4.3.8 Enhanced Swales

General Application
Water Quality BMP

Description: Enhanced swales are 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.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 5 acres.
- 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.
- No soil restrictions.
- Dry swales require a permeable soil layer.
- Wet swales require wetland plants.

ADVANTAGES / BENEFITS:

- Combines stormwater treatment with runoff conveyance system.
- Less expensive than curb and gutter.
- Reduces runoff velocity and the potential for channel/ditch erosion.

DISADVANTAGES / LIMITATIONS:

- Higher maintenance than curb and gutter.
- 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).
- Occasional sediment removal from forebay and channel.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *Yes (requires impermeable liner)*

COST CONSIDERATIONS

Land Requirement:	**High**
Capital Cost:	**Med**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids (dry swale):	**90%**
Total Suspended Solids (wet swale):	**75%**

4.3.8.1 General Description

Enhanced swales (also referred to as *vegetated open channels* or *water quality swales*) are conveyance channels engineered to capture and treat the water quality volume (WQv) for a drainage area. They differ from a normal drainage channel or conventional swale because they incorporate specific features that enhance stormwater pollutant removal effectiveness.

Enhanced swales are designed with limited longitudinal slopes to force the stormwater 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*). Figure 4-39 illustrates each design. 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 overlays an underdrain system. Dry swales are sized to allow the entire WQv 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 WQv is retained.

Figure 4-39. Enhanced Swale Examples

Enhanced Dry Swale **Enhanced Wet Swale**

Enhanced swales must not to be confused with a *filter strip* or *grass channel*, because they afford a much higher level of water quality treatment than the latter BMPs. 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 reductions 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 structural controls in subsections 4.3.9 and 4.3.10, respectively.

4.3.8.2 Stormwater Management Suitability

Enhanced swale systems are designed primarily for stormwater quality and have only a limited ability to provide channel protection or flood protection.

Water Quality (WQv) and Channel Protection (CPv)

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 and biological removal. Generally only the WQv is treated by a dry or wet swale, and another structural BMP must be used to provide extended detention of the CPv. However, for some smaller sites, a swale may be designed to capture and detain the full CPv.

4.3.8.3 Pollutant Removal Capabilities

The dry enhanced swale is presumed to be able to remove 90% of the TSS load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. The TSS removal value for wet swales is 75%. 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 – Dry Swale 90% / Wet Swale 75%

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

4.3.8.4 Application and Feasibility Criteria

Enhanced swales can be used in a variety of development types; however, they are primarily applicable to residential and commercial 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 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 a stormwater basin for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for use in residential subdivisions and in non-residential areas.
- Not generally suitable for high density/ultra-urban areas, as land requirements may preclude their use.
- Not suitable for use as a regional stormwater control.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum
- Space Required – Approximately 10 to 20% of the tributary impervious area
- Channel Slope – Channel slope shall not exceed 4%
- 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 stormwater discharging from a hotspot land use; wet swale is below water table or placed in poorly drained soils
- Soils – Engineered media for dry swale

Other Constraints / Considerations

- Aquifer Protection – Exfiltration from the enhanced swale should be prevented in enhanced swales that serve hotspot land uses.

4.3.8.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of an enhanced swale. Enhanced swales that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- A dry or wet swale shall be located on a property such that the topography allows for the design of a channel with sufficiently mild slope, as discussed in part C below (unless small drop structures are used), and sufficient cross-sectional area to maintain non-erosive velocities. Site designers shall also take into account the location and use of other site features, such as buffers and undisturbed natural areas when determining the location of an enhanced swale, and should attempt to aesthetically "fit" the facility into the landscape.
- Enhanced swale systems shall have a contributing drainage area of 5 acres or less.
- A wet swale shall only 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.
- Each enhanced swale shall be placed in an easement that is recorded with the deed. The easement shall be defined from the centerline of the grass channel to the same width as that specified for stormwater pipes in the local regulations.

