A = Site area (acres)

12 = Unit conversion factor (in/ft)

Step 4B If using the practice for Water Quality treatment, determine the length and channel base width of the enhanced swale practice and the Pretreatment Volume required

Determine Swale Dimensions:

Size bottom width, depth, length, and slope necessary to store WQ_v with less than 18 inches of ponding at the downstream end.

- ▶ Slope cannot exceed 4% (1 to 2% recommended)
- ▶ Bottom width should range from 2 to 8 feet
- ▶ Ensure that side slopes are no greater than 2:1 (4:1 recommended)

See subsection 4.8.5-C (Physical Specifications / Geometry) for more details

Step 5. For a hybrid approach that would provide partial runoff reduction and the remaining amount of volume through traditional water quality treatment, calculate the following parameters:

Calculate Target RRV (refer to step 3A)

Calculate % Achieved Ratio (% of Overall Reduction provided by RRV):

$[\text{RRv (provided by practice)} / \text{Target RRV}] (100) = \text{RR \% Achieved}$

Where:

RRv provided = Volume of Runoff Reduction that the practice actually provides

Target RRV = Volume of Runoff Reduction that is required per local requirements

RR % Achieved = The portion of overall water quality requirement volume provided by RRV

Calculate WQv (refer to step 4A)

Calculate % Remaining to treat for WQ (% of Overall Treatment provided by WQv):

$100 - (\text{RR \% Achieved}) = \text{Remaining WQ to treat, as a percentage}$

Where:

WQ % Remaining = The remaining portion of volume that must be treated to reach the overall water quality goal.

Calculate the remaining volume to be traditionally treated by WQv

$(\text{WQv}) [(\text{WQ \% Remaining}) / 100] = \text{WQv remaining}$

Step 6. Compute number of check dams (or similar structures) required to detain WQ_v

Step 7. Calculate draw-down time

Dry swale: Planting soil should pass a maximum rate of 1.5 feet in 24 hours and must completely filter WQ_v within 48 hours.

Wet swale: Must hold the WQ_v.

Step 8 Check 2-year and 25-year velocity erosion potential and freeboard

Check for erosive velocities and modify design as appropriate. Provide 6 inches of freeboard.

Step 9. Design overflow weir or flow-orifice at downstream berm, headwalls, or ~~and~~ checkdams

Step 10. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQ_v (or RR_v) to the bioretention area.

Size low flow orifice, weir, or other device to pass Q_{wb} .

Step 11. Size underdrain system

See subsection 4.2.5 (Physical Specifications/Geometry)

Step 12. Design emergency overflow

An overflow must be provided to bypass and/or convey larger flows to the downstream drainage system or stabilized watercourse. Non-erosive velocities need to be ensured at the outlet point. The overflow should be sized to safely pass the peak flows anticipated to reach the practice, up to a 100-year storm event.

Step 1. Compute runoff control volumes from the Unified Stormwater Sizing Criteria

Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_e).

Details on the Unified Stormwater Sizing Criteria are found in Section 1.4.

Step 2. Determine if the development site and conditions are appropriate for the use of an enhanced swale system (dry or wet swale).

Consider the Application and Site Feasibility Criteria in subsections 3.2.6.4 and 3.2.6.5-A (Location and Siting).

Step 3. Confirm local design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 3.2.6.5-J (Additional Site-Specific Design Criteria and Issues).

Check with local officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Determine pretreatment volume

The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage. The forebay storage volume counts toward the total WQ_v requirement, and should be subtracted from the WQ_v for subsequent calculations.

Step 5. Determine swale dimensions

Size bottom width, depth, length, and slope necessary to store WQ_v with less than 18 inches of ponding at the downstream end.

- Slope cannot exceed 4% (1 to 2% recommended)
- Bottom width should range from 2 to 8 feet
- Ensure that side slopes are no greater than 2:1 (4:1 recommended)

See subsection 3.2.6.5-C (Physical Specifications / Geometry) for more details

Step 6. Compute number of check dams (or similar structures) required to detain WQ_v

Step 7. Calculate draw-down time

Dry swale:—Planting soil should pass a maximum rate of 1.5 feet in 24 hours and must completely filter WQ_v within 48 hours.

