2.2.2 Enhanced Swales

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.

KEY CONSIDERATIONS

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 "Conveyance" storm event with minimum freeboard, as specified in Local Criteria

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)
- Concerns with aesthetics of 4"-6" high grass in residential areas

MAINTENANCE REQUIREMENTS:

- Maintain grass heights of approximately 4 to 6 inches (dry swale)
- Remove sediment from forebay and channel

POLLUTANT REMOVAL (DRY SWALE)

80%	**Total Suspended Solids**
25/40%	**Nutrients** – Total Phosphorous / Total Nitrogen Removal
40%	**Metals** – Cadmium, Copper, Lead, and Zinc Removal
No Data	**Pathogens** – Coliform, Streptococci, E. Coli Removal

STORMWATER MANAGEMENT SUITABILITY

P	Water Quality Protection
S	Streambank Protection
S	On-Site Flood Control
S	Downstream Flood Control

Accepts Hotspot Runoff: Yes (requires impermeable liner)

IMPLEMENTATION CONSIDERATIONS

H	Land Requirement
M	Capital Cost
L	Maintenance Burden

Residential Subdivision Use: Yes
Hi Density/Ultra-Urban: No
Drainage Area: 5 Ac. Max.
Soils: No Restrictions
Other Considerations:

- Permeable Soil Layer (dry swale)
- Wetland plants (wet swale)

L = Low M = Moderate H = High

2.2.2.1 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 (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 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 Dry Swale

Figure 2.2.2-1 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 limited application structural controls in subsections 2.2.12 and 2.2.3, respectively.

2.2.2.2 Stormwater Management Suitability

Enhanced swale systems are designed primarily for stormwater quality and have only a limited ability to provide streambank 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 and biological removal.

Section 2.2.2.3 provides pollutant removal efficiencies that can be used for planning and design purposes.

Streambank Protection

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

On-Site Flood Control

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.

Downstream Flood Control

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.

2.2.2.3 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) available at www.cwp.org and the National Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org

2.2.2.4 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 nonerosive velocities. The following criteria should be evaluated to ensure the suitability of a 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 treating a hotspot or an aquifer recharge zone. Wet swale is below water table or placed in poorly drained soils
- Soils – Engineered media for dry swale

Other Constraints / Considerations

- Aquifer Protection – Infiltration should not be allowed for hotspots

2.2.2.5 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 nonerosive 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 the use of a pea gravel flow spreader 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 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 is collected and conveyed by a perforated pipe and gravel underdrain system to the outlet. Figure 2.2.2-2 provides a plan view and cross-section 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 2.2.2-3 provides a plan view and cross-section 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 3 storm events ("Streambank Protection", "Conveyance", and 100-year) must be nonerosive for the soil and vegetative cover provided.
- If the system is on-line, channels should be sized to convey runoff from a flood event safely with a minimum 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 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.
- 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 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 dissipaters 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 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. Below is some specific guidance for dry and wet swales:

Dry Swale

- ➢ Information on appropriate turf grass species for North Central Texas can be found in Appendix F (*Landscaping and Aesthetics Guidance)*.

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 North Central Texas can be found in 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 2.1.11 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 infiltration of hotspot runoff from dry swales; use impermeable liner

Soils

No additional criteria

Special Downstream Watershed Considerations

- ➢ Aquifer Protection – No infiltration of hotspot runoff from dry swales; use impermeable liner

2.2.2.6 Design Procedures

Step 1. Compute runoff control volumes from the Stormwater Management Design Approach

Calculate the Water Quality Volume (WQ_v), Streambank Protection Volume (SP_v), On-Site Flood Control Volume (V_s), and the Downstream Flood Control Volume (V_f).

Details on the Stormwater Management Design Approach are found in the Murfreesboro Stormwater Planning, Low Impact Design and Credit Guide.

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 2.2.2.4 and 2.2.2.5-A (Location and Siting).

Step 3. Confirm local design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 2.2.2.5-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 2.2.2.5-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 low flow and design event 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 10. Design inlets, sediment forebay(s), and underdrain system (dry swale)

See subsection 2.2.2.5-D through H for more details.

Step 11. 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 2.2.2.5-I (Landscaping) and Appendix F for more details.

See Appendix D-5 for an Enhanced Swale Design Example

2.2.2.7 Inspection and Maintenance Requirements

Table 2.2.2-1 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 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

Regular inspection and maintenance is critical to the effective operation of an enhanced swale system as designed. Maintenance responsibility for a dry or wet 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.