B. GENERAL DESIGN

- Enhanced swales that are located "on-line" shall also be designed to safely pass larger flows in accordance with the local jurisdiction's design criteria for open channels (Chapter 2). Flow enters the channel through a pretreatment forebay. Runoff can also enter along the sides of the channel as sheet flow through the use of a pea gravel flow spreader trench located along the top of the bank of the swale.

Dry Swale

- A dry swale system shall consist of an open conveyance channel with a filter bed of permeable soils that overlay 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 is collected and conveyed by a perforated pipe and gravel underdrain system to the outlet. Figure 4-40 presented at the end of this section provides a plan view and profile schematic for the design of a dry swale system.

Wet Swale

- A wet swale or wetland channel shall consist 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 4-41 presented at the end of this section provides a plan view and profile schematic for the design of a wet swale system.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

General

- The enhanced swale shall have a minimum slope of 1%, and the slope shall not exceed 4%. A 1% to 2% slope is considered ideal. Where topography necessitates a slope steeper than 2%, 6 to 12-inch drop structures must be designed and constructed to limit the energy slope to within the recommended 1 to 2% range. Energy dissipation is required below the drops. The drops shall be spaced a minimum of 50 feet apart.

- The maximum WQv ponding depth in the enhanced swale shall not exceed 18 inches at the end point of the swale. An average depth of 12-inches shall be maintained.
- Enhanced swales shall have a bottom width ranging from 2 to 8 feet to ensure adequate filtration. Wider channels will be permitted, but must contain berms, walls, or a compound cross-section to prevent channel braiding or uncontrolled sub-channel formation.
- Enhanced swales shall have a trapezoidal or compound cross-section. Side slopes shall not exceed 2:1. The local jurisdiction may approve side slopes up to 4:1 where side inflows by sheet flow will not be substantial, and where such swales can be easily maintained. Side slopes greater than 2:1 in residential areas are strongly discouraged.
- Enhanced swales shall be designed such that the peak velocity for the 2-year storm must be conveyed in a non-erosive manner, given the soil and vegetative cover provided.
- If the enhanced swale is on-line, the swale shall be sized to convey runoff for the locally regulated peak discharge.

Dry Swale

- Dry swale channels shall be sized to store and infiltrate the entire water quality volume (WQv) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. Ponding shall occur for no longer than 48 hours, though a 24-hour ponding time is more desirable.
- The bed of a dry swale shall consist of a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated longitudinal underdrain (PVC AASHTO M 252, HDPE or other suitable underdrain pipe material) in a 6-inch gravel layer. The soil media shall 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 shall be placed between the gravel layer and the overlying soil.
- Excavation of the dry swale and its associated underdrain shall 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 (WQv) 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 shall include energy dissipators, such as riprap.
- Pretreatment of runoff in both a dry and wet swale system shall be provided by a sediment forebay located at the inlet. The pretreatment volume shall be equal to 0.1 inches per impervious acre (363 ft^3). This storage can be obtained by providing check dams at pipe inlets and/or driveway crossings.
- Enhanced swale systems that receive direct concentrated runoff (as opposed to shallow concentrated or overland flow) shall have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control.
- A pea gravel diaphragm and gentle side slopes shall be provided along the top of channels to provide pretreatment for lateral sheet inflows.

E. OUTLET STRUCTURES

Dry Swale

- The underdrain system shall discharge in a non-erosive manner.

Wet Swale

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

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided for the length of the enhanced swale from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the entire enhanced swale.

G. LANDSCAPING

- The water quality management plan shall specify the landscape design of the enhanced swale, and shall include appropriate grass species and/or wetland plants based on specific site, soil and hydric conditions present. Vegetation shall be limited to grasses and non-woody wetland plants. Trees and other large woody plant species are not appropriate for use in an enhanced swale and are prohibited.

Dry Swale

- Turf grasses that require minimal maintenance shall be used in dry swales. Native grasses are preferred, but not required. Maintenance of the turf grasses shall be performed as appropriate to maintain a stable and viable coverage of the swale bottom and side slopes.