Wet swale:—Must hold the WQ_v .

Step 8. Check 2-year and 25-year velocity erosion potential and freeboard

Check for erosive velocities and modify design as appropriate. Provide 6 inches of freeboard.

Step 9. Design low flow orifice at downstream headwalls and checkdams

Design orifice to pass WQ_v in 6 hours. Use Orifice equation.

Step 1013. Design inlets, sediment forebay(s), and underdrain system (dry swale)

See subsection 3-2.64.8.5-D through H for more details.

Step 144. Prepare Vegetation and Landscaping Plan

A landscaping plan for a dry or wet swale should be prepared to indicate how the enhanced swale system will be stabilized and established with vegetation.

See subsection 3-2.64.8.5-I (Landscaping) and Appendix F-D for more details.

See Appendix DC-5 for an Enhanced Swale Design Example

3-2.64.8.7 Inspection and Maintenance Requirements



All best management practices require proper maintenance. Without proper maintenance, BMPs will not function as originally designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. For additional information on inspection and maintenance requirements, see Appendix XX.

Regular inspection and maintenance is critical to the effective operation of a bioslope as designed. Maintenance responsibility for a bioslope should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Table 3-2.64.8-1 Typical Maintenance Activities for Enhanced Swales
(Source: WMI, 1997; Pitt, 1997)

Activity	Schedule
For dry swales, mow grass to maintain a height of 4 to 6 inches. Remove grass clippings.	As-needed (frequent/seasonally)
- Inspect grass along side slopes for erosion and formation of rills or gullies and correct. - Remove trash and debris accumulated in the inflow forebay. - Inspect and correct erosion problems in the sand/soil bed of dry swales. - Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established. - Replant wetland species (for wet swale) if not sufficiently established. - Inspect pea gravel diaphragm for clogging and correct the problem.	Annually (Semi-annually the first year)
- Roto-till or cultivate the surface of the sand/soil engineered soil bed of dry swales if the swale does not draw down within 48 hours. - Remove sediment build-up within the bottom of the swale once it has accumulated to 25% of the original design volume.	As-needed

All best management practices require proper maintenance. Without proper maintenance, BMPs will not function as originally designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. For additional information on inspection and maintenance requirements, see Appendix XX.



Regular inspection and maintenance is critical to the effective operation of an enhanced swale as designed. Maintenance responsibility for an enhanced swale should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