2.2.2.8 Example Schematics

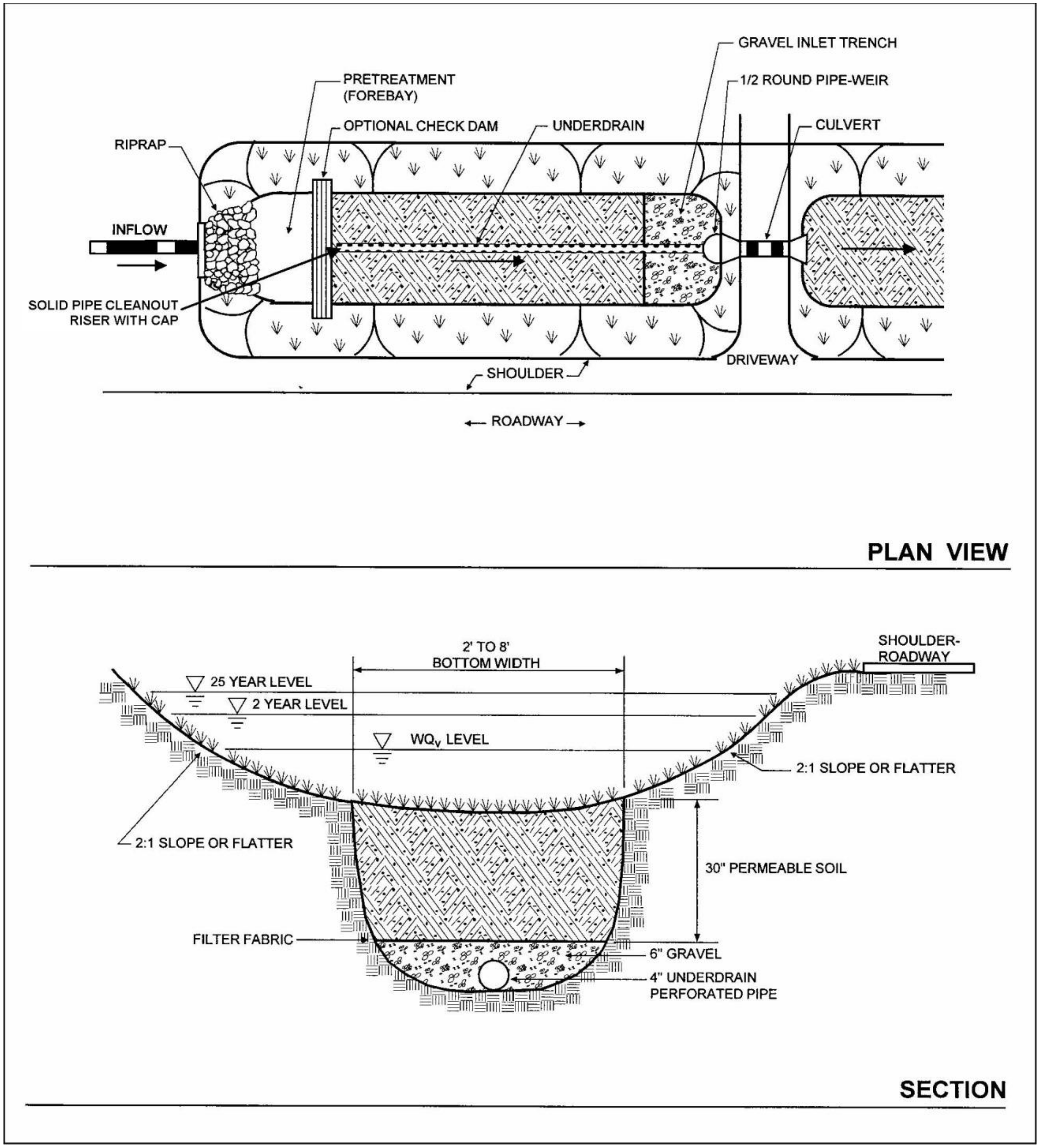

Figure 2.2.2-2 Schematic of Dry Swale
(Source: Center for Watershed Protection)