Wet Swale

- At the time of construction, emergent vegetation shall be planted in the swale, or wetland soils may be spread on the swale bottom for seed stock. More information on wetland plants can be found at the following websites:
  - http://wetlands.fws.gov/
  - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
- Where wet swales do not intercept the groundwater table, a water balance calculation shall be performed to ensure an adequate water budget to support the specified wetland species. See Chapter 3 for guidance on water balance calculations.

H. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of an enhanced swale.

Physiographic Factors - Local terrain design constraints

- Low Relief – Reduced need for use of check dams
- High Relief – Not feasible if slopes are greater than 4%
- Karst – No exfiltration of runoff from dry swales located in hotspot land uses; an impermeable liner shall be utilized for swales that control stormwater discharges from hotspot land uses.

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of runoff from land uses that have a high pollution potential. May require liner for type "A" and "B" soils; Pretreat runoff from polluted areas and hotspot land uses; 2 to 4 foot separation distance from water table

4.3.8.6 Design Procedures

Step 1. Compute appropriate runoff control volumes and peak discharges

Calculate WQv, CPv, and the locally regulated peak discharges, in accordance with the guidance presented in Chapter 3.

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 subsections 4.3.8.4 and 4.3.8.5-A (Location and Siting). Check with the local jurisdiction and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Determine pretreatment volume

The sediment forebay should be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage. The forebay storage volume counts toward the total WQv requirement, and should be subtracted from the WQv for subsequent calculations.

Step 4. Determine swale dimensions and compute number of check dams (or similar structures) required to detain WQv as per the above stated design criteria.

Size bottom width, depth, length, and slope necessary to store WQv 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

Step 5. Calculate draw-down time

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

Wet swale: Must hold the WQv.

Step 6. Check for erosion potential and freeboard at the local design storm flows

Check for erosive velocities and modify design as appropriate. Provide 6 inches of freeboard for the 25-year event.

Step 7. Design low flow orifice at downstream headwalls and check dams

Design orifice to pass WQv in six hours.

Step 8. Design inlets, sediment forebay(s), and underdrain system (dry swale)

See design criteria above for further details.

Step 9. Prepare Vegetation and Landscaping Plan

A landscaping plan for a dry or wet swale shall be submitted with the stormwater management plan that indicates the vegetation proposed for the swale, and how the enhanced swale system will be stabilized and established with vegetation.

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4.3.8.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.8.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of enhanced swales as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for enhanced swales, along with a suggested frequency for each activity. Individual enhanced swales may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the swale in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• Inspect after seeding and after first major storm for any damage to vegetation, side slopes and bottom.	Post construction
• Inspect for signs of erosion, unhealthy or damaged vegetation, denuded areas, channelization of flow, debris and litter, and areas of sediment accumulation. Perform inspections at the beginning and end of the wet season. Additional inspections after periods of heavy rainfall are desirable.	Semi-annually
• Inspect level spreader for clogging (if applicable), grass along side slopes for erosion and formation of rills or gullies, and sand/soil bed for erosion problems. Inspect pea gravel diaphragm for clogging. • Inspect sediment forebays and/or pretreatment areas for debris and sediment accumulation.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow grass to maintain a height of 3–4 inches, for safety, aesthetic, or other purposes, if needed. Litter should always be removed prior to mowing. Grass clippings, if captured, should not be dumped in the swale. • Irrigate swale during dry season (April through October) or when necessary to maintain the vegetation. • Repair damaged areas (e.g., erosion rills or gullies) and re-establish vegetation where needed. Remove invasive species manually. The use of fertilizers, herbicides and pesticides should occur only when absolutely necessary, and then in minimal amounts.	As needed (frequent, seasonally)
• Remove litter, branches, rocks blockages, and other debris and dispose of properly. • Clear accumulated debris and sediment from the inlet flow spreader (if applicable) and pea gravel diaphragm.	Semi-annually
• Inspect pea gravel diaphragm for clogging and correct the problem. • Plant an alternative grass species if the original grass cover has not been successfully established. Reseed and apply mulch to damaged areas.	Annually (if needed)
• Remove all accumulated sediment that may obstruct flow through the swale. Sediment accumulating near culverts and in channels should be removed when it builds up to 3 in. at any spot, or covers vegetation, or once it has accumulated to 10% of the original design volume. Replace the grass areas damaged in the process. • Remove all accumulated sediment in the sediment forebay and pretreatment areas. • Repair areas of erosion around swale and underdrain outlets. Reestablish soil stabilization measures (e.g., rip-rap stone, turf grasses) as needed. • Roto-till or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours. Re-establish swale vegetation after roto-till activities.	As needed (infrequent)

The local jurisdiction encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of enhanced swales. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the enhanced swale.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
ENHANCED SWALE INSPECTION CHECKLIST

Location: _____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: _____

Date: _____ Time: _____ Site conditions:_____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Enhanced Swale		
Healthy vegetation?		
Erosion on bottom or side slopes?		
Animal burrows in swale?		
Clear of debris and functional?		
Check dams in place (if applicable)?		
Evidence of sediment accumulation?		
Unintentional obstructions or blockages?		
Clogged pea gravel diaphragm?		
Undesirable vegetation growth?		
Visible pollution?		
Other (describe)?		
Inlet/Outlet Channels		
Clear of debris and functional?		
Sediment accumulation?		
Signs of erosion?		
Other (describe)?		
Sediment Forebays or Pretreatment Areas		
Evidence of sediment accumulation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature: _____ **Inspector Name (printed)**_____

4.3.8.8 Example Schematics

Figure 4-40. Schematic of a Dry Swale
(Source: Center for Watershed Protection)

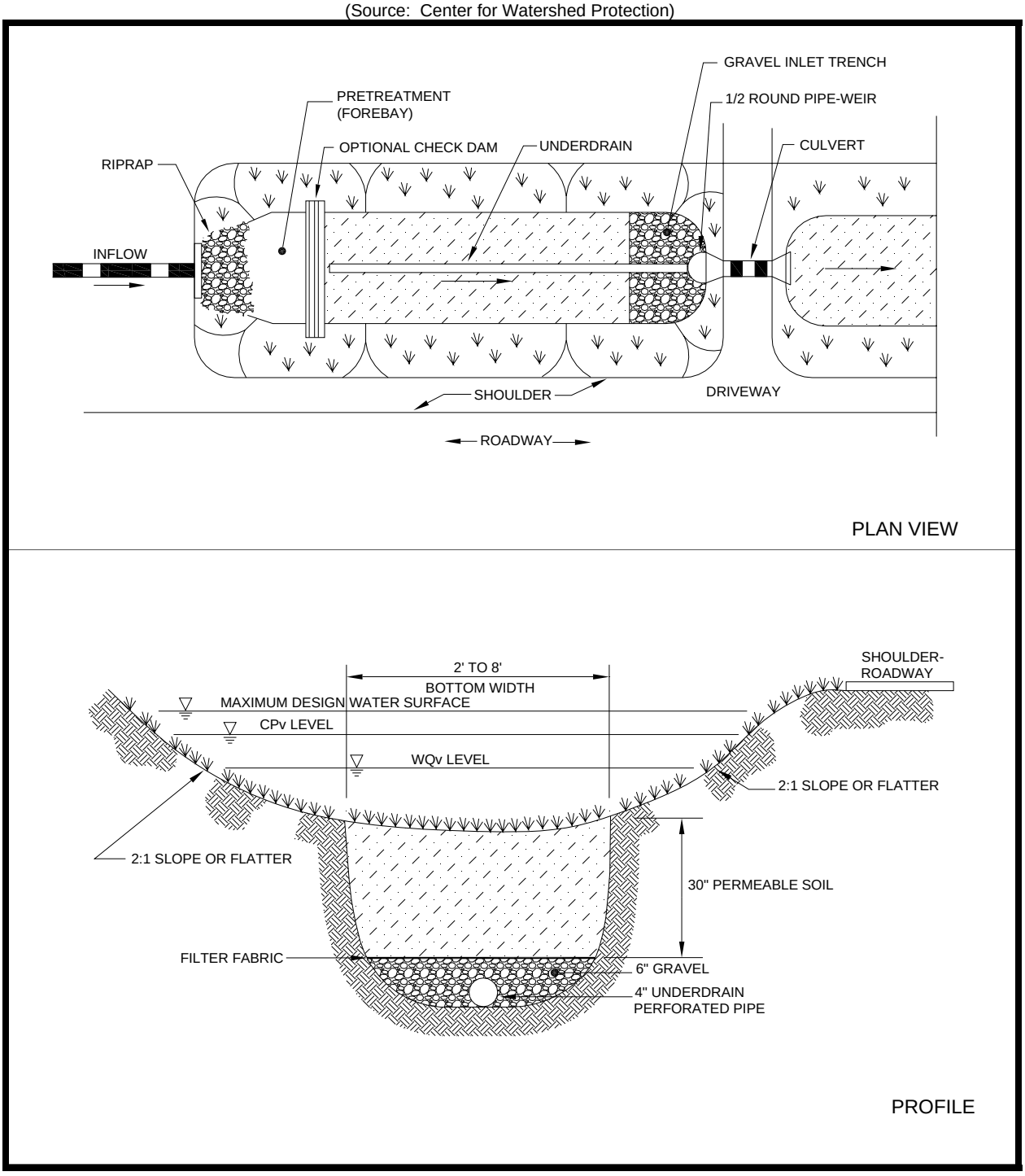
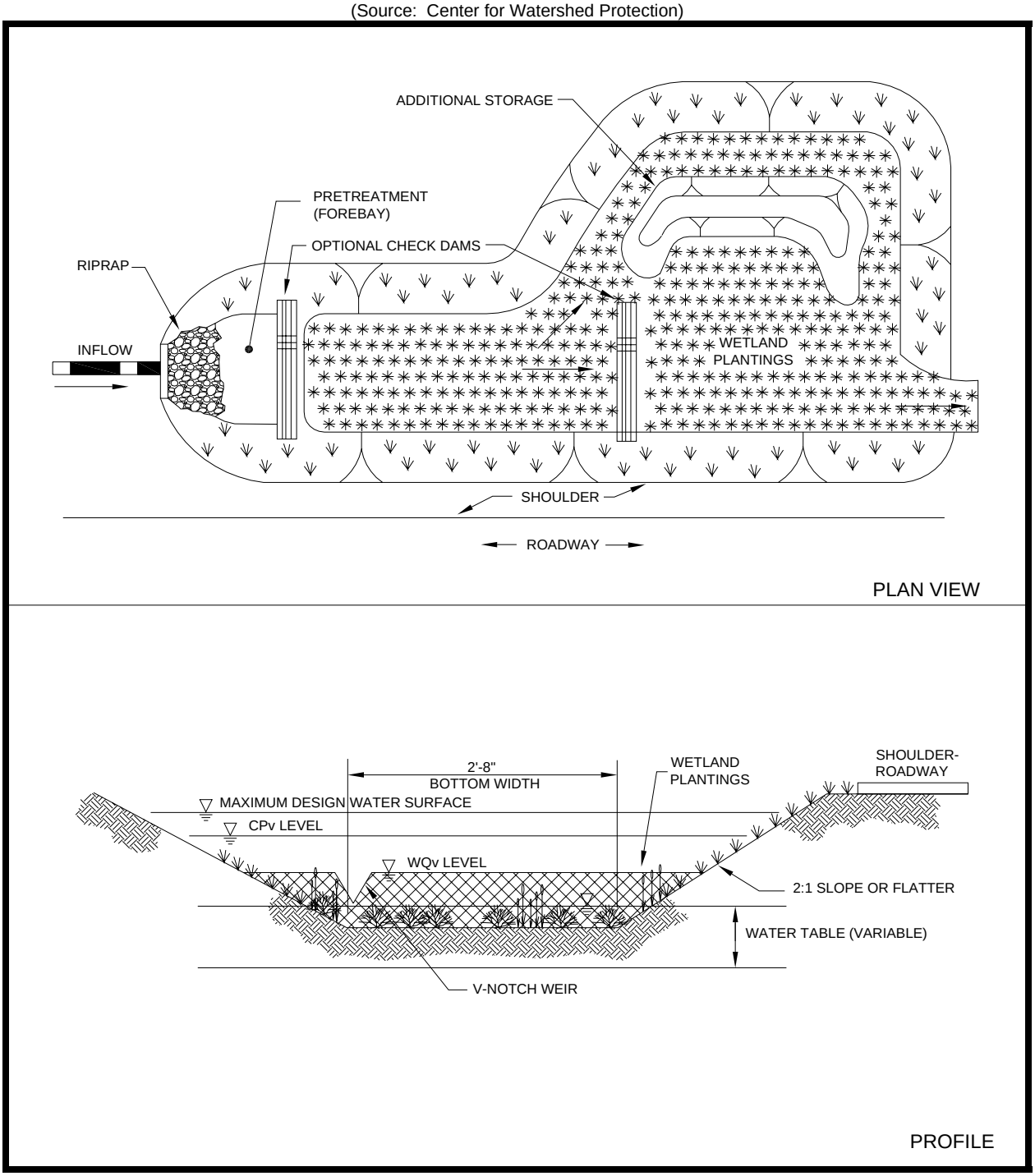


Figure 4-41. Schematic of a Wet Swale

(Source: Center for Watershed Protection)



4.3.8.9 Design Form

The local jurisdiction recommends the use of the following design procedure forms when designing enhanced swales. Proper use and completion of the form may allow a faster review of the Water quality Management Plan by the local jurisdiction.

Design Procedure Form: Enhanced Swales

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements Compute Runoff Coefficient, Rv	Rv = _____
Compute WQv	WQv = _____ acre-ft
1b. Compute CPv	CPv = _____ acre-ft
ENHANCED SWALE DESIGN	
2. Is the use of an enhanced swale appropriate?	***See subsections 4.3.8.4 and 4.3.8.5 - A***
Confirm design criteria and applicability.	***See subsection 4.3.8.5 - J***
3. Pretreatment Volume (Forebay) V_{pre} =(I)(.1")(1'/12")	V_{pre} = _____ acre-ft
4. Determine swale dimensions Assume trapezoidal channel with max depth of 18 inches	
	Length = _____ ft Width = _____ ft Side Slopes = _____ Area = _____ ft^2
Compute number of check dams (or similar structures) required to detain WQv	Slope = _____ ft/ft Depth = _____ ft Distance = _____ ft Number = _____ each
5. Calculate draw-down time Require k = 1.5 ft per day for dry swales	t = _____ hr
6. Check erosion potential and freeboard Requires separate computer analysis for velocity	V_{min} = _____ fps
Overflow wier (use weir equation) Use weir equation for slot length ($Q = CLH^{3/2}$)	Weir Length = _____ ft
7 Design low flow orifice at headwall Area of orifice from orifice equation $Q = CA(2gh)^{0.5}$ C varies with orifice condition	Area = _____ ft^2 diameter _____ inches
8 Design inlets, sediment forebays, outlet structures, maintenance access, and safety features.	***See subsection 4.3.8.5 - D through H***
9. Design landscaping plan (including wetland vegetation)	

Notes: _____

4.3.8.10 References

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4.3.8.11 Suggested Reading

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