3.2.64.8-8 Example Schematics

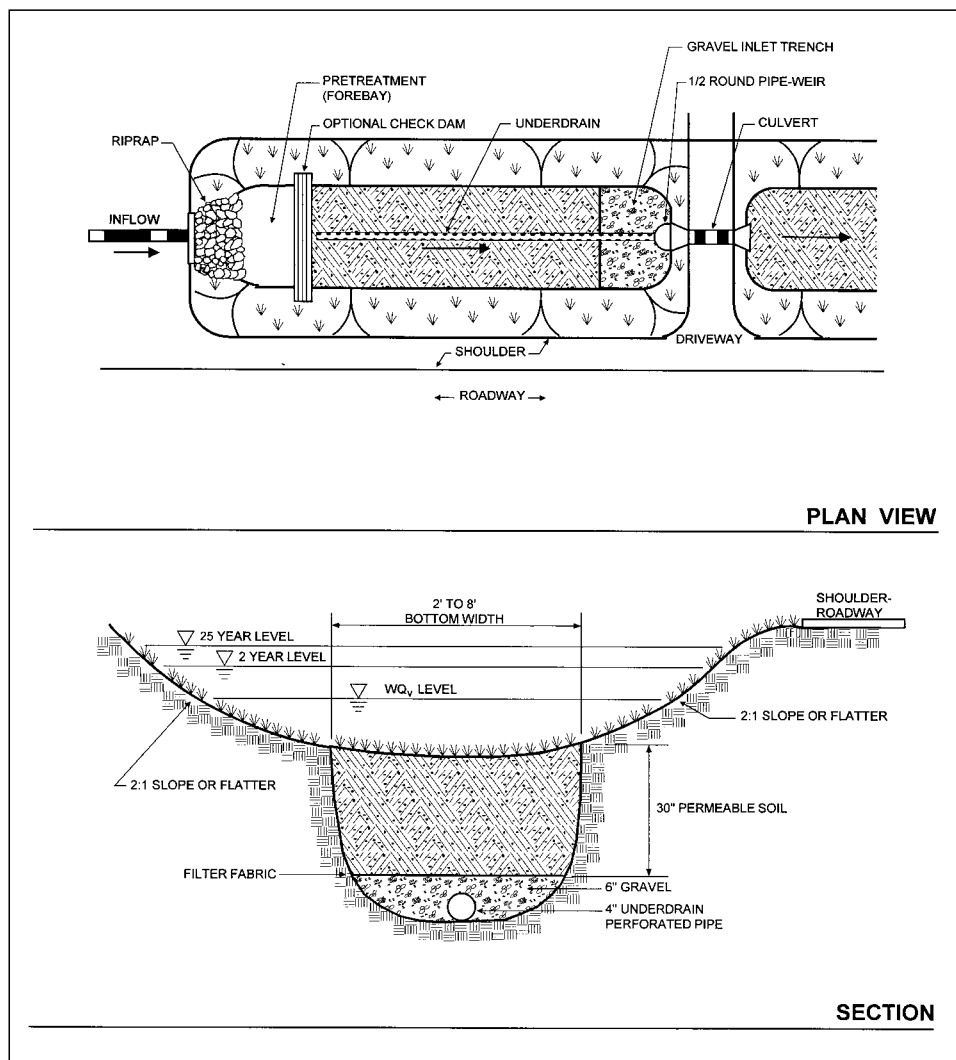


Figure 3.2.64.8-2 Schematic of Dry Swale

(Source: Center for Watershed Protection)

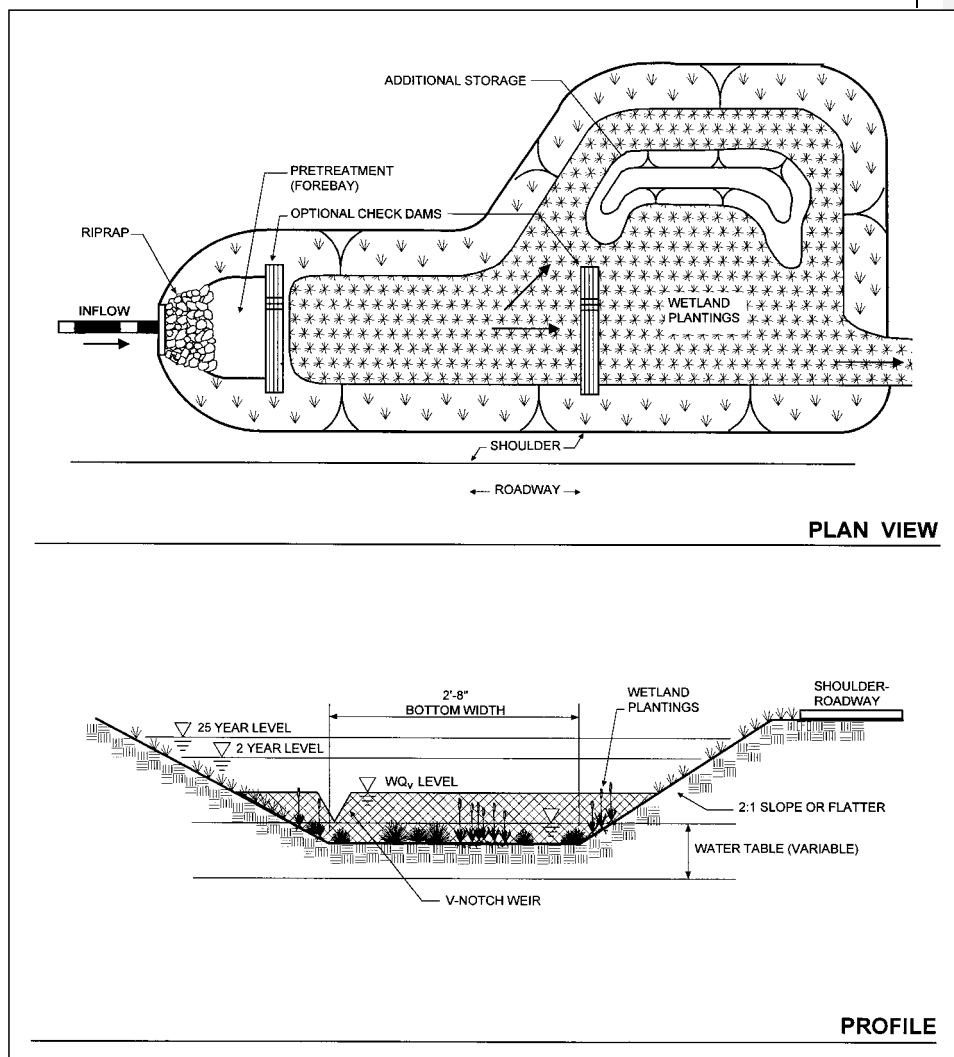


Figure 3.2.64.8-3 Schematic of Wet Swale

(Source: Center for Watershed Protection)

3.2.6.9 Design Forms

Design Procedure Form: Enhanced Swales

PRELIMINARY HYDROLOGIC CALCULATIONS

- 1a. Compute WQ_v volume requirements
Compute Runoff Coefficient, R_v
Compute WQ_v

$$R_v = \underline{\hspace{2cm}}$$
$$WQ_v = \underline{\hspace{2cm}} \text{ acre-ft}$$

- 1b. Compute Cp_v
Compute average release rate
Compute Q_{p-25}
Compute (as necessary) Q_t

$$Cp_v = \underline{\hspace{2cm}} \text{ acre-ft}$$
$$\text{release rate} = \underline{\hspace{2cm}} \text{ cfs}$$
$$Q_{p-25} = \underline{\hspace{2cm}} \text{ acre-ft}$$
$$Q_t = \underline{\hspace{2cm}} \text{ acre-ft}$$

ENHANCED SWALE DESIGN

2. Is the use of an enhanced swale appropriate?

See subsections 3.2.6.4 and 3.2.6.5 - A

3. Confirm local design criteria and applicability.

See subsection 3.2.6.5 - J

4. Pretreatment Volume

$$Vol_{pre} = I (0.1") (1'/12")$$

$$Vol_{pre} = \underline{\hspace{2cm}} \text{ acre-ft}$$

5. Determine swale dimensions

Assume trapezoidal channel with max depth of 18 inches

$$\text{Length} = \underline{\hspace{2cm}} \text{ ft}$$
$$\text{Width} = \underline{\hspace{2cm}} \text{ ft}$$
$$\text{Side Slopes} = \underline{\hspace{2cm}}$$
$$\text{Area} = \underline{\hspace{2cm}} \text{ ft}^2$$

6. Compute number of check dams (or similar structures)
required to detain WQ_v

$$\text{Slope} = \underline{\hspace{2cm}} \text{ ft/ft}$$
$$\text{Depth} = \underline{\hspace{2cm}} \text{ ft}$$
$$\text{Distance} = \underline{\hspace{2cm}} \text{ ft}$$
$$\text{Number} = \underline{\hspace{2cm}} \text{ each}$$

7. Calculate draw-down time

Require $k = 1.5$ ft per day for dry swales

$$t = \underline{\hspace{2cm}} \text{ hr}$$

8. Check 25-year velocity erosion potential and freeboard
Requires separate computer analysis for velocity

$$V_{min} = \underline{\hspace{2cm}} \text{ fps}$$

Overflow wier (use weir equation)

Use weir equation for slot length ($Q = CLH^{3/2}$)

$$\text{Weir Length} = \underline{\hspace{2cm}} \text{ ft}$$

9. Design low flow orifice at headwall

Area of orifice from orifice equation

$$Q = CA(2gh)^{0.5}$$

$$\text{Area} = \underline{\hspace{2cm}} \text{ ft}^2$$
$$\text{diam} = \underline{\hspace{2cm}} \text{ inch}$$

10. Design inlets, sediment forebays, outlet structures,
maintenance access, and safety features.

See subsection 3.2.6.5 - D through H

11. Attach landscaping plan (including wetland vegetation)

See Appendix F

Notes: _____

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