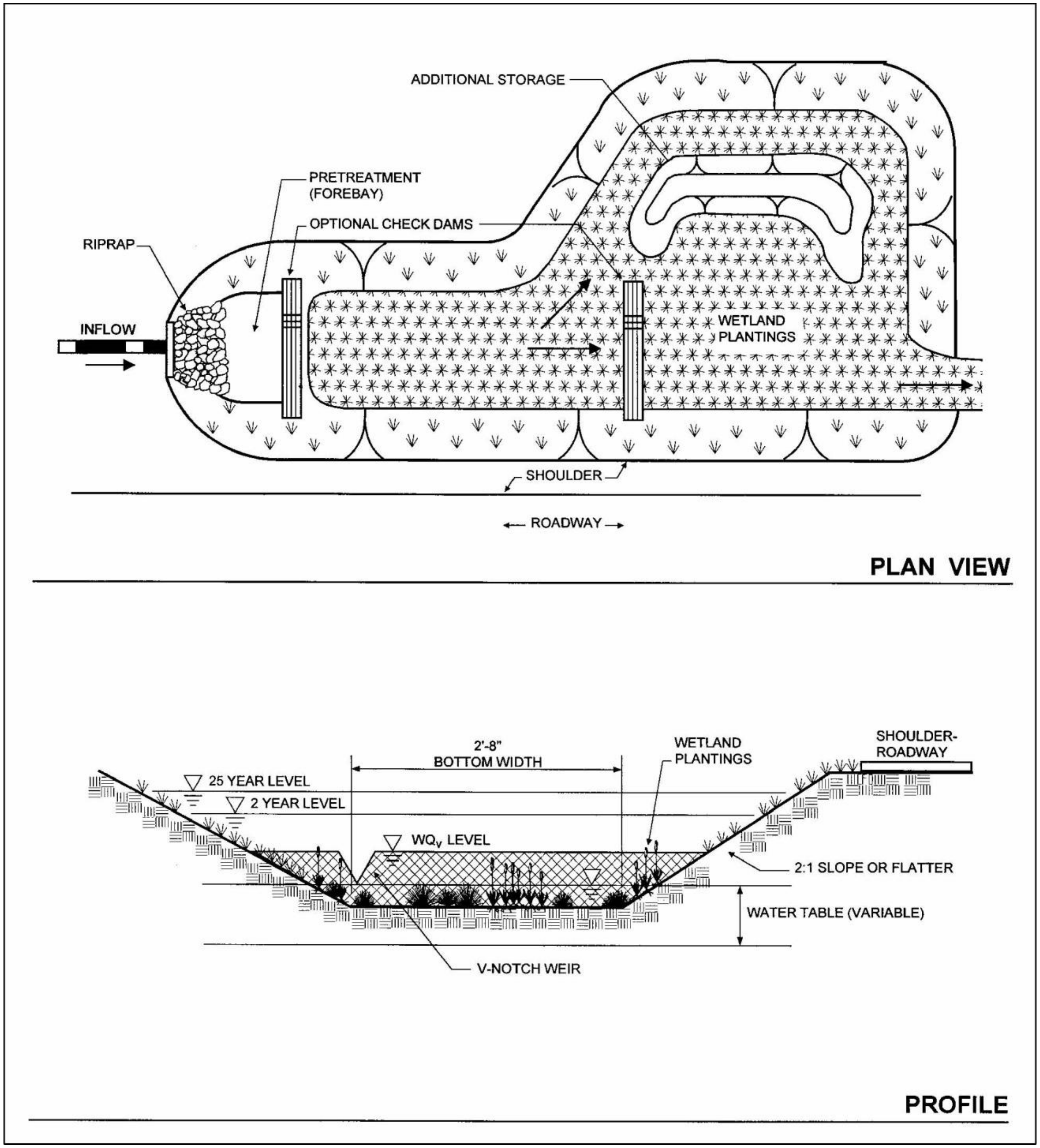

Figure 2.2.2-3 Schematic of Wet Swale
(Source: Center for Watershed Protection)

2.2.2.9 Design Forms

Design Procedure Form: Enhanced Swales

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements Compute Runoff Coefficient, Rv Compute WQv	Rv = _______________ WQv = ______________ acre-ft
1b. Compute SPv Compute average release rate Compute Qp (100-year detention volume required) Compute (as necessary) Qf	SPv = _______________ acre-ft release rate = _________ cfs Qp = ________________ acre-ft Qf = _________________ cfs
ENHANCED SWALE DESIGN	
2. Is the use of an enhanced swale appropriate?	***See subsections 2.2.2.4 and 2.2.2.5 -A***
3. Confirm local design criteria and applicability.	
4. Pretreatment Volume Volume = I (0.1")(1'/12")	***See subsection 2.2.2.5 –J*** Vol_{pre} = ______________ acre-ft
5. Determine swale dimensions Assume trapezoidal channel with max depth of 18 inches	Length = _____________ ft Width = ______________ ft Side Slopes = _________ Area = _______________ ft2
6. Compute number of check dams (or similar structures) required to detain WQv	Slope = ______________ ft/ft Depth = ______________ ft Distance = ____________ ft Number = _____________ each
7. Calculate draw-down time Require k = 1.5 ft per day for dry swales	t = ___________________ hr
8. Check low flow and design storm velocity erosion potential and freeboard Requires separate computer analysis for velocity	Vmin = ________________ fps
Overflow weir (use weir equation) Use weir equation for slot length ($Q = CLH^{3/2}$)	Weir Length = __________ ft
9. Design low flow orifice at headwall Area of orifice from orifice equation Q = CA(2gh)0.5	Area = ________________ ft2 diam = ________________ inch
10. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features.	***See subsection 2.2.2.5 -D through H See Appendix F***
11. Attach landscaping plan (including wetland vegetation)	

Notes: