Chapter 7: Virginia Stormwater Management Handbook (version 1.1)

Design Specifications for Construction BMPs

The Virginia Stormwater Management Handbook (Handbook) is intended to be a web-based living document that can be updated in a timely manner to reflect changes in laws, regulations, technology, and best management practices.

The Virginia Department of Environmental Quality (DEQ) will utilize a public notice and engagement process when making substantive updates to BMP specifications and other technical content in the Handbook.

- The most current version of the Handbook can always be found online at https://online.encodeplus.com/regs/deq-va/index.aspx

Version 1.1
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VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

CHAPTER 7 DESIGN SPECIFICATIONS FOR CONSTRUCTION BMPS

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7.1 Introduction to the New Virginia Construction Best Management Practices

In this chapter, the Virginia Stormwater Management Handbook update provides guidance on the standards and specifications for construction best management practices (BMPs). Construction BMPs, formerly referred to as erosion and sediment (E&S or ESC) controls, are those practices installed during land-disturbing activity to control the impact of construction on the local watershed.

This Handbook builds on the BMPs established in the 1992 Virginia Erosion and Sediment Control Handbook (VESCH) by incorporating the latest in industry standards and practices, correcting errors and omissions, and consolidating information from multiple sources into one update.

7.2 Significant Updates

Several significant updates have been introduced with the Handbook. The updates include not only additional guidance and BMPs for the designer, but an updated framework, numbering, and nomenclature used to integrate the construction and post-construction BMPs into one guidance framework.

Practices approved for use outside of the 1992 VESCH through the variance and standards and specifications process have been incorporated as either new construction BMPs or as components to an updated construction BMP.

7.2.1 Construction BMP Specifications Framework

The specifications framework for construction BMPs has been developed as an integrated framework with the post-construction BMPs described in Chapter 8. The specification framework includes the following sections:

- **Definition** – The clear and distinct description of the BMP.
- **Purpose and Applicability of Best Management Practice** – This section describes the purpose of the BMP and the general conditions under which the BMP should be considered for specification. The purpose of this section is to provide guidance in the selection of the appropriate BMP for the project.
- **Planning and Considerations** – This section provides guidance for consideration in the selection of BMPs as it relates to potential environmental and community impacts and how the BMP may interact with the surrounding environment. The purpose of this section is to provide guidance in the selection of the appropriate BMP for the project.
- **Stormwater Performance Summary** – This section of the specification provides guidance to the designer in selection of the appropriate BMPs to comply with the minimum standards. This section also provides a rating for the erosion control and sediment removal efficiency of the BMP. This section is provided for awareness purposes, as there are no target removal efficiency requirements.
- **Design Criteria** – This section provides the design criteria that generally must be followed to properly specify and implement each BMP.
- **Construction Specifications** – This section provides detailed installation, materials, and assembly directions for the construction of the BMP. Construction details are also included in this section.
- **Operations and Maintenance Considerations** – This section provides detailed guidance on the operations and maintenance procedure required to ensure adequate performance of the BMP.

7.2.2 Construction BMP Numbering and Nomenclature

The construction BMPs contained within this chapter feature a leading ‘C’ in the nomenclature to designate the BMP as a “Construction BMP.”

The nomenclature following the “C” identifies the subcategory of construction BMP:

- C-ECM – Erosion Control Measures;
- C-SCM – Sediment Control Measures;
- C-SSM – Surface Stabilization Measures;
- C-PCM – Perimeter Control Measures; and
- C-ENV – Environmentally Sensitive Area Protection.

The trailing number is the unique identifier for the BMP (e.g., Silt Fence [C-PCM-04]).

7.3 Overview of Best Management Practices

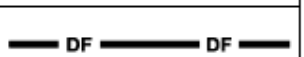
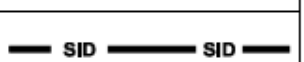
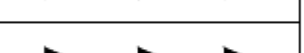
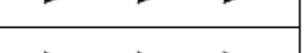
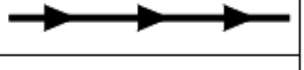
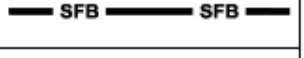
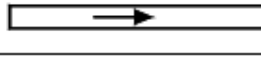
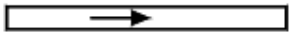
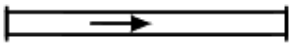
The following are summary overviews of the construction BMPs specified for use in Virginia. Complete standards and specifications for these practices are included in this chapter.

The construction BMPs are numbered and categorized in the following subsections.

– CAD and PDF files for Chapter 7.3

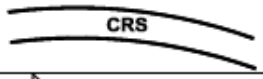
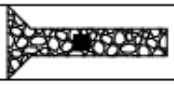
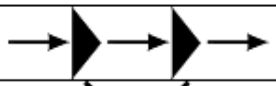
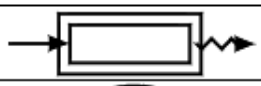
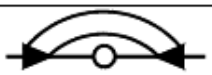
7.3.1 Erosion Control Measures – C-ECM

These construction BMPS are intended to prevent sheet, rill and gully erosion. These BMPs reduce the overland flow velocities, shorten the length of flow, and divert and convey runoff safely through the site.

EROSION CONTROL MEASURES		
C-ECM-01 STRAW WATTLES	SW	
C-ECM-02 IMPERMEABLE DIVERSION FENCE	DF	
C-ECM-03 SLOPE INTERRUPTION DEVICE	SID	
C-ECM-04 TEMPORARY DIVERSION DIKE	DD	
C-ECM-05 DIVERSION	DV	
C-ECM-06 TEMPORARY FILL DIVERSION	FD	
C-ECM-07 TEMPORARY RIGHT-OF-WAY DIVERSION	RWD	
C-ECM-08 WATERBARS AND SHEET FLOW BREAKERS	SFB	
C-ECM-09 STORMWATER CONVEYANCE CHANNEL	SCC	
C-ECM-10 SUBSURFACE DRAIN	SD	
C-ECM-11 PAVED FLUME	PF	
C-ECM-12 TEMPORARY SLOPE DRAIN	SLD	
C-ECM-13 RIPRAP	RR	
C-ECM-14 TEMPORARY LEVEL SPREADER	LS	
C-ECM-15 OUTLET PROTECTION	OP	
C-ECM-16 FLEXIBLE TRANSITION MAT	FM	

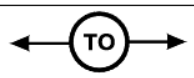
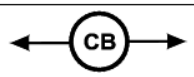
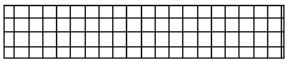
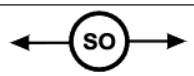
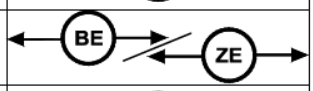
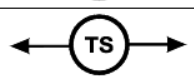
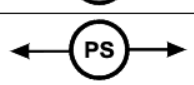
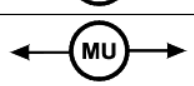
7.3.2 Sediment Control Measures – C-SCM

These construction BMPs are intended to prevent sediment transported by surface flows from leaving the site. These BMPs typically provide a means to capture or filter sediment practices.

SEDIMENT CONTROL MEASURES		
C-SCM-01 DUST CONTROL	DC	
C-SCM-02 CONSTRUCTION ROAD STABILIZATION	CRS	
C-SCM-03 TEMP STONE CONSTRUCTION ENTRANCE	CE	
C-SCM-04 INLET PROTECTION	IP	
C-SCM-05 CULVERT INLET PROTECTION	CIP	
C-SCM-06 WOOD CHIP FILTER BERM	FB	
C-SCM-07 ROCK CHECK DAMS	CD	
C-SCM-08 ROCK FILTER OUTLET	RFO	
C-SCM-09 TURBIDITY CURTAIN	TC	
C-SCM-10 DEWATERING STRUCTURE	DS	
C-SCM-11 TEMPORARY SEDIMENT TRAP	ST	
C-SCM-12 TEMPORARY SEDIMENT BASIN	SB	
C-ECM-13 CONCRETE WASHOUT PIT	CW	

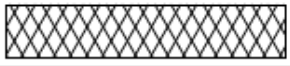
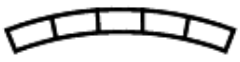
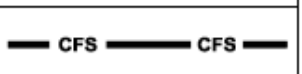
7.3.3 Surface Stabilization Measures – C-SSM

These construction BMPs are intended for use where final grade has been established to protect disturbed soil from surface runoff. The BMPs include both temporary covering and permanent vegetative cover that can become part of the final landscape.

SURFACE STABILIZATION MEASURES		
C-SSM-01 TREE PRESERVATION AND PROTECTION	TP	
C-SSM-02 TOPSOILING	TO	
C-SSM-03 SURFACE ROUGHENING	SR	
C-SSM-04 COMPOST BLANKETS	CB	
C-SSM-05 SOIL STABILIZATION BLANKETS AND MATTING	B/M	
C-SSM-06 SODDING	SO	
C-SSM-07 BERMUDAGRASS AND ZOYSIAGRASS ESTABLISHMENT	BE/ZE	
C-SSM-08 TREES, SHRUBS, VINES, AND GROUND COVER	VEG	
C-SSM-09 TEMPORARY SEEDING	TS	
C-SSM-10 PERMANENT SEEDING	PS	
C-SSM-11 MULCHING	MU	

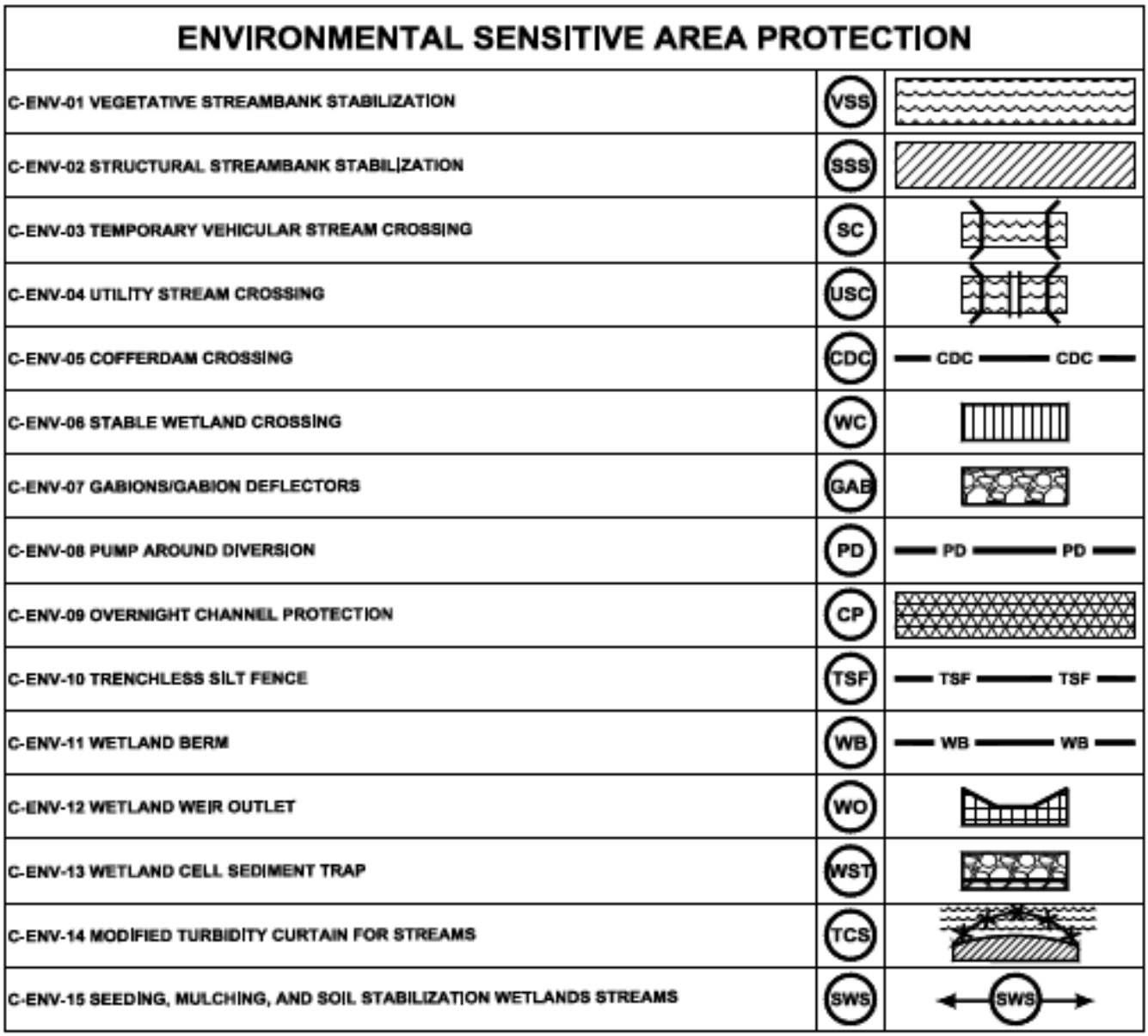
7.3.4 Perimeter Control Measures – C-PCM

These construction BMPs are intended to intercept sheet flow from slopes and remove sediment and other contaminants through ponding, settling, and physical filtration, effectively preventing contaminants from leaving the site and entering surface waters.

PERIMETER CONTROL MEASURES		
C-PCM-01 SAFETY FENCE	SAF	
C-PCM-02 STRAW BALE BARRIER	STB	
C-PCM-03 BRUSH BARRIER	BB	
C-PCM-04 SILT FENCE	SF	
C-PCM-05 COMPOST FILTER SOCK	CFS	

7.3.5 Environmentally Sensitive Area Protection – C-ENV

These construction BMPs are intended for use in environmentally sensitive areas, typically stream corridors, wetlands, and floodplains. These BMPs are typically applied where crossing or working within an environmentally sensitive area is necessary.



7.4 Standards and Specifications for Construction BMPs

Standards and specifications for construction BMPs are presented below.

List of BMPs

Select the title of the best management practice you want to view.

C-ECM-01	Straw Wattles
C-ECM-02	Impermeable Diversion Fence
C-ECM-03	Slope Interruption Device

C-ECM-04	Temporary Diversion Dike
C-ECM-05	Diversion
C-ECM-06	Temporary Fill Diversion
C-ECM-07	Temporary Right-of-Way Diversion
C-ECM-08	Waterbars and Sheet Flow Breakers
C-ECM-09	Stormwater Conveyance Channel
C-ECM-10	Subsurface Drains
C-ECM-11	Paved Flume
C-ECM-12	Temporary Slope Drain
C-ECM-13	Riprap
C-ECM-14	Level Spreader
C-ECM-15	Outlet Protection
C-ECM-16	Flexible Transition Mat
C-ENV-01	Vegetative Streambank Stabilization
C-ENV-02	Structural Streambank Stabilization
C-ENV-03	Temporary Vehicular Stream Crossing
C-ENV-04	Utility Stream Crossing
C-ENV-05	Cofferdam Crossing
C-ENV-06	Stable Wetland Crossing
C-ENV-07	Gabions
C-ENV-08	Pump Around Diversion
C-ENV-09	Overnight Channel Protection
C-ENV-10	Trenchless Silt Fence
C-ENV-11	Wetland Berm
C-ENV-12	Wetland Weir Outlet
C-ENV-13	Wetland Cell Sediment Trap
C-ENV-14	Modified Turbidity Curtain for Streams
C-ENV-15	Seeding, Mulching, and Soil Stabilization Wetland Streams
C-PCM-01	Safety Fence
C-PCM-02	Straw Bale Barrier
C-PCM-03	Brush Barrier
C-PCM-04	Silt Fence
C-PCM-05	Compost Filter Sock
C-SCM-01	Dust Control
C-SCM-02	Construction Road Stabilization
C-SCM-03	Temporary Stone Construction Entrance
C-SCM-04	Inlet Protection
C-SCM-05	Culvert Inlet Protection
C-SCM-06	Wood Chip Filter Berm
C-SCM-07	Rock Check Dams
C-SCM-08	Rock Filter Outlet
C-SCM-09	Turbidity Curtain
C-SCM-10	Dewatering Structure

C-SCM-11	Temporary Sediment Trap
C-SCM-12	Temporary Sediment Basin
C-SCM-13	Concrete Washout Pit
C-SSM-01	Tree Preservation and Protection
C-SSM-02	Topsoiling
C-SSM-03	Surface Roughening
C-SSM-04	Compost Blankets
C-SSM-05	Soil Stabilization Blankets
C-SSM-06	Sodding
C-SSM-07	Bermudagrass and Zoysiagrass Establishment
C-SSM-08	Trees, Shrubs, Vines, and Ground Cover
C-SSM-09	Temporary Seeding
C-SSM-10	Permanent Seeding
C-SSM-11	Mulching

C-ECM-01 Straw Wattles

1.0 Definition

Straw wattles are temporary erosion and sediment control best management practices (BMPs) consisting of weed- and seed-free agricultural straw wrapped in biodegradable netting, tubular plastic, or similar encasing material for the purpose of slowing water and trapping sediment.

2.0 Purpose and Applicability of Best Management Practice



Source: Flickr 2014

Straw wattles are used to break up the continuous length of a slope and to prevent concentrated flows from developing. Straw wattles reduce velocity, can spread the flow of rill and sheet runoff, and can filter and retain sediment. Straw wattles are most commonly available in 8- to 12-inch diameters.

Straw wattles can also be used to reduce flow rates and sedimentation to sinkholes that will be left in an undisturbed natural state located outside of the limits of disturbance (LODs) but that receive water flow from the LOD. Triangular dikes combined with straw wattles are the best method of reducing sediment load in a drainage channel leading to a sinkhole.

3.0 Planning and Considerations

Straw wattles are placed in shallow trenches and staked along the contour of disturbed or newly constructed slopes. Because of their lightweight composition, trenching and staking are required.

Straw wattles are biodegradable and do not necessarily need to be removed after site stabilization, although stakes should be.

Do not use straw wattles as check dams in conveyance channels or in areas of concentrated runoff.

Straw wattles are intended for use with low rates of flow, not to exceed 1 cubic foot per second at any point.

Straw wattles are not suitable to withstand vehicular traffic.

Straw wattles generally have a maximum longevity of 12 to 18 months.

4.0 Stormwater Performance Summary

MS-4 First-Step Measures – Construct sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment as a first step in any land-disturbing activity and make functional before the upslope land disturbance takes place.

9VAC25-875-560.

Erosion Control Efficiency: Moderate

Sediment Control Efficiency: Low

5.0 Design Criteria

Do not exceed a flowrate of 1 cubic foot per second to any point along the wattle from the maximum point upstream along a perpendicular flow path.

Determine the vertical spacing for slope installations based on the design criteria in Table C-ECM-01-1:

Table C-ECM-01-1 Design Criteria for Straw Wattles

Slope Gradient	Maximum Vertical Spacing (ft)
1:1	10
2:1	20
3:1	30
4:1	40

6.0 Construction Specifications

Fill wattles with compacted weed- and seed-free agricultural straw compressed inside a biodegradable encasement and tie both ends closed.

Set wattles in a 2-inch-deep trench or place wattles over bare soil or atop Soil Stabilization Blankets and Matting (C-SSM-05). See spec for installation procedures.

At a minimum, use 1-inch by 1-inch (nominal) by 36-inch stakes for wattles less than or equal to 12 inches in diameter.

Do not allow stakes to project more than 2 inches above the crown of the straw wattle.



Source: Olsen, Rikli, & Sillars, 2023

Secure wattles by stakes placed a maximum of every 4 linear feet. Set stakes through the center of the wattle and drive the stake into the ground at least 24 inches.

Install wattles parallel to the contour, with ends facing upstream at a 45-degree angle.

7.0 Operations and Maintenance Considerations

Inspect straw wattles weekly and after major rainfall events to ensure continued performance. If routine inspections observe flows bypassing around straw wattles, immediately correct the installation. When the accumulated sediment reaches half the height of the wattle roll, carefully remove the sediment and replace the wattle, taking care not to damage it (Resource Conservation District of Santa Cruz County n.d.).

Once a wattle is installed, unless damaged, it should remain in that location until its intended removal date. Wattles are not designed to be reused. Straw wattles are biodegradable, and in some applications may be left on site to decompose and allow vegetation to grow through it. However, it is advised to remove the stakes. Straw wattles generally have a maximum longevity of 12 to 18 months. Develop a replacement schedule when project durations are expected to exceed this length of time.

Wattles should only be removed after stabilization has been achieved. Proper wattle installation will capture sediment on the upslope side, accumulating fertile soil that will encourage vegetation to establish. When wattles are removed, the trench must be filled back in.

8.0 References

Dominion Energy. 2019. Standards & Specifications for Erosion & Sediment Control and Stormwater Management for Construction and Maintenance of Linear Electric Transmission Facilities (TE VEP 8000). May 2029.

Flickr. 2014. Hydroseeding a River Park neighborhood levee section. https://www.flickr.com/photos/usacehq/15919425935/in/photostream/

Olsen, Rikli, & Sillars. 2023. Investigation of Straw Wattle Influence on Surficial Slope Stability. Available online at: https://www.researchgate.net/publication/265478363_Investigation_of_Straw_Wattle_Influence_on_Surficial_Slope_Stability

Resource Conservation District of Santa Cruz County. No date. A Guide to Straw Wattle Installation. Available online at: https://www.rcdsantacruz.org/images/brochures/pdf/Straw_Wattle_Installation_Guildelines.pdf

C-ECM-02 Impermeable Diversion Fence

1.0 Definition

Impermeable diversion fence is a temporary barrier of impermeable sheeting over chain-link fence located to direct water to a desired location.

– CAD and PDF files for C-ECM-02 Impermeable Diversion Fence



Source: The Advanced Group 2023

2.0 Purpose and Applicability of Best Management Practice

Impermeable diversion fence is used to direct sediment-laden runoff to a sediment trapping device or to intercept and divert clean water away from disturbed areas.

Appropriate uses of diversion fences include:

1. To divert sediment-laden runoff from a disturbed area to a sediment trapping device;
2. To segment drainage areas for reducing acreage to sediment control devices; and
3. To divert clean water from an undisturbed area to a stable outlet at non-erosive velocities.

3.0 Planning and Considerations

Constructed along the limit of disturbance (LOD) or across disturbed areas, a diversion fence is used when there is insufficient space to construct an earth dike, temporary swale, or perimeter dike swale.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance occurs.

9VAC25-875-560.

Erosion Control Efficiency: MODERATE

Sediment-Removal Efficiency: LOW

5.0 Design Criteria

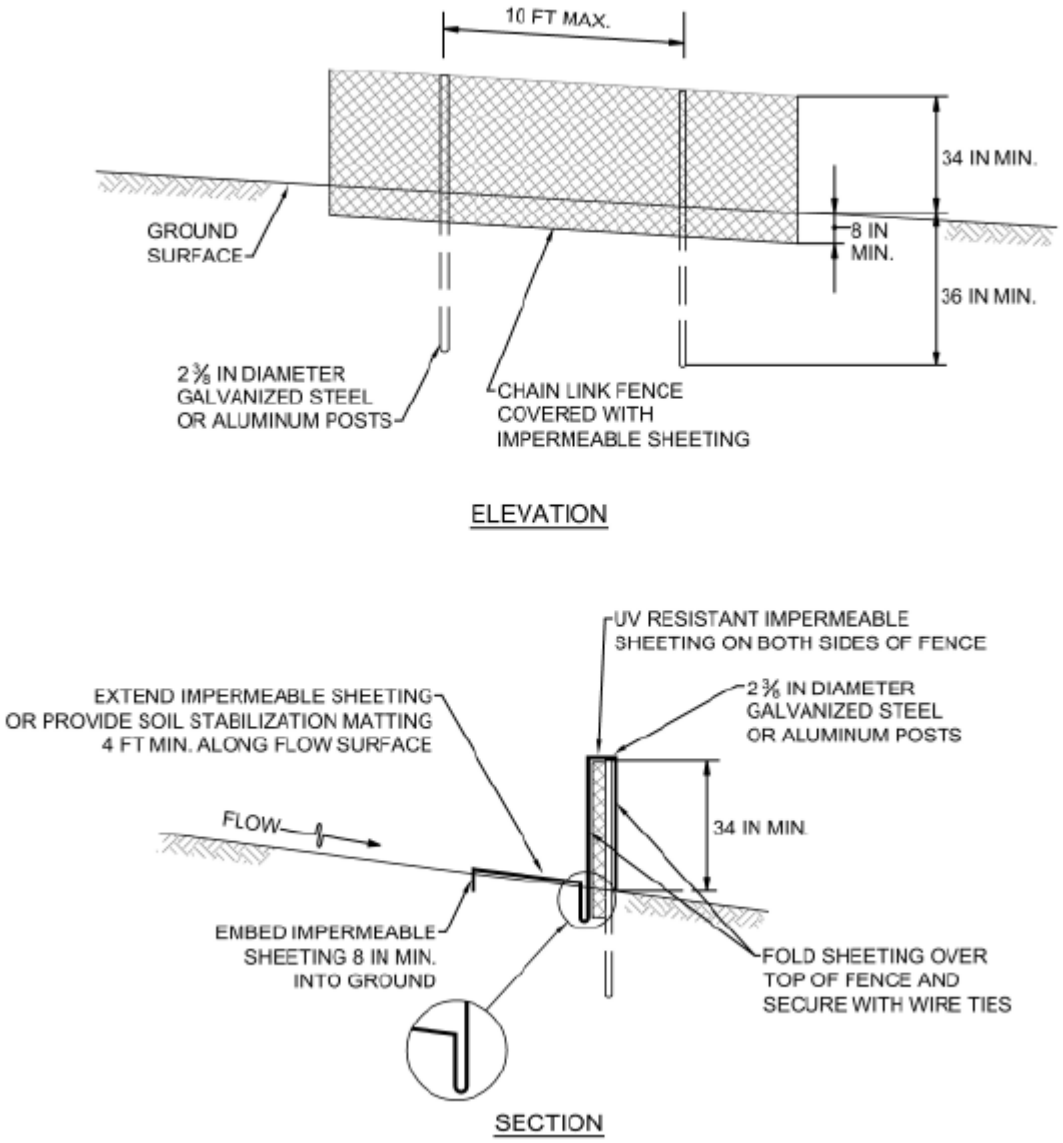
Table C-SCM-02-1 Impermeable Diversion Fence Design Parameters

Parameter	Notes on Proper Use
Slope	The maximum slope along the fence is 10%. Maintain positive drainage along the entire length of the diversion fence. Provide spot elevations for diversion fence where the longitudinal slopes are flatter than 1%.
Drainage Area	The maximum drainage area is 2 acres. For drainage areas larger than 2 acres, an engineering design may be used based on the 2-year frequency storm with Natural Resources Conservation Service (NRCS) methodologies (e.g., TR-55, TR-20) assuming that the worst soil cover conditions will prevail in the contributing drainage area over the life of the diversion fence.
Discharge	Ensure that discharge velocities from the diversion fence are non-erosive. Discharge the outlet of the diversion fence to a sediment control device suitable for accepting concentrated flow where a diversion fence is used to convey runoff from disturbed areas. Silt fence and super silt fence are unacceptable for receiving discharges from diversion fences. Discharge the diversion fence to an undisturbed, stable area at a non-erosive velocity, refer to the lowest permissible velocity based on the channel slope in the Permissible Velocities for Grass-Lined Channels table in Stormwater Conveyance Channel (C-ECM-09) where diversion fence is used to convey clean water runoff; otherwise, provide outlet protection. When diversion fence is used in conjunction with a sediment trapping device, sequence construction so that the diversion fence installation follows that of the sediment trapping device(s).

6.0 Construction Specifications

1. Use 42-inch-high, 9 gauge or thicker chain-link fencing (2.375-inch maximum opening).
2. Use 2.375-inch-diameter galvanized steel posts of 0.095-inch wall thickness and 6-foot length spaced no further than 10 feet apart. The posts do not need to be set in concrete.
3. Fasten chain-link fence securely to the fenceposts with wire ties.
4. Secure 10 mil or thicker ultraviolet (UV) -resistant, impermeable sheeting to chain-link fence with ties spaced every 24 inches at the top, mid-section, and below ground surface.
5. Extend the impermeable sheeting a minimum of 4 feet along the flow surface and embed a minimum of 8 inches into ground. Soil-stabilized matting may be used in lieu of impermeable sheeting along the flow surface.
6. When two sections of sheeting adjoin each other, overlap by 6 inches and fold with the seam facing downgrade.
7. Keep the flow surface along the diversion fence and the point of discharge free of erosion. Remove accumulated sediment and debris. Maintain positive drainage. Replace impermeable sheeting if torn. If undermining occurs, reinstall the fence.

Figure C-ECM-02-1 Construction Specifications for Installing Impermeable Diversion Fence



(Source: Maryland DOE, 2011)

7.0 Operations and Maintenance Considerations

Maintain the flow surface along the diversion fence and the point of discharge free of erosion and subsidence.

Remove accumulated sediment and debris and maintain positive drainage.

Replace impermeable sheeting if torn. Reinstall the fence if undermining occurs.

Impermeable diversion fence should be removed and properly disposed of when the tributary area is permanently stabilized. Following fence removal, permanently stabilize any areas disturbed during removal.

8.0 References

The Advanced Group. 2023. Impermeable Fencing. Located at: https://www.advancedns.com.au/environmental-protection/impermeable-fencing.

Maryland Department of the Environment. 2011. Detail C-9. Diversion Fence. Located at: https://mde.maryland.gov/programs/water/StormwaterManagementProgram/Documents/erosion%20sediment%20control%20details/Sect%20C%20Water%20Conveyance/PDF%20Files/C-9_Diversion%20Fence.pdf

C-ECM-03 Slope Interruption Device

1.0 Definition

A slope interruption device is a three-dimensional tubular runoff and erosion control device used for sediment filtration and slope interruption.

2.0 Purpose and Applicability of Best Management Practice

The slope interruption device is a temporary measure used to reduce the velocity and slope length of runoff on slopes. A co-benefit of their use may also be sediment filtration.

Slope interruption slows runoff velocity and reduces soil erosion by dissipating the energy of overland sheet flow runoff, reducing its erosive potential while also trapping moving sediment and soluble pollutants.

Reducing runoff velocity reduces the potential of rill erosion formation on slopes. Slope interruption devices trap sediment and soluble pollutants by filtering runoff as it passes through the matrix of the slope interruption and by allowing water to temporarily pond behind the interruption device and the deposition of suspended solids.

3.0 Planning and Considerations

Slope interruption devices assist in preventing cut-and-fill slopes from becoming a critical erosion hazard. Install slope interruption devices horizontally across the hill slope and perpendicular to sheet flow, where erosion control practices or runoff velocity control is needed. Slope interruption is most effective where runoff is in the form of sheet flow and on long slopes prone to rill erosion.

Slope interruption can be applied to areas of high sheet runoff, erosion, and slopes up to a 1H:1V grade.

Use slope interruption devices in conjunction with other forms of slope erosion control such as BMP C-SSM-05 Soil Stabilization Blankets and Matting.

Slope interruption may also be used in sensitive environmental areas where wildlife migration may be impeded using silt fences or where trenching may damage plant roots.

Figure C-ECM-03-1 Slope Interruption Device Accumulating Sediment



Source: ERTEC Environmental Systems 2022

4.0 Stormwater Performance Summary

MS-7: CUT AND FILL SLOPES - Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. Slopes that are found to be eroding excessively within one year of permanent stabilization shall be provided with additional slope stabilizing measures until the problem is corrected.

9VAC25-875-560

Erosion Control Efficiency: High

Sediment Removal Efficiency: Moderate

5.0 Design Criteria

Slope spacing between slope interruption devices depends on rainfall intensity and duration, slope steepness, and slope length.

Design the spacing between slope interruption devices in accordance with Table C-ECM-03-1 below.

Table C-ECM-03-1 Slope Interruption Device Spacing

Maximum Spacing (feet)	Slope (H:V)
10	greater 2:1
15	from 2:1 to 4:1
20	From 4:1 to 10:1
50	Flatter than 10:1

6.0 Construction Specifications

1. Smooth soil surface and remove all obstructions greater than 2 inches in diameter.
2. Install slope interruption device parallel to the contour and perpendicular to sheet flow runoff. Do not construct slope interruption devices to concentrate runoff or channel water.
3. Install slope interruption devices to maintain intimate contact with the soil surface.
4. Install slope interruption devices before hydraulic or dry land seeding applications. The slope interruption device may be installed before or after the installation of soil stabilization blankets and matting. Do not install slope interruption devices underneath the soil stabilization blankets and matting.
5. Install slope interruption so that both ends of the device extend at least 8 feet upslope at 45 degrees to the main slope interruption alignment.
6. Install anchoring devices in accordance with the manufacturer's specifications to anchor the slope interruption in place.
7. Backfill and compact loose soil against the upslope/upstream side of the slope interruption device to one third the height of the device, filling the seam between the soil surface and the device.
8. Overlap adjacent slope interruption device ends by a minimum of 1 foot.

7.0 Operations and Maintenance Considerations

Inspect slope interruption devices after each rainfall and immediately repair or replace damaged devices in accordance with the manufacturer's specifications. Remove sediment from the upslope side of the slope interruption device when accumulation has reached half the height of the device.

During inspections, if rill erosion is noticed, immediately take measures to re-grade and stabilize problem areas.

Once the hill slope has been permanently stabilized, the slope interruption devices can be removed and disposed offsite. Permanently stabilize any areas disturbed during removal of the slope interruption devices.

8.0 References

ERTEC Environmental Systems. 2022. Protecting Global Lands and Waterways. Product Brochure. Available at: https://ertecsystems.com/wp-content/uploads/2022/02/ERTEC-Brochure.

James Madison University. 2021. *JMU: Annual Standards and Specifications for ESC & SWM*. March 11.

C-ECM-04 Temporary Diversion Dike

1.0 Definition

A temporary diversion dike is a temporary ridge of compacted soil constructed to convey clean stormwater runoff through or around a disturbed land area. In most cases, temporary diversion dikes collecting sediment-laden water work as conveyance in conjunction with other erosion and sediment control devices.

– CAD and PDF C-ECM-04 Temporary Diversion Dike

2.0 Purpose and Applicability of Best Management Practice

A temporary diversion dike is used to protect work areas from upslope runoff and to divert sediment-laden water to appropriate traps or stable outlets.

Use a temporary diversion dike wherever stormwater runoff must be temporarily diverted to protect disturbed areas and slopes or retain sediment on site during construction. Specific locations and conditions include:

- Above disturbed existing slopes and above cut or fill slopes to prevent runoff over the slope;
- Across unprotected slopes, as slope breaks, to reduce slope length;
- Below slopes to divert excess runoff to stabilized outlets;
- Where needed to divert sediment-laden water to construction best management practices (BMPs);
- At or near the perimeter of the construction area to keep sediment from leaving the site; and
- Above disturbed areas before stabilization to prevent erosion and maintain acceptable working conditions.

Temporary diversion dikes may also serve with a Temporary Sediment Trap (C-SCM-11) when the site has been over-excavated on a flat grade; they may also be used in conjunction with a sediment fence.

Temporary diversion dikes can also be used to divert clean water around disturbed or environmentally sensitive areas.

3.0 Planning and Considerations

A temporary diversion dike is intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during construction and establish permanent stabilization on sloping disturbed areas. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away.

When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility.

Stabilize temporary diversion dikes immediately following installation with temporary or permanent vegetation in accordance with Temporary Seeding (C-SSM-09) and Permanent Seeding (C-SSM-10) to prevent erosion of the dike itself.

The gradient of the channel behind the dike is also an important consideration. Construct the dike to have a positive grade to ensure drainage, but if the gradient is too great, take precautions to prevent erosion due to high-velocity channel flow behind the dike. Design the cross-section of the channel that runs behind the dike to be a parabolic or trapezoidal shape to help inhibit a high velocity of flow, which could arise in a vee ditch.

Diversion dikes become a logical choice for a control measure once the control limits of the silt fence, compost filter sock, or straw bale barrier have been exceeded.

Temporary diversion dikes are often used as a perimeter control in association with a sediment trap, a sediment basin, or a series of sediment-trapping facilities on moderate to large construction sites. If installed properly in the first phase of grading, maintenance costs are very low. Often, cleaning of sediment trapping facilities is the only associated maintenance requirement.

4.0 Stormwater Performance Summary

MS-4: FIRST STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down a cut or fill slope unless contained in an adequate temporary or permanent channel, flume, or slope drain structure.

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Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: LOW

5.0 Design Criteria

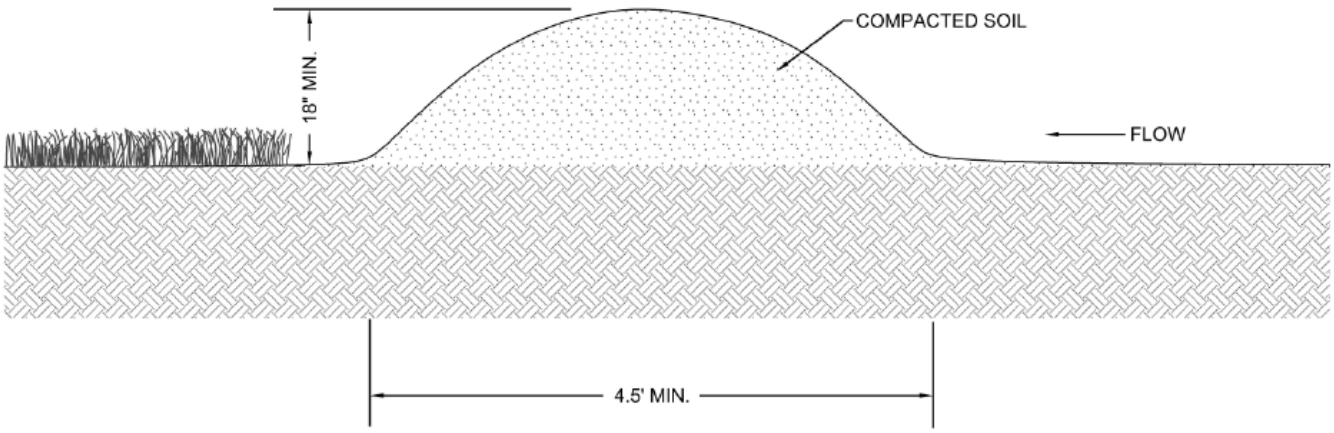
No formal design is required, but the following criteria should be met.

Table C-ECM-04-1 Design Criteria for Temporary Diversion Dike

Parameter	Notes on Proper Use
Drainage Area	The maximum allowable drainage area is 5 acres calculated from the area tributary to the lowest point on the BMP.
Capacity	Peak runoff from the 10-year storm.
Height	The minimum allowable height measured from the upslope side of the dike is 18 inches, which includes the minimum 6 inches of required freeboard.
Ridge Design	Side slopes of 2H:1V or flatter, along with a minimum top width of 2 feet and a minimum of 6 inches of freeboard.

Table C-ECM-04-1 Design Criteria for Temporary Diversion Dike	
Parameter	**Notes on Proper Use**
Grade	Design the channel behind the dike to have a positive grade to a stabilized outlet. If the channel slope is less than or equal to 2%, no stabilization is required. If the slope is greater than 2%, stabilize the channel in accordance with Stormwater Conveyance Channel (C-ECM-09).
Outlet	1. Release the diverted runoff, if free of sediment, through a stabilized outlet or channel or Level Spreader (C-ECM-14). 2. Divert and release sediment-laden runoff through a sediment trapping facility such as a Temporary Sediment Trap (C-SCM-11) or Temporary Sediment Basin (C-SCM-12).

Figure C-ECM-04-1 Temporary Diversion Dike



Source: VA DSWC

6.0 Construction Specifications

1. Install temporary diversion dikes as a first step in the land-disturbing activity and make the diversion dikes functional before upslope land disturbance.
2. Remove and properly dispose of all trees, brush, stumps, and other objectionable material.
3. Adequately compact the dike to prevent failure.
4. Ensure that the minimum constructed cross-section meets all design requirements.
5. Ensure that the top of the dike is not lower at any point than the design elevation plus the specified settlement.
6. Provide sufficient room around diversions to permit machine regrading and cleanout.
7. Apply temporary or permanent seeding and mulch to the dike immediately following its construction.
8. Locate the dike to minimize damage by construction operations and traffic.

7.0 Operations and Maintenance Considerations

Inspect temporary diversion dikes after every storm and repair the dike, flow channel, outlet, or sediment trapping facility as necessary. In karst areas, the upslope edge of the diversion dike should be inspected for subsidence, especially at the downstream end and at the associated outlet structure/BMP. Subsidence is considered a mode of failure.

Bi-weekly (whether a storm event has occurred or not), inspect the control measure and repair if needed. Repair damage caused by construction traffic or other activity before the end of each working day.

Construct temporary diversions to operate with 6 inches or more of freeboard. Make height adjustments if frequent instances of overtopping are observed.

8.0 References

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-ECM-05 Diversion

1.0 Definition

A diversion is a channel constructed across a slope with a supporting earthen ridge on the lower side.

– CAD and PDF files for C-ECM-05-1 Diversions

2.0 Purpose and Applicability of Best Management Practice

Diversions may be temporary conveyances to manage stormwater runoff at construction sites or they may be permanent stormwater management structures. Diversions are used to reduce slope length and to intercept and divert stormwater runoff to stabilized outlets at non-erosive velocities. Diversions apply to the following site conditions:

- Where runoff from areas of higher elevation may damage property, cause erosion, and/or interfere with the establishment of vegetation or the intended land use on lower areas;
- Where surface and/or shallow subsurface flow is damaging to sloped upland areas;
- Where the slope length needs to be reduced to minimize soil loss;
- Where runoff to sensitive site areas must be diverted, such as sinkholes in karst areas; and

- Where large drainage areas must be reduced for the purpose of flow distribution to post-construction stormwater BMPs.

3.0 Planning and Considerations

Diversions can be useful tools for managing surface water flows and preventing soil erosion. The characteristics of the watershed contributing runoff to the diversion must be analyzed to ensure that the diversion will function without overtopping or erosion.

On moderately sloped areas, diversion may be placed at intervals to trap and divert sheet flow before it has a chance to concentrate and cause rill and gully erosion.

Diversions may be placed at the tops of cut or fill slopes to prevent runoff from upland drainage areas from flowing on the slope. Diversions can also protect structures, parking lots, adjacent properties, and other special areas from flooding.

Diversions are preferable to other types of artificial stormwater conveyance systems because these measures more closely simulate natural flow patterns and characteristics. Flow velocities are generally kept to a minimum.

When properly coordinated into the landscape design of a site, diversions can be visually pleasing as well as functional.

As with any earthen structure, it is important to establish adequate vegetation as soon as possible after installation and stabilize the drainage area above the diversion such that sediment will not enter and accumulate in the diversion channel. See BMP C-ECM-07, BMP C-SSM-09, and BMP C-SSM-10.

Berm diversion is not necessary if constructed on the top of a slope. The berm aspect of a diversion is only necessary to provide additional freeboard and slope interception. The velocity and depth are based on 2-year storms and 10-year storms.

When material of slope (swale) contains karst features, a diversion should be replaced with another similar device that will not risk soil integrity and performance of the measure.

When designing for a sediment trap or basin, consider using a temporary right-of-way diversion on undisturbed areas to reduce the quantity of stormwater that feeds into the sediment trap or basin.

When conveying concentrated flow, plan the diversion in accordance with an appropriate outlet measure; refer to Table C-ECM-05-1 Diversion Design Criteria. To reduce velocity in the channel along with adding sediment trapping capability to the measure, consider using rock check dams (BMP C-SCM-07). Spacing calculations should be provided in instances where check dams are used in collaboration with diversions.

Care must be taken when siting the outlet of the diversion. Diversion outlets should be directed to stabilized areas where the discharge will not cause erosion. Outlets must not discharge to sinkholes or other karst features.

4.0 Stormwater Performance Summary

MS-4: FIRST STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

MS-5: EARTHEN STRUCTURE STABILIZATION – Stabilization measures shall be applied to earthen structures such as dams, dikes and diversions immediately after installation.

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

MS-9: SEEPAGE – Whenever water seeps from a slope face, adequate drainage or other protection shall be provided.

MS-19: STORMWATER STANDARD – Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff...

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Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: N/A

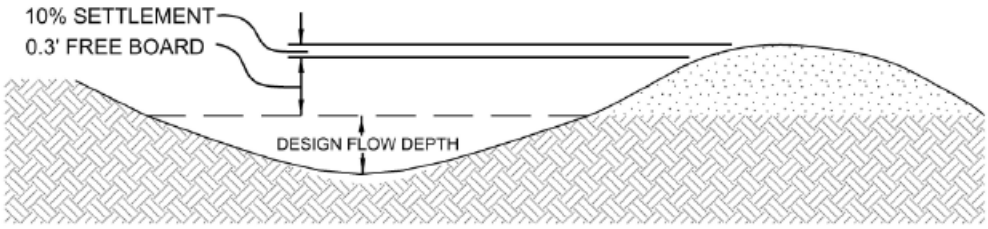
5.0 Design Criteria

Table C-ECM-05-1 Diversion Design Criteria

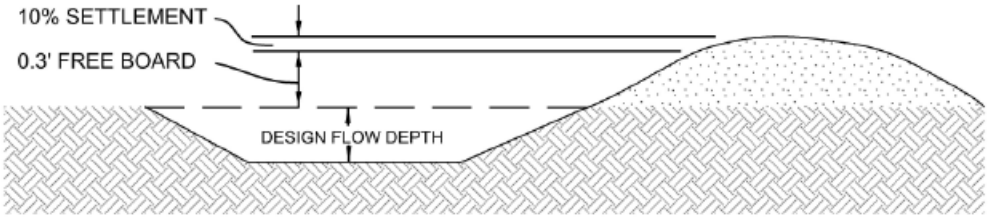
Topic	Requirement
Location	Determine the diversion location by considering outlet conditions, topography, land use, soil type, length of slope, seepage planes (where seepage is a problem), and the development layout.
Capacity	Design the diversion channel to have a minimum capacity to carry the runoff expected from a 10-year, 24-hour frequency storm with a freeboard of at least 0.3 foot (see Figure C-ECM-05-1). Design diversions to protect homes, schools, industrial buildings, roads, parking lots, and comparable high-risk areas, as well as those designed to function in connection with other structures, to have sufficient capacity to carry peak runoff expected from a storm frequency consistent with the hazard involved.
Channel Design	The diversion channel may be parabolic, trapezoidal, or vee-shaped and designed and constructed according to stormwater conveyance channels (BMP C-ECM-09).
Ridge (Berm) Design	Design the supporting ridge cross-section to meet the following criteria (see Figure C- ECM-05-1): • Side slopes no steeper than 2H:1V; • Width at the design water elevation a minimum of 4 feet; • Minimum freeboard of 0.3 foot; and • 10% settlement factor included in the design.
Outlet	Design diversions to have adequate outlets that will convey concentrated runoff without erosion. Acceptable outlets include stormwater conveyance channel (BMP C-ECM-09), level spreader (BMP C-ECM-14), outlet protection (BMP C-ECM-15), and paved flume (BMP C-ECM-11).

Table C-ECM-05-1 Diversion Design Criteria	
Topic	**Requirement**
Stabilization	Use turf reinforcement mats and other rolled erosion control products (see BMP C- SSM-05) to provide erosion protection immediately after construction and before the establishment of vegetation. Seed and mulch the ridge and channel immediately following construction in accordance with BMP C-SSM-10. Seed and mulch disturbed areas draining into the diversion before the diversion is constructed in accordance with BMP C-SSM-10. Ensure that sediment trapping measures remain in place to prevent soil movement into the diversion if the upslope area is not stabilized. See BMP C-SSM-09, BMP C-SSM-10, and BMP C-ECM-07.

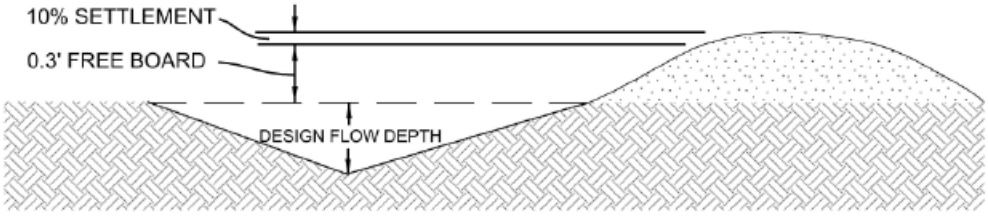
Figure C-ECM-05-1 Diversion Cross-Sections



TYPICAL PARABOLIC DIVERSION



TYPICAL TRAPEZOIDAL DIVERSION



TYPICAL VEE-SHAPED DIVERSION

6.0 Construction Specifications

1. Remove and dispose of all trees, brush, stumps, obstructions, and other objectionable material so as not to interfere with the proper functioning of the diversion.
2. Excavate or shape the diversion to line, grade, and cross-section as required to meet the criteria specified herein, free of irregularities that will impede flow.
3. Compact fills as needed to prevent unequal settlement that would cause damage in the completed diversion. Use fill composed of soil that is free from excessive organic debris, rocks, or other objectionable materials.
4. Spread or dispose of all earth removed and not needed in construction so that the material will not interfere with the function of the diversion.

5. Permanently stabilize disturbed areas in accordance with the applicable standard and specification contained in this handbook. Permanent stabilization techniques include permanent seeding (BMP C-SSM-10) and soil stabilization blankets and matting (BMP C-SSM-05).
6. After permanent stabilization, inspect to maintain vegetative cover. Mow as required to maintain open channel section and reseed bare areas as necessary.

7.0 Operations and Maintenance Considerations

Before final stabilization, inspect the diversion after every rainfall event (0.01-inch or greater depth) and at least once every week.

Remove accumulated sediment from the channel and make repairs when required.

Reseed areas that fail to establish a vegetative cover as necessary.

Inspect outlets for obstructions, subsidence, erosive conditions, animal burrows, and other intrusions, and make immediate repairs when required.

8.0 References

New York Department of Environmental Conservation. 2016. New York State Standards and Specifications for Erosion and Sediment Control. November.

Virginia Department of Environmental Quality. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-ECM-06 Temporary Fill Diversion

1.0 Definition

A temporary fill diversion is a channel with a supporting ridge of soil on the lower side, constructed along the top of an active earth fill.

– CAD and PDF Files for C-ECM-06 Temporary Fill Diversion

2.0 Purpose and Applicability of Best Management Practice

Temporary fill diversions are used to divert storm runoff away from the unprotected slope of the fill to a stabilized outlet or sediment trapping facility. A temporary fill diversion applies to site conditions where the drainage area at the top of an active earth fill slopes toward the exposed slope and where continuous fill operations preclude the use of a diversion (see C-ECM-05). Use a temporary fill diversion only for less than one week.

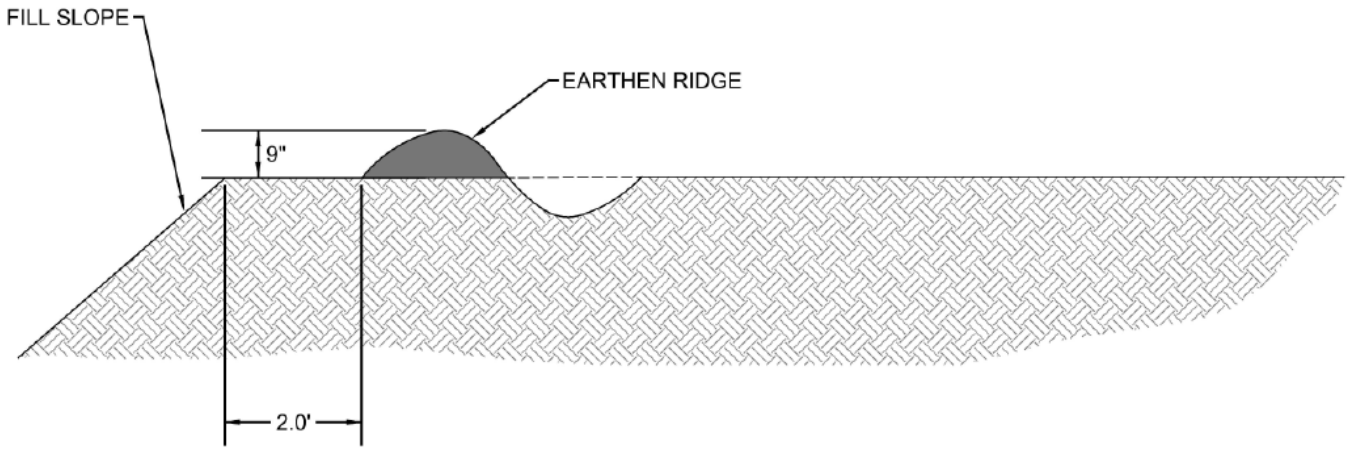
3.0 Planning and Considerations

Temporary fill diversion is intended to provide limited daily slope protection until final elevations are reached and a more permanent measure can be constructed.

This practice can be constructed using a motor grader or a small dozer. To shape the temporary fill diversion, the piece of machinery used may run near the top edge of the fill with its blade tilted to form the channel as depicted on Figure C-ECM-06-1. This work would be conducted at the end of the working day to provide a channel with a berm to protect the slope. Wherever possible, slope the temporary fill diversion to direct water to a stabilized outlet. If the runoff is diverted over the fill itself, the practice may cause erosion by concentrating water at a single point.

Complete the filling operation in a safe manner as quickly as possible, and then install the permanent slope protection and slope stabilization measures as soon after completion as possible.

Figure C-ECM-06-1 Temporary Fill Diversion



4.0 Stormwater Performance Summary

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

9VAC25-875-560

Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: N/A

5.0 Design Criteria

No formal design is required other than compliance with the criteria shown in Table C-ECM-06-1.

Table C-ECM-06-1 Design Criteria

Topic	Requirement
Drainage Area	The maximum allowable drainage area is 5 acres.
Height	The minimum height of the supporting ridge is 9 inches (see Figure C-ECM-06-1).
Grade	Provide positive grade in the channel to a stabilized outlet.
Location	Locate the temporary fill diversion a minimum of 2 feet inside the top edge of the fill (see Figure C-ECM-06-1.
Outlet	Release the diverted runoff through a stabilized outlet, slope drain, or sediment trapping measure (see C-SCM-11 and C-SCM-12).

6.0 Construction Specifications

1. Construct the temporary fill diversion at the top of the fill at the end of each workday as needed.

2. Construct the supporting ridge with a uniform height along its entire length. Without uniform height, the temporary fill diversion may be susceptible to breaching.

7.0 Operations and Maintenance Considerations

Because the practice is temporary and, under most situations, will be covered the next workday, minimal maintenance is required. If the practice is to remain in use for more than one day, inspect the temporary fill diversion at the end of each workday and repair the measure if needed. Avoid the placement of any material atop the structure while it is in use. Do not permit construction traffic to cross the diversion.

8.0 References

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-ECM-07 Temporary Right-of-Way Diversion

1.0 Definition

A temporary right-of-way diversion is a ridge of compacted soil, loose rock, or gravel constructed across disturbed steep slopes and similar sloping areas that is removed following construction once permanent stabilization has begun.

– CAD and PDF files for C-ECM-07 Temporary Right-Of-Way Diversions

2.0 Purpose and Applicability of Best Management Practice

A temporary right-of-way diversion is used to shorten the flow length and break up sheet flow within a terrain at pre-designed intervals, thereby reducing the potential for rill erosion, by diverting stormwater runoff to a stabilized outlet.

Temporary right-of-way diversions are typically used to control stormwater runoff on access roads and skid trails, pipeline and utility line corridors, and long slope areas where perimeter controls may not be adequate to handle the runoff from the disturbed area. Temporary right-of-way diversions are not appropriate for incised roadways where there is no opportunity to discharge runoff to either side.



Flow Path along a Right of Way Diversion.
Source: Texas A&M Forest Service

Generally, earthen right-of-way diversions apply where there will be little or no construction traffic within the work area. Gravel structures are more applicable to roads and other areas that accommodate vehicular traffic.

Temporary right-of-way diversions are removed once final grading is completed and permanent vegetative stabilization is being conducted. Restoration is typically completed by removing the rock or stone material or grading the compacted soil to remove the temporary ridge.

3.0 Planning and Considerations

Construction of utility lines and roads often requires the clearing of long strips of right-of-way over sloping terrain. The volume and velocity of stormwater runoff tends to increase in these cleared strips, and the potential for erosion is much greater because the vegetative cover is diminished or removed.

Disturbance and compaction promote gully formation in these cleared strips by increasing the volume and velocity of runoff. Gully formation may be especially severe in tire tracks and ruts. To prevent gullying, runoff can often be diverted across the width of the right-of-way to constructed outlets using small, pre-designed diversions. Give special consideration to each individual outlet area as well as to the cumulative effect of added diversions.

To compensate for the loss of vegetation, it is usually a good practice to break up the flow length within the cleared strip so that runoff does not have a chance to concentrate and cause erosion. At proper intervals, temporary right-of-way diversions can significantly reduce the amount of erosion that will occur until the area is permanently stabilized.

A right-of-way diversion can be both a temporary practice (as presented in this specification) or a permanent practice.

4.0 Stormwater Performance Summary

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down a cut or fill slope unless it is contained in an adequate temporary or permanent channel, flume, or slope drain structure.

9VAC25-875-560

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: N/A

5.0 Design Criteria

No formal design is required. The following criteria should be met:

Table C-ECM-07-1 Design Criteria for Temporary Right-of-Way Diversion

Parameter	Notes on Proper Use
Height	The minimum allowable height of the diversion is 18 inches.
Sideslopes	To allow the passage of construction traffic, construct the sideslopes to be 2H:1V or flatter with a minimum base width of 6 feet.
Width	Construct the right-of-way diversion completely across the disturbed portion of the right- of-way.
Spacing	Use Table C-ECM-07-2 to determine the spacing of right-of-way diversions.
Grade	Construct right-of-way diversions with cross-slope gradients of 2% or less to ensure that water entering the right-of-way diversion does not cause erosion within the right-of-way diversion channel or downgradient of the right-of-way diversion outlet. Wherever erodible soils are present, or where there is not a sufficient vegetative filter strip (50-foot minimum) between the right-of-way diversion and a receiving surface water, provide a temporary protective liner along the right-of-way diversion channel. Vegetate all right-of-way diversions immediately following construction. Do not place obstructions, (e.g., straw bales, silt fence, compost filter sock, rock filters) in or across right-of-way diversions.
Outlet	Design outlet protection at the ends of temporary right of way diversions in accordance with Table C-ECM-07-3.

Table C-ECM-07-2 Spacing of Temporary Right-of-Way Diversions		
Slope (%)	Spacing for Erosion Resistant Soil (ft.) k<0.37	Spacing for Highly Erodible Soil (ft.) k>0.37
< 7%	100	75
7% to 25%	75	55
25% to 40%	50	35
> 40%	25	18

Source: Va. DSWC

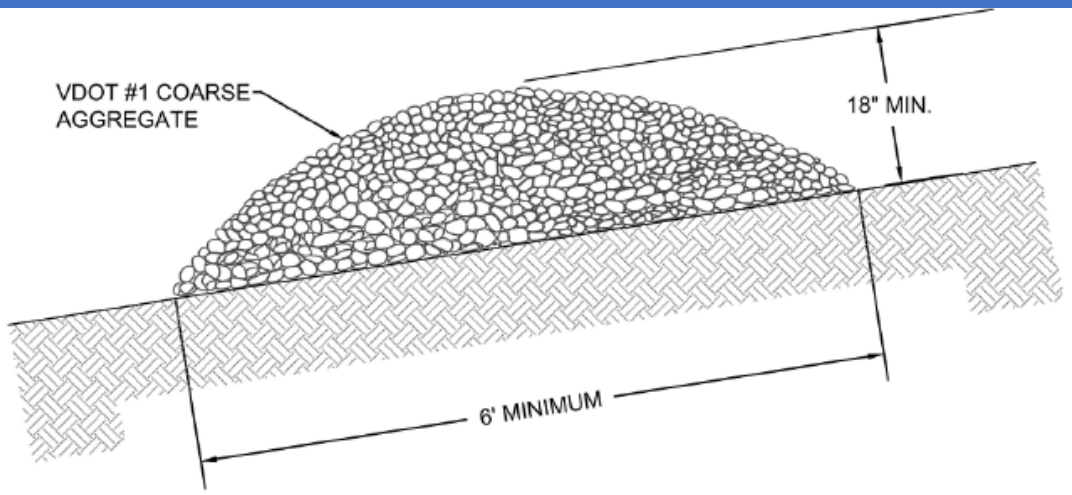
Temporary Right-of-Way Diversion Outlet Protection Measures

The following section outlines standard outlet protection measures to be installed at the outfall of each temporary right-of-way diversion.

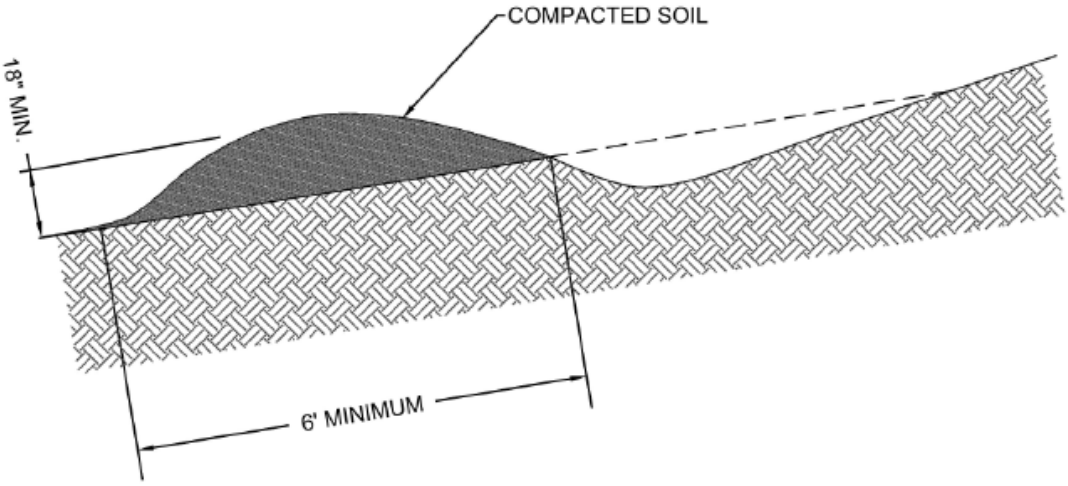
If the area draining to the temporary right-of-way diversion exceeds 2 acres in area, design and install an appropriately sized Temporary Sediment Trap (BMP C-SCM-11) or Temporary Sediment Basin (BMP C-SCM-12) at the outlet of the temporary right-of-way diversion.

Table C-ECM-07-3 Temporary Right-of-Way Diversion Outlet Protection Types	
Type	Description
Temporary Sump with Compost Filter Sock	Install a temporary sump with compost filter sock at the outlet of the temporary right-of-way. 1. Excavate a sump at the outfall of the temporary right-of-way diversion with the following dimensions: ▪ Minimum depth of 2 feet; ▪ Minimum width of 2 feet; and ▪ Minimum length of 10 feet. 2. Install 24-inch-diameter compost filter sock around the downgradient perimeter of the sump.
Compost Filter Sock J-Hook	Install a compost filter sock j-hook at the outlet of the temporary right-of-way diversion. 1. Install a 12-foot-long compost filter sock j-hook beginning at the end of the temporary right-of-way diversion, such that the first 2 feet are parrallel to the contours and the last 10 feet run upslope. 2. Install a base layer of three 12-foot-long segments of 24-inch compost filter sock laid side by side. 3. Install an intermediate layer of two 12-foot-long segments of 18-inch compost filter sock on top of the base layer. 4. Intall a top layer of one 12-foot-long section of 12-inch compost filter sock. 5. Stake the base and top layers of compost filter sock in accordance with Temporary Sediment Trap (C-SCM-11) for the compost filter sock outlet.
Rock Outlet Apron	Install a rock outlet apron at the outlet of the temporary right-of-way diversion in accordance with Outlet Protection (BMP C-ECM-15).

Figure C-ECM-07-1 Temporary Right-of-Way Diversions



TYPICAL GRAVEL STRUCTURE



TYPICAL EARTHEN STRUCTURE

Source: VDEQ, 1992

Virginia Department of Transportation (VDOT) #3, #357, or #5 coarse aggregate may be used in lieu of VDOT #1 coarse aggregate in areas of vehicular traffic where additional compaction of stone material is needed.

6.0 Construction Specifications

1. Install the right-of-way diversion as soon as the right-of-way has been cleared and/or graded.

2. Machine- or hand-compact all earthen diversions in 8-inch lifts.
3. Install the appropriately designed constructed outlet at the downgradient end of the right-of-way diversion in accordance with Table C-ECM-07-3. In karst areas, sediment traps and basins as outlet areas are prone to subsidence and should be inspected regularly and after each precipitation event. Subsidence is considered a mode of failure, and subsidence features should be repaired promptly following discovery using capped, inverted graded filters (e.g., VDOT Sinkhole Treatment Details).
4. Stabilize earthen diversions that will not be subject to construction traffic in accordance with Temporary or Permanent Seeding (BMP C-SSM-09 or C-SSM-10).
5. Install the right-of-way diversions and the constructed outlet and ensure functionality by the end of each workday, especially when work will be discontinued for several days, as on a weekend. Be aware of the weather forecast.

7.0 Operations and Maintenance Considerations

Inspect right-of-way diversions weekly and after each rainfall. Where construction is actively occurring or on active roads, inspect right-of-way diversions daily and repair damage caused by construction traffic or other activity before the end of the workday.

Keep the right-of-way diversion channel flow line clear of sediment accumulations and any obstructions that impede flow. Maintain earthen right-of-way diversion temporary or permanent stabilization. Restore damaged or eroded right-of-way diversions to original dimensions within 24 hours of inspection. Inspect constructed outlets and make repairs as needed including mitigation of any sinkholes that may form in or adjacent to outlet structures.

Maintain right-of-way diversions until the roadway, skid trail, or right-of-way has achieved permanent stabilization. Earthen right-of-way diversions on retired roadways, skid trails, and rights-of-way may be left in place after permanent stabilization has been achieved. Remove right-of-way diversions from all residential lawns and agricultural fields following completion of construction and remove all gravel right-of-way diversions. Provide permanent vegetative stabilization to earthen right-of-way diversions left as permanent structures.

8.0 References

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

Texas A&M Forest Service. Undated. Best Management Practices Pictorial Directory. Located at: https://tfsweb.tamu.edu/uploadedFiles/TFSMain/Manage_Forest_and_Land/Water_Resources_and_BMPs/Stewardship(1)/TFS%20BMP%20Pictorial%20Directory.pdf

C-ECM-08 Waterbars and Sheet Flow Breakers

1.0 Definition

Waterbars and sheet flow breakers are used to shorten sheet flow length, reduce velocity, and flatten slopes within a terrain at pre-designed intervals. Waterbars and sheet flow breakers are permanent best management practices, intended to remain after permanent stabilization of the site has been achieved.

– CAD and PDF Files for C-ECM-08 Waterbars and Sheet Flow Breakers

2.0 Purpose and Applicability of Best Management Practice

Waterbars and sheet flow breakers are typically used to control stormwater runoff on logging roads and skid trails, pipeline and utility line corridors, recreational trails, and long slope areas susceptible to rill erosion caused by sheet flow of stormwater.

Waterbars and sheet flow breakers are not appropriate for incised roadways where there is no opportunity to discharge runoff to either side.

3.0 Planning and Considerations

Construction of utility lines and roads often requires the clearing of long strips of right-of-way over sloping terrain. The volume and velocity of stormwater runoff tend to increase in these cleared strips, and the potential for erosion is much greater because the vegetative cover is diminished or removed.

Disturbance and compaction promote gully formation in these cleared strips by increasing the volume and velocity of runoff. Gully formation may be especially severe in tire tracks and ruts. To prevent gullying, runoff can often be diverted across the width of the right-of-way to constructed outlets using small, pre-designed diversions. Give special consideration to each individual outlet area as well as to the cumulative effect of added diversions.

On permanent unpaved paths, trails, and / or roads, it is a good practice to break up the length of sheet flow within the cleared strip so that runoff does not have a chance to concentrate and cause erosion. At proper intervals, waterbars and sheet flow breakers can significantly reduce the potential for rill erosion in these managed areas.

Temporary right-of-way diversions can be converted to a permanent structure (i.e., waterbar) after site construction. These temporary diversions can be planted with permanent vegetation and left in place following construction to break up long slopes and convey runoff to either side of the right-of-way.

4.0 Stormwater Performance Summary

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down a cut or fill slope unless it is contained in an adequate temporary or permanent channel, flume, or slope drain structure.

9VAC25-875-560

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: N/A

5.0 Design Criteria

No formal design is required. The following criteria should be met:

Table C-ECM-08-1 Design Criteria for Waterbars and Sheet Flow Breakers

Parameter	Notes on Proper Use
Height	Height may vary based on the practice selected; however, except with in the case of open-top culverts, the maximum height of the waterbar or sheet flow breaker should be 18 inches.
Sideslopes	Construct the sideslopes to be 2H:1V or flatter with a minimum base width of 6 feet, and a maximum base width of 12 feet.
Width	Construct the waterbar or sheet flow breaker completely across the area subject to sheet flow.

Table C-ECM-08-1 Design Criteria for Waterbars and Sheet Flow Breakers	
Parameter	**Notes on Proper Use**
Spacing	Use Table C-ECM-08-3 and Table C-ECM-08-4 to determine the spacing waterbars and sheet flow breakers.
Area	The drainage area to any one waterbar or sheet flow breaker must be less than 2 acres.
Grade	Waterbars and permanent sheet flow breakers should have a maximum 2.0%-3.0% outslope to divert sheet flow to a well stabilized outlet.
Outlet	Design waterbars and permanent sheet flow breakers to discharge to a rock apron designed in accordance with BMP C-ECM-15 or another constructed outlet, such as a basin. For a more streamlined approach, designers may also choose to install outlet protection in accordance with the dimensions in Table C-ECM-08-5.

Table C-ECM-08-2 Types of Sheet Flow Breakers	
Type	**Description**
Waterbar	A waterbar is an earthen right-of-way diversion that is permanently stabilized in accordance with Permanent Seeding and Soil Stabilization Blankets and Matting (C-SSM-10 and C-SSM-05, respectively) and left in place as a vegetated permanent practice.
Open-Top Culvert	Open-top culverts may be used to intercept runoff from access roads and divert the runoff to well-vegetated (erosion resistant) areas or sediment removal facilities. Such culverts are typically more easily traversed than right-of-way diversions or broad-based dips but can require more maintenance if crossed by heavy equipment or exposed to sediment-laden runoff. Do not use open-top culverts for stream crossings or in lieu of pipe culverts. Install open-top culverts at the spacing shown in Table C-ECM-08-4.
Water Deflector	Deflectors may be used instead of open-top culverts to direct runoff from an access road to a well-vegetated area or stabilized outlet. This method of directing runoff from an access road works best on low-traffic roads. Install water deflectors at the spacing shown in Table C-ECM-08-4.
Broad-Based Dip	Broad-based dips are an alternative method to ditch relief or cross-drain culverts to remove water across access roads to well-vegetated areas or an appropriately designed outlet. Due to the nature of broad-based dips, do not construct broad-based dips on roads with grades exceeding 10%. Where access roads exceed 10% gradients, use waterbars or other sheet flow breakers. Do not use broad-based dips to pass continuous flowing water across the road or under extended damp conditions such as where springs are located. Design broad-based dips with the maximum spacing provided in Table C-ECM-08-4.

Table C-ECM-08-3 Maximum Spacing of Waterbars		
Slope (%)	**Spacing for Erosion Resistant Soil (ft.) k<0.37**	**Spacing for Highly Erodible Soil (ft.) k>0.37**
< 2%	445	335
2% to 5%	335	250
6% to 15%	200	150
16% to 30%	135	100
> 31%	65	50

Table C-ECM-08-4 Spacing of Sheet Flow Breakers – Open-Top Culverts, Water Deflectors, and Broad-based Dips		
Slope (%)	**Spacing for Erosion Resistant Soil (ft.) k<0.37**	**Spacing for Highly Erodible Soil (ft.) k>0.37**
< 2%	400	300
2%	315	235
4%	265	200
5%	240	180
6%	220	165
7%	205	155
8%	200	150
9%	190	145
10%	180	140

Source: Adapted from PADEP, 2012

Table C-ECM-08-5 Standard Rock Apron Outlet Dimensions				
Mean D_{50} Riprap Size (in)	**Riprap Thickness (in)**	**Length (ft)**	**Initial Width (ft)**	**Terminal Width (ft)**
6	18	12	4.5	16.5

1. Apron length is based on the methodology outlined in 9.0 Appendix C-ECM-08.
2. Apron initial width is based on three times waterbar berm height of 18 inches.
3. Riprap size and thickness are based on a maximum velocity of 9.0 feet per second.

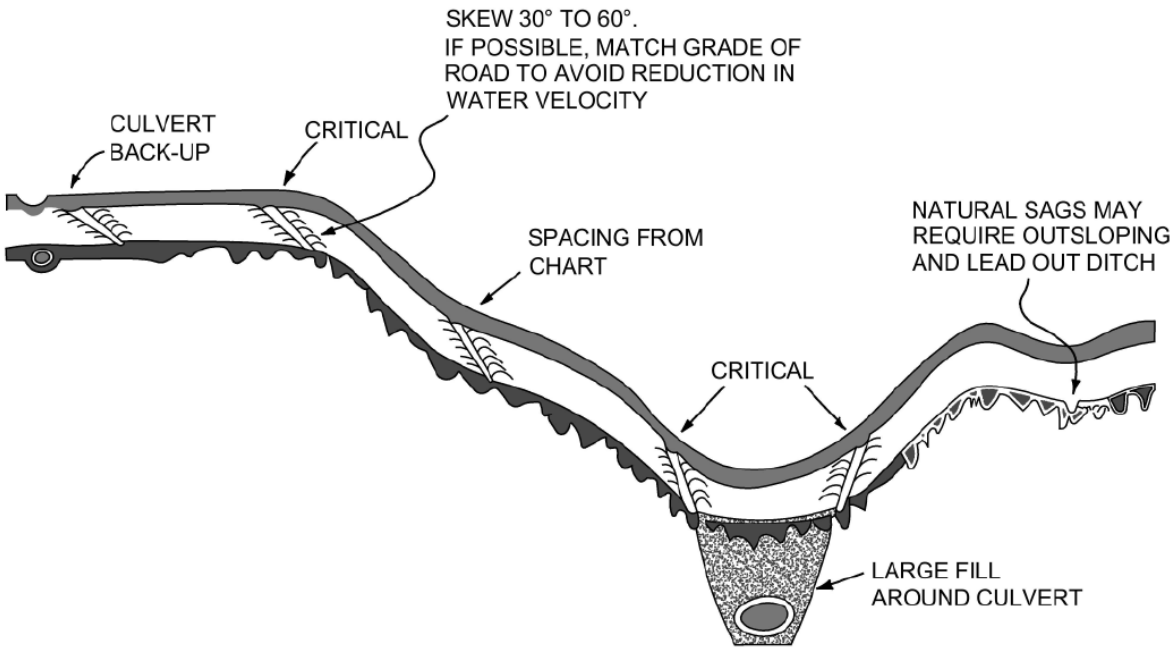
6.0 Construction Specifications

1. Installation of waterbars and sheet flow breakers should occur at a time when site stabilization is imminent to avoid conflicts with construction vehicles.
2. Machine- or hand-compact all earthen waterbars and sheet flow breakers in 8-inch lifts.
3. Install the appropriately designed constructed outlet at the downgradient end of the practice.
4. Stabilize waterbars and sheet flow breakers that will not be subject to construction traffic in accordance with Temporary or Permanent Seeding (BMP C-SSM-09 or C-SSM-10).

Waterbars

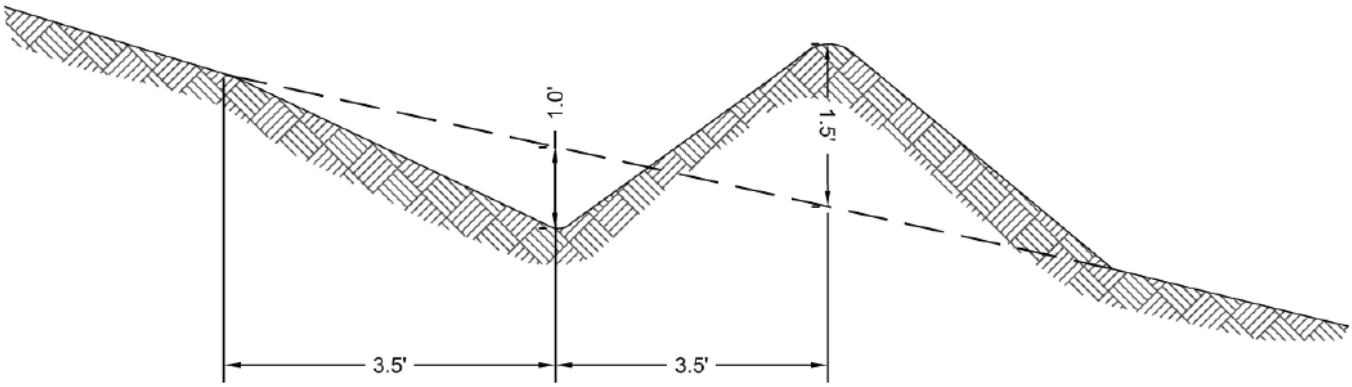
1. Compaction of the excavated material used to make the berm on the downhill side of the waterbar should occur by using wheel rolling or walking the excavation equipment over the downhill berm.
2. Construct with a 30-to-60-degree angle from centerline of right-of-way. Maintain 2.0% outslope for drainage.

Figure C-ECM-08-1 Typical Waterbar Locations



Source: Warren, 1994

Figure C-ECM-08-2 Typical Waterbar Profile



Source: Warren, 1994

Open Top Culverts

1. Construct open-top culverts using two 3-inch by 8-inch cedar or pressure-treated lumber sides and a 3-inch by 12-inch pressure-treated lumber base fastened together with 60d galvanized nails spaced 9 inches on center.

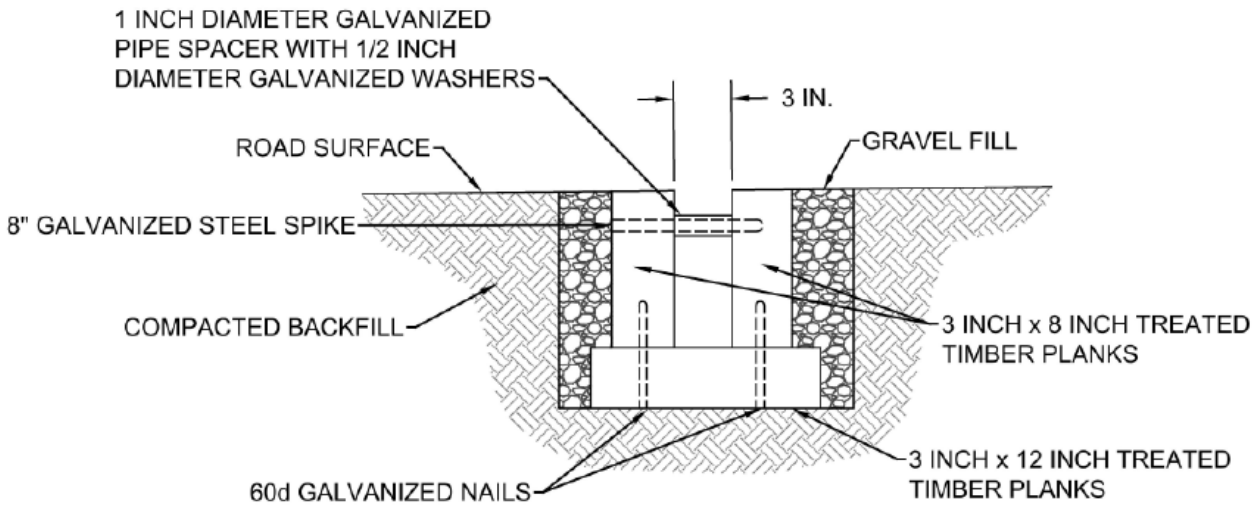
Figure C-ECM-08-4 An open-top culvert along a low-volume driveway



Source: PADEP, 2012

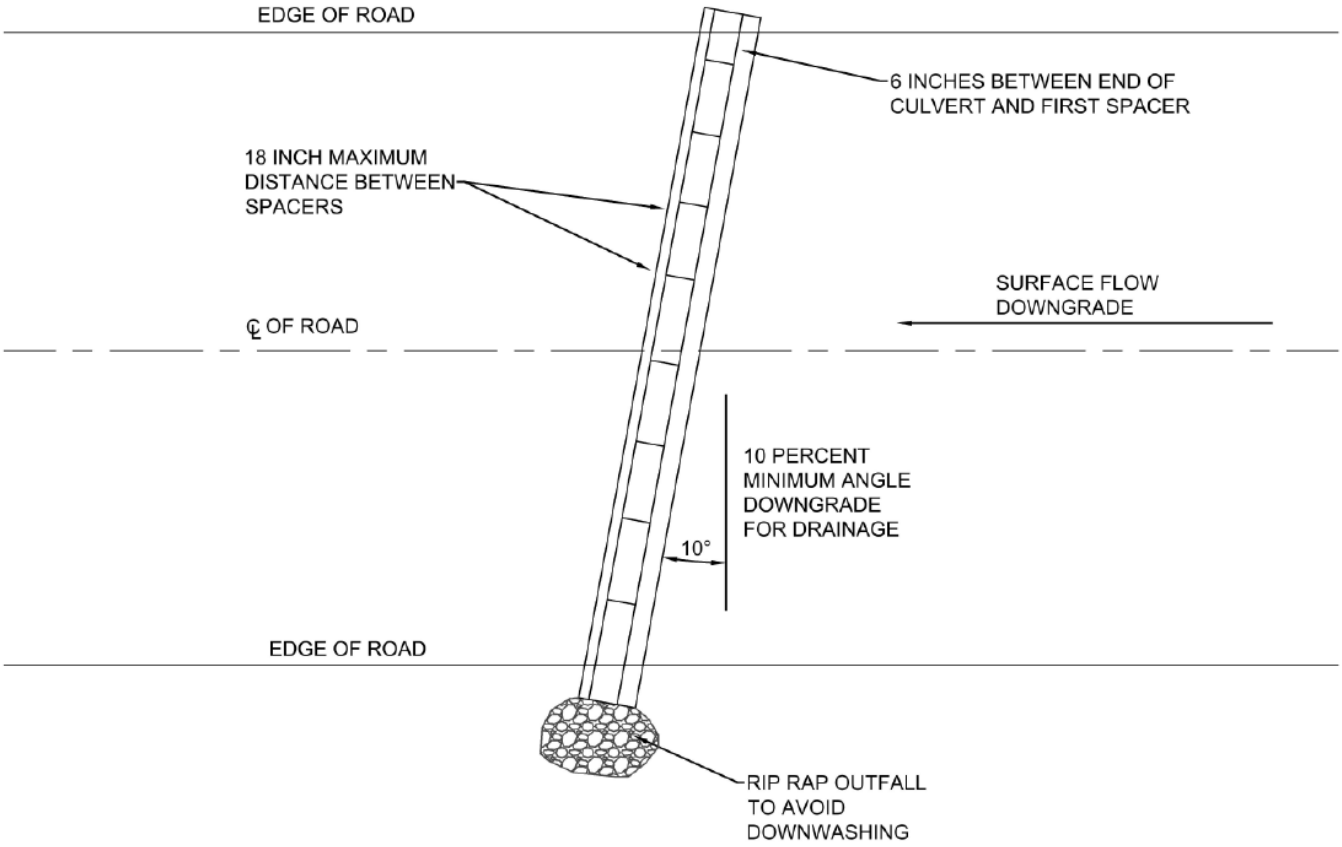
2. Place 1-inch-diameter galvanized pipe spacers with 0.5-inch-diameter galvanized washers in the open-top culvert at a maximum 18-inch distance between spacers. Hold the spacers in place with an 8-inch galvanized steel spike installed through the pipe and washers. Leave 6 inches between the end of the culvert and the first spacer. Maintain a minimum 3-inch opening in the top of the culvert across the length of the culvert.
3. Install the culvert with a 10˚ minimum and 30˚ maximum downslope angle to the road and 2.0% outslope to allow for drainage. Install the culvert flush with the surface of the road. If placed too high, stormwater will not enter the structure; if placed too low, it may quickly fill with road material and sediment loosened during installation. Extend the outlet of the open-top culvert beyond the edge of the road. Remove any berms or other debris that could interfere with water flowing from the outlet. Provide suitable outlet protection (see BMP C-ECM-15) at the culvert outlet.

Figure C-ECM-08-5 Typical cross section of open-top culvert



Source: PADEP, 2012

Figure C-ECM-08-6 Typical plan view of open-top culvert

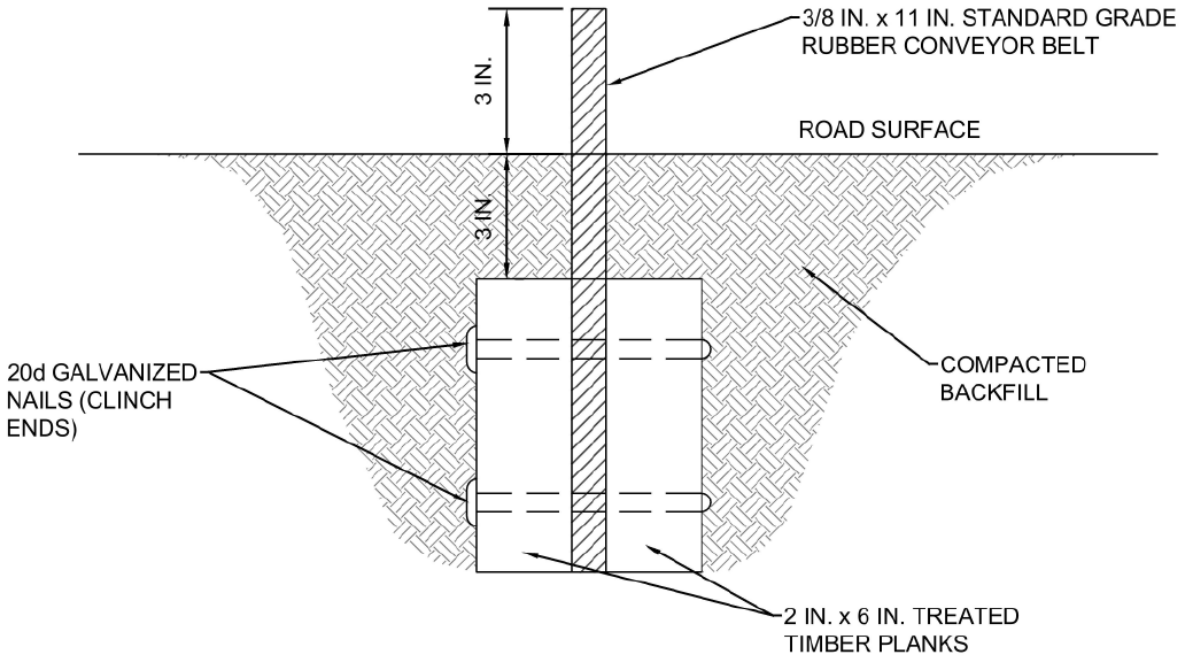


Source: PADEP, 2012

Water Deflectors

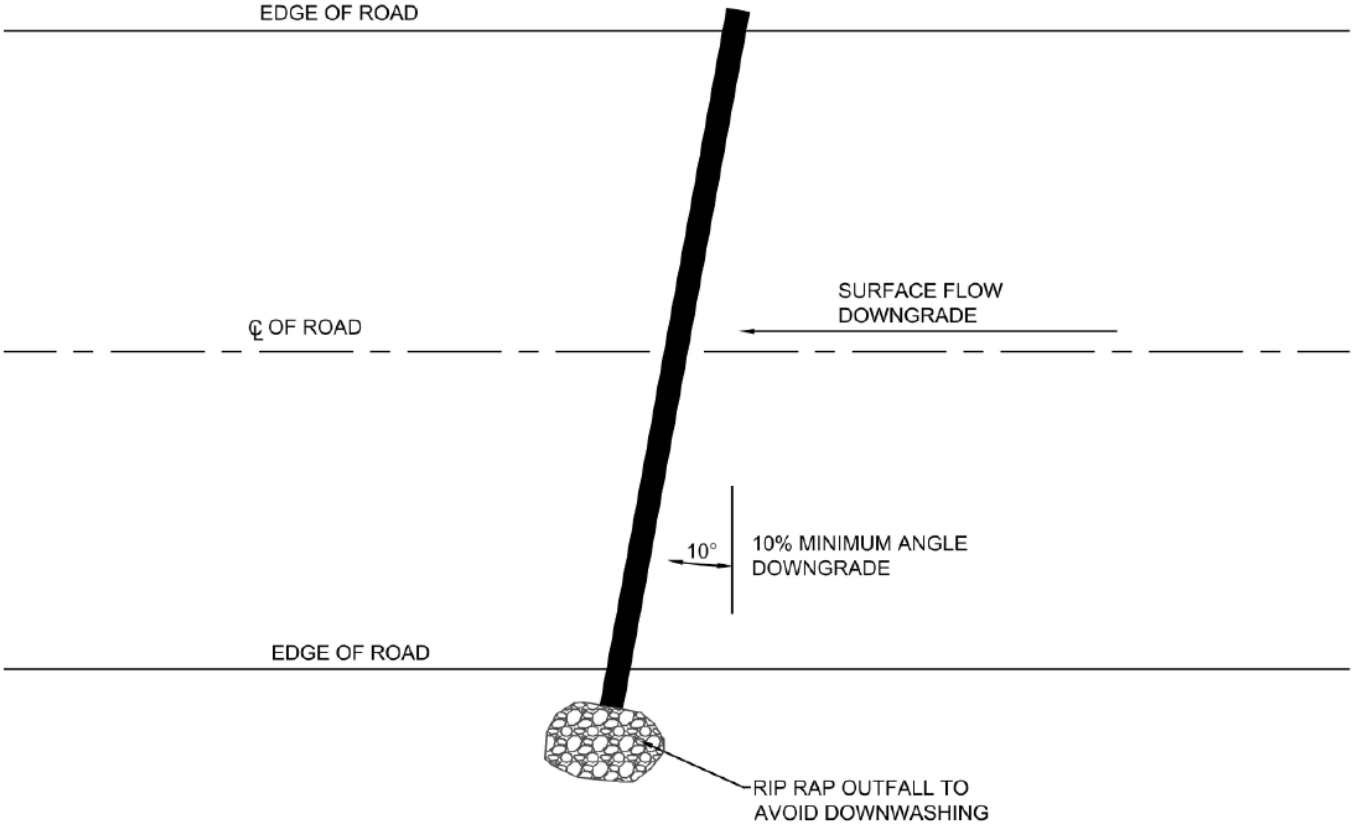
1. Construct water deflectors using a 0.375-inch-thick by 11-inch-wide standard grade rubber (such as used in a conveyor belt) held between two 2-inch by 6-inch pressure-treated lumber planks and fastened together with multiple 20d galvanized nails with clinch ends.
2. Install water deflector into an excavated trench in the access road so that a minimum of 3 inches of the rubber belt is exposed above the road surface. Install the deflector at a 10˚ minimum and 30˚ maximum downslope angle to the road to allow for drainage.

Figure C-ECM-08-7 Water Deflector Typical Cross Section



Source: PADEP, 2012

Figure C-ECM-08-8 Water Deflector Typical Plan View

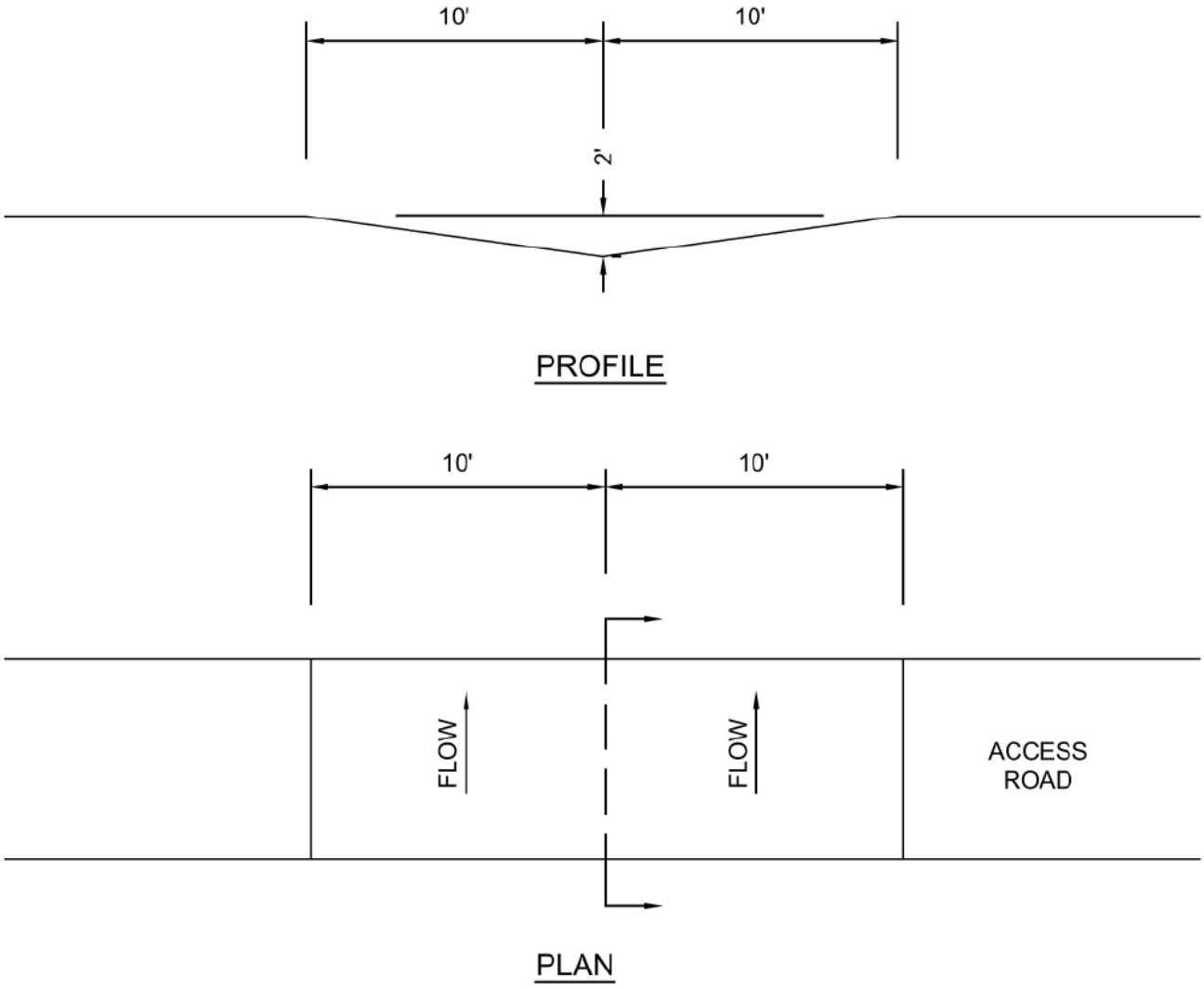


Source: PADEP, 2012

Broad Based Dips

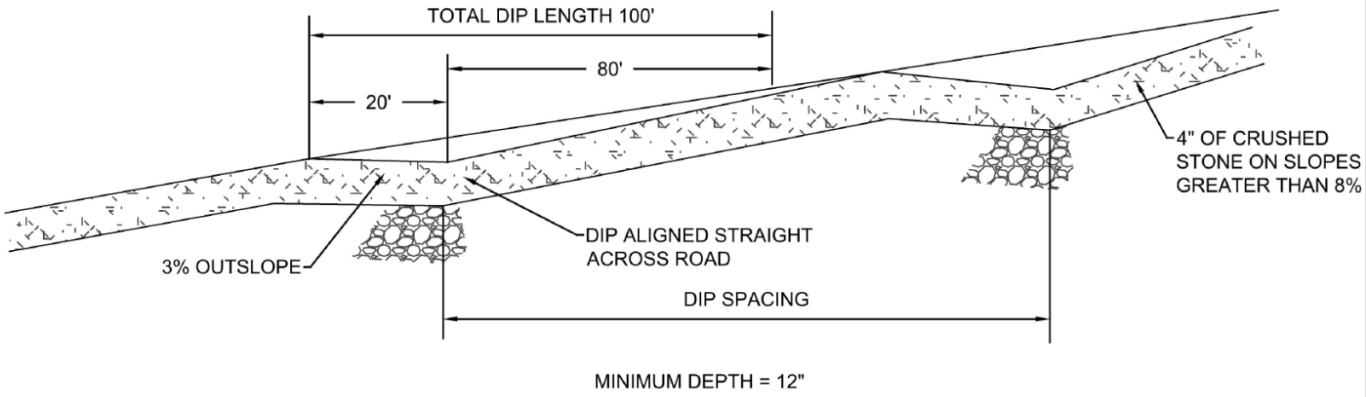
1. Design broad-based dips so that discharges are to the downslope sides of access roads with a maximum gradient of 3% in the dip.
2. For access roads with grades up to 5% (low gradient roads), construct the dip to be 2 feet below the road grade over a total length of 20 feet (10 feet on either side of the dip).
3. For access road between 5% and 10%, construct the dip to be a minimum of 12 inches below grade with a 3% outslope and a total length of 100 feet.

Figure C-ECM-08-9 Broad-based Dip for Low Gradient (≤5%) Approach



Source: PADEP, 2012

Figure C-ECM-08-10 Broad-based Dip for High Gradient (>5% - 10%) Approach



Source: PADEP, 2012

7.0 Operations and Maintenance Considerations

Inspect waterbars or sheet flow breakers weekly and after each rainfall. Keep the waterbars or sheet flow breakers channel flow line clear of sediment accumulations and any obstructions that impede flow. Ensure stabilization is maintained within the waterbar itself, and that erosion does not occur within the berm.

Restore damaged or eroded waterbars or sheet flow breakers to original dimensions within 24 hours of inspection. Inspect constructed outlets and make repairs as needed including mitigation of any sinkholes that may form in or adjacent to outlet structures.

Earthen waterbars or sheet flow breakers on retired roadways, skid trails, and rights-of-way may be left in place after permanent stabilization has been achieved. Provide permanent vegetative stabilization to earthen waterbars or sheet flow breakers left as permanent structures.

Maintenance of waterbars shall be provided until the tributary drainage area to the waterbar has been permanently stabilized.

Open top culverts should be inspected quarterly, and after rainfall events of depth greater than 1-inch per 24-hours. In case where the practice is used on active trails or skid roads, more frequent inspections will be required.

Damaged or non-functioning culverts should be repaired immediately.

Water deflectors should be inspected monthly, and after rainfall events of depth greater than 1-inch per 24-hours. Replace belts when they become worn, or otherwise no longer effective.

8.0 References

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

Vermont Department of Environmental Conservation. Shoreland Best Management Practices. Available online at: https://dec.vermont.gov/watershed/lakes-ponds/lakeshores-lake-wise/bmp

Warren, Charles. 1994. Water Bar Placement and Construction Guide for Siuslaw Roads.

9.0 Appendix C-ECM-08

Design of the Minimum Rock Apron Outlet Dimensions

This appendix provides documentation of the methodology used to size the minimum rock apron outlet dimensions provided in Table C-ECM-08-5 of this Construction BMP to ensure flow leaving the waterbar or sheet flow breaker is non-erosive sheet flow. The minimum rock apron outlet dimensions are based on the contributing drainage area to the waterbar or sheet flow breaker.

Flow Rate Computation

To calculate the dimensions of the rock apron outlet, the flow rate to each waterbar or sheet flow breaker resulting from the 10-year, 24-hour storm event was calculated. The National Resources Conservation Service Technical Release 55 Hydrologic Method and HydroCAD® software were used to compute the runoff flow rate of the contributing drainage area to the waterbar or sheet flow breaker.

The rainfall pattern was modeled as a SCS Type C distribution for the 10-year, 24-hour storm event. Rainfall data were obtained from the National Oceanic and Atmospheric Administration Atlas 14 data server for Richmond, Virginia (Latitude: 37.5522°, Longitude: -77.4221°). The total storm precipitation value for a 24-hour duration for the 10-year storm used was 5.07 inches.

The land cover within the contributing drainage area to the waterbar or sheet flow breaker was modeled as meadow. The soils were assumed to be hydrologic soil group (HSG) D soils. Based on the meadow land cover with HSG D soils, a Runoff Curve Number of 78 was used for the model. The drainage area to the waterbar or sheet flow breaker was modeled at 2.0 acres.

The time of concentration for the contributing drainage area is 8.1 minutes based on a 100-foot length of sheet flow with a slope of 0.30 feet/foot and a Manning's n of 0.13 for range (natural), and a 1,200-foot length of shallow concentrated flow with a slope of 0.30 feet/foot and a velocity factor of 7.0 feet per second (fps) for short grass pasture.

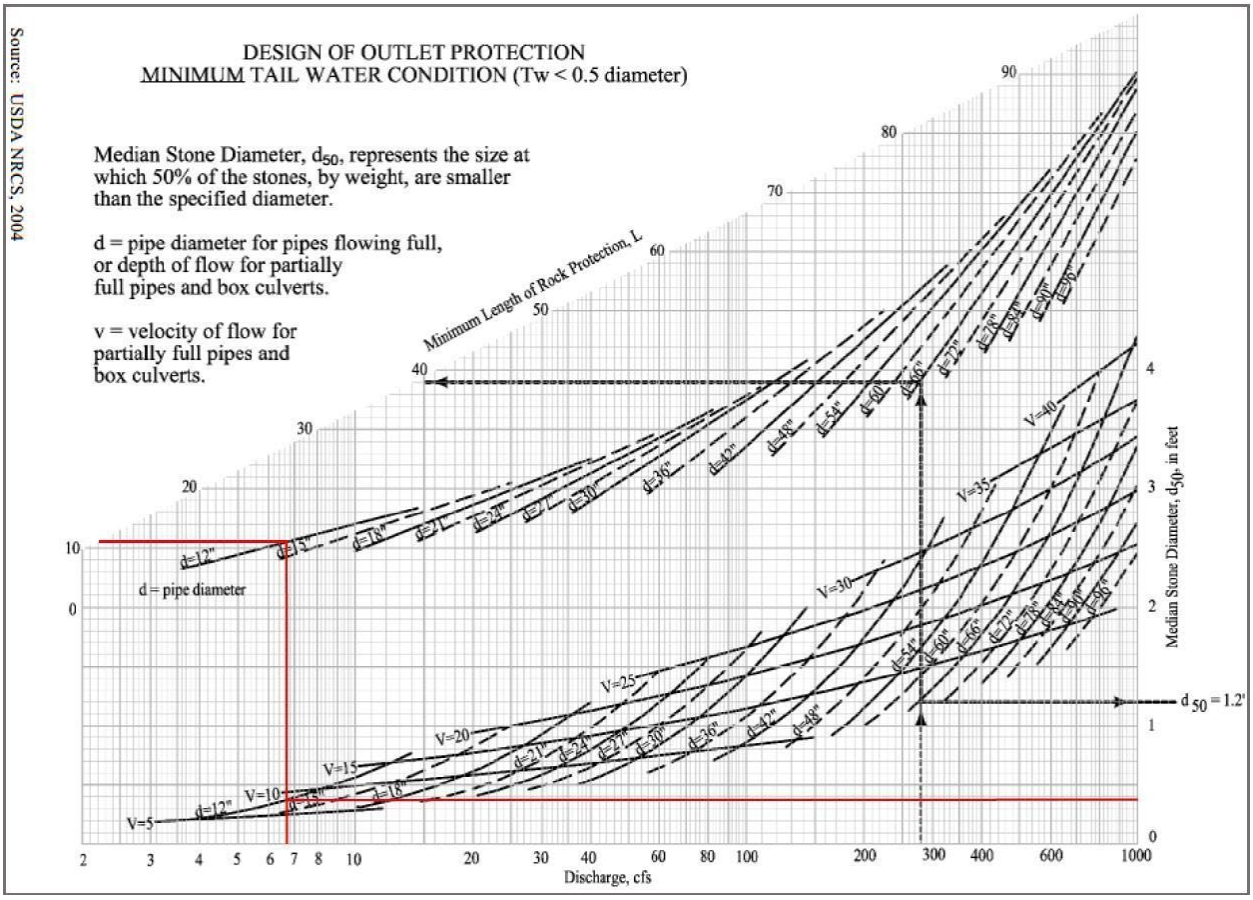
The runoff flow rate to the waterbar or sheet flow breaker was determined to be 6.73 cubic feet per second (cfs), as provided in the attached HydroCAD Report.

Waterbar or Sheet Flow Breaker Flow Computation

A 50-foot-long waterbar or sheet flow breaker was modeled in HydroCAD as a channel with no bottom width, 2H:1V sideslopes, a 1.5-foot depth, a slope of 0.020 feet/foot, and Manning's n of 0.30. The length of the waterbar or sheet flow breaker was modeled with a 50-foot length to coincide with the average permanent right-of-way easement of a linear gas pipeline. The resulting average depth of flow within the waterbar or sheet flow breaker at peak storage is 0.93 feet.

Rock Apron Outlet Computation

Using Figure C-ECM-14-5 – Minimum Tailwater Condition, a discharge rate of 6.73 cfs, and a depth of flow of 12 inches, the apron length was determined to be 12 feet and the median stone size (d_{50}) was determined to be 6 inches (minimum median stone size). The rock apron thickness was determined to be 1.5 times the maximum diameter of the rock but not less than 9 inches. The upstream apron width was determined to be 4.5 feet, based on three times the total waterbar or sheet flow breaker depth of 18 inches. The downstream end of the apron was determined to be 16.5 feet, based on upstream apron width plus the length of the apron of 12 feet.


Source: USDA NRCS, 2004
DESIGN OF OUTLET PROTECTION
MINIMUM TAIL WATER CONDITION (Tw < 0.5 diameter)
Median Stone Diameter, d50, represents the size at which 50% of the stones, by weight, are smaller than the specified diameter.
d = pipe diameter for pipes flowing full, or depth of flow for partially full pipes and box culverts.
v = velocity of flow for partially full pipes and box culverts.
Minimum Length of Rock Protection, L
d = pipe diameter
V=5
V=10
V=15
V=20
V=25
V=30
V=35
V=40
d50 = 1.2'
Median Stone Diameter, d50, in feet
Discharge, cfs

NOAA Atlas 14, Volume 2, Version 3
Location name: Richmond, Virginia, USA*
Latitude: 37.5522°, Longitude: -77.4221°
Elevation: 135 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.374 (0.338-0.413)	0.443 (0.402-0.489)	0.519 (0.470-0.572)	0.581 (0.525-0.642)	0.653 (0.587-0.718)	0.706 (0.634-0.777)	0.757 (0.675-0.833)	0.802 (0.712-0.883)	0.857 (0.754-0.945)	0.900 (0.787-0.993)
10-min	0.597 (0.541-0.659)	0.709 (0.643-0.782)	0.831 (0.753-0.917)	0.930 (0.840-1.03)	1.04 (0.936-1.14)	1.12 (1.01-1.24)	1.20 (1.07-1.32)	1.27 (1.13-1.40)	1.36 (1.19-1.49)	1.42 (1.24-1.56)
15-min	0.746 (0.676-0.824)	0.891 (0.808-0.983)	1.05 (0.953-1.16)	1.18 (1.06-1.30)	1.32 (1.19-1.45)	1.42 (1.28-1.57)	1.52 (1.36-1.67)	1.60 (1.42-1.76)	1.71 (1.50-1.88)	1.78 (1.56-1.96)
30-min	1.02 (0.926-1.13)	1.23 (1.12-1.36)	1.49 (1.35-1.65)	1.70 (1.54-1.88)	1.95 (1.76-2.15)	2.14 (1.92-2.36)	2.33 (2.08-2.56)	2.50 (2.22-2.75)	2.72 (2.39-2.99)	2.88 (2.52-3.18)
60-min	1.28 (1.16-1.41)	1.54 (1.40-1.70)	1.92 (1.74-2.11)	2.22 (2.00-2.45)	2.60 (2.34-2.86)	2.91 (2.61-3.20)	3.21 (2.86-3.53)	3.50 (3.11-3.85)	3.90 (3.43-4.29)	4.21 (3.68-4.64)
2-hr	1.52 (1.37-1.70)	1.84 (1.66-2.05)	2.30 (2.08-2.56)	2.70 (2.43-3.00)	3.22 (2.88-3.56)	3.64 (3.24-4.03)	4.08 (3.60-4.50)	4.53 (3.97-5.00)	5.15 (4.46-5.67)	5.64 (4.85-6.23)
3-hr	1.64 (1.48-1.84)	1.99 (1.79-2.22)	2.49 (2.24-2.78)	2.92 (2.61-3.25)	3.49 (3.10-3.88)	3.96 (3.50-4.39)	4.44 (3.90-4.92)	4.94 (4.31-5.47)	5.62 (4.85-6.22)	6.18 (5.28-6.84)
6-hr	1.99 (1.78-2.24)	2.40 (2.14-2.70)	3.00 (2.67-3.37)	3.53 (3.14-3.97)	4.26 (3.76-4.77)	4.88 (4.28-5.44)	5.53 (4.81-6.18)	6.23 (5.37-6.94)	7.21 (6.14-8.02)	8.04 (6.76-8.94)
12-hr	2.38 (2.14-2.68)	2.86 (2.57-3.24)	3.61 (3.23-4.07)	4.28 (3.81-4.82)	5.23 (4.61-5.86)	6.06 (5.29-6.78)	6.95 (6.00-7.74)	7.92 (6.75-8.79)	9.32 (7.82-10.4)	10.6 (8.72-11.7)
24-hr	2.75 (2.50-3.05)	3.33 (3.04-3.70)	4.27 (3.88-4.74)	5.07 (4.59-5.61)	6.26 (5.62-6.89)	7.27 (6.49-8.00)	8.40 (7.43-9.22)	9.65 (8.46-10.6)	11.5 (9.96-12.6)	13.1 (11.2-14.4)
2-day	3.21 (2.92-3.55)	3.89 (3.53-4.29)	4.96 (4.49-5.47)	5.84 (5.28-6.44)	7.14 (6.41-7.86)	8.24 (7.35-9.07)	9.43 (8.35-10.4)	10.7 (9.43-11.8)	12.6 (11.0-13.9)	14.2 (12.2-15.7)
3-day	3.39 (3.08-3.74)	4.10 (3.73-4.52)	5.22 (4.75-5.76)	6.15 (5.58-6.77)	7.51 (6.77-8.26)	8.66 (7.76-9.51)	9.89 (8.81-10.9)	11.2 (9.92-12.3)	13.2 (11.5-14.5)	14.9 (12.8-16.3)
4-day	3.57 (3.25-3.93)	4.32 (3.94-4.76)	5.49 (5.01-6.05)	6.46 (5.88-7.10)	7.88 (7.13-8.66)	9.07 (8.16-9.95)	10.4 (9.26-11.3)	11.8 (10.4-12.9)	13.8 (12.1-15.1)	15.5 (13.4-17.0)
7-day	4.11 (3.76-4.51)	4.94 (4.52-5.43)	6.19 (5.65-6.79)	7.22 (6.59-7.92)	8.71 (7.91-9.53)	9.96 (8.99-10.9)	11.3 (10.1-12.4)	12.7 (11.4-13.9)	14.8 (13.1-16.2)	16.5 (14.4-18.2)
10-day	4.67 (4.29-5.11)	5.60 (5.15-6.12)	6.93 (6.36-7.57)	8.01 (7.34-8.74)	9.55 (8.72-10.4)	10.8 (9.82-11.8)	12.1 (11.0-13.2)	13.6 (12.2-14.8)	15.6 (13.8-17.0)	17.2 (15.2-18.8)
20-day	6.28 (5.80-6.80)	7.49 (6.92-8.11)	9.05 (8.35-9.81)	10.3 (9.48-11.1)	12.0 (11.0-13.0)	13.3 (12.2-14.4)	14.7 (13.4-15.9)	16.1 (14.6-17.4)	18.0 (16.2-19.5)	19.4 (17.4-21.1)
30-day	7.80 (7.26-8.38)	9.25 (8.60-9.93)	11.0 (10.2-11.8)	12.3 (11.4-13.2)	14.0 (12.9-15.0)	15.3 (14.1-16.5)	16.6 (15.3-17.9)	17.9 (16.4-19.3)	19.6 (17.9-21.1)	20.9 (19.0-22.5)
45-day	9.82 (9.16-10.5)	11.6 (10.8-12.4)	13.6 (12.6-14.5)	15.0 (14.0-16.1)	17.0 (15.7-18.1)	18.4 (17.1-19.7)	19.8 (18.3-21.1)	21.1 (19.5-22.6)	22.8 (21.0-24.4)	24.0 (22.0-25.8)
60-day	11.6 (10.9-12.4)	13.7 (12.9-14.5)	15.8 (14.8-16.8)	17.4 (16.3-18.5)	19.5 (18.2-20.6)	21.0 (19.6-22.2)	22.4 (20.9-23.8)	23.8 (22.1-25.2)	25.5 (23.6-27.1)	26.7 (24.7-28.5)

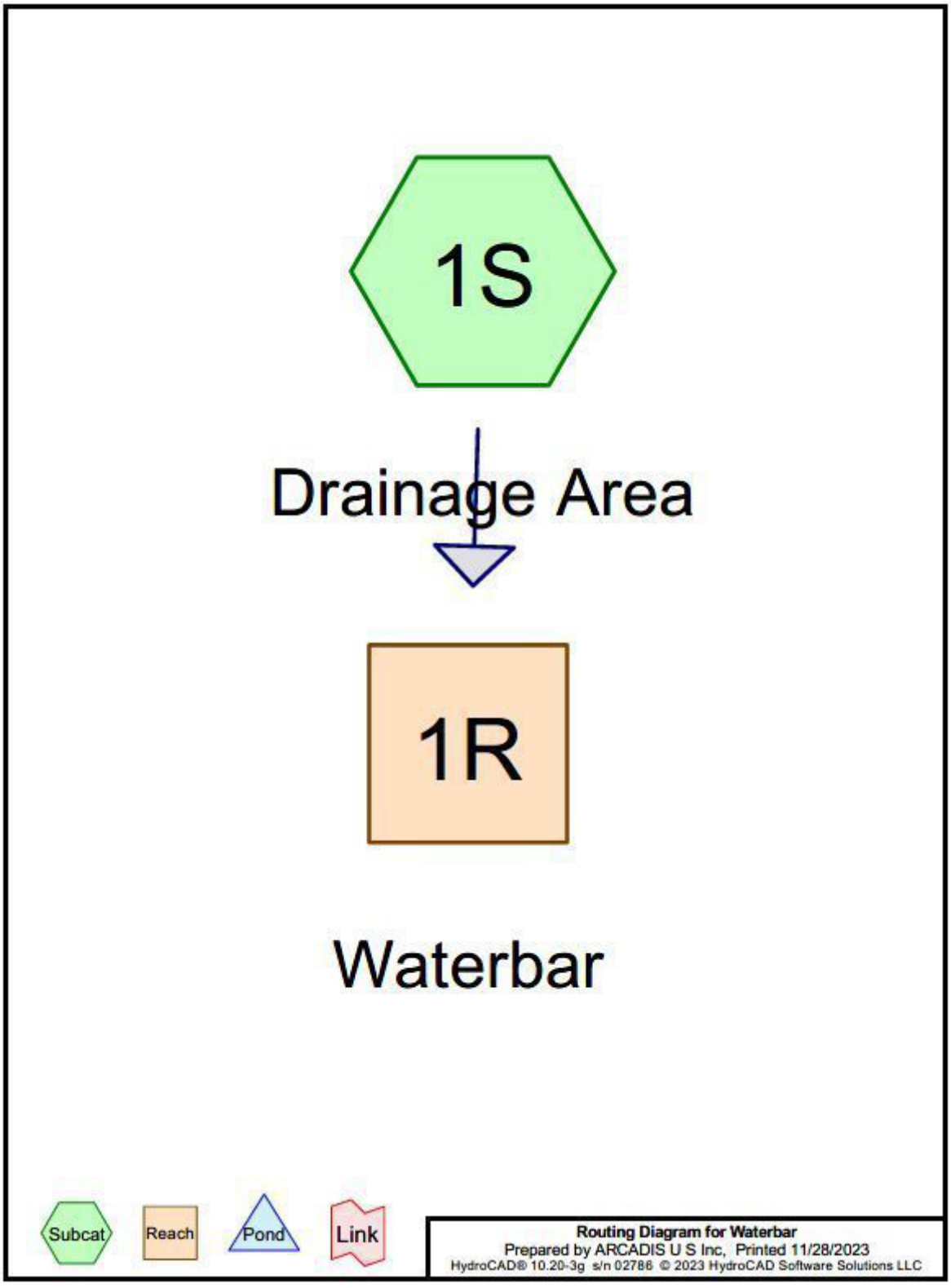
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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PF graphical


1S
Drainage Area
1R
Waterbar
Subcat
Reach
Pond
Link
Routing Diagram for Waterbar
Prepared by ARCADIS U S Inc, Printed 11/28/2023
HydroCAD® 10.20-3g s/n 02786 © 2023 HydroCAD Software Solutions LLC

Summary for Subcatchment 1S: Drainage Area

Runoff = 6.73 cfs @ 12.15 hrs, Volume= 20,119 cf, Depth= 2.77"
Routed to Reach 1R : Waterbar

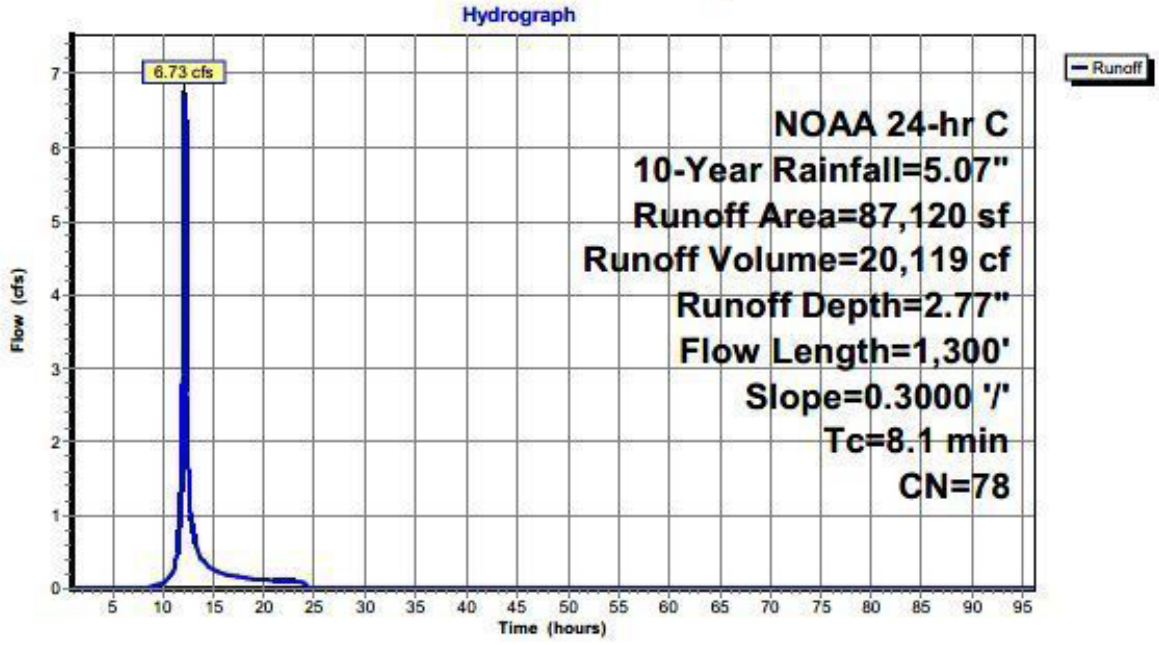
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-96.00 hrs, dt= 0.01 hrs
NOAA 24-hr C 10-Year Rainfall=5.07"

Area (sf)	CN	Description
87,120	78	Meadow, non-grazed, HSG D
87,120		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.9	100	0.3000	0.57		**Sheet Flow,** Range n= 0.130 P2= 3.33"
5.2	1,200	0.3000	3.83		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.1	1,300	Total			



Subcatchment 1S: Drainage Area



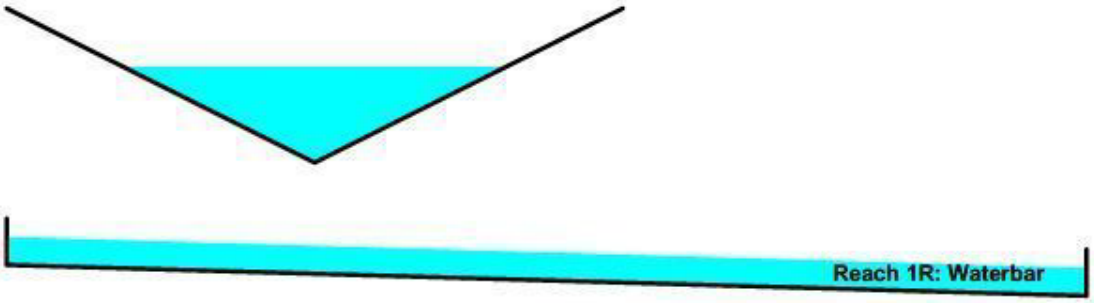
Summary for Reach 1R: Waterbar

Inflow Area = 87,120 sf, 0.00% Impervious, Inflow Depth = 2.77" for 10-Year event
Inflow = 6.73 cfs @ 12.15 hrs, Volume= 20,119 cf
Outflow = 6.73 cfs @ 12.16 hrs, Volume= 20,119 cf, Atten= 0%, Lag= 0.1 min
Routed to nonexistent node 2R

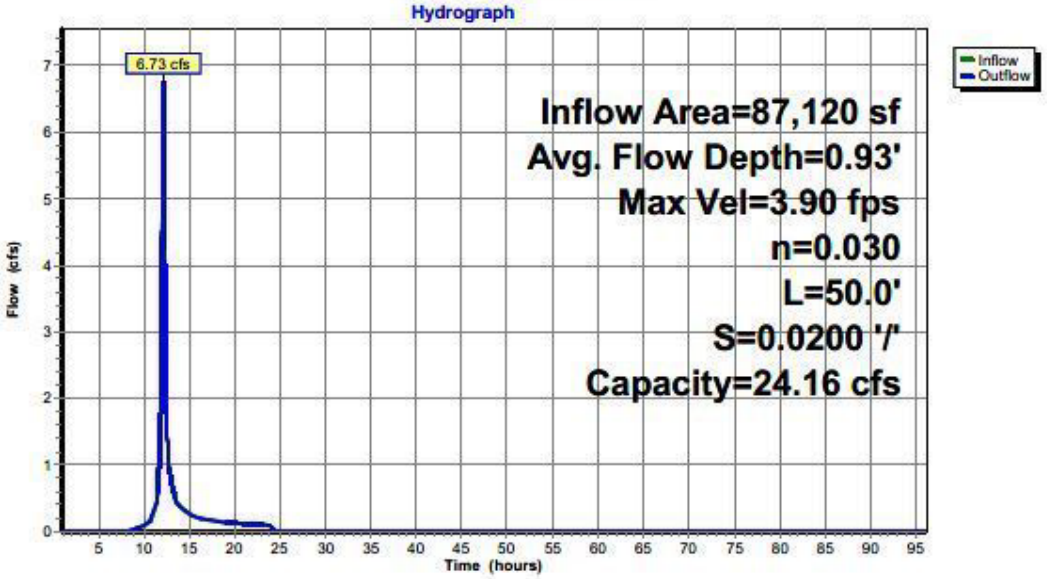
Routing by Dyn-Stor-Ind method, Time Span= 1.00-96.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.90 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.56 fps, Avg. Travel Time= 0.5 min

Peak Storage= 86 cf @ 12.16 hrs
Average Depth at Peak Storage= 0.93' , Surface Width= 3.72'
Defined Flood Depth= 96.50' Flow Area= 571.7 sf, Capacity= 4,069.95 cfs
Bank-Full Depth= 1.50' Flow Area= 4.5 sf, Capacity= 24.16 cfs

0.00' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.0 '/' Top Width= 6.00'
Length= 50.0' Slope= 0.0200 '/'
Inlet Invert= 100.00', Outlet Invert= 99.00'



Reach 1R: Waterbar



C-ECM-09 Stormwater Conveyance Channel

1.0 Definition

A stormwater conveyance channel is a permanent, designed waterway that is shaped, sized, and lined with appropriate vegetation or structural material such that the channel safely conveys stormwater runoff within or away from a developing area.

– CAD and PDF files for C-ECM-09 Stormwater Conveyance Channel

2.0 Purpose and Applicability of Best Management Practice

A stormwater conveyance channel conveys concentrated surface runoff water to a receiving channel or system without damage from erosion. They are also used to collect runoff from disturbed areas and convey it to a sediment removal facility such as a temporary sediment trap or basin (see C-SCM-11 and C-SCM-12) before discharge into receiving surface waters, as well as to divert runoff from undisturbed upslope areas and convey it around areas of earth disturbance (Pennsylvania Department of Environmental Protection [PADEP] 2012).

Stormwater conveyance channels generally apply to artificial channels, including roadside ditches and intermittent natural channels that are constructed or modified to accommodate flows generated by land development.

Implement the stormwater conveyance channel only after analyzing channel adequacy for capacity and velocity as discussed in Section 5.0 Design Criteria.

Install and stabilize stormwater conveyance channels before introducing post-development stormwater flows.

Stormwater conveyance channels do not generally apply to continuously flowing natural streams. Major streams need full design considerations and calculations. Provisions for protecting the banks of such streams are described in Vegetative Streambank Stabilization (C-ENV-01) and Structural Streambank Stabilization (C-ENV-02).

3.0 Planning and Considerations

The design of a channel cross-section and lining is based primarily on the volumetric flow rate and velocity of flow expected in the channel. If conditions are appropriate, grass or riprap channels are preferred. Only use concrete channels when grass-lined or riprap-lined channels prove to be infeasible.

In addition to the primary design considerations of capacity and velocity, consider these other factors when selecting a cross-section and lining: land availability, compatibility with land use and the surrounding environment, safety, maintenance requirements, outlet conditions, and the specific soil erodibility potential. If a riprap design is chosen, use filter fabric to act as a separator and stabilizer between the stone and the earth.

In steep slope situations (bed slope > 10%), consider the use of temporary slope drains (C-ECM-12). Align all channels and berms to provide positive drainage. Avoid sharp turns, high angles of confluence, and very low gradients (< 1% bed slope) wherever possible (PADEP 2012).

Design channels that require protective liners to be either trapezoidal or parabolic in cross-section. Do not use vee-shaped channels with fabric or geotextile liners due to the tendency for gaps to be left under the lining at the bottom of the channel (PADEP 2012).

4.0 Stormwater Performance Summary

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

9VAC25-875-560

Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-ECM-09-1 Design Criteria

Topic	Requirement
Cross- Section Design	V-shaped channels are generally used where the quantity of water to be handled is relatively small, such as in roadside channels. A grass or sod lining will suffice where velocities in the channel are low. For steeper slopes where high velocities are encountered, a riprap lining may be appropriate. Parabolic channels are often used where the quantity of water to be handled is larger and where space is available for a wide, shallow channel with low velocity flow. Use riprap where higher velocities are expected and where some dissipation of energy (velocity) is desired. Combinations of grass and riprap are also useful where there is continuous low flow in the channel. Trapezoidal channels are often used where the quantity of water to be carried is large and conditions require the water to be carried at a relatively high velocity. Trapezoidal ditches are generally lined with riprap. Figure C-ECM-09-1 and Figure C-ECM-09-2 illustrate the various types of cross-sections and channel linings.
Outlet Design	Consider the outlet conditions for all channels, which is particularly important for the transition from an artificial lining to a vegetated or non-vegetated lining. Ensure that appropriate measures are taken to dissipate the energy of the flow to prevent scour of the receiving channel. Also see Outlet Protection (C-ECM-15).
Capacity	Design all channels to satisfy MS-19 of the Virginia Erosion and Sediment Control regulations. If channel modifications are necessary, ensure the capacity of the channel is sufficient to convey the 10-year, 24-hour frequency design storm with a freeboard of at least 0.5 foot. If pre-development flooding problems exist, the consequences of flooding are severe, or drainage systems that convey larger storms converge with the channel in question, consider increasing the capacity beyond the 10-year, 24-hour frequency storm capacity.

Table C-ECM-09-1 Design Criteria	
Topic	**Requirement**
Permissible Velocity & Allowable Shear Stress	Design conveyance channels so that the velocity of flow expected from a 2-year, 24- hour frequency storm does not exceed the permissible velocity for the type of lining used. Grass-lined channels provide good protection against erosion while also providing an aesthetic setting for conveyance of runoff. However, the velocities that grass linings can handle are much lower than those in riprap or concrete-lined channels. For grass linings, select the appropriate type of vegetation for the site conditions (e.g., drainage tolerance, shade tolerance, maintenance requirements). See Permanent Seeding (C-SSM-10) and Sodding (C-SSM-06). Where there will be a base flow in grass-lined channels, provide a stone center, a subsurface drain, or other suitable means to handle the base flow. Figure C-ECM-09-2 shows typical cross-sections for stone center channels. Refer to Riprap (C-ECM-13) to choose the correct stone size and for filter fabric specifications. Permissible velocities for non-lined and grass-lined channels are shown in Table C-ECM-15-3 and Table C-ECM-09-2. Protect channels or outlets against erosion by vegetative means as soon after construction as practical. Ensure that vegetation is well established before diversions or other channels are discharged into grass-lined channels. Consider using turf- reinforcement mats and other rolled erosion control products (C-SSM-05) or sodding (C-SSM-06) of channels to provide erosion protection as soon after construction as possible and before the establishment of vegetation. Protect the center line of the waterway with one of these materials to avoid center gullies and to protect seedlings from erosion before establishment (New York Department of Environmental Conservation [NYDEC] 2016). Riprap-lined channels can be designed to withstand most flow velocities by choosing a stable stone size (see C-ECM-13). Install riprap with a filter fabric or gravel (granular) underlining. Carefully design the transition from riprap lining to grass and earth linings to meet the allowable velocities of each type of lining. The permissible velocity design method may be used for linings of channels with bed slopes less than 10%, while the allowable shear method is acceptable for all channel bed slopes (PADEP 2012).
Depth	Ensure the design water surface elevation of a channel receiving water from diversions or other tributary channels is equal to or less than the design water surface elevation of the diversion or other tributary channel at the point of intersection. Water surface elevation is typically noted in 0.5-foot increments. Design the top widths of parabolic and v-shaped, grass-lined channels not to exceed 30 feet and the bottom widths of trapezoidal, grass-lined channels not to exceed 15 feet unless multiple or divided waterways, riprap center, or other means are provided to control meandering of low flows.

Table C-ECM-09-1 Design Criteria	
Topic	**Requirement**
Outlet	Protect the outlets of all channels from erosion. See Outlet Protection (C-ECM-15).
Calculations	Calculate the peak flow rate in accordance with the guidelines in Appendix A. Determine whether the soil(s) in which the channel will be constructed have any limitations that will affect the stability of the channel or its protective lining. Soils having K factors less than or equal to 0.37 may be considered erosion-resistant; consider all others to be highly erodible (PADEP 2012). Determine dimensions for roadside and median channels in accordance with applicable design procedures outlined in the latest edition of the Virginia Department of Transportation (VDOT) Drainage Manual (2021). Helpful design charts are also included in that publication to aid in the design of concrete-lined channels for many cross-sectional shapes. Channel dimensions for parabolic, grass-lined channels may be determined from the tables in Appendix C-ECM-09-a. Calculate the anticipated velocity using Manning's Equation in accordance with the guidelines in Appendix A and calculate the design shear stress.

Table C-ECM-09-2 Maximum Velocities for Grass-Lined Channels			
Cover Type	**Slope (%)**	**Erosion Resistant Soils (feet/second)**	**Easily Eroded Soils (feet/second)**
Bermudagrass	0 – 5 5 – 10	6 5	4.5 3.8
Kentucky bluegrass Reed Canarygrass Tall fescue	0 – 5 5 – 10 > 10	5 4 3	3.8 3 2.3
Grass-legume mixture	0 – 5 5 – 10	4 3	3 2.3
Red fescue	0 – 5	2.5	1.9
Sources: Virginia Department of Environmental Quality 1992; Ree 1949; Temple et al. 1987; NOVA 2007			

6.0 Construction Specifications

Table C-ECM-09-3 Construction Specifications	
Topic	**Requirement**
General	Remove and properly dispose all trees, brush, stumps, roots, obstructions, and other unsuitable material. Excavate or shape the channel to the proper grade and cross-section. Ensure proper compaction of any fills to prevent unequal settlement. Remove and properly dispose any excess soil.
Grass-Lined Channels	The method used to establish grass in the ditch or channel will depend on the severity of the conditions encountered. The methods available for grass establishment are set forth in Permanent Seeding (C-SSM-10) and Sodding (C-SSM-06). Use turf reinforcement mats and other rolled erosion control products. See Soil Stabilization Blankets and Matting (C-SSM-05) to provide erosion protection as soon after construction as possible and before the establishment of vegetation (NYDEC 2016).
Riprap-Lined Channels	Install riprap in accordance with Riprap (C-ECM-13).
Concrete-Lined Channels	Construct concrete-lined channels in accordance with all applicable VDOT specifications. The following items highlight those specifications: Ensure that the subgrade is moist at the time the concrete is poured. Provide traverse joints for crack control at approximately 20-foot intervals and when more than 45 minutes elapses between the times of consecutive concrete placements. Ensure that all sections are at least 6 feet long. Crack control joints may be formed by using a 0.125-inch-thick removable template, by scoring or sawing to a depth of at least 0.75 inch, or by an approved leave-in type insert. Install expansion joints every 100 feet.

7.0 Operations and Maintenance Considerations

Table C-ECM-09-4 Operation and Maintenance Specifications	
Topic	**Requirement**
Grass-Lined Channels	During initial establishment, immediately repair grass-lined channels and re-establish grass if necessary. After grass has been established, inspect the channel periodically to determine if the grass is withstanding flow velocities without damage. If the channel is to be mowed, cut the grass in the channel in a manner that will not damage the grass.
Riprap-Lined Channels	Periodically inspect riprap-lined channels to ensure that scour is not occurring beneath the fabric underlining of the riprap layer. Inspect the channel to determine that the stones are not dislodged by large flows. Replace any dislodged or displaced stones.
Concrete-Lined Channels	Periodically inspect concrete-lined channels to ensure there is no undermining of the channel. Pay particular attention to the outlet of the channel. If scour is occurring at the outlet, install appropriate measures. See Outlet Protection (C-ECM-15).

Table C-ECM-09-4 Operation and Maintenance Specifications	
Topic	**Requirement**
Sediment Deposition	If the channel is below a high sediment-producing area, trap the sediment before it enters the channel. Field experience has demonstrated that many newly constructed conveyance channels become damaged and require costly repairs because of improper upslope controls. If sediment is deposited in a grass-lined channel, promptly remove the sediment to prevent damage to the grass. Remove sediment deposited in riprap-lined and concrete-lined channels when the sediment reduces the capacity of the channel.

Figure C-ECM-09-1 Typical Waterway Sections

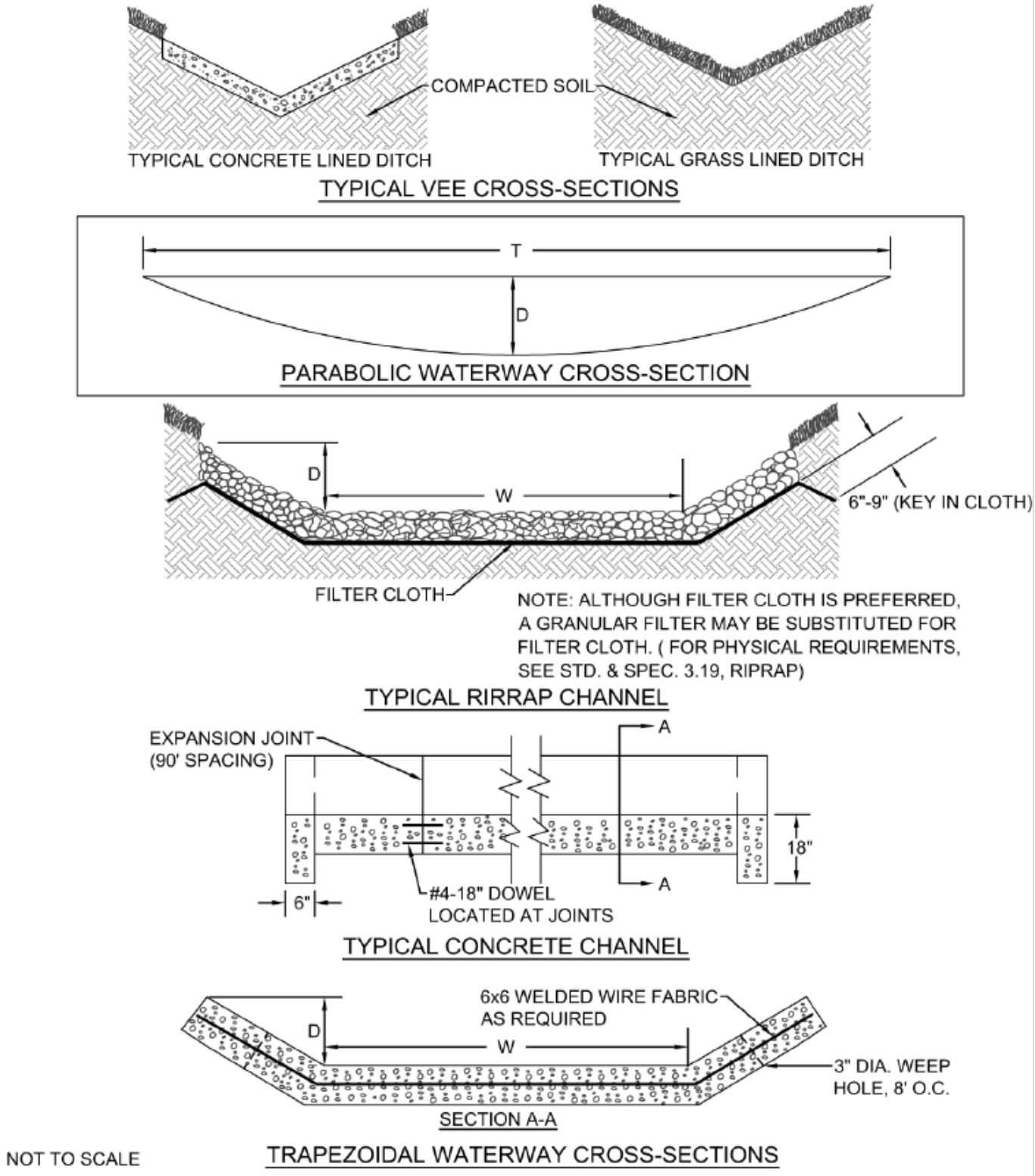
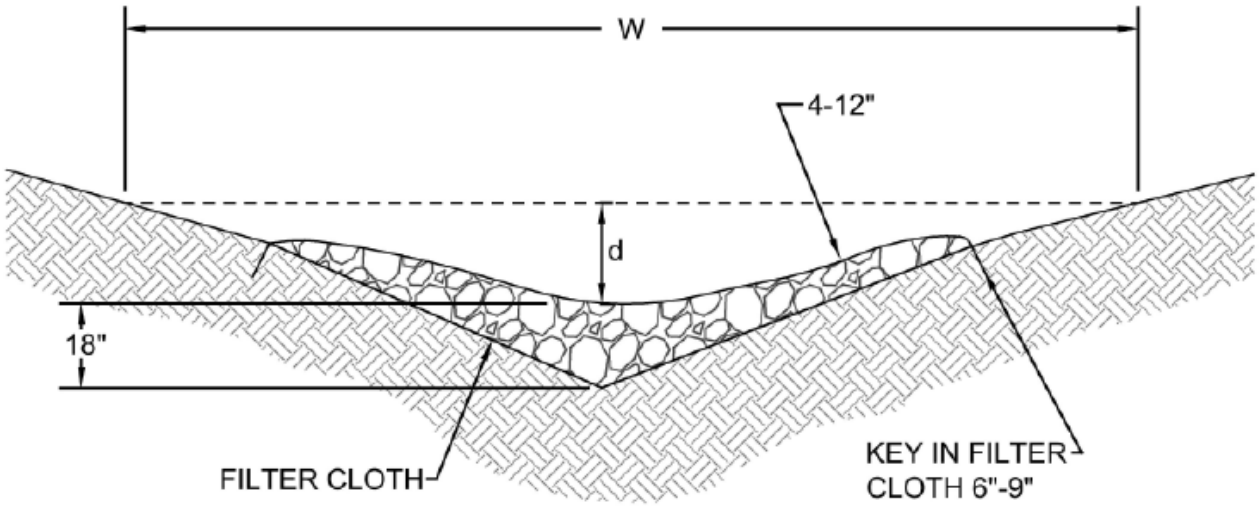
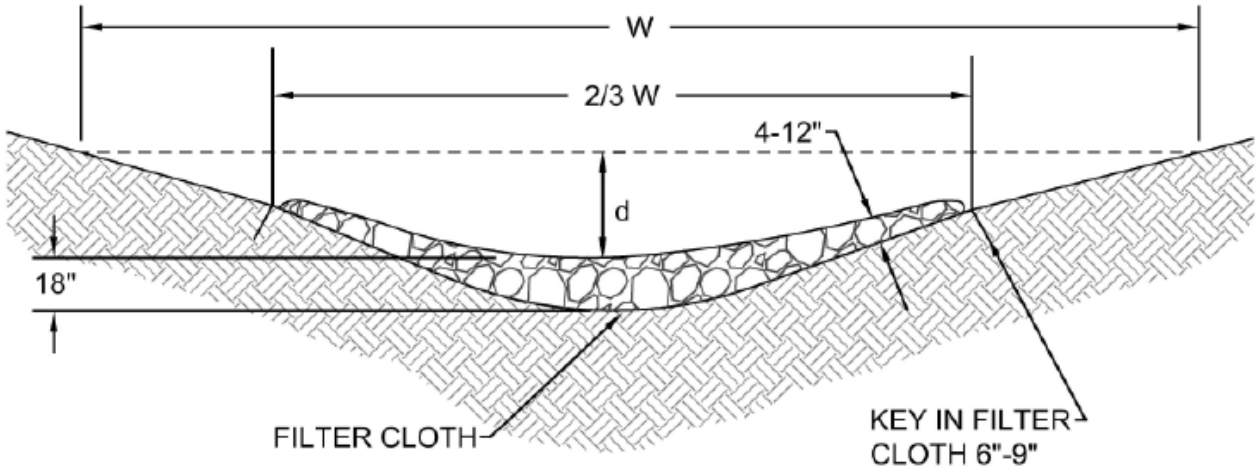


Figure C-ECM-09-2 Stone Lined Waterways



V-SHAPED WATERWAY WITH STONE CENTER DRAIN

NOTE: A GRANULAR FILTER MAY BE SUBSTITUTED FOR FILTER CLOTH



PARABOLIC WATERWAY WITH STONE CENTER DRAIN

NOTE: A GRANULAR FILTER MAY BE SUBSTITUTED FOR FILTER CLOTH

8.0 References

NYDEC. 2016. New York State Standards and Specifications for Erosion and Sediment Control. November.

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987 Stability Design of Grass-Lined Open Channels. United States Department of Agriculture, Agricultural Research Service, Agriculture Handbook Number 667. Issued September.

VDOT. 2021. Drainage Manual. Virginia Department of Transportation, Location and Design Division. Issued April 2002. Revised January 2021. Available online at: https://virginiadot.org/business/locdes/hydra-drainage-manual.asp.

Virginia Department of Environmental Quality. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

9.0 Appendix C-ECM-09-a

Design of Parabolic Grass-Lined Channels

Design the channel for capacity and erosion resistance. Capacity will be at a minimum when the grass is long and not mowed; this condition corresponds to V2 in Table C-ECM-09-5 below. Erosion will most likely occur when the grass is short; this condition corresponds to V1 in Table C-ECM-09-5. A design based on Table C-ECM-09-5 will result in a channel with adequate capacity when vegetation in the channel is long and thick, that will remain stable when the vegetation is short or recently mowed, and that will have adequate freeboard for the design flow.

Use the following procedure to design a grass-lined parabolic channel based on Table C-ECM-09-2 and Table C-ECM-09-5 (PADEP 2012):

1. Determine the required channel capacity (Q), which is the peak rate of runoff for the selected design storm.
2. Select an appropriate grass lining and note the maximum permissible velocity (V1) from Table C-ECM-09-2.
3. Choose the appropriate sheet of Table C-ECM-09-5 for the channel slope. Using the maximum permissible velocity (V1) and the required flow capacity (Q), read the top width (T) and the depth (D) for the correct parabolic section.
4. The top width (T), area (A), wetted perimeter (P), and hydraulic radius (R) can be calculated for the channel dimensions using the equations provided in Table C-ECM-09-6 (see Appendix C-ECM-09-b).

Example Problem

Design a parabolic waterway to be lined with Kentucky 31-Tall Fescue that will carry 50 cubic feet per second (cfs) on a 3% slope.

Solution:

1. Q = 50 cfs (given)
2. V1 = 5 ft./sec. for Kentucky 31-Tall Fescue (from Table C-ECM-08-2)
3. From sheet 9 of Table C-ECM-09-5 (for 3% slope): Read the top width (T) and depth (D) for Q = 50 cfs and V1 = 5.0 feet per second (fps)

T = 16.3 feet

D = 1.45 feet

Table C-ECM-09-5 Design Tables for Parabolic Grass-Lined Channels

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.25 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	11.3	3.27	1.00																								
30	13.2	3.09	1.09																								
35	15.2	3.01	1.13																								
40	17.3	2.99	1.15	12.1	3.61	1.36																					
45	19.3	2.94	1.18	13.4	3.49	1.42																					
50	21.4	2.93	1.18	14.7	3.41	1.48																					
55	23.5	2.92	1.19	16.1	3.38	1.50																					
60	25.5	2.89	1.21	17.5	3.35	1.52																					
65	27.6	2.89	1.21	18.8	3.30	1.56																					
70	29.7	2.89	1.21	20.2	3.28	1.57	14.4	3.98	1.81																		
75	31.7	2.87	1.23	21.6	3.27	1.58	15.3	3.91	1.86																		
80	33.8	2.87	1.23	23.0	3.26	1.58	16.3	3.90	1.87																		
90	38.0	2.87	1.23	25.8	3.25	1.60	18.1	3.80	1.94																		
100	42.1	2.85	1.24	28.6	3.23	1.61	20.0	3.76	1.98																		
110	46.3	2.85	1.24	31.4	3.22	1.62	21.9	3.73	2.01																		
120	50.4	2.84	1.25	34.1	3.20	1.64	23.9	3.73	2.00	17.0	4.47	2.34															
130	54.6	2.85	1.24	36.9	3.19	1.64	25.8	3.70	2.02	18.3	4.42	2.39															
140	58.7	2.84	1.25	39.7	3.19	1.65	27.7	3.68	2.04	19.6	4.37	2.43															
150	62.9	2.85	1.25	42.5	3.19	1.65	29.6	3.67	2.06	20.9	4.33	2.47															
160	67.0	2.84	1.25	45.3	3.18	1.65	31.6	3.68	2.05	22.2	4.30	2.50															
170	71.1	2.84	1.26	48.1	3.18	1.65	33.5	3.66	2.07	23.5	4.27	2.53	18.5	4.95	2.76												
180	75.3	2.84	1.25	50.9	3.18	1.66	35.4	3.65	2.08	24.8	4.24	2.55	19.5	4.90	2.80												
190	79.4	2.84	1.26	53.7	3.18	1.66	37.4	3.66	2.07	26.1	4.22	2.57	20.5	4.87	2.84												
200	83.5	2.84	1.26	56.5	3.18	1.66	39.3	3.65	2.08	27.5	4.23	2.56	21.5	4.83	2.87												
220	91.8	2.84	1.26	62.1	3.18	1.66	43.2	3.65	2.08	30.1	4.19	2.60	23.5	4.77	2.92												
240	100.0	2.83	1.26	67.6	3.17	1.67	47.0	3.63	2.10	32.7	4.15	2.64	25.5	4.72	2.97												
260	108.3	2.84	1.26	73.2	3.17	1.67	50.9	3.63	2.10	35.4	4.15	2.64	27.5	4.68	3.01	21.4	5.50	3.29									
280	116.6	2.84	1.26	78.8	3.17	1.67	54.8	3.63	2.10	38.1	4.14	2.64	29.5	4.64	3.05	22.9	5.44	3.35									
300	124.8	2.84	1.26	84.4	3.17	1.67	58.6	3.62	2.11	40.8	4.14	2.65	31.5	4.61	3.08	24.5	5.42	3.37									

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.50 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	10.2	2.28	0.95																								
20	13.3	2.18	1.02																								
25	16.5	2.15	1.05	10.5	2.60	1.35																					
30	19.7	2.12	1.06	12.4	2.51	1.42	9.5	2.91	1.60																		
35	22.8	2.09	1.09	14.3	2.45	1.48	10.9	2.81	1.69																		
40	26.0	2.08	1.09	16.3	2.44	1.49	12.3	2.74	1.76																		
45	29.2	2.08	1.10	18.2	2.41	1.52	13.7	2.69	1.81																		
50	32.4	2.08	1.10	20.2	2.40	1.53	15.1	2.64	1.86	11.1	3.22	2.07															
55	35.6	2.08	1.11	22.1	2.38	1.55	16.6	2.64	1.86	12.0	3.11	2.18															
60	38.8	2.08	1.11	24.1	2.38	1.55	18.0	2.61	1.90	13.0	3.07	2.23															
65	42.0	2.08	1.11	26.0	2.36	1.57	19.5	2.61	1.89	14.0	3.03	2.27															
70	45.2	2.08	1.11	28.0	2.36	1.57	20.9	2.59	1.92	15.0	3.01	2.31															
75	48.4	2.08	1.11	29.9	2.35	1.59	22.4	2.59	1.92	16.0	2.98	2.34	12.7	3.48	2.52												
80	51.6	2.08	1.11	31.9	2.36	1.58	23.8	2.58	1.94	17.0	2.96	2.36	13.4	3.41	2.60												
90	57.9	2.07	1.12	35.8	2.35	1.59	26.7	2.56	1.96	19.1	2.95	2.37	15.0	3.37	2.64												
100	64.3	2.07	1.11	39.7	2.34	1.60	29.6	2.55	1.97	21.1	2.92	2.42	16.5	3.31	2.72	13.3	3.77	2.96									
110	70.7	2.08	1.11	43.6	2.34	1.61	32.6	2.56	1.96	23.2	2.92	2.42	18.1	3.29	2.75	14.5	3.70	3.05									
120	77.0	2.07	1.12	47.5	2.33	1.61	35.5	2.56	1.97	25.2	2.89	2.45	19.6	3.24	2.81	15.7	3.64	3.12									
130	83.4	2.08	1.12	51.5	2.34	1.61	38.4	2.55	1.98	27.3	2.90	2.45	21.2	3.23	2.82	16.9	3.60	3.18									
140	89.7	2.08	1.12	55.4	2.34	1.61	41.3	2.55	1.98	29.3	2.88	2.47	22.8	3.22	2.84	18.1	3.56	3.23									
150	96.0	2.08	1.12	59.3	2.34	1.61	44.2	2.55	1.99	31.4	2.88	2.47	24.3	3.19	2.88	19.4	3.56	3.23	15.5	4.09	3.52						
160	102.3	2.08	1.12	63.2	2.34	1.61	47.1	2.54	1.99	33.5	2.89	2.47	25.9	3.19	2.88	20.6	3.53	3.27	16.4	4.02	3.60						
170	108.6	2.08	1.12	67.1	2.34	1.62	50.0	2.54	1.99	35.5	2.87	2.48	27.5	3.19	2.89	21.9	3.54	3.27	17.4	4.01	3.62						
180	114.9	2.08	1.12	70.9	2.33	1.62	52.9	2.54	1.99	37.6	2.88	2.48	29.1	3.19	2.89	23.1	3.51	3.30	18.3	3.96	3.69						
190	121.2	2.08	1.12	74.8	2.33	1.62	55.8	2.54	2.00	39.6	2.87	2.49	30.6	3.16	2.92	24.3	3.49	3.34	19.3	3.96	3.70						
200	127.4	2.08	1.13	78.7	2.33	1.62	58.7	2.54	2.00	41.7	2.87	2.49	32.2	3.16	2.93	25.6	3.50	3.33	20.2	3.91	3.77	16.8	4.48	3.96			
220	140.0	2.08	1.13	86.5	2.33	1.62	64.5	2.54	2.00	45.8	2.87	2.50	35.4	3.16	2.93	28.1	3.49	3.35	22.1	3.87	3.83	18.3	4.39	4.08			
240	152.6	2.08	1.13	94.3	2.33	1.63	70.3	2.54	2.01	49.9	2.86	2.51	38.6	3.16	2.93	30.6	3.48	3.36	24.1	3.87	3.84	19.9	4.36	4.12			
260	165.2	2.08	1.13	102.1	2.33	1.63	76.1	2.54	2.01	54.0	2.86	2.51	41.7	3.15	2.95	33.1	3.47	3.38	26.0	3.84	3.88	21.5	4.34	4.15			
280	177.7	2.08	1.13	109.8	2.33	1.63	81.9	2.54	2.01	58.2	2.87	2.50	44.9	3.15	2.95	35.6	3.46	3.39	28.0	3.84	3.88	23.0	4.28	4.24	19.0	4.88	4.50
300	190.3	2.08	1.13	117.6	2.33	1.63	87.7	2.54	2.01	62.3	2.86	2.51	48.0	3.14	2.97	38.1	3.45	3.40	29.9	3.82	3.92	24.6	4.27	4.26	20.2	4.80	4.61

Table C-ECM-09-5 Design Tables for Parabolic Grass-Lined Channels

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.75 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	13.7	1.76	0.92	8.0	2.22	1.24																				
20	18.2	1.75	0.93	10.4	2.10	1.35																				
25	22.6	1.73	0.95	12.8	2.03	1.42	9.5	2.33	1.66																	
30	27.1	1.73	0.95	15.3	2.02	1.44	11.2	2.25	1.76	8.9	2.56	1.94														
35	31.5	1.72	0.96	17.8	2.01	1.45	13.0	2.23	1.79	10.2	2.47	2.05														
40	36.0	1.72	0.96	20.2	1.98	1.48	14.8	2.21	1.81	11.6	2.44	2.09														
45	40.4	1.71	0.96	22.7	1.98	1.49	16.5	2.17	1.86	12.9	2.39	2.16														
50	44.9	1.72	0.96	25.2	1.98	1.49	18.3	2.16	1.87	14.3	2.38	2.18	10.6	2.82	2.47											
55	49.3	1.72	0.96	27.6	1.96	1.51	20.1	2.16	1.88	15.7	2.37	2.19	11.6	2.80	2.51											
60	53.7	1.72	0.97	30.1	1.96	1.51	21.9	2.16	1.89	17.1	2.36	2.20	12.5	2.73	2.61											
65	58.1	1.72	0.97	32.5	1.95	1.52	23.6	2.14	1.92	18.4	2.33	2.25	13.5	2.71	2.63	11.2	3.04	2.83								
70	62.5	1.72	0.97	35.0	1.96	1.52	25.4	2.14	1.92	19.8	2.33	2.25	14.4	2.66	2.71	12.0	3.01	2.87								
75	66.9	1.72	0.97	37.4	1.95	1.53	27.2	2.14	1.92	21.2	2.33	2.26	15.4	2.65	2.73	12.8	2.99	2.91								
80	71.2	1.71	0.97	39.9	1.95	1.53	29.0	2.14	1.92	22.5	2.31	2.29	16.4	2.65	2.74	13.5	2.92	3.01								
90	80.0	1.71	0.97	44.8	1.95	1.53	32.5	2.12	1.94	25.3	2.31	2.29	18.4	2.63	2.76	15.1	2.89	3.07	12.4	3.26	3.30					
100	88.8	1.72	0.98	49.7	1.95	1.54	36.1	2.13	1.94	28.1	2.31	2.29	20.4	2.62	2.78	16.7	2.86	3.11	13.7	3.22	3.36					
110	97.6	1.72	0.98	54.7	1.95	1.53	39.7	2.13	1.94	30.8	2.30	2.31	22.4	2.61	2.79	18.3	2.84	3.15	14.9	3.15	3.48					
120	106.3	1.72	0.98	59.6	1.95	1.54	43.2	2.12	1.95	33.6	2.30	2.31	24.4	2.61	2.81	19.9	2.82	3.18	16.2	3.13	3.52	13.4	3.49	3.81		
130	115.0	1.72	0.98	64.5	1.95	1.54	46.8	2.12	1.95	36.4	2.30	2.31	26.3	2.58	2.85	21.5	2.81	3.20	17.5	3.11	3.55	14.5	3.49	3.82		
140	123.7	1.72	0.98	69.4	1.95	1.54	50.3	2.12	1.96	39.1	2.29	2.33	28.3	2.58	2.85	23.1	2.80	3.22	18.7	3.07	3.63	15.5	3.44	3.91		
150	132.4	1.72	0.98	74.2	1.95	1.55	53.9	2.12	1.95	41.9	2.30	2.32	30.3	2.58	2.86	24.7	2.79	3.24	20.0	3.06	3.65	16.5	3.39	3.98		
160	141.1	1.72	0.98	79.1	1.95	1.55	57.4	2.12	1.96	44.6	2.29	2.33	32.3	2.58	2.86	26.3	2.78	3.26	21.3	3.05	3.67	17.6	3.39	3.98	14.4	3.77	4.37
170	149.7	1.72	0.98	84.0	1.95	1.55	60.9	2.12	1.97	47.4	2.30	2.33	34.3	2.58	2.86	28.0	2.80	3.24	22.6	3.04	3.68	18.6	3.36	4.05	15.3	3.77	4.38
180	158.3	1.72	0.98	88.8	1.95	1.55	64.5	2.12	1.96	50.1	2.29	2.34	36.3	2.58	2.86	29.6	2.79	3.25	23.9	3.04	3.69	19.6	3.33	4.11	16.1	3.73	4.46
190	166.9	1.72	0.98	93.7	1.95	1.55	68.0	2.12	1.97	52.8	2.29	2.34	38.3	2.58	2.86	31.2	2.78	3.26	25.2	3.03	3.70	20.7	3.33	4.10	17.0	3.73	4.45
200	175.5	1.72	0.99	98.5	1.95	1.55	71.5	2.12	1.97	55.6	2.29	2.34	40.2	2.57	2.89	32.8	2.78	3.27	26.5	3.03	3.71	21.7	3.31	4.15	17.8	3.70	4.52
220	192.8	1.72	0.99	108.3	1.95	1.55	78.6	2.12	1.97	61.1	2.29	2.34	44.2	2.57	2.89	36.0	2.77	3.29	29.1	3.02	3.73	23.8	3.29	4.18	19.5	3.67	4.58
240	210.1	1.72	0.99	118.0	1.95	1.56	85.6	2.12	1.98	66.6	2.29	2.35	48.2	2.57	2.89	39.2	2.76	3.31	31.7	3.01	3.75	25.9	3.28	4.22	21.2	3.64	4.63
260	227.3	1.72	0.99	127.7	1.95	1.56	92.7	2.12	1.98	72.1	2.29	2.35	52.2	2.57	2.89	42.5	2.77	3.30	34.3	3.01	3.76	28.0	3.26	4.24	22.9	3.62	4.67
280	244.5	1.72	0.99	137.4	1.95	1.56	99.7	2.12	1.98	77.6	2.29	2.35	56.2	2.57	2.89	45.7	2.76	3.31	36.9	3.00	3.77	30.1	3.25	4.26	24.7	3.63	4.65
300	261.7	1.72	0.99	147.1	1.95	1.56	106.8	2.12	1.98	83.0	2.29	2.36	60.1	2.57	2.90	48.9	2.76	3.32	39.5	3.00	3.78	32.2	3.25	4.28	26.4	3.62	4.68

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	15.7	1.55	0.91	9.9	1.80	1.24																				
20	20.9	1.54	0.92	13.0	1.74	1.31	8.8	2.04	1.65																	
25	26.0	1.53	0.93	16.2	1.73	1.32	10.9	1.99	1.70	8.9	2.21	1.87														
30	31.1	1.52	0.94	19.3	1.70	1.35	12.9	1.94	1.78	10.5	2.14	1.98														
35	36.2	1.52	0.94	22.5	1.70	1.36	15.0	1.93	1.80	12.1	2.08	2.06	9.2	2.37	2.37											
40	41.3	1.52	0.95	25.7	1.70	1.36	17.1	1.92	1.81	13.7	2.04	2.12	10.4	2.32	2.45											
45	46.4	1.52	0.95	28.8	1.69	1.37	19.2	1.91	1.82	15.4	2.04	2.12	11.7	2.32	2.46											
50	51.5	1.52	0.95	32.0	1.70	1.37	21.2	1.89	1.85	17.0	2.02	2.16	12.9	2.28	2.52	9.9	2.61	2.86								
55	56.5	1.51	0.95	35.1	1.69	1.38	23.3	1.89	1.86	18.7	2.02	2.16	14.1	2.25	2.57	10.8	2.57	2.93								
60	61.6	1.52	0.95	38.3	1.69	1.37	25.4	1.89	1.86	20.3	2.00	2.19	15.3	2.23	2.61	11.7	2.54	3.00								
65	66.6	1.52	0.96	41.4	1.69	1.38	27.5	1.89	1.86	22.0	2.01	2.19	16.6	2.24	2.60	12.7	2.55	2.98	10.6	2.88	3.16					
70	71.6	1.51	0.96	44.6	1.70	1.38	29.5	1.88	1.88	23.6	1.99	2.21	17.8	2.22	2.63	13.6	2.52	3.03	11.3	2.82	3.26					
75	76.6	1.51	0.96	47.7	1.69	1.38	31.6	1.88	1.88	25.3	2.00	2.21	19.0	2.21	2.66	14.5	2.50	3.08	12.0	2.77	3.35					
80	81.6	1.52	0.96	50.8	1.69	1.38	33.7	1.88	1.88	26.9	1.99	2.22	20.3	2.22	2.64	15.4	2.48	3.11	12.7	2.73	3.43					
90	91.7	1.52	0.96	57.1	1.69	1.39	37.8	1.88	1.89	30.2	1.98	2.24	22.8	2.21	2.65	17.3	2.47	3.13	14.2	2.69	3.49	11.8	2.99	3.78		
100	101.7	1.52	0.96	63.4	1.69	1.39	42.0	1.88	1.89	33.5	1.98	2.24	25.2	2.19	2.69	19.2	2.47	3.14	15.7	2.67	3.55	13.0	2.94	3.88		
110	111.7	1.52	0.97	69.6	1.69	1.39	46.1	1.87	1.90	36.8	1.98	2.25	27.7	2.19	2.70	21.0	2.44	3.20	17.3	2.68	3.53	14.3	2.94	3.88	12.4	3.23	4.07
120	121.7	1.52	0.97	75.8	1.69	1.39	50.2	1.87	1.90	40.1	1.98	2.26	30.2	2.19	2.70	22.9	2.44	3.20	18.8	2.66	3.57	15.5	2.91	3.96	13.4	3.17	4.19
130	131.6	1.51	0.97	82.1	1.69	1.39	54.4	1.87	1.90	43.4	1.97	2.26	32.7	2.19	2.70	24.8	2.44	3.20	20.3	2.64	3.61	16.7	2.88	4.03	14.4	3.12	4.30
140	141.5	1.51	0.97	88.3	1.69	1.39	58.5	1.87	1.90	46.7	1.97	2.26	35.2	2.19	2.70	26.6	2.42	3.24	21.8	2.63	3.64	17.9	2.85	4.08	15.5	3.12	4.31
150	151.4	1.52	0.97	94.5	1.69	1.40	62.6	1.87	1.91	50.0	1.98	2.26	37.6	2.18	2.72	28.5	2.42	3.23	23.3	2.62	3.66	19.2	2.86	4.07	16.5	3.08	4.39
160	161.3	1.52	0.97	100.7	1.69	1.40	66.7	1.87	1.91	53.3	1.98	2.26	40.1	2.18	2.72	30.4	2.43	3.23	24.8	2.61	3.68	20.4	2.84	4.11	17.6	3.08	4.39
170	171.1	1.52	0.97	106.8	1.69	1.40	70.8	1.87	1.91	56.5	1.97	2.28	42.6	2.19	2.72	32.2	2.41	3.26	26.3	2.60	3.70	21.7	2.85	4.10	18.6	3.05	4.46
180	180.9	1.52	0.98	113.0	1.69	1.40	74.9	1.87	1.91	59.8	1.97	2.27	45.0	2.18	2.73	34.1	2.42	3.25	27.9	2.61	3.68	22.9	2.83	4.14	19.6	3.02	4.52
190	190.6	1.52	0.98	119.1	1.69	1.40	79.0	1.87	1.91	63.1	1.98	2.27	47.5	2.18	2.73	35.9	2.41	3.27	29.4	2.61	3.69	24.1	2.81	4.17	20.7	3.03	4.51
200	200.4	1.52	0.98	125.3	1.69	1.40	83.0	1.87	1.92	66.3	1.97	2.28	49.9	2.18	2.74	37.8	2.41	3.27	30.9	2.60	3.71	25.4	2.82	4.15	21.7	3.00	4.57
220	220.1	1.52	0.98	137.6	1.69	1.41	91.2	1.87	1.92	72.9	1.97	2.28	54.9	2.18	2.74	41.5	2.41	3.28	33.9	2.59	3.73	27.9	2.82	4.17	23.8	2.99	4.61
240	239.8	1.52	0.98	150.0	1.69	1.41	99.4	1.87	1.93	79.5	1.98	2.28	59.8	2.18	2.75	45.3	2.41	3.28	37.0	2.60	3.72	30.4	2.81	4.18	25.9	2.97	4.64
260	259.4	1.52	0.98	162.3	1.69	1.41	107.6	1.87	1.93	86.0	1.97	2.28	64.8	2.18	2.74	49.0	2.41	3.29	40.0	2.59	3.75	32.9	2.81	4.20	28.0	2.96	4.67
280	279.0	1.52	0.98	174.6	1.70	1.41	115.8	1.87	1.93	92.5	1.97	2.29	69.7	2.18	2.75	52.7	2.40	3.30	43.0	2.58	3.76	35.3	2.79	4.24	30.2	2.97	4.65
300	298.5	1.52	0.98	186.9	1.70	1.41	123.9	1.87	1.93	99.1	1.98	2.29	74.6	2.18	2.75	56.4	2.40	3.30	46.1	2.59	3.75	37.8	2.79	4.24	32.3	2.97	4.67

Table C-ECM-09-5 Design Tables for Parabolic Grass-Lined Channels

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.25 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	18.1	1.40	0.88	11.5	1.59	1.21	7.7	1.85	1.55																		
20	24.0	1.38	0.89	15.2	1.56	1.25	10.1	1.79	1.64	7.7	2.03	1.89															
25	30.0	1.38	0.89	19.0	1.56	1.25	12.5	1.75	1.69	9.5	1.97	1.97	7.8	2.19	2.16												
30	35.9	1.38	0.90	22.7	1.55	1.27	14.9	1.73	1.71	11.2	1.90	2.09	9.2	2.11	2.28												
35	41.8	1.38	0.90	26.4	1.54	1.28	17.3	1.71	1.75	13.0	1.88	2.12	10.5	2.02	2.44	8.3	2.36	2.64									
40	47.7	1.38	0.90	30.1	1.54	1.28	19.7	1.70	1.77	14.8	1.87	2.15	12.0	2.02	2.44	9.4	2.32	2.72									
45	53.6	1.38	0.90	33.9	1.54	1.28	22.1	1.69	1.78	16.6	1.86	2.17	13.4	1.99	2.50	10.5	2.28	2.78									
50	59.4	1.38	0.91	37.6	1.54	1.28	24.5	1.69	1.79	18.4	1.85	2.18	14.9	1.99	2.50	11.5	2.22	2.90	9.4	2.49	3.16						
55	65.3	1.38	0.91	41.3	1.54	1.28	26.9	1.69	1.80	20.2	1.84	2.19	16.3	1.97	2.54	12.6	2.20	2.94	10.3	2.47	3.20						
60	71.1	1.38	0.91	44.9	1.53	1.29	29.3	1.68	1.81	22.0	1.84	2.20	17.7	1.96	2.57	13.7	2.19	2.97	11.2	2.45	3.23						
65	76.9	1.38	0.91	48.6	1.54	1.29	31.7	1.68	1.81	23.7	1.82	2.24	19.2	1.97	2.56	14.8	2.18	2.99	12.0	2.40	3.34	9.8	2.76	3.55			
70	82.7	1.38	0.91	52.3	1.54	1.29	34.1	1.68	1.81	25.5	1.82	2.24	20.6	1.95	2.58	15.9	2.17	3.01	12.9	2.39	3.36	10.5	2.74	3.61			
75	88.4	1.38	0.91	55.9	1.53	1.30	36.5	1.68	1.82	27.3	1.82	2.24	22.1	1.96	2.57	17.0	2.16	3.03	13.8	2.39	3.38	11.1	2.67	3.76			
80	94.2	1.38	0.91	59.6	1.54	1.30	38.9	1.68	1.82	29.1	1.82	2.24	23.5	1.95	2.59	18.1	2.16	3.05	14.7	2.38	3.39	11.8	2.65	3.80	10.3	2.92	3.96
90	105.8	1.38	0.91	66.9	1.53	1.30	43.7	1.68	1.82	32.7	1.82	2.25	26.4	1.95	2.60	20.3	2.14	3.07	16.4	2.34	3.48	13.2	2.62	3.87	11.4	2.83	4.14
100	117.3	1.38	0.92	74.3	1.54	1.30	48.5	1.68	1.83	36.3	1.82	2.25	29.3	1.95	2.61	22.5	2.14	3.10	18.2	2.34	3.49	14.6	2.59	3.92	12.6	2.80	4.21
110	128.9	1.38	0.92	81.6	1.54	1.31	53.3	1.68	1.83	39.8	1.81	2.27	32.2	1.95	2.61	24.7	2.13	3.11	20.0	2.34	3.50	16.0	2.58	3.97	13.8	2.77	4.27
120	140.4	1.38	0.92	88.9	1.54	1.31	58.1	1.68	1.83	43.4	1.81	2.27	35.0	1.94	2.64	26.9	2.12	3.13	21.7	2.31	3.56	17.4	2.56	4.00	15.0	2.75	4.32
130	151.8	1.38	0.92	96.1	1.53	1.31	62.9	1.68	1.83	47.0	1.82	2.27	37.9	1.94	2.64	29.1	2.12	3.14	23.5	2.31	3.56	18.8	2.55	4.04	16.2	2.74	4.36
140	163.2	1.38	0.92	103.4	1.54	1.31	67.6	1.68	1.84	50.5	1.81	2.28	40.8	1.94	2.64	31.3	2.12	3.14	25.3	2.31	3.56	20.2	2.54	4.06	17.4	2.72	4.39
150	174.6	1.38	0.92	110.6	1.53	1.31	72.4	1.68	1.83	54.1	1.81	2.28	43.7	1.94	2.64	33.5	2.12	3.15	27.0	2.30	3.60	21.6	2.53	4.08	18.6	2.71	4.42
160	186.0	1.38	0.92	117.8	1.53	1.32	77.1	1.68	1.84	57.6	1.81	2.29	46.5	1.93	2.65	35.7	2.12	3.16	28.8	2.30	3.60	22.9	2.50	4.16	19.8	2.70	4.45
170	197.3	1.39	0.92	125.0	1.54	1.32	81.9	1.68	1.84	61.2	1.81	2.28	49.4	1.94	2.65	37.9	2.12	3.16	30.6	2.30	3.59	24.3	2.50	4.17	21.0	2.69	4.47
180	208.5	1.38	0.93	132.2	1.54	1.32	86.6	1.68	1.84	64.7	1.81	2.29	52.2	1.93	2.66	40.1	2.12	3.16	32.3	2.29	3.62	25.7	2.49	4.18	22.2	2.69	4.49
190	219.8	1.39	0.93	139.3	1.54	1.32	91.3	1.68	1.84	68.2	1.81	2.29	55.1	1.94	2.65	42.3	2.12	3.16	34.1	2.30	3.62	27.1	2.49	4.19	23.4	2.68	4.51
200	231.0	1.39	0.93	146.5	1.54	1.32	96.0	1.68	1.84	71.8	1.82	2.29	57.9	1.93	2.66	44.5	2.12	3.17	35.8	2.29	3.64	28.5	2.49	4.20	24.6	2.68	4.52
220	253.7	1.39	0.93	160.9	1.54	1.32	105.5	1.68	1.84	78.9	1.82	2.29	63.7	1.94	2.66	48.9	2.12	3.17	39.4	2.29	3.63	31.3	2.48	4.22	27.0	2.67	4.55
240	276.3	1.39	0.93	175.3	1.54	1.33	115.0	1.69	1.84	85.9	1.81	2.30	69.4	1.94	2.66	53.3	2.11	3.18	42.9	2.29	3.65	34.1	2.48	4.23	29.4	2.66	4.57
260	298.9	1.39	0.93	189.7	1.54	1.33	124.4	1.68	1.85	93.0	1.81	2.30	75.1	1.93	2.67	57.6	2.11	3.19	46.5	2.29	3.64	36.9	2.48	4.24	31.8	2.65	4.59
280	321.3	1.39	0.93	204.0	1.54	1.33	133.9	1.69	1.85	100.1	1.82	2.30	80.8	1.93	2.67	62.0	2.11	3.19	50.0	2.29	3.65	39.7	2.47	4.25	34.2	2.65	4.61
300	343.7	1.39	0.93	218.2	1.54	1.33	143.3	1.69	1.85	107.1	1.81	2.30	86.5	1.94	2.67	66.4	2.11	3.19	53.5	2.28	3.66	42.5	2.47	4.26	36.6	2.65	4.62

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.50 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	20.1	1.29	0.86	13.2	1.43	1.17	8.9	1.65	1.51																		
20	26.8	1.29	0.86	17.5	1.42	1.19	11.7	1.60	1.58	8.1	1.86	1.95	6.7	2.09	2.10												
25	33.4	1.28	0.86	21.8	1.41	1.21	14.5	1.57	1.63	9.9	1.78	2.10	8.1	1.95	2.34												
30	40.0	1.28	0.87	26.2	1.42	1.20	17.4	1.57	1.63	11.8	1.75	2.15	9.6	1.90	2.43	8.0	2.13	2.60									
35	46.5	1.28	0.87	30.5	1.41	1.21	20.2	1.56	1.65	13.7	1.74	2.18	11.1	1.86	2.50	9.2	2.06	2.72									
40	53.1	1.28	0.87	34.8	1.41	1.21	23.0	1.55	1.67	15.6	1.73	2.20	12.6	1.84	2.56	10.4	2.02	2.82	8.2	2.38	3.03						
45	59.6	1.28	0.88	39.0	1.40	1.22	25.9	1.55	1.66	17.5	1.72	2.22	14.2	1.85	2.55	11.7	2.02	2.82	9.1	2.31	3.16						
50	66.1	1.28	0.88	43.3	1.41	1.22	28.7	1.55	1.67	19.4	1.71	2.24	15.7	1.83	2.58	12.9	1.99	2.89	10.0	2.26	3.27						
55	72.6	1.28	0.88	47.6	1.41	1.22	31.5	1.55	1.68	21.3	1.71	2.25	17.2	1.82	2.61	14.2	1.99	2.89	10.9	2.22	3.36	9.3	2.47	3.54			
60	79.0	1.28	0.88	51.8	1.41	1.22	34.3	1.54	1.69	23.2	1.70	2.25	18.8	1.82	2.60	15.4	1.97	2.94	11.9	2.22	3.36	10.1	2.45	3.59			
65	85.5	1.28	0.88	56.0	1.40	1.23	37.1	1.54	1.69	25.1	1.70	2.26	20.3	1.82	2.62	16.6	1.95	2.98	12.8	2.19	3.43	10.8	2.39	3.73			
70	91.9	1.28	0.88	60.3	1.41	1.22	39.9	1.54	1.69	27.0	1.70	2.26	21.8	1.81	2.64	17.9	1.96	2.96	13.8	2.20	3.42	11.6	2.38	3.76	9.8	2.62	4.03
75	98.2	1.28	0.89	64.5	1.41	1.23	42.7	1.54	1.69	28.9	1.70	2.27	23.3	1.80	2.66	19.1	1.95	3.00	14.7	2.18	3.48	12.4	2.37	3.79	10.5	2.62	4.04
80	104.6	1.28	0.89	68.7	1.41	1.23	45.5	1.54	1.70	30.8	1.70	2.27	24.9	1.81	2.64	20.4	1.95	2.98	15.7	2.18	3.46	13.2	2.36	3.81	11.1	2.58	4.15
90	117.5	1.28	0.89	77.1	1.41	1.23	51.1	1.54	1.70	34.6	1.70	2.28	27.9	1.80	2.67	22.9	1.95	3.00	17.6	2.17	3.50	14.7	2.31	3.93	12.4	2.54	4.24
100	130.3	1.28	0.89	85.6	1.41	1.23	56.7	1.54	1.70	38.3	1.69	2.30	31.0	1.80	2.66	25.4	1.94	3.02	19.5	2.16	3.53	16.3	2.30	3.96	13.7	2.51	4.32
110	143.0	1.28	0.89	94.0	1.41	1.24	62.3	1.54	1.71	42.1	1.69	2.30	34.0	1.79	2.68	27.9	1.94	3.03	21.4	2.15	3.56	17.9	2.30	3.98	15.0	2.49	4.38
120	155.8	1.28	0.89	102.4	1.41	1.24	67.9	1.54	1.71	45.9	1.69	2.30	37.1	1.80	2.68	30.4	1.94	3.03	23.3	2.14	3.57	19.5	2.29	3.99	16.3	2.47	4.43
130	168.4	1.28	0.90	110.7	1.41	1.24	73.4	1.54	1.71	49.7	1.69	2.30	40.1	1.79	2.69	32.9	1.94	3.04	25.2	2.14	3.59	21.1	2.29	4.01	17.6	2.45	4.48
140	181.0	1.28	0.90	119.1	1.41	1.24	79.0	1.54	1.71	53.4	1.69	2.31	43.2	1.80	2.68	35.3	1.93	3.07	27.1	2.14	3.60	22.7	2.29	4.02	18.9	2.44	4.51
150	193.6	1.28	0.90	127.4	1.41	1.24	84.5	1.54	1.72	57.2	1.69	2.31	46.2	1.79	2.70	37.8	1.93	3.07	29.0	2.13	3.61	24.2	2.27	4.07	20.2	2.43	4.54
160	206.2	1.28	0.90	135.7	1.41	1.24	90.0	1.54	1.72	60.9	1.69	2.32	49.3	1.80	2.69	40.3	1.93	3.07	30.9	2.13	3.62	25.8	2.27	4.08	21.6	2.45	4.51
170	218.6	1.28	0.90	144.0	1.41	1.24	95.6	1.54	1.72	64.7	1.69	2.31	52.3	1.80	2.69	42.8	1.93	3.07	32.8	2.13	3.62	27.4	2.27	4.08	22.9	2.44	4.53
180	231.1	1.28	0.90	152.2	1.41	1.25	101.0	1.54	1.72	68.4	1.69	2.32	55.3	1.80	2.70	45.3	1.93	3.07	34.7	2.13	3.63	29.0	2.27	4.08	24.2	2.43	4.56
190	243.5	1.28	0.90	160.4	1.41	1.25	106.5	1.54	1.72	72.1	1.69	2.32	58.3	1.80	2.71	47.7	1.92	3.08	36.5	2.12	3.66	30.6	2.27	4.08	25.5	2.42	4.58
200	255.8	1.28	0.91	168.6	1.41	1.25	112.0	1.54	1.72	75.9	1.69	2.32	61.3	1.79	2.71	50.2	1.93	3.08	38.4	2.12	3.66	32.1	2.26	4.12	26.8	2.42	4.60
220	280.9	1.28	0.91	185.2	1.41	1.25	123.0	1.54	1.73	83.4	1.69	2.32	67.4	1.80	2.71	55.2	1.93	3.08	42.2	2.12	3.67	35.3	2.26	4.12	29.5	2.42	4.58
240	305.8	1.28	0.91	201.7	1.41	1.25	134.1	1.54	1.73	90.9	1.69	2.32	73.5	1.80	2.71	60.1	1.92	3.09	46.0	2.12	3.67	38.5	2.26	4.12	32.1	2.41	4.62
260	330.7	1.28	0.91	218.2	1.41	1.26	145.1	1.54	1.73	98.3	1.69	2.33	79.5	1.80	2.72	65.1	1.93	3.09	49.8	2.12	3.68	41.7	2.26	4.12	34.7	2.41	4.64
280	355.5	1.28	0.91	234.7	1.41	1.26	156.0	1.54	1.73	105.8	1.69	2.33	85.5	1.79	2.72	70.0	1.93	3.10	53.6	2.12	3.68	44.8	2.25	4.14	37.4	2.41	4.63
300	380.2	1.28	0.91	251.1	1.41	1.26	167.0	1.54	1.73	113.2	1.69	2.33	91.6	1.80	2.72	74.9	1.92	3.11	57.4	2.12	3.68	48.0	2.25	4.14	40.0	2.41	4.65

Table C-ECM-09-5 Design Tables for Parabolic Grass-Lined Channels

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B"

Grade 1.75 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	21.8	1.21	0.84	14.2	1.33	1.17	10.0	1.50	1.48	6.9	1.74	1.84															
20	29.0	1.20	0.85	18.9	1.33	1.18	13.2	1.46	1.53	9.0	1.66	1.98	7.6	1.83	2.12												
25	36.2	1.20	0.85	23.5	1.32	1.20	16.4	1.45	1.56	11.2	1.64	2.01	9.3	1.75	2.27	7.6	1.93	2.51									
30	43.4	1.21	0.85	28.2	1.32	1.20	19.6	1.44	1.58	13.3	1.60	2.08	11.1	1.72	2.32	9.0	1.88	2.62									
35	50.5	1.20	0.85	32.8	1.31	1.21	22.8	1.43	1.59	15.5	1.60	2.09	12.8	1.68	2.40	10.4	1.84	2.70	8.2	2.11	2.98						
40	57.6	1.20	0.85	37.4	1.31	1.21	26.0	1.43	1.60	17.6	1.58	2.13	14.6	1.68	2.42	11.8	1.81	2.77	9.3	2.08	3.06						
45	64.6	1.20	0.86	42.0	1.31	1.21	29.2	1.43	1.61	19.8	1.58	2.13	16.4	1.68	2.43	13.2	1.79	2.82	10.3	2.01	3.21	8.6	2.26	3.41			
50	71.6	1.20	0.86	46.6	1.31	1.21	32.4	1.43	1.61	21.9	1.57	2.16	18.2	1.67	2.44	14.7	1.80	2.80	11.4	2.00	3.25	9.5	2.24	3.48			
55	78.6	1.20	0.86	51.2	1.31	1.22	35.6	1.43	1.61	24.1	1.58	2.15	19.9	1.66	2.48	16.1	1.79	2.83	12.5	1.99	3.28	10.3	2.17	3.64	8.6	2.51	3.77
60	85.6	1.20	0.87	55.8	1.31	1.22	38.8	1.43	1.61	26.2	1.57	2.17	21.7	1.66	2.48	17.5	1.78	2.86	13.6	1.98	3.31	11.2	2.16	3.67	9.2	2.41	4.00
65	92.6	1.20	0.87	60.3	1.31	1.22	41.9	1.42	1.62	28.4	1.57	2.16	23.5	1.66	2.48	18.9	1.77	2.88	14.7	1.97	3.33	12.1	2.15	3.70	9.9	2.38	4.08
70	99.5	1.20	0.87	64.9	1.32	1.22	45.1	1.42	1.62	30.5	1.57	2.18	25.2	1.65	2.50	20.3	1.76	2.90	15.8	1.96	3.35	13.0	2.14	3.73	10.6	2.35	4.15
75	106.4	1.20	0.87	69.4	1.31	1.22	48.2	1.42	1.63	32.7	1.57	2.17	27.0	1.65	2.50	21.8	1.78	2.88	16.9	1.96	3.36	13.9	2.13	3.75	11.4	2.37	4.11
80	113.3	1.20	0.87	73.9	1.31	1.22	51.4	1.43	1.62	34.8	1.57	2.18	28.8	1.66	2.50	23.2	1.77	2.90	17.9	1.94	3.43	14.8	2.13	3.77	12.1	2.35	4.17
90	127.2	1.20	0.87	83.0	1.31	1.23	57.7	1.42	1.63	39.1	1.57	2.18	32.3	1.65	2.52	26.0	1.76	2.93	20.1	1.93	3.45	16.6	2.12	3.81	13.5	2.31	4.28
100	141.0	1.20	0.87	92.1	1.32	1.23	64.0	1.42	1.64	43.4	1.57	2.18	35.8	1.64	2.53	28.9	1.76	2.92	22.3	1.93	3.46	18.4	2.11	3.83	14.9	2.28	4.37
110	154.9	1.21	0.87	101.2	1.32	1.23	70.4	1.43	1.63	47.7	1.57	2.19	39.4	1.65	2.52	31.7	1.76	2.94	24.5	1.92	3.47	20.1	2.08	3.91	16.4	2.29	4.36
120	168.6	1.20	0.88	110.2	1.32	1.23	76.6	1.42	1.64	51.9	1.57	2.20	42.9	1.64	2.53	34.6	1.76	2.93	26.7	1.92	3.48	21.9	2.08	3.93	17.8	2.26	4.43
130	182.3	1.21	0.88	119.2	1.32	1.23	82.9	1.42	1.64	56.2	1.57	2.20	46.4	1.64	2.54	37.4	1.76	2.95	28.9	1.92	3.49	23.7	2.07	3.93	19.2	2.25	4.48
140	196.0	1.21	0.88	128.1	1.32	1.23	89.2	1.43	1.64	60.4	1.57	2.21	49.9	1.64	2.55	40.2	1.75	2.96	31.1	1.92	3.49	25.5	2.07	3.94	20.7	2.25	4.47
150	209.6	1.21	0.88	137.1	1.32	1.23	95.4	1.42	1.64	64.7	1.57	2.20	53.4	1.64	2.55	43.1	1.76	2.95	33.3	1.92	3.49	27.3	2.07	3.95	22.1	2.24	4.51
160	223.1	1.21	0.88	146.0	1.32	1.24	101.6	1.42	1.65	68.9	1.57	2.21	56.9	1.64	2.55	45.9	1.76	2.96	35.4	1.91	3.52	29.1	2.07	3.95	23.6	2.25	4.49
170	236.6	1.21	0.88	154.9	1.32	1.24	107.9	1.43	1.64	73.1	1.57	2.21	60.4	1.64	2.55	48.7	1.76	2.96	37.6	1.91	3.52	30.9	2.07	3.95	25.0	2.24	4.53
180	250.0	1.21	0.89	163.7	1.32	1.24	114.0	1.43	1.65	77.4	1.57	2.21	63.9	1.64	2.55	51.5	1.75	2.97	39.8	1.92	3.52	32.6	2.06	3.99	26.4	2.23	4.56
190	263.4	1.21	0.89	172.6	1.32	1.24	120.2	1.43	1.65	81.6	1.57	2.21	67.4	1.64	2.55	54.3	1.75	2.97	42.0	1.92	3.52	34.4	2.06	3.99	27.9	2.23	4.54
200	276.7	1.21	0.89	181.4	1.32	1.24	126.4	1.43	1.65	85.7	1.57	2.22	70.8	1.64	2.56	57.1	1.75	2.98	44.1	1.91	3.54	36.2	2.06	3.99	29.3	2.23	4.57
220	303.8	1.21	0.89	199.2	1.32	1.24	138.8	1.43	1.65	94.2	1.57	2.22	77.8	1.64	2.57	62.8	1.76	2.97	48.5	1.91	3.53	39.8	2.07	3.99	32.2	2.22	4.58
240	330.8	1.21	0.89	217.0	1.32	1.24	151.2	1.43	1.66	102.7	1.57	2.22	84.8	1.64	2.57	68.4	1.75	2.98	52.9	1.92	3.53	43.3	2.06	4.02	35.1	2.22	4.58
260	357.7	1.21	0.89	234.7	1.32	1.25	163.6	1.43	1.66	111.1	1.57	2.22	91.8	1.64	2.57	74.1	1.76	2.98	57.2	1.91	3.54	46.9	2.06	4.01	38.0	2.22	4.59
280	384.5	1.21	0.89	252.3	1.32	1.25	176.0	1.43	1.66	119.5	1.57	2.23	98.7	1.64	2.58	79.7	1.76	2.98	61.6	1.92	3.54	50.5	2.06	4.01	40.9	2.22	4.59
300	411.2	1.21	0.90	269.9	1.32	1.25	188.3	1.43	1.66	127.9	1.57	2.23	105.7	1.64	2.57	85.3	1.76	2.99	65.9	1.91	3.55	54.0	2.06	4.03	43.7	2.21	4.62

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 2.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	24.7	1.14	0.79	15.0	1.25	1.18	11.0	1.40	1.43	7.8	1.56	1.81															
20	32.8	1.14	0.79	20.0	1.25	1.18	14.5	1.37	1.49	10.3	1.53	1.88	7.5	1.71	2.29	6.3	1.91	2.44									
25	41.0	1.14	0.79	24.9	1.24	1.20	18.1	1.37	1.50	12.7	1.48	1.96	9.3	1.68	2.36	7.7	1.82	2.62									
30	49.0	1.14	0.80	29.8	1.24	1.20	21.6	1.35	1.52	15.2	1.48	1.98	11.0	1.63	2.47	9.1	1.77	2.76	7.6	1.97	2.95						
35	57.1	1.14	0.80	34.7	1.24	1.21	25.1	1.35	1.54	17.7	1.47	1.99	12.8	1.62	2.50	10.5	1.73	2.86	8.8	1.94	3.03						
40	65.1	1.14	0.80	39.6	1.24	1.21	28.7	1.35	1.53	20.2	1.47	2.00	14.6	1.62	2.51	12.0	1.73	2.86	9.9	1.88	3.18	8.2	2.13	3.38			
45	73.1	1.14	0.80	44.5	1.24	1.21	32.2	1.35	1.54	22.6	1.46	2.03	16.4	1.61	2.52	13.5	1.73	2.86	11.1	1.87	3.21	9.1	2.08	3.52			
50	81.0	1.14	0.81	49.3	1.24	1.22	35.7	1.35	1.55	25.1	1.46	2.03	18.1	1.59	2.57	14.9	1.71	2.92	12.3	1.86	3.24	10.0	2.03	3.64	8.6	2.29	3.76
55	88.9	1.14	0.81	54.2	1.24	1.21	39.2	1.34	1.55	27.6	1.46	2.03	19.9	1.60	2.57	16.4	1.71	2.91	13.5	1.85	3.26	11.0	2.03	3.65	9.3	2.21	3.96
60	96.8	1.14	0.81	59.0	1.24	1.22	42.7	1.34	1.55	30.0	1.45	2.05	21.7	1.60	2.57	17.8	1.69	2.95	14.7	1.85	3.28	11.9	2.00	3.74	10.1	2.19	4.01
65	104.6	1.14	0.81	63.8	1.24	1.22	46.2	1.35	1.55	32.5	1.46	2.04	23.4	1.58	2.60	19.3	1.70	2.94	15.8	1.82	3.36	12.9	2.00	3.73	10.9	2.18	4.06
70	112.4	1.14	0.81	68.6	1.24	1.22	49.7	1.35	1.56	34.9	1.45	2.05	25.2	1.59	2.60	20.7	1.69	2.98	17.0	1.82	3.36	13.8	1.98	3.81	11.7	2.16	4.10
75	120.2	1.14	0.81	73.4	1.24	1.22	53.1	1.34	1.56	37.3	1.45	2.06	27.0	1.59	2.60	22.2	1.69	2.96	18.2	1.82	3.37	14.8	1.98	3.79	12.5	2.15	4.14
80	127.9	1.14	0.82	78.1	1.24	1.23	56.6	1.35	1.56	39.8	1.45	2.06	28.7	1.58	2.62	23.6	1.69	2.99	19.4	1.82	3.37	15.8	1.99	3.78	13.3	2.14	4.17
90	143.6	1.14	0.82	87.8	1.24	1.23	63.5	1.34	1.57	44.7	1.45	2.06	32.3	1.59	2.61	26.5	1.68	3.00	21.8	1.82	3.38	17.7	1.97	3.83	14.9	2.12	4.22
100	159.2	1.14	0.82	97.4	1.24	1.23	70.5	1.34	1.57	49.6	1.45	2.07	35.8	1.58	2.63	29.4	1.68	3.01	24.1	1.80	3.43	19.6	1.96	3.87	16.5	2.11	4.26
110	174.8	1.14	0.82	106.9	1.24	1.23	77.4	1.34	1.57	54.5	1.45	2.07	39.3	1.58	2.64	32.3	1.68	3.02	26.5	1.80	3.43	21.5	1.95	3.90	18.1	2.10	4.30
120	190.3	1.14	0.82	116.5	1.24	1.23	84.3	1.34	1.58	59.4	1.45	2.07	42.8	1.58	2.65	35.2	1.68	3.02	28.9	1.80	3.43	23.4	1.94	3.92	19.7	2.09	4.33
130	205.7	1.14	0.82	126.0	1.24	1.23	91.2	1.34	1.58	64.2	1.45	2.08	46.4	1.58	2.64	38.1	1.68	3.03	31.3	1.80	3.43	25.4	1.95	3.90	21.3	2.09	4.35
140	221.0	1.14	0.82	135.4	1.24	1.24	98.0	1.34	1.58	69.1	1.45	2.08	49.9	1.58	2.64	41.0	1.68	3.03	33.6	1.80	3.46	27.3	1.95	3.92	22.9	2.08	4.37
150	236.3	1.14	0.83	144.9	1.25	1.24	104.9	1.34	1.58	73.9	1.45	2.08	53.4	1.58	2.65	43.9	1.68	3.03	36.0	1.80	3.45	29.2	1.95	3.93	24.5	2.08	4.38
160	251.5	1.14	0.83	154.3	1.25	1.24	111.7	1.34	1.59	78.7	1.45	2.09	56.9	1.58	2.65	46.7	1.67	3.05	38.3	1.79	3.47	31.1	1.94	3.94	26.1	2.08	4.40
170	266.6	1.14	0.83	163.7	1.25	1.24	118.5	1.34	1.59	83.6	1.45	2.08	60.3	1.58	2.66	49.6	1.68	3.05	40.7	1.80	3.46	33.0	1.94	3.95	27.7	2.07	4.41
180	281.7	1.14	0.83	173.0	1.25	1.24	125.2	1.34	1.59	88.4	1.45	2.09	63.8	1.58	2.66	52.3	1.68	3.04	43.0	1.79	3.48	34.9	1.94	3.96	29.3	2.07	4.41
190	296.7	1.14	0.83	182.3	1.25	1.24	132.0	1.34	1.59	93.2	1.45	2.09	67.3	1.58	2.66	55.3	1.68	3.06	45.4	1.80	3.47	36.8	1.94	3.97	30.8	2.06	4.46
200	311.7	1.14	0.83	191.6	1.25	1.24	138.7	1.34	1.60	97.9	1.45	2.10	70.7	1.58	2.67	58.2	1.68	3.05	47.7	1.79	3.49	38.7	1.94	3.97	32.4	2.06	4.47
220	342.1	1.14	0.83	210.4	1.25	1.25	152.4	1.35	1.60	107.6	1.45	2.10	77.7	1.58	2.67	63.9	1.68	3.06	52.5	1.80	3.47	42.5	1.93	3.99	35.6	2.06	4.48
240	372.4	1.14	0.84	229.2	1.25	1.25	165.9	1.34	1.60	117.2	1.45	2.10	84.7	1.58	2.67	69.7	1.68	3.06	57.2	1.80	3.48	46.4	1.94	3.97	38.8	2.06	4.49
260	402.3	1.14	0.84	247.9	1.25	1.25	179.3	1.34	1.60	126.8	1.45	2.10	91.7	1.58	2.67	75.4	1.68	3.07	61.9	1.80	3.49	50.2	1.94	3.99	42.0	2.06	4.49
280	432.6	1.14	0.84	266.5	1.25	1.25	193.0	1.34	1.61	136.4	1.45	2.10	98.6	1.58	2.68	81.1	1.68	3.07	66.6	1.80	3.49	54.0	1.94	3.99	45.2	2.06	4.49
300	462.3	1.14	0.84	285.1	1.25	1.25	206.5	1.35	1.61	146.0	1.46	2.10	105.5	1.58	2.69	86.8	1.68	3.07	71.2	1.79	3.51	57.8	1.94	4.00	48.4	2.06	4.50

Table C-ECM-09-5 Design Tables for Parabolic Grass-Lined Channels

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 3.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	28.1	0.98	0.80	19.2	1.05	1.13	13.4	1.15	1.44	10.3	1.24	1.74	7.6	1.37	2.12	5.8	1.56	2.44									
20	37.4	0.98	0.80	25.6	1.05	1.10	17.8	1.14	1.46	13.7	1.23	1.76	10.0	1.33	2.22	7.6	1.50	2.59	6.8	1.58	2.74						
25	46.7	0.99	0.80	31.9	1.05	1.11	22.2	1.14	1.47	17.0	1.21	1.80	12.5	1.33	2.23	9.4	1.46	2.69	8.4	1.54	2.85	6.9	1.68	3.18			
30	55.9	0.99	0.81	38.2	1.05	1.11	26.6	1.14	1.47	20.3	1.20	1.82	14.9	1.31	2.27	11.2	1.44	2.75	9.9	1.48	3.02	8.2	1.64	3.28	6.7	1.88	3.50
35	65.0	0.99	0.81	44.4	1.04	1.12	31.0	1.14	1.47	23.7	1.21	1.81	17.3	1.30	2.30	13.0	1.43	2.80	11.5	1.47	3.07	9.5	1.62	3.36	7.7	1.82	3.68
40	74.1	0.99	0.81	50.6	1.04	1.12	35.3	1.14	1.48	27.0	1.20	1.83	19.7	1.29	2.33	14.8	1.42	2.83	13.1	1.46	3.10	10.8	1.60	3.42	8.7	1.78	3.82
45	83.2	0.99	0.81	56.8	1.04	1.13	39.7	1.14	1.48	30.3	1.20	1.84	22.1	1.29	2.34	16.6	1.41	2.85	14.7	1.45	3.12	12.1	1.59	3.46	9.7	1.75	3.92
50	92.2	0.99	0.81	63.0	1.04	1.13	44.0	1.14	1.48	33.6	1.20	1.84	24.6	1.30	2.32	18.4	1.40	2.87	16.3	1.45	3.14	13.4	1.58	3.50	10.7	1.72	4.01
55	101.1	0.99	0.82	69.1	1.04	1.13	48.3	1.14	1.49	36.9	1.20	1.84	27.0	1.30	2.34	20.2	1.40	2.88	17.9	1.45	3.15	14.7	1.57	3.53	11.7	1.70	4.09
60	110.1	0.99	0.82	75.3	1.05	1.13	52.6	1.14	1.49	40.2	1.20	1.85	29.4	1.29	2.34	22.0	1.40	2.89	19.5	1.45	3.16	16.0	1.57	3.55	12.7	1.69	4.15
65	118.9	0.99	0.82	81.4	1.05	1.13	56.9	1.14	1.49	43.4	1.20	1.86	31.8	1.29	2.35	23.8	1.40	2.90	21.1	1.45	3.16	17.3	1.57	3.56	13.8	1.70	4.11
70	127.8	0.99	0.82	87.4	1.04	1.14	61.1	1.14	1.50	46.7	1.20	1.86	34.2	1.29	2.35	25.6	1.40	2.90	22.7	1.45	3.17	18.5	1.55	3.63	14.8	1.69	4.16
75	136.6	0.99	0.82	93.5	1.05	1.14	65.4	1.14	1.50	49.9	1.20	1.87	36.6	1.29	2.35	27.4	1.40	2.91	24.2	1.44	3.21	19.8	1.55	3.64	15.8	1.68	4.20
80	145.3	0.99	0.83	99.5	1.05	1.14	69.6	1.14	1.50	53.1	1.20	1.87	38.9	1.29	2.37	29.2	1.40	2.91	25.8	1.44	3.21	21.1	1.55	3.64	16.9	1.69	4.16
90	163.1	0.99	0.83	111.7	1.05	1.14	78.2	1.14	1.50	59.7	1.20	1.87	43.7	1.29	2.38	32.7	1.39	2.96	29.0	1.44	3.21	23.7	1.54	3.66	18.9	1.67	4.23
100	180.8	0.99	0.83	123.8	1.05	1.15	86.7	1.14	1.51	66.2	1.20	1.88	48.5	1.29	2.38	36.3	1.39	2.95	32.2	1.44	3.21	26.3	1.54	3.67	21.0	1.67	4.23
110	198.3	0.99	0.83	135.9	1.05	1.15	95.2	1.14	1.51	72.7	1.20	1.88	53.3	1.29	2.38	39.9	1.39	2.95	35.4	1.44	3.21	28.9	1.54	3.67	23.1	1.68	4.22
120	215.8	0.99	0.83	148.0	1.05	1.15	103.7	1.14	1.51	79.2	1.20	1.88	58.1	1.29	2.38	43.5	1.39	2.95	38.5	1.43	3.23	31.5	1.54	3.68	25.1	1.67	4.27
130	233.3	0.99	0.83	160.0	1.05	1.15	112.1	1.14	1.51	85.7	1.20	1.88	62.8	1.29	2.39	47.0	1.39	2.96	41.7	1.44	3.23	34.1	1.54	3.68	27.2	1.67	4.26
140	250.6	0.99	0.84	171.9	1.05	1.15	120.5	1.14	1.52	92.1	1.20	1.89	67.6	1.29	2.38	50.6	1.39	2.96	44.8	1.43	3.24	36.7	1.54	3.68	29.3	1.67	4.25
150	267.8	0.99	0.84	183.8	1.05	1.16	128.9	1.14	1.52	98.5	1.20	1.89	72.3	1.29	2.39	54.1	1.39	2.97	48.0	1.44	3.24	39.3	1.55	3.68	31.3	1.67	4.28
160	285.0	0.99	0.84	195.7	1.05	1.16	137.2	1.14	1.52	104.9	1.20	1.89	77.0	1.29	2.39	57.7	1.39	2.96	51.1	1.44	3.25	41.8	1.54	3.70	33.4	1.67	4.27
170	302.0	0.99	0.84	207.5	1.05	1.16	145.5	1.14	1.52	111.3	1.20	1.89	81.7	1.29	2.40	61.2	1.39	2.97	54.3	1.44	3.24	44.4	1.54	3.70	35.4	1.67	4.29
180	319.0	0.99	0.84	219.2	1.05	1.16	153.8	1.14	1.53	117.7	1.20	1.89	86.4	1.29	2.40	64.7	1.39	2.98	57.4	1.44	3.25	47.0	1.55	3.69	37.5	1.67	4.28
190	335.9	0.99	0.85	231.0	1.05	1.16	162.1	1.14	1.53	124.0	1.20	1.90	91.1	1.30	2.40	68.2	1.39	2.98	60.5	1.44	3.25	49.5	1.54	3.71	39.5	1.67	4.30
200	352.7	0.99	0.85	242.6	1.05	1.16	170.3	1.14	1.53	130.3	1.20	1.90	95.7	1.29	2.40	71.7	1.39	2.99	63.6	1.44	3.26	52.1	1.55	3.70	41.6	1.67	4.28
220	387.1	0.99	0.85	266.3	1.05	1.17	187.0	1.14	1.53	143.1	1.20	1.90	105.1	1.29	2.41	78.8	1.39	2.99	69.9	1.44	3.26	57.2	1.54	3.71	45.7	1.67	4.29
240	421.2	0.99	0.85	289.9	1.05	1.17	203.6	1.14	1.53	155.9	1.20	1.90	114.5	1.29	2.41	85.9	1.39	2.99	76.2	1.44	3.26	62.3	1.54	3.72	49.8	1.67	4.30
260	455.2	0.99	0.85	313.4	1.05	1.17	220.2	1.14	1.54	168.6	1.20	1.91	123.9	1.30	2.41	92.9	1.39	2.99	82.4	1.44	3.27	67.5	1.55	3.72	53.9	1.67	4.31
280	489.0	0.99	0.85	336.9	1.05	1.17	236.7	1.14	1.54	181.3	1.20	1.91	133.3	1.30	2.41	99.9	1.39	3.00	88.6	1.44	3.27	72.6	1.55	3.72	58.0	1.67	4.31
300	522.6	0.99	0.86	360.2	1.05	1.17	253.2	1.15	1.54	193.9	1.20	1.91	142.6	1.30	2.42	106.9	1.39	3.00	94.9	1.44	3.27	77.7	1.55	3.73	62.0	1.67	4.33

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 4.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	33.1	0.87	0.77	23.6	0.93	1.01	16.3	1.00	1.36	12.1	1.08	1.69	9.2	1.15	2.08	7.4	1.27	2.34	5.7	1.43	2.69						
20	44.0	0.87	0.77	31.4	0.93	1.01	21.7	1.00	1.37	16.1	1.08	1.70	12.3	1.16	2.08	9.7	1.23	2.48	7.4	1.35	2.94	6.4	1.47	3.12			
25	54.9	0.87	0.77	39.1	0.93	1.02	27.1	1.00	1.37	20.1	1.08	1.71	15.3	1.15	2.11	12.1	1.22	2.50	9.2	1.33	3.01	7.9	1.43	3.26	6.5	1.56	3.62
30	65.7	0.87	0.78	46.8	0.93	1.02	32.4	0.99	1.38	24.0	1.07	1.73	18.3	1.14	2.13	14.4	1.20	2.57	11.0	1.32	3.05	9.3	1.38	3.46	7.7	1.52	3.78
35	76.4	0.87	0.78	54.5	0.93	1.02	37.7	0.99	1.39	27.9	1.07	1.74	21.3	1.14	2.14	16.8	1.20	2.57	12.7	1.30	3.14	10.9	1.39	3.42	8.9	1.49	3.90
40	87.1	0.87	0.78	62.1	0.93	1.03	43.0	0.99	1.39	31.9	1.07	1.74	24.3	1.14	2.15	19.2	1.21	2.56	14.5	1.30	3.15	12.4	1.38	3.47	10.2	1.50	3.87
45	97.7	0.87	0.78	69.7	0.93	1.03	48.3	0.99	1.39	35.8	1.07	1.74	27.2	1.13	2.17	21.5	1.20	2.59	16.3	1.30	3.16	13.9	1.37	3.51	11.4	1.48	3.95
50	108.3	0.87	0.78	77.3	0.93	1.03	53.5	0.99	1.40	39.7	1.07	1.75	30.2	1.13	2.17	23.9	1.20	2.58	18.1	1.30	3.16	15.4	1.36	3.54	12.6	1.46	4.01
55	118.8	0.87	0.78	84.7	0.93	1.04	58.7	0.99	1.40	43.6	1.07	1.75	33.2	1.13	2.17	26.2	1.20	2.60	19.8	1.29	3.21	16.9	1.36	3.56	13.8	1.45	4.06
60	129.2	0.87	0.79	92.2	0.93	1.04	63.9	0.99	1.40	47.4	1.07	1.76	36.1	1.13	2.18	28.5	1.19	2.62	21.6	1.29	3.20	18.4	1.36	3.57	15.1	1.46	4.02
65	139.6	0.87	0.79	99.6	0.93	1.04	69.1	0.99	1.41	51.3	1.07	1.76	39.0	1.13	2.19	30.9	1.20	2.61	23.4	1.29	3.19	19.9	1.35	3.58	16.3	1.46	4.06
70	149.9	0.88	0.79	107.0	0.93	1.04	74.2	0.99	1.41	55.1	1.07	1.77	42.0	1.13	2.19	33.2	1.20	2.62	25.1	1.28	3.23	21.4	1.35	3.59	17.5	1.45	4.09
75	160.2	0.88	0.79	114.3	0.93	1.05	79.3	0.99	1.42	58.9	1.07	1.77	44.9	1.13	2.19	35.5	1.20	2.62	26.9	1.29	3.22	22.9	1.35	3.60	18.7	1.45	4.12
80	170.4	0.88	0.79	121.6	0.93	1.05	84.4	0.99	1.42	62.7	1.07	1.77	47.8	1.13	2.20	37.8	1.20	2.63	28.6	1.28	3.24	24.4	1.35	3.60	20.0	1.46	4.08
90	191.1	0.88	0.80	136.5	0.93	1.05	94.8	0.99	1.42	70.4	1.07	1.78	53.7	1.13	2.20	42.4	1.19	2.65	32.1	1.28	3.26	27.4	1.35	3.62	22.4	1.45	4.13
100	211.8	0.88	0.80	151.2	0.93	1.05	105.1	0.99	1.42	78.1	1.07	1.78	59.6	1.13	2.20	47.1	1.20	2.64	35.7	1.29	3.24	30.4	1.35	3.63	24.9	1.45	4.12
110	232.3	0.88	0.80	165.9	0.93	1.06	115.3	0.99	1.43	85.8	1.07	1.78	65.4	1.13	2.21	51.7	1.19	2.65	39.2	1.29	3.25	33.4	1.35	3.63	27.3	1.44	4.16
120	252.7	0.88	0.80	180.5	0.93	1.06	125.5	0.99	1.43	93.4	1.07	1.78	71.2	1.13	2.22	56.3	1.19	2.66	42.7	1.28	3.26	36.3	1.34	3.66	29.8	1.45	4.14
130	273.0	0.88	0.80	195.1	0.93	1.06	135.6	0.99	1.43	101.0	1.07	1.79	77.0	1.13	2.22	60.9	1.19	2.66	46.2	1.29	3.26	39.3	1.34	3.66	32.2	1.44	4.16
140	293.2	0.88	0.80	209.5	0.93	1.06	145.7	0.99	1.44	108.5	1.07	1.79	82.8	1.13	2.22	65.5	1.20	2.66	49.6	1.28	3.28	42.3	1.35	3.66	34.6	1.44	4.18
150	313.3	0.88	0.81	223.9	0.93	1.07	155.8	0.99	1.44	116.0	1.07	1.80	88.6	1.13	2.22	70.1	1.20	2.66	53.1	1.28	3.28	45.3	1.35	3.66	37.1	1.45	4.17
160	333.3	0.88	0.81	238.2	0.93	1.07	165.8	1.00	1.44	123.5	1.07	1.80	94.3	1.13	2.23	74.6	1.20	2.67	56.6	1.28	3.28	48.2	1.35	3.67	39.5	1.44	4.18
170	353.1	0.88	0.81	252.4	0.93	1.07	175.8	1.00	1.44	131.0	1.07	1.80	100.0	1.13	2.23	79.2	1.20	2.67	60.0	1.28	3.29	51.2	1.35	3.67	41.9	1.44	4.19
180	372.8	0.88	0.81	266.5	0.93	1.07	185.7	1.00	1.45	138.4	1.07	1.80	105.7	1.13	2.24	83.7	1.20	2.68	63.5	1.28	3.29	54.1	1.35	3.68	44.3	1.44	4.20
190	392.4	0.88	0.81	280.6	0.93	1.08	195.6	1.00	1.45	145.8	1.07	1.81	111.4	1.13	2.24	88.2	1.20	2.68	66.9	1.28	3.30	57.0	1.34	3.69	46.7	1.44	4.21
200	411.9	0.88	0.82	294.6	0.93	1.08	205.4	1.00	1.45	153.2	1.07	1.81	117.1	1.14	2.24	92.7	1.20	2.68	70.3	1.28	3.30	60.0	1.35	3.68	49.1	1.44	4.21
220	450.9	0.88	0.82	322.5	0.93	1.08	225.0	1.00	1.46	168.2	1.07	1.81	128.6	1.14	2.24	101.9	1.20	2.68	77.2	1.28	3.31	65.9	1.35	3.69	54.0	1.44	4.21
240	489.5	0.88	0.82	350.2	0.93	1.09	245.3	1.00	1.46	183.2	1.07	1.81	140.0	1.14	2.25	110.9	1.20	2.69	84.1	1.28	3.32	71.8	1.35	3.70	58.8	1.44	4.22
260	528.1	0.88	0.82	377.9	0.93	1.09	265.2	1.00	1.46	198.0	1.07	1.82	151.5	1.14	2.25	120.0	1.20	2.69	91.0	1.28	3.32	77.7	1.35	3.70	63.7	1.44	4.21
280	566.5	0.88	0.82	405.6	0.93	1.09	284.9	1.00	1.47	212.9	1.08	1.82	162.8	1.14	2.25	129.0	1.20	2.70	97.9	1.28	3.32	83.5	1.35	3.71	68.5	1.44	4.22
300	604.8	0.88	0.83	433.2	0.93	1.09	304.6	1.00	1.47	227.6	1.08	1.83	174.2	1.14	2.25	138.1	1.20	2.69	104.8	1.29	3.32	89.4	1.35	3.71	73.3	1.44	4.23

Table C-ECM-09-5 Design Tables for Parabolic Grass-Lined Channels

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 5.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	34.8	0.80	0.79	25.2	0.86	1.02	17.7	0.92	1.36	14.3	0.96	1.61	10.6	1.04	2.00	8.4	1.12	2.34	6.7	1.23	2.67	5.4	1.36	3.00			
20	46.3	0.80	0.79	33.5	0.86	1.02	23.5	0.92	1.37	19.0	0.96	1.62	14.1	1.04	2.02	11.1	1.10	2.41	8.8	1.19	2.81	7.0	1.28	3.29	6.1	1.40	3.44
25	57.7	0.80	0.80	41.7	0.86	1.03	29.3	0.92	1.38	23.7	0.96	1.63	17.5	1.03	2.06	13.8	1.09	2.46	10.9	1.17	2.90	8.7	1.26	3.37	7.5	1.35	3.64
30	69.0	0.80	0.80	49.9	0.86	1.04	35.0	0.91	1.39	28.3	0.95	1.65	21.0	1.03	2.06	16.6	1.10	2.44	13.0	1.15	2.96	10.4	1.25	3.41	8.9	1.32	3.78
35	80.3	0.80	0.80	58.1	0.86	1.04	40.8	0.91	1.39	33.0	0.95	1.65	24.4	1.02	2.08	19.3	1.09	2.46	15.2	1.18	2.94	12.1	1.24	3.45	10.3	1.30	3.87
40	91.5	0.81	0.80	66.2	0.86	1.04	46.5	0.91	1.40	37.6	0.95	1.66	27.8	1.02	2.09	22.0	1.09	2.47	17.3	1.15	2.97	13.8	1.24	3.47	11.8	1.30	3.85
45	102.6	0.81	0.81	74.2	0.86	1.05	52.2	0.91	1.40	42.2	0.95	1.66	31.3	1.03	2.08	24.7	1.09	2.48	19.4	1.15	2.99	15.4	1.22	3.55	13.2	1.29	3.91
50	113.7	0.81	0.81	82.3	0.86	1.05	57.9	0.92	1.40	46.8	0.95	1.66	34.7	1.03	2.08	27.3	1.08	2.51	21.5	1.15	3.01	17.1	1.22	3.55	14.7	1.30	3.88
55	124.7	0.81	0.81	90.2	0.86	1.05	63.5	0.91	1.41	51.4	0.96	1.66	38.0	1.02	2.11	30.0	1.08	2.51	23.7	1.15	2.98	18.8	1.22	3.55	16.1	1.29	3.93
60	135.7	0.81	0.81	98.2	0.86	1.05	69.1	0.91	1.41	56.0	0.96	1.66	41.4	1.02	2.11	32.7	1.08	2.51	25.8	1.15	3.00	20.5	1.22	3.55	17.5	1.28	3.97
65	146.5	0.81	0.81	106.1	0.86	1.05	74.7	0.92	1.41	60.5	0.96	1.67	44.8	1.02	2.10	35.3	1.08	2.53	27.9	1.15	3.00	22.1	1.22	3.59	18.9	1.28	4.00
70	157.3	0.81	0.82	113.9	0.86	1.06	80.2	0.91	1.42	65.0	0.96	1.67	48.1	1.02	2.11	38.0	1.08	2.53	30.0	1.15	3.01	23.8	1.22	3.58	20.4	1.29	3.96
75	168.1	0.81	0.82	121.7	0.86	1.06	85.8	0.92	1.42	69.5	0.96	1.67	51.4	1.02	2.12	40.6	1.08	2.54	32.0	1.15	3.04	25.4	1.21	3.62	21.8	1.28	3.98
80	178.8	0.81	0.82	129.4	0.86	1.06	91.3	0.92	1.42	74.0	0.96	1.67	54.8	1.02	2.12	43.3	1.09	2.53	34.1	1.15	3.04	27.1	1.22	3.61	23.2	1.28	4.00
90	200.5	0.81	0.82	145.2	0.86	1.07	102.4	0.92	1.43	83.0	0.96	1.68	61.5	1.02	2.12	48.6	1.08	2.54	38.3	1.15	3.05	30.4	1.21	3.63	26.1	1.28	4.00
100	222.2	0.81	0.82	160.9	0.86	1.07	113.5	0.92	1.43	92.1	0.96	1.68	68.2	1.02	2.13	53.9	1.08	2.54	42.5	1.15	3.05	33.8	1.22	3.61	28.9	1.28	4.03
110	243.7	0.81	0.82	176.5	0.86	1.07	124.6	0.92	1.43	101.0	0.96	1.69	74.8	1.02	2.14	59.2	1.09	2.55	46.7	1.15	3.05	37.1	1.22	3.63	31.8	1.28	4.02
120	265.0	0.81	0.83	192.0	0.86	1.07	135.6	0.92	1.43	110.0	0.96	1.69	81.4	1.02	2.15	64.4	1.08	2.56	50.8	1.15	3.07	40.4	1.21	3.64	34.6	1.28	4.04
130	286.3	0.81	0.83	207.5	0.86	1.08	146.6	0.92	1.43	118.9	0.96	1.69	88.1	1.02	2.14	69.7	1.09	2.56	55.0	1.15	3.06	43.7	1.21	3.65	37.5	1.28	4.03
140	307.4	0.81	0.83	222.8	0.86	1.08	157.5	0.92	1.44	127.8	0.96	1.69	94.6	1.02	2.15	74.9	1.08	2.57	59.1	1.15	3.07	47.0	1.21	3.65	40.3	1.28	4.04
150	328.4	0.81	0.83	238.1	0.87	1.08	168.3	0.92	1.44	136.6	0.96	1.70	101.2	1.02	2.15	80.1	1.08	2.57	63.2	1.15	3.08	50.2	1.21	3.67	43.1	1.28	4.05
160	349.3	0.81	0.83	253.2	0.86	1.08	179.1	0.92	1.44	145.4	0.96	1.70	107.7	1.02	2.16	85.3	1.09	2.57	67.3	1.15	3.09	53.5	1.21	3.67	45.9	1.28	4.06
170	370.0	0.81	0.84	268.3	0.87	1.09	189.9	0.92	1.45	154.1	0.96	1.70	114.2	1.02	2.16	90.4	1.08	2.58	71.4	1.15	3.09	56.8	1.21	3.67	48.7	1.28	4.07
180	390.7	0.82	0.84	283.3	0.87	1.09	200.6	0.92	1.45	162.9	0.96	1.70	120.7	1.02	2.17	95.6	1.09	2.58	75.5	1.15	3.09	60.0	1.21	3.69	51.5	1.28	4.07
190	411.2	0.82	0.84	298.2	0.87	1.09	211.2	0.92	1.45	171.5	0.96	1.71	127.1	1.02	2.17	100.7	1.08	2.59	79.6	1.15	3.09	63.3	1.21	3.68	54.3	1.28	4.07
200	431.6	0.82	0.84	313.0	0.87	1.09	221.8	0.92	1.46	180.2	0.96	1.71	133.5	1.02	2.18	105.8	1.09	2.59	83.6	1.15	3.10	66.5	1.21	3.69	57.1	1.28	4.08
220	473.3	0.82	0.84	343.4	0.87	1.10	243.4	0.92	1.46	197.8	0.97	1.71	146.6	1.02	2.18	116.2	1.09	2.60	91.9	1.15	3.10	73.1	1.22	3.69	62.7	1.28	4.09
240	514.8	0.82	0.84	373.6	0.87	1.10	264.9	0.92	1.46	215.3	0.97	1.72	159.6	1.02	2.18	126.5	1.09	2.60	100.1	1.15	3.10	79.6	1.21	3.70	68.3	1.28	4.09
260	556.1	0.82	0.85	403.6	0.87	1.10	286.3	0.92	1.46	232.7	0.97	1.72	172.6	1.03	2.19	136.8	1.09	2.61	108.2	1.15	3.11	86.1	1.21	3.71	73.9	1.28	4.10
280	597.1	0.82	0.85	433.5	0.87	1.10	307.6	0.92	1.47	250.1	0.97	1.72	185.5	1.03	2.19	147.1	1.09	2.61	116.4	1.15	3.11	92.6	1.21	3.71	79.5	1.28	4.10
300	638.0	0.82	0.85	463.1	0.87	1.11	328.7	0.92	1.47	267.4	0.97	1.73	198.4	1.03	2.19	157.3	1.09	2.61	124.5	1.15	3.12	99.1	1.22	3.71	85.1	1.28	4.10

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 6.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	40.5	0.72	0.76	26.9	0.81	1.02	19.6	0.85	1.34	14.8	0.90	1.66	11.7	0.96	1.97	9.4	1.02	2.31	7.6	1.09	2.67	6.1	1.18	3.05	5.0	1.32	3.33
20	53.9	0.72	0.76	35.7	0.81	1.03	26.1	0.85	1.34	19.6	0.89	1.69	15.6	0.96	1.97	12.5	1.01	2.33	10.1	1.08	2.71	8.0	1.14	3.23	6.5	1.24	3.63
25	67.1	0.72	0.76	44.5	0.81	1.03	32.5	0.85	1.35	24.5	0.90	1.69	19.4	0.95	2.00	15.3	1.00	2.39	12.5	1.06	2.80	10.0	1.14	3.24	8.1	1.23	3.69
30	80.3	0.72	0.76	53.2	0.80	1.04	38.9	0.85	1.35	29.3	0.89	1.70	23.3	0.96	1.99	18.6	1.00	2.39	15.0	1.06	2.80	11.9	1.12	3.32	9.6	1.20	3.84
35	93.4	0.72	0.76	61.9	0.81	1.04	45.3	0.85	1.35	34.1	0.89	1.70	27.1	0.96	2.00	21.6	0.99	2.42	17.4	1.05	2.84	13.9	1.13	3.31	11.2	1.20	3.84
40	106.4	0.73	0.77	70.6	0.81	1.04	51.6	0.85	1.36	38.9	0.89	1.71	30.9	0.95	2.01	24.7	1.00	2.41	19.9	1.05	2.83	15.8	1.12	3.36	12.7	1.19	3.93
45	119.3	0.73	0.77	79.2	0.81	1.04	57.9	0.85	1.36	43.7	0.90	1.71	34.6	0.95	2.03	27.7	1.00	2.42	22.3	1.05	2.86	17.7	1.11	3.40	14.3	1.19	3.92
50	132.1	0.73	0.77	87.7	0.81	1.05	64.1	0.84	1.37	48.4	0.89	1.71	38.4	0.95	2.03	30.7	0.99	2.43	24.7	1.05	2.87	19.7	1.12	3.38	15.8	1.18	3.98
55	144.9	0.73	0.77	96.2	0.81	1.05	70.4	0.85	1.37	53.1	0.89	1.72	42.2	0.95	2.03	33.7	0.99	2.44	27.1	1.04	2.89	21.6	1.11	3.40	17.4	1.18	3.96
60	157.5	0.73	0.77	104.6	0.81	1.05	76.5	0.84	1.38	57.8	0.89	1.72	45.9	0.95	2.04	36.7	1.00	2.44	29.6	1.05	2.87	23.5	1.11	3.42	18.9	1.18	4.01
65	170.1	0.73	0.78	113.0	0.81	1.06	82.7	0.85	1.38	62.5	0.90	1.72	49.6	0.95	2.04	39.7	1.00	2.44	32.0	1.05	2.88	25.4	1.11	3.43	20.5	1.18	3.98
70	182.6	0.73	0.78	121.3	0.81	1.06	88.8	0.85	1.38	67.2	0.90	1.72	53.3	0.95	2.05	42.7	1.00	2.44	34.4	1.05	2.88	27.4	1.11	3.41	22.0	1.18	4.01
75	195.1	0.73	0.78	129.6	0.81	1.06	94.9	0.85	1.39	71.8	0.90	1.73	57.0	0.95	2.05	45.6	1.00	2.46	36.7	1.04	2.91	29.3	1.11	3.42	23.6	1.18	3.99
80	207.4	0.73	0.78	137.8	0.81	1.06	100.9	0.85	1.39	76.4	0.90	1.73	60.6	0.95	2.06	48.6	1.00	2.45	39.1	1.05	2.91	31.2	1.11	3.42	25.1	1.18	4.02
90	232.6	0.73	0.78	154.5	1.81	1.07	113.2	0.85	1.40	85.8	0.90	1.73	68.1	0.95	2.06	54.6	1.00	2.45	43.9	1.05	2.92	35.0	1.11	3.44	28.2	1.18	4.02
100	257.7	0.73	0.78	171.2	0.81	1.07	125.5	0.85	1.40	95.1	0.90	1.74	75.5	0.95	2.06	60.5	1.00	2.46	48.7	1.05	2.92	38.8	1.11	3.46	31.3	1.18	4.03
110	282.6	0.74	0.78	187.8	0.81	1.07	137.7	0.85	1.40	104.4	0.90	1.74	82.8	0.95	2.07	66.4	1.00	2.47	53.5	1.05	2.92	42.6	1.11	3.47	34.4	1.18	4.03
120	307.3	0.74	0.79	204.2	0.81	1.08	149.8	0.85	1.40	113.6	0.90	1.74	90.2	0.95	2.07	72.3	1.00	2.47	58.3	1.05	2.92	46.4	1.11	3.47	37.4	1.18	4.06
130	331.9	0.74	0.79	220.6	0.81	1.08	161.9	0.85	1.41	122.8	0.90	1.75	97.5	0.95	2.08	78.2	1.00	2.48	63.0	1.05	2.93	50.2	1.11	3.48	40.5	1.18	4.05
140	356.3	0.74	0.79	236.8	0.81	1.08	173.9	0.85	1.41	131.9	0.90	1.75	104.7	0.95	2.09	84.0	1.00	2.48	67.7	1.05	2.94	54.0	1.11	3.48	43.5	1.18	4.07
150	380.5	0.74	0.79	253.0	0.81	1.09	185.8	0.85	1.41	141.0	0.90	1.75	112.0	0.96	2.09	89.9	1.00	2.48	72.5	1.05	2.93	57.8	1.11	3.48	46.6	1.18	4.06
160	404.6	0.74	0.79	269.0	0.81	1.09	197.7	0.85	1.42	150.1	0.90	1.76	119.2	0.96	2.09	95.7	1.00	2.49	77.2	1.05	2.94	61.5	1.11	3.49	49.6	1.18	4.08
170	428.6	0.74	0.79	285.0	0.81	1.09	209.5	0.85	1.42	159.1	0.90	1.76	126.4	0.96	2.09	101.5	1.00	2.49	81.8	1.05	2.95	65.3	1.11	3.49	52.7	1.18	4.07
180	452.4	0.74	0.79	300.8	0.81	1.09	221.3	0.85	1.42	168.1	0.90	1.76	133.5	0.96	2.10	107.2	1.00	2.50	86.5	1.05	2.95	69.0	1.11	3.49	55.7	1.18	4.08
190	476.1	0.74	0.80	316.6	0.81	1.10	233.0	0.85	1.43	177.0	0.90	1.77	140.6	0.96	2.10	113.0	1.00	2.50	91.1	1.05	2.96	72.7	1.11	3.50	58.7	1.18	4.08
200	499.6	0.74	0.80	332.3	0.81	1.10	244.6	0.85	1.43	185.9	0.90	1.77	147.7	0.96	2.11	118.7	1.00	2.50	95.8	1.05	2.96	76.4	1.11	3.51	61.7	1.18	4.09
220	547.7	0.74	0.80	364.5	0.81	1.10	268.4	0.85	1.43	204.1	0.91	1.77	162.1	0.96	2.11	130.3	1.00	2.51	105.2	1.05	2.96	83.9	1.11	3.51	67.8	1.18	4.09
240	595.6	0.74	0.80	396.5	0.81	1.11	292.1	0.85	1.43	222.1	0.91	1.78	176.5	0.96	2.11	141.9	1.00	2.51	114.5	1.05	2.97	91.4	1.11	3.52	73.8	1.18	4.11
260	643.2	0.74	0.80	428.3	0.81	1.11	315.7	0.85	1.43	240.1	0.91	1.78	190.7	0.96	2.12	153.4	1.00	2.52	123.9	1.05	2.97	98.9	1.11	3.52	79.9	1.18	4.10
280	690.5	0.75	0.81	459.9	0.81	1.11	339.1	0.85	1.44	258.0	0.91	1.78	205.0	0.96	2.12	164.9	1.00	2.52	133.2	1.05	2.97	106.3	1.11	3.53	85.9	1.18	4.11
300	737.3	0.75	0.81	491.4	0.81	1.11	362.4	0.85	1.44	275.8	0.91	1.78	219.1	0.96	2.13	176.3	1.00	2.52	142.4	1.05	2.98	113.7	1.11	3.53	91.9	1.18	4.12

Table C-ECM-09-5 Design Tables for Parabolic Grass-Lined Channels

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 8.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	43.1	0.64	0.80	31.6	0.71	0.98	22.2	0.76	1.31	18.0	0.79	1.56	13.7	0.84	1.92	11.0	0.89	2.26	9.2	0.95	2.54	7.4	0.99	3.00	6.2	1.09	3.26
20	57.3	0.64	0.80	42.0	0.71	0.99	29.5	0.76	1.32	24.0	0.79	1.56	18.2	0.84	1.94	14.7	0.89	2.25	12.2	0.93	2.59	9.8	0.98	3.08	8.1	1.04	3.49
25	71.4	0.65	0.80	52.3	0.71	0.99	36.7	0.76	1.33	29.9	0.79	1.57	22.7	0.84	1.95	18.3	0.89	2.28	15.2	0.93	2.62	12.2	0.97	3.12	10.1	1.04	3.53
30	85.4	0.65	0.80	62.6	0.71	0.99	43.9	0.76	1.33	35.8	0.79	1.57	27.2	0.84	1.95	21.9	0.89	2.29	18.1	0.92	2.67	14.6	0.97	3.15	12.1	1.03	3.55
35	99.3	0.65	0.80	72.8	0.72	0.99	51.1	0.76	1.34	41.6	0.79	1.58	31.7	0.84	1.95	25.5	0.89	2.30	21.1	0.92	2.67	17.0	0.96	3.16	14.0	1.02	3.64
40	113.1	0.65	0.81	82.9	0.72	1.00	58.2	0.76	1.34	47.4	0.79	1.59	36.1	0.84	1.96	29.0	0.88	2.32	24.1	0.92	2.67	19.4	0.96	3.17	16.0	1.02	3.63
45	126.8	0.65	0.81	93.0	0.72	1.00	65.3	0.76	1.34	53.2	0.79	1.59	40.5	0.84	1.97	32.6	0.88	2.32	27.0	0.92	2.69	21.8	0.97	3.17	18.0	1.02	3.62
50	140.4	0.65	0.81	102.9	0.72	1.01	72.3	0.76	1.35	59.0	0.79	1.59	44.9	0.84	1.97	36.1	0.88	2.33	30.0	0.92	2.68	24.2	0.97	3.17	19.9	1.02	3.67
55	153.9	0.65	0.81	112.8	0.72	1.01	79.3	0.76	1.35	64.7	0.79	1.60	49.3	0.84	1.97	39.6	0.88	2.34	32.9	0.92	2.70	26.5	0.96	3.20	21.9	1.02	3.65
60	167.3	0.65	0.81	122.7	0.72	1.01	86.2	0.76	1.36	70.4	0.79	1.60	53.7	0.84	1.97	43.1	0.88	2.34	35.8	0.92	2.70	28.9	0.97	3.19	23.8	1.02	3.69
65	180.6	0.65	0.82	132.4	0.72	1.01	93.1	0.76	1.36	76.0	0.79	1.61	58.0	0.84	1.98	46.6	0.88	2.35	38.7	0.92	2.71	31.3	0.97	3.18	25.7	1.01	3.71
70	193.9	0.65	0.82	142.2	0.72	1.01	100.0	0.76	1.37	81.7	0.79	1.61	62.3	0.84	1.98	50.1	0.88	2.35	41.6	0.92	2.71	33.6	0.97	3.20	27.7	1.02	3.69
75	207.0	0.65	0.82	151.8	0.72	1.02	106.8	0.76	1.37	87.2	0.79	1.62	66.6	0.84	1.99	53.5	0.88	2.36	44.5	0.92	2.72	35.9	0.96	3.22	29.6	1.02	3.71
80	220.1	0.66	0.82	161.4	0.72	1.02	113.6	0.76	1.37	92.8	0.79	1.62	70.9	0.84	1.99	56.9	0.88	2.37	47.3	0.92	2.73	38.2	0.96	3.23	31.5	1.01	3.72
90	246.8	0.66	0.82	180.9	0.72	1.02	127.4	0.76	1.38	104.1	0.79	1.62	79.5	0.84	2.00	63.9	0.88	2.37	53.1	0.92	2.74	42.9	0.96	3.23	35.4	1.02	3.72
100	273.3	0.66	0.82	200.3	0.72	1.03	141.1	0.76	1.38	115.4	0.79	1.62	88.1	0.84	2.00	70.8	0.88	2.38	58.9	0.92	2.74	47.6	0.97	3.24	39.2	1.01	3.75
110	299.6	0.66	0.83	219.6	0.72	1.03	154.8	0.76	1.38	126.5	0.79	1.63	96.7	0.84	2.01	77.7	0.88	2.38	64.7	0.92	2.74	52.3	0.97	3.23	43.1	1.02	3.74
120	325.7	0.66	0.83	238.8	0.72	1.03	168.4	0.76	1.39	137.7	0.79	1.63	105.3	0.84	2.01	84.6	0.88	2.39	70.4	0.92	2.75	56.9	0.97	3.25	46.9	1.01	3.75
130	351.7	0.66	0.83	257.9	0.72	1.04	181.9	0.76	1.39	148.7	0.79	1.64	113.8	0.84	2.01	91.4	0.88	2.40	76.1	0.92	2.75	61.6	0.97	3.24	50.7	1.01	3.76
140	377.5	0.66	0.83	276.8	0.72	1.04	195.3	0.76	1.39	159.7	0.79	1.64	122.2	0.84	2.02	98.2	0.88	2.40	81.8	0.92	2.76	66.2	0.97	3.25	54.5	1.01	3.77
150	403.1	0.66	0.83	295.6	0.72	1.04	208.6	0.76	1.40	170.7	0.80	1.64	130.6	0.84	2.02	105.0	0.88	2.40	87.4	0.92	2.77	70.8	0.97	3.25	58.3	1.01	3.78
160	428.5	0.66	0.83	314.2	0.72	1.04	221.9	0.76	1.40	181.5	0.79	1.65	139.0	0.85	2.02	111.7	0.88	2.41	93.1	0.92	2.77	75.3	0.97	3.27	62.1	1.01	3.78
170	453.8	0.66	0.84	332.8	0.72	1.05	235.1	0.76	1.40	192.4	0.80	1.65	147.3	0.85	2.03	118.4	0.88	2.42	98.7	0.92	2.77	79.9	0.97	3.27	65.9	1.02	3.78
180	478.9	0.66	0.84	351.2	0.72	1.05	248.2	0.76	1.41	203.1	0.80	1.65	155.6	0.85	2.03	125.1	0.88	2.42	104.3	0.93	2.78	84.4	0.97	3.28	69.6	1.02	3.79
190	503.9	0.66	0.84	369.5	0.72	1.05	261.2	0.77	1.41	213.8	0.80	1.66	163.9	0.85	2.03	131.8	0.89	2.42	109.8	0.92	2.79	89.0	0.97	3.27	73.4	1.02	3.79
200	528.5	0.67	0.84	387.7	0.73	1.05	274.1	0.77	1.42	224.4	0.80	1.66	172.1	0.85	2.04	138.4	0.89	2.43	115.3	0.92	2.79	93.5	0.97	3.28	77.1	1.02	3.80
220	579.5	0.67	0.84	425.1	0.73	1.06	300.7	0.77	1.42	246.2	0.80	1.66	188.8	0.85	2.04	151.8	0.88	2.44	126.6	0.93	2.80	102.6	0.97	3.29	84.7	1.02	3.80
240	630.1	0.67	0.84	462.2	0.73	1.06	327.0	0.77	1.42	267.9	0.80	1.67	205.5	0.85	2.05	165.2	0.89	2.44	137.8	0.93	2.80	111.8	0.97	3.29	92.2	1.02	3.81
260	680.4	0.67	0.85	499.1	0.73	1.06	353.3	0.77	1.42	289.4	0.80	1.67	222.1	0.85	2.05	178.6	0.89	2.45	149.0	0.93	2.80	120.8	0.97	3.30	99.7	1.02	3.82
280	730.4	0.67	0.85	535.6	0.73	1.07	379.3	0.77	1.43	310.8	0.80	1.68	238.6	0.85	2.05	191.9	0.89	2.45	160.1	0.93	2.81	129.9	0.97	3.30	107.2	1.02	3.82
300	780.0	0.67	0.85	572.1	0.73	1.07	405.2	0.77	1.43	332.1	0.80	1.68	255.0	0.85	2.06	205.1	0.89	2.46	171.2	0.93	2.81	138.9	0.97	3.31	114.7	1.02	3.82

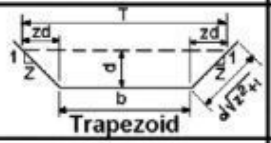
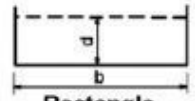
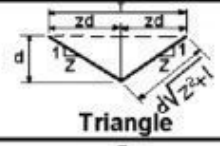
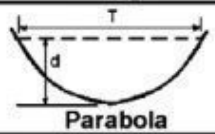
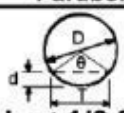
V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 10.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	51.4	0.56	0.77	38.3	0.63	0.92	27.2	0.69	1.18	19.6	0.73	1.56	15.7	0.76	1.86	12.6	0.81	2.18	10.6	0.85	2.45	8.7	0.90	2.83	7.2	0.94	3.28
20	68.2	0.55	0.78	50.9	0.63	0.92	36.2	0.69	1.18	26.1	0.73	1.56	20.9	0.76	1.87	16.8	0.81	2.18	14.0	0.84	2.53	11.5	0.88	2.91	9.5	0.92	3.39
25	85.0	0.56	0.78	63.4	0.63	0.92	45.1	0.69	1.19	32.5	0.73	1.57	26.1	0.76	1.87	20.9	0.80	2.20	17.5	0.84	2.52	14.3	0.87	2.96	11.9	0.92	3.37
30	101.6	0.56	0.78	75.8	0.63	0.92	53.9	0.69	1.20	38.8	0.72	1.58	31.2	0.76	1.88	25.0	0.80	2.22	20.9	0.83	2.55	17.1	0.87	2.98	14.2	0.91	3.42
35	118.1	0.56	0.78	88.1	0.63	0.93	62.7	0.69	1.20	45.2	0.73	1.58	36.3	0.76	1.88	29.1	0.80	2.22	24.3	0.83	2.57	19.9	0.87	3.00	16.5	0.91	3.46
40	134.4	0.56	0.79	100.3	0.64	0.93	71.3	0.69	1.21	51.5	0.73	1.59	41.3	0.76	1.90	33.2	0.80	2.22	27.7	0.83	2.58	22.7	0.87	3.00	18.9	0.91	3.43
45	150.7	0.56	0.79	112.5	0.64	0.93	80.0	0.69	1.21	57.7	0.72	1.60	46.4	0.76	1.90	37.2	0.80	2.24	31.1	0.83	2.58	25.5	0.87	3.01	21.2	0.91	3.45
50	166.8	0.56	0.79	124.5	0.64	0.93	88.5	0.69	1.21	63.9	0.72	1.60	51.3	0.76	1.91	41.3	0.80	2.23	34.5	0.83	2.58	28.3	0.87	3.01	23.5	0.91	3.44
55	182.8	0.56	0.79	136.4	0.64	0.93	97.1	0.69	1.21	70.1	0.73	1.60	56.3	0.76	1.92	45.3	0.80	2.24	37.8	0.83	2.60	31.1	0.87	3.00	25.8	0.91	3.47
60	198.6	0.56	0.79	148.2	0.64	0.94	105.5	0.69	1.22	76.2	0.72	1.61	61.2	0.76	1.92	49.3	0.80	2.25	41.1	0.83	2.61	33.8	0.87	3.02	28.1	0.91	3.47
65	214.3	0.57	0.79	160.0	0.64	0.94	113.9	0.69	1.22	82.3	0.73	1.62	66.2	0.76	1.92	53.2	0.80	2.26	44.4	0.83	2.62	36.5	0.87	3.04	30.3	0.91	3.51
70	229.9	0.57	0.79	171.6	0.64	0.94	122.2	0.69	1.23	88.4	0.73	1.62	71.0	0.76	1.93	57.2	0.80	2.26	47.7	0.83	2.63	39.3	0.87	3.03	32.6	0.91	3.50
75	245.4	0.57	0.80	183.2	0.64	0.94	130.5	0.69	1.23	94.4	0.73	1.62	75.9	0.76	1.94	61.1	0.80	2.27	51.0	0.83	2.63	42.0	0.87	3.04	34.9	0.91	3.50
80	260.7	0.57	0.80	194.6	0.64	0.95	138.6	0.69	1.24	100.3	0.73	1.63	80.7	0.76	1.94	65.0	0.80	2.27	54.3	0.83	2.63	44.7	0.87	3.04	37.1	0.91	3.52
90	292.1	0.57	0.80	218.1	0.64	0.95	155.4	0.69	1.24	112.5	0.73	1.64	90.5	0.76	1.95	73.0	0.81	2.27	60.9	0.83	2.64	50.1	0.87	3.06	41.7	0.91	3.52
100	323.3	0.57	0.80	241.5	0.64	0.95	172.1	0.69	1.24	124.6	0.73	1.64	100.3	0.76	1.95	80.9	0.81	2.28	67.5	0.83	2.65	55.6	0.87	3.06	46.2	0.91	3.53
110	354.3	0.57	0.80	264.6	0.64	0.96	188.6	0.69	1.25	136.7	0.73	1.64	110.0	0.76	1.96	88.7	0.81	2.29	74.1	0.83	2.65	61.0	0.87	3.07	50.7	0.91	3.54
120	385.0	0.57	0.80	287.6	0.64	0.96	205.0	0.69	1.25	148.7	0.73	1.65	119.6	0.76	1.97	96.5	0.81	2.29	80.6	0.83	2.66	66.4	0.87	3.08	55.2	0.91	3.55
130	415.5	0.57	0.81	310.3	0.65	0.96	221.3	0.69	1.26	160.6	0.73	1.65	129.3	0.76	1.97	104.3	0.81	2.30	87.1	0.83	2.67	71.8	0.87	3.08	59.7	0.91	3.55
140	445.7	0.57	0.81	333.0	0.65	0.96	237.5	0.69	1.26	172.5	0.73	1.65	138.8	0.76	1.97	112.1	0.81	2.30	93.5	0.83	2.68	77.1	0.87	3.09	64.2	0.91	3.55
150	475.7	0.58	0.81	355.4	0.65	0.97	253.6	0.69	1.26	184.2	0.73	1.66	148.4	0.76	1.97	119.8	0.81	2.30	100.0	0.83	2.68	82.5	0.88	3.09	68.6	0.91	3.57
160	505.5	0.58	0.81	377.7	0.65	0.97	269.5	0.69	1.27	195.9	0.73	1.66	157.8	0.76	1.98	127.4	0.81	2.31	106.4	0.83	2.69	87.8	0.88	3.10	73.0	0.91	3.58
170	535.0	0.58	0.81	399.7	0.65	0.97	285.3	0.69	1.27	207.6	0.73	1.66	167.2	0.76	1.98	135.0	0.81	2.32	112.8	0.83	2.69	93.0	0.87	3.11	77.5	0.91	3.57
180	564.3	0.58	0.81	421.7	0.65	0.97	301.0	0.70	1.28	219.1	0.73	1.67	176.6	0.76	1.99	142.6	0.81	2.32	119.1	0.83	2.70	98.3	0.88	3.11	81.8	0.91	3.59
190	593.4	0.58	0.82	443.4	0.65	0.98	316.6	0.70	1.28	230.6	0.73	1.67	185.9	0.76	1.99	150.1	0.81	2.33	125.4	0.83	2.71	103.5	0.88	3.12	86.2	0.91	3.59
200	622.2	0.58	0.82	465.0	0.65	0.98	332.1	0.70	1.28	242.1	0.73	1.68	195.2	0.76	1.99	157.6	0.81	2.33	131.7	0.83	2.71	108.7	0.88	3.13	90.6	0.92	3.59
220	681.9	0.58	0.82	509.6	0.65	0.98	364.1	0.70	1.29	265.5	0.73	1.68	214.1	0.76	2.00	173.0	0.81	2.33	144.6	0.83	2.71	119.3	0.88	3.13	99.4	0.91	3.60
240	741.1	0.58	0.82	553.8	0.65	0.99	395.9	0.70	1.29	288.8	0.73	1.68	233.0	0.76	2.00	188.2	0.81	2.34	157.4	0.84	2.72	129.9	0.88	3.13	108.3	0.92	3.60
260	799.9	0.58	0.82	597.7	0.65	0.99	427.4	0.70	1.29	312.0	0.73	1.69	251.7	0.77	2.01	203.4	0.81	2.34	170.1	0.84	2.72	140.4	0.88	3.14	117.0	0.92	3.61
280	858.2	0.58	0.83	641.3	0.65	0.99	458.7	0.70	1.30	335.0	0.73	1.69	270.4	0.77	2.01	218.5	0.81	2.35	182.7	0.84	2.73	150.9	0.88	3.15	125.8	0.92	3.62
300	916.0	0.59	0.83	684.6	0.65	0.99	489.8	0.70	1.30	357.9	0.73	1.69	289.0	0.77	2.01	233.5	0.81	2.35	195.4	0.84	2.73	161.3	0.88	3.15	134.5	0.92	3.62

10.0 Appendix C-ECM-09-b

Table C-ECM-09-6 Geometric Elements of Channel Sections

Section	Area a	Wetted Perimeter P	Hydraulic Radius r	Top Width T
 Trapezoid	$bd + zd^2$	$b + 2d\sqrt{z^2+1}$	$\frac{bd + zd^2}{b + 2d\sqrt{z^2+1}}$	$b + 2zd$
 Rectangle	bd	$b + 2d$	$\frac{bd}{b + 2d}$	b
 Triangle	zd^2	$2d\sqrt{z^2+1}$	$\frac{zd}{2\sqrt{z^2+1}}$	$2zd$
 Parabola	$\frac{2}{3}dT$	$T + \frac{8d^2}{3T}$ [1]	$\frac{2dT^2}{3T^2+8d^2}$ [1]	$\frac{3a}{2d}$
 Circle < 1/2 full [2]	$\frac{D^2}{8}\left(\frac{\pi\theta}{180} - \sin\theta\right)$	$\frac{\pi D\theta}{360}$	$\frac{45D}{\pi\theta}\left(\frac{\pi\theta}{180} - \sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$
 Circle > 1/2 full [3]	$\frac{D^2}{8}\left(2\pi - \frac{\pi\theta}{180} + \sin\theta\right)$	$\frac{\pi D(360-\theta)}{360}$	$\frac{45D}{\pi(360-\theta)}\left(2\pi - \frac{\pi\theta}{180} + \sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$

[1] Satisfactory approximation for the interval $0 < d/T \le 0.25$
When $d/T > 0.25$, use $p = 1/2\sqrt{16d^2 + T^2} + \frac{T^2}{8d}\sin h^{-1}\frac{4d}{T}$

[2] $\theta = 4\sin^{-1}\sqrt{d/D}$

[3] $\theta = 4\cos^{-1}\sqrt{d/D}$

} Insert θ in degrees in above equations

National Engineering Handbook, Section 5, ES-33

Source: PADEP 2012

C-ECM-10 Subsurface Drain

1.0 Definition

A subsurface drain is a perforated conduit (such as pipe, tubing, or tile) installed below grade to intercept, collect, and convey excess groundwater to a satisfactory outlet location (North Carolina Sediment Control Division et al. 2013).

– CAD and PDF Files for C-ECM-10-1 Subsurface Drain

2.0 Purpose and Applicability of Best Management Practice

Subsurface drains are used to:

1. Improve the soil-water conditions for vegetative growth by lowering the water table (New Jersey Department of Agriculture 2017).

2. Prevent sloping soils from becoming excessively wet and subject to sloughing.
3. Improve the quality of the growth medium in excessively wet areas by lowering the water table.
4. Drain stormwater detention areas or structures. Install cleanouts where subsurface drains are used to drain stormwater detention areas or structures.

Use of subsurface drains applies wherever excess water needs to be removed from the soil to improve soil-water conditions. Ensure the soil is sufficiently deep and permeable to allow installation of an effective system. Provide an outlet for the drainage system either consisting of a gravity outlet or by pumping. These standards do not apply to building foundation drains, storm drainage systems, or deep excavations (North Carolina Sediment Control Division et al. 2013).

Design the outlet of the subsurface drain to safely handle the quantity and quality of effluent to be released considering possible impacts above or below the point of discharge (New Jersey Department of Agriculture 2017).

3.0 Planning and Considerations

Subsurface drainage systems are broken down into two types (relief drains and interceptor drains) as described in Table C-ECM-10-1.

Table C-ECM-10-1 Design Considerations for Subsurface Drains

Type	Notes on Proper Use
Relief Drains	Relief drains are used either to lower the water table to improve the growth of vegetation or to remove surface water in areas that are relatively flat and large. Relief drains are installed along a slope and drain in the direction of the slope. Relief drains can be installed in a gridiron pattern, a herringbone pattern, or a random pattern (see Plate 1). The system can be designed for either a single or dual purpose by providing a subirrigation/drainage system in addition to altering the elevation of the water table (North Carolina Sediment Control Division et al. 2013).
Interceptor Drains	Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. Interceptor drains are installed across a slope (perpendicular) and drain to the side of the slope. Interceptor drains usually consist of a single pipe or series of single pipes instead of a patterned layout (see Plate 2). Interceptor drains can also be used to stabilize shallow foundations such as paved channels of construction access roads (North Carolina Sediment Control Division et al. 2013).

4.0 Stormwater Performance Summary

MS-9: WATER SEEPS – Whenever water seeps from a slope face, adequate drainage or other protection shall be provided.

MS-16: UTILITY CONSTRUCTION – Underground utility lines shall be installed in accordance with the following standards in addition to other applicable criteria.

9VAC25-875-560.

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: LOW

5.0 Design Criteria

Table C-ECM-10-2 Design Criteria for Subsurface Drains

Parameter	Notes on Proper Use
Location	Tree roots can often clog subsurface drain systems. Consequently, locate subsurface drains such that there are no trees within 50 feet of the drain.
Capacity of Drains	The capacity of the underground drainage system is determined by calculating the maximum rate of groundwater or overland flow to be intercepted.
Relief Drains	Locate relief drains through the centers of wet areas. Install relief drains in the same direction as the slope and evenly throughout the wet area. Install relief drains in a uniform pattern such that the drains remove a minimum of 1 inch of groundwater in 24 hours (0.042 cubic foot per second [cfs]/acre). Increase the design capacity accordingly to accommodate any surface water that enters the system directly (see Plate 3).
Interceptor Drains	Locate interceptor drains on the uphill sides of wet, unstable areas. Install interceptor drains on a positive grade across the slope and drain to the side of the slope. Design interceptor drains or relief drains installed in a random pattern to remove a minimum of 1.5 cfs/1,000 feet of length. Increase the inflow rate for sloping land according to the values in Table C-ECM-10-3. In addition, if a flowing spring or surface water enters directly into the system, accommodate this flow by increasing the design capacity to address this flow (see Plate 3).
Velocity and Grade	To prevent silting, design the drains with a minimum velocity of 1.4 feet per second. Grade the line to achieve at least this velocity. Avoid steep grades. Table C-ECM-10-4 lists maximum velocities for various soil textures.
Envelopes	Use envelopes around all drains for proper bedding and improved flow of groundwater into the drain. Construct the envelope consisting of 3 inches of clean, washed Virginia Department of Transportation (VDOT) #68 aggregate placed completely around the drain. Encompass the stone with a filter fabric separator to prevent the migration of surrounding soil particles into the drain (see Plate 4). Use filter fabric that meets the physical requirements noted in Riprap (BMP C-ECM-13).
Drain Size	Size subsurface drains for the required capacity using the formulas provided in Appendix A. Use a minimum diameter of 4 inches for a subsurface drain.

Table C-ECM-10-2 Design Criteria for Subsurface Drains	
Parameter	**Notes on Proper Use**
Depth & Spacing	**Relief Drains** – Equally space relief drains installed in a uniform pattern between drains and install the drains at the same depth. Maximum depth is limited by the allowable load on the pipe, depth to impermeable layers in the soil, and outlet requirements. The minimum depth is 24 inches under normal conditions. Where the drain will not be subject to equipment loading or frost action, 12 inches is acceptable. Spacing between drains depends on soil permeability and the depth of the drain. In general, a depth of 3 feet and a spacing of 50 feet is adequate. A more economical system may be designed, if the necessary information is available, using the equations provided in Appendix A with the figure showing the details in Plate 4. **Interceptor Drain** – The depth of installation of an interceptor drain is influenced mainly by the depth to which the water table is proposed to be lowered. The maximum depth is limited by the allowable load on the pipe and the depth to an impermeable layer. Minimum depth should be the same as those for relief drains. One interceptor drain is usually sufficient. However, if multiple drains are to be used, determining the required spacing can be difficult. The best approach is to install the first drain. Subsequently, if seepage or high-water table problems occur downslope, install an additional drain at a suitable distance downslope. This distance can be calculated using equations provided in Appendix A with the figure showing the details in Plate 4.
Surface Water	Plate 3 shows two types of surface water inlets. Do not use the grated inlet where excessive sedimentation might be a problem.
Outlet	Design the outlet of the subsurface drain to discharge into a channel or some other watercourse, which will remove the water from the outlet. Locate the outlet above the mean water level in the receiving channel. Protect the outlet from erosion, undermining, damage from periods of submergence, and the entry of small animals into the drain. Construct the outlet to consist of a 10-foot section of corrugated metal, cast iron, steel, high-density polyethylene (HDPE), or schedule 40 polyvinyl chloride (PVC) pipe without perforations. Do not use envelope material around the pipe. Bury at least two thirds of the outlet pipe length.
Materials	Acceptable materials for subsurface drains include perforated, continuous closed-joint conduits of HDPE, concrete, corrugated metal, asbestos cement, bituminous fiber, and PVC. Ensure the strength and durability of the pipe meet the requirements of the site in accordance with the manufacturer's specifications.

Source: Va. DSWC

Table C-ECM-10-3 Water Removal Rates for Sloping Land*	
Land Slope (%)	**Water Removal Rates (cfs/1,000 feet)**
2 – 5	1.65
6 – 12	1.80
> 12	1.95

* These rates depend on the soil types where the drains are installed. Heavier soils may result in slower water removal rates.

Source: Va. DSWC

Table C-ECM-10-4 Maximum Velocities for Various Soil Textures	
Soil Texture	**Maximum Velocity (ft./sec.)**
Sandy and Sandy Loam	3.5
Silt and Silt Loam	5.0
Silty Clay Loam	6.0
Clay and Clay Loam	7.0
Coarse Sand or Gravel	9.0

Source: Va. DSWC

6.0 Construction Specifications

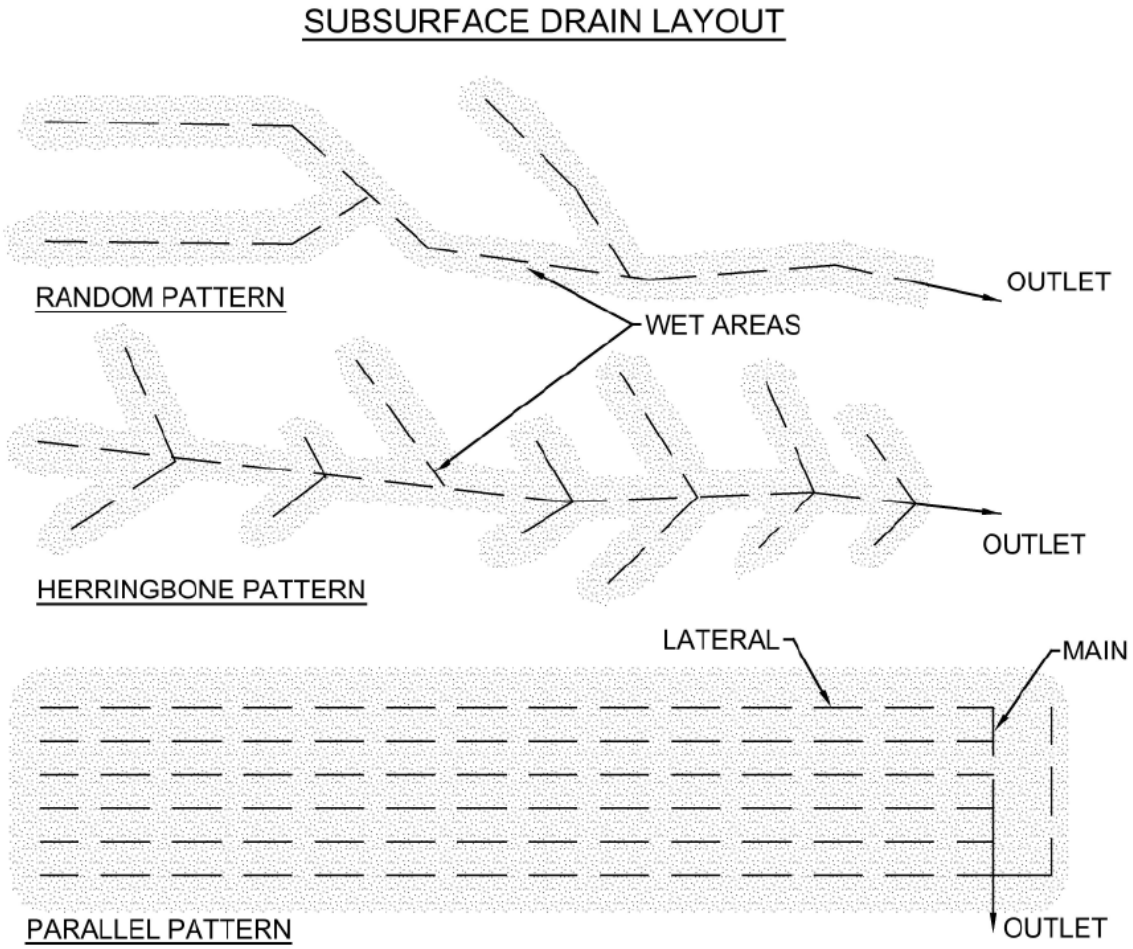
1. Construct the trench on a continuous grade with no reverse grades or low spots and to be 3 inches below the invert of the pipe.
2. Stabilize soft or yielding soils under the drain with gravel or other suitable material.
3. Do not use deformed, warped, or otherwise unsuitable pipe.
4. Place envelopes or filter material as specified with at least 3 inches of material on all sides of the pipe and place filter fabric around the envelope before backfilling.
5. Conduct backfilling immediately after placement of the pipe. No sections of pipe should remain uncovered overnight or during a rainstorm. Backfill the trench so that the pipe is not displaced or damaged.
6. Ensure the outlet section of the drain consists of at least 10 feet of non-perforated corrugated metal, cast iron, steel, smooth-walled HDPE, self-reinforced polypropylene (SRPP), or schedule 40 PVC pipe. Bury at least two thirds of its length.
7. Place a suitable trash/animal guard securely measure over the pipe outlet to keep out smaller animals such as rodents (North Carolina Sediment Control Division et al. 2013).
8. Do not exceed 500 feet for the interval/spacing between riser pipes used for flushing.

7.0 Operations and Maintenance Considerations

1. Periodically check subsurface drains to ensure that they are free-flowing and not clogged with sediment and that animals are not living in the pipes (North Carolina Sediment Control Division et al. 2013).
2. Keep the outlet clean and free of debris; clear away debris from trash/animal guard immediately as necessary.

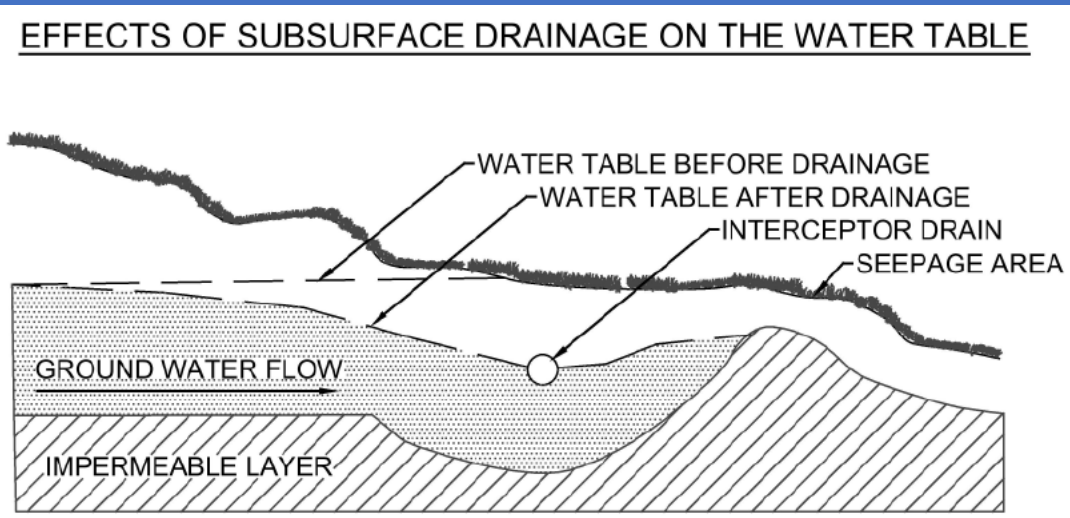
3. Keep surface inlets open and free of sediment and other debris and clear away sediment and other debris immediately as necessary.
4. Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain.
5. Where drains are crossed by heavy vehicles, check the line to ensure that it is not crushed.
6. Inspect the subsurface drains and maintain the system with periodic high-pressure flushing via the cleanouts.

Figure C-ECM-10-1 Subsurface Drain Layout



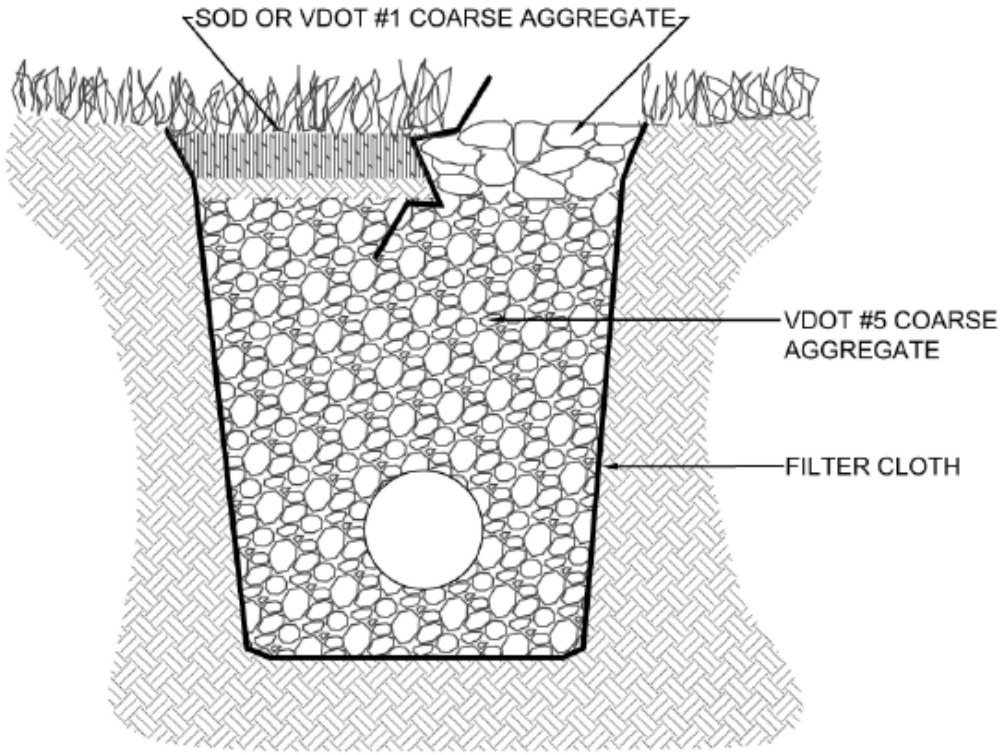
Source: USDA-SCS

Figure C-ECM-10-2 Effects of Subsurface Drainage on the Water Line

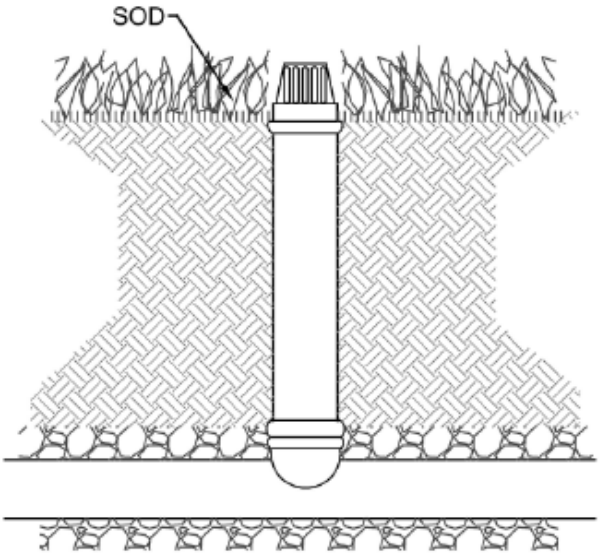


Source: USDA-SCS

Figure C-ECM-10-3 Surface Inlets



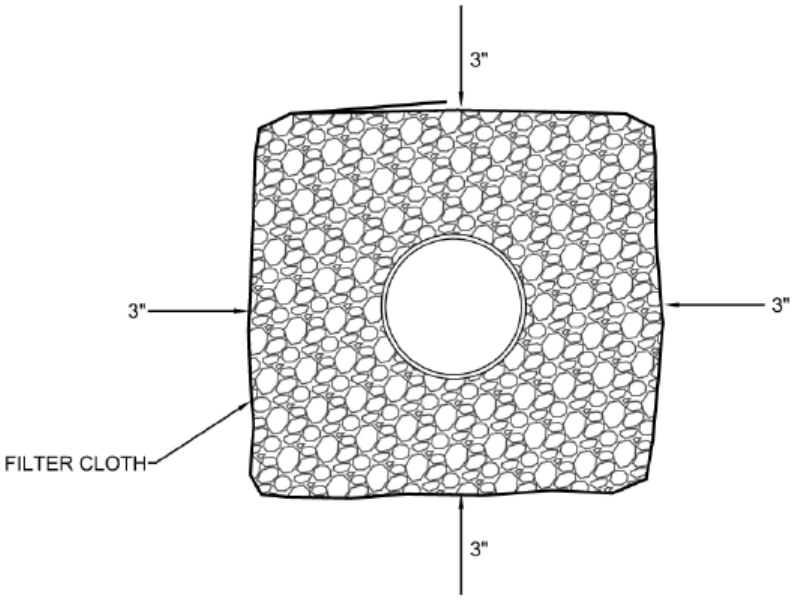
NATURAL INLET



GRATED INLET

Source: USDA-SCS

Figure C-ECM-10-4 Effects of Subsurface Drainage on the Water Line



Source: USDA-SCS

8.0 References

New Jersey Department of Agriculture. 2-17. The Standards for Soil Erosion and Sediment Control in New Jersey. July.

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

USDA NRCS. National Engineering Handbook. Chapter 14 water management (drainage). 2021.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

9.0 Appendix A

Subsurface drains are not generally designed to flow under pressure, and the hydraulic gradient is parallel with the grade line. Consequently, the flow is considered to be open channel, and Manning's Equation can be used to determine the flowrate of the drain. Determine the drain size using the following procedure.

1. Determine the flow the drain is to carry.
2. Determine the gradient of the drain.
3. From Table C-ECM-10-5, determine "n" for the type of drainpipe to be used. Choose the correct Figure (Figure-C-ECM-09-5 through Figure-C-ECM-09-7) for the "n" just determined.

4. Enter the appropriate plate with the gradient and the flow of the pipe. The intersection of the two lines must be to the right of the line for 1.4 feet per second. If it is not, increase the gradient, flow capacity, or both.

Example 1

Given:

A random subsurface drain is to be installed on a 1% grade, 700 feet long, using corrugated plastic pipe.

Calculate:

The required size of the drainpipe.

Solution:

From the Section 5.0 Design Criteria, the required capacity of the pipe is:

$$\text{Capacity} = \frac{700 \text{ feet}}{1{,}000 \text{ feet}} \text{ x } \underset{1{,}000 \text{ feet}}{1.5 \text{ cfs}} = 1.05 \text{ cfs}$$

* From Table C-ECM-10-5, n = 0.015 for corrugated plastic pipe.

* From Figure C-ECM-10-6, choose an 8-inch pipe.

Example 2

Given:

A relief drain installed in a gridiron pattern of eight laterals, 500 feet long, 0.5% grade, and 50 feet on centers. A main 400 feet in length on a 0.5% grade will connect to the laterals. Use bituminized fiber pipe for the main and laterals.

Calculate:

The required size of the drain pipe.

Solution:

The drainage area for each lateral is 25 feet on either side of the pipe times the length.

Therefore:

$$\frac{50 \text{ ft x } 500 \text{ ft}}{43{,}560 \frac{\text{sf}}{\text{acre}}} = 0.57 \text{ acres}$$

From the Section 5.0 Design Criteria, design the drains to remove 1 inch of water in 24 hours or 0.042 cfs/acre.

$$0.42 \frac{\text{cfs}}{\text{acre}} \text{ x } 0.57 \text{ acre} = 0.02 \text{ cfs}$$

From Table C-ECM-10-5, n = 0.013 for bituminized fiber pipe.

From Figure C-ECM-10-5, a 4-inch pipe must be used for the laterals.

The first 25 feet of the main will drain 25 feet on either side of the pipe. The remaining 375 feet will drain only 25 feet on the side opposite from the laterals. In addition, the main will drain the laterals.

Drainage from Main:

$$\frac{25 \text{ ft x } 50 \text{ ft}}{43{,}560 \frac{\text{sf}}{\text{acre}}} + \frac{375 \text{ ft x } 25 \text{ ft}}{43{,}560 \frac{\text{sf}}{\text{acre}}} = 0.24 \text{ acre}$$

Drainage from Laterals:

8 x 0.57 acre = 4.56 acre

Total = 0.24 + 4.56 = 4.8 acre

Required Capacity:

0.042 cfs/acre x 4.8 acre = 0.20 cfs

From Figure C-ECM-10-5, choose a 5-inch pipe for the main.

Spacing of Relief Drains

If the necessary information is known, the following equation can be used to calculate drain spacing in lieu of the recommended standard:

$$S = \sqrt{\frac{4k\,(M^2 + 2\,AM)}{q}}$$

Where,

S = drain spacing (feet)

K = average hydraulic conductivity (in./hr.) (for practical purposes, hydraulic conductivity is equal to permeability).

M = vertical distance, after drawdown, of water table above drain at midpoint between lines (feet)

A = depth of barrier below the drain (feet)

q = drainage coefficient, rate of water removal (in./hr.)

Also, see Figure C-ECM-10-8.

This equation applies to most areas in Virginia. Limitations of the equation are listed in the Soil Conservation Service (SCS) National Engineering Handbook, Section 16, Drainage of Agricultural Land (66).

Spacing of Interceptor Drains

If one interceptor drain is not sufficient, the spacing of multiple drains can be calculated using the following equation:

$$Le = \frac{k\,i}{q}\,(de - dw + W_2)$$

Where:

Le = the distance downslope from the drain to the point where the water table is at the desired depth after drainage (feet). Locate the second drain at this point.

k = the average hydraulic conductivity of the subsurface profile to the depth of the drain (in./hr.)

q = drainage coefficient, rate of water removal (in/hr.)

i = the hydraulic gradient of the water table before drainage (feet/foot)

de = the effective depth of the drain (feet)

dw = the desired minimum depth to water table after drainage (feet)

W_2 = the distance from the ground surface to the water table, before drainage, at the distance (Le) downslope from the drain (feet)

Also, see Figure-C-ECM-09-9.

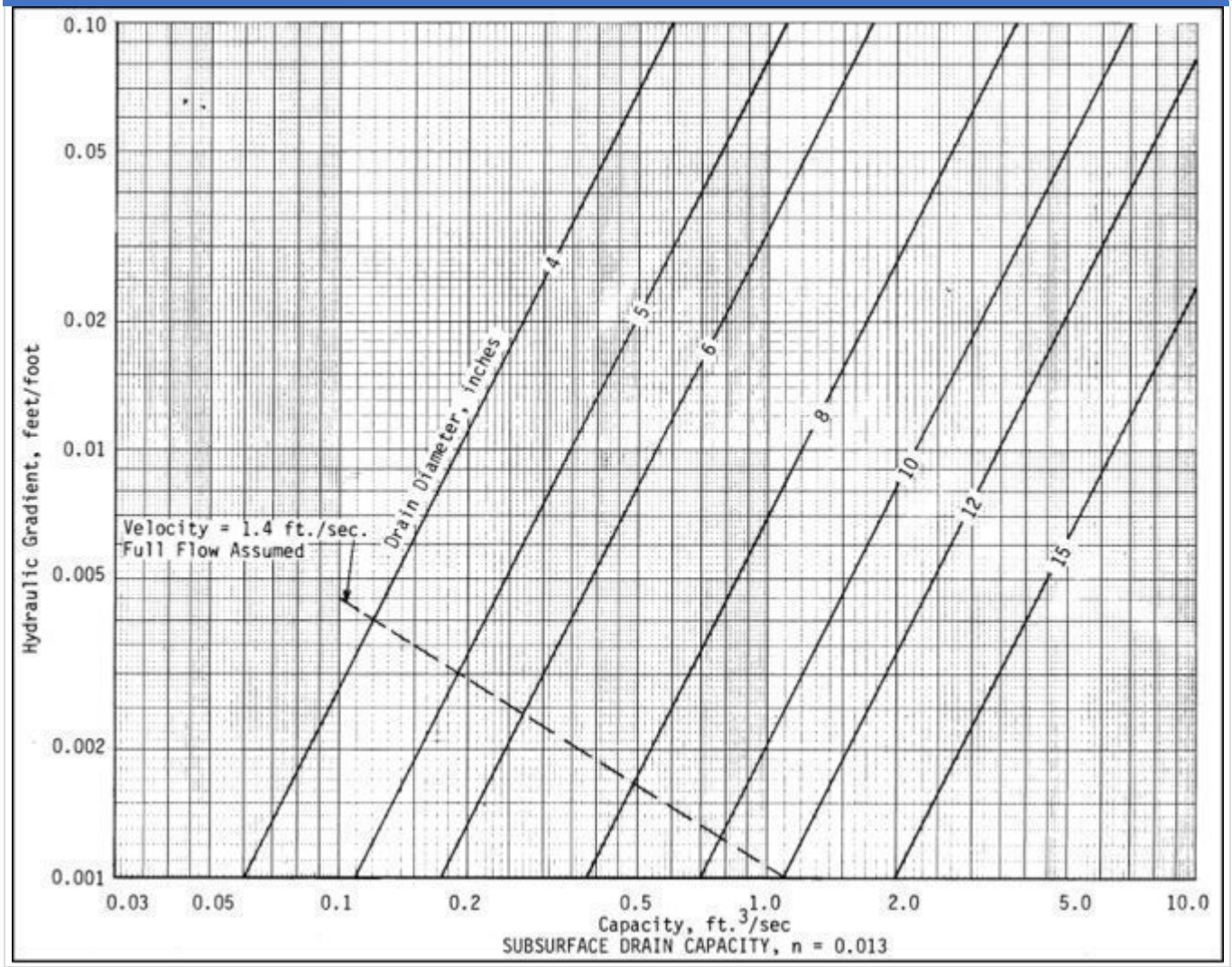
Further information on the equation can be obtained from the SCS National Engineering Handbook, Section 16, Drainage of Agricultural Land (66).

Table C-ECM-10-5 "n" Values for Subsurface Drain Pipes

Composition of Pipe or Tubing	"n" Value
Asbestos Cement	0.013
Bituminized Fiber	0.013
Concrete	0.015
Corrugated Plastic	0.015
Corrugated Metal	0.025

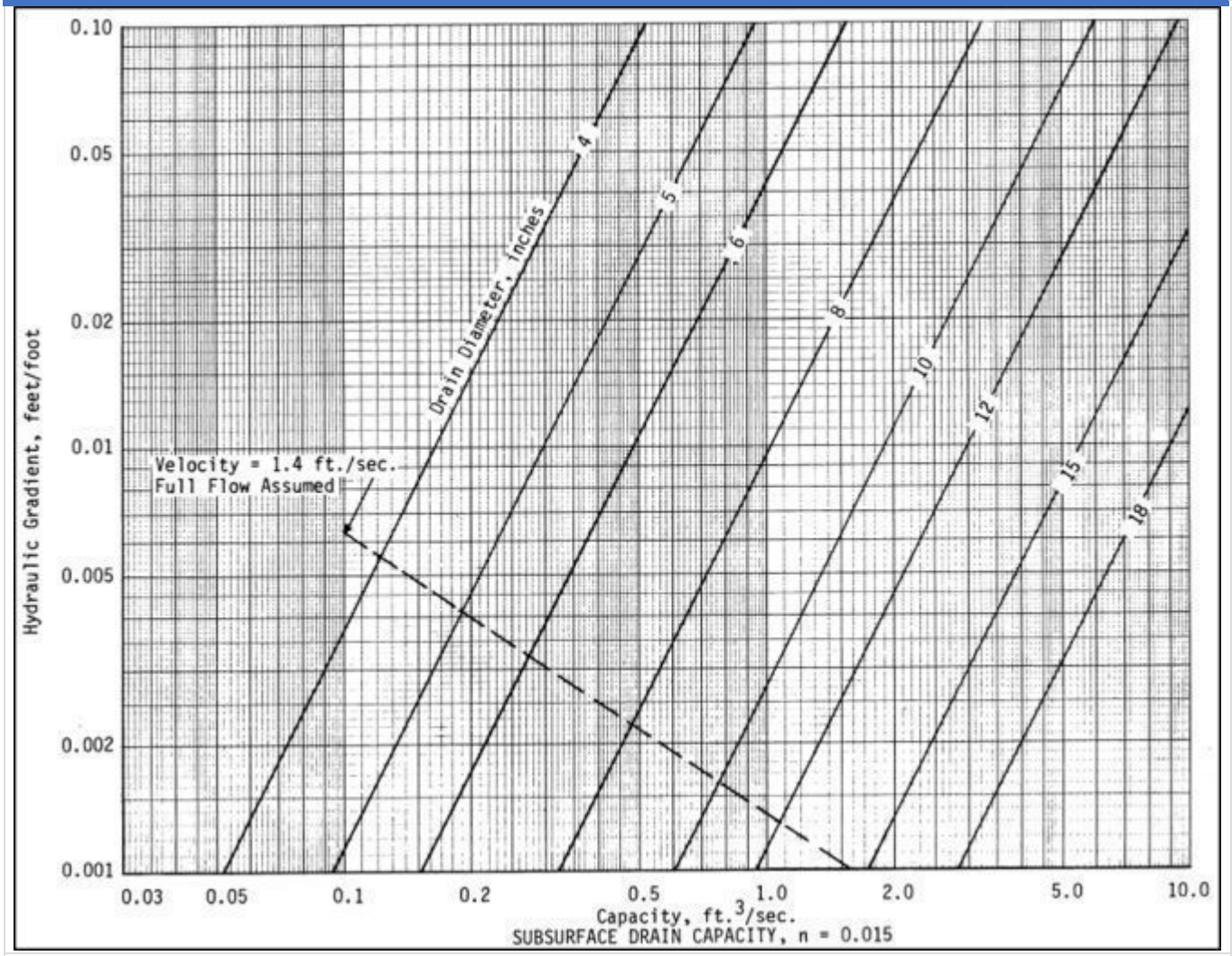
Source: Va. DSWC

Figure C-ECM-10-5 Surface Drain Capacity (n=0.013)



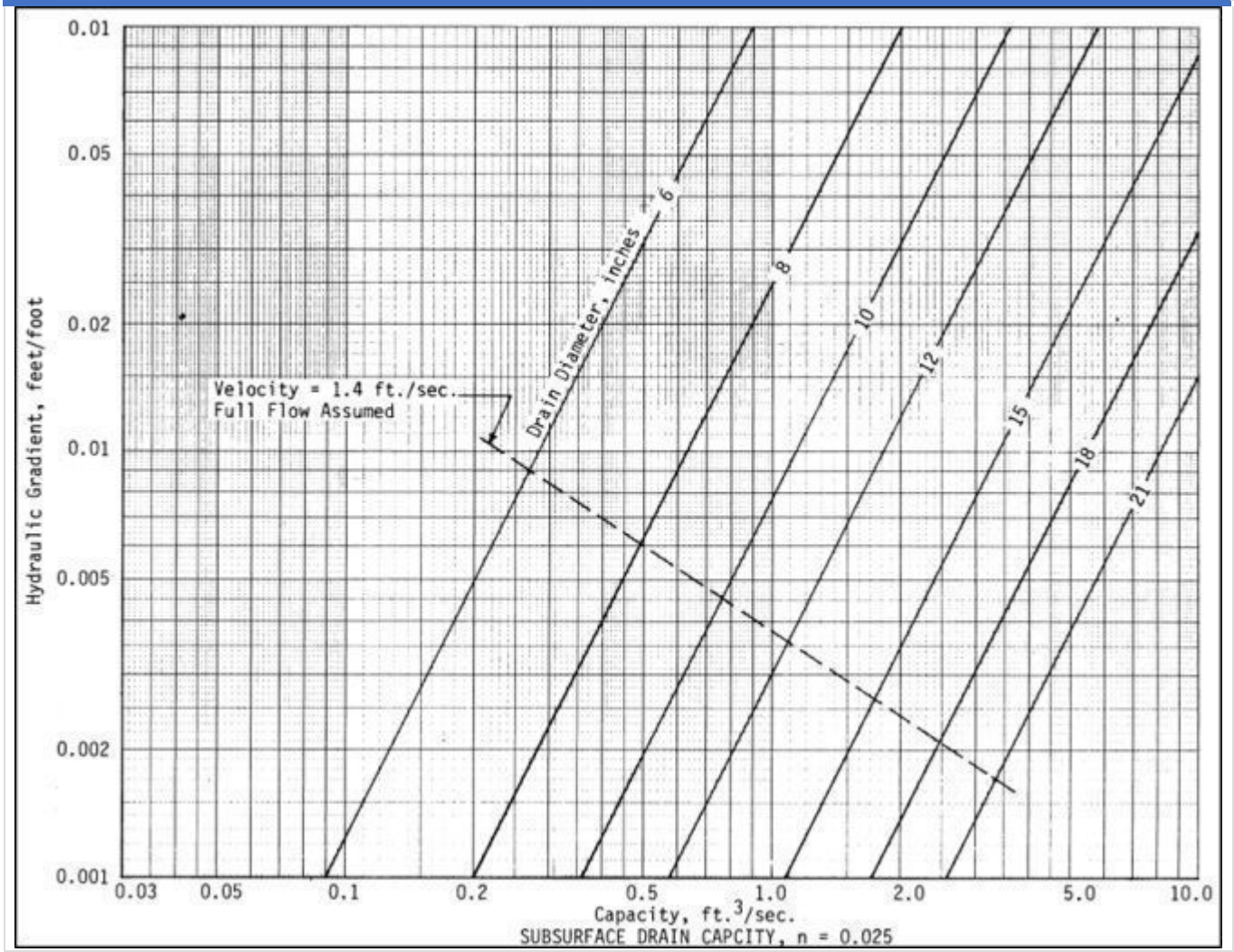
Source: USDA-SCS

Figure C-ECM-10-6 Surface Drain Capacity (n=0.015)



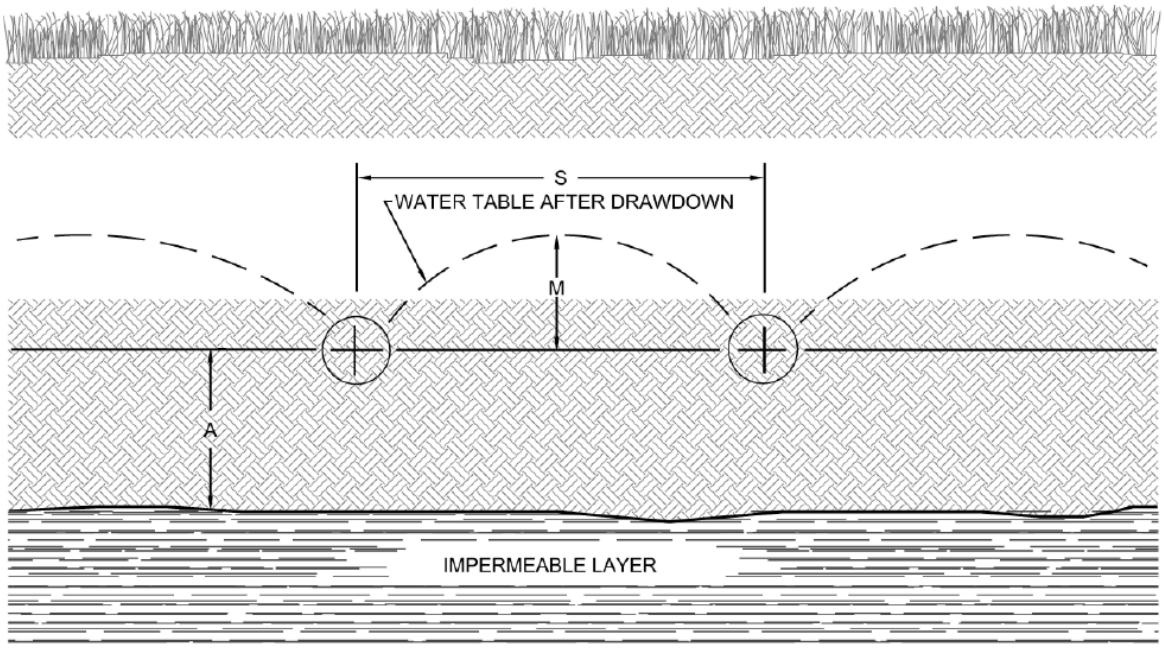
Source: USDA-SCS

Figure C-ECM-10-7 Surface Drain Capacity (n=0.025)



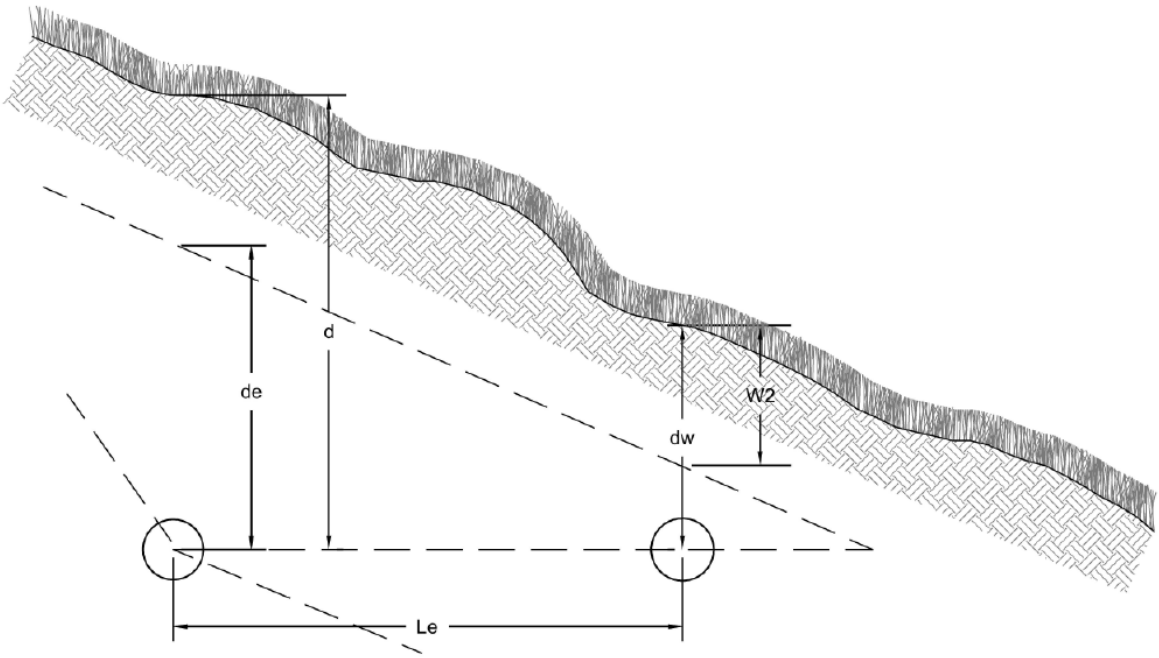
Source: USDA-SCS

Figure C-ECM-10-8 Relief Drain Spacing



Source: USDA-SCS

Figure C-ECM-10-9 Interceptor Drain Spacing



Source: USDA-SCS

C-ECM-11 Paved Flume

1.0 Definition

A paved flume is a permanent paved channel constructed on a slope to convey water from a higher to lower elevation in a short distance (New York Department of Environmental Conservation [NYDEC] 2016).

– CAD and PDF files for C-ECM-11-1 Paved Flume

2.0 Purpose and Applicability of Best Management Practice

To convey stormwater runoff safely down the face of a cut or fill slope without causing erosion downstream of the slope.

Use of a paved flume applies where concentrated stormwater runoff must be conveyed from the top to the bottom of cut or fill slopes on a permanent basis and a riprap-lined channel is not capable of conveying the runoff without erosion.

3.0 Planning and Considerations

Paved flumes are used routinely on highway cuts and fills to convey concentrated stormwater runoff from the top to the bottom of the slope without erosion.

These structures apply equally to cut and fill slopes for construction projects other than highways.

Give consideration to protecting structures against buoyancy failures. The potential for buoyancy failures due to hydrostatic uplift forces exists in channels constructed in periodically saturated areas (i.e., all channels will experience saturation of the subgrade by virtue of the function of the channel), especially if an outfall is submerged.



Paved Flume Under Dry Conditions
Source: Blucor Contracting, Inc.

Use and carefully construct paved flumes, as field experience has revealed a significant number of post-construction problems with these controls. If the base contains some unsuitable material or is too “soft”, the flume will be subject to undermining and fracturing. There are also many cases where the outlet velocities and flowrates of stormwater in a paved flume are so great that erosion and flooding at the end of the structure are inevitable, regardless of the type of treatment installed at the outlet. In these cases, give strong consideration to a riprap-lined channel or to a system of inlets, manholes, and pipe to safely convey the stormwater to the receiving channel or drainage structure.

4.0 Stormwater Performance Summary

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

MS-11: OUTLET PROTECTION – Before newly constructed stormwater conveyance channels or pipes are made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and receiving channel.

9VAC25-875-560

Erosion Control Efficiency: High

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-ECM-11-1 Design Criteria for Paved Flumes

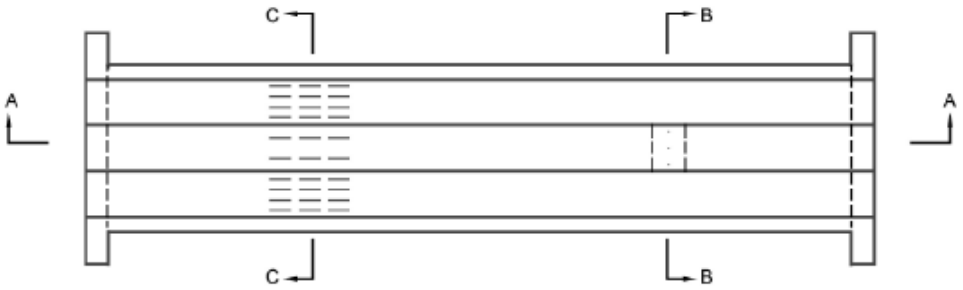
Topic	Requirement
Capacity	Design paved flumes to be capable of conveying a minimum of the peak flow expected from a 10-year frequency storm. Design paved flumes to handle additional freeboard or enough bypass expected throughout the life of the structure (NYDEC 2016).
Cross-Sections	Figure C-ECM-10-1 illustrates a typical trapezoidal cross-section of a Virginia Department of Transportation (VDOT) "Standard Paved Flume (PG-4)" (VDOT 2021). Where additional flow capacity is required, larger trapezoidal cross-sections may be designed. The following criteria apply to all trapezoidal flume designs: • Slope: design the maximum slope of the structure to be 1.5H:1V. • Curtain Walls: Provide curtain walls at the beginnings and ends of all paved flumes not abutted to another structure. Design the curtain wall to be as wide as the flume channel, extend at least 18 inches into the soil below the channel, and have a thickness of 6-inches. Design curtain walls to be reinforced with #4 reinforcing steel bars placed on 6-inch centers. • Anchor Lugs: Install anchor lugs spaced at a maximum of 10 feet on center for the length of the flume. Where no curtain wall is required, install an anchor lug within 2 feet of the end of the flume. Anchor lugs are to be as wide as the bottom of the flume channel, extending at least 1 foot into the soil below the channel, and having a thickness of 6 inches. Reinforce anchor lugs with #4 reinforcing steel bars placed on 4-inch centers. • Channel: Design the flume channel to have at least a 4-inch thickness of class A-3 concrete with welded wire fabric (6 X 6 - W2.1 x W2.1) in the center for reinforcement. • Expansion Joints: Provide expansion joints approximately every 90 feet. Locate 18-inch dowels of #4 reinforcing steel at 5-inch centers at all required joints.
Drainage Filters	Use a drainage filter with all paved fumes to prevent piping and reduce uplift pressures. Size of the filter material will depend on the soil material at and surrounding the paved flume (NYDEC 2016; North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service [NCDEQ] 2013).
Inlet	Ensure the inlet to the chute has the following minimum dimensions: side walls 2- feet high, length 6-feet, width equal to the flume channel bottom, and side slopes the same as flume channel side slopes (NCDEQ 2013).

Table C-ECM-11-1 Design Criteria for Paved Flumes	
Topic	**Requirement**
Outlet	Protect the outlets of paved flumes from erosion. The use of an energy dissipator with outlet protection (BMP C-ECM-15) is recommended to temporarily reduce the existing velocity of the flow, thus preventing undermining of the structure, and providing a stable transition zone between the flume and the receiving channel or drainage structure at the base of the slope. Figure C-ECM-10-2 and Figure C-ECM-10-3 show a "Standard Energy Dissipator (EG-1)" (VDOT 2021), which is designed for use in conjunction with the "Standard Paved Flume (PG-4)". Use outlet protection with the use of an "EG-1" structure to further dissipate flow energy and provide a smooth transition into the receiving channel. Larger energy dissipator systems may be similarly designed for larger flume cross-sections.
Alignment	Keep flume channels straight because they often carry supercritical flow velocities (NCDEQ 2013).
Small Flumes	Where the drainage area is less or equal to 10 acres, the design dimensions for paved flumes may be selected from the appropriate information below in Table C-ECM-11-2.

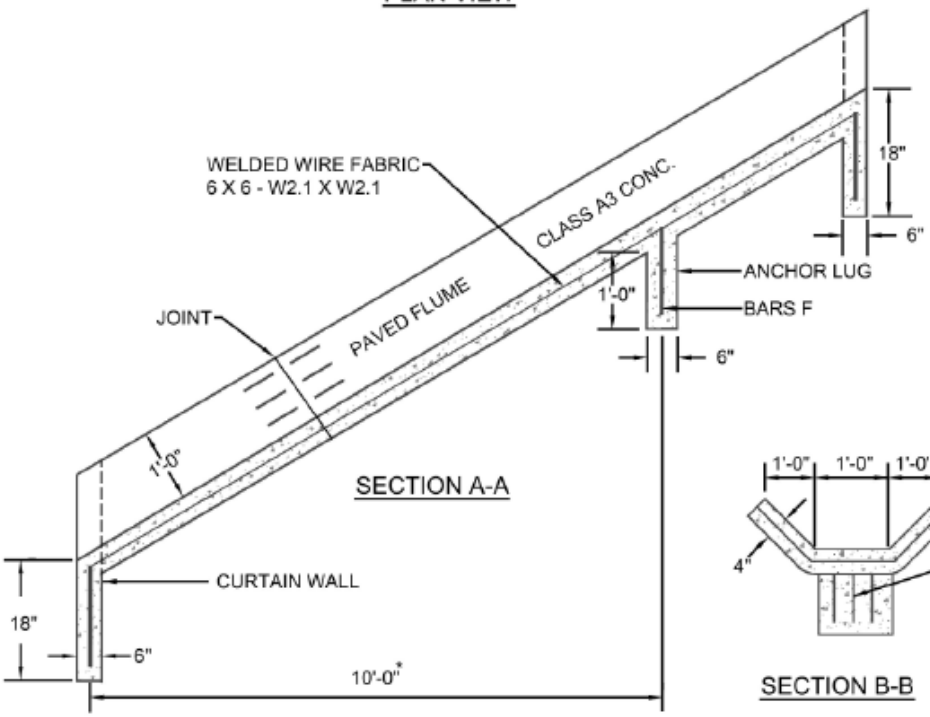
Table C-ECM-11-2 Flume Dimensions for Small Drainage Area					
Drainage Area (acres)	**Min. Bottom Width (feet)**	**Min. Inlet Depth (feet)**	**Min. Channel Depth (feet)**	**Max. Channel Slope (feet)**	**Max. Side Slope (feet)**
5	4	2	1.3	1.5H:1V	1.5H:1V
10	8	2	1.3	1.5H:1V	1.5H:1V

Note: Due to complexity of inlet and outlet design, drainage areas have been limited to 10 acres per flume.

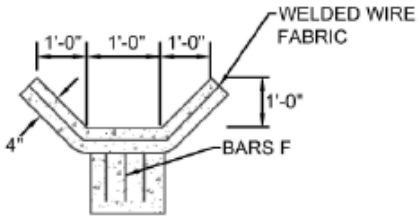
Figure C-ECM-11-1 Paved Flume



PLAN VIEW



SECTION A-A

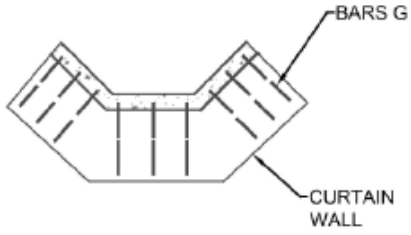


SECTION B-B

* 10'-0" C-C MAXIMUM TYPICAL SPACING BETWEEN ANCHOR LUGS. WHERE CURTAIN WALL IS NOT REQUIRED ANCHOR LUG IS TO BE A MAXIMUM OF 2' FROM END OF CHANNEL.

SCHEDULE OF REINFORCING STEEL

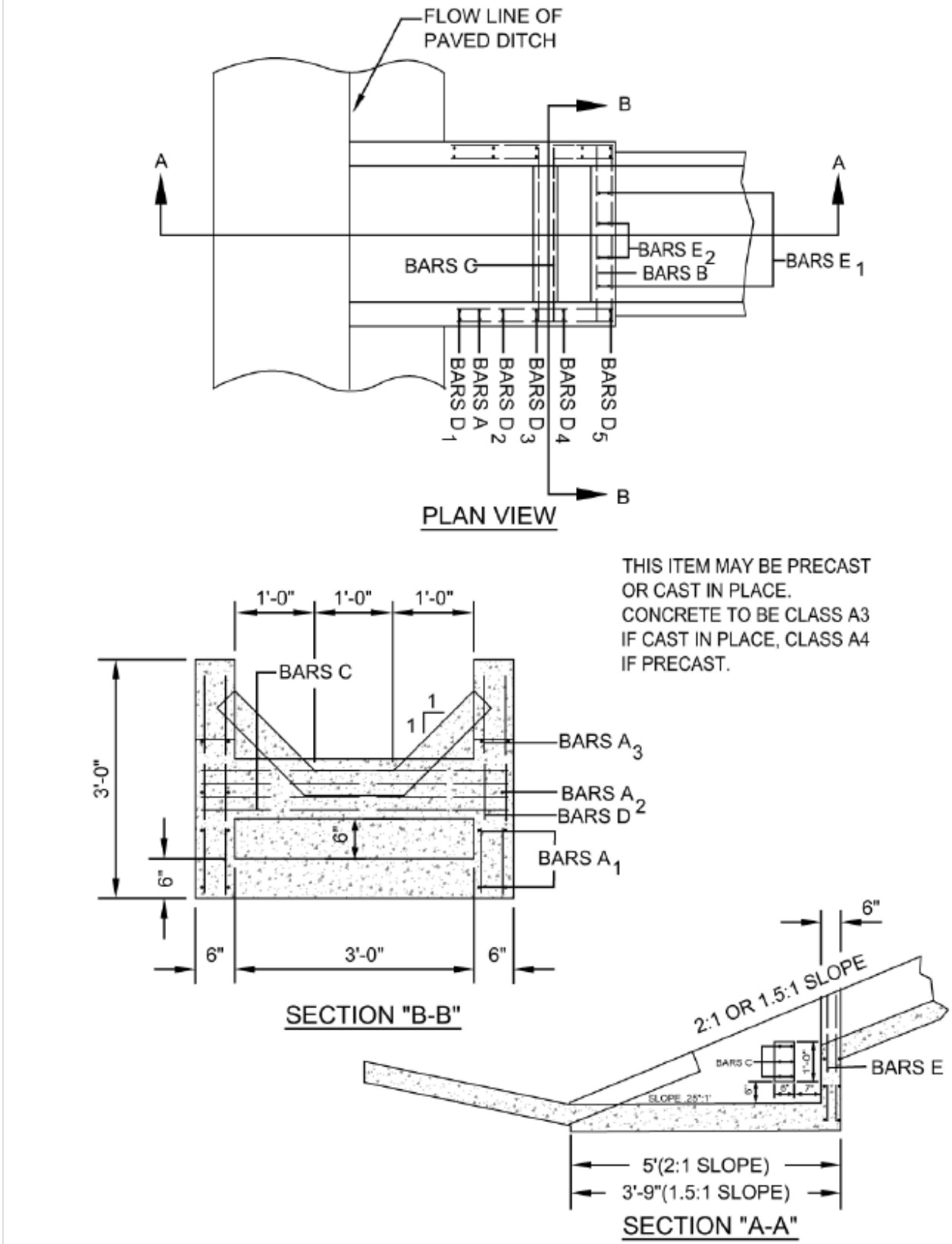
MARK	NO.	LENGTH		SIZE	SPACING C-C	SHAPE
		2:1	1 1/2:1			
F	3	1'-2"	1'-2"	4	4"	STRAIGHT
G	9	1'-5"	1'-5"	4	6"	STRAIGHT
DOWELS	30	1'-6"	1'-6"	4	5"	STRAIGHT



SECTION C-C

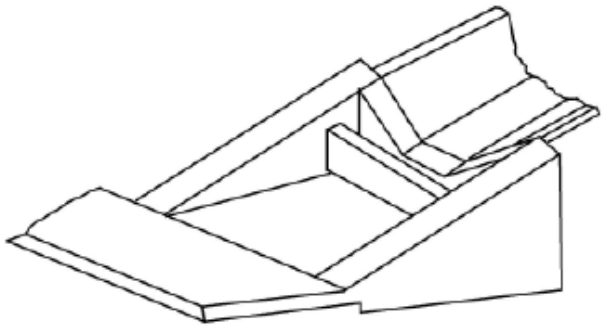
NO. SHOWN ARE FOR ONE ANCHOR LUG, CURTAIN WALL AND JOINT

Figure C-ECM-11-2 Energy Dissipator



Source: VDOT Road and Bridge Standards

Figure C-ECM-11-3 Energy Dissipator



ISOMETRIC

SCHEDULE OF REINFORCING STEEL

MARK	NO.	LENGTH		SIZE	SPACING C-C	SHAPE
		2:1	1.5:1			
A_1	8	2'-10"	2'-10"	3	8"	STRAIGHT
A_2	4	2'-6 1/4"	1'-10"	3	8"	STRAIGHT
A_3	4	1'-0 3/4"	0'-10"	3	8"	STRAIGHT
B	6	3'-9"	3'-9"	3	8"	STRAIGHT
C	8	3'-8"	3'-8"	3	2 1/2"	STRAIGHT
D_1	4	1'-2 1/2"	0'-8"	3	8"	STRAIGHT
D_2	4	1'-6 1/2"	1'-1 1/2"	3	8"	STRAIGHT
D_3	4	1'-10 1/2"	1'-7"	3	8"	STRAIGHT
D_4	4	2'-2 1/2"	2'-0 1/2"	3	8"	STRAIGHT
D_5	4	2'-6 1/2"	2'-6"	3	8"	STRAIGHT
E_1	4	1'-11 1/2"	1'-11 1/2"	3	8"	STRAIGHT
E_2	4	1'-5 1/2"	1'-5 1/2"	3	8"	STRAIGHT

APPROXIMATE QUANTITIES			
		CONCRETE	REINFORCING STEEL
		CU. YDS.	LBS.
ENERGY DISSIPATOR	2:1	0.7479	61.20
	1.5:1	0.5921	57.63

Source: VDOT

Road and Bridge Standards

6.0 Construction Specifications

1. Construct the subgrade to the required elevations. Remove and replace all soft and/or unsuitable material with stable material. Thoroughly compact and shape the subgrade to a smooth, uniform surface. Ensure the subgrade is moist when the concrete is poured.
2. On fill slopes, ensure the soil adjacent to the flume is well compacted for a minimum of 5 feet on either side (NYDEC 2016).
3. Where drainage filters are placed under a structure, do not pour the concrete on the filter. Place a plastic liner, a minimum of 4 mils thick, over the filter to prevent contamination of the filter layer (NYDEC 2016).
4. Form anchor lugs and curtain walls to be continuous with the channel lining.
5. Provide traverse joints for crack control at approximately 20-foot intervals and when more than 45 minutes elapse between consecutive concrete placements. Ensure all sections are at least 6 feet long. Form crack control joints by using a 0.125-inch-thick removable template, by scoring or sawing to a depth of at least 0.75 inch, or by an approved leave-in type of insert.
6. Take adequate precautions to protect freshly poured concrete from extreme temperatures and other weather factors to ensure proper and required curing of concrete (NCDEQ 2013).
7. Immediately after construction, perform final grading and seed all disturbed areas.

7.0 Operations and Maintenance Considerations

Before permanent stabilization of the slope, inspect the structure after each rainfall. Immediately repair any damage to the slope, flume, or outlet area. After the slope is stabilized, inspect the structure to ensure continued adequate functioning. Inspect the structure periodically and after major rainfall events. Inspect the outlet and rock riprap to ensure presence and stability, if applicable (NCDEQ 2013; NYDEC 2016).

8.0 References

NCDEQ. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

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C-ECM-12 Temporary Slope Drain

1.0 Definition

A temporary slope drain is a flexible tubing or conduit extending from the top to the bottom of a cut or fill slope.

– CAD and PDF for C-ECM-12-1 Temporary Slope Drain

2.0 Purpose and Applicability of Best Management Practice

Temporary slope drains temporarily conduct concentrated stormwater runoff safely down the face of a cut or fill slope without causing erosion on or below the slope.

This practice applies on cut or fill slopes where there is a potential for upslope flows to move over the face of the slope, causing erosion and preventing adequate stabilization.

3.0 Planning and Considerations

There is often a significant lag between the time at which a cut or fill slope is completed and the time at which a permanent drainage system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. This condition also occurs on slope construction that is temporarily delayed before final grade is reached. Temporary slope drains can provide valuable protection for exposed slopes until permanent drainage structures can be installed or vegetation can be established.

Temporary slope drains can be used in conjunction with diversion dikes to convey runoff from the entire drainage area above a slope to the base of the slope without erosion. It is important that these temporary structures be installed properly because their failure will often result in severe gully erosion on the site and sedimentation below the slope. Securely entrench the entrance section, ensure all connections are watertight, and securely stake the conduit.

4.0 Stormwater Performance Summary

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

9VAC25-875-560

Sediment Removal Efficiency: N/A

Erosion Control Efficiency: Moderate

5.0 Design Criteria

Table C-ECM-12-1 Design Criteria for Temporary Slope Drains

Topic	Requirement
Drainage Area	The maximum allowable drainage area per slope drain is 5 acres.
Flexible Conduit	Use a slope drain that consists of heavy-duty, flexible material designed for this purpose. Ensure the diameter of the slope drain is consistent over its entire length. Install reinforced hold-down grommets spaced at 10-foot (or less) intervals to secure the drain in place. Size slope drains as listed in Table C-ECM-12-2.

Table C-ECM-12-1 Design Criteria for Temporary Slope Drains	
Topic	**Requirement**
Entrance Sections	Design the entrance to the slope drain to consist of a standard Virginia Department of Transportation (VDOT) flared end section for metal pipe culverts (see Figures C-ECM-11-2 and C-ECM-11-3) with appropriate inlet protection as set forth in Culvert Inlet Protection (BMP C-SCM-05). If ponding will cause a problem at the entrance and make such protection impractical, install appropriate sediment-removing measures at the outlet of the pipe. Use extension collars that consist of 12-inch-long corrugated metal pipe. Provide watertight fittings (see). Note: End sections made of heavy-duty, flexible material may be used if determined by the certified plan reviewer to provide a stable inlet or outlet section.
Dike Design	Use an earthen dike to direct stormwater runoff into the temporary slope drain and construct the earthen dike as set forth in Diversion (BMP C-ECM-05). Refer to for placement of dike in relation to the slope drain. Design the height of the dike at the centerline of the inlet to be equal to the diameter of the pipe plus 6 inches. Where the dike height is greater than 18 inches at the inlet, slope the dike at the rate of 3H:1V or flatter to connect with the remainder of the dike (see).
Outlet Protection	Protect the outlet of the slope drain from erosion as set forth in Outlet Protection (BMP C-ECM-15).

Table C-ECM-12-2 Slope Drain Sizing	
Maximum Drainage Area (acres)	**Pipe Diameter (inches)**
0.5	12
1.5	18
2.5	21
3.5	24
5.0	30

Source: Virginia Department of Conservation and Recreation [VDCR] 2004

6.0 Construction Specifications

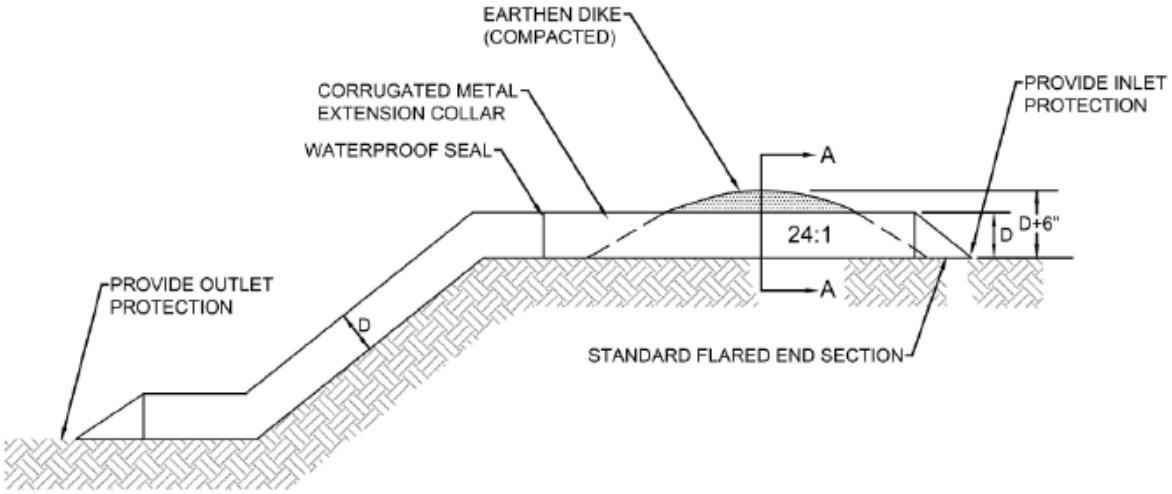
1. Place the slope drain pipe on undisturbed soil or well-compacted fill.
2. Slope the entrance section toward the slope drain at the minimum rate of 0.5 inch per foot.
3. Hand-tamp the soil around and under the entrance section in 8-inch lifts to the top of the dike to prevent piping failure around the inlet.
4. Securely stake the slope drain pipe to the slope using reinforced hold-down grommets spaced at 10-foot intervals.
5. Ensure the slope drain sections are securely fastened together and have watertight fittings.

6. Install culvert inlet protection and outlet protection in accordance with BMP C-SCM-05 and BMP C-ECM-15.

7.0 Operations and Maintenance Considerations

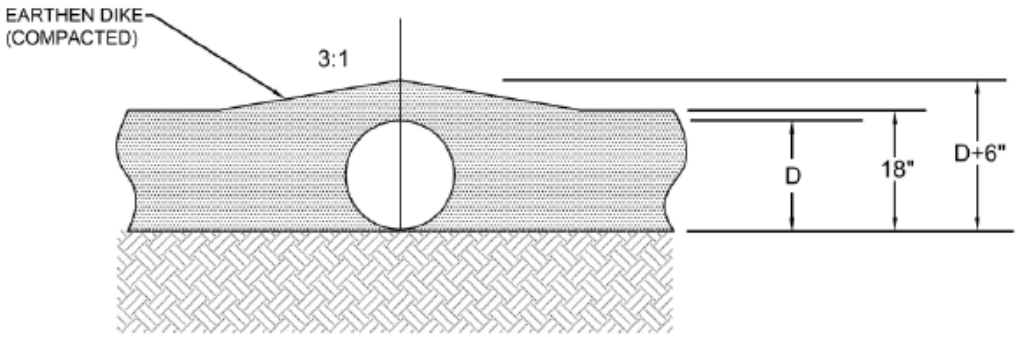
Inspect the slope drain structure weekly and after every storm and make repairs if necessary. Avoid the placement of any material on the slope drain and prevent construction traffic across the slope drain. When the protected area has been permanently stabilized, remove the temporary measures, properly dispose of materials, and appropriately stabilize all disturbed areas (North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service 2013).

Figure C-ECM-12-1 Temporary Slope Drain



SECTION VIEW

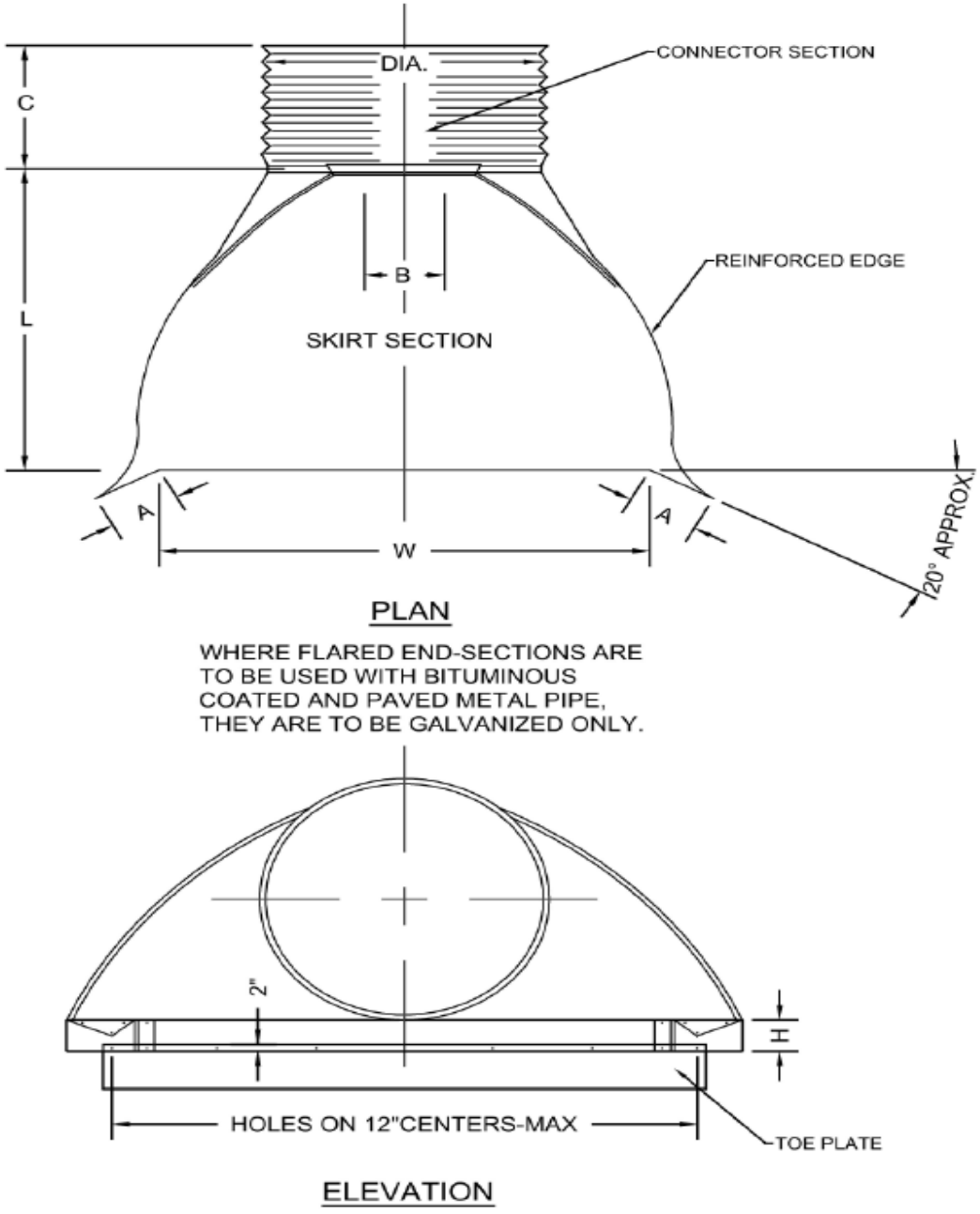
NOTE: SEDIMENT MAY BE CONTROLLED AT OUTLET IF UPLAND PONDING WILL CREATE PROBLEMS



SECTION A - A

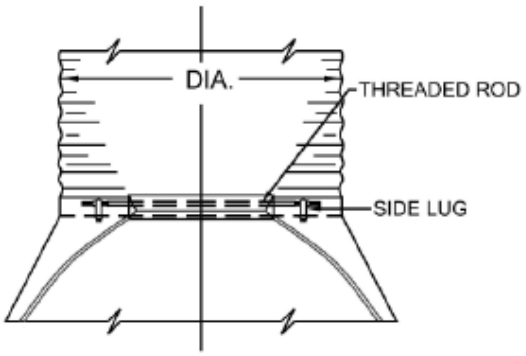
Source: VDCR 2004

Figure C-ECM-12-2 Flared End Section



Source: VDOT 2008

Figure C-ECM-12-3 Flared End Section 2



ALTERNATE CONNECTION

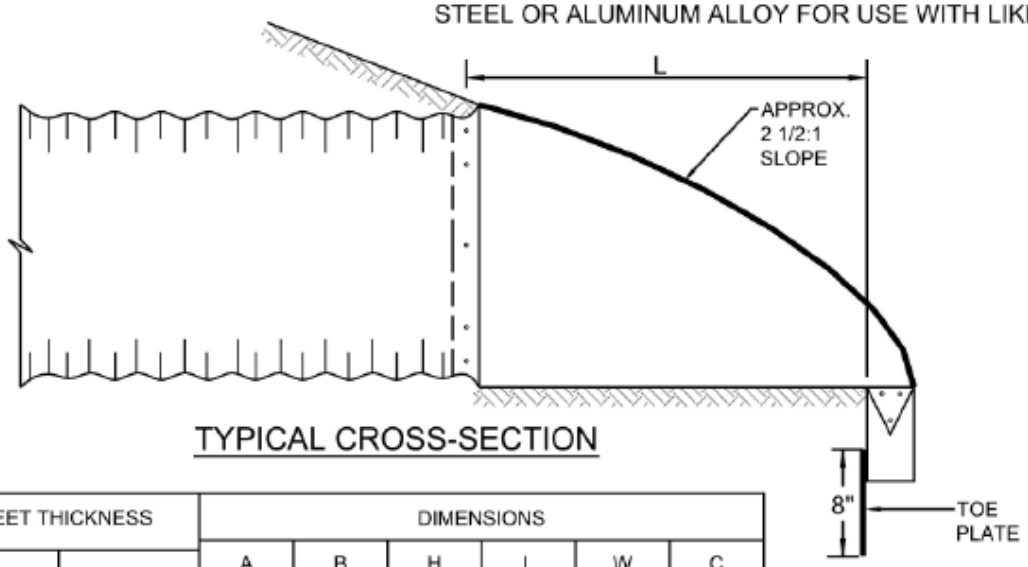
TOE PLATE, WHERE NEEDED, TO BE PUNCHED TO MATCH IN SKIRT LIP. 3/8" GALV. BOLTS TO BE FURNISHED. LENGTH OF TOE PLATE IS W + 10" FOR 12" TO 30" DIA. PIPE AND W + 22" FOR 36" TO 60" DIA. PIPE.

SKIRT SECTION FOR 12" TO 30" DIA. PIPE TO BE MADE IN ONE PIECE.

SKIRT SECTION FOR 36" TO 54" DIA. PIPE MAY BE MADE FROM TWO SHEETS JOINED BY RIVETING OR BOLTING ON CENTER LINE, 60" MAY BE CONSTRUCTED IN 3 PIECES.

CONNECTOR SECTION, CORNER PLATE AND TOE PLATE TO BE SAME SHEET THICKNESS AS SKIRT.

END-SECTIONS AND FITTINGS ARE TO BE GALVANIZED STEEL OR ALUMINUM ALLOY FOR USE WITH LIKE PIPE.



TYPICAL CROSS-SECTION

PIPE DIA.	SHEET THICKNESS		DIMENSIONS					
	STEEL	ALUMINUM	A 1"TOL.	B MAX.	H 1"TOL.	L $1\frac{1}{2}$" TOL.	W 2"TOL.	C
12"	.064"	.060"	6"	6"	6"	21"	24"	24"
15"	.064"	.060"	7"	8"	6"	26"	30"	24"
18"	.064"	.060"	8"	10"	6"	31"	36"	24"
21"	.064"	.060"	10"	12"	6"	36"	42"	24"
24"	.064"	.060"	10"	13"	6"	41"	48"	24"
27"/30"	.064"	.075"	12"	16"	8"	51"	60"	24"
36"	.064"	.075"	14"	19"	9"	60"	72"	36"
42"	.064"	.105"	16"	22"	11"	69"	84"	36"
48"	.064"	.105"	18"	27"	12"	78"	90"	24"
54"	.064"/.079"	.105"	18"	30"	12"	84"	102"	36"
60"	.064"/.079"	.105"/.135"	18"	33"	12"	87"	114"	36"

Source: VDOT 2008

8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

VDCR. 2004. The Virginia Stream Restoration and Stabilization Best Management Practices Guide. Virginia Department of Environmental Quality. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

VDOT. 2008. Road and Bridge Standards, Section 100: Drainage Items. Available online at: https://vdot.virginia.gov/business/locdes/Standards_CompleteSections.asp.

C-ECM-13 Riprap

1.0 Definition

Riprap is a permanent, erosion-resistant ground cover of large, loose, angular stone installed with filter fabric or granular underlining.

– CAD and PDF for C-ECM-13-1 Riprap

2.0 Purpose and Applicability of Best Management Practice

The purposes of riprap are:

1. To protect the soil from the erosive forces of concentrated runoff;
2. To slow the velocity of concentrated runoff while enhancing the potential for infiltration; and
3. To stabilize slopes with seepage problems and/or non-cohesive soils.



Source: Flickr, 2011

Use of riprap applies where soil and water interface and the soil conditions, water turbulence and velocity, expected vegetative cover, and other conditions are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, roadside ditches, drop structures, at the toes of slopes, as transition from concrete channels to vegetated channels, diversion channels for utility line crossings, temporary culvert crossings, at temporary right-of-way diversion outlets, rock check dams, rock filter outlets, temporary sediment trap outlets, and temporary sediment basin emergency spillways.

3.0 Planning and Considerations

Table C-ECM-13-1 Riprap Design Considerations	
Parameter	**Notes on Proper Use**
Sequence of Construction	Because riprap is used where erosion potential is high, sequence construction so that the riprap is placed with the minimum possible delay. Areas in which riprap is to be placed should be disturbed only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, place the riprap before or in conjunction with the construction of the pipe or channel so that the riprap is in place when the pipe or channel begins to operate; see Outlet Protection (BMP C-ECM-15).
Graded vs. Uniform Riprap	Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones that vary in size from small to large. A sample of uniform riprap would contain stones that are all consistent in size. For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a uniform pattern, requiring more hand or mechanical labor. Riprap sizes can be designed by either the diameter or the weight of the stones. It is often misleading to think of riprap in terms of diameter because the stones are angular instead of spherical. However, it is simpler to specify the diameter of an equivalent size of spherical stone. Table C-ECM-13-2 lists some typical stones by weight, spherical diameter, and the corresponding rectangular dimensions. These stone sizes are based on an assumed specific weight of 165 pounds per cubic foot (lb/ft^3). Because graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is accomplished by specifying a diameter of stone in the mixture for which some percentage, by weight, will be smaller. For example, d85 refers to a mixture of stones in which 85% of the stone by weight would be smaller than the diameter specified. Most designs are based on d50. In other words, the design is based on the nominal size of stone in the mixture. Table C-ECM- 12-3 lists Virginia Department of Transportation (VDOT) standard graded riprap sizes by diameter and weight of the stone. To ensure use of stone of substantial weight when installing riprap structures, follow the specified weight ranges for individual stones and composition requirements. Such guidelines will help to prevent inadequate stone from being used when constructing the measures and will promote more consistent stone classification statewide. Table C-ECM-13-4 notes these requirements.

Table C-ECM-13-2 Size of Riprap Stones			
Weight (lbs.)	Mean Spherical Diameter (ft.)	Rectangle Length (ft.)	Rectangle Height/Width (ft.)
25	0.7	1.1	0.4
50	0.8	1.4	0.5
75	1.0	1.6	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1,000	2.2	3.7	1.25
1,500	2.6	4.7	1.5
2,000	2.75	5.4	1.8
4,000	3.6	6.0	2.0
6,000	4.0	6.9	2.3
8,000	4.5	7.6	2.5
20,000	6.1	10.0	3.3

Source: VDOT 2017

Table C-ECM-13-3 Graded Riprap Design Values			
Riprap Class	D15 Weight (lbs.)	D15 Spherical Diameter (ft.)	D50 Spherical Diameter (ft.)
Class AI	25	0.7	0.9
Class I	50	0.8	1.1
Class II	150	1.3	1.6
Class III	500	1.9	2.2
Type I	1,500	2.6	2.8
Type II	6,000	4.0	4.5

Source: VDOT 2017

Table C-ECM-13-4 Graded Riprap Weight Analysis		
Riprap Class/Type	**Weight Range* (lbs.)**	**Requirements for Stone Mixture**
Class AI	25 – 75	Max. 10% > 75 lbs.
Class I	50 – 150	60% > 100 lbs.
Class II	150 – 500	50% > 300 lbs.
Class III	500 – 1,500	50% > 900 lbs.
Type I	1,500 – 4,000	Average weight = 2,000 lbs.
Type II	6,000 – 20,000	Average weight = 8,000 lbs.

* In all classes/types of riprap, a maximum 10% of the stone in the mixture may weigh less than the lower end of the range.

Source: Adapted from VDOT 2020.

4.0 Stormwater Performance Summary

MS-11: OUTLET PROTECTION – Before any newly constructed stormwater conveyance channel can be made operational, adequate outlet protection and any required temporary or permanent channel lining will be installed in both the conveyance channel and receiving channel.

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: MODERATE

5.0 Design Criteria

Table C-ECM-13-5 Design Criteria for Riprap	
Parameter	**Notes on Proper Use**
Gradation	Use riprap composed of a well-graded mixture down to the 1-inch size particle such that 50% of the mixture by weight is larger than the d50 size as determined from the design procedure. A well-graded mixture, as used herein, is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. Design the diameter of the largest stone size in such a mixture to be 1.5 times the d50 size. After determining the riprap size that will be stable under the flow conditions, consider that size to be a minimum size. Based on riprap gradations available in the area, select the size or sizes that equal or exceed the minimum size. Consider the possibility of damage in selecting a riprap size.
Thickness	Design the minimum thickness of the riprap layer to be two times the maximum stone diameter but not less than 6 inches.

Table C-ECM-13-5 Design Criteria for Riprap	
Parameter	**Notes on Proper Use**
Quality of Stone	Use stone for riprap that consists of field stone or rough unhewn quarry stone of approximately rectangular shape. Ensure the stone is hard, angular, and of such quality that it will not disintegrate on exposure to water or weathering. Use stone that is suitable in all respects for the purpose intended. Ensure the specific gravity of the individual stones is at least 2.5. Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot and otherwise meets the requirement of this standard and specification.
Filter Fabric Underlining	Place a lining of engineering filter fabric (geotextile) between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. Table C-ECM-13-5 notes the minimum physical properties of the filter fabric. Do not use filter fabric on slopes greater than 1.5H:1V, as slippage may occur. Use filter fabric in conjunction with a layer of coarse aggregate (granular filter blanket is described in the next row) when the riprap to be placed is Class II or larger.
Granular Filter	Although the filter fabric underlining or bedding is the preferred method of installation, a granular (stone) bedding is a viable option when the following relationships exist: $\frac{d_{15filter}}{d_{85base}} < 5 < \frac{d_{15filter}}{d_{15base}} < 40$ and $\frac{d_{50filter}}{d_{50base}} < 40$ In these relationships, “filter” refers to the overlying material, and “base” refers to the underlying material. Continue the relationships between the filter material and the base material and between the riprap and the filter material. More than one layer of base material may be needed. Design each layer of filter material to be approximately 6 inches thick.
Riprap at Outlets	Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlets of drainage structures are contained in Outlet Protection (BMP C-ECM-15). Install a filter fabric underlining for riprap used as outlet protection.
Riprap for Channel Stabilization	Design riprap for channel stabilization to be stable for the condition of bank-full flow in the reach of the channel being stabilized. Use the design procedure in Appendix A - Riprap Design in Channel, which is extracted from the Federal Highway Administration's Design of Stable Channels with Flexible Linings. This method establishes the stability of the rock material relative to the forces exerted upon it. Extend riprap up the banks of the channel to a height equal to the maximum depth of flow or to a point where vegetation can be established to adequately protect the channel. Riprap should extend down the bank and across the bottom of the channel a distance equal to the thickness of the blanket.

Table C-ECM-13-5 Design Criteria for Riprap	
Parameter	**Notes on Proper Use**
Freeboard and Height of Bank	For riprap and other lined channels, design the height of channel lining above the water surface based on the size of the channel, flow velocity, curvature, inflows, wind action, and flow regulation. The height of the bank above the water surface varies similarly depending on the previously identified factors plus the type of soil. Plate 2 is based on information developed by the U.S. Bureau of Reclamation for average freeboard and bank height in relation to channel capacity. Use this chart to calculate a minimum freeboard for placement of riprap and top of bank.
Riprap for Slope Stabilization	Design riprap for slope stabilization so that the natural angle of repose of the stone mixture is greater than the gradient of the slope being stabilized (see Plate 3).
Riprap for Lakes and Ponds Subject to Wave Action	Riprap used for shoreline protection on lakes and ponds may be subject to wave action. The waves affecting the shoreline may be wind-driven or created by boat wakes. Consult the latest edition of the VDOT Drainage Manual (Design of Slope Protection to Resist Wave Action) for specific design criteria in determining the required size of stones and the design wave height for such an installation. Use the equations in Appendix B - Riprap Design Equations for Lakes and Ponds Subject to Wave Action to calculate other pertinent design parameters. For more in-depth design criteria concerning these installations, see the U.S. Army Corps of Engineers' Shore Protection Manual.
Riprap for Abrupt Channel Contractions	Refer to latest edition of the VDOT Drainage Manual for design criteria.
Riprap for Installations Subject to Tidal and Wave Action	The design of riprap structures for tidal areas is beyond the scope of the Virginia Erosion and Sediment Control Law and Virginia Erosion and Sediment Control Regulations. Notably, a riprap design for shoreline protection in tidal areas must meet all applicable state and federal requirements and be carried out by a qualified professional.

Table C-ECM-13-6 Requirements for Filter Fabric Used with Riprap		
Physical Property	**Test Method**	**Requirements**
Grab Tensile	ASTM D4632	250 lbs.
Grab Elongation	ASTM D4632	15%
Trapezoid Tear	ASTM D4533	90 lbs.
CBR Puncture Resistance	ASTM D6241	900 lbs.
Apparent Opening Size	ASTM D4751	40 U.S. Sieve

Only use fabrics not meeting these specifications when design procedure and supporting documentation are supplied to determine fabric strength.

CBR = California bearing ratio

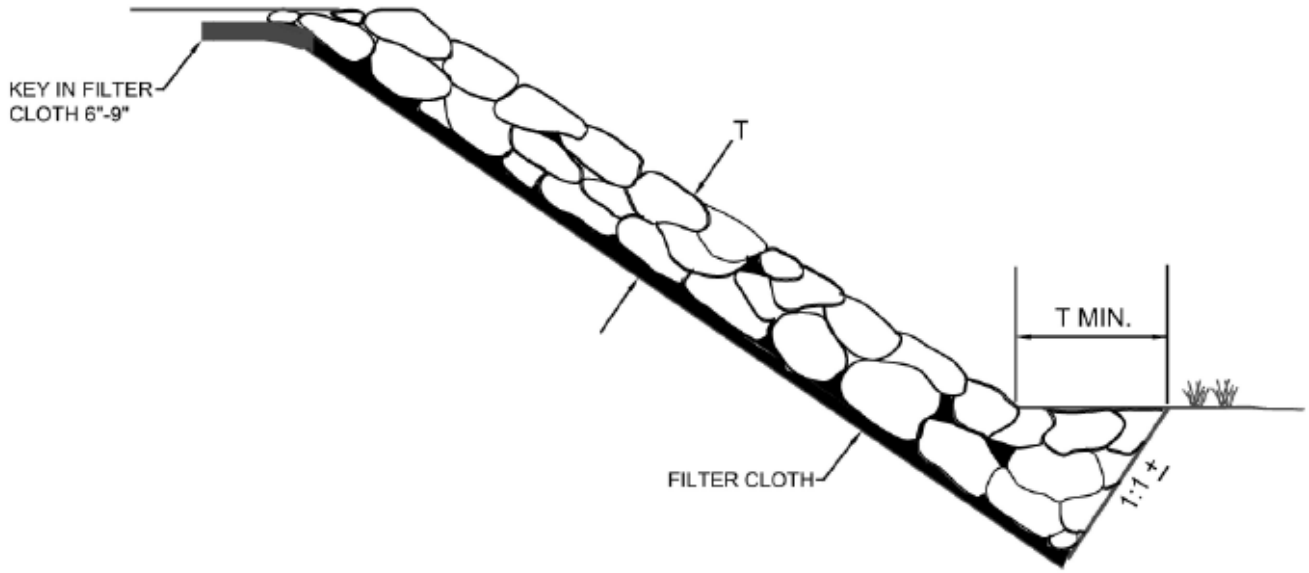
6.0 Construction Specifications

Table C-ECM-13-7 Material Specifications for Riprap	
Material	**Notes on Proper Use**
Subgrade Preparation	Prepare the subgrade for the riprap or filter to the required lines and grades. Compact any fill required in the subgrade to a density approximately equal to that of the surrounding undisturbed material. Remove brush, trees, stumps, and other objectionable material.
Filter Fabric or Granular Filter	Place filter fabric immediately after slope preparation. For granular filters, spread the stone in a uniform layer to the specified depth (normally 6 inches). Where more than one layer of filter material is used, spread the layer so that there is minimal mixing of the layers. When installing filter fabric, place the cloth directly on the prepared slope. Overlap the edges of the sheets by at least 12 inches, ensuring upstream cloth overlaps downstream cloth. Install anchor pins, 15 inches long, spaced every 3 feet along the overlap. Bury the upper and lower ends of the cloth at least 12 inches. Take care not to damage the cloth when placing the riprap. If damage occurs, remove and replace the damaged sheet. For large stone (Class II or greater), install a 6-inch layer of granular filter over the cloth to prevent damage to the cloth.
Stone Placement	Immediately follow placement of the filter with placement of riprap. Place the riprap so that it produces a dense, well-graded mass of stone with few voids. The desired distribution of stones throughout the mass may be attained by selective loading at the quarry, controlled dumping of successive loads during final placing, or by a combination of these methods. Place the riprap to its full thickness in one operation. Do not place the riprap in layers. Do not place the riprap by dumping into chutes or similar methods that are likely to segregate the stone sizes. Take care not to dislodge the underlying material when placing the stones. Ensure the finished slope is free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Ensure the final thickness of the riprap blanket is within plus or minus one quarter of the specified thickness.

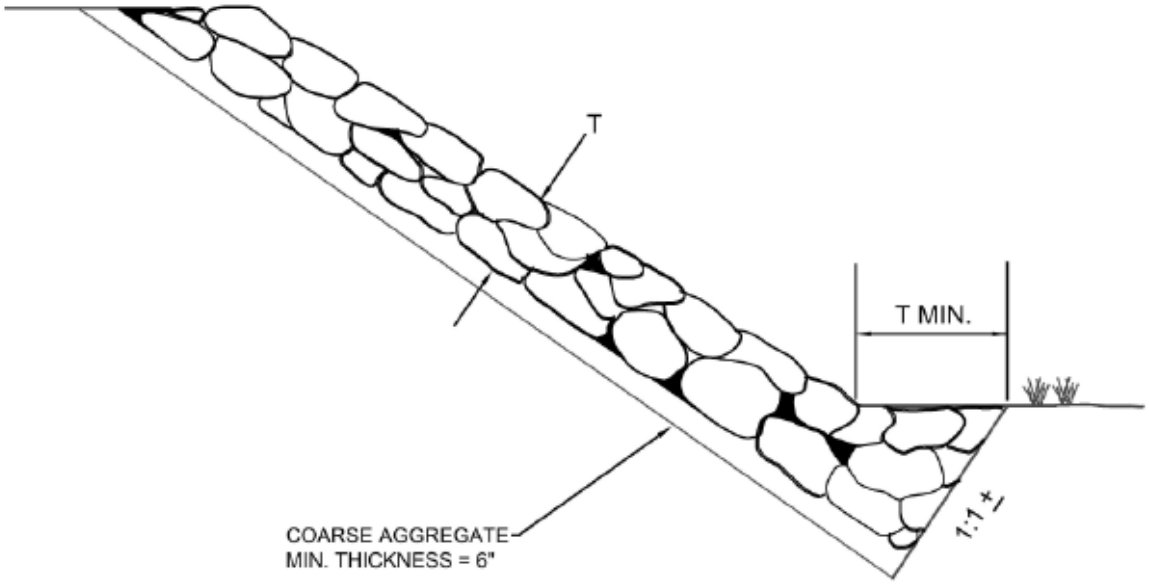
7.0 Operations and Maintenance Considerations

Periodically inspect the placed riprap to determine if high flows have caused scour beneath the riprap or filter fabric or dislodged any of the stone. Take care to properly control sediment-laden construction runoff, which may drain to the point of the new installation. Immediately perform any repairs needed.

Figure C-ECM-13-1 Toe Requirements for Riprap Bank Stabilization



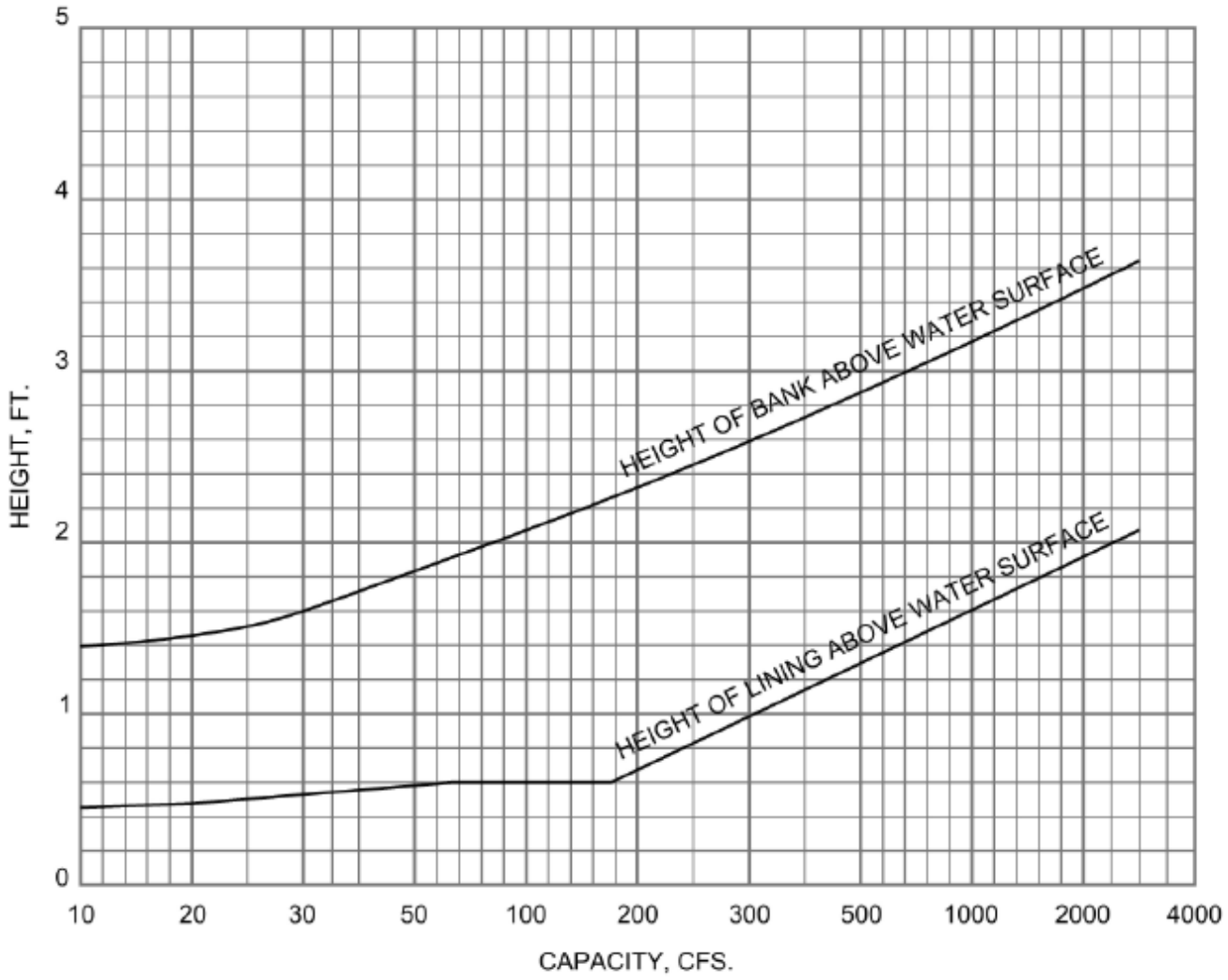
FILTER CLOTH UNDERLINER (PREFERRED)



GRANULAR FILTER

Source: VDOT 2017

Figure C-ECM-13-2 Recommended Freeboard and Height of Bank of Lined Channels



Source: U.S. Bureau of Reclamation

8.0 References

Flickr. 2011. Protecting the Road with Rip Rap. Located at: https://www.flickr.com/photos/tranbc/6073853523

Kilgore, R.T. and G.K. Cotton. 2005. Design of Roadside Channels with Flexible Linings. Hydraulic Engineering Circular No. 15. Third Edition. September.

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9.0 Appendix A – Riprap Design in Channel

The design method described below is adapted from Hydraulic Engineering Circular No. 15 of the Federal Highway Administration (Kilgore and Cotton 2005). The method applies to both straight and curved sections of channel in which the flow is tangent to the bank of the channel.

Tangent Flow – Federal Highway Administration Method

This design method determines a stable rock size for straight and curved sections of channels. It is assumed that the shape, depth of flow, and slope of the channel are known. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3H:1V, the stone size must be modified accordingly. The final design size will be stable on both sides of the channel and the bottom.

1. Enter Plate 3 with the maximum depth of flow (feet) and channel slope (feet/foot). Where the two lines intersect, choose the d50 size of stone (Select the d_{50} for the diagonal line above the point of intersection).
2. If channel sideslopes are steeper than 3H:1V, continue with Step 3; if not, the procedure is complete.
3. Enter Plate 4 with the sideslope and the base width to maximum depth ratio (B/d). Where the two lines intersect, move horizontally left to read K_1.
4. Determine from Plate 5 the angle of repose for the d50 size of stone and the sideslope of the channel (Use 42° for d_{50} greater than 1.0. Do not use riprap on slopes steeper than the angle of repose for the size of stone).
5. Enter Plate 6 with the sideslope of the channel and the angle of repose for the d_{50} size of stone. Where the two lines intersect, move vertically down to read K_2.
6. Compute $d_{50} \times K_1/K_2 = d'_{50}$ to determine the correct size stone for the bottom and sideslopes of straight sections of channel.

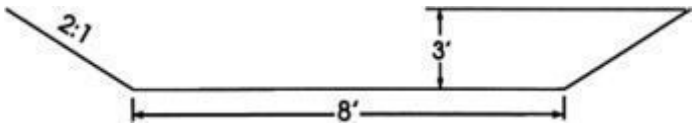
For Curved Sections of Channel

1. Compute the radius of the curve (R_o) measured at the outside edge of the bottom.
2. Compute the ratio of the top width of the water surface (Bs) to the radius of the curve (R_o), B_s/R_o.
3. Enter Plate 7 with the ratio B_s/R_o. Move vertically until the curve is intersected. Move horizontally left to read K_3.
4. Compute $d'_{50} \times K_3 = d_{50c}$ to determine the correct size stone for bottom and sideslopes of the curved sections of channel.

Example Problem

Given:

A trapezoidal channel 3 feet deep, 8 feet wide at the bottom, 2H:1V sideslopes, and a 2% slope.



Calculate:

A stable riprap size for the bottom and sideslopes of the channel.

Solution:

1. From Plate 3, for a 3-foot-deep channel on a 2% grade, d_{50} = 0.75 foot or 9 inches.
2. Because the sideslopes are steeper than 3H:1V, continue with step 3.
3. From Plate 4, B/d = 8/3 = 2.67, Z = 2, K1 = 0.82.

4. From Plate 5, for d_{50} = 9 inches, = 41°.
5. From Plate 6, for Z = 2 and = 41°, K_2 = 0.73.
6. d_{50} x K_1/K_2 = d'_{50} = 0.75 x 0.82/0.73 = 0.84 foot.

   0.84 foot x 12 inches/1 foot = 10.08. Use d'_{50} = 10 inches.

Given:

The preceding channel has a curved section with a radius of 50 feet.

Calculate:

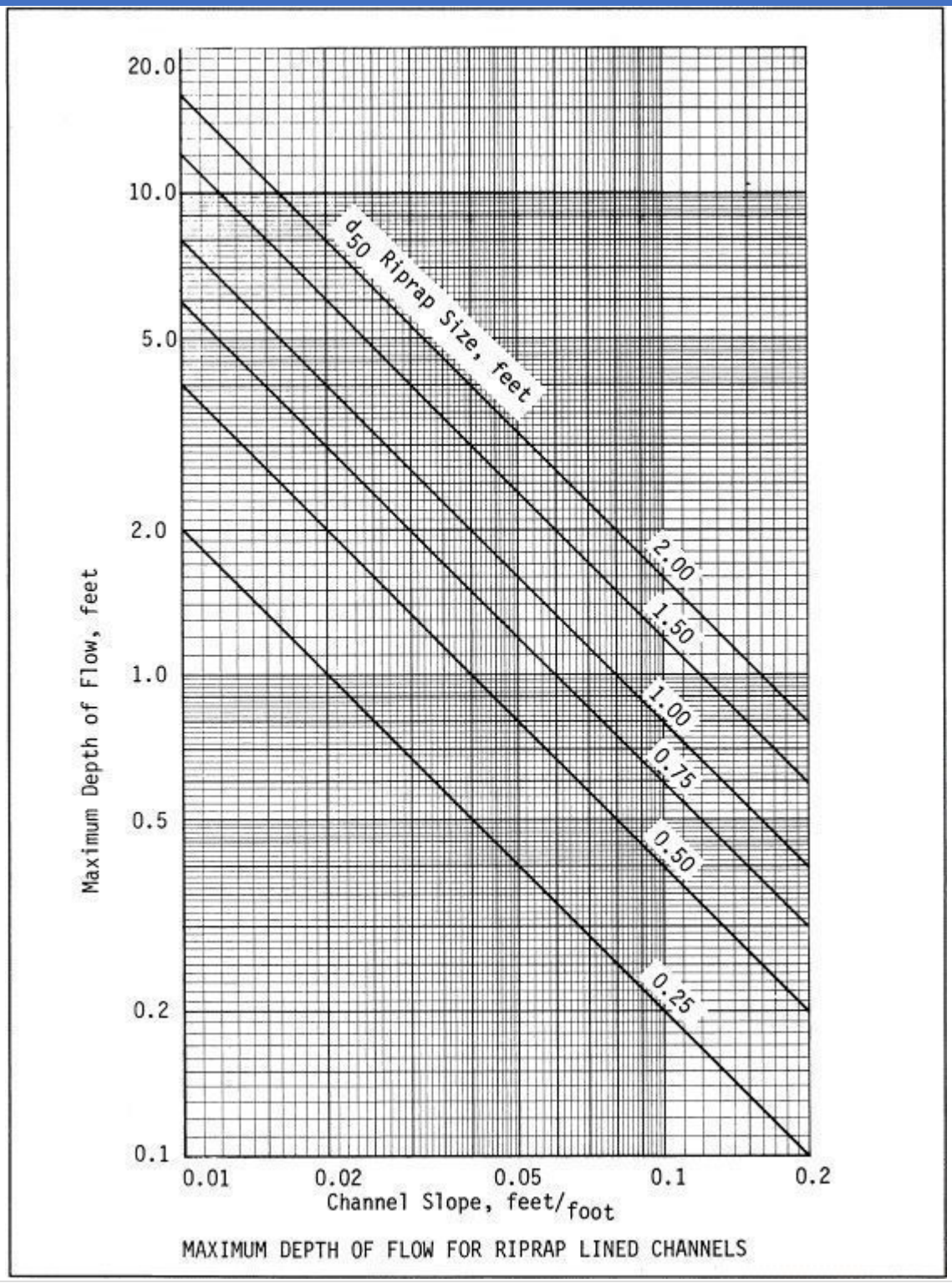
A stable riprap size for the bottom and sideslopes of the curved section of channel.

Solution:

1. R_o = 50 feet
2. B_s/R_o = 20/50 = 0.40
3. From Plate 7, for B_s/R_o = 0.40, K_3 = 1.1
4. d'_{50} x K_3 = 0.84 x 1.1 = 0.92 foot

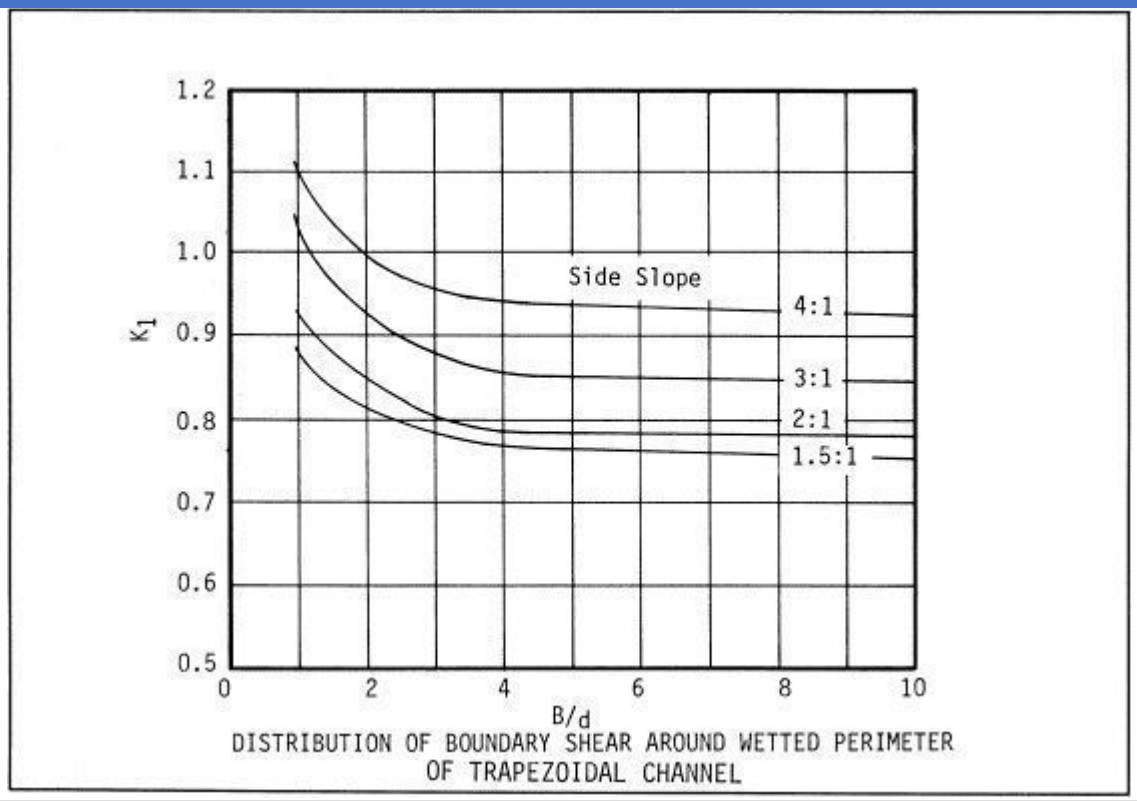
   0.92 foot x 12 inches/1 foot = 11.0.

Figure C-ECM-13-3 Maximum Depth of Flow for Riprap Lined Channels



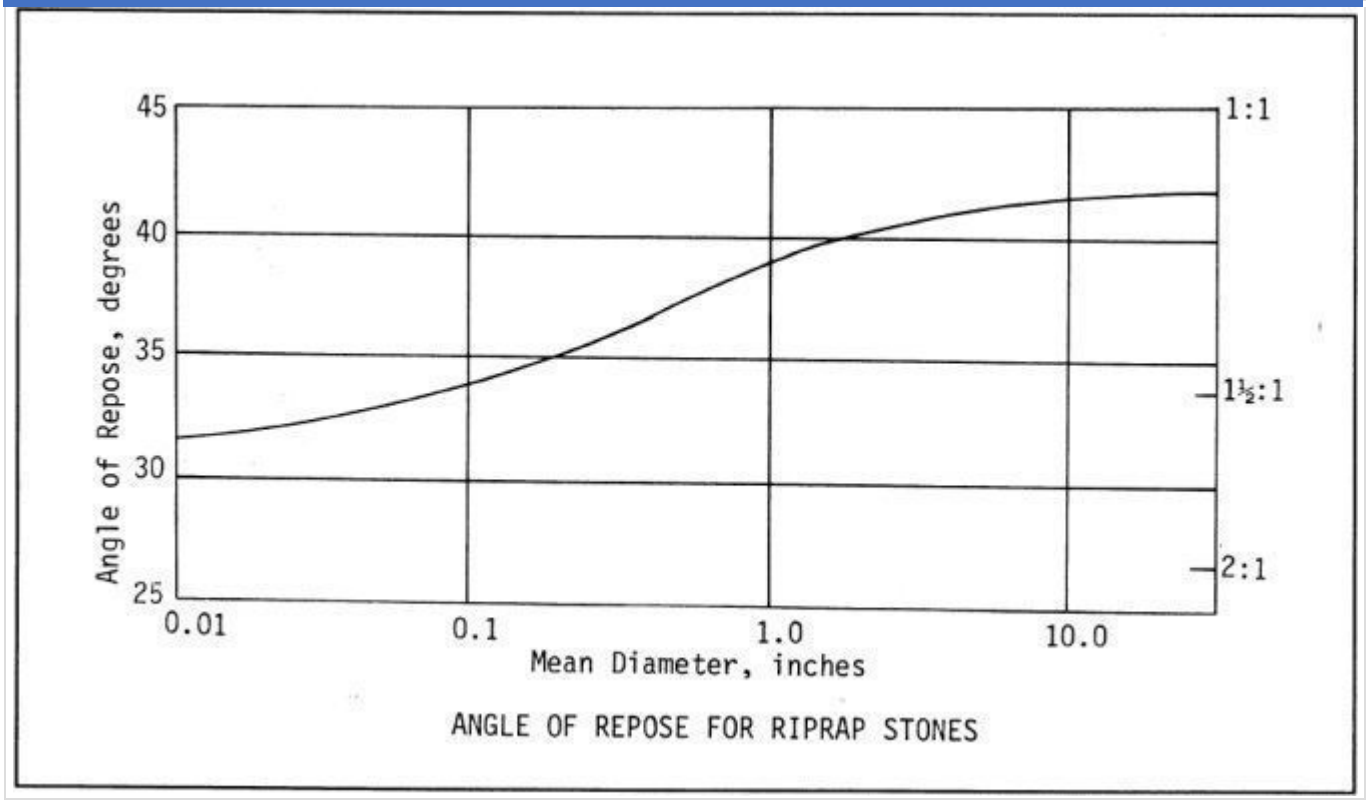
Source: VDOT 2017

Figure C-ECM-13-4 Distribution of Boundary Shear Around Wetted Perimeter of Trapezoidal Channel



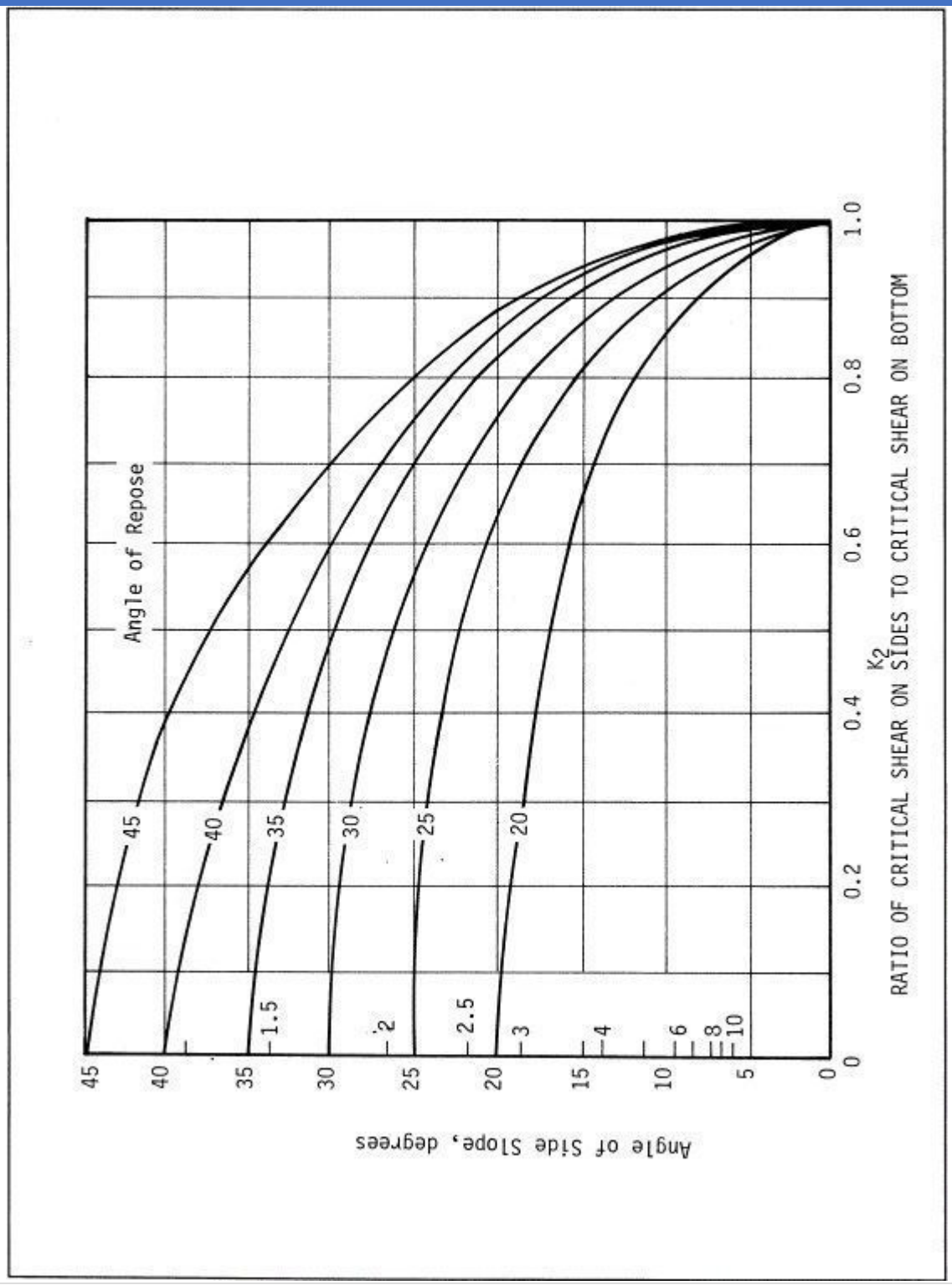
Source: VDOT 2017

Figure C-ECM-13-5 Angle of Repose for Riprap Stones



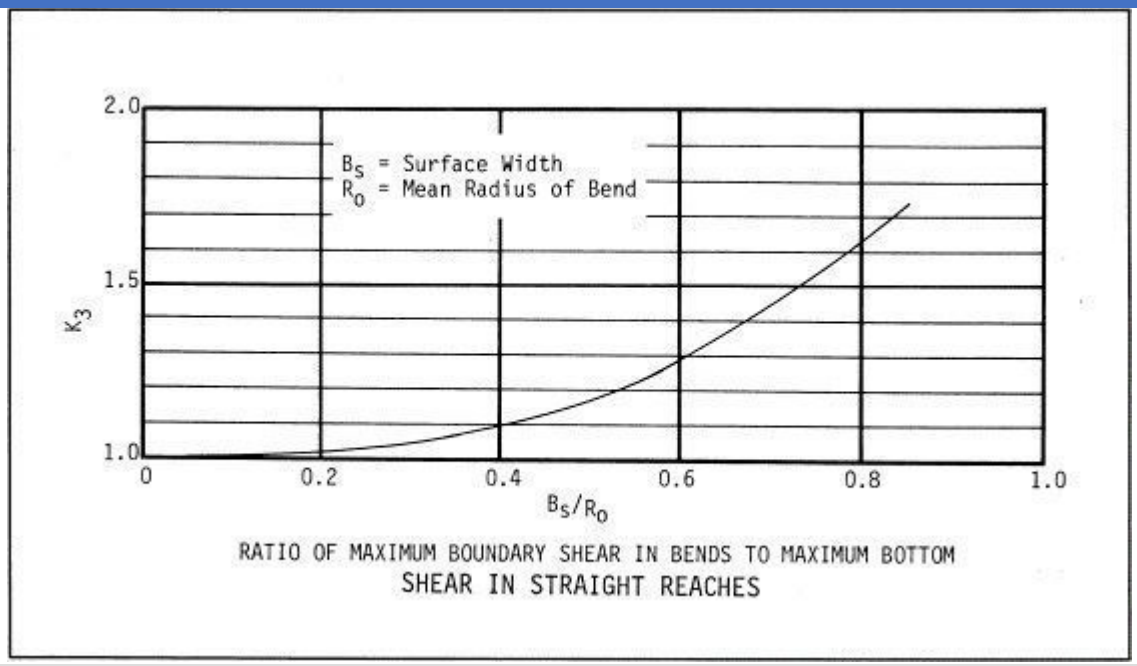
Source: VDOT 2017

Figure C-ECM-13-6 Ratio of Critical Shear on Sides to Critical Shear on Bottom



Source: VDOT 2017

Figure C-ECM-13-7 Ratio of Maximum Boundary Shear in Bends to Maximum Bottom Shear in Straight Reaches



Source: VDOT 2017

10.0 Appendix B – Riprap Design Equations for Lakes and Ponds Subject to Wave Action

In many instances, riprap is installed along the shoreline of non-tidal ponds and lakes to protect them from the continual scour of wind-driven waves. The following methods/equations will produce minimum design parameters for size of stone, depth of buried toe (or width of riprap apron), and height of structure above average water level.

I. **Size of Riprap Required** – See VDOT Drainage Manual ("Design of Slope Protection to Resist Wave Action").
II. **DWH (Design Wave Height)** – See VDOT Drainage Manual ("Design of Slope Protection to Resist Wave Action") or U.S. Army Corps of Engineers' Shore Protection Manual.
III. **Depth of Buried Toe** = DWH at design wind speed.
IV. **Width of Riprap Apron (Alternative to Buried Toe)** = DWH x 2.
V. **Height of Structure (Above the Average Water Level)** = DWH x 1.5.

C-ECM-14 Temporary Level Spreader

1.0 Definition

Riprap is a permanent, erosion-resistant ground cover of large, loose, angular stone installed with filter fabric or granular underlining.

– CAD and PDF for C-ECM-14 Temporary Level Spreader

2.0 Purpose and Applicability of Best Management Practice

A level spreader is used to intercept concentrated sediment-free runoff from stabilized areas and convert it to sheet flow where it can be released to a well-vegetated stabilized area in a non-erosive manner.

Use a temporary level spreader where there is a need to divert stormwater away from disturbed areas to avoid overstressing erosion control measures, and where sediment-free stormwater runoff can be released in sheet flow down a stabilized slope without causing erosion. The level spreader should provide a stable outlet for measures including diversions, dikes, or right-of-way diversions.

If a level spreader is to be used with higher design flows, use a rigid spreader lip as discussed below. If a level spreader is proposed for use in Virginia Department of Transportation (VDOT) rights-of-way, refer to the appropriate VDOT standards and specifications for specific regulations. For other permanent installations, refer to P-SUP-08 for more information.

3.0 Planning and Considerations

Temporary diversion dikes (BMP C-ECM-04) and temporary right-of-way diversions (BMP C-ECM-07) each call for a stable outlet for concentrated stormwater flows. The level spreader is a relatively low-cost structure to convert smaller volumes of concentrated flow to sheet flow for release without causing erosion downstream where conditions are suitable (see).

Construct the level spreader prior to site prep in previously undisturbed soil where the outlet area below the level lip is uniform with a maximum slope of 10% and is stabilized by existing vegetation.

Ensure that the outlet lip is constructed to be completely level in a stable, undisturbed soil. Any depressions in the lip will concentrate the flow, resulting in erosion.

Under higher design flow conditions, use a rigid outlet lip design to create the desired sheet flow conditions. Treat runoff water containing high sediment loads in a sediment-trapping device before releasing the runoff to a level spreader.

4.0 Stormwater Performance Summary

MS-8: CONCENTRATED RUNOFF – Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

MS-11: OUTLET PROTECTION – Before newly constructed stormwater conveyance channels or pipes are made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and receiving channel.

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Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: Low

5.0 Design Criteria

Use of the level spreader applies only where the spreader can be constructed on undisturbed soil and the area below the level lip is uniform with a slope of 10% or less and is stabilized by natural vegetation (Virginia Department of Environmental Quality [VDEQ] 1992).

Table C-ECM-14-1 Design Criteria Parameters	
Topic	**Requirement**
Capacity	Determine the capacity of the spreader by estimating peak flow from the 10-year storm. Restrict the drainage area so that maximum flows into the spreader will not exceed 30 cubic feet per second (cfs). See Appendix A – Hydrologic and Hydraulic Methods and Computations.
Spreader Dimensions	When water enters the spreader from one end, as from a diversion, select the appropriate length, width, and depth of the spreader from Table C-ECM-14-2. Construct the level spreader with a minimum depth of 6 inches, as measured from the lip. Increase the depth to expand temporary storage capacity, improve trapping of debris, and enhance settling of any suspended solids. Construct a 20-foot transition section in the diversion channel so the width of the diversion will smoothly meet the width of the spreader to ensure uniform outflow.
Grade	Provide a smooth transition grade, less than or equal to 1%, for the last 20 feet of the diversion channel entering the level spreader. Grade the level spreader channel to 0% grade. The side slopes of the spreader should be 2H:1V or flatter and should be tied into higher ground to prevent flow around the spreader.
Spreader Lip	*Vegetated spreader lips should have a maximum design flow of 4 cfs.* Use a rigid lip of non-erodible material, such as pressure-treated timbers or concrete curbing, for higher design flows. *Rigid spreader lips should have a maximum design flow of 30 cfs.* Note: Refer to Table C-ECM-13-2 to determine the length of the spreader lip based on design flow.
Outlet Area	Discharge the runoff from level spreader on a generally smooth area to preserve sheet flow and prevent concentration. This area should be well-vegetated with a maximum slope of 10%.
Vegetation	Seed and mulch all disturbed areas immediately after construction.

Sources: Henrico Department of Public Works 2022; VDEQ 1992; North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service (NCDEQ) 2013

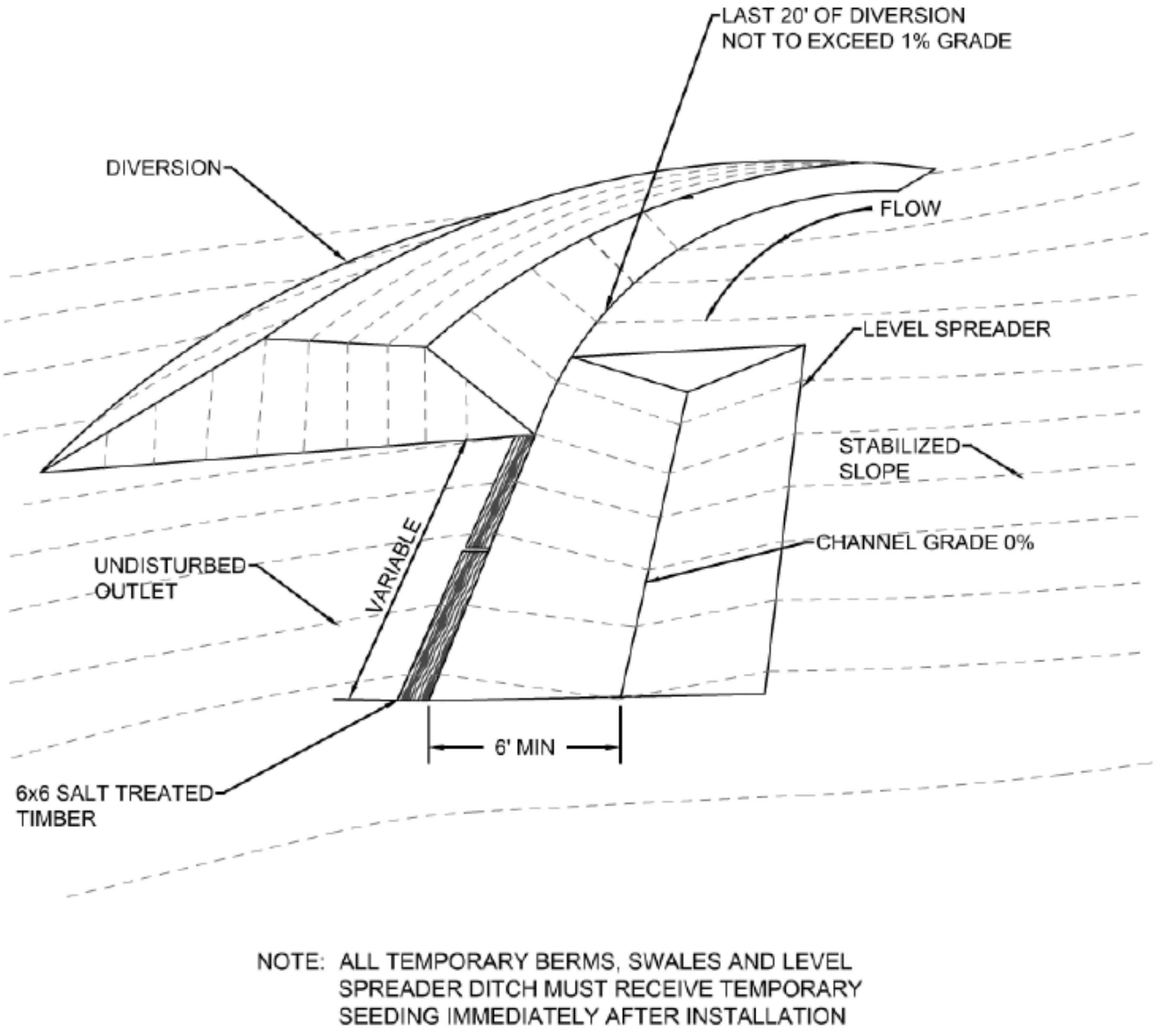
Table C-ECM-14-2 below provides the (1) minimum width of the level spreader, (2) the minimum depth of the level spreader along the entire length of the spreader, and (3) the minimum length of the level spreader based upon design flow to the level spreader from the vegetated diversion.

Table C-ECM-14-2 Level Spreader Sizing			
Minimum Dimensions for Level Spreader			
Design Flow (cfs)	**Spreader Width (feet)**	**Depth (feet)**	**Length (feet)**
0 – 10	6	0.5	10

Table C-ECM-14-2 Level Spreader Sizing			
Minimum Dimensions for Level Spreader			
10 – 20	6	0.6	20
20 – 30	6	0.7	30

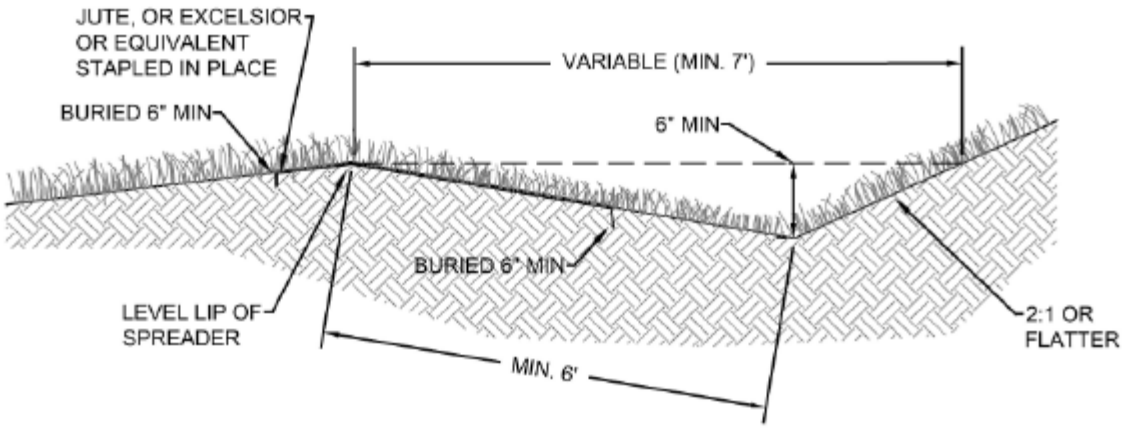
Source: NCDEQ 2013

Figure C-ECM-14-1 Level Spreader Perspective View

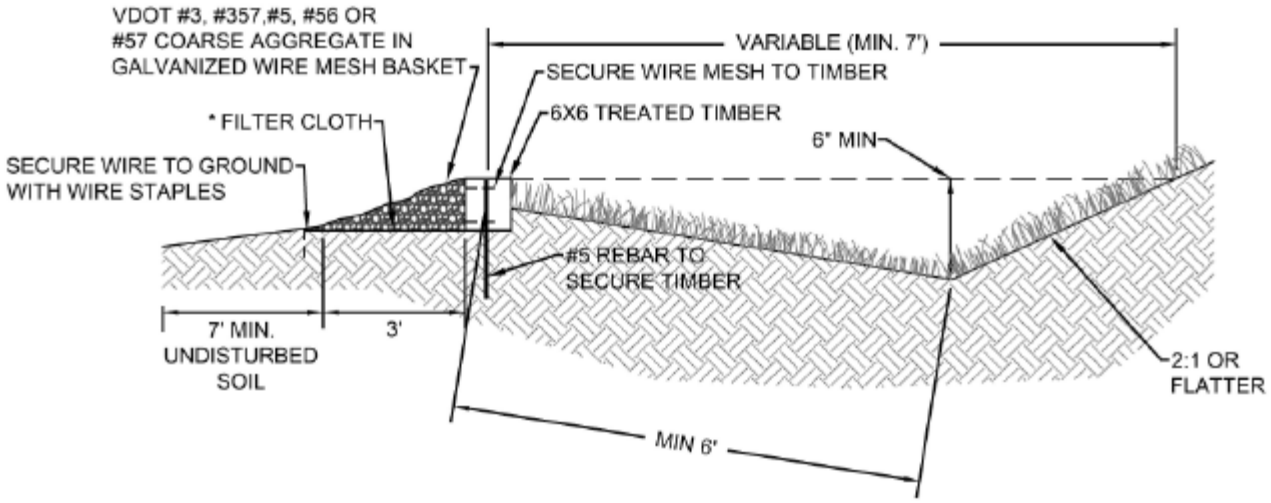


Source: NCDEQ 2013

Figure C-ECM-14-2 Level Spreader Cross-Sections



LEVEL SPREADER WITH VEGETATED LIP CROSS-SECTION



LEVEL SPREADER WITH RIGID LIP CROSS-SECTION

*Minimum physical requirements of filter cloth notes in STD C-ECM-13 RIP-RAP

Source: Virginia Department of Conservation and Recreation 2004; NCDEQ 2013

6.0 Construction Specifications

1. Construct level spreaders on undisturbed soil (not fill material).
2. Shape the entrance to the spreader so that runoff enters directly onto the 0% channel.

3. Construct a 20-foot transition section from the diversion channel to blend smoothly to the width and depth of the spreader.
4. Construct the spreader lip at 0% grade to ensure uniform spreading of stormwater runoff.
5. Vegetated Lip Only – Construct the spreader lip on undisturbed soil to uniform height and 0% grade over the length of the spreader. Protect the lip of an earthen level spreader with an erosion-resistant material, such as a reinforced erosion control blanket or turf reinforcement mat, to prevent erosion and enable establishment of vegetation.

   For a vegetated lip, install erosion control matting a minimum of 4 feet wide that extends 6 inches over the level lip. Bury the upstream edge at least 6 inches deep in a vertical trench. Secure the downstream edge in place with closely spaced, heavy-duty staples, at least 12 inches long. Install the protective covering for vegetated lip a minimum of 4 feet wide extending 6 inches over the lip and buried 6 inches deep in a vertical trench on the lower edge. Butt the upper edge against smoothly cut sod and securely hold in place with closely spaced heavy-duty wire staples (see).
6. Rigid Lip Only – Provide a smooth transition between the level spreader and the native ground downslope.

   Entrench the rigid level lip at least 2 inches below existing ground and securely anchor to prevent displacement. Install an apron of VDOT #1, #2, or #3 coarse aggregate to the top of the level lip and extended downslope at least 3 feet. Place filter fabric under stone and use galvanized wire mesh to hold stone securely in place (see).
7. Discharge the released runoff onto undisturbed stabilized areas with slope not exceeding 10%. Slope should be sufficiently smooth to preserve sheet flow and prevent flow from concentrating.
8. Immediately after construction, appropriately seed and mulch the entire disturbed area of the spreader.
9. Ensure that the end of the level spreader is constructed high enough to prevent water conveyance at this location and fulfill the proper intent of the best management practice.

7.0 Operations and Maintenance Considerations

Inspect the level spreader at least once a year and after every measurable rainfall event (i.e., 0.1 inch per 24 hours) and make repairs immediately as needed.

Maintain the level spreader lip at zero grade to allow proper function of the measure. Avoid the placement of any material on the level spreader and prevent construction traffic across the structure.

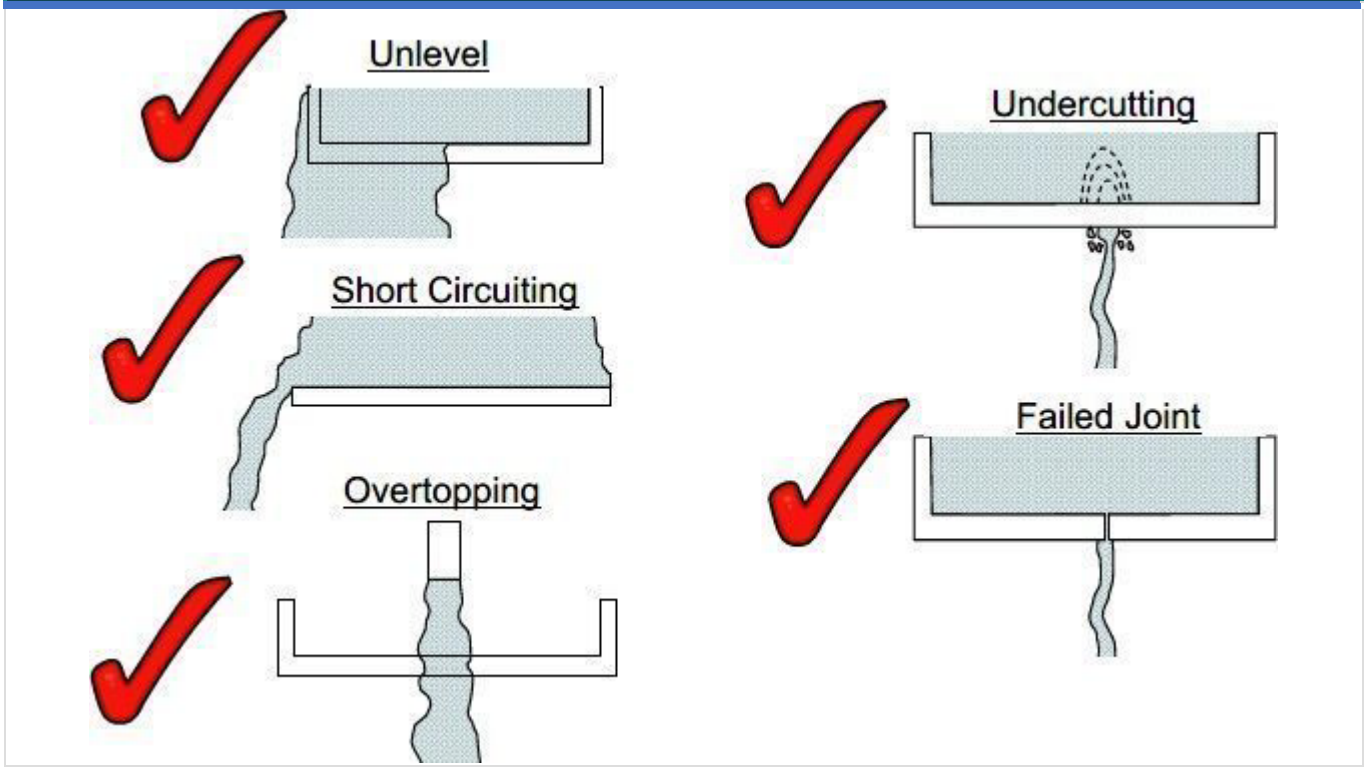
Immediately repair any damage to the level spreader. Inspect the level spreader in the same conditions for subsidence along the perimeter of the measure.

Inspect for low points, sags, cracks, breaks, etc. in the level spreader that would result in concentrated flow discharging over the spreader. Any identified alterations to the grade of the level spreader must be repaired immediately.

Debris buildup within the channel should be removed when it has accumulated to 20% of channel capacity.

7.1 Common Level Spreader Failures

Figure C-ECM-14-4 Common Level Spreader Failures



Source: Rocco 2007

Inspect the downstream area of the level spreader for any development of water channelization or subsidence.

Inspect the upstream diversion channel after every rainfall. If any changes in soil morphology are observed within the undisturbed soil and are seen to be forming a sinkhole or soil intrusion, carefully monitor that location. If an existing sinkhole is discovered where runoff is found to be diverting, that sinkhole may be transitioned and classified into a United States Environmental Protection Agency (USEPA) Class V injection well. More information on Class V injection wells is provided at the following USEPA website: https://www.epa.gov/uic/basic-information-about-class-v-injection-wells#:~:text=A%20Class%20V%20well%20is%20used%20to%20inject,simple%20shallow%20wells%20to%20complex%20experimental%20injection%20technologies (USEPA 2023).

8.0 References

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C-ECM-15 Outlet Protection

1.0 Definition

Outlet protection takes the form of structurally lined aprons or other forms of energy-dissipating devices placed at the outlets of pipes, curb openings, ditch turnouts, or paved channel sections to slow discharge velocity from the outlet to prevent an erosive condition.

– CAD and PDF for C-ECM-15 Outlet Protection

2.0 Purpose and Applicability of Best Management Practice

Outlet protection prevents scouring at stormwater outlets, protects the outlet structure, and minimizes the potential for downstream erosion by reducing the velocity and energy of concentrated stormwater flows. Outlet protection applies to the outlets of all pipes and engineered channel sections. Discharge velocities from pipe outfalls, outlet channels, or similar structures should not cause erosion in downstream channels.

3.0 Planning and Considerations

The outlets of pipes and structurally lined channels are points of critical erosion potential. Stormwater transported through man-made conveyance systems at design capacity generally reaches a velocity that exceeds the capacity of the receiving channel or area to resist erosion. To prevent scour at stormwater outlets, a flow transition structure is needed, which will absorb the initial impact of the flow and reduce the flow velocity to a level that will not erode the receiving channel or area.

The most used device for outlet protection is a rock lined apron. These aprons are generally lined with riprap, grouted riprap, or concrete and are constructed at a zero grade for a distance that is related to the outlet flowrate and the tailwater level. Criteria for designing such an apron are contained in this practice. The site grading plan and drainage structure profiles must accommodate and show the full length of the outlet protection apron at zero grade.

Consider riprap stilling basins or plunge pools to reduce flow velocity rapidly in lieu of aprons where high flows would require excessive apron length. See the plunge pool design guidance in this specification. In karst areas, use an impermeable liner in lieu of a filter fabric to prevent infiltration of stormwater into groundwater at the site location.

Consider other energy dissipaters, such as concrete impact basins or paved outlet structures, where site conditions warrant. Alternative methods of energy dissipation are identified in Hydraulic Design of Energy Dissipaters for Culverts and Channels (Thompson and Kilgore 2006).

4.0 Stormwater Performance Summary

MS-11: OUTLET PROTECTION – Before any newly constructed stormwater conveyance channel can be made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and the receiving channel.

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Erosion Control Efficiency: High

Sediment Removal Efficiency: Low

5.0 Design Criteria

For outlet protection design standards within the Virginia Department of Transportation (VDOT) right-of-way, the designer should consult with the appropriate VDOT Drainage Manual.

The design of structurally lined aprons at the outlets of pipes and paved channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous rock linings of channels or streams; see Stormwater Conveyance Channel (C-ECM-09).

Do not protect the pipe or channel outlets at the tops of cut slopes or on slopes steeper than 10% using just outlet protection because of the reconcentration and large velocity of flow encountered as the flow leaves the structural apron.

Adequate outlet protection should be installed and stabilized before newly constructed stormwater conveyance channels or pipes are made operational.

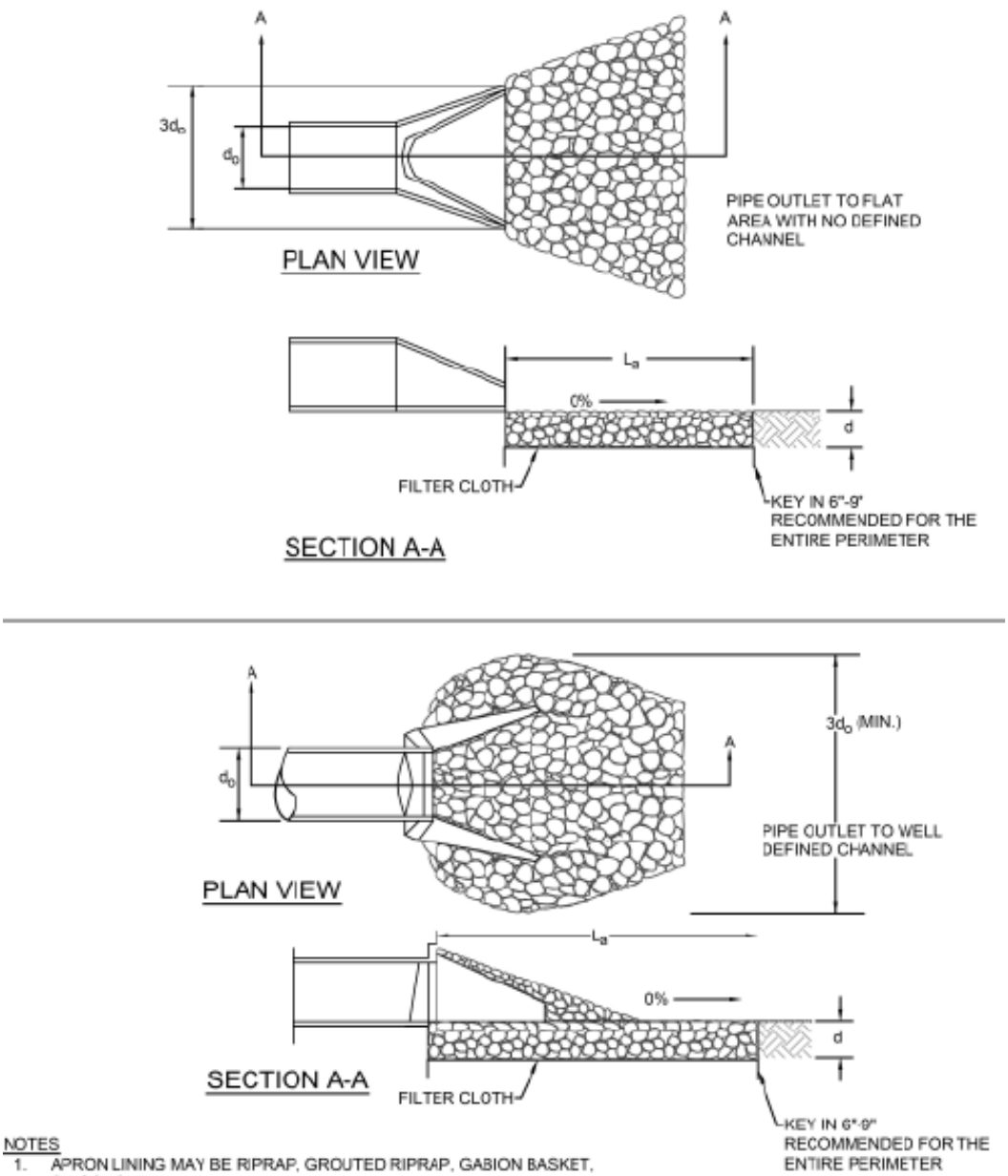
Design outlet protection according to the following criteria.

Pipe Outlets

Table C-ECM-15-1 Outlet Protection Design Criteria Specifications	
Parameter	**Notes on Proper Use**
Tailwater Depth	Determine the depth of tailwater immediately below the pipe outlet for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth (see Appendix A, Hydraulic and Hydrologic Calculations). *If the tailwater depth is less than half the diameter of the outlet pipe, classify it as a* **Minimum Tailwater Condition**. *If the tailwater depth is greater than half the pipe diameter, classify it as a* **Maximum Tailwater Condition**. Pipes that outlet onto flat areas with no defined channel may be assumed to have a **Minimum Tailwater Condition**. Notably, in most cases where post- development stormwater runoff has been concentrated or increased, Minimum Standard MS-19 will be satisfied only by outfall into a defined channel.
Apron Length	Determine the apron length from the curves according to the tailwater condition: Minimum Tailwater (see Figure C-ECM-15-3) and Maximum Tailwater (see Figure C-ECM-15-4)
Apron Width	When the pipe discharges directly into a well-defined channel, the apron should extend across the channel bottom and up the channel banks to an elevation 1 foot above the maximum tailwater depth or to the top of the bank (whichever is less). If the pipe discharges onto a flat area with no defined channel, the width of the apron should be determined as follows: 1. The upstream end of the apron, adjacent to the pipe, should be three times as wide as the inner diameter of the outlet pipe. 2. For a **Minimum Tailwater Condition**, the downstream end of the apron should be as wide as three times the outlet pipe inner diameter plus the length of the apron. For a **Maximum Tailwater Condition**, design the downstream end to be as wide as three times the pipe diameter plus 0.4 time the length of the apron.
Thickness	Design the minimum thickness of riprap to be 1.5 times the diameter of the maximum stone size but not less than 6 inches.
Bottom Grade	Design and construct the apron with no slope along its length (0% grade). Design and construct structurally lined aprons at the outlets of pipes and paved channels to be at a 0% grade for a distance related to the outlet flowrate and the tailwater depth.
Sideslopes	If the pipe discharges into a well-defined channel, ensure the sideslopes of the channel are not steeper than 2H:1V.
Alignment	Locate the apron so there are no bends in the horizontal alignment.
Materials	The apron may be lined with riprap, grouted riprap, concrete, or gabion baskets. Determine the median sized stone (d50) for riprap from the curves on Figure C-ECM-15-3 and Figure C-ECM-15-4 according to the tailwater condition. Ensure the gradation, quality, and placement of riprap conform to Riprap (C-ECM-13).

Table C-ECM-15-1 Outlet Protection Design Criteria Specifications	
Parameter	**Notes on Proper Use**
Filter Fabric	In all cases, place filter fabric between the riprap and the underlying soil to prevent soil movement into and through the riprap. Use a material that meets or exceeds the physical properties for filter fabric identified in Riprap (C-ECM-13). Use AASHTO M-288, Class II Woven Filter Cloth or approved equivalent. See Figure C-ECM-15-1 for orientation details. In karst areas, use an impermeable liner, in lieu of a filter fabric, that meets field strength requirements to be able to withstand tearing, breaking, and other challenges during heavy storm events.

Figure C-ECM-15-1 Pipe Outlet Conditions



NOTES
1. APRON LINING MAY BE RIPRAP, GROUTED RIPRAP, GABION BASKET, OR CONCRETE.
2. La IS THE LENGTH OF THE RIPRAP APRON AS CALCULATED USING FIGURE C-ECM-15-3 AND FIGURE C-ECM-15-4
3. d = 1.5 TIMES THE MAXIMUM STONE DIAMETER, BUT NO LESS THAN 6 INCHES.

Source: VA DSWC

Outlet Protection Design

When designing outlet protection for a channel or swale, use the guidance for a pipe having an equivalent cross-sectional area and design discharge to the channel or swale.

When a pipe is flowing full, the anticipated velocity can be calculated from the continuity equation:

$$V = \frac{Q}{A}$$

where:

V = Velocity (feet per second [fps])

Q = Design Discharge (cubic feet per second [cfs])

A = Cross-sectional Area of the Pipe (square feet [ft2])

When a pipe is not flowing full, a different procedure should be used to determine the velocity. Due to the increased friction that occurs along the wetted perimeter, full flow does not represent the greatest flow capacity of a pipe. For circular pipes, peak flow occurs at 93% of the total inside diameter. Likewise, the average velocity of a pipe flowing half full is equal to that for one flowing full. Therefore, the anticipated velocity should be determined either using Manning's equation (for circular channels), standard design nomographs, or Figure C-ECM-15-5**, limited to pipes with gradients <0.05 ft/ft.**

To use Figure C-ECM-15-5, the full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} D^{\frac{8}{3}} S^{\frac{1}{2}}$$

Use the Continuity Equation to determine the full flow velocity:

$$V_f = \frac{Q_f}{A}$$

Calculate the ratio of partial to full flow discharge:

$$\frac{d}{D} = \frac{Q_d}{Q_f}$$

where:

d/D = Ratio of Part Full to Full Flow Discharge

Q_d = Design Discharge (cfs)

Q_f = Full-Flow Discharge (cfs)

D = Diameter (ft)

S = Slope of pipe

Using Figure C-ECM-15-5, find the value for the d/D ratio. Project a vertical line from the d/D ratio upward to the FLOW curve, then a horizontal line to the VELOCITY curve, and then follow a vertical line downward to determine the velocity ratio. Multiply the velocity ratio by the velocity calculated from the Continuity Equation to determine the less-than-full velocity.

For pipes with slopes equal to or greater than 0.05 ft/ft, use the Manning's equation. The velocity is calculated for full flow conditions even though the pipe is typically flowing only partially full. Partial flows will be very close to the full-flow velocity for depths of flow between 30% and 100% of the pipe diameter in steep slope conditions. Manning's equation for full pipe flow is as follows:

$$V = \frac{1.486}{n} \left[\frac{D}{4}\right]^{\frac{2}{3}} \sqrt{S}$$

where:

V = Velocity (feet per second [ft/s])

D = Pipe diameter (ft)

S = Pipe slope (feet per foot [ft/ft])

For pipes with high anticipated velocities (>13.0 ft/s), drop structures or other energy reducing structures are recommended to reduce velocity before discharge.

Paved Channel Outlets

1. The flow velocity at the outlets of paved channels flowing at design capacity should not exceed the permissible velocity of the receiving channel (see Table C-ECM-15-2 and Table C-ECM-15-3).
2. The end of the paved channel should merge smoothly with the receiving channel section. There should be no flooding at the end of the paved section. Where the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section, typically of riprap, should be provided. The maximum side divergence of the transition should be 1 in 3F where:

$$F = \frac{V}{\sqrt{gd}}$$

where:

F = Froude number

V = Velocity at beginning of transition (ft/s)

d = depth of flow at beginning of transition (ft)

g = 32.2 feet per second squared (ft/s2)

3. Bends or curves in the horizontal alignment at the transition are not allowed unless the Froude number (F) is 1.0 or less, or the section is specifically designed for turbulent flow. The transition from supercritical flow (F > 1) to a subcritical flow (F < 1) should occur within the riprap apron and should be calculated before installation of a riprap outlet protection device to ensure accuracy and quality of the measure.

Example:

For a paved channel transitioning into a grass-lined channel, with a grassed channel slope of 8% vegetated with Bermudagrass, the permissible velocity of the grass-lined channel in erosion-resistant soils should be no greater than 5 fps. If the depth of the water in the grass-lined channel is 6 inches, and the depth of the water in the paved channel is 12 inches, the following velocity comparison/equivalency can be used:

$$\frac{V_{PC}}{\sqrt{gd_{PC}}} = \frac{V_{GC}}{\sqrt{gd_{GC}}}$$

where:

PC = Paved Channel

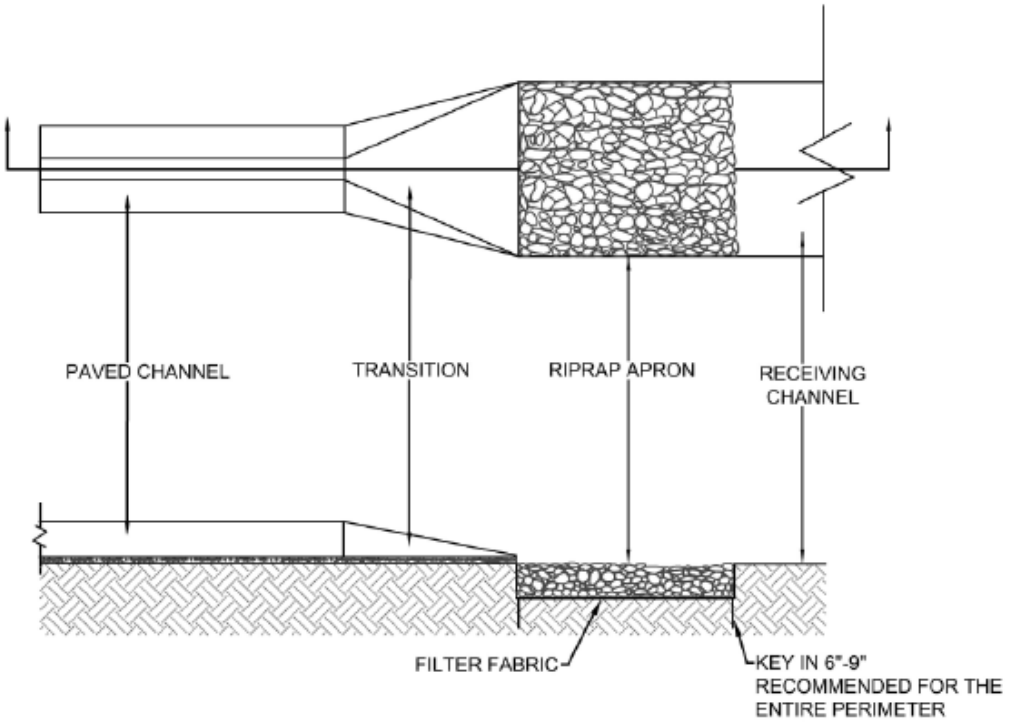
GC = Grass Channel

Therefore:

$$V_{PC} = \frac{V_{GC}}{\sqrt{gd_{GC}}}\sqrt{gd_{PC}}$$

$$V_{PC} = \frac{5}{\sqrt{32.2*0.5}}\frac{5}{\sqrt{32.2*0.5}}\sqrt{32.2*1} = 7.07 \text{ ft/s}$$

Figure C-ECM-15-2 Paved Channel Outlet Specifications



NOTES:

1. RIPRAP APRON REDUCES THE FLOW VELOCITY BELOW THE PERMISSIBLE VELOCITY OF THE NATURAL RECEIVING CHANNEL.
2. TRANSITION SIDE DIVERGENCE IS 1 IN 3 FEET, WHERE:

$$F = \text{FROUDE NUMBER} = \frac{V}{\sqrt{gd}}, \text{ WHERE}$$

V = VELOCITY AT THE BEGINNING OF THE TRANSITION
d = DEPTH OF FLOW AT THE BEGINNING OF THE TRANSITION
g = 32.2 ft/s^2

Source: Va. DSWC

Table C-ECM-15-2 Permissible Velocities for Grass-Lined Channels

Channel Slope	Lining	Erosion-Resistant Soil Velocity (ft/s)	Easily Eroded Soil Velocity (ft/s)
0 – 5%	Bermudagrass	6	4.5
	Reed canarygrass Tall fescue Kentucky bluegrass	5	3.75
	Grass-legume mixture	4	3

Table C-ECM-15-2 Permissible Velocities for Grass-Lined Channels			
Channel Slope	**Lining**	**Erosion-Resistant Soil Velocity (ft/s)**	**Easily Eroded Soil Velocity (ft/s)**
	Red fescue Redtop Annual Lespedeza Small grains Temporary vegetation	2.5	1.875
5 – 10%	Bermudagrass	5	3.75
	Reed canarygrass Tall fescue Kentucky bluegrass	4	3
	Grass-legume mixture	3	2.25
>10%	Bermudagrass	4	3
	Reed canarygrass Tall fescue Kentucky bluegrass	3	2.25

Source: Schwab, G., et al., 1966

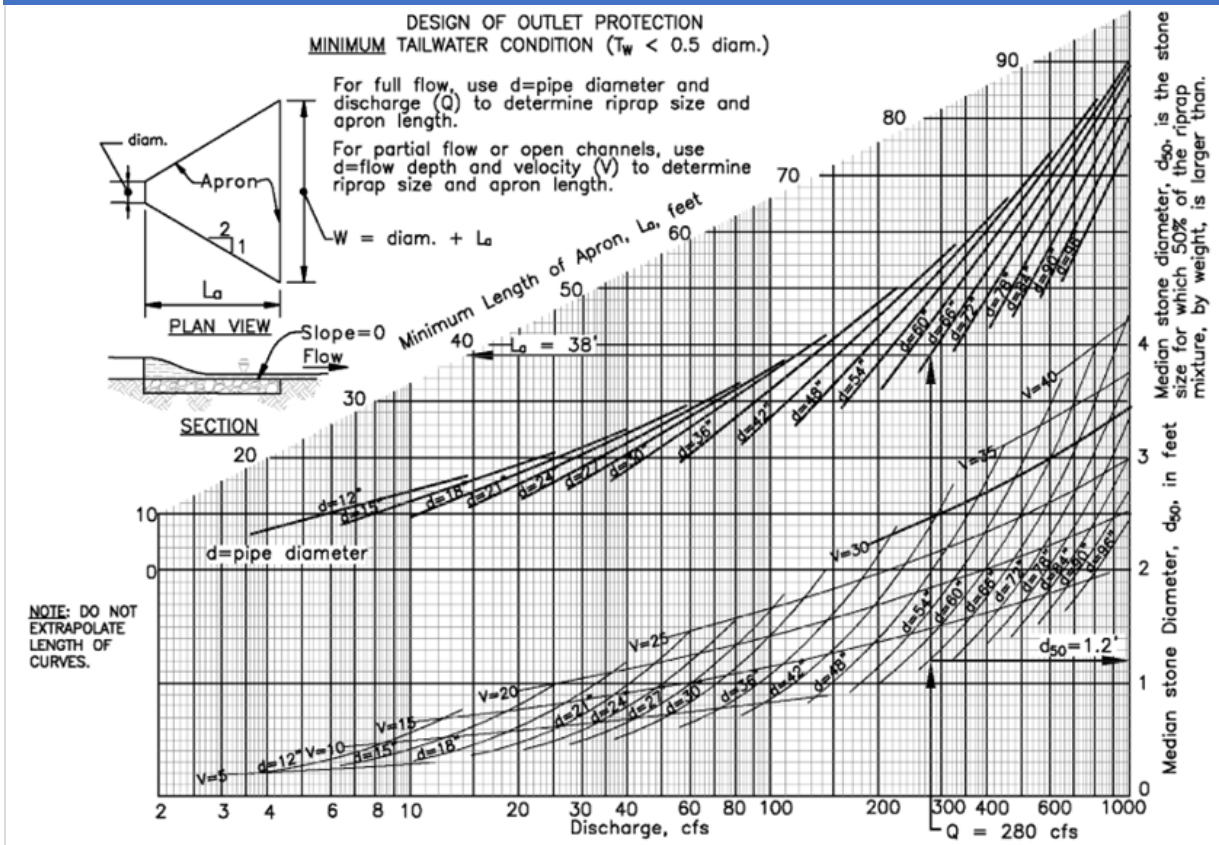
1. A velocity of 3 ft/s should be the maximum if only a sparse cover can be established or maintained because of shade, soils, or climate.
2. A velocity of 3 to 4 ft/s should be used under normal conditions if the vegetation is to be established by seeding.
3. A velocity of 4 to 5 ft/s should be used only if a dense, vigorous sod is obtained quickly or if water can be diverted out of the waterway while vegetation is establishing.
4. A velocity of 5 to 6 ft/s may be used on well established, good quality sod. Special maintenance may be required.
5. A velocity of 6 to 7 ft/s may be used only on established, excellent quality sod and only under special circumstances in which flow cannot be handled at a lower velocity. Under these conditions, special maintenance and appurtenant structures will be required.
6. If stone centers or other erosion-resistant materials supplement the vegetative lining, the velocities in the Table C-ECM-15-2 may be increased by 2 ft/s.
7. When base flow exists, a rock-lined low-flow channel should be designed and incorporated into the vegetative lined channel section.

Table C-ECM-15-3 Permissible Velocities for Earth Linings	
Soil Types	**Permissible Velocities (ft/s)**
Fine Sand (non-colloidal)	2.5
Sandy Loam (non-colloidal)	2.5
Silt Loam (non-colloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0

Table C-ECM-15-3 Permissible Velocities for Earth Linings	
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (non-colloidal)	5.0
Graded, Silt to Cobbles (colloidal)	5.5
Alluvial Silts (non-colloidal)	3.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (non-colloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Plans	6.0

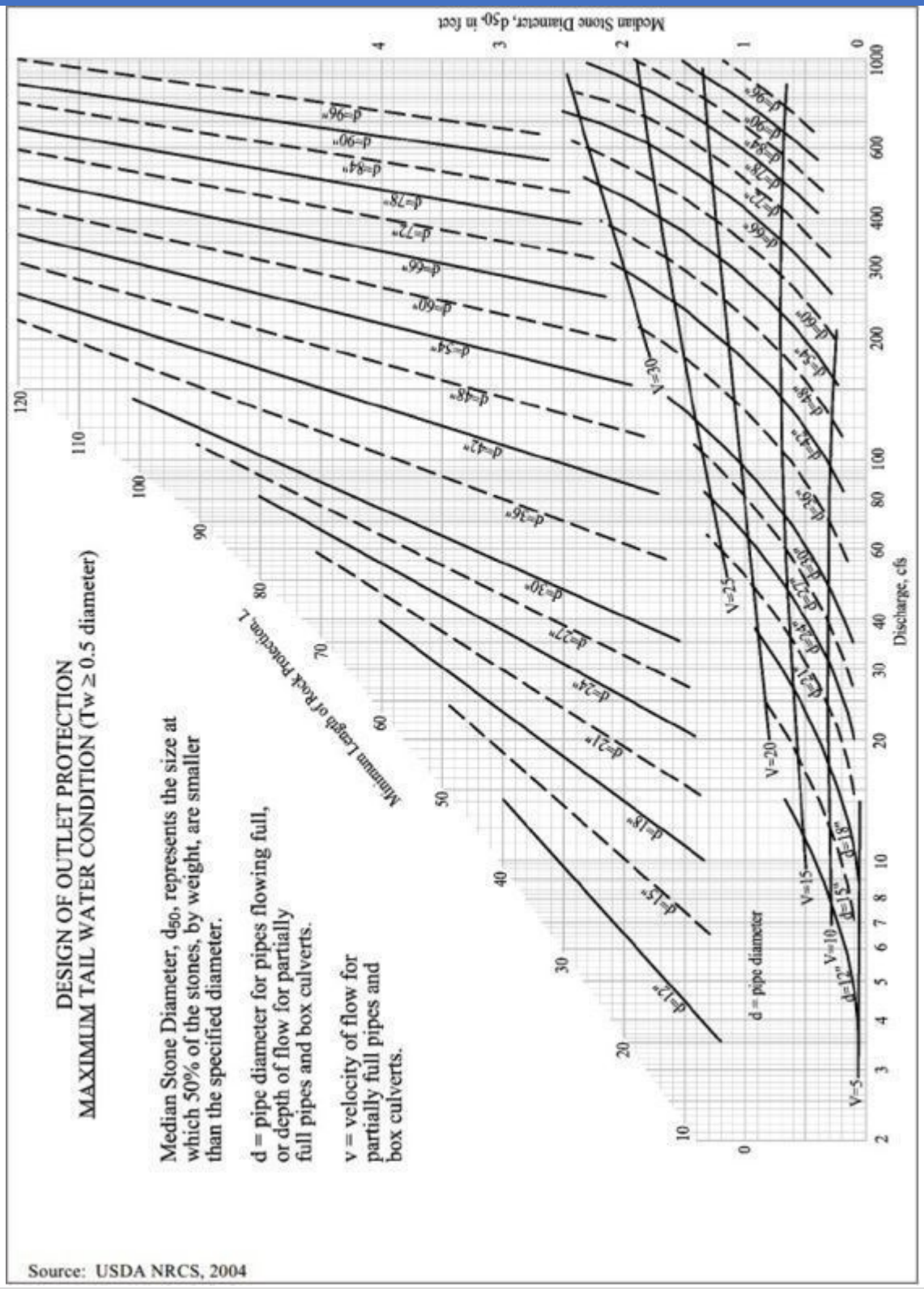
Source: Schwab, G., et al, 1966

Figure C-ECM-15-3 Minimum Tailwater Condition Tw < 0.5*d



Source: DC E&S Manual, 2017

Figure C-ECM-15-4 Maximum Tailwater Condition Tw >= 0.5*d



Nomograph Use Process

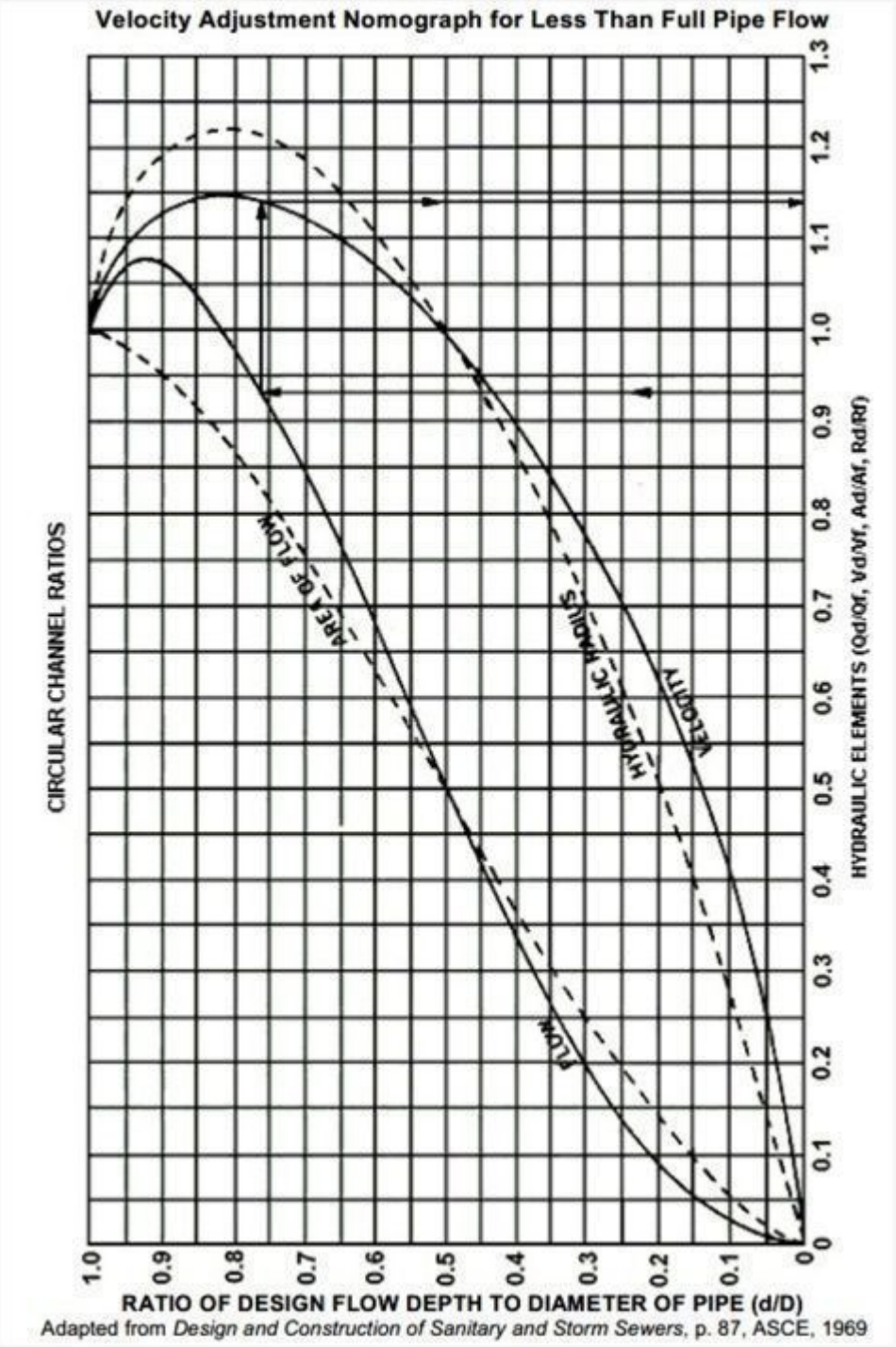
Step1. Find design flow (Q) or velocity (V); this is the flows that directly travels into the outlet protection apron as seen in the outlet protection design equations.

Step2. Find median stone size (D50); this corresponds to the intersection of the flow/velocity and the lower curved line of the proposed influent pipe size to the outlet protection apron. Take the intersection point and draw a line perpendicular to the RIGHT SIDE of the nomograph, indicating the appropriate median stone size (D50).

Step3. Find the apron length (L); this corresponds to the intersection of the flow/velocity and the upper curved line of the proposed influent pipe size to the outlet protection apron. Take the intersection point and draw a line to the LEFT SIDE of the nomograph, indicating the appropriate apron length (L).

*These two parameters allow the design engineer to properly size the outlet protection apron and propose an appropriate location for the measure.

Figure C-ECM-15-5 Circular Channel Ratios



Source: ASCE 1969

Plunge Pool (see Figure C-ECM-15-6 – Plunge Pool Design

Where discharge velocity and energy at a pipe outlet are sufficient to erode the downstream channel reach, pipe outlets are cantilevered, or high flows require excessive apron length, a plunge pool is a means of reducing velocity before traditional outlet protection.

This practice applies to outlets of all types such as road culverts, sediment basins, and stormwater management facilities. Plunge pools are an alternative to rock outlet protection and are preferable where space is constrained. A plunge pool may be temporary or permanent based on design. The designer should note that traditional outlet protection, such as an apron, may be required downstream of the plunge pool. Base the plunge pool location on land use and feasibility; intended use is limited to the proposed or existing channel. For calculations of scouring, refer to Chapter 10 of HEC-14 (Riprap Basin and Aprons).

Plunge Pool Design

1. Select type of plunge pool (larger stone required for Type 1):

   Type I: Plunge pool is depressed half the size of the culvert rise.

   Type II: Plunge pool is depressed the full height of the culvert rise.

2. Determine the riprap (d50) stone size for the plunge pool type and design storm flow.

   Type I: $d50 = (0.0125d^2/Tw) \times (Q/d^{2.5})^{4/3}$

   Type II: $d50 = (0.0082d^2/Tw) \times (Q/d^{2.5})^{4/3}$

3. Determine plunge pool dimensions.

   $C = (3 \times d) + (6 \times F)$

   $B = (2 \times d) + (6 \times F)$

   where:

   d_{50} = the median stone size (feet), refer to Riprap (C-ECM-12)

   d = the culvert diameter or span (feet)

   T_w = the tailwater depth (feet)

   Q = the design flow for the culvert, minimum 10-year, 24-hour storm (cfs)

   B = the plunge pool width (feet)

   C = the plunge pool length (feet)

   $D = 2 \times d_{50}$ = riprap thickness (feet)

   E = the culvert diameter or span (feet) equal to d

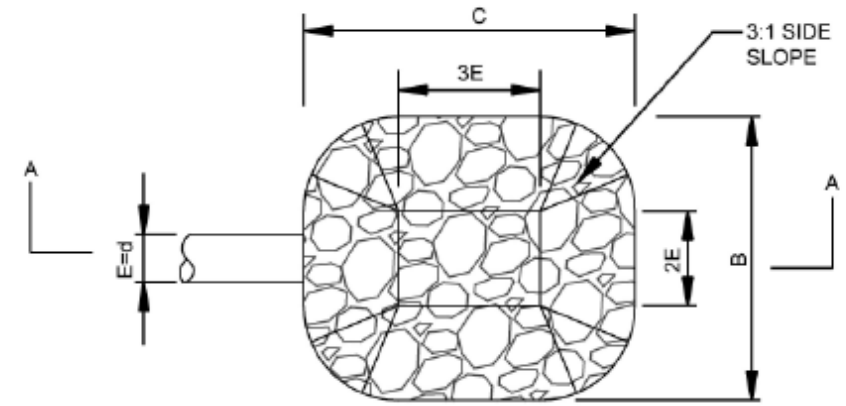
   3E = the plunge pool bottom length in feet

   2E = the plunge pool bottom width (feet)

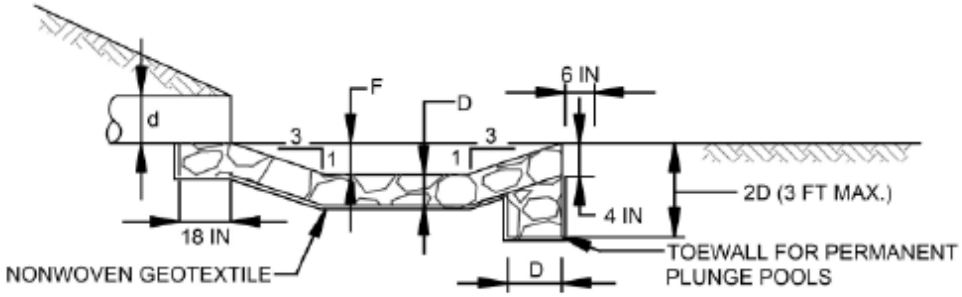
   F = plunge pool depth (feet) = d (for Type II) or 0.5 d (for Type I)

4. For permanent uses, provide a toe wall at the downstream end at a depth twice the (D) dimension and at a width equal to the (D) dimension on non-woven geotextile. Extend the riprap a minimum of 18 inches under the outlet pipe if the outlet does not have a footer or headwall.
5. Provide an underdrain to a suitable outfall if standing water in the plunge pool is an issue or as required by the certified plan reviewer.
6. Provide the design values on the plans for the following dimensions indicated on Figure C-ECM-15-6: B, C, D, E, and F.

Figure C-ECM-15-6 Plunge Pool Design



PLAN VIEW



SECTION A-A

CONSTRUCTION SPECIFICATIONS

1. USE SPECIFIED CLASS OF RIPRAP.
2. USE NONWOVEN GEOTEXTILE AS SPECIFIED IN SECTION H-1 MATERIALS, AND PROTECT FROM PUNCHING, CUTTING, OR TEARING. REPAIR ANY DAMAGE OTHER THAN AN OCCASIONAL SMALL HOLE BY PLACING ANOTHER PIECE OF GEOTEXTILE OVER THE DAMAGED PART OR BY COMPLETELY REPLACING THE GEOTEXTILE. PROVIDE A MINIMUM OF ONE FOOT OVERLAP FOR ALL REPAIRS AND FOR JOINING TWO PIECES OF GEOTEXTILE.
3. PREPARE THE SUBGRADE FOR THE PLUNGE POOL TO THE REQUIRED LINES AND GRADES. COMPACT ANY FILL REQUIRED IN THE SUBGRADE TO A DENSITY OF APPROXIMATELY THAT OF THE SURROUNDING UNDISTURBED MATERIAL.
4. EMBED THE GEOTEXTILE A MINIMUM OF 4 INCHES AND EXTEND THE GEOTEXTILE A MINIMUM OF 6 INCHES BEYOND THE EDGE OF THE SCOUR HOLE.
5. STONE FOR THE PLUNGE POOL MAY BE PLACED BY EQUIPMENT. CONSTRUCT TO THE FULL COURSE THICKNESS IN ONE OPERATION AND IN SUCH A MANNER AS TO AVOID DISPLACEMENT OF UNDERLYING MATERIALS. DELIVER AND PLACE THE STONE FOR THE PLUNGE POOL IN A MANNER THAT WILL ENSURE THAT IT IS REASONABLY HOMOGENEOUS WITH THE SMALLER STONES AND SPALLS FILLING THE VOIDS BETWEEN THE LARGER STONES. PLACE STONE FOR THE PLUNGE POOL IN A MANNER TO PREVENT DAMAGE TO THE GEOTEXTILE. HAND PLACE TO THE EXTENT NECESSARY.
6. AT THE PLUNGE POOL OUTLET, PLACE THE STONE SO THAT IT MEETS THE EXISTING GRADE.
7. MAINTAIN LINE, GRADE, AND CROSS SECTION. KEEP OUTLET FREE OF EROSION. REMOVE ACCUMULATED SEDIMENT AND DEBRIS. AFTER HIGH FLOWS INSPECT FOR SCOUR AND DISLODGED RIPRAP. MAKE NECESSARY REPAIRS IMMEDIATELY.

Source: Maryland Department of the Environment 2011

6.0 Construction Specifications

1. Install and stabilize adequate outlet protection before newly constructed stormwater conveyance channels or pipes are made operational.
2. Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan. Compact any fill required in the subgrade to the density of the surrounding undisturbed material. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.
3. Construct the riprap and gravel filter to conform to the specified grading limits shown on the plans.
4. Use filter fabric, when applicable, that meets the design requirements, and properly protect from punching or tearing during installation. Repair any damage by removing the riprap and placing another piece of filter fabric over the damaged area. Overlap all connecting joints so the top layer is above the downstream layer a minimum of 1 foot. If the damage is extensive, replace the entire filter fabric.
5. Riprap may be placed by equipment; but take care to avoid damaging the filter.
6. Riprap may be field stone or rough quarry stone. Use riprap that is hard, angular, highly weather-resistant, free of fines, and well graded.
7. Construct the apron on zero grade with no overfall at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.
8. Ensure that the apron is properly aligned with the receiving stream and preferably straight throughout its length. If a curve is needed to fit site conditions, place it in the upper section of the apron.
9. Immediately after construction, stabilize all disturbed areas with vegetation.

Where riprap is grouted, apply the following construction specifications:

1. Take precautions to prevent uncured concrete from coming into contact with any surface waters.
2. Place grout in a layer at a thickness equivalent to the d50 stone size over the entire extent of the apron before rock placement.
3. After rock placement, fill void spaces with grout.

7.0 Operations and Maintenance Considerations

Inspect riprap outlet structures weekly and after significant (0.5-inch or greater) rainfall events to identify any erosion around or below the riprap or if stones have been dislodged.

Immediately do all needed repairs to prevent further damage. Accumulated sediment and debris must be removed.

8.0 References

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C-ECM-16 Flexible Transition Mat

1.0 Definition

A flexible scour-protection system that is used as a synthetic alternative to riprap outlet protection.

2.0 Purpose and Applicability of Best Management Practice

A transition mat is a high-density polyethylene (HDPE), ultraviolet (UV) stabilized, plastic sheet approximately 4 feet by 4 feet by 0.5 inch thick that contains multiple voids that allow vegetation to grow through or small gravel and pebbles to accumulate and stabilize the area. The mat protects the area at pipe outlets from scour until the water spreading out in the channel diminishes the turbulent forces. The channel downstream of the outlet, where flow becomes uniform, should still be evaluated to ensure that the channel lining can withstand the anticipated shear stress and/or velocity.

Transition mats may also be used for other applications (e.g., curb outfalls, spillways, overflow structures, stream banks, slopes) if manufacturer's recommendations are followed.

3.0 Planning and Considerations

- Install flow transition mats on a smooth, level, side-to-side (across the width of the flow area) surface to avoid water concentration; refer to Outlet Protection (BMP C-ECM-15).
- Grade the surface where necessary to remove any unevenness.
- Where a change in slope is greater than 25% (e.g., slope changes from 1% to greater than 26%), transition mats are not recommended.
- Transition mats are not appropriate for high-velocity discharges greater than 16 feet per second (fps).
- Locate the finish elevation of the tops of the mats at or slightly below (3-inch maximum) the pipe outlet.
- The width of the mat should be equal to the full width of the downstream channel across the channel bottom and side slopes. Allow for as much expansion of flow width as possible in the design when discharging directly into surface water to reduce velocities and promote infiltration.
- Ensure the downstream slope is as flat as possible to avoid increasing the velocity.
- Install a seeded turf reinforcement mat (TRM) underlayment where thick sod is not present. Use a high-performance TRM for slopes greater than 10H:1V, with the TRMs capable of withstanding velocities of at least 5.5 fps.
- If the following conditions are present, use a double layer of mats, with the open area of the second layer offset from those of the first layer.

- The installation is located on erodible soils or subsidence-prone soils characteristic of karst terrain.
- The installation is in an environmentally sensitive area.
- The anticipated discharge velocity exceeds 7 fps.
- The slope on which the mat is placed is 10H:1V or steeper.

- Anchor transition mats to achieve consistent contact with the underlying surface and prevent seepage underneath the mat.
- Locate the outlet and transition mat where adequate sunlight is available to promote healthy vegetation.

4.0 Stormwater Performance Summary

MS-11: OUTLET PROTECTION – Before newly constructed stormwater conveyance channels or pipes are made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and receiving channel.

9VAC25-875-560

Erosion Control Efficiency: High

Sediment Removal Efficiency: Low

5.0 Design Criteria

Design the outlet protection to withstand the 10-year storm event. Table C-ECM-16-1 lists the recommended dimensions for transition mat and TRM (if used) installations based on pipe diameter.

Table C-ECM-16-1 Design Criteria Specifications

Flexible Transition Mat Application				
Pipe Diameter (inches)	Discharge[a,b,c] (cfs)	Transition Mats		TRM
		Width (feet) x Length (feet)	Quantity	Width (feet) x Length (feet)
12	8	4 x 4	1	6 x 8
24	30	4 x 8	2	11 x 12
36	75	8 x 12	6	17 x 16
48	100	12 x 16	12	23 x 20

Notes:

cfs = cubic feet per second

a. a Provide alternative methods of outlet protection if the design discharge exceeds that for the diameter shown.
b. b Verify discharge rates based on pipe diameters and pipe slopes using the 10-year storm to ensure that discharge quantities coincide with those in the table.
c. c Do not exceed the manufacturer's specification for maximum discharge to the transition mat regardless of the discharge shown in the table above.

6.0 Construction Specifications

1. Continue soil cover beyond the outlet apron area to properly protect the downstream channel and prevent head cutting.

2. Install a soil cover (seeded TRM, sod, or both) across the full width of channel, including the bottom and up both side slopes.
3. Install transition mats at a maximum of 1 to 3 inches below the flowline of the culvert or culvert apron. Install so that there are no waterfall impacts onto the transition mats.
4. Install anchors per manufacturer's installation guidelines.

7.0 Operations and Maintenance Considerations

Failure of a transition mat has occurred when a rill forms under the mat. If rills form under the mat, remove the mat, grade the rill, and provide a higher form of protection. Transition mats are generally permanent installations, and maintenance should not be necessary.

Used in a temporary installation, the transition mats and TRMs can be picked up and moved when appropriate.

Mowing over a vegetated transition mat is allowed; a minimum height of 4 inches is recommended. Mowing is not recommended where soft, saturated soils exist.

Inspect transition mats for underlying subsidence in karst areas.

8.0 References

Iowa Department of Natural Resources. 2006. Iowa Construction Site Erosion Control Manual. Available online at: https://publications.iowa.gov/8127/.

Pennsylvania Department of Environmental Protection. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

C-ENV-01 Vegetative Streambank Stabilization

1.0 Definition

Vegetative streambank stabilization is the use of vegetation to stabilize streambanks.

– CAD and PDF files for C-ENV-01 Vegetative Streambank Stabilization

2.0 Purpose and Applicability of Best Management Practice

Vegetative streambank stabilization is used to protect streambanks from the erosive forces of flowing water along banks in creeks, streams, and rivers subject to erosion from excess runoff.

Vegetative streambank stabilization is generally applicable where bankfull flow velocity does not exceed 5 feet per second (ft/s) and soils are erosion-resistant. At flows higher than 5 ft/s, structural measures are generally required to stabilize bank soils.

Vegetative streambank stabilization does not apply to the banks of streams subject to tidal influence.

3.0 Planning and Considerations

A primary cause of stream channel erosion is the increased frequency of bankfull flows, which can result from upstream development and changing weather patterns.

Most natural stream channels are formed with a bankfull capacity to pass the runoff from a storm with a 1.5- to 2-year recurrence interval. However, in a typical urbanizing watershed, stream channels are subject to a 3- to 5-fold increase in the frequency of bankfull flows. As a result, stream channels that were once parabolic in shape and covered with vegetation are often transformed into wide, rectangular channels with barren banks.

The use of living plants instead of, or in conjunction with, structural measures offers many advantages. The degree of protection, which may be low to start with, increases as the plants grow and spread. The repair and maintenance of structures is unnecessary where self-maintaining streambank plants are established. The protection provided by natural vegetation is more reliable and effective where the cover consists of natural plant communities that are native to the site. Planting vegetation is less damaging to the environment than installing structures. Vegetation also provides habitat for fish and wildlife and is aesthetically pleasing. Plants protect streambanks from erosion by reducing stream velocity, binding soil in place with a root mat, and covering the soil surface when high flows tend to flatten vegetation against the banks. For these reasons, always consider vegetation first.

The addition of vegetation to the streambank will lower the carrying capacity of the stream. The designer should analyze all impacts of this project with the proper hydrologic and hydraulic models. Evaluate the erosion potential for the stream to determine the best solutions. Consider the following items in the evaluation:

1. The frequency of bankfull flow based on anticipated watershed development;
2. The channel slope and flow velocity by design reaches;
3. The antecedent soil conditions;
4. Present and anticipated channel roughness (Manning's n) values;
5. The locations of channel bends along with bank conditions; and
6. The locations of unstable areas and trouble spots. Steep channel reaches, high erosive banks, and sharp bends may require structural stabilization measures such as riprap, while the remainder of the streambank may require only vegetation.

Table C-ENV-01-1 provides a comprehensive list of design considerations for vegetative streambank stabilization.

Where streambank stabilization is required and velocities appear too high for the use of vegetation, consider structural measures (see Structural Streambank Stabilization BMP C-ENV-02) or the use of permanent erosion control matting (see Soil Stabilization Blankets and Matting BMP C-SSM-05). Notably, obtain any applicable approval or permits from other state or federal agencies before working in such areas. The design engineer should ensure that all necessary permitting work is coordinated with the US Army Corps of Engineers (USACE) and/or the Virginia Department of Environmental Quality (VDEQ) as applicable.

For permanent streambank stabilization, refer to the Virginia Stream Restoration and Stabilization Best Management Practice (BMP) Guide.

Table C-ENV-01-1 Vegetative Streambank Stabilization Design Considerations	
Area to be Stabilized	**Notes on Proper Use**
Vegetation Zones Along Watercourses	At the edges of all natural watercourses, plant communities exist in a characteristic succession of vegetative zones, the boundaries of which depend on site conditions, such as the steepness and shape of the bank, and the seasonal and local variations in water depth and flowrate. Streambanks commonly exhibit the following zonation (see Figure C-ENV-01-1). Aquatic Plant Zone: This zone is normally permanently submerged. In Virginia, this zone is inhabited by plants, such as pondweeds and water lilies, which reduce the water's flowrate by friction. The roots of these plants help to bind the soil, and they further protect the channel from erosion because the water flow tends to flatten them against the banks and bed of the stream. Reed-Bank Zone: The lower part of this zone is normally submerged for only about half the year. In Virginia, this zone is inhabited by rushes, reed grasses, cattails, and other plants that bind the soil with their roots, rhizomes, and shoots and slow the water's flowrate by friction.
Vegetation Zones Along Watercourses	Shrub Zone: This zone is flooded only during periods of average high water. In Virginia, the shrub zone is inhabited by trees and shrubs, such as willow, alder, dogwood, and viburnum, with a high regenerative capacity. These plants hold the soil with their root systems and slow water speed by friction. The plants also protect tree trunks from damage caused by breaking ice and help to prevent the formation of strong eddies around large trees during flood flows. Shrub zone vegetation is particularly beneficial along the impact bank of a stream meander, where maximum scouring tends to occur. Infringement of shrub vegetation into the channel tends to reduce the channel width, increasing probability of floods. However, brief flooding of riverside woods and undeveloped bottomlands does no significant damage, and the silt deposits in these wooded areas are less of a problem than they are on failed banks. Tree Zone: This zone is flooded only during periods of very high water (i.e., the 2-year bankfull flow or greater flows). Typical plants in Virginia that inhabit this zone are trees in the ash-elm, alder-ash, and oak-hornbeam associations. These trees hold soil in place with their root systems.

4.0 Stormwater Performance Summary

MS-15: BED AND BANK STABILIZATION – The bed and banks of a watercourse shall be stabilized immediately after work in the watercourse is completed.

9VAC25-875-560

Erosion Control Efficiency: High

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-ENV-01-2 provides general guidelines for maximum allowable velocities in streams to be protected by vegetation.

1. Ensure that channel bottoms are stable before stabilizing channel banks.
2. Keep velocities at bankfull flow non-erosive for the site conditions.
3. Provide mechanical protection, such as riprap, on the outside of channel bends if bankfull stream velocities approach the maximum allowable for site conditions.
4. Be sure that requirements of other state or federal agencies are met in the design when other approvals or permits are necessary.

Table C-ENV-01-2 Conditions in which Vegetative Streambank Stabilization is Acceptable

Frequency of Bankfull Flow (times/year)	Maximum Allowable Velocity for Highly Erodible Soil (ft/s) k>0.37	Maximum Allowable Velocity for Erosion Resistant Soil (ft/s) k<0.37
> 4	4	5
1 to 4	5	6
< 1	6	6

If permanent design is proposed from streambank stabilization, the Virginia Stream Restoration and Stabilization BMP Guide should be referenced.

6.0 Construction Specifications

6.1 Planting Guidelines

Guidelines will be presented only for the reed-bank and shrub zones. The aquatic plant zone is difficult to implant and establish naturally when reed-bank vegetation is present. There are presently many experts in this field at the federal, state, and private sector levels who can be consulted concerning successful establishment of plants in the aquatic zone. The tree zone is least significant in terms of protecting banks from more frequent erosion-force flows because this zone is seldom flooded. Also, shade from trees in this zone can prevent adequate establishment of vegetation in other zones. Planting specifications are detailed further in Table C-ENV-01-3.

Table C-ENV-01-3 Planting Specifications	
Planting Activity	**Notes on Proper Execution**
Establishing Reed-Bank Vegetation	There are various methods of planting reed-bank vegetation. The following plants are considered suitable: Reed canary grass (*Phalaris arundinacae*); Great bulrush (*Scirpus lacustris*); and Common cattail (*Typha latifolia*). Planting in Clumps: The oldest and most common method of planting reeds is planting in clumps (see Figure C-ENV-01-2). The stems of the reed colony are scythed, then square clumps are cut out of the ground and placed in pits prepared in advance on the chosen site. The clumps are planted at a depth at which the clumps will be submerged to a maximum of two thirds of their height. Planting Rhizomes and Shoots: Less material is needed for the planting of rhizomes and shoots, a procedure that can be used to establish reed grass, bulrush, cattail, and other plants. Slips are taken from existing beds during the dormant season, after the stems have been cut. Rhizomes and shoots are carefully removed from the earth without bruising the buds or the tips of the sprouts. The rhizomes and shoots are placed in holes or narrow trenches along the line of the average summer water level so that only the stem sprouts show above the soil. Planting Stem Slips: It is possible to plant stem slips along slow-moving streams (see Figure C-ENV-01-2). Usually, three slips are set in a pit 12 to 20 inches deep. If the soil is packed or strong, make the holes with a dibble bar or some other metal planting tool. Locate the pits approximately 1 foot apart.

Table C-ENV-01-3 Planting Specifications	
Planting Activity	**Notes on Proper Execution**
Establishing Reed-Bank Vegetation	Reed Rolls: In many cases, the previously described methods do not consolidate the banks sufficiently during the period immediately after planting. Combined structures have therefore been designed, in which protection of the bank is at first ensured by structural materials. Along slow to fast streams, the most effective method of establishing reed-bank vegetation has been found to be the use of reed rolls (see Figure C-ENV-01-2). A trench 18 inches wide and deep is dug behind a row of stakes. Wire netting, such as 0.5-inch hardware cloth, is then stretched from both sides of the trench between upright planks. Onto this netting is dumped fill material such as coarse gravel, sod, or soil and other organic material. This material is then covered by reed clumps until the two edges of the wire netting can just be held together with wire. Ensure the upper edge of the roll is no more than 2 inches above the level of the water. Finally, the planks are taken out, and any gaps along the sides of the roll are filled in with earth. This method provides greater protection from the possibility of a heavy flow washing away the vegetative materials before they have a chance to become established. Seeding: Reed canary grass can be sown 0.5 inch deep on very damp bank soil, provided that the seeded surface is not covered by water for 6 months after sowing. Seed at a rate of 12 to 15 pounds per acre. Reed canary grass is a cool season grass and should not be seeded in the summer. Vegetation and Stone Facing: Reed-bank and other types of vegetation can be planted in conjunction with riprap or other stone facing by planting clumps, rhizomes, or shoots in the crevices and gaps along the line of the average summer water level.
Establishing Shrub Zone Vegetation	Stands of full-grown trees are of little use for protecting streambanks apart from the binding of soil with their roots. Shrub wood provides much better protection; and in fact, riverside stands of willow trees are often replaced naturally by colonies of shrub-like willows. Use plants that can easily adapt to the stream and site conditions. Seeding and Sodding: Frequently, if the stream is small and a good seedbed can be prepared, grasses can be used alone to stabilize the streambanks. To seed the shrub zone, first grade eroded or steep streambanks to a maximum slope of 2H:1V (3H:1V preferred). Retain existing trees greater than 4 inches in diameter whenever possible. Conserve topsoil for reuse in an upland stockpile area with perimeter controls (silt fence or compost filter sock). Select seeding mixtures and perform operations according to Permanent Seeding (BMP C-SSM-10). Install some type of erosion control blanket, such as jute netting, excelsior blankets, or equivalent according to Soil Stabilization Blankets and Matting (BMP C-SSM-05). Sod can also be placed where grass is suitable. Select and install sod according to Sodding (BMP C-SSM-06). Use turf only where the grass will provide adequate protection, necessary maintenance can be provided, and establishment of other streambank vegetation is not practical or possible.

Table C-ENV-01-3 Planting Specifications	
Planting Activity	**Notes on Proper Execution**
Establishing Shrub Zone Vegetation	Planting Cuttings and Seedlings: Shrub willows, shrub dogwoods, and alders can be put into the soil as cuttings, slips, or stems. In dense shade, shrubs such as the blue arctic willow (*Salix purpurea nana*) and the silky dogwood (*Cornus amomum*) or evergreen ground covers such as lily turf (*Liriope Muscari*) or Hall's honeysuckle (*Linicera hallsiana*) are appropriate. The silky dogwood also works well in sunny areas. On larger streams, “Streamco” purpleosier willow (*Salix purpurea “Streamco”*) and Bankers’ dwarf willow (*Salix x Cotteti*) have been widely used with success. Two native river alders (*Alnus serrulata* and *Alnus rugosa*), which occur throughout the northeast, also show great promise for streambank stabilization, although they have not been fully tested. Again, the first step in the planting process is to grade eroded or steep slopes to a maximum slope of 2H:1V (3H:1V preferred), removing overhanging bank edges. Willows can be planted as 1-year-old, nursery-grown, rooted cuttings or as fresh hardwood cuttings gathered from local mother-stock plantings. Use silky dogwood and alders that are nursery-grown seedlings 1 or 2 years old. Use fresh cuttings that are 0.375 to 0.5 inch thick and 12 to 18 inches long and are kept moist. If not used at once, store the cuttings in cool moist sand. Streambanks are often difficult to plant, even when the banks are well sloped. This is especially true in gravelly or strong banks. Where mattocks or shovels are unsatisfactory tools, a stiff steel bar, such as a crowbar, is better. The best tool for this purpose is a dibble bar: a heavy metal tool with a blade and a foot pedal that is thrust into the ground to make a hole for the plant (see Figure C-ENV-01-3). Plant rooted cuttings vertically in the bank with 1 or 2 inches of wood protruding above the ground surface. Stick the rooted cuttings in a hole large enough to accommodate the root system when well spread. Maneuver the plant roots into the bottom of the hole so the roots will grow down instead of up. Do not twist the roots or expose the roots above the ground surface. After the plant is placed, install the dibble bar a few inches away from the plant to close the hole. Apply slow-release fertilizer on the surface, not in the hole. Tamp the soil adequately to provide complete contact between the soil and the cutting. Plant cuttings 1 foot on center in at least three rows located at the top, middle, and bottom of the shrub zone. Plant seedlings of the river alders vertically in the bank to the depth at which the seedings were growing in the nursery. Use the same procedure described previously. Plant one row of alders at 2-foot intervals at the base of the shrub zone, not more than 1.5 to 3 feet from the average summer water level or from the reeds. A greater distance is of no use unless a belt of tall perennial herb colonies is established between the reeds and the alders. Plant the next row 2 feet up the slope, with a third row 4 feet up the slope. Plant at least three rows. Locate the plants in a diamond pattern. Because these plants are generally not effective for the first 2 years, grasses can be seeded immediately following their planting to provide initial streambank protection. The seed mixtures noted in Table C-ENV-01-4 are appropriate plantings.

Table C-ENV-01-3 Planting Specifications	
Planting Activity	**Notes on Proper Execution**
Establishing Shrub Zone Vegetation	Roughen the seedbed with rakes and fertilize with 500 to 1,000 pounds per acre of 10- 10-10 fertilizer adjusted to meet the needs of the site. Take special care when fertilizing next to water sources to avoid any unnecessary introduction of nitrogen/phosphorus into the water. Broadcast seed, cover lightly, and mulch with 2 tons of straw per acre (two to three bales per 1,000 square feet) or a minimum of 1,500 pounds of wood fiber mulch per acre (2,000 pounds per acre preferred). If straw is used, properly anchor the straw with netting or an effective tackifier. Erosion control blankets/mats are often effective aids in the establishment of grasses or plant material along streambanks; see Soil Stabilization Blankets and Matting (BMP C-SSM-05). Willows and other softwoods can also be bound together in various ways to ensure immediate protection of the streambank. Fascine Rolls: Fascine rolls are bundles of brushwood and sticks, without branches, if possible, that are filled with coarse gravel and rubble and wired tightly around the outside. The fascine rolls are 4 to 20 yards long and 4 to 16 inches in diameter. The fascine rolls are set against the bank so that the parts intended to take root touch the ground above the water level and can access sufficient moisture. Covering with earth improves the contact with the ground and retards the loss of moisture from the wood (See Figure C-ENV-01-4). Willow Mattresses: The degree of streambank protection can be increased using willow mattresses or packed fascine work. Willow mattresses consist of 4- to 8-inch-thick layers of growing branches set perpendicular to the direction of the current or sloping downstream, with the broad ends of the branches oriented downwards. The branches are held together with interweaving wire or other branches at intervals of 24 to 32 inches, set parallel to the direction of the current or at an angle of 30 degrees. If several layers of mattress are necessary, the tops of the lower layers should cover the bases of the upper layers. The bottom layer is fixed at the base in a trench previously dug at the base of the softwood zone. The whole mattress structure should be covered with 2 to 10 inches of earth or fine gravel (See Figure C-ENV-01-4). Packed Fascine Work: Packed fascine work (see Figure C-ENV-01-4) consists essentially of layers of branches laid one across the other to a depth of 8 to 12 inches and covered with fascine rolls. The spaces between the fascine rolls are filled with gravel, stones, and soil so that no gaps remain; and a layer of soil and gravel 8 to 12 inches thick is added on top. Packed fascine work is particularly suitable for repairing large breaches in the banks of streams with high water levels. Combination with Stone Facing: In many places, the bank is not adequately protected by vegetation until the roots are fully developed, and temporary protection must be provided by inanimate materials. There is a wide choice of methods including the planting of woody plants in the crevices of stone facing (See Figure C-ENV-01-4). For structural protection measures, see Structural Streambank Stabilization (BMP C-SSM-02).

Table C-ENV-01-4 – Initial Streambank Plantings: Seed Mixtures by Region* and Application Rates	
Species	**Application Rate (lbs/acre)**
Kentucky-31 Tall Fescue[a]	65
Creeping Red Fescue[a]	15
Redtop Grass[a]	5
Kentucky-31 Tall Fescue[b]	80
Redtop Grass[b]	5
Kentucky-31 Tall Fescue[c]	65
Bermudagrass[c]	15
Redtop Grass[c]	5

*Physiographic Regions are described in Permanent Seeding (BMP C-SSM-10).

a. Appalachian Region
b. Piedmont Region
c. Coastal Plain

Table C-ENV-01-5 Streambank Soil Bioengineering Techniques	
Technique	**Notes on Proper Use**
Coir Fascines	This is a manufactured product also known as coir logs or coconut fiber rolls. Coir fascines consist of coconut husk fibers bound together in a cylindrical bundle by natural or synthetic netting and are manufactured in a variety of standard lengths, diameters, and fill densities for environments of different energy. Coir fascines are flexible and can be fitted to the existing curvature of a streambank. They provide immediate toe protection and bank stabilization while trapping sediment within the coir fascine, which encourages plant growth. Coir fascines are well suited for establishing herbaceous materials, and they can be pre-vegetated before installation. A key advantage of this method is the modularization and standardization of the materials that result in relatively predictable and reliable performance. A disadvantage of coir fascines is that they are expensive to purchase and ship. They require additional anchoring systems, which increases the initial costs and installation time. Material: Fascines fabricated from and filled with 100 percent coir (coconut husk) are preferred for streambank stabilization work because they serve as a stable growing medium on which seeds and young plants can become established. This material provides some resistance to damage from ice flows, floating debris, and other impacts and provides a reinforcing framework for vegetation until the coir filling decays, at which point the plants should be able to protect the banks. For most settings, high tensile strength (minimum 200 lb tensile strength) synthetic mesh is desirable for the knotted or braided mesh exterior of the coir fascine. Although coir mesh versions are available, the mesh frequently loses its strength before vegetation can become fully established, making the material vulnerable to failure. Therefore, coir mesh versions are typically used on sites with low stress levels. The most sturdy and resistant coir fascines are manufactured with a density of 9 pounds per cubic foot. Where ice, debris, steep banks, and other stress factors are not a problem, lower density materials may offer a more cost-effective alternative. The most used size is 12-inch-diameter, although they are available in both larger and smaller sizes. Coir fascines are typically anchored with wooden stakes or earth anchors with cable assemblies.

Table C-ENV-01-5 Streambank Soil Bioengineering Techniques	
Technique	**Notes on Proper Use**
Coir Fascines	Installation: Coir fascines may be installed during any season, provided that the ground can be worked adequately for placement and anchoring. Planting into the coir fascine may be planned for a more desirable season, as needed. Coir fascines can either be placed so that they help position the toe of a bank, where it was located before an erosion event, or in direct contact with the current bank profile. Position the coir fascine so that the top is located at the mean water level during the summer growing season. In most cases, this zone best supports herbaceous vegetation. Due to the distance from the plant to the soil, it is imperative that the coir fascine remain wet. Coir fascines are frequently planted with 2-inch-diameter plugs of herbaceous species that have been rooted in a coir fiber matrix to provide good frictional contact. Protect coir fascines against scouring and flanking in the design. Ensure the anchoring system is adequate to seat the coir fascine securely in contact with the adjacent soil. Use a pair of stakes placed every 2 feet along the coir fascine, one on each side. In cold climates, earth anchors or rope tie-downs are necessary to prevent lifting of the coir fascine as ice forms. Always place wooden stakes between the cable or rope and the coir to keep the cable or rope from cutting clear through the coir fascine. Avoid piercing a high-density coir fascine with stakes. Drive the stakes alongside the coir fascine. Secure the coir fascine by either tightly sandwiching it between the stakes or using ropes or cables to tie around the coir fascine. Tie the coir fascines together end to end to form a continuous unit. This is most convenient to do while they are still on dry land, laid out along the top of bank. Use strong synthetic rope to stitch the ends together, with knots tied at frequent intervals to ensure a reliable connection. When coir fascines are stacked to provide coverage of a wider strip of bank, place the fascines together on the edges where they touch. One row of lacing is typically adequate to hold two tiers together, although two rows of lacing will result in a tighter contact between the tiers, which is useful at holding back cohesive soils. All tiers require appropriate staking or anchoring. After anchoring is complete, coir fascines may be planted. Either live cuttings may be inserted through the coir fascine itself, or 2-inch-diameter plugs may be inserted 6 inches on center along the length of the coir fascine. When the coir fascines are stacked, live poles, live cuttings, or rooted plants may be placed on the first (lower) coir fascine before placing the next one above it.

Table C-ENV-01-5 Streambank Soil Bioengineering Techniques	
Technique	**Notes on Proper Use**
Fascines	A fascine is a long bundle of live cuttings bound together into a rope or sausage-like bundles. The structure provides immediate protection for the toe of the bank. Because this is a surface treatment, it is important to avoid sites that will be too wet or too dry. The live cuttings eventually root and provide permanent reinforcement. Materials: Live cuttings: 0.75 to 2 inches in diameter, 5 to 15 feet long; Cord; braided manila; sisal or pre-stretched cotton twine; or small-gauge, non-galvanized wire; Dead stout stakes: wedge-shaped wooden stakes, 2 to 3 feet long depending on soil conditions; Tools: machete, shovels, clippers, hammer, sledgehammer, saw, and chainsaw; and Fertilizer and other soil amendments. Installation: Collect and soak live cuttings for 14 days or install them the day they are harvested and fabricated. Leave side branches intact. Stagger the live cuttings in a uniform bundle built to a length of about 8 feet. Vary the orientation of the cuttings. Use 8- to 10-foot bundles for ease of handling and transport. The bundles can also be easily spliced together to create a fascine long enough to fit the project site. Tie bundles with twine at approximately 2-foot intervals. The bundles should be 6 to 24 inches in diameter depending on their application. Start installation from a stable point at the upstream end of the eroding bank. Excavate a trench into the bed of the stream, where the bank meets the bed. Dig the trench to be about a half to three quarters the diameter of the bundle. Align the fascine along the toe of the bank of the eroding section. Place the bundle in the trench and stake (use wedge-shaped dead stout stakes) directly through the bundle 3 feet on center. Allow the stake to protrude 2 inches above the top of the bundle. To improve depth of reinforcement and rooting, install live stakes (2 to 3 feet in length) just below (downslope) and in between the previously installed dead stout stakes, leaving 3 inches protruding from the finished ground elevation. Cover the fascine with soil, ensuring good soil to stem contact. Wash it in with water to distribute the soil around the inner stems of the bundle. Ensure some of the bundle remains exposed to sunlight to promote sprouting. Use material from the next up-bank trench. It may be desirable to use erosion control fabric to hold the soil adjacent to and in between the fascine bundles, especially in wet climates. When using erosion control fabric between the fascine bundles, the fabric is first placed in the bottom of the trench, an inch of soil is placed on top and up the sides of the trench and erosion control fabric, and the fascine bundle is then placed in the trench and staked down. Note: Fascines can be oriented perpendicular to the streambank contours, which is called the vertical bundle method. The primary difference between the construction of a vertical bundle and a fascine is that all the cuttings in a vertical bundle are oriented so the cut ends are in the water. It is particularly applicable where there is uncertainty in determining the water table.

Table C-ENV-01-5 Streambank Soil Bioengineering Techniques	
Technique	**Notes on Proper Use**
Live Pole Cuttings or Live Stakes	Live pole cuttings are dormant stems, branches, or trunks of live, woody plant material inserted into the ground with the purpose of getting them to grow. Live stakes are generally shorter material used as stakes to secure other soil bioengineering treatments such as fascines, brush mattresses, erosion control fabric, and coir fascines. However, the terms live stakes and live pole cuttings are often used interchangeably. Both live poles and live cuttings can be used as anchoring stakes. Pole cuttings and stakes are live material, so they will also root and sprout. These cuttings typically do not provide immediate reinforcement of soil layers, as they normally do not extend beyond a failure plane. Over time, they provide reinforcement to the soil mantle, as well as surface protection and roughness to the streambank and some control of internal seepage. They assist in quickly reestablishing riparian vegetation and cause sediment deposition in the treated area. Materials: Live cuttings: 0.75 to 3 inches in diameter, 3 to 20 feet long; and Tools: machete, clippers, dead blow hammer, saw, chain saw, loppers, and rebar. Installation: Cleanly remove all side branches and top growth. Cut the basal (bottom) end to a 45- degree angle or sharpen into a pointed end. Cut the top end flat. Ensure at least two buds or bud scars are present above the ground in the final installation depending on the surrounding vegetation height. Ensure the live cuttings are taller than the surrounding vegetation so that they are not shaded. Collect and soak the live cuttings for 14 days or install them on the day on which they are harvested and fabricated. Use a punch bar or hand auger to create a pilot hole perpendicular to the slope. Ensure the depth of the hole is two thirds to three fourths the length of the live cutting. Make the hole diameter as close to the cutting's diameter as possible to obtain the best soil to stem contact. Ensure the hole is deep enough to intercept the lowest water table of the year or a minimum of 2 feet. To achieve good soil to stem contact, fill the hole around the pole with a water and soil slurry mixture. Add soil around the cutting as the water percolates into the ground and the soil in suspension settles around the cutting. Another method is to tamp soil around the cutting with a rod. Throw a small amount of soil in the hole around the cutting and tamp it down to remove all air pockets, as if installing a wooden fence post. Install the pole into the ground at a right angle to the slope face. Use a dead blow hammer to tap the cutting into the ground. Insert the cutting at a 90-degree angle to the face of the slope. Ensure that the sharpened basal end is installed first. Place stakes on 2- to 4-foot spacing in either a random pattern or triangular grid for most shrub species. Spacing depends on species, moisture, aspect, and soil.

Table C-ENV-01-5 Streambank Soil Bioengineering Techniques	
Technique	**Notes on Proper Use**
Joint Plantings	Joint plantings or vegetated riprap are cuttings of live, woody plant material inserted between the joints or voids of riprap and into the ground below. Typically, the live cuttings do not provide immediate reinforcement of soil layers, as they normally do not extend beyond the failure plane. The live cuttings are intended to root and develop top growth providing several adjunctive benefits to the riprap. These installations provide reinforcement to the soil on which the riprap has been placed, as well as providing roughness (top growth) that typically causes sediment deposition in the treated area. Some control of internal seepage is also provided. These joint planting installations assist in quickly reestablishing riparian vegetation. Joint plantings are frequently used on the lower part of the bank. Materials: Joint plantings: live cuttings 0.75 to 2 inches in diameter and 2.5 to 4 feet long or a length that extends at least 1 foot of the cutting will extend into the ground below the riprap. Tools: machete, clippers, dead blow hammers, sledgehammer, saw, chainsaw, loppers, and rebar. Installation: Cleanly remove all side branches and the top growth from the cuttings. Cut the basal end to a 45-degree angle or sharpen to a point. Cut the top end flat. Ensure at least two buds or bud scars are present above the ground in the final installation, depending on the surrounding vegetation height. Ensure the live cuttings are taller than the surrounding vegetation so that they are not shaded. Collect and soak the live cuttings for 14 days or install them on the day on which they are harvested and fabricated. Make a pilot hole by hammering in a piece of rebar between the rock. A steel stinger can also be used. Carefully extrude the rebar and tamp in the joint planting stem. Insert the basal end first. To achieve good soil to stem contact, fill the hole around the cutting with a water and soil slurry mixture. Plant live cuttings on 1.5- to 2-foot spacing in a random pattern or triangular grid. Spacing depends on species, moisture, aspect, and soil characteristics.

Table C-ENV-01-5 Streambank Soil Bioengineering Techniques	
Technique	**Notes on Proper Use**
Brush Mattress	A brush mattress is a layer of live cuttings placed flat against the sloped face of the bank. Dead stout stakes and string are used to anchor the cutting material to the bank. This measure is often constructed using a fascine, joint planting, or riprap at the toe of the bank, with live cuttings in the upper mattress area. The branches provide immediate protection from parallel streamflow. The cuttings are expected to root into the entire bank face and provide surface reinforcement to the soil. Materials: Live cuttings: 0.75 to 1 inch in diameter that are approximately 2 feet taller than the bank face, which will allow the basal ends to be placed in or at the edge of the water. Up to 20 percent of the cuttings can be dead material to add bulk; Dead stout stakes: wedge-shaped, 1.5 to 4 feet long, depending on soil texture; Ties: string, braided manila, sisal or pre-stretched cotton twine, or galvanized wire; Tools: machete, shovels, clippers, hammer, sledgehammer, punch bar, saw, and machine to shape the bank; and Fertilizer and other soil amendments.

Table C-ENV-01-5 Streambank Soil Bioengineering Techniques	
Technique	**Notes on Proper Use**
Brush Mattress	Installation: Collect and soak the live cuttings for 14 days or install them om the day on which they are harvested. Leave side branches intact. Cut a 2- by 4-inch board diagonally and at a desired length to create the dead stout stakes. Excavate the bank to a slope of 1V:2H or flatter. The distance from the top of the slope to the bottom of the slope is typically 4 to 20 feet. Excavate a 1-foot-wide and 8- to 12-inch- deep trench along the toe of the bank. Drive the dead stout stakes 1 to 3 feet into the ground up the face of the prepared bank. Space the installation of the dead stout stakes on a grid that is 1.5 to 3 foot square. Start the lowest row of dead stout stakes below bankfull width or a fourth of the height of the bank. Extend the tops of the dead stout stakes above the ground 6 to 9 inches. Live cuttings may also be mixed with the dead stout stakes and tamped in between to add deeper initial rooting. However, do not rely on the live cuttings solely for anchoring the brush mattress, as they generally cannot be driven in as securely as the dead stout stakes. Lay the live cuttings up against the face of the bank. The basal ends of the cuttings are installed into the trench with the growing tips oriented up bank. Retain the live cuttings' side branches and overlap the side branches in a slight crisscross pattern. Depending on the sizes of the branches, approximately 8 to 15 branches are installed per linear foot of bank. Use a fascine or some form of anchoring along the bottom portion of the brush mattress to ensure the basal ends of the live cuttings are pressed against the bank. Stand on the live cuttings and secure them by tying string, cord, wire, braided manila, sisal, or pre-stretched cotton twine in a diamond pattern between the dead stout stakes. Short lengths of tying material are preferred over long lengths. In the event of a failure, only a small portion of the treatment would be compromised if short lengths are used. Otherwise, there are risks of losing larger portions of the project if long lengths of tying material are used to anchor the cuttings to the dead stout stakes. After tying the string to the stakes, drive the dead stout stakes 2 to 3 inches further into the bank to firmly secure the live cuttings to the bank face. This improves the soil to stem contact. Wash loose soil into the mattress between and around the live cuttings so that the bottom halves of the cuttings are covered with a 3- to 4-inch layer of soil. Backfill the trench with soil or a suitable toe protection such as rock. Trim the terminal bud at the top of bank so that stem energy will be routed to the lateral buds for more rapid root and stem sprouting.

7.0 Operations and Maintenance Considerations

Streambanks are always vulnerable to new damage. Repairs are needed periodically. Inspect streambanks after every high-water event is over. Fix gaps in the vegetative cover at once with new plants and mulch if necessary. Fresh cuttings from other plants on the bank can be used, or the cuttings can be taken from mother-stock plantings if they are available. Remove trees that become established on the bank at once.



Streambank wasting in need of restoration.
Photo Credit: NC Forest Service

While soil bioengineering projects tend to be self- renewing and grow stronger with time, project areas require periodic monitoring and maintenance, particularly during the establishment stage. Maintenance is especially important on highly erosive sites. Remove debris and eliminate invasive or undesirable species, and replant vegetation in spot areas. It is recommended that a comprehensive plan for the management of invasive species be developed.

The success of a soil bioengineering streambank stabilization project depends on the establishment and growth of the vegetative component. It is important to monitor soil bioengineering projects after project completion to ensure plant survival and development.

Figure C-ENV-01-1 Typical Annual Curve of Water Correlated with Typical Vegetative Zones

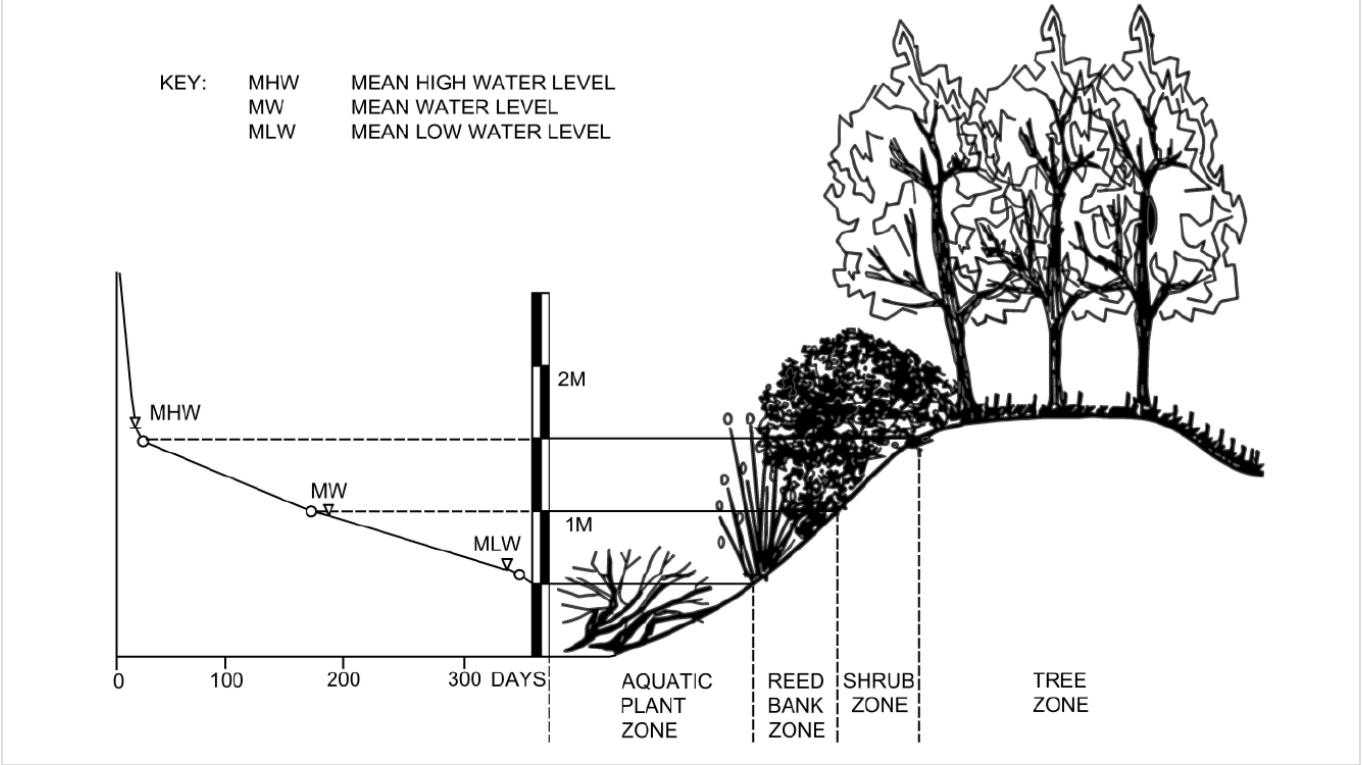


Figure C-ENV-01-2 Methods of Establishing Reed Bank Vegetation

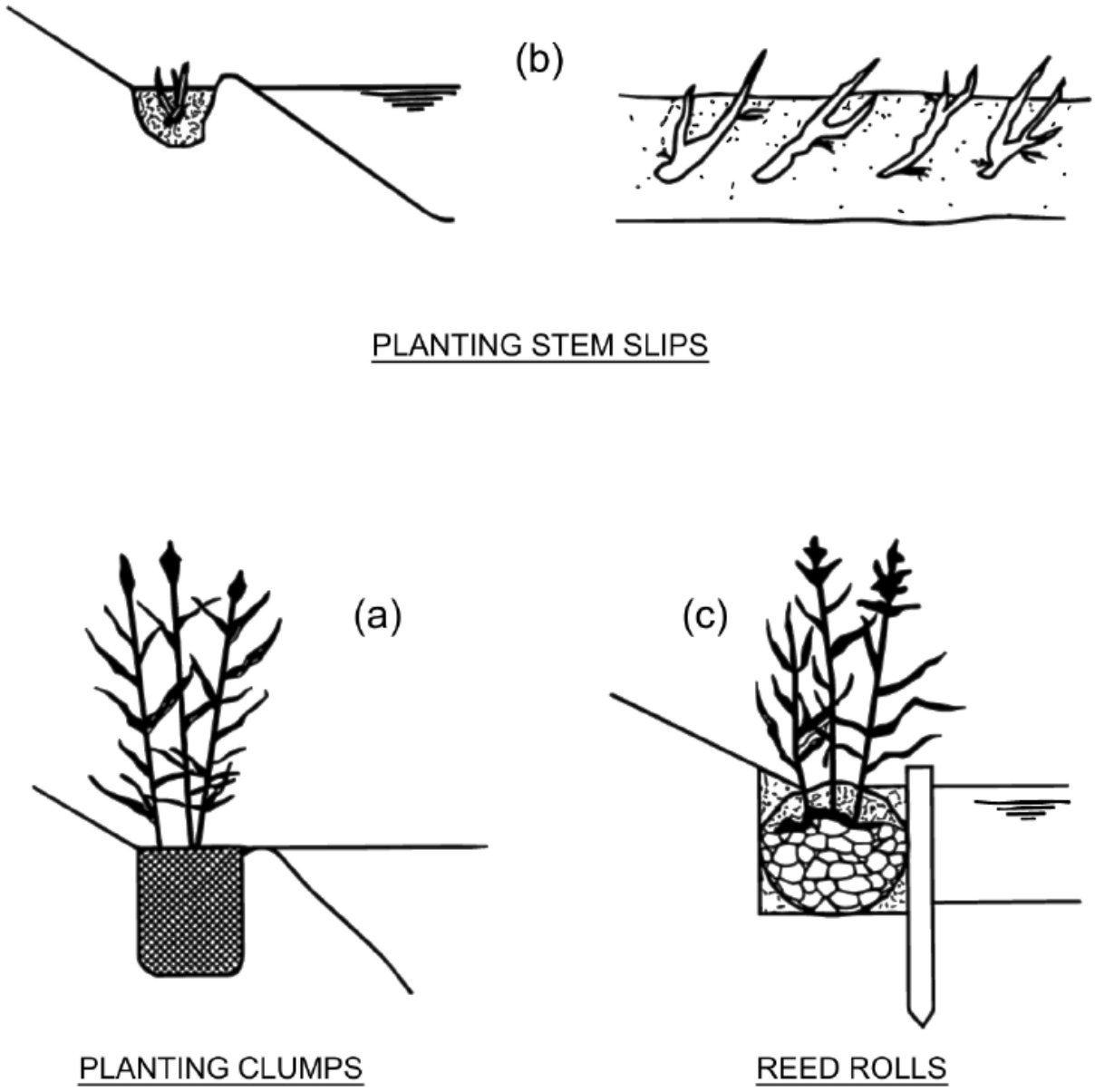
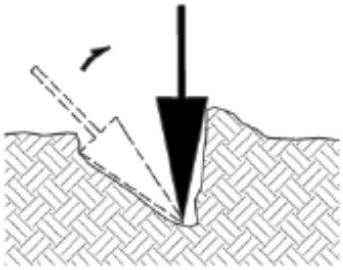


Figure C-ENV-01-3 Dibble Planting

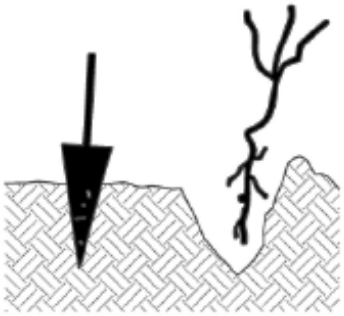




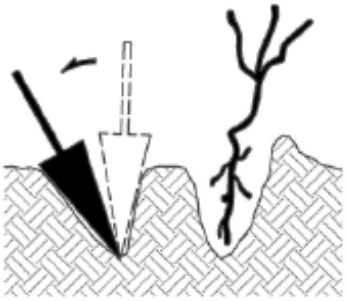
1. INSERT DIBBLE AT ANGLE AND PUSH FORWARD TO UPRIGHT POSITION.



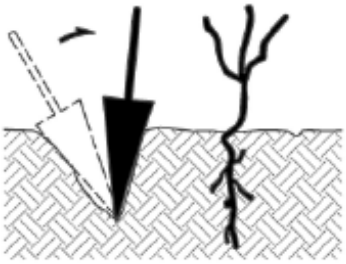
2. REMOVE DIBBLE AND PLACE SEEDLING AT CORRECT DEPTH.



3. INSERT DIBBLE 2 INCHES TOWARD PLANTER FROM SEEDLING.



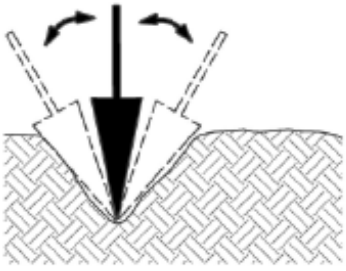
4. PULL HANDLE OF DIBBLE TOWARD PLANTER FIRMING SOIL AT BOTTOM OF ROOTS.



5. PUSH HANDLE OF DIBBLE FORWARD FROM PLANTER FIRMING SOIL AT TOP OF BOOTS.



6. INSERT DIBBLE 2 INCHES FROM LAST HOLE.



7. PUSH FORWARD THEN PULL BACKWARD FILLING HOLE.

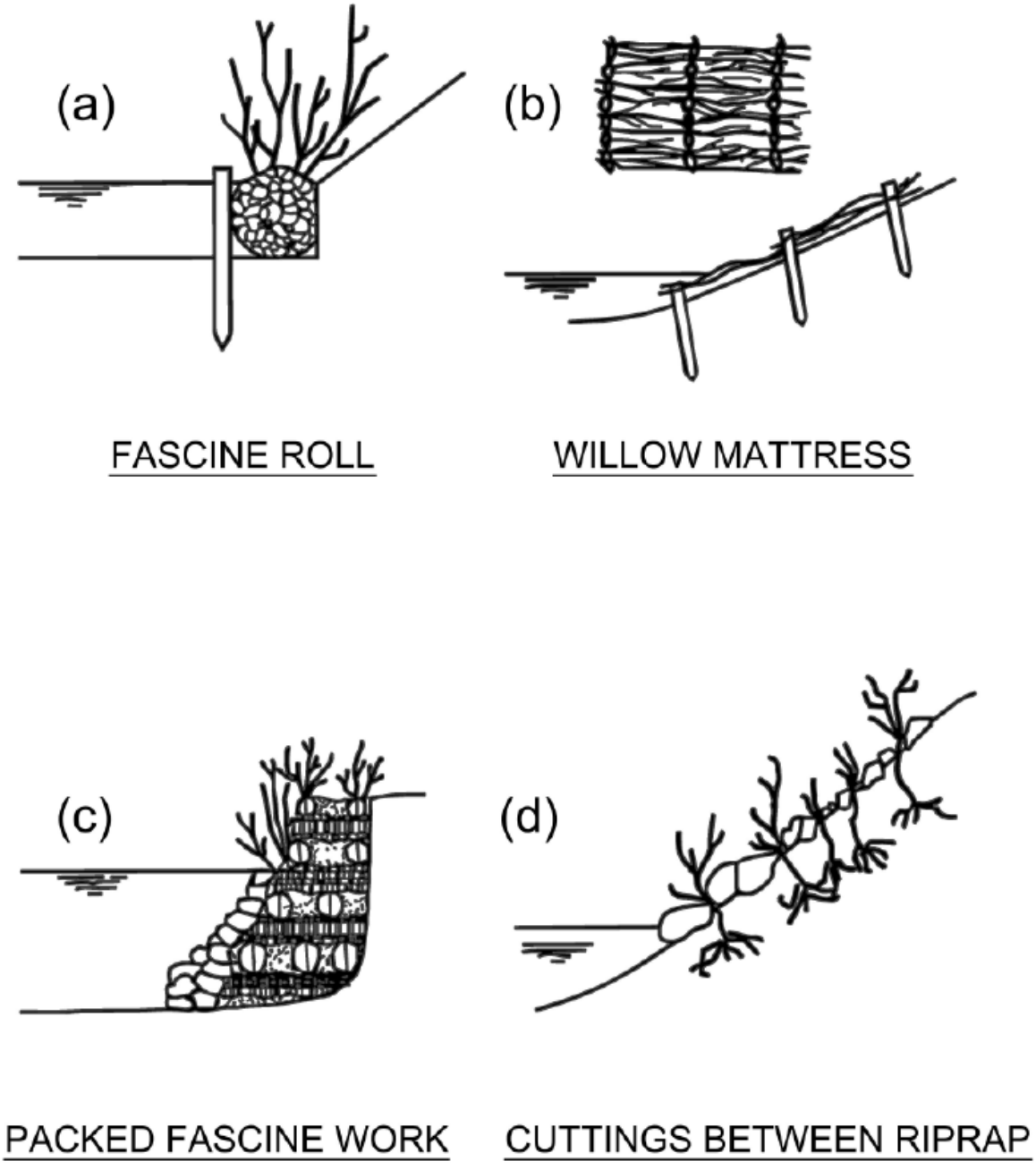


8. FILL IN LAST HOLE BY STAMPING WITH HEEL.



9. FIRM SOIL AROUND SEEDING WITH FEET.

Figure C-ENV-01-4 Methods of Establishing Shrub Zone Vegetation



8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-ENV-02 Structural Streambank Stabilization

1.0 Definition

Structural streambank stabilization constitutes methods of stabilizing the banks of live streams with permanent structural measures.

– CAD and PDF files for C-ENV-02 Structural Streambank Stabilization

2.0 Purpose and Applicability of Best Management Practice

Structural streambank stabilization is used to protect streambanks from the erosive forces of flowing water.

Structural streambank stabilization is applicable to streambank sections that are subject to excessive erosion due to increased flows or disturbance during construction and where flow velocities exceed 5 feet per second (ft/s) or where vegetative streambank protection is inappropriate.

3.0 Planning and Considerations

Stream channel erosion problems vary widely in type and scale, and many different structural stabilization techniques have been employed with varying degrees of effectiveness. The purpose of this specification is to identify some of the practices that are available and to establish some broad guidelines for their selection and design. Ensure such structures are planned and designed in advance by an engineer or other qualified individual with appropriate experience. Many of the referenced practices involve the use of manufactured products. Design and install manufactured products in accordance with the manufacturers' specifications.

Before selecting a structural stabilization technique, carefully evaluate the possibility of using vegetative stabilization (see Vegetative Streambank Stabilization [BMP C-ENV-01]), alone or in conjunction with structural measures, to achieve the desired protection. Vegetative techniques are generally less costly and more compatible with natural stream characteristics.

4.0 Stormwater Performance Summary

MS-15: BED AND BANK STABILIZATION – The bed and banks of a watercourse shall be stabilized immediately after work in the watercourse is completed.

9VAC25-875-560

Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-ENV-02-1 Structural Streambank Stabilization Design Criteria	
Parameter	**Notes on Proper Use**
General Guidelines	Because each reach of channel requiring protection is unique, install measures for streambank protection according to a plan and adapted to the specific site. Develop designs according to the following principles: Ensure protective measures to be applied are compatible with improvements planned or being carried out by others. Control the bottom scour, by either natural or artificial means, before any permanent type of bank protection can be considered feasible. This is not necessary if the protection can be safely and economically constructed to a depth well below the anticipated lowest depth of bottom scour. Start and end streambank protection at a stabilized or controlled point on the stream. Modify channel alignment only after evaluating the effect on land use, interdependent wastewater systems, hydraulic characteristics, and existing structures. Give special attention to maintaining and improving habitat for fish and wildlife. Calculate the design velocity based on the peak discharge of the 10-year, 24-hour storm event. Ensure structural measures are effective for this design flow and can withstand greater flows without serious damage. Meet all requirements of state law and permit requirements of local, state, and federal agencies. Stabilize all areas disturbed by construction as soon as the structural measures are complete.

Table C-ENV-02-1 Structural Streambank Stabilization Design Criteria	
Parameter	**Notes on Proper Use**
Streambank Protection Measures	Riprap: Heavy angular stone placed (preferably) or dumped onto the streambank to provide armor protection against erosion. Design and install riprap according to specs and standards (Riprap [BMP C-ECM-13]). Where riprap is proposed for streambank protection, install the riprap as shown on Figure C-ECM-12-1. Provide provision for the passage of aquatic life through the stabilization area once the stone is in place. In most cases, the riprap need not extend more than 12 inches above the normal flow depth, often evidenced by a lack of vegetation or a strand line. If additional stream bank above that elevation has been disturbed, consider using a perennial vegetative cover. When possible, slope banks to 2H:1V or flatter, and place a gravel filter or filter fabric on the smoothed slopes before installing riprap. Place the toe of the riprap at least 1 foot below the stream channel bottom or below the anticipated depth of channel degradation. Where necessary, riprap the entire length between well-stabilized points of the stream channel. Reinforced Concrete: May be used to armor eroding sections of the streambank by constructing concrete retaining walls or bulkheads. Positive drainage behind these structures must be provided. Reinforced concrete may also be used as a channel lining; see Stormwater Conveyance Channel (BMP C-ECM-09).

Table C-ENV-02-1 Structural Streambank Stabilization Design Criteria	
Parameter	**Notes on Proper Use**
Streambank Protection Measures	Gabions: Rectangular, rock-filled wire baskets are pervious, semi-flexible building blocks that can be used to armor the beds and/or banks of channels or to divert flow away from eroding channel sections. Gabions offer important advantages for bank protection. Gabions can provide vertical protection in high-energy environments where construction area is restricted. Gabions can also be a more affordable alternative, especially where rock of the needed size for riprap is unavailable. Gabion wire mesh baskets can be used to stabilize streambank toes and entire slopes. Gabions can also be compatible with many soil bioengineering practices. Gabions come in two basic types: woven wire mesh and welded wire mesh. Woven wire mesh is a double-twisted, hexagonal mesh consisting of two wires twisted together in two 180-degree turns. Welded wire mesh has a uniform square or rectangular pattern and a resistance weld at each intersection. Between these two types there are two styles of gabions: gabion baskets and gabion mattresses. Baskets are 12 inches or more tall, while mattresses typically range from 5 to 12 inches tall. Gabion baskets can be particularly effective for toe stabilization on problem slopes. Gabion baskets provide the size and weight to stay in place, with the further advantage of being tied together as a unit. Baskets can be installed in multiple rows to increase stability and provide a foundation for other measures above them. Gabion mattresses are best suited for revetment-type installations, channel linings, and waterways. Gabion mattresses may also be used for basket foundations and scour aprons. Design and install gabions in accordance with manufacturer's standards and specifications (Figure C-ENV-02-1 – Gabions). At a minimum, construct gabions of a hexagonal triple-twist mesh of heavily galvanized steel wire (galvanized wire may also receive a poly-vinyl chloride coating). Ensure the design water velocity for channels using gabions does not exceed that specified in Table C-ENV-02-2. Vegetated Gabion: In some locations, traditional gabions may be unacceptable from either an aesthetic or ecological perspective. A modification to traditional gabion protection that may satisfy these concerns is the vegetated gabion. A vegetated gabion incorporates topsoil into the void spaces of the gabion. The resulting gabion volume consists of 30 to 40 percent soil that allows root propagation between the stones. The resulting structure is interlocked with stone, wire, and roots. Log Cribbing: A retaining structure built of logs backfilled with rock to protect streambanks from erosion. Log cribbing is normally built on the outside of stream bends to protect the streambank from the impinging flow of the stream (see Figure C-ENV-02-3 – Log Cribbing). The construction of a timber and rock crib requires considerable hand labor, and its useful life depends on the length of time the logs will hold the rock in place before rotting. As with gabions, the cribbing allows for the protection of unstable banks with stones that would be too small if used in a riprap revetment. While not exactly duplicating a riprap revetment, similar design characteristics are required for its design, such as scour, filtration, drainage, and length.

Table C-ENV-02-1 Structural Streambank Stabilization Design Criteria	
Parameter	**Notes on Proper Use**
Streambank Protection Measures	Deflectors (groins or jetties): Structural barriers that project into the stream to divert flow away from eroding streambank sections. Figure C-ENV-02-2 – Deflectors contains general guidelines for designing and installing deflectors. Grid Pavers: Modular concrete units with interspersed void areas that can be used to armor the streambank while maintaining porosity and allowing the establishment of vegetation. These structures may be obtained in pre-cast blocks or mats, or the grid pavers may be formed and poured in place. Design and install grid pavers in accordance with manufacturer's instructions (Figure C-ENV-02-4 – Grid Pavers). Cellular Confinement Systems: May be used to stabilize streambanks when the manufacturer's recommendations are followed. Excavate the area of installation as necessary so that the top of the panel is flush with, or slightly lower than, the adjacent terrain or final grade. Level the surface of the slope and remove stones and debris. Fill and compact gullies. Replace unsuitable material, shape and compact the subgrade, and install an underlayment suitable for water bodies prior to stretching and anchoring the panel(s). Miscellaneous Hard Armor Techniques: Other products on the market may be suitable for streambank stabilization. These include, but are not necessarily limited to, cable concrete, articulated concrete, and concrete jacks. Where such products are proposed, consider the specific site conditions, such as access by construction equipment, anticipated flows, soil limitations, site dimensions, public use, and aesthetics, which might make some products less desirable than others. Also consider the manufacturer's recommendations, product limitations, cost, and project life as other factors when choosing a suitable stabilization method. Fluvial Geomorphology (FGM) Techniques: Stream channel stabilization using structures that mimic natural features (e.g., rock vanes, W rock weirs, J-hooks) have been shown to be quite effective when used correctly. They can also be very ineffective when the proper stream assessments, design, or construction practices have not been followed. Refer to Chapter 11, Rosgen Geomorphic Channel Design of Part 654 Stream Restoration Design of the National Engineering Handbook for information regarding FGM techniques. The advantage for many of the methods described in these references is that flow is directed to the center of the channel, away from erodible banks.

Table C-ENV-02-1 Structural Streambank Stabilization Design Criteria	
Parameter	**Notes on Proper Use**
	The installation of riprap, gabions, or deflectors under significant wave action or under tidal conditions requires special design considerations to ensure stability of the measure and the area it protects. The design/installation of these measures for tidal areas is beyond the scope of the Virginia Erosion and Sediment Control Law and Virginia Erosion and Sediment Control regulations.
Installation of Structures Under Wave and/or Tidal Action	The Virginia Department of Conservation and Recreation's Shoreline Erosion Advisory Service can be consulted regarding minimum design parameters for tidal installations. Where there is significant wave action affecting the shoreline of a non-tidal lake or pond, use the design parameters presented in Riprap (BMP C-ECM-13). Notably, there are many other site-specific factors that should be incorporated into a design; hence, it is recommended that the design parameters presented only be used as minimum requirements and that a qualified professional be consulted when contemplating the installation of such a structure.

Table C-ENV-02-2 Gabion Thickness relative to Maximum Velocity	
Gabion Thickness (feet)	**Maximum Velocity (ft/s)**
0.5	6
0.75	11
1	14

6.0 Construction Specifications

A key requirement at this phase is to correctly implement the proposed design, which involve the layout, construction supervision, and water quality controls during construction.

6.1 Layout

It is necessary to pre-stake the alignment of the channel and to provide for protection of existing vegetation outside of the construction alignment. The layout involves making necessary onsite adjustments to the design based on constraints that may have been previously overlooked. Terrain irregularities, vegetation, property boundaries, and channel changes since the field data were collected can all require local modifications to placement. Locate staging areas for the collection and temporary storage of materials. Flag stockpile areas, boundary references/facilities requiring special identification, and the locations of structure placement and type.

6.2 Construction Supervision (Oversight)

Perform daily site inspections and construction coordination. Check grades, dimensions, structure placement, slopes, angles, and footers as an ongoing requirement. Coordinate this work during construction rather than waiting and providing a post-construction inspection to find problems after the work is completed. The daily field review and documentation at this phase will facilitate the proper implementation of the design.

6.3 Water Quality Controls

As part of the layout, locate sediment detention basins, diversions, silt fence or compost filter sock, and pump sites to prevent onsite and downstream sediment problems and as required by federal, state, and local ordinances. Stage construction to minimize sedimentation problems. Monitoring of water quality during construction may be required; thus, preventative measures will reduce future problems.

Special attention should be afforded to the original water quality of sinking or losing streams, or if the outfall of the stream consists of a cave, sinkhole, or other karst feature. In these instances, sedimentation trapping measures should be installed upstream of these features.

7.0 Operations and Maintenance Considerations

Maintain all structures in an “as built” condition. Repair structural damage caused by storm events as soon as possible to prevent further damage to the structure or erosion of the streambank.

Figure C-ENV-02-1 Gabions

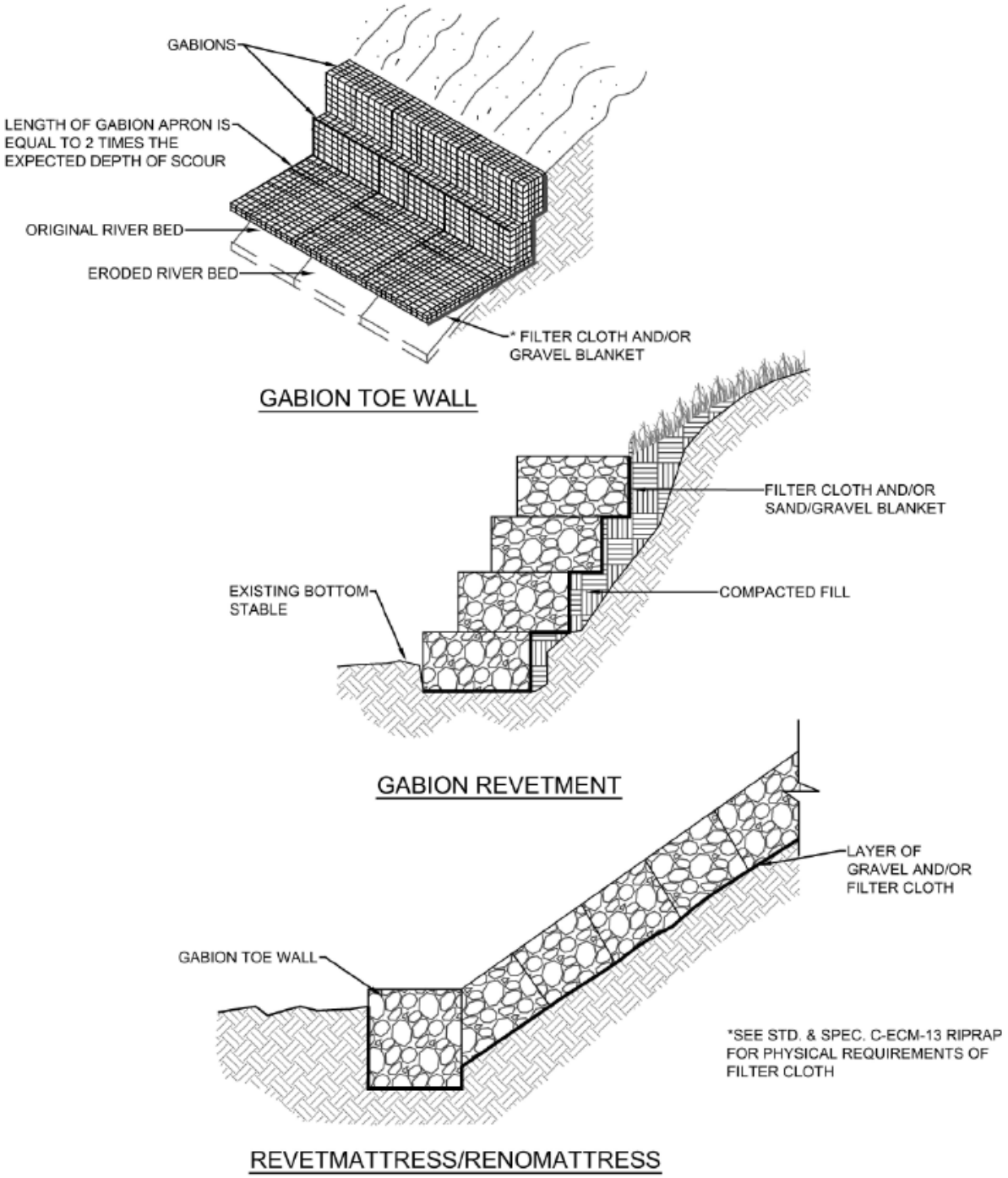
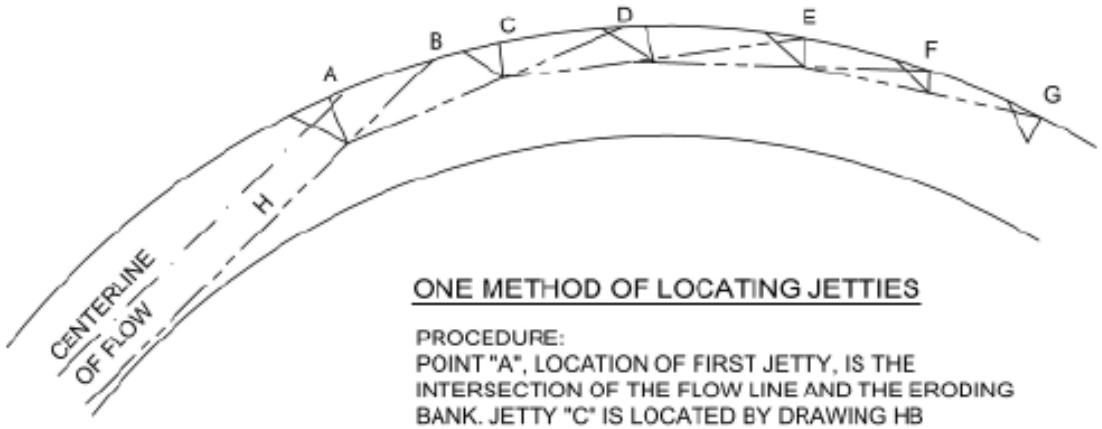
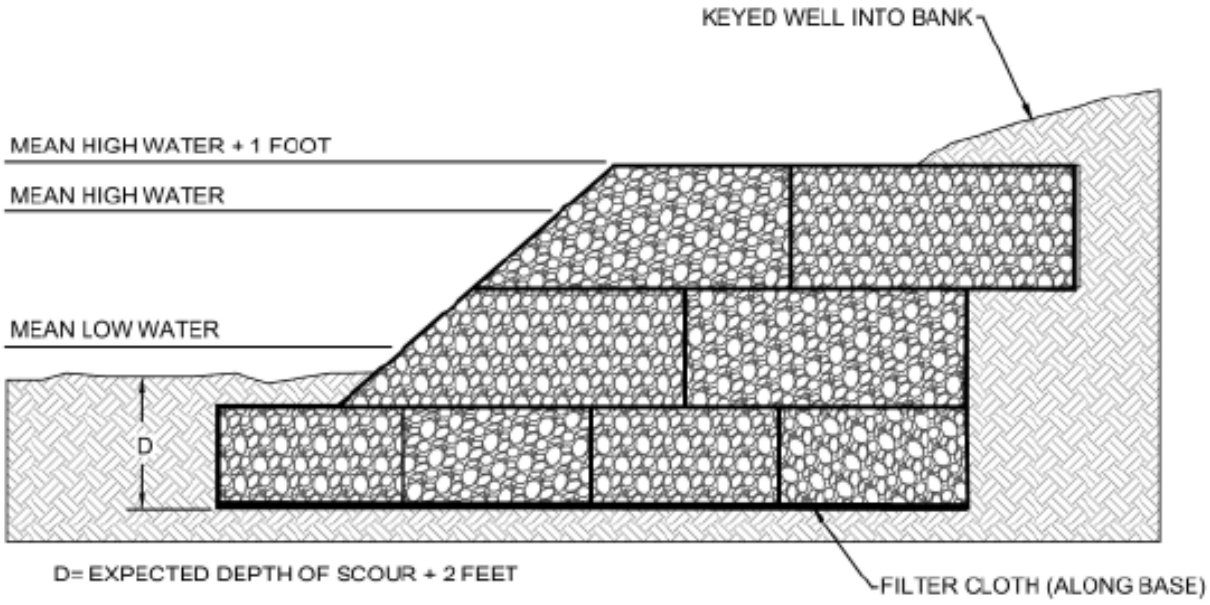


Figure C-ENV-02-2 Deflectors



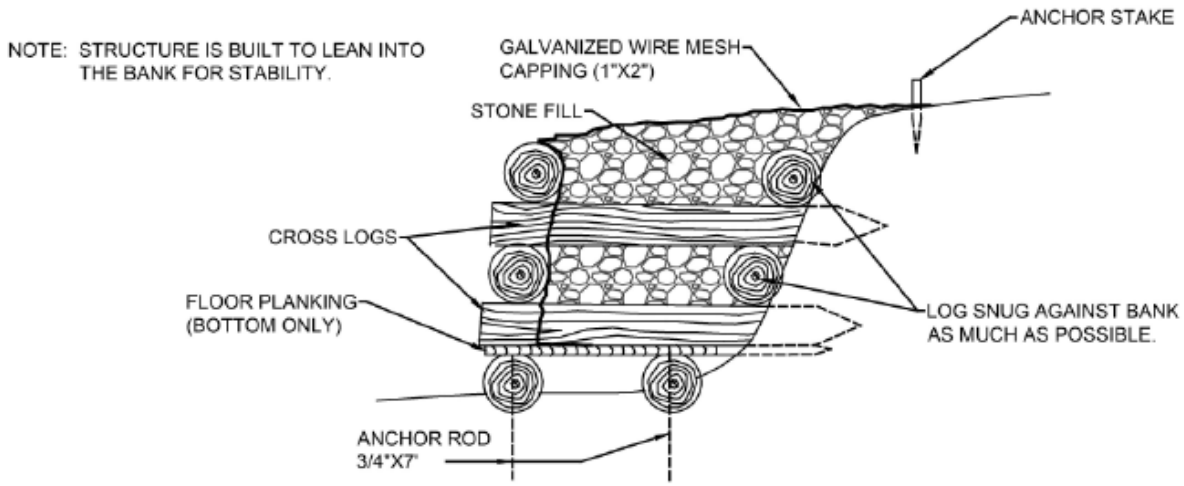
ONE METHOD OF LOCATING JETTIES

PROCEDURE:
POINT "A", LOCATION OF FIRST JETTY, IS THE INTERSECTION OF THE FLOW LINE AND THE ERODING BANK. JETTY "C" IS LOCATED BY DRAWING HB PARALLEL TO THE FLOW LINE AND ACROSS THE TOE OF JETTY "A". AC IS TWICE AB. JETTY "D" IS LOCATED BY PROJECTING A LINE ACROSS THE TOE OF JETTIES "A" AND "C" THE REMAINING JETTIES ARE LOCATED THE SAME AS "D". SUPPLEMENTARY JETTY "K" IS LOCATED AC DISTANCE UPSTREAM FROM "A".

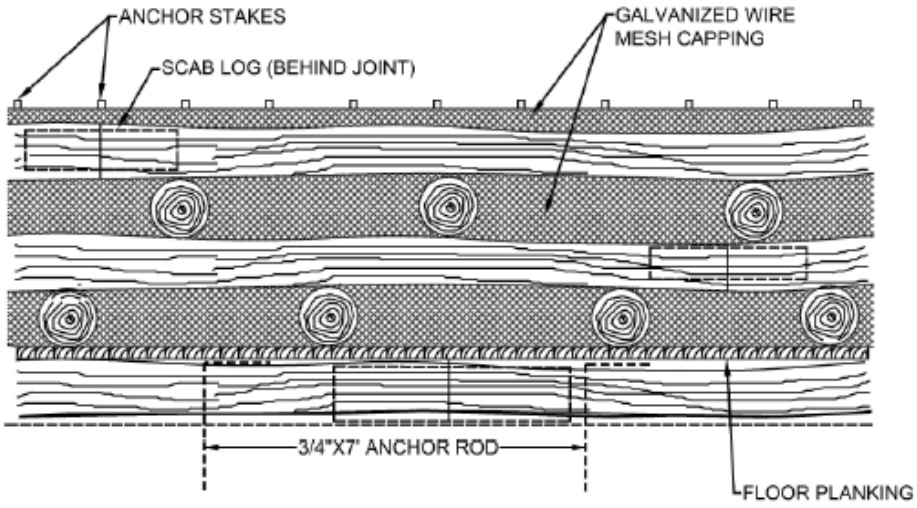


TYPICAL GABION DEFLECTOR

Figure C-ENV-02-3 Log Cribbing



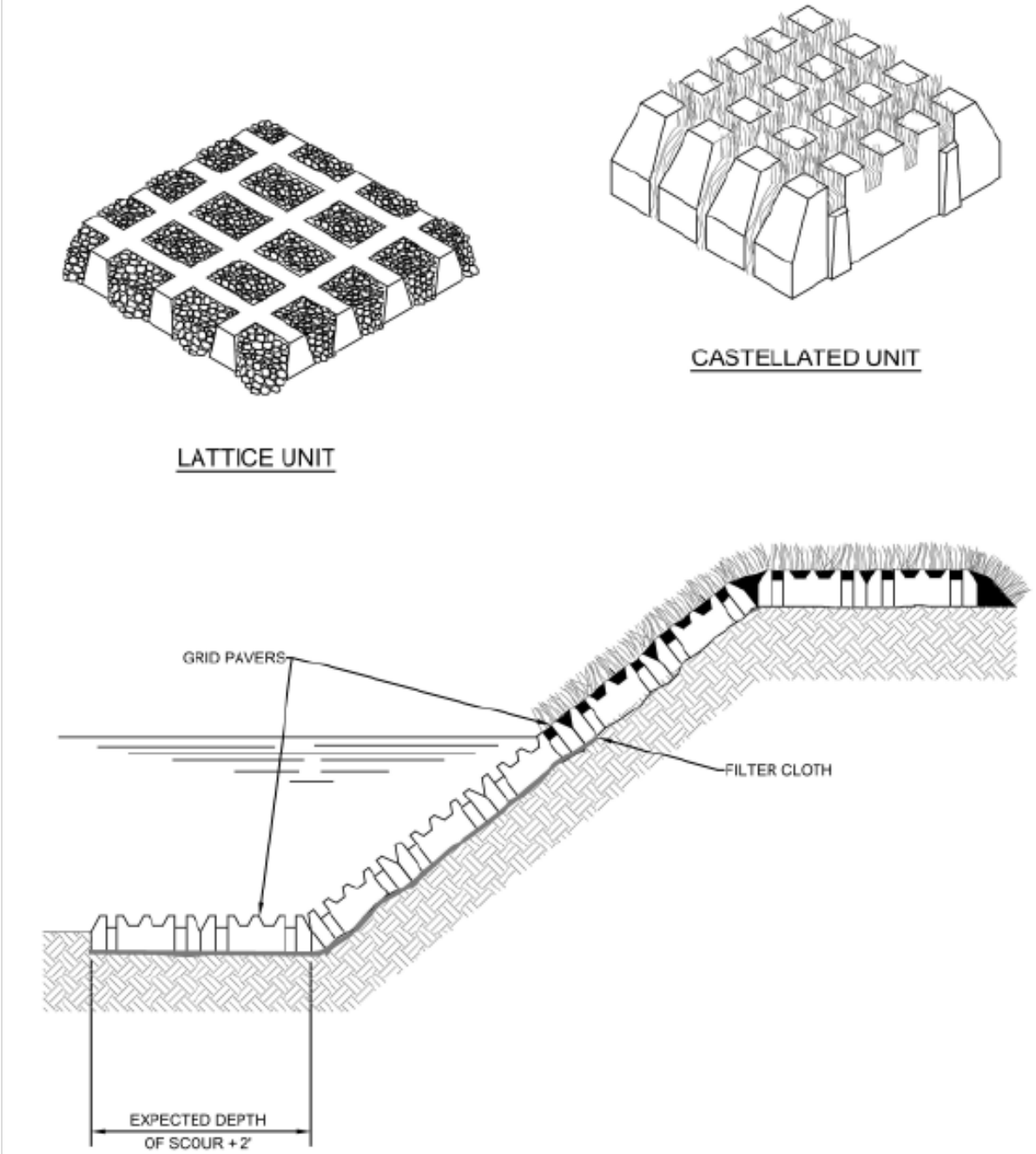
SIDE VIEW



FRONT VIEW

Source: Introductory Guide to Stream Improvement

Figure C-ENV-02-4 Grid Pavers



Source: VA DSWC

8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-

mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

United States Department of Agriculture. 2007. Natural Resources Conservation Service. National Engineering Handbook. Part 654, Stream Restoration Design.

C-ENV-03 Temporary Vehicular Stream Crossing

1.0 Definition

A temporary vehicular stream crossing is a temporary structural span installed across a flowing watercourse for use by construction traffic. Structures may include bridges, round pipes, pipe arches, or oval pipes.

– CAD and PDF for C-ENV-03 Temporary Vehicular Stream Crossing

2.0 Purpose and Applicability of Best Management Practice



Temporary vehicular stream crossings provide a means for construction traffic to cross flowing streams without damaging the channel or banks and keep sediment generated by construction traffic out of the stream.

Temporary vehicular stream crossings are generally applicable to flowing streams with drainage areas less than 1 square mile. Design structures that must handle flow from larger drainage areas using methods that more accurately define the actual hydrologic and hydraulic parameters that will affect the functioning of the structure.

3.0 Planning and Considerations

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and continually tracking sediment and other pollutants into the flow regime. These structures also, however, represent a channel constriction, which can cause flow backups or washouts during periods of high flow. For this reason, the temporary nature of stream crossings is stressed. Plan for the temporary vehicular stream crossing to be in service for the shortest practical period and to be removed as soon as their function is completed.

The specifications contained in this section pertain primarily to flow capacity and resistance to washout of the structure. From a safety and utility standpoint, design the span to be capable of withstanding the expected loads from heavy construction equipment that will cross the structure. Ensure the design considers that such structures are subject to the rules and regulations of the U.S. Army Corps of Engineers for in-stream modifications.

A Section 401 State Certification of Water Quality, Section 404 dredge and fill permit, or state permit may be a requirement for a temporary stream crossing. Additionally, a permit with the U.S. Fish and Wildlife Service may be a requirement if authorities know endangered or threatened species or critical habitat to be present in the work area (USEPA 2021).

A temporary bridge crossing is a structure made of wood, metal, or other materials that provides access across a stream or waterway. The temporary bridge crossing is the preferred practice for temporary waterway crossings. Normally, bridge construction causes the least amount of disturbance to the stream bed and banks compared to the other types of crossings, and they can also be quickly removed and reused. In addition, temporary bridges pose the least chance for interference with fish migration when compared to the other temporary access waterway crossings.

A temporary culvert crossing is a structure consisting of stone and a section(s) of circular pipe, pipe arches, or oval pipes of reinforced concrete, corrugated metal, high-density polyethylene (HDPE), steel reinforced polyethylene (SRPE) pipe, polypropylene, or structural plate, which is used to convey flowing water through the crossings. Temporary culverts are used where the channel is too wide for normal bridge construction, or the anticipated loading of construction vehicles may prove unsafe for single-span bridges. There is some disturbance within the stream during construction and removal of the temporary culvert crossing. The stone, along with the temporary culverts, can be salvaged and reused.

4.0 Stormwater Performance Summary

MS-13: TEMPORARY VEHICULAR STREAM CROSSING – When a live watercourse must be crossed by construction vehicles more than twice in any 6-month period, a temporary vehicular stream crossing constructed of non-erodible material shall be provided.

MS-15: BED AND BANK STABILIZATION – The bed and banks of a watercourse shall be stabilized immediately after work in the watercourse has been completed.

9VAC25-875-560

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: N/A

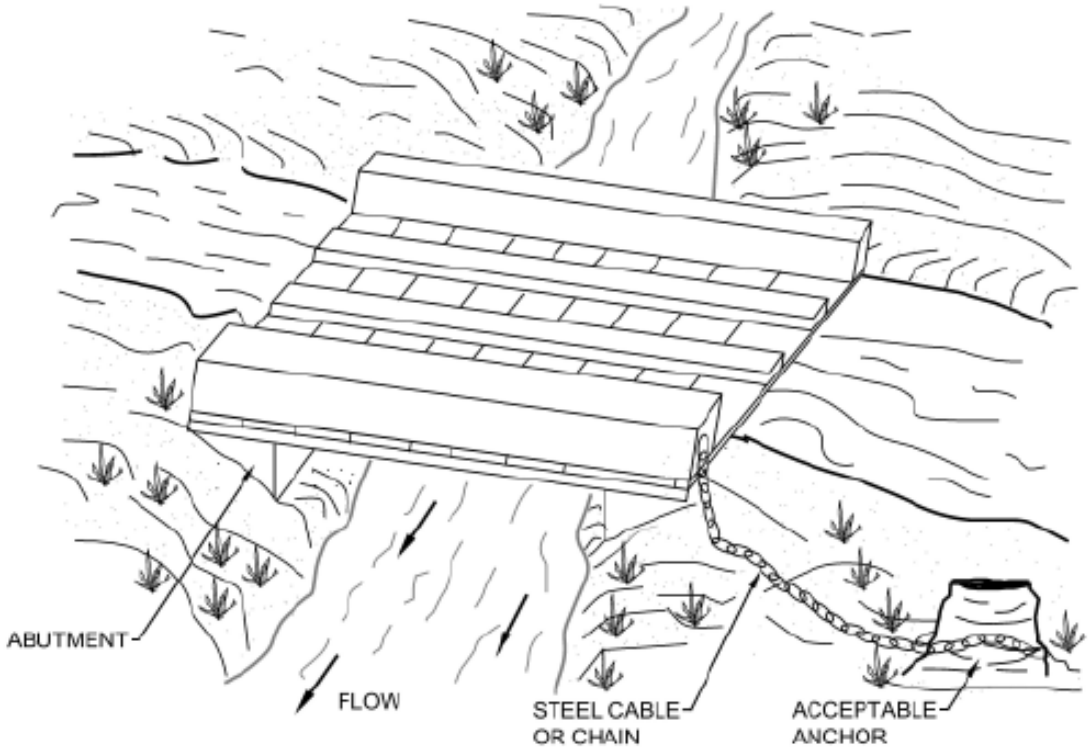
5.0 Design Criteria

Table C-ENV-03-1 Temporary Bridge Crossing Design Criteria

Parameter	Notes on Proper Use
Construction	Structures may be designed in various configurations. However, use materials to construct the bridge that can withstand the anticipated loading of the construction traffic. Figure C-ENV-03-1 shows one example of such a crossing.
Crossing Alignment	Design the temporary waterway crossing to be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15 degrees from a line drawn perpendicular to the center line of the stream at the intended crossing location.

Table C-ENV-03-1 Temporary Bridge Crossing Design Criteria	
Parameter	**Notes on Proper Use**
Roadway Approach	Design the centerlines of both roadway approaches to coincide with the crossing alignment centerline for a minimum distance of 50 feet from each bank of the waterway being crossed. The 50-foot approach distance should be measured from the top of the waterway bank. If physical or right-of-way restraints preclude the 50 feet minimum, a shorter distance may be explored. Consult with the VESMP Authority for assistance. Limit all fill materials associated with the roadway approach to a maximum height of 2 feet above the existing floodplain elevation. For approaches that slope to the waterway, construct a water diverting structure, such as a dike, waterbar, or swale (across the roadway on both roadway approaches), 50 feet (maximum) on either side of the waterway crossing. Design the diverting structure in accordance with the criteria outlined in Temporary Right-of-Way Diversion/Waterbar (BMP C-ECM-07) or Temporary Diversion Dike (BMP C-ECM-04).
Perimeter Controls	Employ appropriate perimeter controls, such as Silt Fence (BMP C-PCM-04) or Turbidity Curtain (BMP C-SCM-09), when necessary, along banks of streams parallel to the streams.
Width	Design all crossings to have one traffic lane with a minimum width of 12 feet and a maximum width of 20 feet.
Additional Criteria	Further design/construction recommendations for temporary bridge construction are provided in Construction Specifications.

Figure C-ENV-03-1 Temporary Bridge Crossing



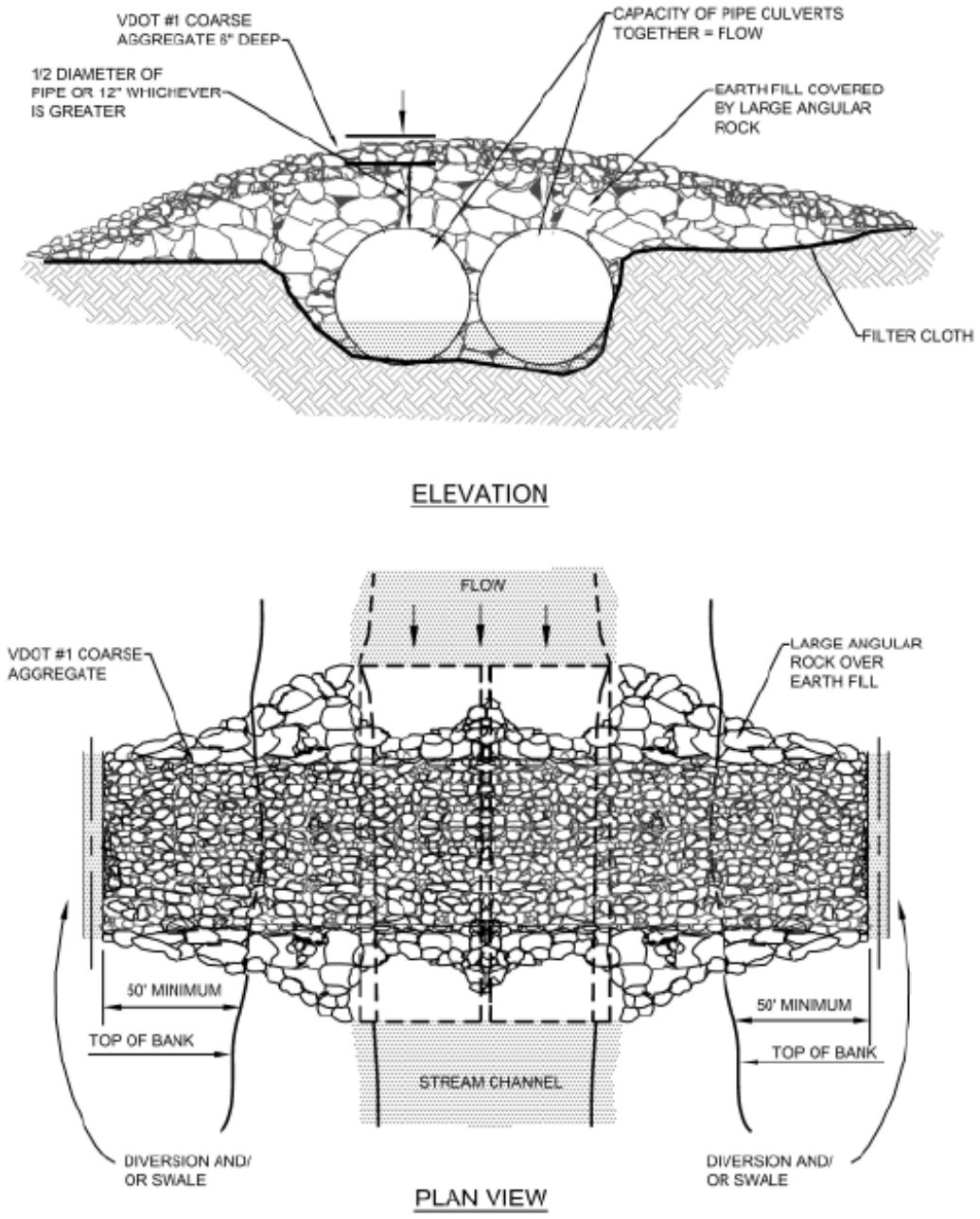
Source: Maryland Department of the Environment 2011

Table C-ENV-03-2 Temporary Culvert Crossing Design Criteria

Parameter	Notes on Proper Use
Construction	Where culverts are installed, use Virginia Department of Transportation (VDOT) #1 Coarse Aggregate or larger to form the crossing. Ensure the depth of stone cover over the culvert is equal to one half the diameter of the culvert or 12 inches, whichever is greater. To protect the sides of the stone from erosion, design and use the riprap in accordance with Riprap (BMP C-ECM-13) (see Figure C-ENV-03-2).
Capacity	If the structure remains in place for up to 14 days, design the culvert to be large enough to convey the flow from a 2-year frequency storm without notably altering the stream flow characteristics. See Table C-ENV-03-3 for aid in selecting an appropriate culvert size (note all assumptions). If the structure remains in place 14 days to 1 year, design the culvert to be large enough to convey the flow from a 10-year frequency storm. In this case, complete the hydrologic calculation and subsequent culvert size for the specific watershed characteristics. If the structure must remain in place longer than 1 year, design the culvert crossing as a permanent measure by a qualified professional.
Size	Multiple culverts may be used in place of one large culvert if they have the equivalent capacity of the larger one. Do not use culverts less than 18 inches in diameter.

Table C-ENV-03-2 Temporary Culvert Crossing Design Criteria	
Parameter	**Notes on Proper Use**
Load	Design all culverts with sufficient cover and loading capacity to support their cross- sectioned area under maximum expected loads.
Length	Ensure the length of the culvert is adequate to extend the full width of the crossing including sideslopes.
Slope	Design the slope of the culvert to be at least 0.25 inch per foot (4 percent).
Crossing Alignment	Where conditions allow, install the temporary waterway crossing at right angles to the stream. Where approach conditions dictate, the crossing may vary 15 degrees from a line drawn perpendicular to the centerline of the stream at the intended crossing location.
Roadway Approach	Design the centerlines of both roadway approaches to coincide with the crossing alignment centerline for a minimum distance of 50 feet from each bank of the waterway being crossed. If physical or right-of-way restraints preclude the 50-foot minimum, a shorter distance may be provided. Limit all fill materials associated with the roadway approach to a maximum height of 2 feet above the existing floodplain elevation. Design the approaches to the structure to consist of stone pads meeting the following specifications: 1. Stone: VDOT #1 2. Minimum thickness: 6 inches 3. Minimum width: equal to the width of the structure Construct a water diverting structure, such as a swale (across the roadway on both roadway approaches), 50 feet (maximum) on either side of the waterway crossing. The water diverting structure will prevent roadway surface runoff from directly entering the waterway. The 50-foot distance is measured from the top of the waterway bank. Design the diverting structure in accordance with the criteria outlined in Temporary Right-Of-Way Diversion (BMP C-ECM-07) or Temporary Diversion Dike (BMP C-ECM-04). If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not necessary.

Figure C-ENV-03-2 Temporary Culvert Crossing



Source: Va. DSWC

Table C-ENV-03-3 Pipe Diameter for Stream Crossings

Drainage Area (Acres)	Average Slope of Watershed (1%)	Average Slope of Watershed (4%)	Average Slope of Watershed (8%)	Average Slope of Watershed (16%)
1 – 25	24	24	30	30
26 – 50	24	30	36	36

Table C-ENV-03-3 Pipe Diameter for Stream Crossings				
Drainage Area (Acres)	Average Slope of Watershed (1%)	Average Slope of Watershed (4%)	Average Slope of Watershed (8%)	Average Slope of Watershed (16%)
51 – 100	30	36	42	48
101 – 150	30	42	48	48
151 – 200	36	42	48	54
301 – 350	42	48	60	60
351 – 400	42	54	60	60
451 – 500	42	54	60	72
501 – 550	48	60	60	72
551 – 600	48	60	60	72
601 – 640	48	60	72	72

1. Note: Table is based on USDA-SCS Graphical Peak Discharge Method for 2-year frequency storm event, CN = 65; Rainfall depth = 3.5 inches (average for Virginia).
2. Source: Va. DSWC.

6.0 Construction Specifications

Temporary Bridge Crossing (see Figure C-ENV-03-1)

1. Keep clearing and excavation of the stream bed and banks to a minimum.
2. Construct the temporary bridge structure at or above bank elevation to prevent the entrapment of floating materials and debris.
3. Place abutments parallel to and on stable banks.
4. Construct bridges to span the entire channel. If the channel width exceeds 8 feet (as measured from top-of-bank to top-of-bank), then a footing, pier, or bridge support may be constructed within the waterway. One additional footing, pier, or bridge support will be permitted for each additional 8-foot width of the channel. Do not construct a footing, pier, or bridge support within the channel for waterways less than 8 feet wide.



5. Construct stringers using logs, sawn timber, pre-stressed concrete beams, metal beams, or other approved materials.
6. Ensure decking materials are of sufficient strength to support the anticipated load. Place all decking members perpendicular to the stringers, butted tightly, and securely fastened to the stringers. Construct decking materials to be butted tightly to prevent any soil material tracked onto the bridge from falling into the waterway below.
7. Securely fasten run planking (optional) to the length of the span. Provide one run plank for each track of the equipment wheels. Although run planks are optional, they may be necessary to properly distribute loads.

8. Install curbs or fenders along the outer sides of the deck. Curbs or fenders are an option that will provide additional safety.
9. Securely anchor bridges at only one end using steel cable or chain. Anchoring at only one end will prevent channel obstruction if floodwaters float the bridge. Acceptable anchors are large trees, large boulders, or driven steel anchors. Ensure anchoring is sufficient to prevent the bridge from floating downstream and possibly causing an obstruction to the flow.
10. Stabilize all areas disturbed during installation within 7 calendar days of that disturbance in accordance with Minimum Standard #1.
11. When the temporary bridge is no longer needed, immediately remove all structures including abutments and other bridging materials. Consider the need for inspections and repairs prior to permit termination before the crossing is removed.
12. To achieve final cleanup, remove the temporary bridge from the waterway, protect the banks from erosion, and remove all construction materials. Store all removed materials outside the floodplain of the stream. Remove the bridge and clean up the area without construction equipment working in the waterway channel.

Temporary Culvert Crossing (see Figure C-ENV-03-2)



1. Keep clearing and excavation of the stream bed and banks to a minimum.
2. Install the invert elevation of the culvert on the natural streambed grade to minimize interference with fish migration.
3. Place filter fabric on the streambed and streambanks before placement of the pipe culvert(s) and aggregate. Ensure the filter fabric covers the streambed and extend a minimum of 6 inches and a maximum of 1 foot beyond the end of the culvert and bedding material. Filter fabric reduces settlement and improves crossing stability. See Riprap (BMP C-ECM-13) for required physical qualities of the filter fabric.
4. Extend the culvert(s) a minimum of 1 foot beyond the upstream and downstream toes of the aggregate placed around the culvert. Ensure the culvert length does not exceed 40 feet.
5. Cover the culvert(s) with a minimum of 1 foot of aggregate. If multiple culverts are used, separate the culverts by at least 12 inches of compacted aggregate fill. At a minimum, ensure the bedding and fill material used in the construction of the temporary access culvert crossings conforms with the aggregate requirements cited in Section 5.0 Design Criteria.
6. When the crossing has served its purpose, remove all structures including culverts, bedding, and filter fabric materials. Remove the structure and clean up the area without construction equipment working in the waterway channel. Consider the need for inspections and repairs prior to permit termination before the crossing is removed
7. Upon removal of the structure, immediately shape the stream to its original cross-section and properly stabilize.

7.0 Operations and Maintenance Considerations

Inspect temporary vehicular stream crossings after every rainfall and at least once a week, whether it has rained or not, and repair all damages immediately.

Inspect stream for bank erosion and in-stream degradation. If bank erosion is occurring, stabilize banks using erosion control practices such as erosion control blankets. If in-stream degradation is occurring, armor the culvert outlet(s) with riprap to dissipate energy. If sediment is accumulating upstream of the crossing, remove excess sediment as needed to maintain the functionality of the crossing.

Remove the temporary crossing when it is no longer needed for construction. Take care to minimize the amount of sediment lost into the stream upon removal. Once the crossing has been removed, stabilize the stream banks with seed and erosion control blankets.

8.0 References

Maryland Department of the Environment. 2011. 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control. December.

USEPA. 2021. Temporary Stream Crossings. Stormwater Best Management Practice. EPA-832-F-21-028Y. December.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-ENV-04 Utility Stream Crossing

1.0 Definition

Utility stream crossing is a strategy for crossing small waterways when in-stream utility construction is involved.

– CAD and PDF for C-ENV-04 Temporary Vehicular Stream Crossing

2.0 Purpose and Applicability of Best Management Practice

Utility stream crossing helps to protect sediment from entering a stream from construction within approach areas and minimizes the amount of disturbance within the stream itself.

Utility stream crossing is generally applicable to flowing streams with drainage areas less than 1 square mile. For crossing streams with larger drainage areas, use structures or methodology that more accurately define the actual hydrologic and hydraulic parameters, which will affect the functioning of the structure.

3.0 Planning and Considerations

Utility construction, by virtue of its sprawling, linear nature, frequently crosses and impacts live streams. There is a potential for excessive sediment loss into a stream by both the disturbance of the approach areas and by the work within the stream bed and banks.

It is often difficult to decide what type of control to use as a utility stream crossing. Trenchless technologies involve pipe installation with minimal surface and environmental disruptions and include jack and bore, micro tunneling, and horizontal directional drilling (HDD).



Trenchless utility installation prevents disturbance within the watercourse and is a preferred method if it is practical. However, where in-stream work is unavoidable, consider providing adequate mitigation of sediment loss while minimizing the amount of encroachment (Minimum Standard #12) and time spent working in the channel. There is some "give and take" as far as the installation of controls – sometimes there is less damage to the environment created by providing substantial controls for the approach areas and refraining from installing extensive measures in the stream itself. However, when the installation of the utility line within streambed and banks will take an extended period of construction time, consider the use of substantial in-stream controls or stream diversion to prevent excessive sedimentation damage.

Because choosing the right method for a utility stream crossing is difficult, ensure designers and plan reviewers visit the sites of proposed crossings to ensure that the most appropriate method is chosen. Ensure the designer and plan reviewer are aware that modifications are subject to other state and federal construction permits.

The following are several methods for dealing with utility stream crossings (with varying construction time and stream size scenarios) that allow for "work in the dry" to prevent excessive sedimentation damage. By no means are these methods all-inclusive. As with other control measures, site-specific design and innovative variations are encouraged.

4.0 Stormwater Performance Summary

MS-12: WATERCOURSE CONSTRUCTION – When work in a live watercourse is performed, precautions will be taken to minimize encroachment, control sediment transport, and stabilize the work area to the greatest extent possible during construction. Non-erodible material will be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

MS-14: OTHER WATERCOURSE REGULATIONS – All applicable federal, state, and local requirements pertaining to working in or crossing live watercourses will be met.

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: MODERATE

5.0 Design Criteria

Table C-ENV-04-1 Design Criteria for Utility Stream Crossings

Design Component	Notes on Proper Use
Drainage Area	Ensure the drainage area is no larger than 1 square mile (640 acres).
Damming Methods	Refer to Cofferdam Crossing (C-ENV-05) for cofferdam and alternative damming methods to complete the crossings.
Filter Fabric	Use a filter fabric in the construction of the utility crossing that conforms to physical requirements noted in Riprap (BMP C-ECM-13).
Water Diverting Structures	Use water diverting structures at all trenching and/or construction road approaches (50 feet on either side of the crossing). Refer to Temporary Vehicular Stream Crossing (BMP C-ENV-03).

Table C-ENV-04-1 Design Criteria for Utility Stream Crossings	
Design Component	**Notes on Proper Use**
Additional Criteria	Design criteria more specific to each crossing are provided on Figure C-ENV-04-1 through Figure C-ENV-04-5.
Dewatering	Before complete dewatering of the work area, remove trapped fish and other aquatic wildlife and relocate to the water body downstream of the lower barrier.

6.0 Construction Specifications

Table C-ENV-04-2 Construction Specifications for Utility Stream Crossings	
Design Component	**Notes on Proper Use**
Diversion Channel Crossing	Diversion channel crossing is the preferred method if construction will remain in the area of stream for an extended period (longer than 72 hours) and site conditions (such as width of stream) make diversion practical. 1. Ensure the diversion channel crossing is operational before working in the stream (construction will be performed “in the dry” when no stream flow is present). 2. Construct the temporary diversion channel to have a minimum bottom width of 6 feet or equal to bottom width of existing streambed, whichever is less. Refer to Figure C-ENV-04-1 and Figure C-ENV-04-2. 3. Construct the temporary diversion channel with a maximum sideslope steepness of 2H:1V. Construct the depth and grade of the temporary diversion channel to be sufficient to ensure continuous flow of water in the diversion. However, the depth and grade may vary dependent on site conditions. 4. There are three types of diversion channel linings that can be used based on expected velocity of bank full flow. Refer to Figure C-ENV-04-2 and Table C-ENV-04-1. 5. TYPE A stream diversions may be seeded with a standard seed mix for the type of soils encountered and the time of year in which seed is sown. Achieve an average growth of 2 inches throughout the diversion with an 85% cover before water is turned through it. 6. Secure stream diversion liners at the upstream and downstream sides with non- erodible weights such as riprap. Ensure these weights allow normal flow of the stream. Do not mix soil in with stream diversion weights. Weights may also be needed along the stream diversion's length to secure the liner. 7. Overlap stream diversion liners when a single or continuous liner is not available or is impractical. Install overlaps so that continuous flow of the steam is maintained and an upstream section overlaps a downstream section by a minimum of 18 inches. Make overlaps along the cross-section so that a liner is placed in the steam diversion bottom first and additional pieces of liner on the slopes overlap the bottom piece by a minimum of 18 inches. 8. Entrench stream diversion liners at the tops of the diversion slopes (slope breaks) along with a line of silt fence. Silt fence may be excluded if the diversion liner is extended to such a point that siltation of the stream will not occur. If silt fence is excluded, secure the diversion liner. Extend liners from slope break to slope break as shown on Figure C-ENV-04-2. 9. Use staples employed in securing Soil Stabilization Blankets and Matting (BMP C-SSM-05) or non-erodible weights (riprap) as necessary to anchor stream diversion liners to the sideslopes of the diversion. Do not use wooden stakes on the diversion's bottom or

Table C-ENV-04-2 Construction Specifications for Utility Stream Crossings	
Design Component	**Notes on Proper Use**
	side slopes. 10. Use non-erodible materials, such as riprap, jersey barriers, sandbags, plywood, or sheet piling, as flow barriers to divert the stream away from its original channel and prevent or reduce water backup into a construction area. 11. Remove the downstream flow barrier before the upstream barrier when opening a stream diversion for the transport of water. 12. Redivert streams upon completion of the utility crossing for which the diversion was built. Before diversion, remove any materials (flow barrier) used to prevent water backup into the downstream end of the original streambed. Do not place this material in the downstream end of the diversion until after water has been rediverted to the original waterway. Redivert the stream by removing all the materials damming the upstream end of the original streambed and then placing it in the upstream end of the stream diversion. Seal off the diversion at the downstream end and then backfill. 13. Once started, do not discontinue any work to relocate a stream until it is completed. 14. Redivert the stream only after backfilling and stabilization of original streambed and banks. Ensure re-stabilization consists of the installation of non-grouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of its utility trench, whichever is greater) with slopes of 3H:1V or greater. Refer to Riprap (BMP C-ECM-13) for installation requirements. For slopes of 3H:1V or less, vegetative stabilization may be used pending approval by the certified plan reviewer. Immediately stabilize the streambed, banks, and the approach areas following the attainment of final grade. 15. Place any dewatering discharge from this operation into an approved Dewatering Structure (BMP C-SCM-10).

Table C-ENV-04-2 Construction Specifications for Utility Stream Crossings	
Design Component	**Notes on Proper Use**
Flume Pipe Crossing	Flume pipe crossing is to be used when in-stream construction will last less than 72 hours and the stream is narrow (less than 10 feet wide), making cofferdam construction impractical. 1. Make the flume pipe crossing operational before the start of construction in the stream. 2. Ensure the materials used (culvert(s), stone, and filter fabric) meet the physical constraints of those used in Temporary Vehicular Stream Crossing (BMP C-ENV-03). 3. Install a large flume pipe (or culvert) of an adequate size to support normal water channel flow (see Figure C-ENV-04-3) in the stream bed across the proposed pipeline trench centerline. Place Virginia Department of Transportation (VDOT) #1 Coarse Aggregate (minimum size) or riprap close to each end of the flume pipe to dam off the creek, forcing the water to flow through the flume pipe (see Figure C-ENV-04-3). 4. Pump the entrapped water from the creek within the dammed-off area and in the proposed trench centerline into an approved Dewatering Structure (BMP C-SCM-10). 5. Dig the trench under the flume pipe. Install the pipe sections within the trench to the proper depth under the flume pipe. After pipe sections are installed, backfill and restabilize the stream channel. 6. Ensure re-stabilization consists of the installation of non-grouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of the utility trench, whichever is greater) with slopes of 3H:1V or greater. Refer to Riprap (BMP C-ECM-13) for installation requirements. For slopes of 3H:1V or less, vegetative stabilization may be used pending approval by the certified plan reviewer. Immediately stabilize the streambed, banks, and the approach areas following the attainment of final grade. 7. After completion of backfilling, restoration of stream banks, and leveling of stream bed, remove the flume pipe. Remove or spread the gravel in the stream bed depending on permit requirements. Do not remove sediment controls in approach areas until all construction is completed in the stream crossing area. Return all ground contours to their original condition.  Active Flume Pipe Utility Stream Crossing

Table C-ENV-04-2 Construction Specifications for Utility Stream Crossings	
Design Component	**Notes on Proper Use**
Cofferdam Utility Crossing	Cofferdam utility crossing is to be used when stream diversion is not practical and the stream is wide enough (10 feet or wider) to accommodate cofferdam installation.  Active Cofferdam Utility Stream Crossing 1. Perform construction in low-flow periods. 2. Construct the crossing in a manner that will not prohibit the flow of the stream (see Figure C-ENV-04-4). 3. As with all utility line crossings, control approach areas with perimeter measures such as silt fence, compost filter sock, or straw bales. 4. Remove large rocks, woody vegetation, or other material from the streambed and banks that may impede placement of the riprap, sandbags, sheet metal, or wood planks or installing the utility pipe or line. 5. Form a cofferdam in a semicircle along the side of the stream in which the utility installation will begin. Surround and underlay the cofferdam with filter fabric as shown on Figure C-ENV-04-4. The height of and area within the dam will depend on the size of the work area and the amount of stream flow. Stack materials as high as will be necessary to keep water from overtopping the dam and flooding the work area. Refer to Cofferdam Crossing (BMP C-ENV-05) for additional details on cofferdams. 6. When the stream flow is successfully diverted by the cofferdam, dewater the work area and stabilize it with aggregate (VDOT #57 or #68 Coarse Aggregate) or sand. Make sure to discharge the water into a sediment trapping device; see Dewatering Structure (BMP C-SCM-10). 7. Install the utility pipe or line in half the streambed as noted on Figure C-ENV-04-4. Remove the riprap or other materials and begin placing them on the other side of the stream. 8. Ensure re-stabilization consists of the installation of non-grouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of its utility trench, whichever is greater) with slopes of 3H:1V or greater. Refer to Riprap (BMP C-ECM-13) for installation requirements. For slopes of 3H:1V or less, vegetative stabilization may be used pending approval by certified plan reviewer. Immediately stabilize the streambed, banks, and the approach areas following the attainment of final grade.
Dam and Pump Bypass	Dam and pump bypass crossing is used when in-stream construction

Table C-ENV-04-2 Construction Specifications for Utility Stream Crossings	
Design Component	**Notes on Proper Use**
Crossing	will last less than 72 hours and the stream is narrow (less than 10 feet wide), making cofferdam construction impractical. 1. Perform construction in low-flow periods. 2. As with all utility line crossings, control approach areas with perimeter measures such as silt fence, compost filter sock, or straw bales. 3. Remove large rocks, woody vegetation, or other material from the streambed and banks that may impede placement of the cofferdam or installing the utility pipe or line. 4. Form an upstream and downstream cofferdam at both ends of the in-stream work area by placing the cofferdam across the entire upstream and downstream width of the stream in which the utility will be installed. Surround and underlay the cofferdams with filter fabric as shown on Figure C-ENV-04-5. The height of and area within the dams will depend on the size of the work area and the amount of stream flow. Stack materials as high as necessary to keep water from overtopping the dams and flooding the work area. Refer to Cofferdam Crossing (BMP C-ENV-05) for additional details on cofferdams. 5. When the stream flow is successfully diverted by the cofferdam, dewater the work area and stabilize it with aggregate (Virginia Department of Transportation [VDOT] #57 or #68 Coarse Aggregate) or sand. Make sure to discharge the water into a sediment trapping device; see Dewatering Structure (BMP C-SCM-10). Pump water from the work area to a Dewatering Structure (BMP C-SCM-10) located such that the water drains back into the channel below the downstream cofferdams. 6. Pump stream flow around the work area upstream to downstream. Select a pump(s) sized to adequately pump the stream base flow at a head greater than the in-stream barrier height. 7. Discharge the pump onto a stable velocity dissipater made of riprap or sandbags at the downstream end. Maintain the bypass pump intake at the upstream end a sufficient distance from the bottom to prevent pumping of channel bottom materials. 8. Install the utility pipe or line across the streambed as noted on Figure C-ENV-04-5. Remove the riprap or other materials from the stream. 9.

Table C-ENV-04-2 Construction Specifications for Utility Stream Crossings	
Design Component	**Notes on Proper Use**
	Ensure re-stabilization consists of the installation of non-grouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of its utility trench, whichever is greater) with slopes of 3H:1V or greater. Refer to Riprap (BMP C-ECM-13) for installation requirements. For slopes of 3H:1V or less, vegetative stabilization may be used pending approval by certified plan reviewer. Immediately stabilize the streambed, banks, and the approach areas following the attainment of final grade.  Active Dam and Pump Bypass Stream Crossing
	10. Use only original parent material to reestablish the streambed when Active Dam and Pump Bypass Stream Crossing construction activities are completed.

Table C-ENV-04-3 Diversion Channel Linings		
Lining Material	**Classification**	**Acceptable Velocity Range (fps)**
Filter Fabric*, Polyethylene, or Grass	TYPE A	0 – 2.5
Filter Fabric *	TYPE B	2.5 – 9.0
Class I Riprap and Filter Fabric *	TYPE C	9.0 – 13.0

* Filter fabric must meet the minimum physical requirements noted in Riprap (BMP C-ECM-13).

fps = feet per second

Source: Virginia Department of Transportation (VDOT) Standard Sheets.

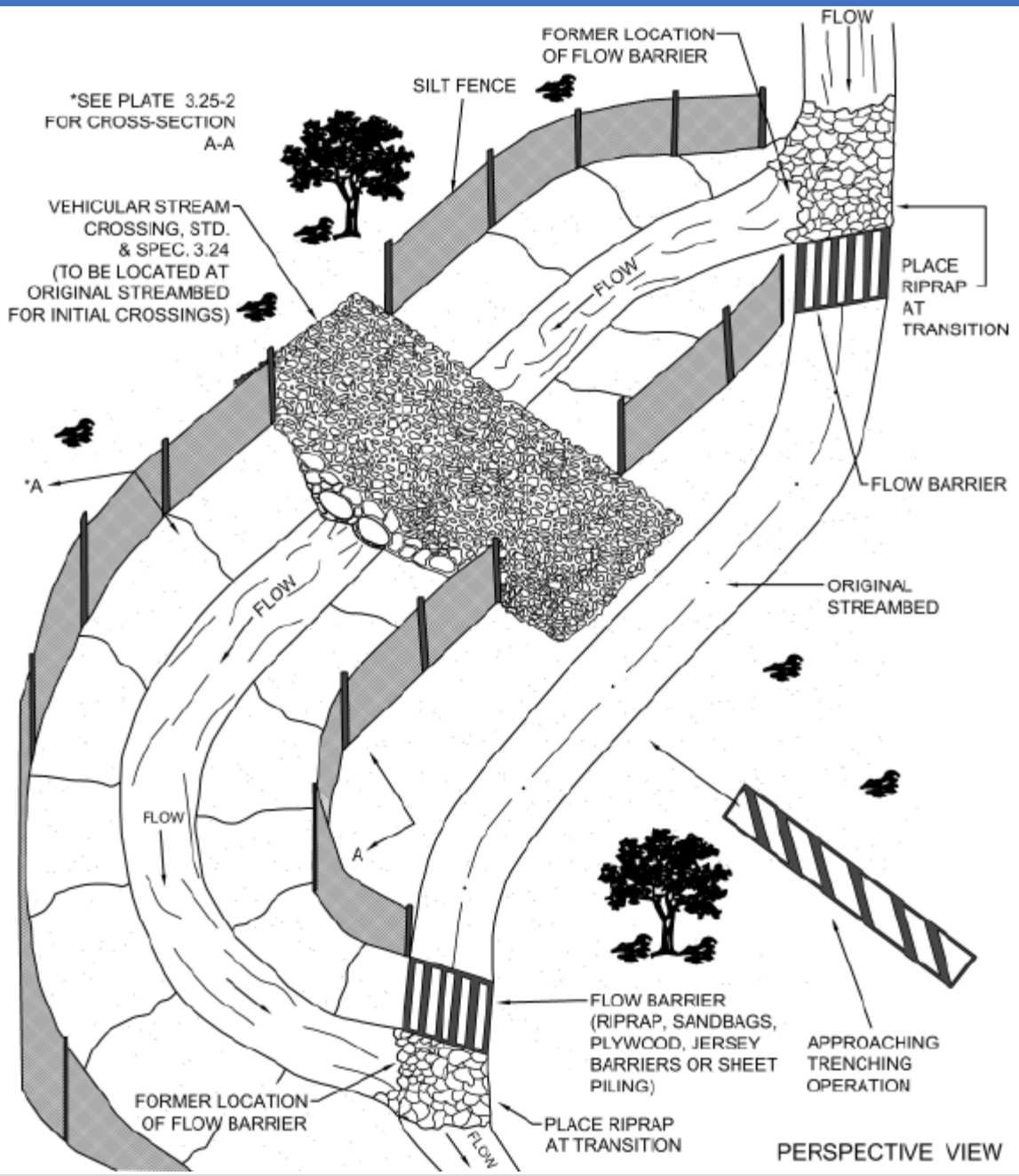
Table C-ENV-04-4 Trenchless Technology	
Technique	**Notes on Proper Use**
Jack and Bore	Jack and bore, or auger boring, is one of the most popular methods of trenchless technologies. A sending pit and a receiving pit are excavated on either side of the crossing location. A jack and bore machine is placed in the sending pit. A hole is cut underground horizontally from the sending pit to the receiving pit using a rotating cutter head attached to an auger string. As the machine drills the hole, the new pipe or line is pushed into the drilled hole using a jacking frame. The rotating auger brings the spoil material back to the machine. The jack and bore machine is removed, and the pits are backfilled and surfaces restored.
Micro tunneling	Micro tunneling is defined as a remotely controlled and guided pipe jacking technique that provides continuous support to the excavation face and does not require personnel entry into the tunnel. Like jack and bore, a sending and receiving pit are excavated at either side of the crossing location, and the micro tunneling boring machine is placed in the sending pit. The rotating cutting head excavates the soil while pipe sections are pushed through the drilled hole using a jacking frame. There is a closed-loop slurry system in which excavated soil is mixed with clean water and bentonite that is transported to discharge cables into a separation system for recirculation or routing to storage tanks.
HDD	HDD, horizontal directional drilling or directional boring, is a method of installing pipes underground using a steerable arc-drilling rig. HDD is surface launched, resulting in no need for sending and receiving pits to be excavated. First, a drill bit tool creates a pilot hole from the entry to the receiving locations at an angle of 5 to 30 degrees from the ground surface. The second phase is reaming, which enlarges the hole by approximately 50% and prepares it for pipe placement. A reamer tool replaces the drill bit and is pulled back or pushed forward by the HDD machinery to expand the pilot hole. The third phase is pipe pullback, in which the new pipe is attached to the reamer and pulled through the HDD borehole into place. Drilling fluid is used to suspend and remove soil cuttings, stabilize the hole, reduce friction, cool and lubricate the drill bit, and control soil pressures below the surface. Typically, drilling fluid consists of a mixture of water, bentonite, soda ash, and chemicals that prevent swelling.

7.0 Operations and Maintenance Considerations

Take care to inspect any stream crossing area at the end of each day to make sure that the construction materials are positioned securely. This will ensure that the work area stays dry and that no construction materials float downstream.

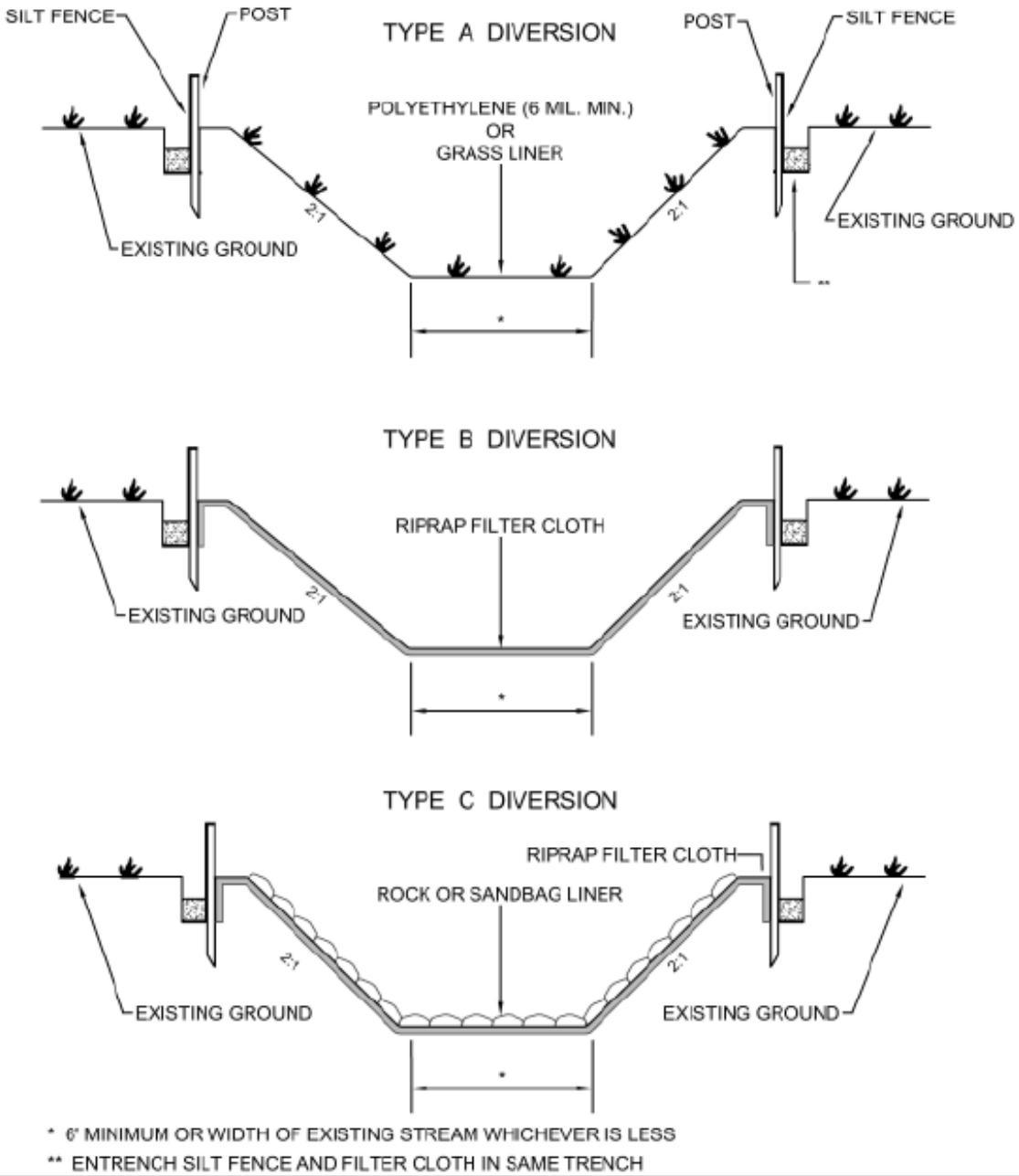
Continuously monitor the performance and configuration of the crossing for any changes in stream flow or diversion pipe or pump performance. Monitor the upstream or backwatered areas for headwater depths in relation to the heights of the dams to ensure water is not rising to the tops of the dams or flowing in undesirable locations. Keep the inlet of the diversion pipe and pump intake free from debris and ensure the intake protection is functioning. Maintain the pumps in operating condition and provide a backup pump in case of failure. Inspect the stable discharge point for indicators of erosion and repair any erosion observed.

Figure C-ENV-04-1 Diversion Channel Crossing



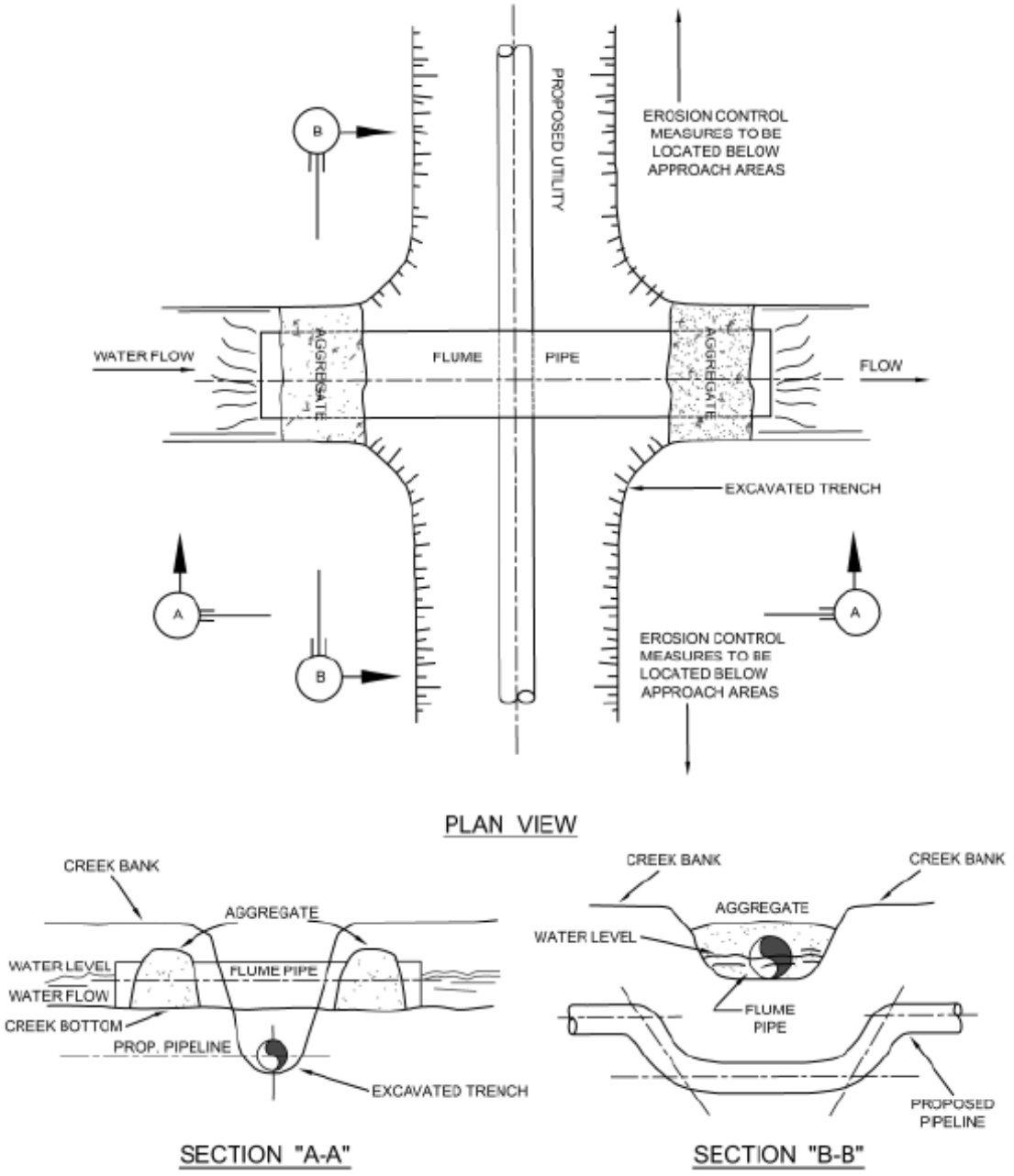
Source: Va. DSWC

Figure C-ENV-04-2 Diversion Channel Crossing Acceptable Linings



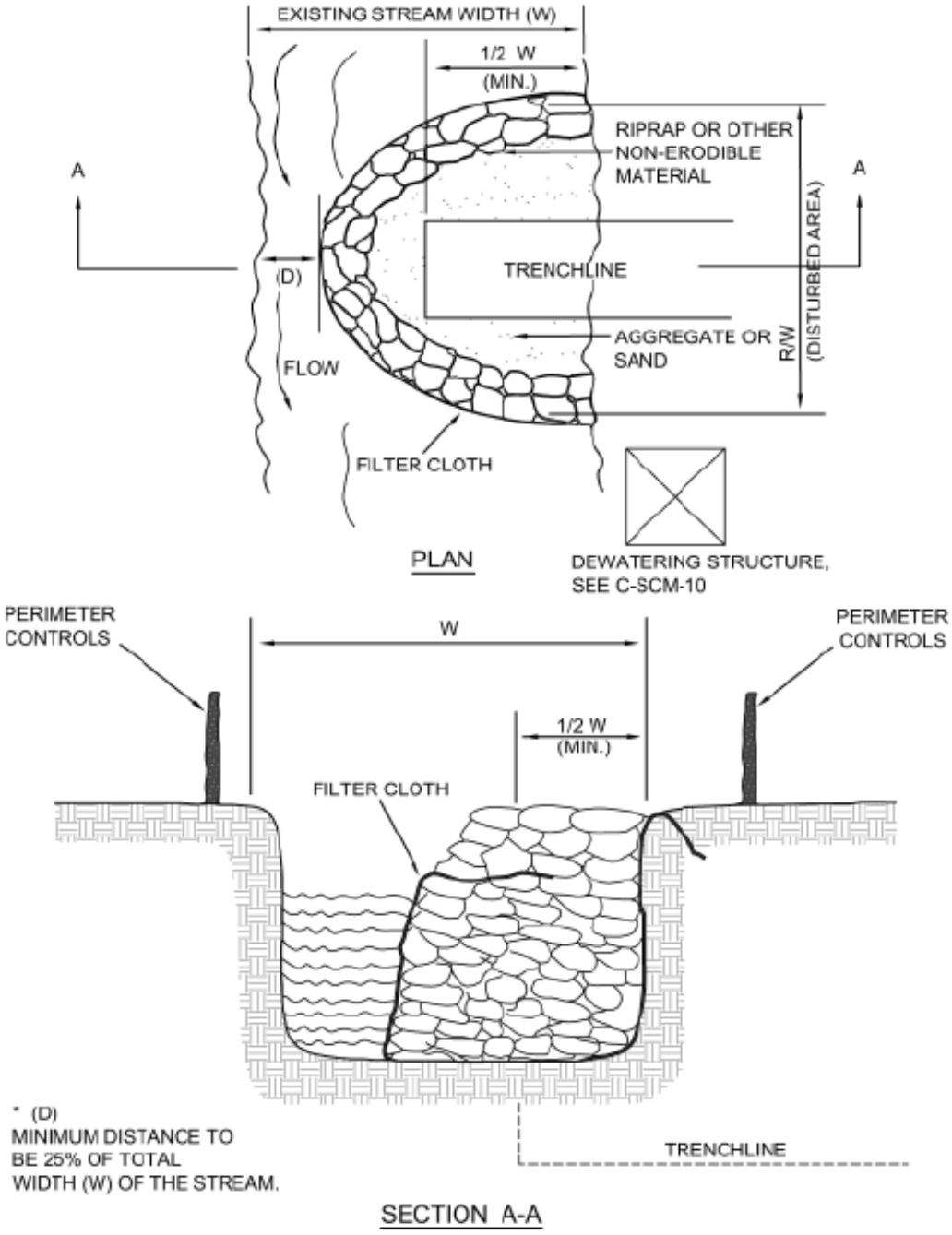
Source: Adapted from VDOT Standard Sheets

Figure C-ENV-04-3 Flume Pipe Crossing



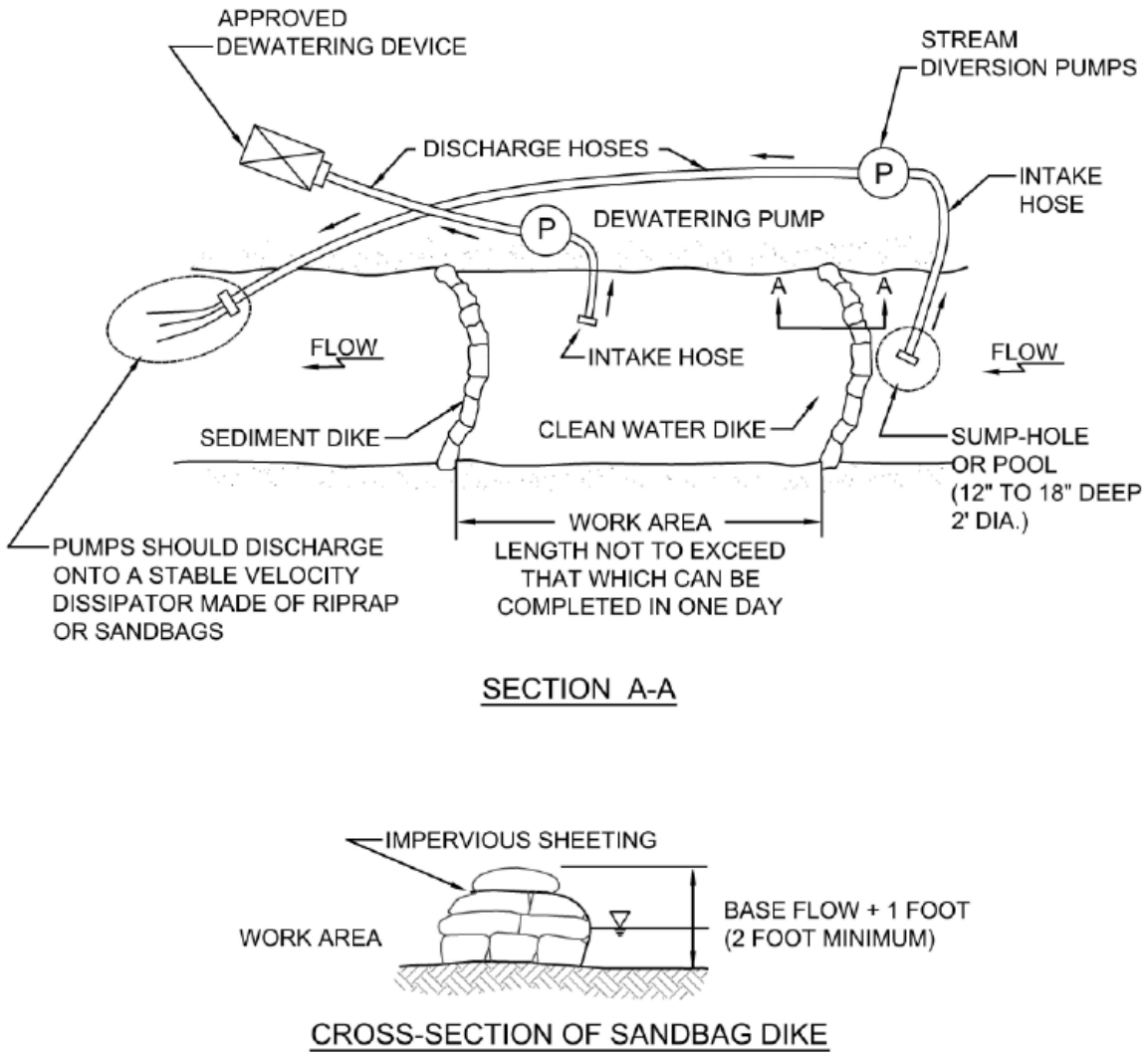
Source: Va. DSWC

Figure C-ENV-04-4 Cofferdam Crossing



Source: Va. DSWC

Figure C-ENV-04-5 Sandbag Dike



Source: Maryland Department of the Environment 2011

8.0 Reference

Maryland Department of the Environment. 2011. 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control. December.

C-ENV-05 Cofferdam Crossing

1.0 Definition

A cofferdam is a temporary structure within a waterway or body of water designed to provide a dry work area for temporary construction and to contain disturbed soil and/or suspended sediments.

– CAD and PDF for C-ENV-05 Cofferdam Crossing

2.0 Purpose and Applicability of Best Management Practice

Cofferdams allow work to be performed in a waterway or body of water while minimizing turbidity and sedimentation in adjacent and/or downstream areas.

Cofferdams are used as a temporary measure when work will be conducted in a waterway (stream, river, or other linear feature that conveys water) or body of water (lake, pond, or other impoundment). Water is either intercepted upstream and discharged downstream or diverted around the work site.

Typical activities requiring the use of cofferdams include shoreline stabilization of a waterbody; installation or replacement of a culvert, bridge, pier, or abutment; open-cutting for the installation of utilities; and stream restoration projects. Cofferdams may also be used to allow work in otherwise unsuitable conditions.

Where a cofferdam is needed, refer to Utility Stream Crossing (BMP C-ENV-04) and Pump Around Diversion (BMP C-ENV-08).

This practice standard should not take the place of engineered sheetpile, cellular, slurry wall, tie-back wall, brace excavation, or embankment cofferdams. Cofferdams designed using this standard may necessitate review by a licensed engineer depending on the size and scale of the cofferdam.

3.0 Planning and Considerations

Five typical cofferdam types are described herein, but others are possible. Design alternative cofferdams based on the general criteria of this standard and adapt the design to meet the requirements of similar cofferdam types. As an example, rather than stone for the stone and impermeable barrier cofferdam, sandbags or gravel bags may be used. In addition, the upstream and downstream cofferdam types can be different.

Do not leave cofferdams in for long periods, as cofferdams are temporary structures. Incorporate additional considerations for long-term cofferdam usage such as issues with ice flow or aquatic life movement. Long-term cofferdams may have to be built to withstand a less frequent (higher magnitude) storm event. ***Remove cofferdams immediately after the work in the waterbody is complete.***

Any work within a stream may be subject to the rules and regulations of the U.S. Army Corps of Engineers. A permit may also be required from the Virginia Department of Environmental Quality and Virginia Department of Conservation and Recreation.

Additional requirements may apply where state or federally threatened or endangered species or other species of local interest are present.

Before the installation or removal of a cofferdam, a Turbidity Curtain (BMP C-SCM-09) or a Modified Turbidity Curtain for Streams (BMP C-ENV-14) may be installed to contain turbid water and allow suspended solids resulting from the installation of the cofferdam to settle out. Do not place turbidity curtains across stream flow, as they may reduce flow and catch debris. Place the curtains parallel to flow or the shoreline to contain sedimentation that may occur during the installation of the cofferdam.

When installing a cofferdam in a linear water feature, make every effort to block only a portion of the waterway by using a partial cofferdam. The reason for using a partial cofferdam is to maintain stream flow and allow the movement of aquatic life during construction. Block the entire flow only when necessary.

4.0 Stormwater Performance Summary

MS-12: WATERCOURSE CONSTRUCTION – When work in a live watercourse is performed, precautions will be taken to minimize encroachment, control sediment transport, and stabilize the work area to the greatest extent possible during construction. Non-erodible material will be used for the

construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

MS-14: OTHER WATERCOURSE REGULATIONS – All applicable federal, state, and local requirements pertaining to working in or crossing live watercourses will be met.

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-ENV-05-1 Design Criteria for Cofferdam Crossings

Parameter	Notes on Proper Use
Diversion/ Bypass Flow	Size the diversion or bypass flow to safely convey the 2-year, 24-hour peak flow at a minimum. Design the cofferdam to overtop for any events greater than the 2-year, 24- hour peak elevation, unless higher peak flows are being bypassed. It is the responsibility of property owners and those performing work to safely convey flows to prevent damage to off-site properties. If waterway information is not available, the ordinary high-water (OHW) mark (OHWM) can be used as an indicator. The term "low-flow conditions" refers to flow at or below the OHWM. The OHWM refers to a clear line developed by typical fluctuations in water levels. Ensure the construction of any cofferdam, within a linear water feature and regardless of duration, does not cause a significant water level difference upstream or downstream of the project site. Maintain the stream velocity below the cofferdam at a rate equal to existing pre-installation flow conditions above the cofferdam.
Materials	Construct cofferdams of non-erodible materials such as stone, metal, geosynthetics, or other products as approved by the certified plan reviewer. Ensure the cofferdam materials are free of potential pollutants such as soil, silt, sand, clay, grease, or oil. Use non-toxic and non-hazardous substances to assemble or maintain cofferdams. Ensure any material used to minimize seepage underneath diversion structures, such as grout, is non-toxic, non-hazardous, and as close to neutral pH (7) as possible. Acceptable cofferdam materials include sandbags, sand totes, Jersey wall sections, collapsible fabric membrane dams, A-frame, water filled bags/tubes, sheet piling, plastic wrapped hay bales/soil/aggregate/riprap, plastic sealed plywood, plastic sealed trench box lids, or other suitable materials. Refer to the Utility Stream Crossing (BMP C-ENV-04) for alternative stream crossing methods.
Filter Fabric	Use filter fabric in the construction of the cofferdam that conforms to physical requirements noted in Riprap (BMP C-ECM-13) to line the water side of the cofferdam to prevent water passage into the work area.

Table C-ENV-05-1 Design Criteria for Cofferdam Crossings	
Parameter	**Notes on Proper Use**
Scheduling	To avoid or minimize impacts, schedule construction in a linear water feature during seasonal or temporary periods of low- or no-flow conditions. During scheduling, also consider seasonal releases of water from dams, water demands due to crop irrigation, and timed to minimize impacts on fish and other aquatic life. Do not use cofferdams across a stream bed when fish passage/spawning is of concern unless properly mitigated.
Velocity Dissipator	Riprap- or sandbag-lined “plunge pool” sized to be non-erosive at the discharge pipe velocity.

Table C-ENV-05-2 Types of Cofferdams	
Type	**Notes on Proper Use**
Sandbag or Sand Tote	Suggested for temporary barriers in shallow water up to 3 feet. Sandbags or sand totes may be filled on site or pre-filled and made of burlap or polypropylene materials that are resistant to ultraviolet (UV) radiation, tearing, and puncture. Ensure sandbag or tote material is woven tightly enough to prevent leakage of the fill material (i.e., sand, or fine gravel). Refer to Plate 1.
Bladder	Only use inflatable bladders where there is a relatively flat base material. Wide variations in the base elevation will result in an improper seal, which will allow water seepage. Bladder cofferdams are appropriate for both full and partial cofferdam situations. Construct inflatable bladder cofferdams in accordance with manufacturer specifications. Follow the specific sizing, installation requirements, maintenance, allowable flow velocities, and other pertinent information per the manufacturer specifications. Ensure all cofferdams are duel-chambered to avoid rolling. Refer to Plate 2.
A-Frame	Only use A-frame cofferdams where there is a relatively flat base material. Wide variations in the base elevation will result in an improper seal, which will allow water seepage. A-frame cofferdams are appropriate for both full and partial cofferdam situations. Construct A-frame cofferdams in accordance with manufacturer specifications. Follow the specific sizing, installation requirements, maintenance, allowable flow velocities, and other pertinent information per the manufacturer specifications. Refer to Plate 3.

Table C-ENV-05-2 Types of Cofferdams	
Type	**Notes on Proper Use**
Stone & Impermeable Barrier	Only use stone and impermeable barrier cofferdams in intermittent streams of lower flow velocity. These cofferdams may be used in partial cofferdam situations in higher velocity linear water features and waterbodies. This cofferdam method could be an option where underground electrical and gas lines may be present. It may also be a good option for areas with an uneven, stone, or bedrock base material. To install a stone impermeable barrier cofferdam, first place the impermeable barrier on the bottom of the water feature. Extend the barrier out past the edge of the future cofferdam at a sufficient length so that it can be pulled back over the riprap after it has been installed. This will create a seamless barrier on the water side with the opening seam on the work area side. After the barrier is pulled over the riprap, it will likely be necessary to hold the impermeable barrier in place with riprap or sandbags. Appropriately size riprap to ensure that the cofferdam can withstand design flows. Refer to Plate 4.
Steel Sheet	Steel sheet cofferdams are different from sheet pile cofferdams. Sheet pile cofferdams are engineered structures, where steel sheet cofferdams may not be. Steel sheet cofferdams are not recommended for partial cofferdams used in larger waterways or bodies of water. Steel sheet cofferdams are appropriate for both full and partial cofferdam situations. Do not use steel sheet cofferdams where underground electrical and gas lines may be present. Overhead wires located above the potential cofferdam location may also limit the use of this method. In areas with stone or bedrock base materials, the use of steel sheet for cofferdams may be difficult or impractical. Drive the steel sheet into the base material a sufficient distance to avoid undercutting. Ensure steel sheets can create a fully enclosed work area. Refer to Plate 5.
Impermeable Barrier Material	The impermeable barrier used in this standard should consist of one of the following materials: 1. Rubber liner with a thickness of at least 45 mil. This material elongates up to 100% and has good UV resistance. A solvent weld is necessary to affix material into larger sections. 2. Polypropylene liner with a thickness of at least 40 mil. This material elongates up to 80%. A heat gun is necessary to weld pieces together. Fabric puncturing may be a concern for this material. 3. Polyvinyl chloride (PVC) liner with a thickness of at least 40 mil. High elongation properties but not UV stable. A solvent weld is necessary to affix material into larger sections.

6.0 Construction Specifications

1. Before commencement of instream activities, properly install all appropriate soil erosion and sediment control measures.
2. During disturbance or removal of vegetation, do not exceed the minimum necessary to complete operations.
3. Do not allow construction equipment to enter standing or flowing water. If equipment access to the work area through water is necessary, construct a non-erodible causeway.
4. For cofferdams used in linear water features, provide for emergency overflow at the center of the cofferdam to prevent erosion along the banks. Ensure the overflow system includes an energy dissipating surface and does not contribute to or cause erosion of the stream.



Inflatable Bladder Cofferdam Crossing
Source: Detroit Tarp

5. Following cofferdam installation, completely dewater the work area to work under dry conditions. Before complete dewatering of the work area, remove trapped fish and other aquatic wildlife, and relocate to the water body downstream of the lower cofferdam. Pumping of water may be required throughout construction to maintain dry conditions. Use the criteria in Dewatering Structure (BMP C-SCM-10) to achieve dry conditions.
6. Maintain the exteriors of vehicles and equipment that will be within the coffered area free of grease, oil, fuel, and residues. Position stationary equipment, such as motors and pumps located within the work area or adjacent to a water body, over drip pans or other confinement area. Store all equipment outside of the floodplain when not in use to avoid inundation during a high-water event.
7. Filter water pumped from the work area to ensure that the discharge results in no visible increase in suspended solids or turbidity in the water surrounding the work area. Ensure the quality of discharge meets all applicable local, state, or federal regulations, whichever is most restrictive. Ensure that the filtered water is discharged in a manner that does not cause erosion.

   Provide stabilization measures to the flow path from the point of discharge to the receiving water body as required. Methods for cleaning water discharged from the work area include Dewatering Structure (BMP C-SCM-10) and Temporary Sediment Trap (BMP C-SCM-11).



A-Frame Cofferdam Crossing
Source: Detroit Tarp

8. Discharge all water pumped from or diverted around the work area on an energy dissipating surface so as not contribute to or cause erosion of the stream.
9. Remove all temporary materials after the completion of construction. Before cofferdam removal, stabilize the work area with appropriate vegetative and/or structural practices, in accordance with plan details and specifications, that are stable enough to accept flows as determined by the certified plan reviewer.
10. Remove the downstream cofferdam first, followed immediately by the removal of the upstream cofferdam.
11. Stabilize disturbed areas with the appropriate vegetation or other stabilization measures upon the completion of work or during periods of inactivity. Remove excavated material or spoils resulting from the activity from the coffered area as soon as possible and do not allow the excavated material or spoils to remain overnight. Restore waterways only with original channel bottom substrate materials following the completion of work.

7.0 Operations and Maintenance Considerations

Because the potential for washout is high, monitor the cofferdam daily and do not leave the cofferdam unattended for longer than 24 hours.

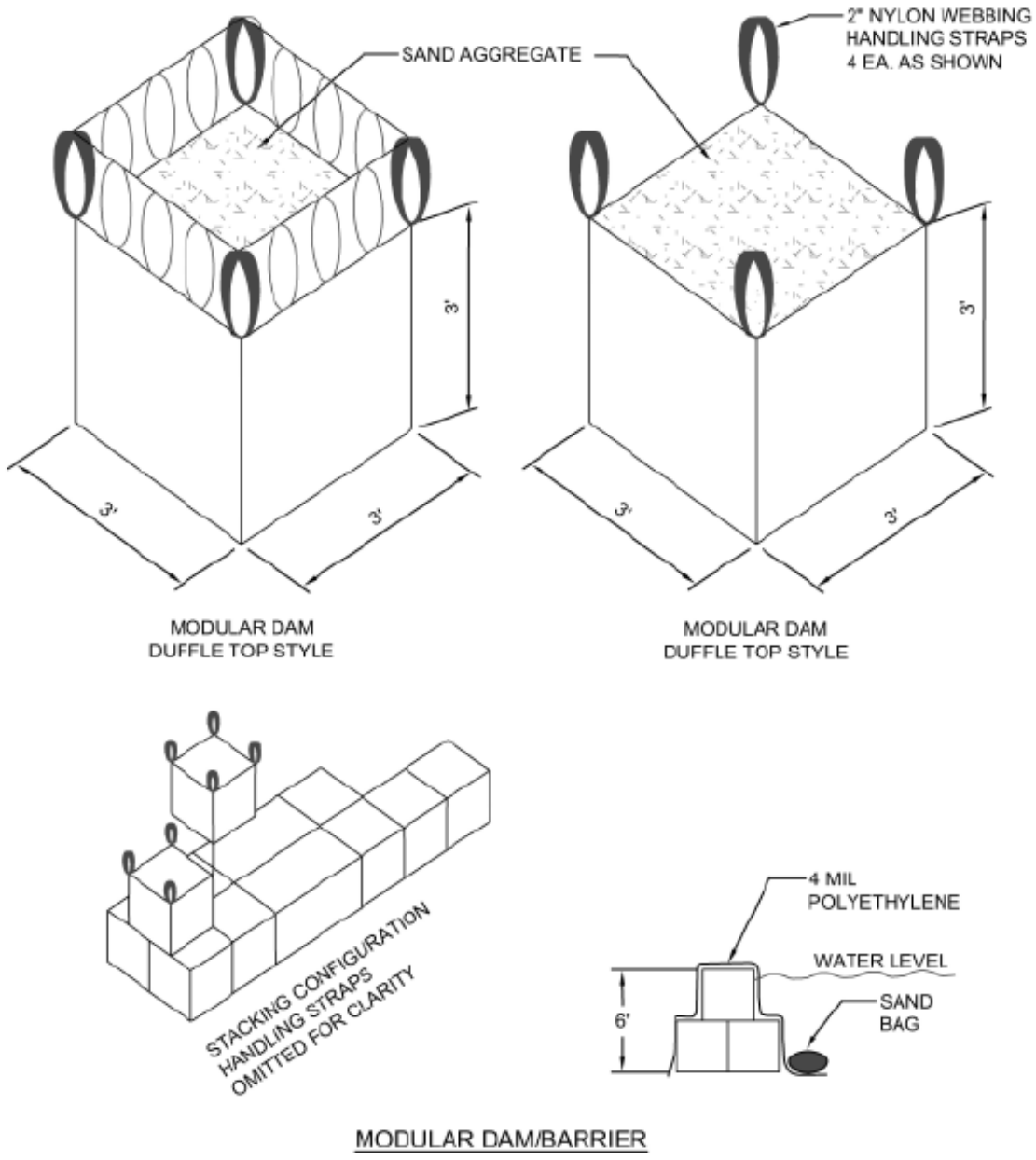
Observe weather reports daily. If a storm event is expected, stabilize the site as appropriate. Make all repairs immediately to prevent further damage to the installation.

Regularly inspect cofferdams for leaks or other deficiencies. Remove sandbags used within the cofferdam, if applicable, by hand to prevent breakage.

Return all disturbed soil within the coffered area to original condition with all possible efforts made to retain the existing soil profile before removal of the dams.

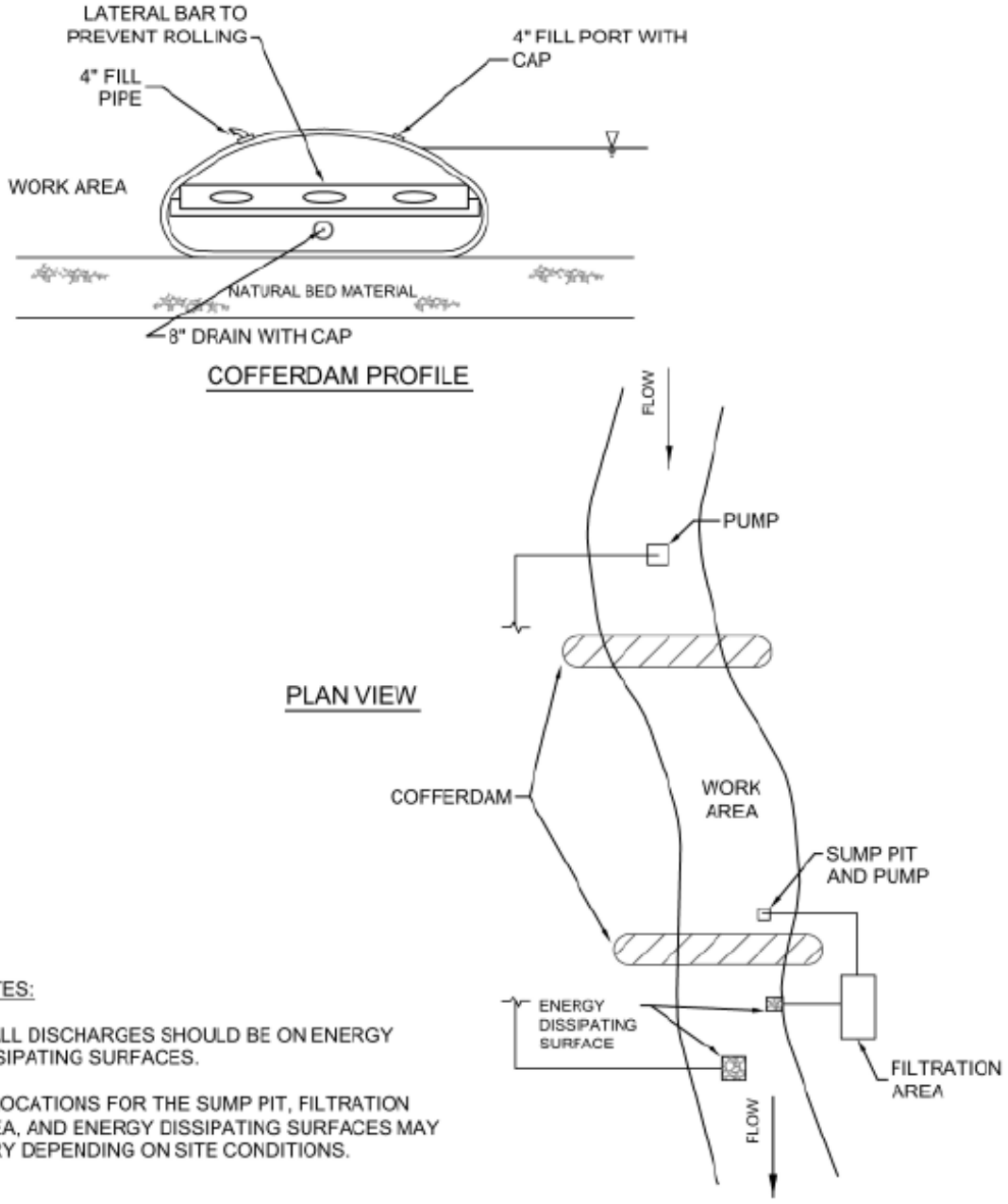
Reseed the sideslopes, stabilize with an appropriate erosion control blanket, and restore the substrate to pre-construction conditions. Initiate stabilization of all remaining disturbed areas immediately following the removal of the cofferdams. Do not leave areas adjacent to water features disturbed overnight.

Figure C-ENV-05-1 Sandbag Tote Dam



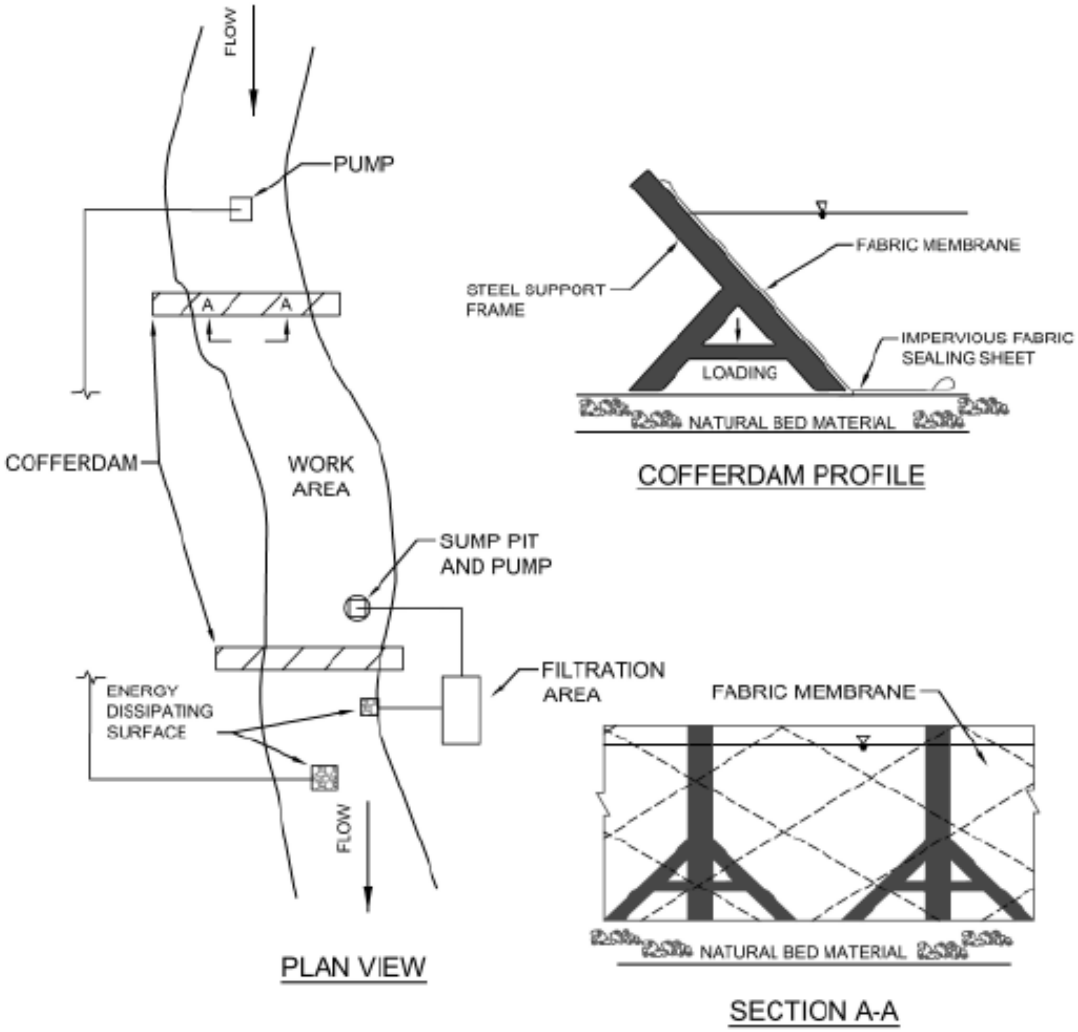
Source: Virginia Department of Conservation and Recreation 2004

Figure C-ENV-05-2 Inflatable Bladder Cofferdam Crossing Plan & Profile



Source: Illinois Environmental Protection Agency 2020

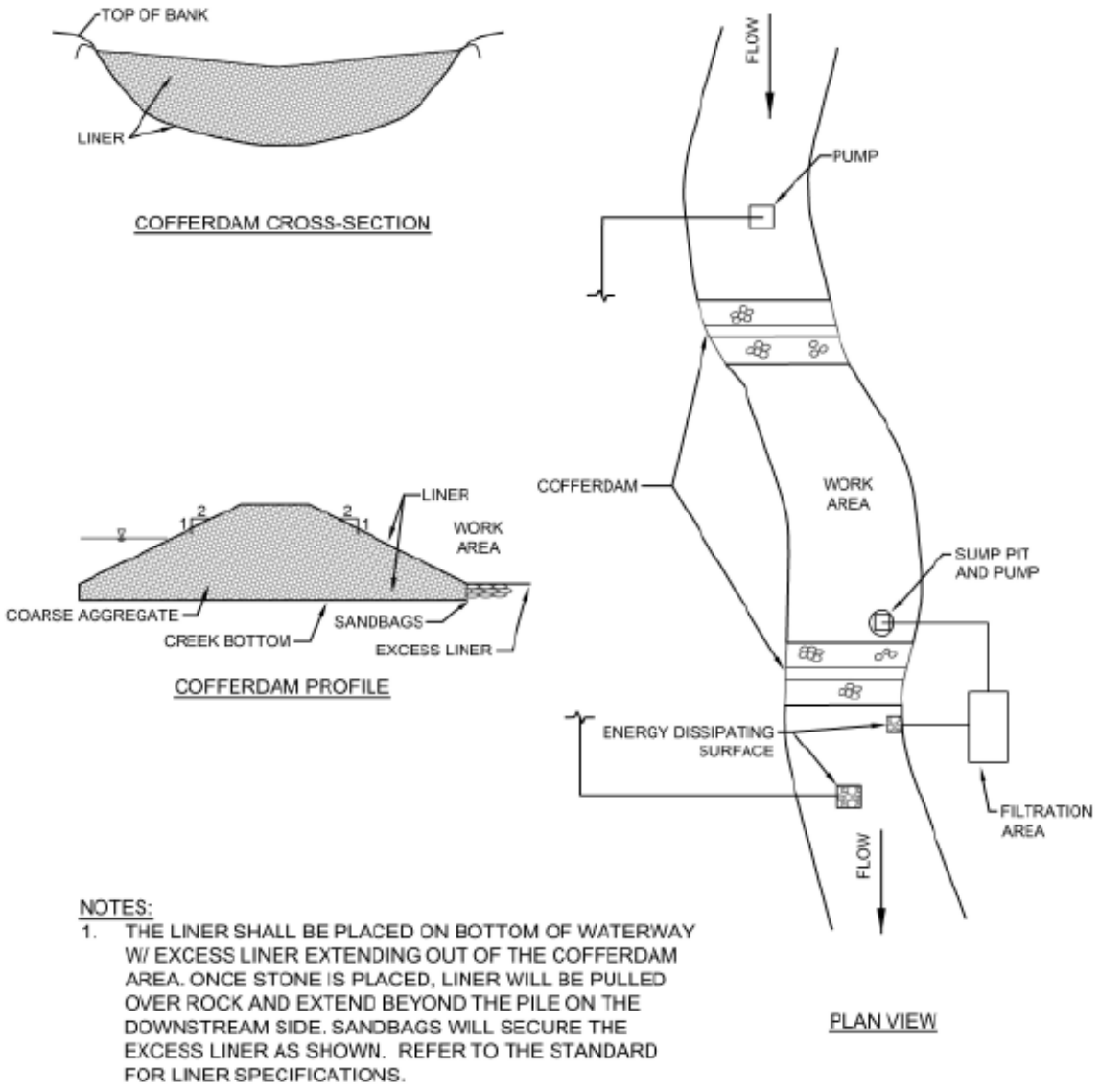
Figure C-ENV-05-3 A-Frame Cofferdam Crossing Plan & Profile



NOTES:
1. ALL DISCHARGES SHOULD BE ON ENERGY DISSIPATING SURFACES.
2. LOCATIONS FOR SUMP PIT, FILTRATION AREA, AND ENERGY DISSIPATING SURFACES MAY VARY DEPENDING ON SITE CONDITIONS
3. A-FRAME SHOULD BE INSTALLED ON MANUFACTURER'S SPECIFICATIONS.

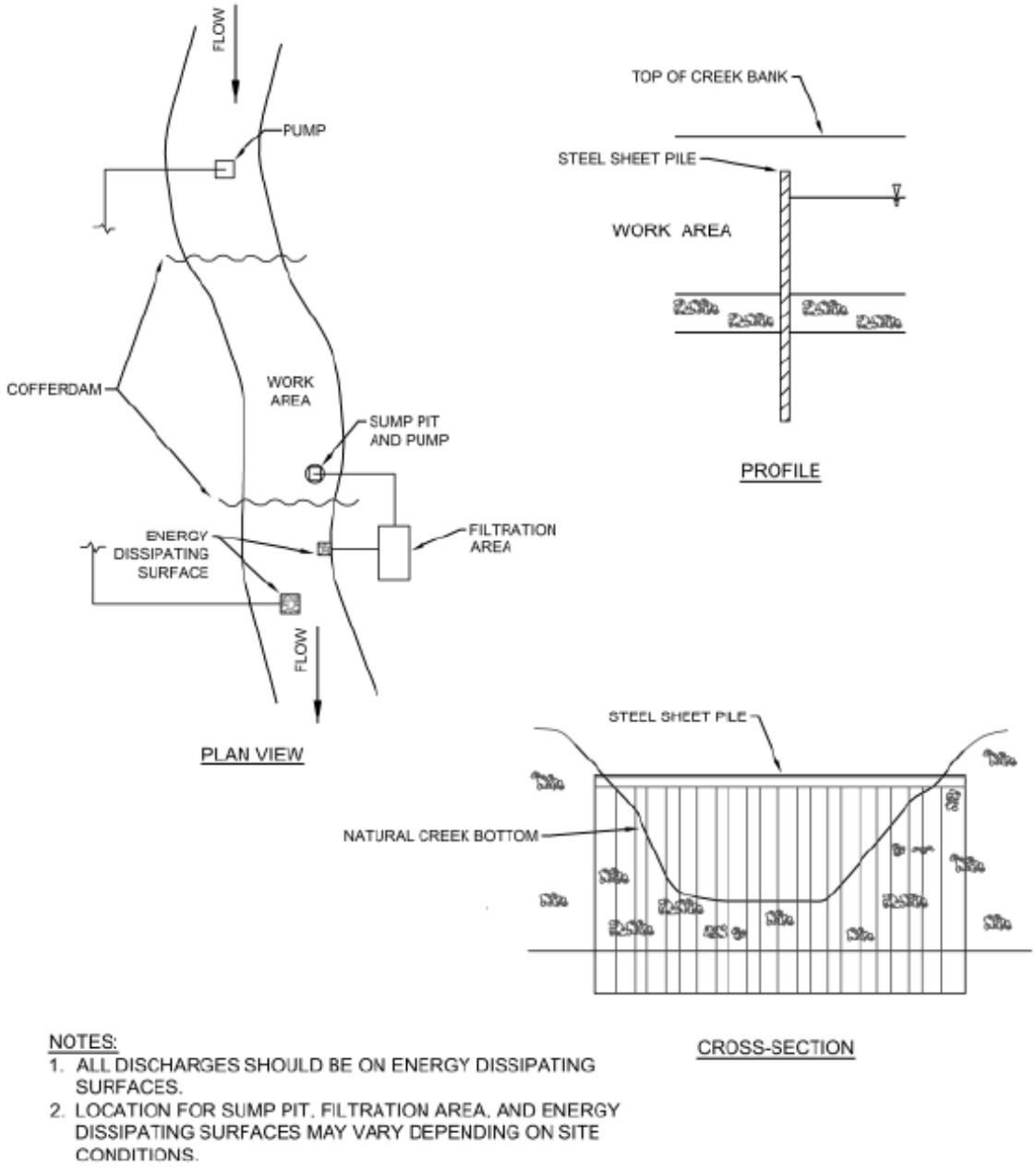
Source: Illinois Environmental Protection Agency 2020

Figure C-ENV-05-4 Stone & Impermeable Barrier Cofferdam Crossing Plan & Profile



Source: Illinois Environmental Protection Agency 2020

Figure C-ENV-05-5 Steel Sheet Cofferdam Crossing Plan & Profile



Source: Illinois Environmental Protection Agency 2020

8.0 References

Illinois Environmental Protection Agency. 2020. Illinois Urban Manual. February. Located at: www.illinoisurbanmanual.org.

Virginia Department of Conservation and Recreation. 2004. The Virginia Stream Restoration & Stabilization Best Management Practices Guide.

C-ENV-06 Stable Wetland Crossing

1.0 Definition

A stable wetland crossing is a method or temporary structure used to cross a wetland with vehicles and/or equipment and/or strategy for crossing wetlands when in-wetland utility construction is involved.

– CAD and PDF for C-ENV-06 Stable Wetland Crossing

2.0 Purpose and Applicability of Best Management Practice

Stable wetland crossings are used during wetland construction or when access through a wetland is unavoidable to minimize soil disturbances and reduce the potential for erosion to occur.

Stable wetland crossings are used where a crossing is needed to gain access, where there are no feasible or prudent alternatives (including upland alternatives) for in-wetland utility construction to be conducted, and where the crossing and/or in-wetland utility construction will not adversely impact the wetland resource (i.e., filling or changing the hydrology of the wetland).

3.0 Planning and Considerations

Where soils that have major hydric components or have hydric inclusions are present on or adjacent to construction, determine whether wetlands exist on or near the project site that could be affected by the proposed earthwork. Where such wetlands exist, identify where the wetlands are to be delineated and shown on the plan map(s). Wetland crossings require permit authorization from federal, state, and/or county authorities.

Conduct a site evaluation to determine the best site for constructing the crossing.

1. Ensure the area has a minimal potential for erosion of the disturbed land cover.
2. Design the area such that various types of crossings can be consolidated into a lesser number of crossings.
3. Avoid areas that have highly saturated wetland soils or habitat deemed important or critical to wildlife.



Active Installation of Wooden Wetland Crossing
Source: Quality Mat Company 2023

Undertake and complete crossings of the wetland during drier periods. For large wetland complexes, consider crossing from opposite sides where possible to avoid crossing the entire wetland. Do not permanently dredge or fill wetlands where it would cause a loss of any wetland area without first obtaining the proper permit approval.

4.0 Stormwater Performance Summary

MS-12: WATERCOURSE CONSTRUCTION – When work in a live watercourse is performed, precautions will be taken to minimize encroachment, control sediment transport, and stabilize the work area to the greatest extent possible during construction. Non-erodible material will be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

MS-14: OTHER WATERCOURSE REGULATIONS – All applicable federal, state, and local requirements pertaining to working in or crossing live watercourses will be met.

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-ENV-06-1 Design Criteria for Stable Wetland Crossings

Design Component	Notes on Proper Use
Equipment and/or Vehicle Crossing	Avoid crossing wetlands with construction equipment and/or vehicles where possible. Where that is not possible, select the location and orientation of the crossing to have the least possible impact upon the wetland. Construct temporary equipment and/or vehicle crossings with materials that can be placed with a minimum disturbance to the soil surface and completely removed when no longer needed. Material used for temporary equipment and/or vehicle crossings must be free from pollutants in toxic amounts. Use temporary pads or mats to minimize rutting and soil compaction. More than one layer of pads or mats may be necessary in areas that are inundated or have deep organic wetland soils. Install a geotextile underlayment under a temporary wood mat. Construct wood mats using a minimum of 4-inch by 4-inch hardwood cabled together with 0.1875-inch galvanized steel cable. Install wood curbing or compost filter sock on either side of the wood mats to prevent sediment from entering the wetland from the wood mat.
In-Wetland Equipment Operation	Operate equipment in wetlands on temporary pads or mats. Do not use tree stumps, rock, brush, or soil imported from outside the wetland to stabilize the construction work area or as equipment pads or mats in wetlands. Limit construction equipment operating in wetland areas to that needed to clear, perform in-wetland utility construction, and restore the disturbed area. Ensure all other construction equipment uses access roads located in upland areas to the maximum extent practicable. Where access roads in upland areas do not provide reasonable access, limit all other construction equipment to one pass through the wetland using temporary pads or mats.
Clearing	Limit tree clearing within wetlands to those necessary to complete construction. Cut vegetation off at ground level, leaving existing root systems in place, and remove vegetation from the wetland for disposal. Protect trees where possible in accordance with Tree Preservation and Protection (BMP C-SSM-01).

Table C-ENV-06-1 Design Criteria for Stable Wetland Crossings	
Design Component	**Notes on Proper Use**
Work Adjacent to Wetlands	Where wetlands are adjacent to the proposed disturbed area, install perimeter control measures along the edges of the proposed disturbed area (silt fence, compost filter sock, hay bale barriers) as necessary to prevent sediment flow into the wetland. Install the perimeter control measures along the edges of the proposed disturbed area before initiating earth disturbance and maintain the measures until revegetation of the disturbed area is complete. Remove perimeter control measures after successful restoration of the disturbed area has been achieved.
Crossing Removal	Remove temporary pads or mats by backing out of the site, removing the pads or mats one at a time. Immediately regrade any rutting or significant indentations identified during pad/mat removal, taking care not to compact soils. Clean pads or mats before transport to another wetland location and before installation in the wetland to remove soil and any invasive plant species seed stock or plant material. Cleaning methods may include but are not limited to shaking or dropping mats in a controlled manner with a piece of machinery to knock off attached soil and debris, spraying with water or air, and sweeping. Inspect crossings following pad or mat removal to determine the level of restoration required.
Wetland Restoration	Revegetate disturbed wetland areas in accordance with Seeding, Mulching, and Soil Stabilization (Wetlands/Streams) (BMP C-ENV-15). Remove perimeter control measures located within and at the boundary between wetland and adjacent upland areas after revegetation and stabilization of the wetland and adjacent upland areas.

The crossing type will be specified on the plan based on the size of the wetland to be crossed, the expected equipment to be used, and the project details (including soil type); substitutions may be made after consultation with the design engineer.

6.0 Construction Specifications

1. Install timber mats or equipment pads through entire wetland area. Equipment necessary for right-of-way clearing may make one pass through the wetland before pads or mats are installed. Install filter fabric under timber mats in accordance with Riprap (BMP C-ECM-13).
2. Cut vegetation to immediately above ground level, leaving the existing root systems in place, and remove the cleared vegetation from the wetland.
3. If flowing or excess surface water is present in the wetland, refer to Utility Stream Crossing (BMP C-ENV-04) for temporary diversion techniques.
4. Remove timber mats or equipment pads from wetlands upon completion and when access is no longer required.



Rubber Equipment Pads for Wetland Crossing
Source: Presto Geosystems 2016

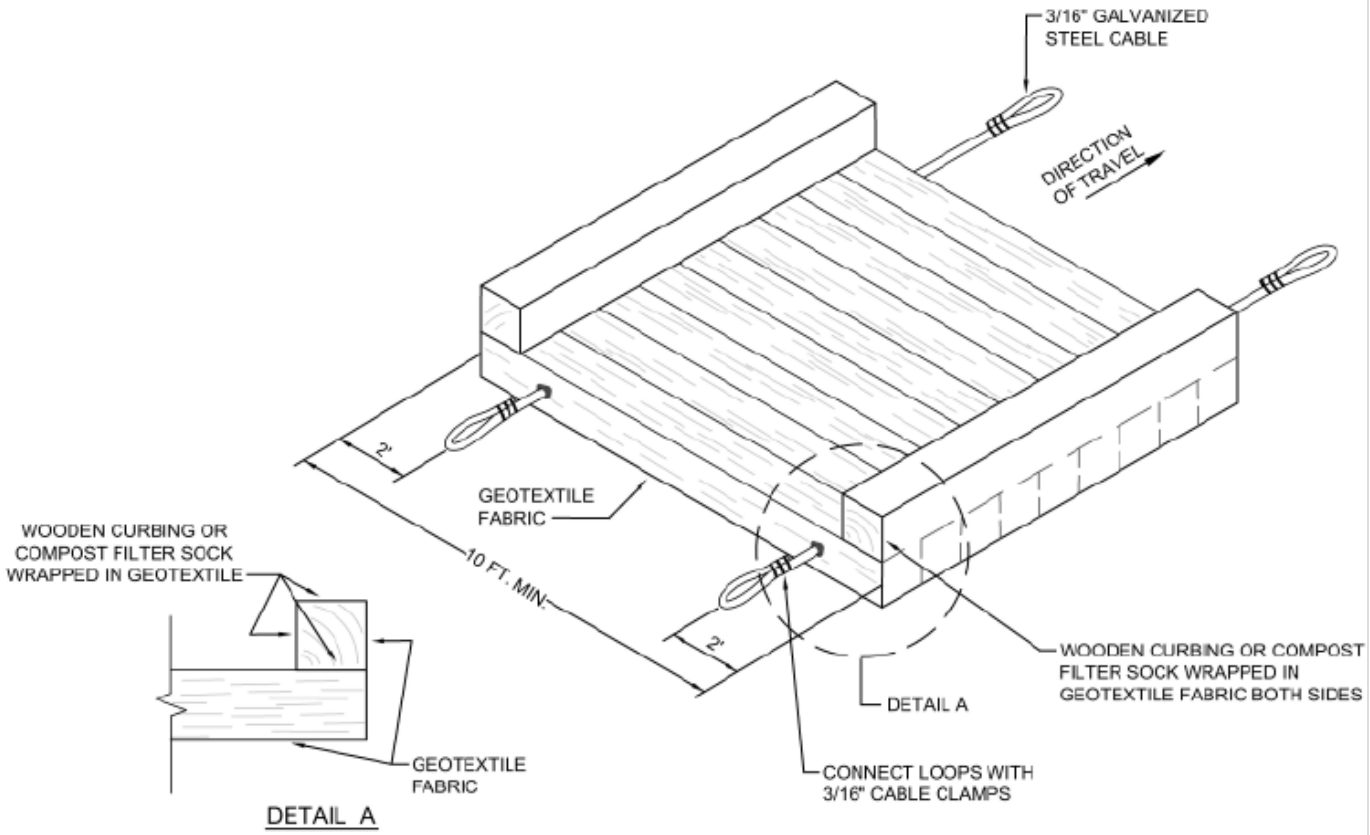
5. Restore the surface to pre-construction contours such that drainage patterns are not altered.
6. Revegetate disturbed wetland areas.
7. Once revegetation is completed, remove temporary perimeter control measures and revegetate areas disturbed during removal of the temporary measures.

7.0 Operations and Maintenance Considerations

Inspect the crossing daily to ensure that the crossing and all perimeter control measures are functioning properly. Periodically clean wetland crossing pads or mats to ensure sediment is not being transported into adjacent protected areas. Immediately replace any destroyed pads or mats.

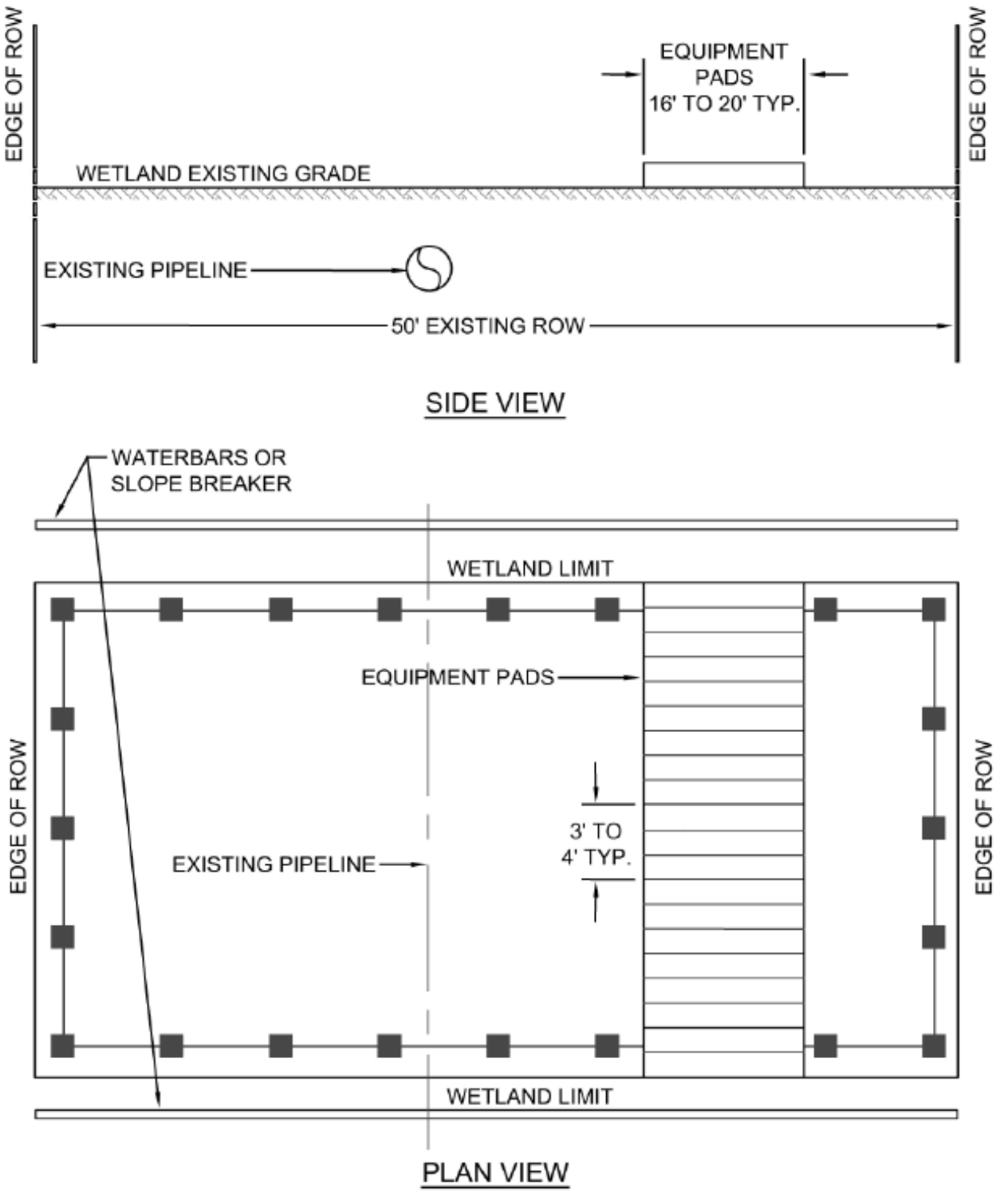
During maintenance, protect wetland crossings using lightweight, rubber-tracked equipment that exerts low ground pressure.

Figure C-ENV-06-1 Wooden Wetland Crossing Detail



Source: VDEQ 1992

Figure C-ENV-06-2 Stable Wetland Crossing Layout Detail



Source: VDEQ 1992

8.0 References

Presto Geosystems. 2016. Geoterra GTO Construction Mats – Portable Site Access Solution. Located at: https://www.prestogeo.com/products/construction-mats/geoterra-gto-construction-mats/?gclid=Cj0KCQjwuZGnBhD1ARIsACxbAVhiFG1yjf9AO_Ykdcf1FECxKVSfnHfTKuKHICGoA5Llm566rtc8BSUaAuISEALw_wcB.

Quality Mat Company. 2023. Quality Mat Company. Located at: www.qmat.com.

U.S. Army Corps of Engineers. 2016. New England District. Construction Mat Best Management Practices (BMPs). March.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

Wetland Studies and Solutions, Inc. 2020. General Erosion and Sediment Control Standards and Specifications for Wetland and Stream Mitigation Banks.

C-ENV-07 Gabions

1.0 Definition

Gabions are rectangular baskets fabricated from a hexagonal mesh of heavily galvanized steel wire filled with rock material.

2.0 Purpose and Applicability of Best Management Practice

Gabions slow the velocity of concentrated runoff and stabilize slopes with seepage problems and/or non-cohesive soils.

Gabions can be used at soil-water interfaces where the soil conditions, water turbulence, water velocity, and expected vegetative cover are such that the soil may erode under the design flow conditions.

Gabions can be used on steeper slopes than riprap and are sometimes the only feasible option for stabilizing an area where there is not enough room to accommodate a "softer," vegetated solution.

The baskets are also used to maintain stability and to protect streambanks and beds as identified in Structural Streambank Stabilization (BMP C-ENV-02) and as channel lining material for stormwater conveyance channels.

3.0 Planning and Considerations

The difference between a gabion basket and a gabion mattress is the thickness and the aerial extent of the basket. The benefit of gabions is that a basket or mattress can be filled with rocks that would individually be too small to withstand the erosive forces of the stream.

The gabion mattress is shallower (0.5 foot to 1.5 feet) than the basket and is designed to protect the bed or banks of a stream against erosion.

Gabion baskets are normally much thicker (approximately 1.5 feet to 3 feet) and cover a much smaller area. Gabion baskets are used to protect banks where mattresses are not adequate or to stabilize slopes, construct drop structures, pipe outlet structures, or nearly any other application where soil must be protected from the erosive forces of water.

Gabion mattresses are used for riverbank and scour protection, bridge and weir protection, channel linings, and embankment stability where the retaining properties of gabion baskets are not required.

Gabion baskets/mattresses can be made from either welded or woven wire mesh. The wire is normally galvanized to reduce corrosion but may be coated with plastic or other material to prevent corrosion and/or damage to the wire mesh containing the rock fill. New materials, such as a heavy-duty polymer plastic material, have been used in some applications in place of the wire mesh. If the wire baskets break, either through corrosion, vandalism, or damage from debris or bed load, the rock fill in the basket can be lost and the protective value of the method endangered.

Gabion baskets/mattresses are often used where available rock size is too small to withstand the erosive and tractive forces present at a project site. The available stone size may be too small due to the cost of transporting larger stone from remote sites or the desire to have a project with a smoother appearance than that obtained using riprap or other methods. Gabion baskets/mattresses also require about one third the thickness of material when compared to riprap designs. Riprap is often preferred, however, due to the low labor requirements for its placement.

The rocks contained within the gabion basket/mattress provide a substrate for a wide variety of aquatic organisms. Vegetation may be difficult to establish unless the voids in the rocks contained within the baskets/mattresses are filled with soil.

If large woody vegetation is allowed to grow in the gabion baskets/mattresses, there is a risk that the baskets/mattresses will break when the large woody vegetation is uprooted or as the root and trunk systems grow. Thus, it is normally not acceptable to allow large woody vegetation to grow in the baskets/mattresses. The possibility of damage must be weighed against the desirability of vegetation on the area protected by gabion baskets/mattresses and the stability of the large woody vegetation. If large woody vegetation is kept out of the baskets/mattresses, grasses and other desirable vegetation types may be established and provide a more aesthetic and ecologically desirable project than gabion baskets/mattresses alone.

The most important consideration for the installation of gabion baskets/mattresses is the stability of the stream. If the stream is undergoing rapid changes in base elevation (downcutting or deposition) or extreme lateral movement, make plans to correct the larger problems that are contributing to the local problem. If the larger problems are not addressed, local protection measures may be overwhelmed or flanked.

4.0 Stormwater Performance Summary

MS-15: BED AND BANK STABILIZATION – The bed and banks of a watercourse shall be stabilized immediately after work in the watercourse has been completed.

MS-11: OUTLET PROTECTION – Before any newly constructed stormwater conveyance channel can be made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and receiving channel.

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Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Primary design considerations for gabion baskets and mattresses are: 1) foundation stability; 2) sustained velocity and shear-stress thresholds that the gabions must withstand; and 3) toe and flank protection.

Table C-ENV-07-1 Design Criteria for Gabions	
Design Component	**Notes on Proper Use**
Toe and Flank Protection	Place the base layers of gabions below the expected maximum scour depth. Alternatively, the toe can be protected with mattresses that will fall into any scoured areas without compromising the stability of the bank or bed protection portion of the project. If bank protection does not extend above the expected water surface elevation for the design flood, install measures such as tiebacks to protect against flanking.
Filter Fabric	The use of a filter fabric behind or under the gabion baskets to prevent the movement of soil material through the gabion baskets is an extremely important part of the design process. Use filter fabric that conforms to physical requirements noted in Riprap (Table C-ECM-13-6). Migration of soil through the baskets can cause undermining of the supporting soil structure and failure of the gabion baskets and mattresses.
Stability of Underlying Bed and Bank Materials	Another critical consideration is the stability of the gabion foundation. This includes both geotechnical stability and the resistance of the soil under the gabions to the erosive forces of the water moving through the gabions. If there is any question regarding the stability of the foundation (e.g., possibility of rotational failures, slip failures) consult a qualified geotechnical engineer before and during the design of the bank/channel protection. Several manufacturers provide guidance on how to check for geotechnical failure. Tilt stacked gabion baskets used for bank stability towards the soils they are protecting by a minimum of about 6 degrees from vertical. Gabions can be stacked with steps facing either out towards the front or back into the slope. While the gabions can be stacked with no tilt, some tilt into the soil being protected is recommended.

Table C-ENV-07-1 Design Criteria for Gabions

Design Component	Notes on Proper Use
Median Stone Size for Gabion Baskets & Mattress	For gabion baskets, use a either gabion stone or Virginia Department of Transportation (VDOT) #3 Coarse Aggregate. Because gabion mattresses are much shallower and more subject to movement than gabion baskets, care should be taken to design the mattresses such that they can withstand the forces applied to them by the water. However, mattresses have been used where very high velocities are present and have performed well. Carefully design projects using gabion mattresses. Determine the median stone size for a gabion mattress from the following equation: $$d_m = S_f C_s C_v d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{0.5} \frac{V}{\sqrt{gdK_1}} \right]^{2.5}$$ where: C_s = stability coefficient (use 0.1) C_v = velocity distribution coefficient = $1.283^{-0.2}$ log (R/W) (minimum of 1.0) and equals 1.25 at end of dikes and concrete channels d_m = average rock diameter in gabions d = local flow depth at V g = acceleration due to gravity K_1 = sideslope correction factor (Table 1) R = centerline bend radius of main channel flow S_f = safety factor (1.1 minimum) V = depth-averaged velocity W = water surface width of main channel γ_s = unit weight of stone γ_w = unit weight of water This equation was developed to design stone size that prevents movement of filler stone in the mattress, eliminating deformation that can occur when stone sizes are not large enough to withstand the forces of the water. The result of mattress deformation is stress on the basket wire, increases in resistance to flow, and the likelihood of basket failure. Select the stone size in the gabion mattress such that the largest stone diameter is not more than about two times the diameter of the smallest stone diameter, and select the mattress size to be at least twice the depth of the largest stone size. Ensure the size range varies by about a factor of two to ensure proper packing of the stone material into the gabions. Because the mattresses normally come in discrete sizes (i.e., 0.5, 1.0, and 1.5 feet in depth) normal practice is to size the stone and then select the basket depth that is deep enough to be at least two times the largest stone diameter. Size the smallest stone such that it cannot pass through the wire mesh.

Table C-ENV-07-1 Design Criteria for Gabions

Design Component	Notes on Proper Use
Shear-Stress Threshold	Maccaferri® Gabions offers a table (Table 2) in their materials giving guidance on sizing stone and allowable velocities for gabion baskets and mattresses. Use the equation above to take the depth of flow into account. Table 2 does, however, give some general guidelines for fill sizes and is a quick reference for maximum allowable velocities. Maccaferri also gives guidance on the stability of gabions in terms of shear stress limits. The following equation gives the shear for the bed of the channel: $\tau_b = \gamma_w S d$ where: τ_m = bank shear = 75% of the bed shear = $\tau_m = 0.75\tau b$ S = bed or water surface slope through the reach These values are then compared to the critical stress for the bed calculated by the following equation: $\tau_c = 0.10(\gamma_s - \gamma_w)d_m$ with critical shear stress for the banks given as: $\tau_s = \tau_c \sqrt{1 - \frac{\sin^2\theta}{0.4304}}$ where: θ = the angle of the bank rotated up from horizontal A design is acceptable if $\tau_b < \tau_c$ and $\tau_m < \tau_s$. If either $\tau_b > \tau_c$ or $\tau_m > \tau_s$, then a check must be made to see if they are less than 120% of τb and τs. If the values are less than 120% of τ_b and τ_s, the gabions will not be subject to more than what Maccaferri defines as “acceptable” deformation. However, it is recommended that stone size be increased to limit deformation if possible.

Table C-ENV-07-1 Design Criteria for Gabions	
Design Component	**Notes on Proper Use**
Sustained Velocity	One of the critical factors in determining stability is the velocity of the water that passes through the gabions and reaches the soil behind the gabion. The water velocity under the filter fabric (i.e., water that moves through the gabions and filter fabric) is estimated to be one quarter to one half of the velocity at the mattress/filter interface. The velocity at the mattress/filter interface (V_b) is estimated to be: $$V_b = \frac{1.486}{n_f}\left(\frac{d_m}{2}\right)^{2/3} S^{1/2}$$ where: n_f = 0.02 for filter fabric, 0.022 for gravel filter material S = the water surface slope (or bed slope) through the reach If the underlying soil material is not stable, additional filter material must be installed under the gabions to ensure soil stability. Maccaferri also provides guidance on the stability of soil under the gabions in terms of velocity criteria. The limit for velocity on the soil is different for each type of soil. The limit for cohesive soils is obtained from a chart, while maximum allowable velocities for other soil types are obtained by calculating V_e, the maximum velocity allowable at the soil interface, and comparing it to V_f, the residual velocity on the bed (i.e., under the gabion mattress and under the filter fabric). Ve for loose soils = 16.1 x $d^{1/2}$ while V_f is calculated by: $$V_f = \frac{1.486}{n_f}\left(\frac{d_m}{2}\right)^{2/3} SV_a^{1/2}$$ where: V_a = the average channel velocity d_m = the average rock diameter If V_f is larger than two to four times V_e, install a gravel filter to further reduce the water velocity at the soil interface under the gabions until V_f is in an acceptable range. To check for the acceptability of the filter use the average gravel size for dm in the V_f equation. If the velocity V_f is still too high, reduce the gravel size to obtain an acceptable value for V_f.
Other Design Considerations	It may be possible to combine gabions with less harsh methods of bank protection on the upper bank and still achieve the desired result of a stable channel. Provisions for large woody vegetation and a more aesthetically pleasing project may also be used on the upper banks or within the gabions. However, the stability of vegetation or other upper bank protection should be carefully analyzed to ensure stability of the upper bank area. A failure in the upper bank region can adversely affect gabion stability and lead to project failure.

Table C-ENV-07-2 K1 Versus Sideslope Angle	
Sideslope	**Sideslope Correction Factor (K1)**
1H:1V	0.46
1.5H:1V	0.71
2H:1V	0.88
3H:1V	0.98
<4H:1V	1.0

Source: Freeman and Fischenich 2000.

Table C-ENV-07-3 Stone Sizes and Allowable Velocities for Gabions					
Type	**Thickness (ft)**	**Filling Stone Range (in.)**	**D50 (in.)**	**Critical Velocity***	**Limit Velocity****
Mattress	0.50	3 – 4	3.4	11.5	13.8
	0.50	3 – 6	4.3	13.8	14.8
	0.75	3 – 4	3.4	14.8	16.0
	0.75	3 – 6	4.7	14.8	20.0
	1.00	3 – 5	4.0	13.6	18.0
	1.00	4 – 6	5.0	16.4	21.0
Basket	1.50	4 – 8	6.0	19.0	24.9
	1.50	5 – 10	7.5	21.0	26.2

Source: Freeman and Fischenich 2000.

6.0 Construction Specifications

1. A gabion project is installed by first smoothing the area to be protected to the desired final slope. The filter fabric and any required gravel filter are then installed according to the design plans.
2. The gabions are next assembled and tied together, folded flat, stacked, and bundled by the supplier. The gabions are bent into the design form, and all ends and diaphragms are laced into place.
3. The assembled gabions are then placed in their proper location and laced (tied) to all surrounding gabions. It is important that all adjacent gabions be laced together, as the lacing prevents movement and the failure of a project due to the loss of one basket out of a protected area. Perform lacing in accordance with the manufacturer's recommendations.
4. After enough gabions are assembled, filling can start. Place the fill carefully in the gabions to prevent damage to the diaphragms and edges. Conduct filling in lifts of no more than 12 inches.



Trapezoidal Gabion Basket Installation Under Dry Conditions

Some hand adjustment may be required to obtain a smooth, attractive face. For gabion baskets taller than 12 inches, installation of tie wires or stiffeners are recommended after each lift to prevent exposed faces from bulging.

5. After filling, the covers are placed on the gabions and secured with tie wires (laced). The gabions can be seeded with grass or other cover vegetation if the soil is intermixed with the lifts of stone and if the hydrology is not limiting. Again, avoid planting large woody vegetation in the area protected by gabions.
6. Take care to determine soil properties if the gabions are to be covered. If the soil is saline or acidic, deterioration of the gabion wire can occur rapidly, leading to project failure. If the soil has a lower permeability than the underlying bank material, water may not be able to move readily through the gabions, resulting in hydrostatic pressure behind the gabions. This can cause a sliding or rotational failure of the gabions. If the soil placed on the gabions is porous enough to allow easy passage of water through the gabion, it may not retain enough water to support the desired vegetation.
7. If a grass cover can be established over gabions, it is possible that the grass will remain stable during high flows because the root system will be firmly attached to the gabion mesh and underlying rock fill. Carefully investigate the problems of adequate moisture and sufficient permeability of the soil. While gabions may be able to support some types of vegetation, use care when recommending covering and filling the gabions with intermixed soil and rock to support vegetation.

7.0 Operations and Maintenance Considerations

Check gabions for broken wires and repair if necessary to protect the stone contained in the gabions from being removed by the force of water passing the cage.

Remove any large woody vegetation that has started to grow in the gabions. Repair any damage to the gabions including replacing lost stone and repairing any damaged wire with wire like that used in the construction of the cages.

Monitor the project area for signs of erosion. If erosion is occurring at the toes of the gabion structures, take measures to protect the gabions from undercutting and subsequent failure. If water is eroding soil from behind a gabion wall, either divert the water or take measures to eliminate the erosion of soil from behind the gabions. This often occurs where surface runoff enters the stream at a location protected by gabions.

Monitor the project for any signs of geotechnical failure. If any of the gabions have shifted or appear to be bulging away from the bank, evaluate the seriousness of the problem. If proper geotechnical evaluations and measures are taken during the design and construction stages, there should be little chance of a major problem due to geotechnical failures.

8.0 References

Freeman, G.E. and J.C. Fischenich. 2000. Gabions for streambank erosion control. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-22). U.S. Army Engineer Research and Development Center. Vicksburg, MS.

Massachusetts Department of Environmental Protection. 2003. Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas. May.

C-ENV-08 Pump Around Diversion

1.0 Definition

The pump-around diversion is a dewatering practice used for temporarily pumping flow around segments of a stream channel during construction; the practice involves installing a temporary pump-around system and instream barriers to divert flow around sections or reaches of the stream.

– CAD and PDF for C-ENV-08 Pump Around Diversion



East Palestine, OH
Source: Michael D. DeVuono, PE

2.0 Purpose and Applicability of Best Management Practice

The pump-around diversion allows for clear water diversion around the designated work area during stream restoration projects. This form of diversion is necessary when restoration practices span the entire width of the stream channel and/or where a linear reach of stream segment is to be simultaneously dewatered and maintained in a dry condition. This practice is also used for utility stream crossings when a piped utility crosses a waterway using an open-trench installation method.

This practice also limits potential for downstream sedimentation because in-stream work will be completed in the dry and all denuded areas will be stabilized before re-introduction of water back into the stream channel.

3.0 Planning and Considerations

Design the total work area of the pump-around diversion not to exceed the length of area that can be completed and stabilized in 1 working day.

Complete the associated work and remove the pump-around diversion at the end of each working day and stabilize the work area. If the length of time to complete and stabilize the work area will exceed 1 working day, use alternative practices.

Limit the use of this practice to base- or low-flow conditions where applicable to ensure adequacy of pump equipment. This practice is most applicable in small to medium watersheds with relatively small base-flow discharges, which allows for multiple pumping options and equipment to sufficiently handle necessary pump capacity.

Limit the use of this practice to watersheds less than 1 square mile in size; however, the size of the watershed may be increased by demonstrating adequate pump capacity and height of in-stream barriers.

Size the pump selected to adequately pump base flow at a head greater than the in-stream barrier height.

The capacity of flow diversion is limited to the capacity of the pump and height of the in-stream barriers.

A downstream riprap or sandbag-lined “plunge pool” may be used at the pump discharge location to allow for dispersion of pump discharge to a non-erosive velocity within the existing stream channel.

4.0 Stormwater Performance Summary

MS-12: Watercourse Construction – When work in a live watercourse is performed, precautions shall be taken to minimize encroachment, control sediment transport, and stabilize the work area to the greatest extent possible during construction. Non-erodible material shall be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

Jurisdiction of wetlands and shorelines in coastal areas and areas under the Chesapeake Bay Preservation Act may have complicated jurisdictional divisions.

MS-14: Other Watercourse Regulations – All applicable federal, state, and local requirements pertaining to working in or crossing live watercourses shall be met.

9VAC25-875-560

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-ENV-08-1 Design Criteria for Pump Around Diversions

Parameters	Notes on Proper Use
Pump Selection	Pump selection requires the computation of total dynamic head (TDH; Godwin 2003): ***TDH = Static Suction Lift + Static Discharge Head + Friction Loss + Velocity Head*** Always use a pump with a capacity greater than that required to pump the desired flow.
Height of Instream Barriers	**For In-stream Barriers Installed and Removed in the Same Workday:** Design the heights of in-stream barriers for the normal base flow depth plus 1 foot of freeboard for pump-around diversions. **For In-stream Barriers for Continuous Pump-Around:** Design the heights of in- stream barriers for the 2-year storm elevation plus 1 foot of freeboard. The minimum in-stream barrier height is 2 feet.

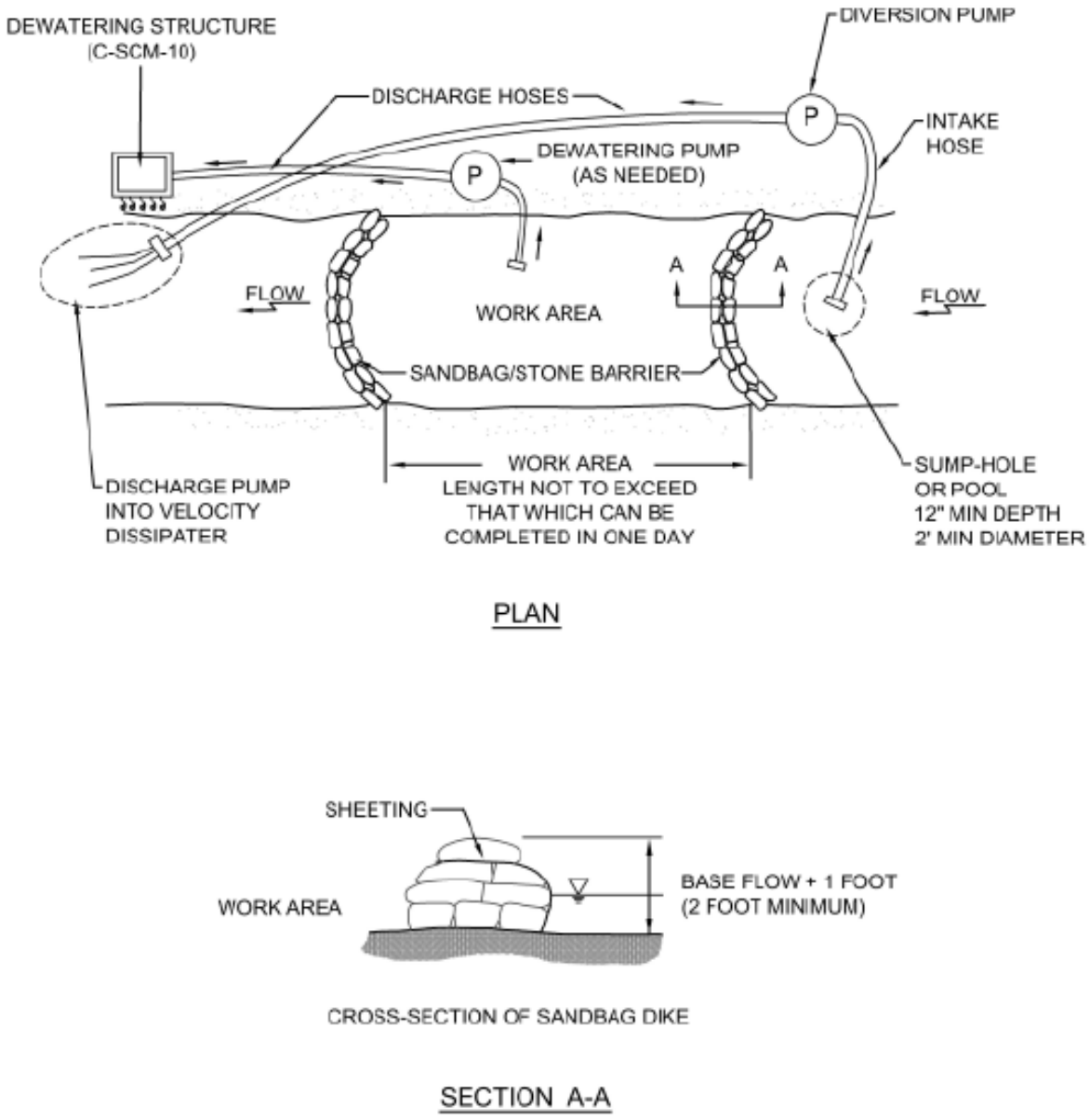
6.0 Construction Specifications

Table C-ENV-08-2 Material Specifications for Pump-Around Diversions

Design Component	Notes on Proper Use
In-stream Barrier	Refer to the in-stream barriers identified in Cofferdam Crossing (BMP C-ENV-05) for additional information on alternative in-stream barriers.
Sheeting	Seamless polyethylene plastic sheeting with a minimum 6-mil thickness impervious and resistant to puncture, tearing, and ultraviolet degradation or equivalent.

Table C-ENV-08-2 Material Specifications for Pump-Around Diversions	
Design Component	**Notes on Proper Use**
Pumping Equipment	Electric, diesel, or gasoline venturi, vacuum, or centrifugal primed pump. Appropriately sized rigid intake and discharge pipe/hose with positive restrained joints. Necessary connectors and properly stored fuel.
Dewatering Structure	Select and install a dewatering structure in accordance with Dewatering Structure (BMP C-SCM-10).
Velocity Dissipater	Riprap or sandbag-lined “plunge pool” sized to be non-erosive at the discharge pipe velocity in accordance with Outlet Protection (BMP C-ECM-15).

Figure C-ENV-08-1 Pump-Around Diversion Practice



Source: Virginia Department of Conservation and Recreation 2004

7.0 Operations and Maintenance Considerations

- Sandy material may be used to fill sandbags. If permitted, material from the channel may be used to fill the bags.
- Determine the length of stream to be dewatered by the amount of work that can be completed in 1 work day.
- Continuous pumping adds increased costs and risks of failure and delays.
- Where possible, use existing pools within the stream in place of an excavated sump hole.
- Strategic placement of the in-stream barrier can eliminate multiple installations during construction.

- Remove all large debris located within the foundation of the barrier to ensure proper sealing and reduce leakage through the barrier.
- Sandbag/stone barrier should be monitored daily for leakage and repaired as necessary.

During active pump-arounds, the performance of the configuration and surrounding area is to be monitored continuously for any changes in the stream flow or pump performance. The backwatered area is to be monitored for headwater depths to not rise to the top of the water barricade or start flowing in undesirable directions out of the stream channel. The intake is to be kept free of debris. Confirm that the intake protection is functioning. Maintain the pump in operating condition, and ensure that adequate fuel is immediately available for the expected work duration until completion. Monitor the stable discharge point for indicators of erosion and revise as necessary to maintain a stable discharge point.

Before complete dewatering of the work area, remove trapped fish and other aquatic wildlife, and relocate to the waterbody downstream of the lower barrier.

Ensure that the filtered water is discharged in a manner that does not cause erosion. Provide stabilization measures to the flow path from the point of discharge to the receiving waterbody as required.

8.0 References

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

Virginia Department of Conservation and Recreation. The Virginia Stream Restoration & Stabilization Best Management Practices Guide. 2004.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-ENV-09 Overnight Channel Protection

1.0 Definition

Overnight channel protection is the temporary stabilization of a stream channel bed using secured filter fabric while in-stream work is not actively taking place. This practice is used during stream restoration projects when there is active disturbance to an existing natural stream channel bed.

– CAD and PDF for C-ENV-09 Overnight Channel Protection

2.0 Purpose and Applicability of Best Management Practice

Overnight channel stabilization is used to temporarily stabilize the disturbed stream bed to prevent excessive sediment movement downstream and accommodate base flow and/or storm flows. It is ***intended for use for a less than 24-hour period*** (Wetland Studies and Solutions, Inc. 2020).

Overnight channel protection is used within an existing or proposed stream channel when active work needs to temporarily cease for a period of less than 24 hours due to inclement weather or other short duration stoppage of work. Overnight channel protection is also used when temporary vehicle access to the stream channel is needed for a period of less than 24 hours to deliver equipment and/or materials and where a crossing has not been installed.

3.0 Planning and Considerations

Only use overnight channel protection when active work operations in the stream channel will cease or vehicle access within the stream channel will be needed for a period of less than 24 hours. If longer periods of work stoppage or vehicular access to the stream channel are needed, install additional stabilization of the stream channel bed and banks including Soil Stabilization Blankets and Matting (BMP C-SSM-05); Temporary Seeding (BMP C-SSM-09) or Permanent Seeding (BMP C-SSM-10) and Mulching (C-SSM-11); or stream diversion measures including Utility Stream Crossing (C-ENV-04), Cofferdam Crossing (BMP C-ENV-05), or Pump-Around Diversion (BMP C-ENV-08).

4.0 Stormwater Performance Summary

MS-12: WATERCOURSE CONSTRUCTION – When work in a live watercourse is performed, precautions shall be taken to minimize encroachment, control sediment transport, and stabilize the work area to the greatest extent possible during construction. Non-erodible material shall be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

MS-14: OTHER WATERCOURSE REGULATIONS – All applicable federal, state, and local requirements pertaining to working in or crossing live watercourses shall be met.

9VAC25-875-560

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: N/A

5.0 Design Criteria

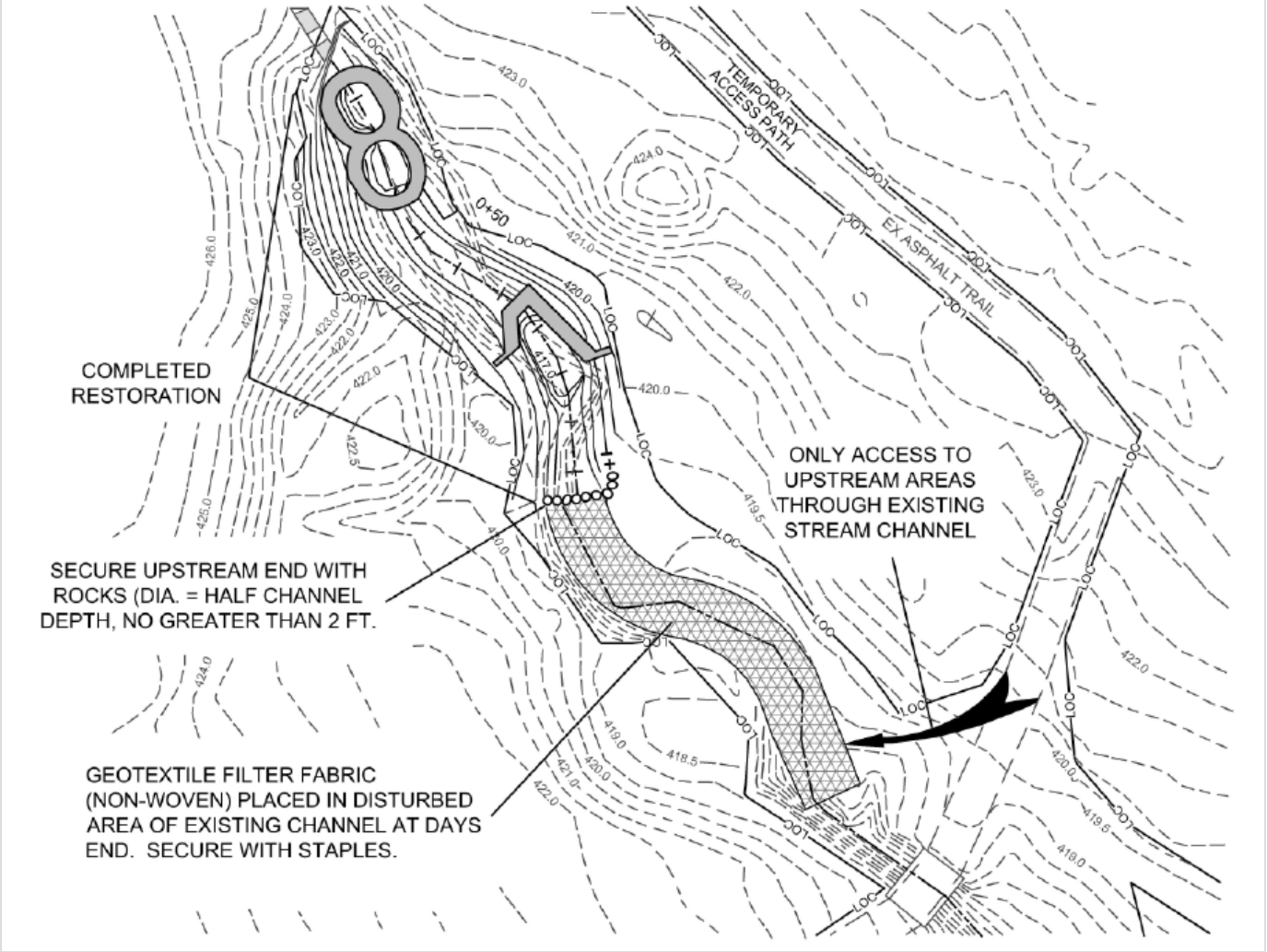
Use filter fabric that meets the minimum physical requirements noted in Riprap (BMP C-ECM-13).

Use staples for anchoring filter fabric that are No. 11 gauge wire or heavier with a minimum length of 6 inches. Use a larger staple with a length of up to 12 inches on loose, sandy, or unstable soils.

6.0 Construction Specifications

1. Place filter fabric in the channel and adequately secure.
2. Ensure the fabric covers the entire disturbed area within the channel and overlaps onto the undisturbed area by a minimum of 3 feet on all sides.
3. Before placement, rough grade the disturbed channel area to provide proper drainage.
4. Secure the upstream edge of the fabric with rocks of sufficient size to prevent movement – roughly half the size of the channel depth but no greater than 2 feet in diameter. If sufficient size rocks are not available on the site, staple the upper edge of the fabric at a maximum spacing of 1 foot.
5. Along the sides and downstream edge of the fabric, use staples at a maximum 2-foot spacing to ensure the fabric is adequately secured to the existing ground surface.
6. Once work in the channel is to resume, remove the staples first along the sides and downstream edge, then remove the rocks along the upstream edge.
7. Roll the fabric beginning at the upstream edge toward the downstream edge, remove from the channel, and continue with channel work.

Figure C-ENV-09-1 Overnight Channel Protection Layout



Source: Wetland Studies and Solutions, Inc. 2020

7.0 Operations and Maintenance Considerations

Inspect the channel to ensure that the protection is installed correctly and functioning properly. Immediately resecure any channel protection filter fabric or rocks that have become dislodged or displaced (Wetland Studies and Solutions, Inc. 2020).

8.0 References

Wetland Studies and Solutions, Inc. 2020. General Erosion and Sediment Control Standards and Specifications for Wetland and Stream Mitigation Banks.

C-ENV-10 Trenchless Silt Fence

1.0 Definition

Trenchless silt and super silt fence is a temporary sediment barrier consisting of a synthetic filter fabric stretched across and attached to supporting posts with no trench.

– CAD and PDF for C-ENV-10 Trenchless Silt Fence

2.0 Purpose and Applicability of Best Management Practice

Trenchless silt fence is used to intercept and detain small amounts of sediment from disturbed areas during construction to prevent sediment from leaving the site where typical silt fence (trenched) would adversely impact the surrounding woody vegetation to be preserved. Trenchless silt fence decreases the velocity of sheet flows.



Trenchless Super Silt Fence Installation
Source: The Davey Resource Group

3.0 Planning and Considerations

Use trenchless silt fence below disturbed areas where sheet and rill erosion would occur adjacent to undisturbed areas in which woody vegetation is to be maintained.

Only use trenchless silt fence where the size of the drainage area is no more than 0.25 acre per 100 feet of silt fence length.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

9VAC25-875-560

Erosion Control Efficiency: LOW

Sediment Removal Efficiency: MEDIUM

5.0 Design Criteria

Due to the detrimental effect on tree roots during placement, typical silt fence (trenched) is not installed at the outer limits of disturbance to maximize the preservation of woody vegetation in the areas surrounding the construction project.

Where silt fence is used on construction projects and existing woody vegetation is to be preserved, use the trenchless silt fence to minimize damage to the surrounding tree roots. The trenchless silt fence is designed to protect the tree's critical root zone (CRZ), which is the minimum area beneath a tree that needs to remain undisturbed to preserve enough of the root mass to provide a tree the greatest chance for survival.

Root aeration matting (RAM) is for permanent grade fills within the CRZ, and root protection matting (RPM) is for temporary construction within the CRZ. RAM and RPM are typically a combination of geotechnical products designed to spread loads, provide tree roots in the rhizosphere with air/gas exchange, and provide moisture access to the roots below. These products are to be installed by an ISA Certified Arborist trained in root protection, product specifications, and installations.

Design trenchless silt fence and its derivations following the maximum slope length provided in Silt Fence (BMP C-PCM-04).

Locate trenchless silt fence at least 5 to 7 feet beyond the base of disturbed slopes with grades greater than 7%.

Do not exceed the maximum slope length in existing, temporary, and final grade above any trenchless silt fence shown in Silt Fence (BMP C-PCM-04). The slope length shown is the distance from the fence to the drainage divide or the nearest upslope channel.

Use trenchless silt fence only where the size of the drainage area is no more than 0.25 acre per 100 feet of standard silt fence length.

In minor swales or ditch lines where the maximum contributing drainage area is no greater than 1 acre and flow is no greater than 1 cubic foot per second.

6.0 Construction Specifications

Use filter fabric, stakes, and reinforcing as specified in Silt Fence (BMP C-PCM-04).

Installation for Standard and Reinforced Trenchless Silt Fence

1. Install posts at a maximum of 6 feet apart when wire support is not used (standard silt fence or high-performance silt fence) and a maximum of 10 feet apart when wire support is used (reinforced silt fence). Drive posts a minimum of 18 inches below ground surface.
2. Install silt fence such that the height is a minimum of 18 inches above the original ground surface for standard silt fence, a minimum of 30 inches above the original ground surface for reinforced silt fence, and does not exceed 34 inches above ground elevation.
3. When wire support is used (reinforced silt fence), standard-strength filter fabric may be used. the wire mesh fence securely to the upslope side of the posts using heavy duty wire staples at least 1 inch long, tie wires, or hog rings. Extend the wire to the existing ground surface and do not extend more than 34 inches above the original ground surface. Staple or wire the standard-strength fabric to the wire fence and extend a minimum of 1 foot onto the existing ground surface. Do not staple the fabric to existing trees.
4. When wire support is not used (standard silt fence or high-performance silt fence), use extra-strength filter fabric. Fasten the filter fabric securely to the upslope side of the posts using 1-inch-long (minimum) heavy-duty wire staples or tie wires and extend a minimum of 1 foot onto the existing ground surface. Do not staple the fabric to existing trees.
5. When attaching two silt fences, first place the end post of one fence inside the end post of the other fence. Rotate both posts at least 180 degrees in a clockwise direction to create a tight seal with the fabric material. Drive both posts a minimum of 18 inches into the ground, and extend the flap a minimum of 1 foot onto the existing ground surface.
6. If a silt fence is to be constructed across a ditch line or swale, ensure the measure is of sufficient length to eliminate end-flow and the plan configuration resembles an arc or horseshoe with the ends oriented upslope. Use extra-strength filter fabric for this application with a maximum 3-foot spacing of posts.
7. Anchor silt fence to the existing ground surface at a spacing of 1 foot on center with landscape nails a minimum of 12 inches long.
8. Install RAM/RPM on top of silt fence overlapped onto existing ground surface.
9. Anchor the RAM/RPM with 12-inch-long landscape nails at a spacing of 3 feet on center.
10. Secure a second layer of silt fence to stakes and overlap the filter fabric a minimum of 1 foot onto the RAM/RPM.
11. Depending on application type, place a minimum of 6 inches of course crushed aggregate or compost filter sock on top of RAM/RPM.
12. Remove the silt fence when the fence has served its useful purpose, but not before the upslope area has been permanently stabilized.

Installation for Trenchless Super Silt Fence

1. Install chain link fence with the fence on the upslope side of the support poles.
2. Install 2.5-inch-diameter galvanized or aluminum poles set at 10-foot maximum spacing. Install poles a minimum of 24 inches below the ground surface and extend a minimum of 33 inches above ground. A posthole drill is necessary to do this for most sites. Poles do not need to be set in concrete.
3. Fasten chain link fence securely to fence posts with wire ties.
4. Ensure chain link is galvanized No. 11.5 Ga. steel wire with 2.25-inch opening, No. 11 Ga. aluminum-coated steel wire in accordance with ASTM-A-491, or galvanized No. 9 Ga. steel wire top and bottom with galvanized No. 11 Ga. steel intermediate wires. Install No. 7 gage tension wire horizontally through holes at top of chain link fence or attach with hog rings at 5-foot (maximum) centers.
5. Stretch filter fabric and securely fasten to the fence with wire fasteners, staples, or preformed clips. Extend the fabric a minimum of 33 inches above the existing ground surface and a minimum of 1 foot onto the existing ground surface. Ensure the filter fabric width is a minimum of 42 inches.
6. Fasten the filter fabric securely to the chain link fence with fasteners, staples, or preformed clips spaced horizontally 24 inches at the ground surface, top, and midsection.
7. When attaching two silt fences, first place the end pole of one fence inside the end pole of the other fence. Rotate both poles at least 180 degrees in a clockwise direction to create a tight seal with the fabric material. Drive both poles a minimum of 36 inches into the ground, and extend the flap a minimum of 1 foot onto the existing ground surface.
8. Place the fabric toe a minimum of 1 foot onto the existing ground surface.
9. Anchor silt fence to the existing ground surface at a spacing of 1 foot on center with landscape nails a minimum of 12 inches long.
10. Install RAM/RPM on top of silt fence overlapped onto existing ground surface.
11. Anchor the RAM/RPM with 12-inch-long landscape nails at a spacing of 3 feet on center.
12. Remove and properly dispose of super silt fence when the disturbed area tributary to the fence is permanently stabilized.

7.0 Operations and Maintenance Considerations

Inspect silt fences immediately after each rainfall and at least daily during prolonged rainfall. Make any repairs immediately.

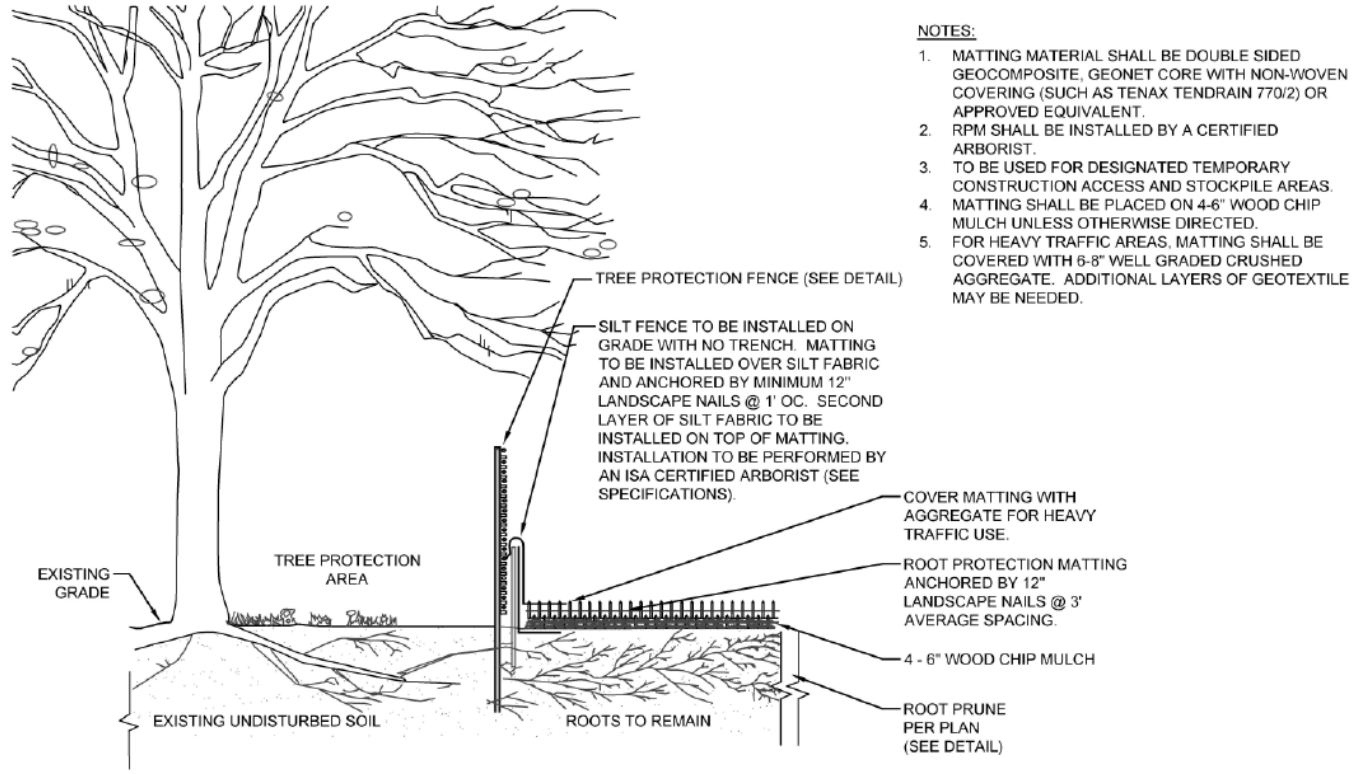
Pay close attention to the repair of damaged silt fence resulting from end runs and undercutting. This is commonly a sign that the fence has either been improperly installed or is placed in a less than optimal location. If the fence cannot be relocated, more frequent inspections may be warranted.

Replace the fabric promptly if the fabric on a silt fence decomposes or becomes ineffective before the end of the expected usable life and the barrier is still necessary.

Remove sediment deposits after each storm event and when deposits reach approximately one half the height of the barrier.

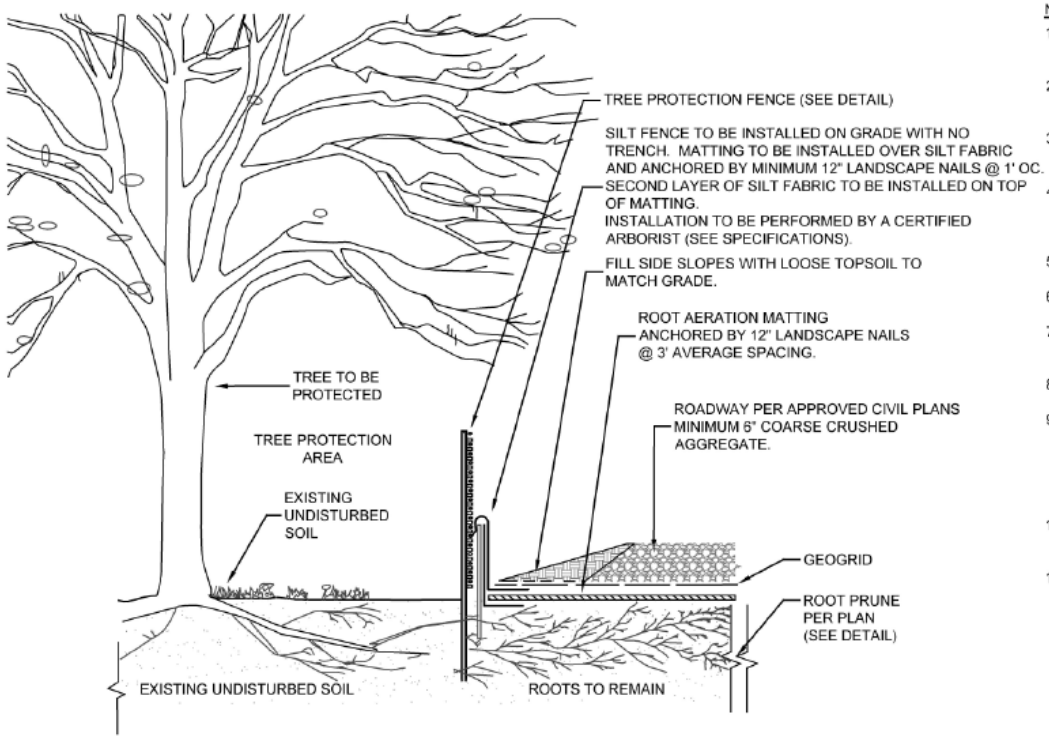
Dress to conform to existing grade, prepare, and seed any sediment deposits remaining in place after the silt fence is no longer required.

Figure C-ENV-10-1 Temporary Root Protection Matting within CRZ



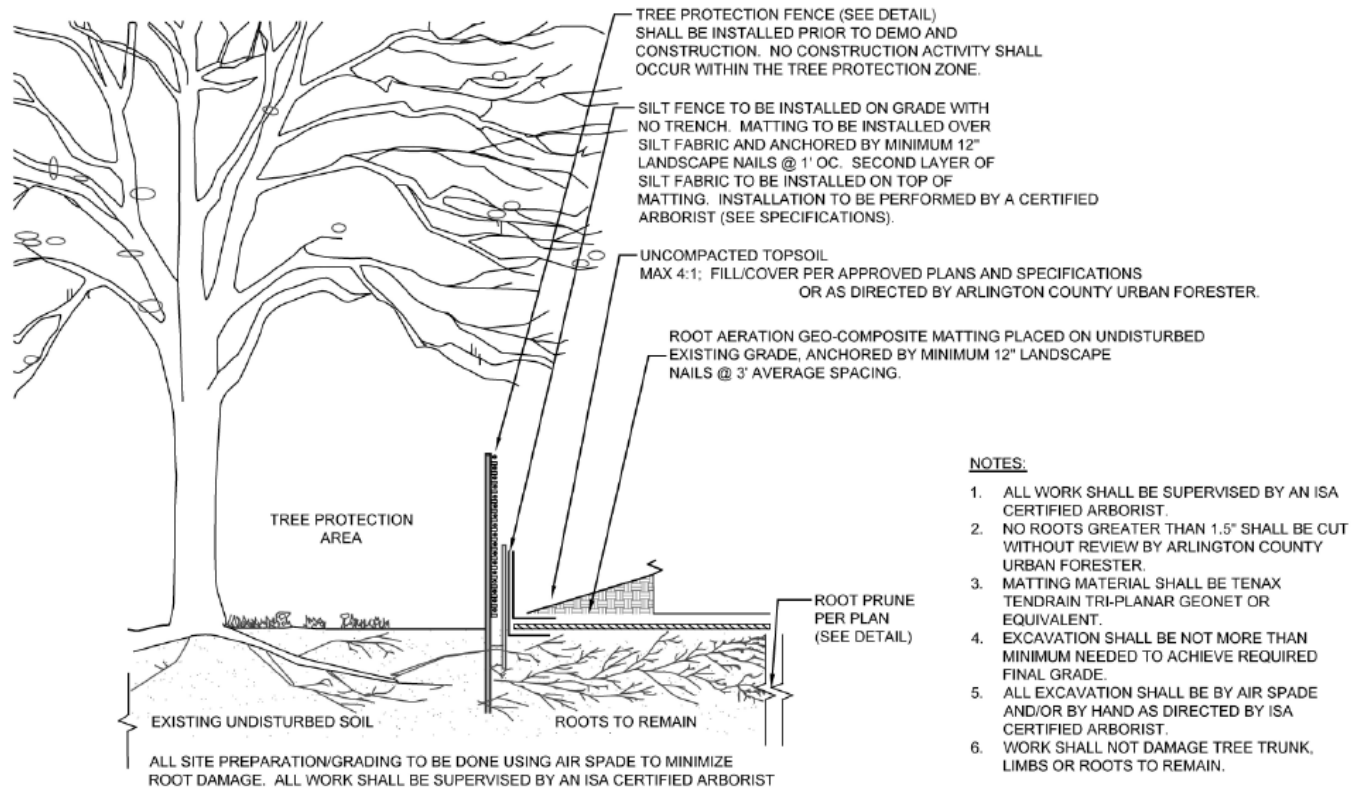
Source: Arlington Virginia Department of Parks and Recreation

Figure C-ENV-10-2 Root Aeration Matting for Roadway



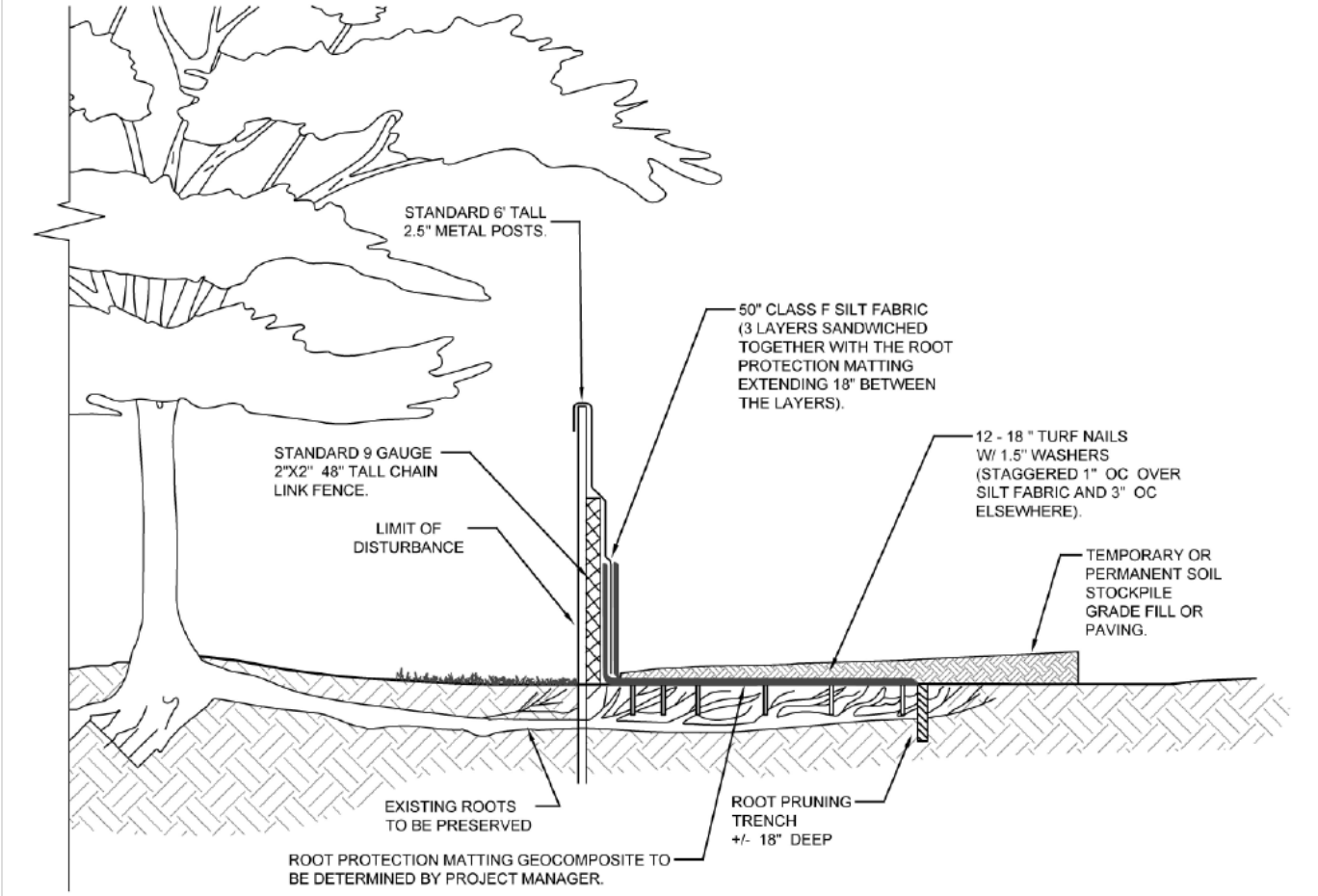
Source: Arlington Virginia Department of Parks and Recreation

Figure C-ENV-10-3 Fill Within CRZ With Root Aeration Matting



Source: Arlington Virginia Department of Parks and Recreation

Figure C-ENV-10-4 Trenchless Super Silt Fence



Source: City of Charlottsville 2010

8.0 References

City of Charlottesville. 2010. Best Management Practices for Tree Preservation, Transplanting, Removal and Replacement. Neighborhood Development Services. January.

Fairfax County Virginia. (n.d.). https://www.fairfaxcounty.gov/landdevelopment/chesapeake-bay-preservation-ordinance

Wetland Studies and Solutions, Inc. 2020. General Erosion and Sediment Control Standards and Specifications for Wetland and Stream Mitigation Banks.

C-ENV-11 Wetland Berm

1.0 Definition

A wetland berm is an earthen berm structure used in the creation, restoration, and enhancement of wetlands through the collection and retention of water that flows by gravity or other means to the bermed area (Angler Environmental 2020).

– CAD and PDF for C-ENV-11 Wetland Berm

2.0 Purpose and Applicability of Best Management Practice

A wetland berm is used to create wetland cells, which are flat areas, typically with less than 2% slopes, surrounded by permanent perimeter earth berms with hydraulic control structures (Wetland Weir Outlet [C-ENV-12]) connecting the cells. Wetlands can be constructed by excavating basins, by building up earth embankments, or through a combination of the two (USEPA 1995).

3.0 Planning and Considerations

Wetland berms are constructed along the perimeters of wetland cells to capture rainfall and runoff and minimize runoff to downstream receiving channels. During construction, wetland berms capture sediment-laden runoff from the area disturbed to create the wetland and serve as temporary sediment trapping devices in accordance with Wetland Cell Sediment Trap (C-ENV-13). The wetland berm should remain in place after vegetative stabilization of the site to contain rainfall and runoff to facilitate long-term wetland hydrology. Design the wetland berm to be accompanied with a stabilized outfall structure in accordance with the Wetland Weir Outlet (C-ENV-12).

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

9VAC25-875-560

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: LOW

5.0 Design Criteria

Table C-ENV-11-1 Design Criteria for Wetland Berms

Parameter	Notes on Proper Use
Height	Design berm heights to range between 1 and 2 feet at the upslope side of the berm.
Sideslope	Design berm sideslope to be a minimum of 2H:1V.
Width	Design berm to have a minimum bottom width of 5 feet.
Outlet	Provide a sediment trap rock outlet structure during construction to allow conveyance of storm events without overtopping. Once site is stabilized, construct a permanent concrete outlet weir.
Materials	Use clay with a hydraulic conductivity less than or equal to 1×10^{-6} centimeters per second (cm/s) or a geomembrane liner in accordance with P-SUP-01 to construct the clay core and key of the wetland berm. Use compacted fill material to construct the remainder of the wetland berm above the clay core and key.

6.0 Construction Specifications

1. Base the sizes, locations, and frequency of structures on site conditions and design the structure(s) to maintain non-erosive discharge velocities.
2. Construct the clay core and key.

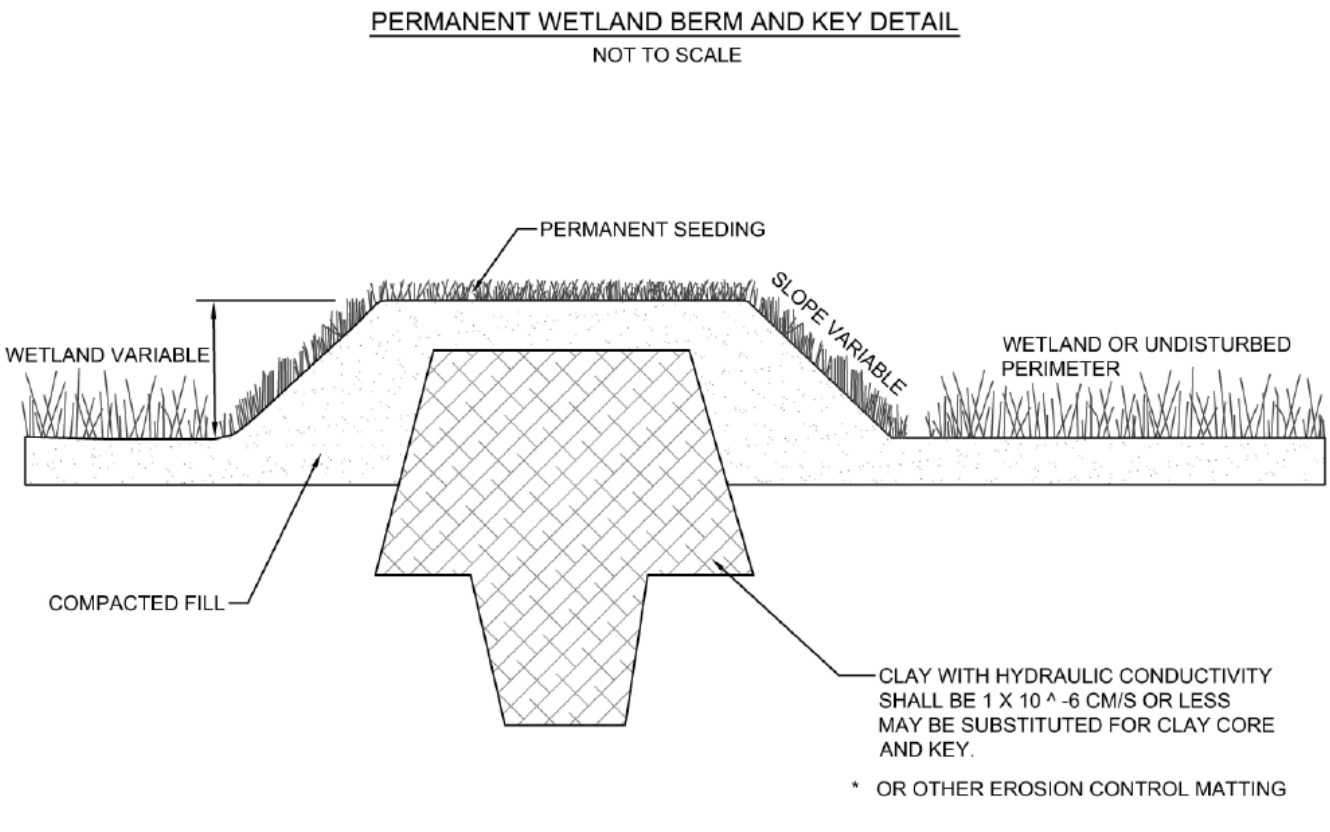
3. Install compacted topsoil over the clay core and key. Topsoil must be composed of soil that is free from excessive organic debris, rock, or other objectionable materials.
4. Place permanent seed on the area in accordance with the specifications for Seeding, Mulch, and Soil Stabilization (Wetlands/Streams) (BMP C-ENV-15) and Soil Erosion Control Blanket or Matting (BMP C-SSM-05).

7.0 Operations and Maintenance Considerations

Immediately following construction, inspect the berm for establishment of a stabilizing permanent vegetative cover. Reseed and mulch areas as needed where seeding fails to establish.

Inspect berms after every runoff-generating storm event during construction. If the integrity of the berm is jeopardized due to erosion, immediately repair the erosion by re-grading the area and stabilizing with native seed, mulch, and/or soil stabilization blanket and matting in accordance with Seeding, Mulch, and Soil Stabilization (Wetlands/Streams) (C-ENV-15) and Soil Erosion Control Blanket or Matting (C-SSM-05)

Figure C-ENV-11-1 Wetland Berm



Source: Angler Environmental 2020

8.0 References

Angler Environmental, a RES Company. 2020. Erosion and Sediment Control for Stream and Wetland Mitigations Banks and Nutrient-Reducing Stream Restoration Projects: 2020 Annual Standards and Specifications. October 14.

United States Environmental Protection Agency (USEPA). 1995. Handbook of Constructed Wetlands: A Guide to Creating Wetlands for Agricultural Wastewater Domestic Wastewater Coal Mine Drainage Stormwater in the Mid-Atlantic Region Volume 1: General Considerations.

C-ENV-12 Wetland Weir Outlet

1.0 Definition

A wetland weir outlet is an overflow water control structure that regulates the volume of water impounded in the created, restored, or enhanced wetland (Angler Environmental 2020).

– CAD and PDF for C-ENV-12 Wetland Weir Outlet

2.0 Purpose and Applicability of Best Management Practice

Typically, the creation, restoration, or enhancement of wetlands for wetland mitigation bank projects include multiple wetland cells that consist of both perimeter and intermediate earth berms with several wetland weir outlets.

3.0 Planning and Considerations

Because of the structural composition of a wetland cell, and because the associated berms and outlets are installed as a first step in the construction process, these structures provide effective erosion and sediment control. The locations, sizes, and frequency of the outlets are based on site conditions and designed to maintain non-erosive discharge velocities. In most cases, the only denuded area draining to the outlet is the wetland cell itself.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

9VAC25-875-560

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Design wetland weir outlets to handle the maximum permitted discharge from the wetland.

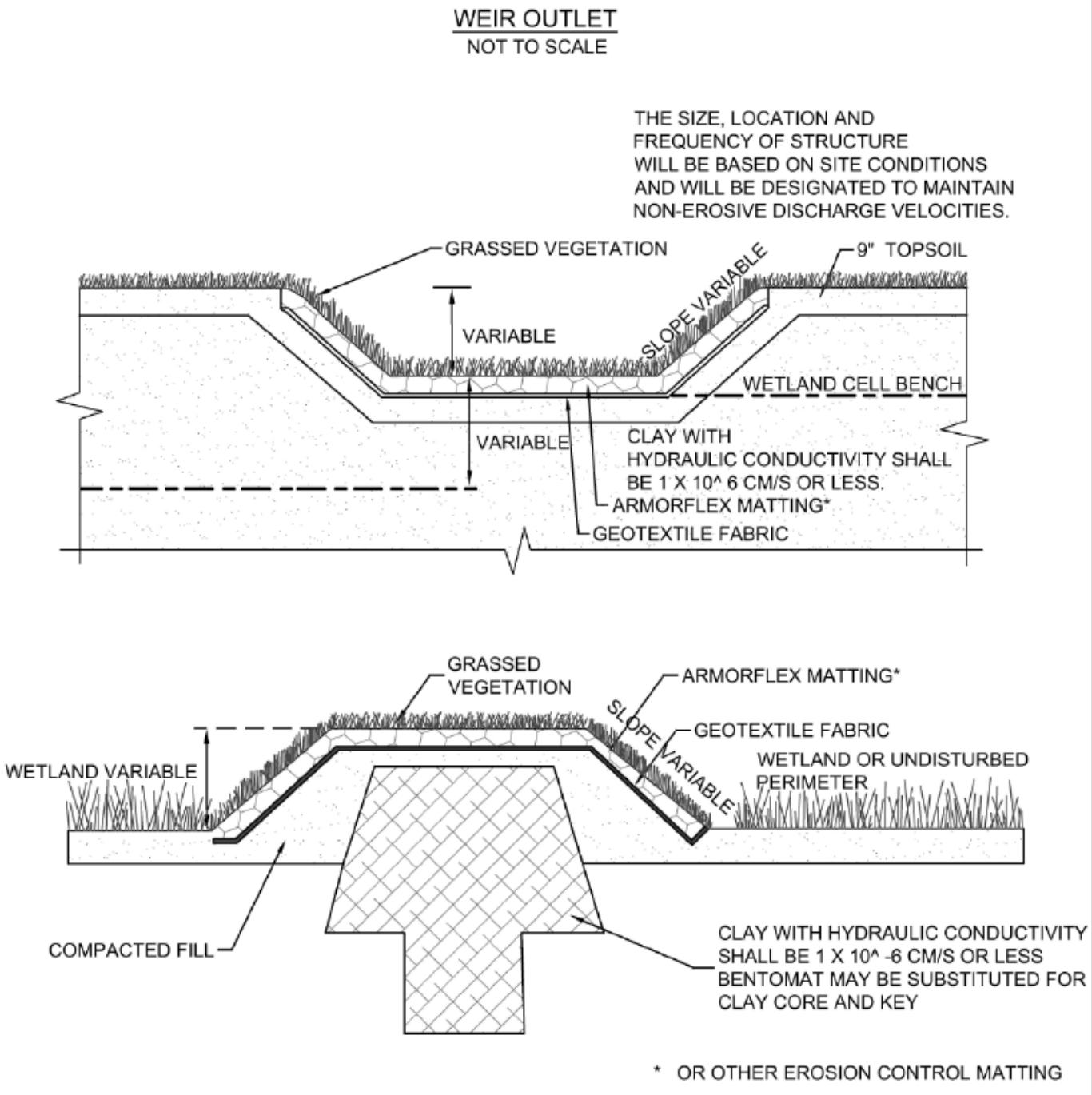
6.0 Construction Specifications

1. Base the sizes, locations, and frequency of structures on site conditions and design the structure(s) to maintain non-erosive discharge velocities.
2. Construct the clay core and key of the outlet using clay with a hydraulic conductivity less than or equal to 1 x 10-6 centimeters per second (cm/s) or a geosynthetic clay liner.
3. Install a 9-inch-thick topsoil layer over the clay core and key.
4. Place filter fabric as specified in Riprap (C-ECM-13) over the topsoil.
5. Place native permanent seed on the area in accordance with the Seeding, Mulch, and Soil Stabilization (Wetlands/Streams) (C-ENV-15) and Soil Erosion Control Blanket or Matting (C-SSM-05) over the filter fabric.

7.0 Operations and Maintenance Considerations

Maintain the weir outlet in a stabilized condition and maintain the design elevations relative to the surrounding storage volume and permanent berm.

Figure C-ENV-12-1 Wetland Weir Outlet



Source: Angler Environmental 2020

8.0 References

Angler Environmental, a RES Company. 2020. Erosion and Sediment Control for Stream and Wetland Mitigations Banks and Nutrient-Reducing Stream Restoration Projects: 2020 Annual Standards and Specifications. October 14.

C-ENV-13 Wetland Cell Sediment Trap

1.0 Definition

Wetland mitigation bank projects create and restore wetlands through the construction of wetland cells that are large, flat areas used as “giant” sediment traps where applicable during construction.

– CAD and PDF for C-ENV-13 Wetland Cell Sediment Trap

2.0 Purpose and Applicability of Best Management Practice

Wetland cell sediment traps are used during wetland construction to detain sediment-laden runoff from the area being disturbed for creation of the mitigation bank wetland.

3.0 Planning and Considerations

Proper waivers from local jurisdictions may be required to use wetland cells as temporary sediment traps.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance.

MS-6: TRAPS AND BASINS – Sediment traps and basins shall be designed and constructed based on the total drainage area they serve.

9VAC25-875-560

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

Sizes of wetland cells can vary to several acres due to the shallow water depths and slower flows through the wetland. Because a wetland cell is designed to have very little slope or no slope at all, and is surrounded by wetland berm(s) with wetland weir outlet(s), the cell provides a storage volume that is much greater than typically required for sediment traps. During construction of a wetland mitigation bank project, the weir outlet will control sediment-laden discharge, as well as convert any concentrated discharge to sheet flow, releasing it uniformly into a lower wetland cell or the undisturbed perimeter.

Because all storage in the wetland cells is dry storage, design each wetland cell sediment trap to have a minimum storage volume of 202 cubic yards per acre.

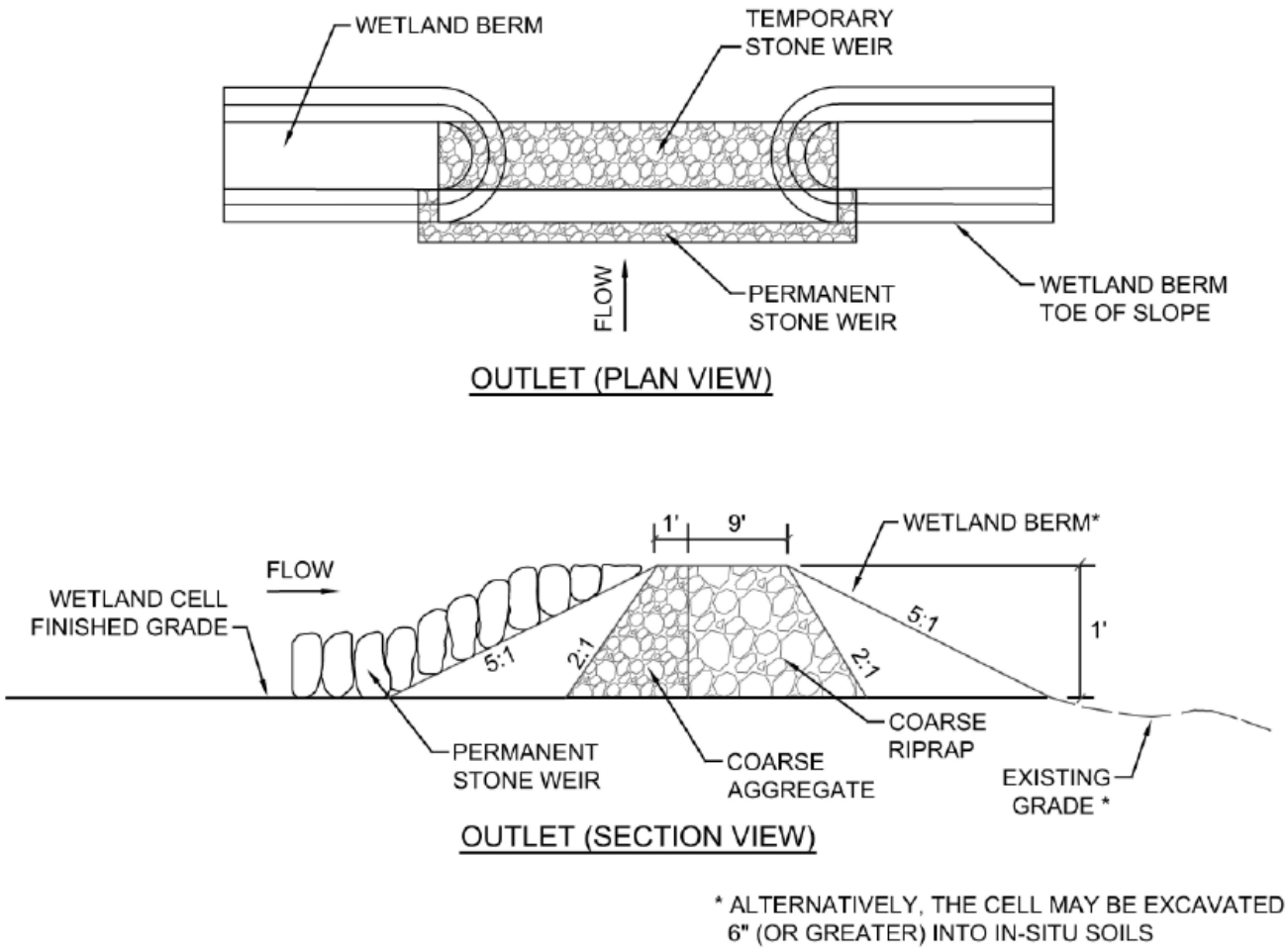
6.0 Construction Specifications

Construct wetland cells to be surrounded by a minimum 1-foot-tall earth berm or excavated at least 6 inches into the in-situ soils.

7.0 Operations and Maintenance Considerations

Inspect the wetland cell sediment trap weekly and immediately after each rainfall to ensure that the sediment trap is functioning properly. Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to one half the design volume of the dry storage. Deposit sediment removed from the wetland cell in a suitable area and in such a manner that it will not erode and cause sedimentation problems.

Figure C-ENV-13-1 Wetland Cell Sediment Trap Layout



Source: 2020 Wetland Studies and Solutions, Inc. 2020

8.0 References

Wetland Studies and Solutions, Inc. 2020. General Erosion and Sediment Control Standards and Specifications for Wetland and Stream Mitigation Banks.

C-ENV-14 Modified Turbidity Curtain for Streams

1.0 Definition

A modified turbidity curtain is a floating or staked barrier installed across stream flow that may also be referred to as a floating boom, silt barrier, or silt curtain.

2.0 Purpose and Applicability of Best Management Practice

Where all other erosion and sediment control measures have been implemented and there is still concern that a significant amount of sediment could be released downstream, a turbidity curtain can be applied. Use modified turbidity curtains for streams as a secondary control measure for the prevention of downstream sedimentation, as well as to further isolate the work from downstream reaches.

3.0 Planning and Considerations

Do not use modified turbidity curtains for streams as the primary control for stream projects; always use this practice in conjunction with other measures. The cross-stream application of a turbidity curtain in stream restoration projects may minimize the transport of sediment from in-stream work areas.

Carefully assess the depth, flow or current of water, and nature of construction to determine if a floating or staked turbidity curtain is required.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

MS-12: WATERCOURSE CONSTRUCTION – When work in a live watercourse is performed, precautions shall be taken to minimize encroachment (work in the dry whenever possible), control sediment transport, and stabilize the work area to the greatest extent possible during construction. Non-erodible material shall be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

MS-14: OTHER WATERCOURSE REGULATIONS – All applicable federal, state, and local regulations pertaining to working in or crossing live watercourses shall be met.

9VAC25-875-560

Erosion Control Efficiency: LOW

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

- Only leave the curtain in place during working hours, and remove the curtain after each working day or when there is an immediate threat of significant rain.
- Locate the curtain downstream of the work area, and install the curtain to span the stream in an area with a minimum base flow depth of greater than or equal to 2 feet. Anchor the curtain solidly on the stream banks.
- Leave a minimum 6-inch gap between the bottom of the turbidity curtain and the stream bed at base flow conditions.
- Design the curtain to conform to the Type III turbidity curtain as specified in Turbidity Curtain (C-SCM-09).

- Remove sediment in the area located upstream of the curtain only after upstream work is completed and other temporary stream diversion techniques are employed adjacent to the area.

6.0 Construction Specifications

Construct the modified turbidity curtain for streams in accordance with the construction specification listed in Turbidity Curtain (C-SCM-09).

7.0 Operations and Maintenance Considerations

1. Maintain the filter curtain throughout the project to ensure the continuous protection of the watercourse.
2. Repair the geotextile fabric as necessary using repair kits available from the manufacturers. Follow manufacturer's instructions to ensure the adequacy of the repair.
3. When the curtain is no longer required, remove the curtain and related components to minimize turbidity. Ensure remaining sediment is sufficiently settled before removing the curtain. Sediment may be removed and the original watercourse depth (or plan elevation) restored. Transport any spoils to an upland area and stabilize the spoils.

8.0 References

Angler Environmental, a RES Company. 2020. Erosion and Sediment Control for Stream and Wetland Mitigations Banks and Nutrient-Reducing Stream Restoration Projects: 2020 Annual Standards and Specifications. October 14.

Georgia Soil and Water Conservation Commission. 2016. Manual for Erosion and Sediment Control in Georgia.

C-ENV-15 Seeding, Mulching, and Soil Stabilization (Wetlands/Streams)

1.0 Definition

Seeding, mulching, and soil stabilization for wetlands and streams involves establishment of perennial vegetative cover on disturbed areas by planting seed; applying a protective blanket of mulch to the soil surface during the establishment of seeding; and planting of forb, shrubs, and/or trees in stream and/or wetland areas during restoration.

2.0 Purpose and Applicability of Best Management Practice

The purpose of seeding, mulching, and soil stabilization of streams and wetlands is to restore the impacted stream and/or wetlands to reduce erosion and decrease sediment yield, permanently stabilize disturbed areas, improve wildlife habitat, and enhance natural beauty.

This practice applies to any disturbed stream or wetland areas that require seeding, mulching, and soil stabilization to establish permanent, long-lived vegetative cover to stabilize the soil.

3.0 Planning and Considerations

A riparian buffer is an area adjacent to a stream, lake, or wetland that contains a combination of trees, shrubs, and/or other perennial plants and is managed differently from the surrounding landscape, primarily to provide conservation benefits. Buffers are used in agricultural, row crop, range, suburban,

and urban settings. A wide variety of state and federal programs support the installation of riparian forest buffers on public and private lands.

Riparian buffers can deliver a number benefits including filtering nutrients, pesticides, and animal waste from agricultural land runoff; stabilizing eroding banks; filtering sediment from runoff; providing shade, shelter, and food for fish and other aquatic organisms; providing wildlife habitat and corridors for terrestrial organisms; protecting cropland and downstream communities from flood damage; producing income from farmland that is frequently flooded or has poor yields; providing space for recreation; and diversifying landowner income.

Several factors can impact the effectiveness of riparian buffers in meeting these objectives. These include site conditions such as adjacent agricultural practices and crop types, stream size, topography, and soils; landscape conditions such as position in the watershed, adjacent land use, and buffer continuity; and other conditions such as markets and public interest.

The riparian buffer areas identified herein include palustrine scrub-shrub (PSS), palustrine emergent (PEM), palustrine forested (PFO), upland, shady PFO, shady variable, sunny PFO, and sunny variable.

4.0 Stormwater Performance Summary

MS-1: STABILIZATION – Permanent or temporary soil stabilization will be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization will be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization will be applied in areas to be left dormant for more than 1 year.

MS-3: PERMANENT VEGETATION – A permanent vegetative cover will be established on denuded areas not otherwise permanently stabilized. Permanent vegetation will not be considered established until achievement of a ground cover that is uniform, mature enough to survive, and will inhibit erosion.

Sediment Removal Efficiency: N/A

Erosion Control Efficiency: HIGH

5.0 Design Criteria

No formal design criteria.

6.0 Construction Specifications

Perform seeding within 7 days of construction completion. Apply seed uniformly with a broadcast seeder or hydroseeder on a firm, friable seedbed.

Species and quantities of seed will vary depending on the type of project, as shown in the schedules on the following pages. The plants specified have been studied over several years of wetland and stream mitigation projects and have been chosen based on climate, topography, soils, land use, planting season, and hydrologic regime. Use at least 75% of the species listed on the following pages depending on availability. Substitution for up to 25% of these species does not constitute a specification revision and does not require revision or approval.

Use straw mulch for wetland projects that is free of weed seeds. Use hay or straw mulch for stream projects that is free of weed seeds. Mulch may be spread by hand or by machine. Apply mulch at the rates specified in Mulching (BMP C-SSM-11) for hay and straw mulch.

Table C-ENV-15-1 Permanent Seeding Vegetation (PEM Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
		Grasses	
5	Lolium perenne spp. multiflorum	Annual Ryegrass	45
	Setaria italica	Italian Bristle Grass	45
6	Elymus riparius	Riverbank Wild Rye	10
	Elymus virginicus	Virginia Wild-Rye	10
	Panicum dichotomiflorum	Smooth Panic Grass	10
	Tripsacum dactyloides	Gama Grass	10
7	Carex comosa	Bearded Sedge	0.5
	Carex lurida	Shallow Sedge	0.5
	Carex vulpinoidea	Fox Sedge	0.5
	Juncus effusus	Soft Rush	0.5
		Forbs	
8	Asclepias incarnata	Swamp Milkweed	0.1
	Eutrochium fistulosum	Joe Pye Weed	0.1
	Symphyotrichum novae-angliae	New England Aster	0.1
	Symphyotrichum puniceum	Purple-Stemmed Aster	0.1
	Vernonia noveboracensis	Ny Ironweed	0.1
9	Eupatorium perfoliatum	Boneset	0.2
	Leersia oryzoides	Rice Cut Grass	0.2
	Ludwigia alternifolia	Bushy Seedbox	0.2
	Scirpus atrovirens	Green Bulrush	0.2
10	Bidens cernua	Nodding Beggar Ticks	0.2
	Bidens frondosa	Beggar Ticks	0.2
	Eutrochium maculatum	Spotted Joe Pye Weed	0.2
	Euthamia graminifolia	Grassleaf Goldenrod	0.2
	Iris versicolor	Blueflag	0.2
11	Persicaria sagittata	Arrow-Leaved Tearthumb	0.2
	Persicaria pensylvanica	Pa Smartweed	0.2
	Solidago rugosa	Wrinkled Goldenrod	0.2

Table C-ENV-15-1 Permanent Seeding Vegetation (PEM Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Verbena hastata	Blue Vervain	0.2

It is expected and preferred that all species in each of the Species Groups are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least:

- All the species in Group 5.
- Three of the four species in Group 6.
- Three of the four species in Group 7.
- Four of the five species in Group 8.
- Three of the four species in Group 9.
- Four of the five species in Group 10.
- Three of the four species in Group 11.

Table C-ENV-15-2 Permanent Seeding Vegetation (PSS Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
		Grasses	
4	Lolium perenne spp. multiflorum	Annual Ryegrass	45
	Setaria italica	Italian Bristle Grass	45
5	Elymus riparius	Riverbank Wild Rye	7.5
	Elymus virginicus	Virginia Wild Rye	7.5
	Dichanthelium clandestinum	Deer Tongue Grass	7.5
	Tripsacum dactyloides	Gama Grass	7.5
	Panicum dichotomiflorum	Smooth Panic Grass	7.5
6	Carex scoparia	Blunt Broom Sedge	0.5
	Carex squarrosa	Squarrose Sedge	0.5
	Carex vulpinoidea	Fox Sedge	0.5
	Juncus effusus	Soft Rush	0.5
		Forbs	
7	Asclepias incarnata	Swamp Milkweed	0.1
	Symphyotrichum novae-angliae	New England Aster	0.1
	Symphyotrichum pilosum	White Oatfield American-Aster	0.1
	Eutrochium fistulosum	Joe Pye Weed	0.1

Table C-ENV-15-2 Permanent Seeding Vegetation (PSS Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Vernonia noveboracensis	New York Ironweed	0.1
8	Eupatorium perfoliatum	Boneset	0.2
	Leersia oryzoides	Rice Cut Grass	0.2
	Ludwigia alternifolia	Bushy Seedbox	0.2
	Scirpus cyperinus	Woolgrass	0.2
9	Helenium autumnale	Common Sneezeweed	0.2
	Helianthus angustifolius	Narrow-Leaf Sunflower	0.2
	Bidens cernua	Nodding Beggar Ticks	0.2
	Verbena hastata	Blue Vervain	0.2
	Verbesina alternifolia	Wingstem	0.2
10	Persicaria pensylvanica	Pa Smartweed	0.2
	Carex intumescens	Greater Bladder Sedge	0.2
11	Cornus amomum	Silky Dogwood	0.2
	Cephalanthus occidentalis	Buttonbush	0.2
	Hibiscus moscheutos	Crimson-Eyed Rose Mallow	0.2
	Ilex verticillata	Winterberry	0.2
	Rosa palustris	Swamp Rose	0.2
	Sambucus nigra spp. canadensis	Elderberry	0.2
	Viburnum dentatum	Southern Arrowwood	0.2

It is expected and preferred that all species in each of the Species Groups are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least:

- All the species in Group 4.
- Four of the five species in Group 5.
- Three of the four species in Group 6.
- Four of the five species in Group 7.
- Three of the four species in Group 8.
- Four of the five species in Group 9.
- All the species in Group 10.
- Five of the seven species in Group 11.

Table C-ENV-15-3 Permanent Seeding Vegetation (PFO Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
		Grasses	
6	Setaria italica	Italian Bristle Grass	45
	Elymus riparius	Riverbank Wild Rye	10
7	Elymus virginicus	Virginia Wild-Rye	10
	Dichanthelium clandestinum	Deer Tongue Grass	10
	Tripsacum dactyloides	Gama Grass	10
	Carex lurida	Shallow Sedge	0.5
	Carex vulpinoidea	Fox Sedge	0.5
		Forbs	
8	Persicaria pensylvanica	Pa Smartweed	0.5
	Scirpus atrovirens	Green Bulrush	0.5
	Bidens frondosa	Beggar Ticks	0.2
	Helenium autumnale	Common Sneezeweed	0.2
9	Onoclea sensibilis	Sensitive Fern	0.2
	Persicaria sagittata	Arrow-Leaved Tearthumb	0.2
	Eutrochium fistulosum	Joe Pye Weed	0.1
	Eupatorium perfoliatum	Boneset	0.1
	Ludwigia alternifolia	Bushy Seedbox	0.1
10	Scirpus cyperinus	Wool Grass	0.1
	Vernonia noveboracensis	Ny Ironweed	0.1
	Symphyotrichum novae-angliae	New England Aster	0.1
	Symphyotrichum puniceum	Purple-Stemmed Aster	0.1
11	Carex comosa	Bearded Sedge	0.1
	Carex squarosa	Squarrose Sedge	0.2
	Helianthus angustifolius	Narrow-Leaf Sunflower	0.2
	Juncus effusus	Soft Rush	0.2
	Verbena hastata	Blue Vervain	0.2
		Shrubs	
12	Viburnum dentatum	Southern Arrowwood	0.5

Table C-ENV-15-3 Permanent Seeding Vegetation (PFO Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Cephalanthus occidentalis	Buttonbush	0.5
	Cornus amomum	Silky Dogwood	0.5
	Ilex verticillata	Winterberry	0.5
	Sambucus nigra spp. canadensis	Elderberry	0.5
		Trees	
13	Acer rubrum	Red Maple	0.5
	Acer negundo	Boxelder	0.5
	Betula nigra	River Birch	0.5
	Liquidambar styraciflua	Sweetgum	0.5
	Platanus occidentalis	American Sycamore	0.5

It is expected and preferred that all species in each of the Species Groups are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least:

- All the species in Group 5.
- Three of the four species in Group 6.
- Three of the four species in Group 7.
- Three of the four species in Group 8.
- Four of the five species in Group 9.
- Two of the three species in Group 10.

Three of the four species in Group 11.

- Four of the five species in Group 12.
- Four of the five species in Group 13.

Table C-ENV-15-4 Permanent Seeding Vegetation (Upland Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
		Grasses	
5	Lolium perenne spp. multiflorum	Annual Ryegrass	45
	Setaria italica	Italian Bristle Grass	45
6	Coreopsis lanceolata	Lance-Leaved Coreopsis	8
	Dichanthelium clandestinum	Deer Tongue Grass	8
	Panicum virgatum	Switchgrass	8
	Sorghastrum nutans	Indiangrass	8

Table C-ENV-15-4 Permanent Seeding Vegetation (Upland Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Tridens flavus	Purpletop	8
		Forbs	
7	Carex normalis	Greater Straw Sedge	0.1
	Hypericum punctatum	Spotted St. Johnswort	0.1
	Solidago juncea	Early Goldenrod	0.1
	Symphyotrichum pilosum	White Oldfield American-Aster	0.1
8	Asclepias tuberosa	Butterfly Milkweed	0.1
	Apocynum cannabinum	Indianhemp	0.1
	Eupatorium perfoliatum	Boneset	0.1
	Euthamia caroliniana	Slender Goldentop	0.1
	Andropogon virginicus	Broomsedge Bluestem	0.1
9	Asclepias syriaca	Common Milkweed	0.2
	Juncus tenuis	Path Rush	0.2
	Penstemon digitalis	Penstemon	0.2
	Verbesina alternifolia	Wingstem	0.2
10	Heliopsis helianthoides	Oxeye Sunflower	0.2
	Rudbeckia hirta	Black Eyed Susan	0.2
	Senna hebecarpa	Wild Senna	0.2
		Shrubs	
11	Amelanchier canadensis	Canadian Serviceberry	0.5
	Hamamelis virginiana	Witch Hazel	0.5
	Viburnum dentatum	Southern Arrow Wood	0.5
	Viburnum prunifolium	Black-Haw	0.5
		Trees	
12	Acer rubrum	Red Maple	0.5
	Carpinus caroliniana	Musclewood	0.5
	Cercis canadensis	Eastern Redbud	0.5
	Cornus florida	Flowering Dogwood	0.5
	Nyssa sylvatica	Black Gum	0.5

Table C-ENV-15-4 Permanent Seeding Vegetation (Upland Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Platanus occidentalis	American Sycamore	0.5

It is expected and preferred that all species in each of the Species Groups are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least:

- All the species in Group 5.
- Four of the five species in Group 6.
- Three of the four species in Group 7.
- Four of the five species in Group 8.
- Three of the four species in Group 9.
- Two of the three species in Group 10.
- Three of the four species in Group 11.
- Five of the six species in Group 12.

Table C-ENV-15-5 Permanent Seeding Vegetation (Shady PFO Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
		Grasses	
10	Lolium perenne spp. multiflorum	Annual Ryegrass	45
	Setaria italica	Italian Bristle Grass	45
11	Elymus riparius	Riverbank Wild Rye	10
	Elymus virginicus	Virginia Wild Rye	10
	Dichanthelium clandestinum	Deer Tongue Grass	10
12	Panicum dichotomiflorum	Smooth Panic Grass	10
	Carex scoparia	Blunt Broom Sedge	0.5
	Carex squarrosa	Squarrose Sedge	0.5
	Carex vulpinoidea	Fox Sedge	0.5
		Forbs	
13	Bidens frondosa	Beggar Ticks	0.1
	Bidens cernua	Nodding Beggar Ticks	0.1
	Eutrochium fistulosum	Joe Pye Weed	0.1
	Solidago rugosa	Wrinkled Goldenrod	0.1
	Symphyotrichum novae-angliae	New England Aster	0.1

Table C-ENV-15-5 Permanent Seeding Vegetation (Shady PFO Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Symphyotrichum puniceum	Purple-Stemmed Aster	0.1
	Vernonia noveboracensis	New York Ironweed	0.1
14	Helianthus angustifolius	Narrow-Leaf Sunflower	0.2
	Iris versicolor	Blueflag	0.2
	Lobelia siphilitica	Great Blue Lobelia	0.2
	Senna hebecarpa	Wild Senna	0.2
	Onoclea sensibilis	Sensitive Fern	0.2
	Penstemon digitalis	Foxglove Penstemon	0.2
	Verbena hastata	Blue Vervain	0.2
	Shrubs		
15	Cephalanthus occidentalis	Buttonbush	0.2
	Cornus amomum	Silky Dogwood	0.2
	Ilex verticillata	Winterberry	0.2
	Lindera benzoin	Northern Spicebush	0.2
	Eupatorium perfoliatum	Common Boneset	0.2
	Viburnum dentatum	Southern Arrow Wood	0.2
	Trees		
16	Acer negundo	Box Elder	0.4
	Acer rubrum	Red Maple	0.4
	Betula nigra	River Birch	0.4
	Carpinus caroliniana	Musclewood	0.4
	Nyssa sylvatica	Black Gum	0.4
	Platanus occidentalis	American Sycamore	0.4

Table C-ENV-15-5 Permanent Seeding Vegetation (Shady PFO Riparian Buffer Areas)

Species Group	Species Name	Common Name	Seed Rate (lbs./acre)
It is expected and preferred that all species in each of the Species Groups are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least: All the species in Group 10. • Three of the four species in Group 11. • Two of the three species in Group 12. • Five of the seven species in Group 13. • Five of the seven species in Group 14. • Five of the six species in Group 15. • Five of the six species in Group 16.			

Table C-ENV-15-6 Permanent Seeding Vegetation (Shady Variable Riparian Buffer Areas)

Species Group	Species Name	Common Name	Seed Rate (lbs./acre)
Grasses			
9	Lolium perenne spp. multiflorum	Annual Ryegrass	45
	Setaria italica	Foxtail Millet/Italian Bristle Grass	45
10	Elymus riparius	Riverbank Wild Rye	10
	Elymus virginicus	Virginia Wild Rye	10
	Dichanthelium clandestinum	Deer Tongue Grass	10
	Senna hebecarpa	Wild Senna	10
11	Agrimonia parviflora	Harvestlice	0.2
	Carex squarrosa	Squarrose Sedge	0.2
	Parthenocissus quinquefolia	Virginia Creeper	0.2
	Juncus tenuis	Path Rush	0.2
Forbs			
12	Anemone virginiana	Thimbleweed	0.1
	Eupatorium perfoliatum	Common Boneset	0.1
	Symphyotrichum pilosum	White Oldfield American-Aster	0.1
	Rhus glabra	Smooth Sumac	0.1
	Solidago speciosa	Showy Goldenrod	0.1
	Vernonia noveboracensis	New York Ironweed	0.1

Table C-ENV-15-6 Permanent Seeding Vegetation (Shady Variable Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
13	Bidens frondosa	Beggar Ticks	0.2
	Geum canadense	White Avens	0.2
	Chamaecrista nicitians	Sensitive Partridge Pea	0.2
	Desmodium glabellum	Dillenius' Tick-Trefoil	0.2

It is expected and preferred that all species in each of the Species Groups 116 are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least:

- All the species in Group 9.
- Three of the four species in Group 10.
- Three of the four species in Group 11.
- Five of the six species in Group 12.
- Five of the seven species in Group 13.
- Four of the five species in Group 14.
- Five of the six species in Group 15.

Table C-ENV-15-7 Permanent Seeding Vegetation (Sunny PFO Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Grasses		
10	Lolium perenne spp. multiflorum	Annual Ryegrass	45
	Setaria italica	Italian Bristle Grass	45
11	Elymus riparius	Riverbank Wild Rye	10
	Elymus virginicus	Virginia Wild Rye	10
	Dichanthelium clandestinum	Deer Tongue Grass	10
	Panicum dichotomiflorum	Fall Panic Grass	10
12	Anemone virginiana	Thimbleweed	0.1
	Symphyotrichum novae-angliae	New England Aster	0.1
	Symphyotrichum pilosum	White Oldfield American-Aster	0.1
	Symphyotrichum prenanthoides	Crooked-Stem Aster	0.1
	Solidago juncea	Early Goldenrod	0.1
13	Carex scoparia	Blunt Broom Sedge	0.2
	Carex squarrosa	Squarrose Sedge	0.2

Table C-ENV-15-7 Permanent Seeding Vegetation (Sunny PFO Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Carex vulpinoidea	Fox Sedge	0.2
	Cyperus esculentus	Yellow Nut Sedge	0.2
	Juncus effusus	Soft Rush	0.2
	Juncus tenuis	Poverty Rush	0.2
		Forbs	
14	Eutrochium fistulosum	Joe Pye Weed/Trumpetweed	0.1
	Eupatorium perfoliatum	Boneset	0.1
	Euthamia graminifolia	Grass Leaved Goldentop	0.1
	Solidago canadensis	Canada Goldenrod	0.1
	Solidago speciosa	Showy Goldenrod	0.1
	Vernonia noveboracensis	Ny Ironweed	0.1
	Lobelia cardinalis	Cardinal Flower	0.1
15	Asclepias syriaca	Common Milkweed	0.2
	Bidens frondosa	Beggar Ticks	0.2
	Helenium autumnale	Common Sneezeweed	0.2
	Helianthus angustifolius	Swamp Sunflower	0.2
	Onoclea sensibilis	Sensitive Fern	0.2
	Penstemon digitalis	Foxglove Beardtongue	0.2
	Verbena hastata	Blue Vervain	0.2
	Verbesina alternifolia	Wingstem	0.2
16	Coreopsis lanceolata	Lance Leaf Tickseed	0.2
	Heliopsis helianthoides	Smooth Oxeye	0.2
	Persicaria pensylvanica	Pa Smartweed	0.2
	Rudbeckia hirta	Black Eyed Susan	0.2
	Leersia oryzoides	Rice Cutgrass	0.2
		Shrubs	
17	Hamamelis virginiana	Witch Hazel	0.2
	Ilex verticillata	Winterberry	0.2
	Lindera benzoin	Northern Spicebush	0.2

Table C-ENV-15-7 Permanent Seeding Vegetation (Sunny PFO Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Aronia melanocarpa	Black Chokeberry	0.2
	Physocarpus opulifolius	Common Ninebark	0.2
	Viburnum dentatum	Southern Arrow Wood	0.2
	Viburnum prunifolium	Black-Haw	0.2
		Trees	
18	Acer rubrum	Red Maple	0.2
	Carpinus caroliniana	American Hornbeam/Musclewood	0.2
	Cercis canadensis	Eastern Redbud	0.2
	Cornus florida	Flowering Dogwood	0.2
	Nyssa sylvatica	Black Gum	0.2
	Platanus occidentalis	American Sycamore	0.2

It is expected and preferred that all species in each of the Species Groups are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least:

- All the species in Group 10.
- Three of the four species in Group 11.
- Four of the five species in Group 12.
- Five of the six species in Group 13.
- Five of the seven species in Group 14.
- Six of the eight species in Group 15.
- Four of the five species in Group 16.
- Five of the seven species in Group 17.

Table C-ENV-15-8 Permanent Seeding Vegetation (Sunny Variable Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
		Grasses	
9	Lolium perenne spp. multiflorum	Annual Ryegrass	45
	Setaria italica	Italian Bristle Grass	45
10	Elymus riparius	Riverbank Wild Rye	10
	Elymus hystrix	Eastern Bottle-Brush Grass	10
	Dichanthelium clandestinum	Deer Tongue Grass	10

Table C-ENV-15-8 Permanent Seeding Vegetation (Sunny Variable Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
	Panicum virgatum	Switchgrass	10
11	Carex scoparia	Blunt Broom Sedge	0.2
	Agrimonia parviflora	Harvestlice	0.2
	Clematis virginiana	Virgin'S Bower	0.2
	Juncus effusus	Soft Rush	0.2
	Juncus tenuis	Path Rush	0.2
		Forbs	
12	Anemone virginiana	Thimbleweed	0.1
	Symphyotrichum novae-angliae	New England Aster	0.1
	Symphyotrichum pilosum	White Oldfield American-Aster	0.1
	Solidago juncea	Early Goldenrod	0.1
13	Eutrochium fistulosum	Joe Pye Weed	0.1
	Euthamia graminifolia	Grass Leaved Goldenrod	0.1
	Solidago speciosa	Showy Goldenrod	0.1
	Senna hebecarpa	Wild Senna	0.1
	Carex granularis	Limestone Meadow-Sedge	0.1
14	Asclepias syriaca	Common Milkweed	0.2
	Helenium autumnale	Common Sneezeweed	0.2
	Geum canadense	White Avens	0.2
	Onoclea sensibilis	Sensitive Fern	0.2
	Penstemon digitalis	Penstemon	0.2
	Chamaecrista nicitians	Sensitive Partridge Pea	0.2
	Desmodium glabellum	Dillenius' Tick-Trefoil	0.2
	Verbesina alternifolia	Wingstem	0.2
15	Coreopsis lanceolata	Lance Leaved Coreopsis	0.2
	Heliopsis helianthoides	Oxeye Sunflower	0.2
	Persicaria pensylvanica	Pa Smartweed	0.2
	Rudbeckia hirta	Black Eyed Susan	0.2
	Rhus glabra	Smooth Sumac	0.2

Table C-ENV-15-8 Permanent Seeding Vegetation (Sunny Variable Riparian Buffer Areas)			
Species Group	**Species Name**	**Common Name**	**Seed Rate (lbs./acre)**
		Shrubs	
16	Amelanchier canadensis	Canadian Serviceberry	0.2
	Hamamelis virginiana	Witch Hazel	0.2
	Prunus americana	American Plum	0.2
	Lindera benzoin	Northern Spicebush	0.2
	Physocarpus opulifolius	Common Ninebark	0.2
	Viburnum dentatum	Southern Arrow Wood	0.2
	Viburnum prunifolium	Black-Haw	0.2
		Trees	
17	Acer rubrum	Red Maple	0.2
	Carpinus caroliniana	American Hornbeam	0.2
	Cercis canadensis	Eastern Redbud	0.2
	Cornus florida	Flowering Dogwood	0.2
	Nyssa sylvatica	Black Gum	0.2
	Platanus occidentalis	American Sycamore	0.2

It is expected and preferred that all species in each of the Species Groups are planted. The tolerances listed in this note are intended to incorporate flexibility according to species availability. At a minimum, provide at least:

- All the species in Group 5.
- Three of the four species in Group 10.
- Four of the five species in Group 11.
- Three of the four species in Group 12.
- Four of the five species in Group 13.
- Six of the eight species in Group 14.
- Four of the five species in Group 15.
- Five of the seven species in Group 16.
- Five of the six species in Group 17.

7.0 Operations and Maintenance Considerations

Even with careful, well-planned seeding operations, failures can occur. When plants have not germinated on an area or have died, reseed these areas immediately to prevent erosion damage.

However, it is extremely important to determine why germination failed and take any corrective action necessary before reseeding the area. Healthy vegetation is the most effective erosion control available.

Inspect all mulches and soil coverings periodically and after rainstorm events to check for erosion. Where erosion is observed in mulched areas, apply additional mulch. Inspect mulches until grasses are firmly established.



Source: Bluegrass Stream, LLC n.d.

8.0 References

Bluegrass Stream LLC. n.d. Kanawha Sapsucker Run Stream Restoration Project. Located at: bluegrassstream.com/Kanawha-sapsucker-run.html.

Bluegrass Stream LLC. 2006. Mud Creek Stream Mitigation Project. Located at: bluegrassstream.com/mud-creek.html.

U.S. Forest Service (USFS). n.d. Riparian Forest Buffers. Located at: fs.usda.gov/nac/practices/riparian-forest-buffers.php.

Wetland Studies and Solutions, Inc. 2020. General Erosion and Sediment Control Standards and Specifications for Wetland and Stream Mitigation Banks.

C-PCM-01 Safety Fence

1.0 Definition

Safety fence is a protective barrier installed to prevent access to a land-disturbing activity or erosion control measure.

– CAD and PDF files for C-PCM-01 Safety Fence

2.0 Purpose and Applicability of Best Management Practice

Safety fence will be used as a best management practice (BMP) to prohibit public access to a land-disturbing activity and/or erosion control measure. Safety fence will also be used to delineate the limits of environmentally sensitive areas to be protected and to prevent encroachment by construction activity.

Safety fence is applicable to any land-disturbing activity, control measure, or series of control measures that can be considered unsafe by virtue of potential for access by the public.

3.0 Planning and Considerations

The safety of the public should always be considered at both the planning and implementation phases of a land-disturbing activity. If there is any question concerning the risk of a particular erosion control measure to the public, the measure should be relocated to a safer area, or an appropriate safety fence should be installed to prevent undesired access. Properly designed and installed safety fences prevent

the trespassing of people into potentially dangerous areas such as children using a sediment basin or a stormwater retention structure as play areas. The installation of these fences will protect people from hazards and the owner from possible litigation.

Two different types of fence are discussed in this specification. The designer, developer, and contractor should always be sure that the most appropriate type of fence is used for a particular need.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment will be constructed as a first step in any land-disturbing activity and will be made functional before upslope land disturbance takes place.

Sediment Removal Efficiency: N/A

5.0 Design Criteria

1. Safety fences should be located to create a formidable barrier to undesired access while allowing for the continuation of necessary construction operations.
2. Safety fences are most applicable to the construction of berms, traps, and dams. In use with those structures, safety fences should be located far enough beyond the outer toe of the embankment to allow for the passage of maintenance vehicles. Fences should not be installed across the slope of a dam or dike.
3. The height of the fence should be a minimum of 5 feet for plastic fence and 6 feet for metal fence. A fence must never be so short as to become an attraction for children to climb on or over.
4. Signs noting potential hazards such as “DANGER-QUICKSAND” or “HAZARDOUS AREA-KEEP OUT” should be posted and easily seen by anyone approaching the protected area.
5. Plastic (polyethylene) fence may be used as safety fencing, primarily in situations where the need is for a temporary barrier (see Figure C-PCM-01-1) such as marking tree protection zones and non-compaction areas. The fence should meet the physical requirements noted in Table C-PCM-01-1.
6. Metal or chain link fence should be used when a potentially dangerous control measure will remain in place permanently such as a stormwater detention or retention basin (see Figure C-PCM-01-1). However, the metal fence may also be used for measures that serve a temporary function at the discretion of those responsible for project safety. The metal fence should meet the following physical requirements:
    a. Fabric should be a minimum 2-inch mesh, 9-gauge zinc-coated steel.
    b. Zinc coating should have a minimum weight of 1.8 ounces per square foot.
    c. Posts should be zinc-coated steel pipe.
    d. Top nails should be zinc-coated steel pipe.
    e. Braces should be made of zinc-coated steel.
    f. Gates should be single- or double-swing, zinc-coated steel. Gates should be a minimum of 12 feet wide.

6.0 Construction Specifications

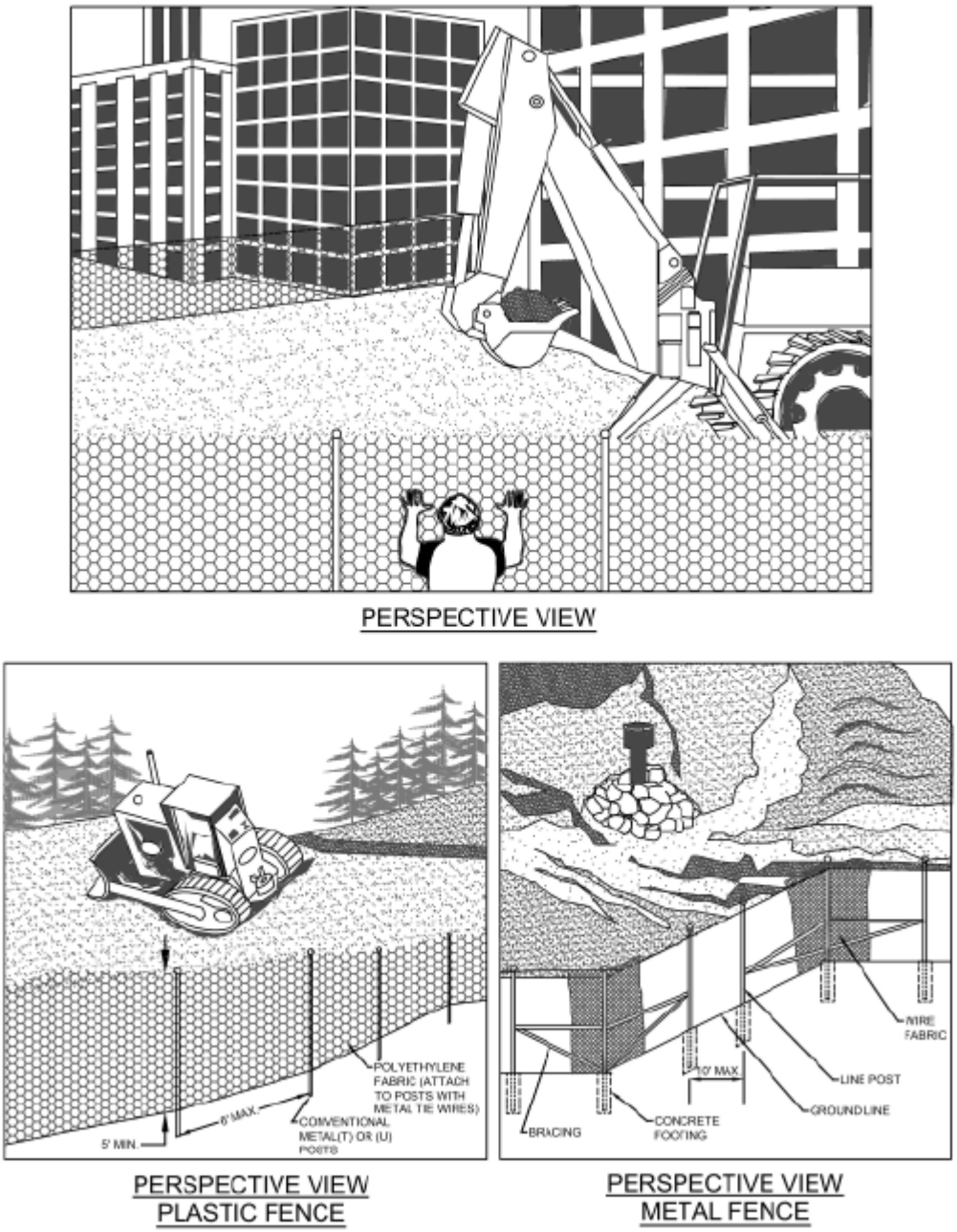
Table C-PCM-01-1 Physical Properties of Plastic Safety Fence

Physical Property	Test	Requirements
Recommended Color	Not applicable	“International Orange”
Tensile Yield	ASTM D636	Average 2,000 pounds (lbs), per 4-foot width

Table C-PCM-01-1 Physical Properties of Plastic Safety Fence		
Physical Property	**Test**	**Requirements**
Ultimate Tensile Strength	ASTM D636	Average 2,900 lbs, per 4-foot width
Elongation at Break (%)	ASTM D636	Greater than 1,000%
Chemical Resistance	Not applicable	Inert to most chemicals and acids

Source: Conwed Plastics.

Figure C-PCM-01-1 Safety Fence



Source: VDOT Stds. VA

DSWC

1. Safety fences should be installed before the erosion and sediment control measure becomes accessible.
2. The polyethylene web of the plastic safety fence should be secured to a conventional metal “T” or “U” post driven into the ground to a minimum depth of 18 inches; posts should be spaced at 6-foot centers. See perspective view on Figure C-PCM-01-1.

3. The metal safety fence should be installed as per the following procedure:



   a. Line posts should be placed at intervals of 10 feet measured from center to center of adjacent posts. In determining the post spacing, measurement will be made parallel with the ground surface. See perspective view on Figure C-PCM-01-1.
   b. Posts will be set in concrete and backfilled or anchored by other acceptable means.
   c. Posts set in the tops of concrete walls should be grouted into pre-formed holes to a minimum depth of 12 inches.
   d. All corner posts, end posts, gate posts, and pull posts should be embedded, braced, and trussed as shown in the "Standard Fence – Chain Link" detail found in the latest version of the Virginia Department of Transportation (VDOT) Road and Bridge Standards.
   e. Fencing fabric should not be stretched until at least 4 days after the posts are grouted into walls or 14 days after the posts are set into concrete.
   f. The fabric should be stretched taut and securely fastened by means of tie clips to the posts at intervals not exceeding 15 inches and to the top rails or tension wires at intervals not exceeding 2 feet. Care should be taken to equalize the tension on each side of each post.
4. Applicable warning signs noting hazardous conditions must be installed immediately upon installation of safety fence.

7.0 Operations and Maintenance Considerations

Safety fence should be checked regularly for weather-related or other damage. Any necessary repairs must be made immediately. Care should be taken to secure all access points (gates) at the end of each working day. All locking devices must be repaired or replaced as necessary.

8.0 References

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-PCM-02 Straw Bale Barrier

1.0 Definition

A straw bale barrier is a temporary barrier made of anchored straw used to intercept sediment-laden runoff from small drainage areas.

– CAD and PDF for C-PCM-02 Straw Bale Barrier

2.0 Purpose and Applicability of Best Management Practice

Straw bale barriers are used to intercept and detain small amounts of sediment from small, disturbed areas to prevent sediment from leaving the construction site and to decrease the velocity of sheet flows.

Straw barriers can be used in the following conditions:

1. Below disturbed areas subject to sheet and rill erosion;
2. Where effectiveness is required for less than 3 months;

3. Where there is no concentration of water in a channel or other drainageway above the barrier; or
4. Where the size of the drainage area is no greater than 0.25 acre per 100 feet of barrier length.

Due to the varied effectiveness of straw bale barriers, limit the use of straw bale barriers as perimeter control measures to where no other practice is feasible.

Do not use straw bale barriers where water may concentrate in defined ditches and minor swales, in live streams or where there is a possibility of a washout, or where rock or another hard surface prevents the full and uniform anchoring of the barrier.

3.0 Planning and Considerations

Based on observations made in Virginia, Pennsylvania, Maryland, and other parts of the nation, straw bale barriers have not been as effective as intended when used to slow down and filter concentrated flows for the following reasons:

1. Improper use in streams and drainageways where high water depth and velocities have destroyed or damaged the control;
2. Improper placement and installation that leads to undercutting and end flow, such as staking the bales directly to the ground with no soil seal or entrenchment; and
3. Inadequate maintenance leading to reduced effectiveness of the barrier.

For these reasons, use straw bale barriers judiciously and with caution as erosion control measures.

4.0 Stormwater Performance Summary

4.1 MS-4: First-Step Measures

Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment will be constructed as a first step in any land-disturbing activity and will be made functional before upslope land disturbance takes place.

Sediment Removal Efficiency: Low

Erosion Control Efficiency: Low

5.0 Design Criteria

Locate straw bale barriers at least 5 to 7 feet from the base of disturbed slopes.

Ensure the size of the drainage area to the straw bale barrier is no greater than 0.25 acre per 100 feet of barrier length. Install the straw bale barriers such that the length of the slope above the straw bale barrier does not exceed the limits shown in Table C-PCM-02-1.

Table C-PCM-02-1 Design Criteria for Straw Bale Barriers

Constructed Slope	Percent Slope	Slope Length (feet)
2:1	50	25
3:1	33	50
4:1	25	75

Note: Where slope gradient changes through the drainage area, steepness refers to the steepest slope section contributing to the straw bale barrier.

Table C-PCM-02-1 is generally adequate for a 1-inch rainfall event. Larger storms could cause failure of this practice. Specifically design the straw bale barriers to store the expected runoff if they are used in sensitive areas for longer than 1 month.

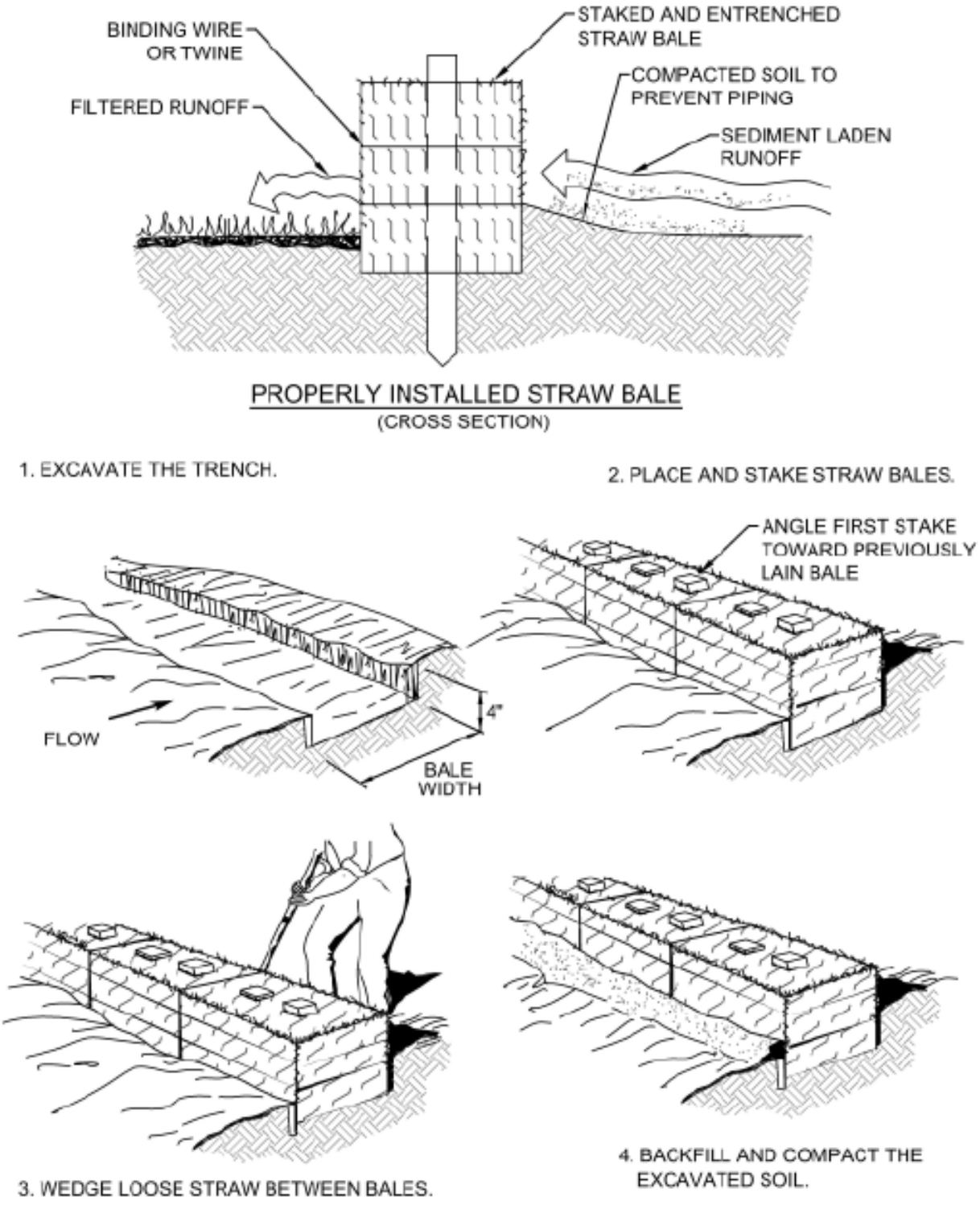
6.0 Construction Specifications

1. Place bales in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.
2. Ensure all bales are either wire-bound or string-tied. Install straw bales such that bindings are oriented around the sides rather than along the tops and bottoms of the bales to prevent deterioration of the bindings (see Figure C-PCM-02-1).
3. Entrench and backfill the barrier. Excavate a trench the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. After the bales are staked and chinked (gaps filled by wedging), backfill the excavated soil against the barrier. Grade the backfill soil to conform to the ground level on the downhill side and build up the backfill to 4 inches against the uphill side of the barrier (see Figure C-PCM-02-1).
4. Securely anchor each bale using at least two stakes (minimum dimensions 2 inches x 2 inches x 36 inches) or standard “T” or “U” steel posts (minimum weight of 1.33 pounds per linear foot) driven through the bale. Drive the first stake or steel post in each bale toward the previously laid bale to force the bales together. Drive the stakes or steel posts a minimum of 18 inches deep into the ground to securely anchor the bales.
5. Chink (fill by wedging) the gaps between bales with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency.
6. Ensure both ends of the barrier extend at least 8 feet upslope at 45 degrees to the main barrier alignment.

7.0 Operations and Maintenance Considerations

1. Inspect straw bale barriers immediately after each rainfall and at least daily during prolonged rainfall.
2. Pay close attention to the repair of damaged bales, end runs, and undercutting beneath bales.
3. Repair or replace bales promptly.
4. Remove sediment deposits after each rainfall. Remove accumulated sediment when the level of deposition reaches approximately one half the height of the barrier.
5. Remove straw bale barriers after they have served their usefulness, but not before the upslope areas have been permanently stabilized; see Permanent Seeding (BMP C-SSM-10), Sodding (BMP C-SSM-06), and Topsoiling (BMP C-SSM-02).
6. After removing the straw bale barrier, dress any sediment deposits remaining in place to conform to the existing grade, prepare, and seed.

Figure C-PCM-02-1 Construction of Straw Bale Barrier



Source: VA DSWC

8.0 References

New York State Department of Environmental Conservation. 2016. New York State Standards and Specifications for Erosion and Sediment Control. November.

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-PCM-03 Brush Barrier

1.0 Definition

A brush barrier is a temporary sediment barrier constructed at the perimeter of a disturbed area from the residue materials available from clearing and grubbing the site.

– CAD and PDF files for C-PCM-03-1 Brush Barrier

2.0 Purpose and Applicability of Best Management Practice

Brush barriers are a best management practice (BMP) used to intercept and retain sediment from disturbed areas of limited extent, preventing sediment from leaving the site.

Brush barriers are installed below disturbed areas subject to sheet and rill erosion, where enough residue material is available for construction of such a barrier.

Brush barriers will reduce flow velocity and provide coarse sediment control.

3.0 Planning and Considerations

During clearing and grubbing, equipment can push or dump the mixture of limbs, small vegetation, and root mat (along with minor amounts of rock) into windrows along the toe of a slope where erosion and accelerated runoff are expected.

Brush barriers may be beneficial on wooded or rocky slopes where other perimeter controls may be less effective.

Brush barriers may be used around sinkholes and any naturally occurring closed depression, but not placed into the sinkholes/depressions.

Field experience has shown that brush barrier installations are not effective when there are large voids created from using material that is too large (such as tree stumps). Ensure brush barrier installations provide a compact, dense barrier. Consider alternative practices if sufficient material is not available onsite.

Do not use brush barriers to treat concentrated flows or for drainage areas more than 0.25 acre per 100 feet of barrier length. Do not use brush barriers within 50 feet of a receiving surface water.

Take care that removal of the BMP does not create an erosive condition needing perimeter controls. Use this practice where removal of the barrier upon completion of construction would not be required.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment will be constructed as a first step in any land-disturbing activity and will be made functional before upslope land disturbance takes place.

Sediment Removal Efficiency: LOW

Erosion Control Efficiency: N/A

Note: Sediment control function can be enhanced by encasing the brush barrier with filtering fabric such as a geotextile. Remove filter fabric before construction ends unless it is made from natural plant fibers unaltered by synthetic materials.

5.0 Design Criteria

Install the brush barrier parallel to contours downslope of drainage areas no greater than 0.25 acre per 100 feet of barrier length; the maximum slope length behind the barrier is 100 feet; and the maximum slope gradient behind the barrier is 50 percent (2H:1V). Do not use material larger than 6 inches in diameter.

Brush barriers may be constructed of chipped site vegetation, live cuttings, fascines, or composted or wood-based mulch. When site vegetation is used, ensure invasive species are not incorporated.

Construct the brush barrier of sufficient height and width to provide treatment for flow and prevent flow from going around or under the brush barrier.

6.0 Construction Specifications

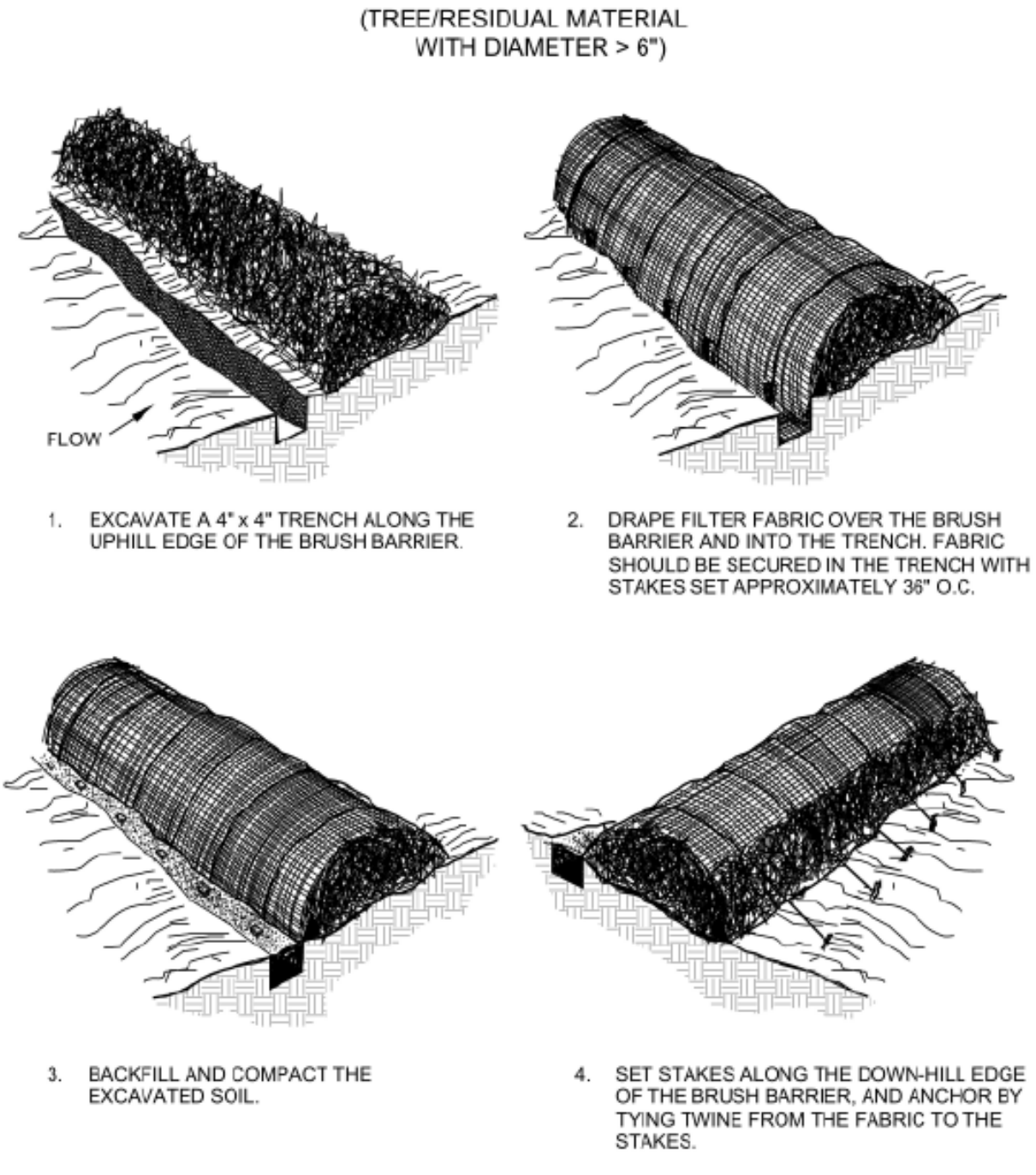
6.1 Brush Barrier Without Filter Fabric

1. Construct the height of a brush barrier to a minimum of 3 feet.
2. Construct the width of a brush barrier to a minimum of 5 feet at its base.
3. Construct the barrier by piling brush, stone, root mat, and other material from the clearing process into a mounded row on the contour. Do not use material larger than 6 inches in diameter to create the mound because the non-homogeneity of the mixture can lead to voids where sediment-laden runoff can easily pass.

6.2 Brush Barrier With Filter Fabric

1. Use filter fabric that meets the minimum physical requirements noted in Silt Fence (C-PCM-04).
2. Cut the filter fabric into lengths sufficient to lay across the barrier from its upslope base to just beyond its peak. Where joints are necessary, splice the fabric together with a minimum 6-inch overlap and securely seal.
3. Excavate a trench to 6 inches wide and 4 inches deep along the length of the barrier and immediately uphill from the barrier.
4. Drape the lengths of filter fabric across the width of the barrier, with the uphill edge placed in the trench and the edges of adjacent pieces overlapping each other.
5. Secure the filter fabric in the trench with stakes set approximately 36 inches on center.
6. Backfill the trench and compact the soil over the filter fabric.
7. Set stakes into the ground along the downhill edge of the brush barrier and anchor the fabric by tying twine from the fabric to the stakes.

Figure C-PCM-03-1 Construction of A Brush Barrier Covered by Filter Fabric



Source: VA DSWC

7.0 Operations and Maintenance Considerations

Inspect brush barriers regularly and after each rainfall to ensure that they retain their initial configuration and filtration function.

- Inspect barriers for scouring on the downslope of berms where ponded overflows occur.
- Inspect barriers and note areas where runoff has blown out or bypassed the barrier.

- Inspect barriers for washouts, undercutting (e.g., animal burrows), and end bypasses along barriers.
- Remove sediment deposits when they reach half the height of the barrier.

Repair or replace filter fabric that has been damaged due to collapse, tearing, decomposition, or other conditions immediately upon discovery.

If blowouts or bypasses occur during more than one significant rain event, then use rock filter outlets along dips and in low corners, amend barrier dimensions for the occurring flow, or use a different practice altogether.

8.0 References

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

USEPA. 2021. Stormwater Best Management Practice – Brush Barrier. EPA-832-F-21-028A. December.

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C-PCM-04 Silt Fence

1.0 Definition

Silt fence (and its derivatives ***wire-supported (reinforced) and super silt fence***) is a temporary sediment barrier consisting of a synthetic filter fabric entrenched and stretched across and attached to supporting posts.

– CAD and PDF for C-PCM-04 Construction of a Silt Fence

2.0 Purpose and Applicability of Best Management Practice

Silt fence intercepts and detains small amounts of sediment from disturbed ground areas during construction to prevent sediment from leaving the site. Silt fence decreases the water velocity of sheet flow and low-level channel flows to moderate-level channel flows.

Super silt fence is used to control runoff from some small, disturbed areas where the maximum slope lengths for standard silt fence and wire-supported (reinforced) silt fence cannot be met and space is insufficient for construction of sediment traps or basins.

Silt fence and its derivatives (wire-supported (reinforced) and super silt fence) are not to be used as check dams in any application.

3.0 Planning and Considerations

Use silt fence downstream or below disturbed areas where erosion would occur in the form of sheet and rill erosion.

Do not use silt fence where rock or other hard surface prevents the full and uniform depth anchoring of the barrier.

Do not use super silt fences where rock or rocky soil prevent the full and uniform anchoring of the fence or proper installation of the fence posts.

Only use super silt fence where access exists or can be made for the construction equipment required to install and remove the chain link fencing.

Super silt fence chain link and posts may be reused on multiple projects and may present a more cost-effective alternative to silt fence.

Super silt fences can mitigate sheet flow from disturbed areas to sinkholes and other karst features.

Do not use this BMP in areas of concentrated flow (except as specified in the Design Criteria).

Reinforced or super silt fence may be used in areas where there is a high potential for physical stress, as at the bottoms of steep fills, where the silt fence may be impacted by loose fill material or dirt clods may roll down the slope face during grading.

Reinforced and super silt fence will resist breakage and overturning from physical impacts much better than regular silt fence and will require much less maintenance.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

9VAC25-875-560

Erosion Control Efficiency: LOW

Sediment Removal Efficiency: MEDIUM

Table C-PCM-04-1 Typical Flow Rates and Filtering Efficiencies of Perimeter Controls

Material	Flow Rate (gallon/minute/foot)	Total Solids Removal Efficiency (%)	Total Suspended Solids Removal Efficiency (%)	Turbidity Reduction (%)
Mulch Filter Berm[a]	0.47	54.8	51.3	8.1
Straw Bale[a]	0.46	65.1	53.8	11.8
8-inch Compost Filter Sock[a]	0.37	84.3	75.9	28.6
12-inch Compost Filter Sock[a]	0.37	85.0	84.9	19.1
Silt Fence	0.11	89.0	87.0	76.0

Footnote:

a. Runoff of 2.9 inches on a 2,500-square-foot watershed to replicate maximum spacing requirements for silt fence typically used for sediment control on disturbed soils for 10% slope (Faucette et al. 2008.).

Source for Mulch Filter Berm, Straw Bale, and Compost Filter Sock: Faucette et al. 2009.

Source for Silt Fence: Faucette et al. 2008.

5.0 Design Criteria

Design silt fence and its derivations in accordance with Figure C-PCM-04-1 Maximum Slope Length for Silt Fence.

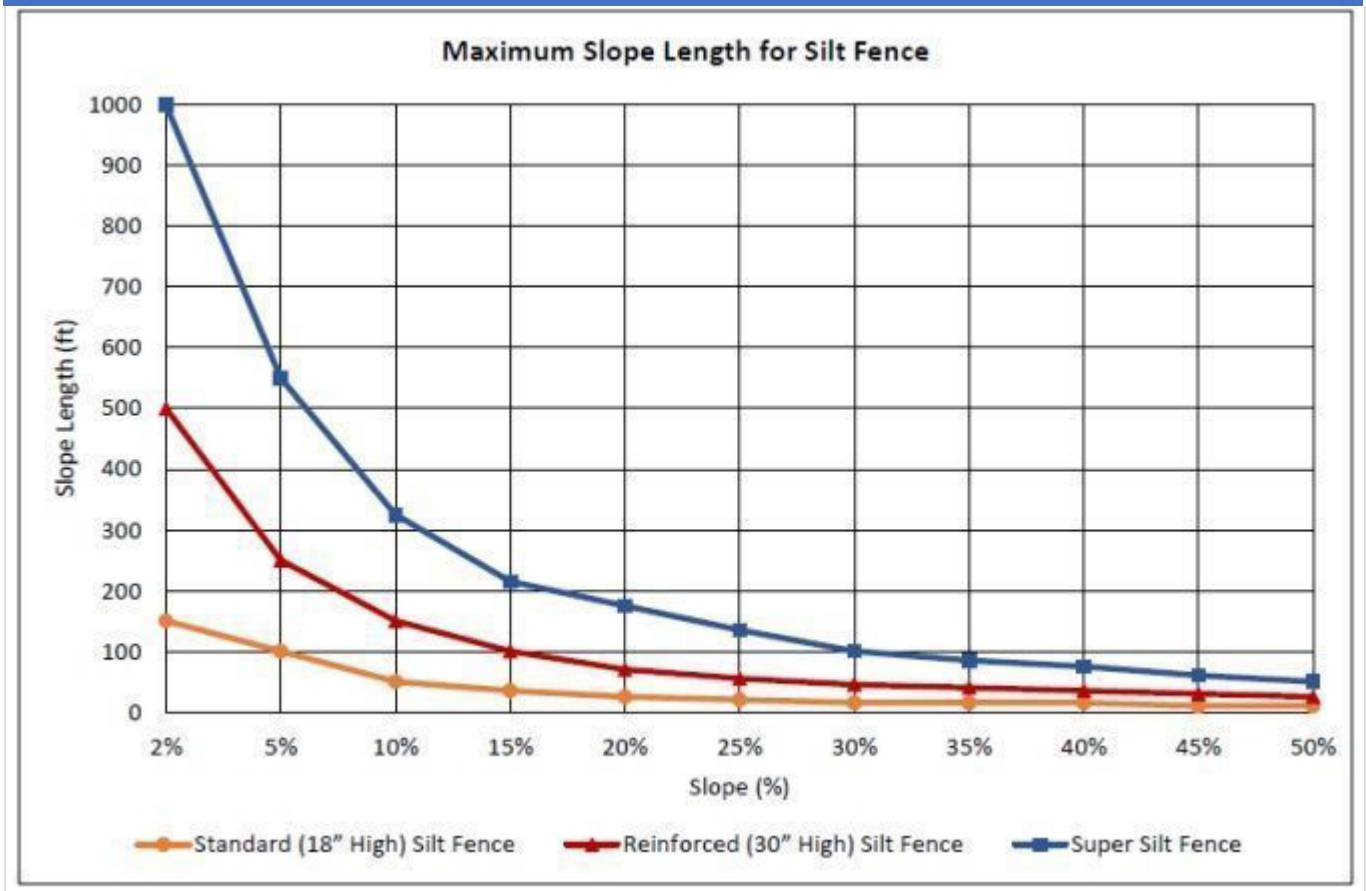
As with straw bale barriers, locate silt fence at least 5 to 7 feet beyond the bases of disturbed slopes with grades greater than 7 percent.

Do not exceed the maximum slope length in existing, temporary, or final grade above any silt fence at any time during the construction, as shown in Table C-PCM-04-2 Maximum Slope Length (feet) Above Fence. The slope length shown is the distance from the fence to the drainage divide or the nearest upslope channel.

If a super silt fence is used to mitigate sheet flow to sinkholes, the fence should be installed around the sinkhole's outer edge ("parapet") within 1 to 2 feet outside the slope in the parapet.

Trenchless silt fence (Specification BMP C-ENV-10) may be used in areas where existing wooded vegetation is to remain and trenched installation would otherwise damage the root ball.

Figure C-PCM-04-1 Maximum Slope Length for Silt Fence



Source: Faucette et al. 2008.

Table C-PCM-04-2 Maximum Slope Length (feet) Above Fence

Slope (%)	Standard (18 inches High) Silt Fence	Reinforced (30 inches High) Silt Fence	Super (33 inches High) Silt Fence
2 (or less)	100	500	1000
5	100	250	550
10	50	150	325
15	35	100	215

Table C-PCM-04-2 Maximum Slope Length (feet) Above Fence			
Slope (%)	Standard (18 inches High) Silt Fence	Reinforced (30 inches High) Silt Fence	Super (33 inches High) Silt Fence
20	25	70	175
25	20	55	135
30	15	45	100
35	15	40	85
40	15	35	75
45	10	30	60
50	10	25	50

Source: Pennsylvania Department of Environmental Protection (PADEP) 2012.

6.0 Construction Specifications

Table C-PCM-04-3 Material Specifications for Silt Fence	
Material Specifications for Silt Fence	
Filter Fabric	Use filter fabric consisting of woven slit film silt fence and is certified by the manufacturer or supplier as conforming to the requirements noted in Table C-PCM-04-4. Ensure fabric has the minimum properties required by state-specific or local specifications, whichever is more stringent. Ensure the fabric is in use no longer than the manufacturer's recommended life span and is replaced with new fabric after the life span has been exceeded. Use fabric with a minimum width of 30 inches for standard silt fence or 36 inches or greater for reinforced and super silt fences. Ensure stakes are hardwood or equivalent steel ("U" or "T") stakes. Use toe anchor trench measurements of a minimum of 4 inches vertical by 4 inches horizontal to anchor bottom of filter fabric into the ground. A silt fence is replaced when clogged with sediment and can no longer be cleaned. Synthetic filter fabric containing ultraviolet ray inhibitors and stabilizers shall be used to provide a minimum of 6 months of expected usable construction life at a temperature range of 0 to 120 degrees Fahrenheit.
Stakes	If wooden stakes are used for silt fence construction, ensure the stake has a nominal diameter of 2 inches when oak is used and 4 inches when pine is used. Use wooden stakes with a minimum length of 5 feet. If steel posts (standard "U" or "T" section) are used for silt fence construction, ensure the posts have a minimum weight of 1.33 pounds per linear foot and a minimum length of 5 feet.

Table C-PCM-04-3 Material Specifications for Silt Fence	
Material Specifications for Silt Fence	
Reinforced Silt Fence	Use wire reinforcement for reinforced silt fence using standard-strength filter fabric with a minimum of 14 gauge and a maximum mesh spacing of 6 inches.
Super Silt Fence	Install 2.5-inch-diameter galvanized or aluminum poles set at 10-foot maximum spacing. Install poles at a minimum depth of 24 inches below the ground surface and extend a minimum of 33 inches above ground. Ensure chain link is galvanized No. 11.5 Ga. steel wire with 2.25-inch opening, No. 11 Ga. aluminum coated steel wire in accordance with ASTM-A-491, or galvanized No. 9 Ga. steel wire top and bottom with galvanized No. 11 Ga. steel intermediate wires.

Table C-PCM-04-4 Physical Properties of Filter Fabric in Standard Silt Fence		
Physical Property	**Test**	**Requirements**
Grab Strength Tensile	ASTM D 4632	124 lbs.
Elongation at Failure	ASTM D 4632	15%
CBR Puncture Resistance	ASTM D 6241	325 lbs.
Minimum Trapezoidal Tear Strength	ASTM D 4533	45 lbs.
Apparent Opening Size – U.S. Standard Sieve	ASTM D 4751	30
Flow Through Rate	ASTM D 4491	10 gallons/minute/square foot
Minimum Ultraviolet (UV) Residual	ASTM D 4355	70%

Notes:

Source: PADEP 2012, Table 4.3, p.75.

ASTM = ASTM International

CBR = California bearing ratio

lbs. = pounds

Table C-PCM-04-5 Physical Properties of Filter Fabric in High-Performance Silt Fence		
Physical Property	**Test**	**Requirements**
Grab Strength Tensile	ASTM D 4632	180 lbs.
Elongation at Failure	ASTM D 4632	15%
CBR Puncture Resistance	ASTM D 6241	650 lbs.
Minimum Trapezoidal Tear Strength	ASTM D 4533	60 lbs.
Apparent Opening Size – U.S. Standard Sieve	ASTM D 4751	30
Flow Through Rate	ASTM D 4491	129 gallons/minute/square foot

Table C-PCM-04-5 Physical Properties of Filter Fabric in High-Performance Silt Fence		
Physical Property	**Test**	**Requirements**
Minimum Ultraviolet (UV) Residual	ASTM D 4355	80%

Notes:

Source: Various

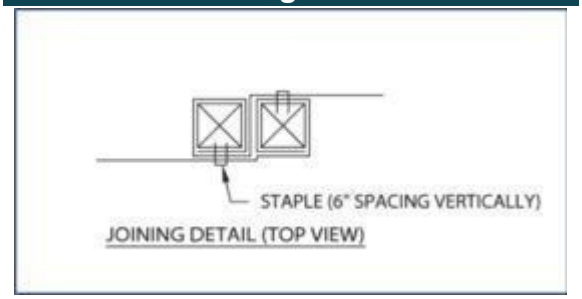
ASTM = ASTM International

CBR = California bearing ratio

lbs. = pounds

Installation for Standard and Reinforced Silt Fence

Figure C-PCM-04-2 Silt Fence Fabric Joining Detail



Source: Tahoe Regional Planning Agency 2014

1. Install silt fence (after trenching) a minimum height of:
   a. 18 inches above the original ground surface for standard silt fence; and
   b. 30 inches above the original ground surface for reinforced silt fence and does not exceed 34 inches above ground elevation.
2. Turn the fence uphill at 45-degree angles at the end of each fence run to prevent run-around bypass.
3. Where silt fence cannot be installed along the contour, J-hooks should be used at the end of each fence run.
4. Purchase the filter fabric in a continuous roll cut to the length of the barrier to avoid the use of joints.
5. At fabric ends, wrap both ends around the support stake and staple (see Figure C-PCM-04-2). If the fabric comes already attached to the stakes, hold the end stakes together while the fabric is wrapped around the stakes at least one revolution (360 degrees) before driving the stakes.
6. Excavate a trench approximately 4 inches wide and 4 inches deep on the upslope side of the proposed location of the measure.
7. When wire support is used (reinforced silt fence), standard-strength filter fabric may be used. For this type of installation, place posts a maximum of 10 feet apart (see Figure C-PCM-04-3). Fasten the wire mesh fence securely to the upslope side of the posts using heavy-duty wire staples at least 1 inch long, tie wires, or hog rings. Extend the wire into the trench a minimum of 2 inches and do not extend more than 34 inches above the original ground surface. Staple or wire the standard-strength fabric to the wire fence and extend 8 inches of the fabric into the trench. Do not staple the fabric to existing trees.
8. When wire support is not used (standard silt fence or high-performance silt fence), use extra-strength filter fabric. Place posts for this type of fabric a maximum of 6 feet apart (see Figure C-PCM-04-3). Fasten the filter fabric securely to the upslope sides of the posts using 1-inch-long (minimum) heavy-duty wire staples or tie wires and extend 8 inches of the fabric into the trench. This method of installation is more commonplace than the use of the reinforced silt fence. Do not staple the fabric to existing trees
9. When attaching two silt fences, first place the end post of one fence inside the end post of the other fence. Rotate both posts at least 180 degrees in a clockwise direction to create a tight seal with the fabric material. Drive both posts a minimum of 18 inches into the ground and bury the flap in a trench.

10. If a silt fence is to be constructed across a ditch line or swale, ensure the measure is of sufficient length to eliminate end-flow, and the plan configuration resembles an arc or horseshoe with the ends oriented upslope (see Figure C-PCM-04-3). Use extra-strength filter fabric for this application with a maximum 3-foot spacing of posts.
11. Drive stakes a minimum of 18 inches below ground surface.
12. Backfill and compact the 4-inch by 4-inch trench with soil over the filter fabric.
13. Remove the silt fence when the fence has served its useful purpose, but not before the upslope area has been permanently stabilized.

Installation for Super Silt Fence

1. Excavate an 8-inch-deep trench, minimizing the disturbance on the downslope side, with the bottom of the trench at level grade.
2. Install the chain link fence in the downslope side of the trench with the fence on the upslope side of the support poles. Install 2.5-inch- diameter galvanized or aluminum poles set at 10-foot maximum spacing. Install poles at a minimum depth of 24 inches below the ground surface and extend a minimum of 33 inches above ground. A posthole drill may be necessary to install poles appropriately for most sites. Poles do not need to be set in concrete.
3. Fasten chain link fence securely to fence posts with wire ties.
4. Ensure chain link is galvanized No. 11.5 Ga. Steel wire with 2.25-inch opening, No. 11 Ga. Aluminum coated steel wire in accordance with ASTM-A-491, or galvanized No. 9 Ga. Steel wire top and bottom with galvanized No. 11 Ga. Steel intermediate wires. Install No. 7 gage tension wire horizontally through holes at the top of the chain link fence or attach with hog rings, wire fasteners, staples, or preformed clips at 5-foot (maximum) centers.
5. Stretch filter fabric and securely fasten to the fence with wire fasteners, staples, or preformed clips. Extend the fabric a minimum of 33 inches above the ground surface. Ensure the filter fabric width is a minimum of 42 inches.



Super Silt Fence Source: PADEP 2012, p.82

6. Fasten the filter fabric securely to the chain link fence with fasteners, staples, or preformed clips spaced horizontally 24 inches at the ground surface, top, and midsection.
7. When attaching two super silt fences, the overlap joining method should be used. See Figure C-PCM-04-5.
8. Place the fabric toe in the bottom of the trench, then backfill and compact the trench.
9. Remove and properly dispose of super silt fence when the disturbed area tributary to the fence is permanently stabilized.

7.0 Operations and Maintenance Considerations

Inspect silt fences immediately after each rainfall and at least daily during prolonged rainfall. Make any repairs immediately.

Pay close attention to the repair of damaged silt fence resulting from end runs and undercutting. This is commonly a sign the fence has either been improperly installed or is placed in a less than optimal location. If the fence cannot be relocated, then more frequent inspections will be warranted.

Replace the fabric promptly if the fabric on a silt fence decomposes or becomes ineffective before the end of the expected usable life and the barrier is still necessary.

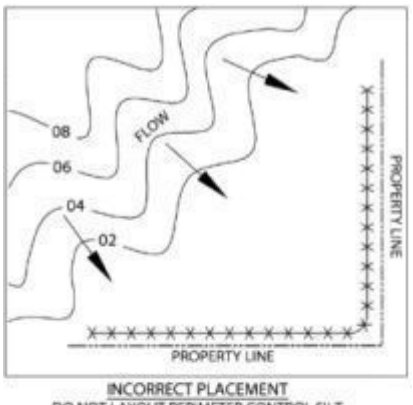


Silt Fence Failure

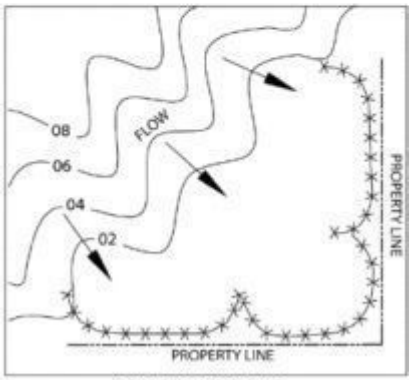
Remove trash, floatables, and large sediment deposits after each storm event and when deposits reach approximately one half the height of the barrier.

Dress to conform to existing grade, prepare, and seed any sediment deposits remaining in place after the silt fence is no longer required.

Where silt fence or any of its derivatives have failed because of concentrated runoff, a rock filter outlet (Specification BMP C-SCM-08) must be placed at the location. **Do not reinstall using the compromised practice.**



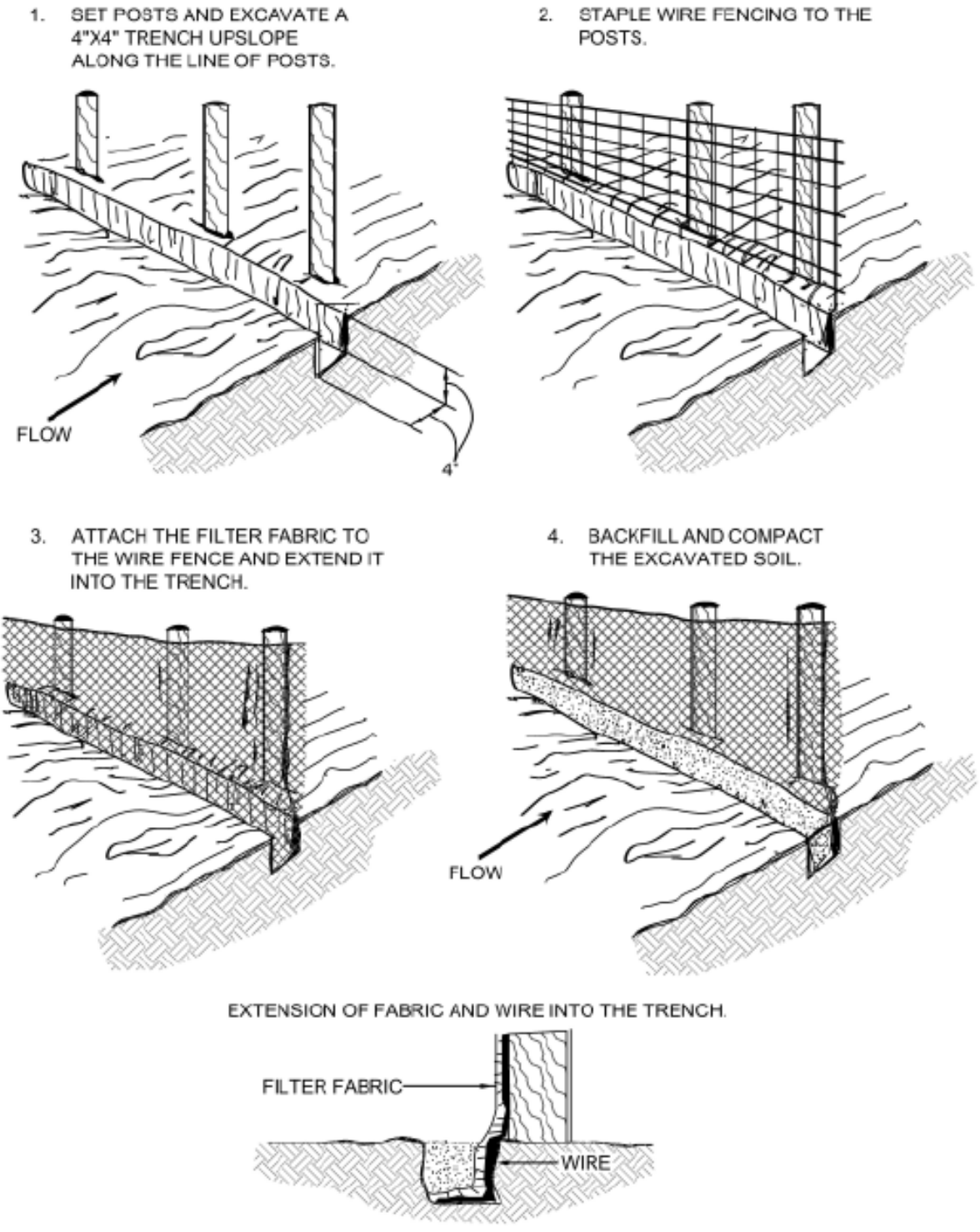
INCORRECT PLACEMENT
DO NOT LAYOUT PERIMETER CONTROL SILT FENCES ALONG PROPERTY LINES. ALL SEDIMENT-LADEN RUNOFF WILL CONCENTRATE AND OVERWHELM THE SYSTEM.



CORRECT PLACEMENT
BREAK-UP SILT FENCE INTO SECTIONS TO PREVENT SEDIMENT-LADEN RUNOFF FROM CONCENTRATING AND OVERWHELMING THE SYSTEM.

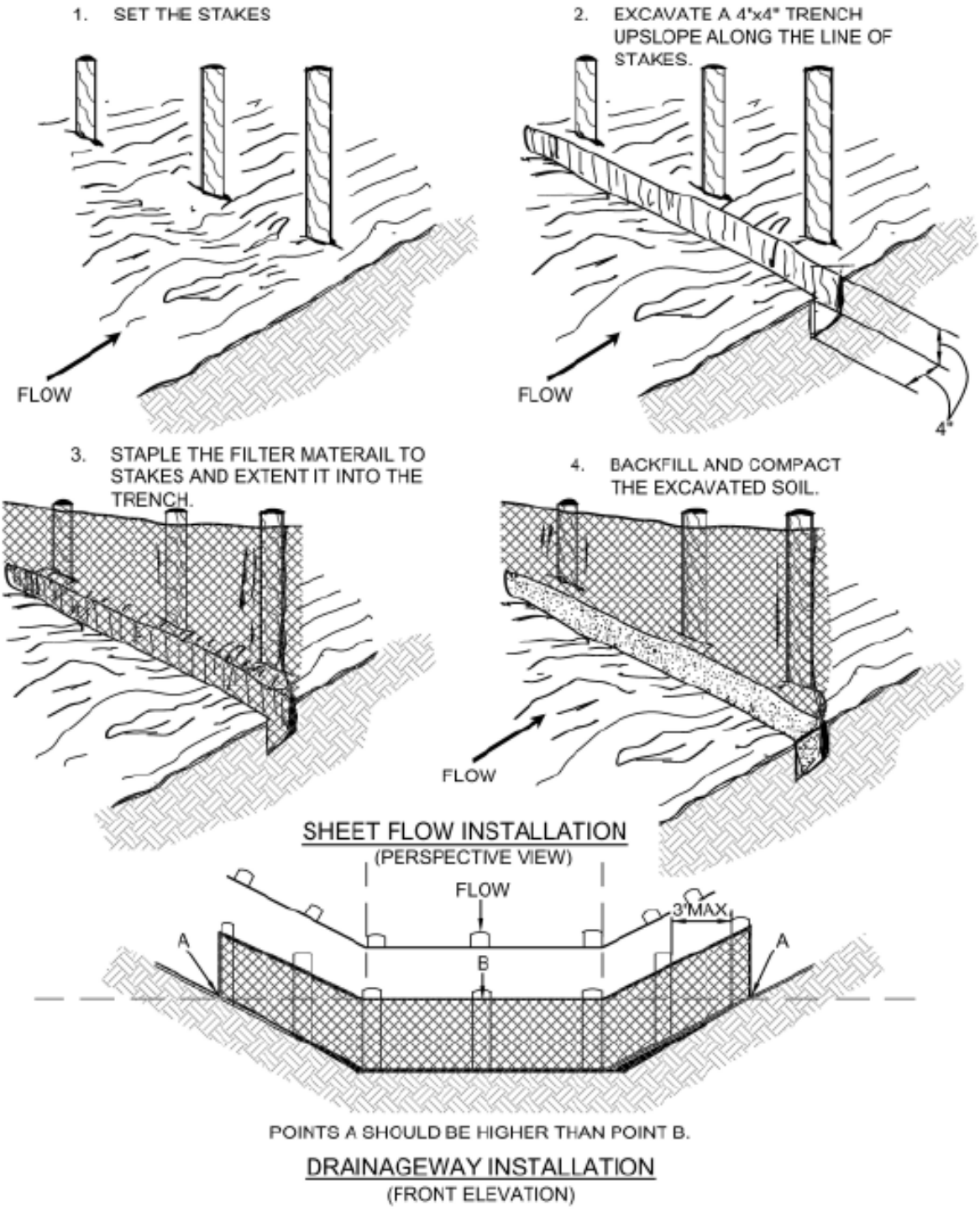
Figure C-PCM-04-3 Construction of Silt Fence with Wire Support Installation

Figure C-PCM-04-3 Construction of Silt Fence with Wire Support Installation



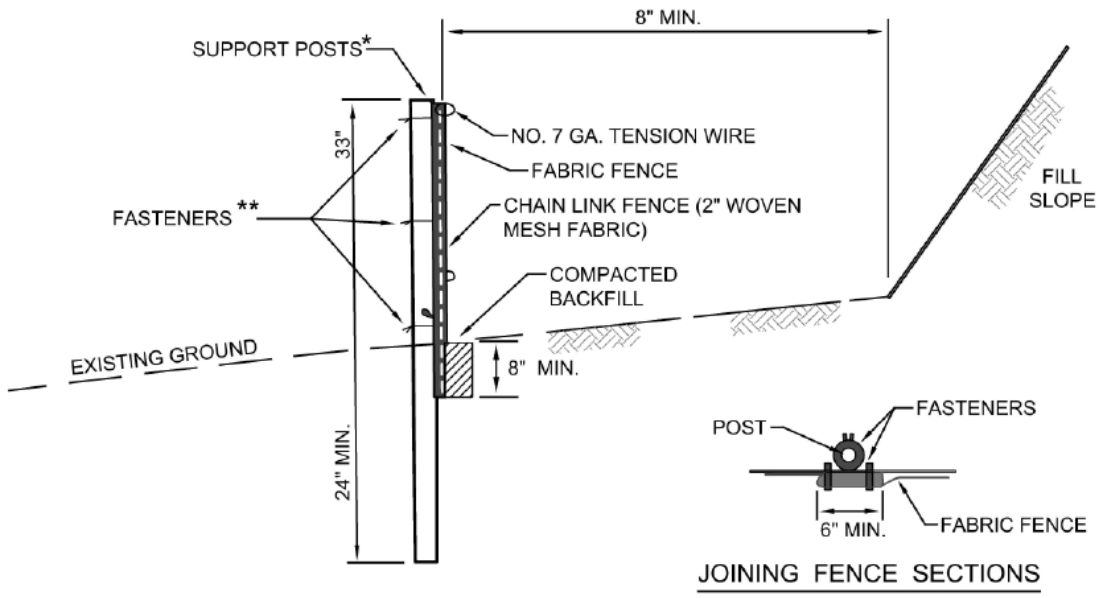
Source: Adapted from Straw & Fab. Barriers, Sherwood & Wyant

Figure C-PCM-04-4 Construction of Silt Fence without Wire Support Installation



Source: Adapted from Straw & Fab. Barriers, Sherwood & Wyant

Figure C-PCM-04-5 Super Silt Fence Installation



* POSTS SPACED @ 10' MAX. USE 2 1/2" DIA. HEAVY DUTY GALVANIZED OR ALUMINUM POSTS.

* * CHAIN LINK TO POST FASTENERS SPACED @ 14" MAX. USE NO. 9 GA. ALUMINUM WIRE OR NO. 9 GALVANIZED STEEL PRE-FORMED CLIPS. CHAIN LINK TO TENSION WIRE FASTENERS SPACED @ 60" MAX. USE NO. 13.5 GA. GALVANIZED STEEL WIRE. FABRIC TO CHAIN FASTENERS SPACED @ 24" MAX C. TO C.

Source: Adapted from PADEP 2012

8.0 References

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C-PCM-05 Compost Filter Sock

1.0 Definition

Compost filter sock, also called a filter log, is a temporary sediment control practice consisting of a biodegradable or photodegradable mesh tube filled with a coarse compost media to filter sediment and other pollutants associated with construction and prevent their migration offsite.



Source: Gilliland Energy 2023

2.0 Purpose and Applicability of Best Management Practice

Compost filter socks can be used in many construction site applications where erosion will occur in the form of sheet erosion. Compost filter socks are a best management practice (BMP) used both at the site perimeter and within the construction areas. These socks may be filled after placement by blowing compost into the tube pneumatically or filled at a staging location and moved into its designed location. Acceptable locations where compost filter socks can be applied include:

- Site perimeters;
- Below disturbed areas subject to sheet runoff with minor sheet or rill erosion;
- Above graded slopes to serve as a diversion berm;
- Check dams;
- Along the toes of stream and channel banks;
- Around area drains or inlets located in a storm drain system;
- Around sensitive trees where trenching of silt fence is not beneficial for tree survival or may unnecessarily disturb established vegetation; and
- On paved surfaces where trenching of silt fence is impossible.

3.0 Planning and Considerations

Compost quality is an important consideration when designing a compost filter sock. Use of sanitized, mature, biologically stable compost ensures that the compost filter sock performs according to design, has no identifiable feedstock constituents or offensive odors, and minimizes soluble nutrient loss.

Compost filter socks can be used in conjunction with land-disturbing activities where erosion will occur in the form of sheet erosion and there is no concentrated flow of stormwater flowing to the sock.

In areas with steep slopes and/or rocky terrain, ensure that soil conditions are such that good continuous contact between the sock and the soil is maintained throughout its length. Provide stakes, as necessary, along the length of the sock to secure to the slope and prevent movement.

For use on impervious surfaces, such as road pavement or parking areas, provide proper anchorage to prevent shifting of the sock or separation of the contact between the sock and the pavement.

These socks may be filled after placement by blowing compost into the tube pneumatically, filled at a staging location and moved into its designed location, or purchased pre-filled with compost on pallets. Note that straw wattles are not a substitute for compost filter socks, as straw wattles are not the same control measures.

The anticipated functional life of a biodegradable filter sock should be 6 months; for photodegradable socks, it should be 1 year. Projects with disturbances anticipated to last longer than the functional life of a sock should plan to replace the socks periodically or use another type of BMP.



Source: GSWCC

Compost filter socks may also be used for other filtering or trapping purposes, such as with Inlet Protection (C-SCM-04), Concrete Washout Pit (C-SCM-13), and Temporary Sediment Trap (C-SCM-11).

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment will be constructed as a first step in any land-disturbing activity and will be made functional before upslope land disturbance takes place.

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

Use compost filter socks with a minimum diameter of 12 inches, unless being used in the following applications, in which case a minimum diameter of 8 inches is required:

- Residential development on lots of 0.25 acre or less or
- Commercial developments of less than 10,000 square feet total lot area, where the life of the project is less than or equal to 6 months.

As with other perimeter controls and sediment barriers, place filter socks parallel to the contour with either end of the sock extended for 8 feet at a 45-degree angle to prevent end-arounds.

Do not exceed the maximum slope lengths above a compost filter sock shown in Table C-PCM-05-1.

When placed, ensure the flat dimension of the sock is at least 1.5 times the nominal diameter.

Do not exceed the maximum drainage area of 0.5 acre for every 100 linear feet of compost filter sock (Keener et al. 2007).

Table C-PCM-05-1 Design Parameter of Sock Thickness

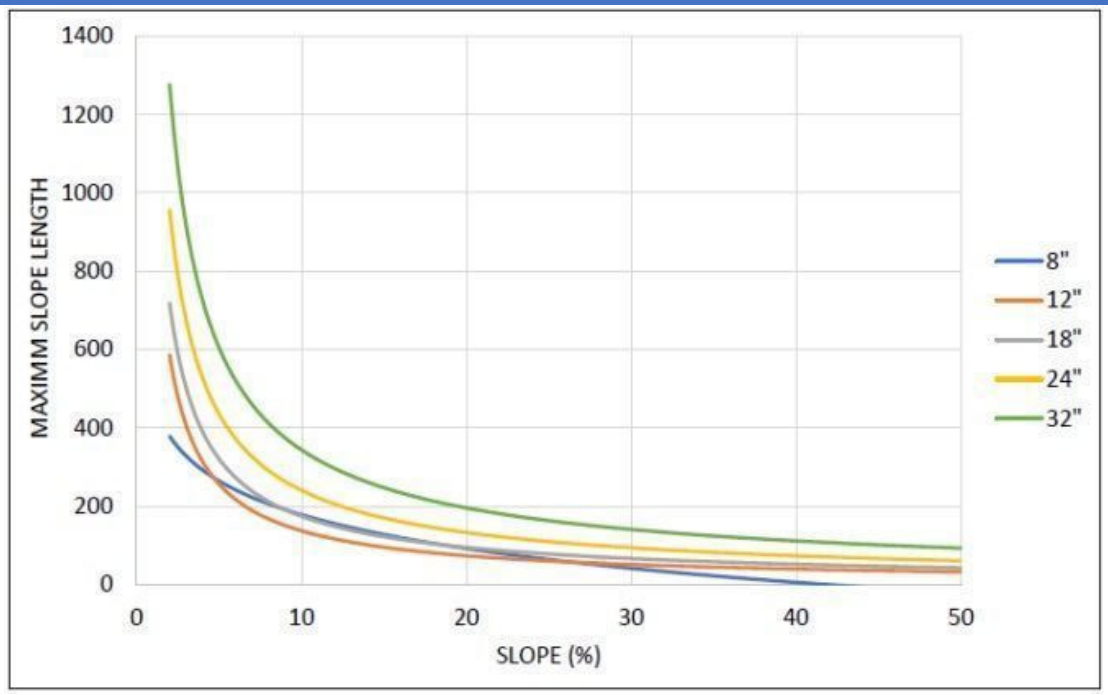
Maximum Slope Lengths Above Compost Filter Sock

Diameter (inches)	Slope (%)						
	2	5	10	20	25	33	50
	Length (feet)						
8	378	264	177	91	64	29	--
12	586	256	137	73	60	47	32

Table C-PCM-05-1 Design Parameter of Sock Thickness							
Maximum Slope Lengths Above Compost Filter Sock							
Diameter (inches)	**Slope (%)**						
	2	**5**	**10**	**20**	**25**	**33**	**50**
	Length (feet)						
18	718	321	174	95	78	61	42
24	956	436	240	133	110	86	60
32	1,277	605	344	195	163	130	93

Source: Adapted from Florida Erosion and Control Designer and Reviewer Manual, Pennsylvania Department of Environmental Protection Erosion and Sediment Control Pollution Control Program Manual, North Carolina Erosion and Sediment Control Planning and Design Manual, Filtrexx Federal Specifications for Compost Filter Socks for Sediment & Erosion Control, and the United States Department of Agriculture.

Figure C-PCM-05-1 Maximum Slope Lengths Above Compost Filter Sock



6.0 Construction Specifications

Table C-PCM-05-2 Compost Sock Fabric Minimum Specifications					
Material Type	**3 mil HDPE**	**5 mil HDPE**	**5 mil HDPE**	**Multi-Filament Polypropylene (MFPP)**	**Heavy Duty Multi-Filament Polypropylene (HDMFPP)**
Material Characteristics	**Photo-degradable**	**Photo-degradable**	**Bio-degradable**	**Photo-degradable**	**Photo-degradable**
Sock Diameters (inches)	12 18	8 12 18 24 32	12 18 24 32	12 18 24 32	12 18 24 32
Mesh Opening (inches)	0.375	0.375	0.375	0.375	0.125
Tensile Strength	26 psi	26 psi	26 psi	44 psi	202 psi
Ultraviolet Stability % Original Strength (ASTM G-155)	23% at 1,000 hour	23% at 1,000 hour		100% at 1,000 hour	100% at 1,000 hour
Minimum Functional Longevity	6 months	9 months	6 months	1 year	2 years
Two-ply systems					
Inner Containment Netting	HDPE biaxial net				
	Continuously wound				
	Fusion-welded junctures				
	0.75-inch x 0.75-inch maximum aperture size				
Outer Filtration Mesh	Composite polypropylene fabric (woven layer and non-woven fleece mechanically fused via needle punch)				
	0				
	1875-inch maximum aperture size				
Sock fabrics composed of burlap may be used on projects lasting 6 months or less.					

Source: Filtrexx & JMD

“ = inch(es)

HDPE = high-density polyethylene

psi = pounds per square inch

Source compost that is a well decomposed, weed-free organic matter derived from agriculture, food, stump grindings, and yard or wood/bark organic matter sources with no objectionable odors.

Ensure the compost is aerobically composted.

Ensure the compost product does not resemble the raw material from which it was derived.

Wood and bark chips, ground construction debris, or reprocessed wood products are not acceptable as the organic component of the mix.

Obtain compost with the physical parameters that comply with the standards in Table C-PCM-05-3.

Provide certification that the compost meets the standards in Table C-PCM-05-3.

Table C-PCM-05-3 Compost Material Standards	
Organic Matter Content	25% - 100% (dry weight basis)
Organic Portion	Fibrous and elongated
pH	6.0 - 8.0
Moisture Content	30% - 60%
Particle Size	99% passing a 2-inch screen and 10 - 50% passing a 0.375-inch screen
Soluble Salt Concentration	5.0 Deci Siemens per meter (dS/m; millimho per centimeter [mmhos/cm]) maximum

Source: SAG / NYS

7.0 Operations and Maintenance Considerations

Do not permit traffic to cross compost filter socks. Design breaks in the barriers for internal circulation and movement of equipment.

Remove accumulated sediment when it reaches half the above-ground height of the sock and dispose in accordance with the erosion and sediment control plan.

Inspect socks weekly and after each runoff event. Repair damaged socks in the manner required by the manufacturer or replace within 24 hours of inspection notification.

Replace compost filter socks according to the manufacturer's frequency recommendations.

Upon stabilization of the area contributory to the sock, remove the stakes. The compost filter sock may be left in place and vegetated or removed in accordance with the stabilization plan. For removal, the mesh can be cut, and the compost spread as an additional mulch to act as a soil supplement. ***If a rubber-fill sock is used, remove the sock and dispose offsite.***



Improperly Maintained Compost Filter Sock
Source: Michael D. DeVuono, PE

8.0 References

Georgia Soil and Water Conservation Commission. 2016. *Manual for Erosion and Sediment Control in Georgia*.

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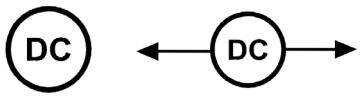
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PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

C-SCM-01 Dust Control

1.0 Definition

Dust control is the reduction of movement of dust on the ground surface and in the air during land disturbance, demolition, and construction.



2.0 Purpose and Applicability of Best Management Practice

Dust control is used to prevent surface and air movement of dust from exposed soil surfaces and reduce the presence of airborne substances that may pose health hazards, traffic safety problems, or harm animal or plant life.

Dust control applies to areas subject to dust on the ground surface and in the air where on-site and off-site damage is likely to occur if preventive measures are not taken.

3.0 Planning and Considerations

Construction inevitably results in the exposure and disturbance of soil. Fugitive dust is emitted both during the activities (i.e., excavation, demolition, vehicle traffic, human activity) and because of wind erosion over exposed earth surfaces. Large quantities of dust are typically generated in “heavy” construction, road and street construction and subdivision, commercial, or industrial development, which involve disturbance of significant areas of the soil surface. Research of construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earth-moving activities comprise the major source of construction dust emissions, but traffic and disturbance of the soil also generate significant dust emissions.

In planning for dust control, limiting the amount of soil disturbance at any one time should be a key objective. Therefore, phased clearing and grading operations and the use of temporary stabilization in accordance with MS-1 (9VAC25-875-560) can significantly reduce dust emissions. Undisturbed vegetative buffers (minimum 50-foot widths) left between graded and protected areas can also be very helpful in dust control.

Where evaporation rates are high, water application to exposed soils may require near constant attention. If too much water is applied, application may create excess runoff from the site and possibly create conditions under which vehicles could track mud onto public roads.

Use chemical applications sparingly and only on mineral soils (not muck soils) because its misuse can create additional surface water pollution from runoff or contaminate groundwater. Chemical applications might also pose a health risk if excessive amounts are used.

During drought, give special attention to controlling dust by employing vegetative cover, mulch, tillage, and spray-on adhesives as temporary measures during construction. Sprinkling the site with water to control dust is a common practice (although not recommended during extreme drought conditions).

4.0 Stormwater Performance Summary

MS-2 - During construction of the project, soil stockpiles and borrow areas shall be stabilized or protected with sediment trapping measures. The applicant is responsible for the temporary protection and permanent stabilization of all soil stockpiles on site as well as borrow areas and soil intentionally transported from the project site.

9VAC25-875-560

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: N/A

5.0 Design Criteria

No formal design procedure is given for dust control.

6.0 Construction Specifications

6.1 Temporary Measures Used During Construction

Table C-SCM-01-1 Design Criteria for Dust Control

Approach	Notes on Proper Use
Vegetative Cover	In areas subject to little or no construction traffic, a vegetatively stabilized surface will reduce dust emissions. See Temporary Seeding (BMP C-SSM-09).
Mulch	When properly applied, mulch offers a fast, effective means of controlling dust. Mulch is not recommended for areas within heavy traffic pathways. Use binders or tackifiers to tack organic mulches. See Mulching (BMP C-SSM-11).
Tillage	This practice is designed to roughen the ground and bring clods to the surface. Use tillage as an emergency measure before wind erosion starts. Begin plowing on the windward side of the site. Chisel-type plows spaced about 12 inches apart, spring-toothed harrows, and similar plows are examples of equipment that may produce the desired effect.
Irrigation	Irrigation is the most used dust control practice. The site is sprinkled with water until the surface is wet. Repeat as needed. Irrigation offers fast protection for haul roads and other heavy traffic routes.
Spray-On Adhesives	Significant progress has been made in recent years in the development of spray-on adhesive products. Most are effective on “mineral” soils and are ineffective on “muck” soils. These adhesives are derived from a variety of compounds, both organic and synthetic based. Many of the adhesives will withstand heavy traffic loads. The organic compounds include derivatives from pine tar and vegetable gum; synthetic compounds may be acrylic- or petroleum-based. Table C-SCM-01-2 list adhesives and provides corresponding information on mixing and application.
Stone	Crushed stone or coarse gravel can be used to stabilize roads or other areas during construction. See Construction Road Stabilization (BMP C-SCM-02).
Barriers	A board fence, wind fence, sediment fence, or similar barrier can help to control air currents and blowing soil. Place barriers perpendicular to prevailing air currents at intervals of about 15 times the barrier height. Where dust is a known problem, existing windbreak vegetation should be preserved.

Table C-SCM-01-1 Design Criteria for Dust Control	
Approach	**Notes on Proper Use**
Calcium Chloride	Apply this chemical by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage. Application rates should be strictly in accordance with suppliers' specified rates.

Table C-SCM-01-2 lists adhesives and provides information on mixing and application.

Table C-SCM-01-2 Adhesives Used in Dust Control			
Adhesive	**Water Dilution (adhesive: water)**	**Type of Nozzle**	**Application Rate (gallons/acre)**
Anionic asphalt emulsion	7:1	Coarse Spray	1,200
Latex emulsion	12.5:1	Fine Spray	235
Resin in water	4:1	Fine Spray	300
Acrylic emulsion (non-traffic)	7:1	Coarse Spray	450
Acrylic emulsion (traffic)	3.5:1	Coarse Spray	350

Table C-SCM-01-3 Permanent Methods of Dust Control	
Approach	**Notes on Proper Use**
Permanent Vegetation	The application of Permanent Seeding (BMP C-SSM-09) and saving existing trees and large shrubs can help reduce movement of soil and air at construction sites.
Stone	Crushed stone or coarse gravel can be used as a permanent cover, which will control soil emissions.

7.0 Operations and Maintenance Considerations

Maintain dust control measures through dry weather until all disturbed areas have been stabilized.

Because the success of dust controls depends on specific site and weather conditions, inspection and maintenance requirements are unique for each site. However, dust control measures involving application of either water or chemicals require more monitoring than structural or vegetative controls to remain effective.

Inspect structural controls for deterioration regularly to ensure the controls are still achieving its intended purpose.

8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina

Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

C-SCM-02 Construction Road Stabilization

1.0 Definition

Construction road stabilization is the stabilization of temporary construction access routes, onsite vehicle transportation routes, and construction parking areas.

– CAD and PDF files for C-SCM-02 Construction Road Stabilization

2.0 Purpose and Applicability of Best Management Practice

This specification applies to temporary or permanent access roads and parking areas for use by construction traffic. Additionally, this specification applies to (but is not limited to) streets and highways, parking areas, and other traffic areas immediately after grading to reduce erosion caused by vehicles during wet weather conditions.

This construction best management practice (BMP) is used to:

1. Reduce the erosion of temporary roadbeds caused by construction traffic during wet weather.
2. Reduce the erosion and subsequent regrading of permanent roadbeds between the time of initial grading and final stabilization.
3. Reduce ground compaction from vehicular traffic.
4. Reduce excess disturbance to root zones and shrubs within ecologically sensitive environments (e.g., wetlands, streams, riparian buffers, forested grounds).

3.0 Planning and Considerations

Areas graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, these exposed areas often become muddy and can generate significant quantities of sediment-laden runoff that may pollute downgradient streams or cause sediment to be transported offsite on the wheels of construction vehicles. During wet weather, dirt roads can be unusable.

Construction of a conventional haul road through forested and/or soft ground results in additional ground disturbance and a potential source of sediment into adjacent streams and waterways.

Both stone and temporary timber deck mats are suitable stabilization materials for a construction access road.

If construction or project access roads are located within 50 feet of and drain to a sinkhole or other karst feature capable of conveying water underground, the edge of the road near the karst feature should be protected using super silt fence (Specification BMP C-PCM-04).

To avoid erosion, compaction, and runoff problems when siting a construction access route or parking area, follow the planning steps recommended by American Electric Power Service Corporation (AEP 2018, p.72) and: :

1. Coordinate with resources agencies (e.g., Virginia Department of Conservation and Recreation, Virginia Department of Wildlife Resources, Virginia Department of Historic Resources) to determine the appropriate areas for access routes, taking into consideration aquatic resources and sensitive areas including karst resources (AEP 2018).

2. Evaluate information from the Natural Resources Conservation Service (NRCS) Web Soil Survey, U.S. Geological Survey, National Wetlands Inventory, and other available resources to determine the most appropriate areas for access routes and/or parking based on areas of erodible soils, karst topography, wet or rocky areas, and areas with seasonally high water tables.
3. Evaluate the site topography to locate natural benches and flatter slopes and use these areas for access routes and/or parking. Avoid long, steep road grades and narrow valleys.
4. Evaluate aquatic resources in the area to minimize stream and/or wetland crossings. Where crossings are unavoidable, consider the following:
    a. Cross at right angles to minimize the length of the crossing.
    b. Cross where the resource is narrowest and upland areas are most stable.
    c. Minimize the number of crossings.
    d. Leave a buffer zone of undisturbed ground between the road and resource, where the road runs parallel to the resource.
    e. Divert water from the road with a temporary diversion to prevent water running directly into the resource.
5. Where possible, use switchbacks to lessen the road grade on steeper sloped areas.
6. Locate roads and/or parking areas on stable geology that includes well-drained soils and rock formations that tend to dip into the slope. Avoid slumps and slide-prone areas characterized by steep slopes, highly weathered bedrock, clay beds, concave slopes, hummocky topography, or rock layers that dip parallel to the slope.
7. Ridge tops can be good places for roads if proper drainage can be constructed. Be aware that conditions may change when constructing during the dry season. Be prepared to add culverts after construction when hidden springs and streams start back up in the winter and spring.
8. If possible, build roads on the drier south- or west-facing slopes.

4.0 Stormwater Performance Summary

MS-4: First-Step Measures – When used appropriately, low-volume construction access roads and driveways will preserve the existing land conditions and topography and reduce erosion. Low-volume access roads and their culverts, diversions, outlet protection, and other used measures shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

MS-17: Vehicular Tracking and Construction Entrances – Where construction vehicle access routes intersect paved or public roads, provisions shall be made to minimize the transport of sediment by vehicular tracking onto the paved surface. Where sediment is transported onto a paved or public road surface, the road surface shall be cleaned thoroughly at the end of each day. Sediment shall be removed from the roads by shoveling or sweeping and transported to a sediment control disposal area. Street washing shall be allowed only after sediment is removed in this manner. This provision shall apply to individual development lots as well as to larger land-disturbing activities.

9VAC25-875-560

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: LOW

5.0 Design Criteria

Table C-SCM-02-1 Design Criteria for Construction Road Stabilization

Design Criteria for Construction Road Stabilization	
Road Cross- Sections	Five road cross-sections are typically used in road construction: (1) crowned fill; (2) crowned turnpike; (3) outslope; (4) inslope with ditch; and (5) crowned and ditched (). The choice of which cross-section to use depends on the drainage needed, soil stability, slope, and the expected volume of traffic on the road. The cross-sections can be used in combination as the terrain changes or as drainage issues are encountered. • **Crowned Fill Section:** Use on flat ground where water standing on a road surface may be a problem. • **Crowned Turnpike Section:** Use on low ground roads where fill is not available. • **Outslope:** Use on moderate slopes for low-volume roads and stable soils. Outsloping can be more dangerous in wet and snowy weather. • **Inslope with Ditch Section:** Use on steep hills, areas with fine-textured soils, winter logging roads, and where drainage is necessary. • **Crowned and Ditched Section:** Use on high-volume roads on steep side hills.
Road Width	Construct roadbeds to be a minimum of 14 feet wide for one-way traffic and 20 feet wide for two-way traffic.
Alignment (Natural Resources Conservation Service 2021)	Adapt the gradient and horizontal alignment to the intensity of use, the mode of travel, the type of equipment and load weights, and the level of development. Frequent grade changes generally cause fewer erosion problems than long, continuous gradients. Design horizontal curves and switchbacks with sufficient radius for trucks and other large vehicles to negotiate easily. Provide a radius no less than 35 feet for standard vehicles and 50 feet for tractor-trailers. Design the lengths of vertical curves, in feet, to use a minimum ‘K’ value of 10 in the design.
Road Grade	Road grade is the single most important factor in planning a low-volume road. Keep road grades to a minimum. If possible, do not exceed 10%. Exceeding these grades typically results in the transport of gravel from the roadbed and generally makes for poorly stabilized conditions. On steeper road grades, ruts form more easily and runoff velocities are higher, which causes gullies and rill erosion along the roadbed.

Table C-SCM-02-1 Design Criteria for Construction Road Stabilization	
Design Criteria for Construction Road Stabilization	
Road Embankment Side Slopes (Pennsylvania Department of Environmental Protection [PADEP] 2012)	Construct all cuts and fills to be 2H:1V or flatter to the extent possible. Minimize cuts and fills where possible. Long and/or high cut/fill slopes are often difficult to stabilize. In soils with low shear strength, these slopes also pose an increased potential for slope failures. Avoid cuts deeper than 3 feet and fill slopes higher than 5 feet where possible. Stabilize cut and fill slopes as soon as possible, but no more than seven (7) calendar days, after reaching final grade in accordance with Permanent Seeding (Specification BMP C-SSM-10) and Soil Stabilization Blankets and Matting (Specification BMP C-SSM-05).
Drainage Ditches	Provide drainage ditches as needed. The design and construction of drainage ditches shall be in accordance with Stormwater Conveyance Channel (Specification BMP C-ECM-09).
Stabilization	Clear the roadbed or parking surface of all vegetation, roots, and other objectionable material. **Stone:** Apply a 6-inch course of Virginian Department of Transportation (VDOT) #1, #2, or #3 Coarse Aggregate immediately after grading or the completion of utility installation within the right-of-way. For additional stability, filter fabric may be applied to the roadbed surface before coarse aggregate placement. Design specifications for filter fabric are provided in Temporary Stone Construction Entrance (Specification BMP C-SCM-03). In “heavy duty” traffic situations, place stone at an 8- to 10-inch depth to avoid excessive dissipation or maintenance needs. **Timber Mat Stabilization:** Typical timber matting will be manufactured hardwood board (usually oak or poplar), laminated pine board, plastic composite, or similar. Dimensions shall vary by manufacturer. Use timber matting on low gradient roads in wet areas.

Table C-SCM-02-1 Design Criteria for Construction Road Stabilization	
Design Criteria for Construction Road Stabilization	
Ditch Relief or Cross-Drain Culvert (PADEP 2012)	Ditch relief or cross-drain culverts are used on crowned or ditched roads to minimize the potential for erosion of roadside ditches as well as flooding of the roadway by reducing the volume of flow conveyed by the ditch. It is important to provide additional culverts at intervals along the roadway where runoff is being conveyed by a ditch. Place ditch relief culverts with slopes of 2% to 4% to help keep the culvert clean and ensure water flow. Install culverts between 25 to 45 degrees to the centerline of the ditch to minimize turbulence at the inlet. Size and space culverts according to Table C-SCM-02-2 for temporary culverts and Table C-SCM-02-3 for permanent culverts or size the culverts for the 10-year storm event based on the drainage area to the culvert. The minimum diameter for any culvert is 12 inches unless other regulatory conditions apply. Otherwise, size the culvert to pass the flow from the 10-year storm event without overtopping the construction road. Extend the culvert 12 inches beyond the base of the road fill on both sides. Firmly pack fill around the culvert, especially the bottom half. Cover the top of the culvert with at least 12 inches of fill, more if heavy loads are anticipated on the road. To be sure that no water bypasses the inlet, install a control backstop of earth, riprap, sandbags, or half-culvert sections on the downhill level of the inlet. Do not discharge onto the side of a road fill. Provide suitable outlet stabilization; see Outlet Protection (Specification BMP C-ECM-15) and, where appropriate, Inlet Protection (Specification BMP C-SCM-04).
Temporary Right-of- Way Diversion	Temporary right-of-way diversions (Specification BMP C-ECM-07) may be used on construction access roads to direct surface water off the road into a constructed outlet but are not recommended for high-volume roads due to difficulty of moving equipment over the diversions (18 inches high with a 6-foot base width) and the need for continual maintenance due to damage from traffic. Temporary right-of-way diversions are useful on infrequently used roads. Temporary right-of-way diversions used on active access roads will often require reinforcement with a log, steel pipe, or other support to maintain the integrity of the diversion between maintenance operations. Do not use temporary right-of-way diversions on in-sloping roadways where there is no opportunity to discharge runoff to either side.

Table C-SCM-02-1 Design Criteria for Construction Road Stabilization

Design Criteria for Construction Road Stabilization	
Turnout (PADEP 2012)	Turnouts are channels that drain water away from roads or roadside ditches into well- vegetated areas. Turnouts are typically located along crowned roadways where runoff cannot sheet flow off the roadway. Like ditch relief culverts, the purpose of turnouts is to minimize the volume of water in a roadside ditch. Locate turnouts to take advantage of natural drainage courses or buffer areas where possible. Grade the approach to a turnout on a 2% to 3% slope to allow constant drainage. Ensure that the spoil from turnout construction is not allowed to form a dam at the end of the turnout. Do not discharge water from a turnout directly into a stream or waterbody. An excavated sump at the end of the turnout can effectively pond and settle out sediment before discharging to a vegetated buffer; however, discharges from a turnout should be handled as other concentrated discharges. Where a suitable vegetative filter strip is not available to remove sediment, install a compost filter sock, rock filter, or other sediment removal BMP at the outlet of the turnout. Design discharges from a turnout to minimize erosion. Consult Outlet Protection (Specification BMP C-ECM-15) for design guidance. Stabilize the turnout as soon as possible after grading in accordance with Permanent Seeding (Specification BMP C-SSM-10) and Soil Stabilization Blankets and Matting (Specification BMP C-SSM-05).
Stream or Wetland Crossing	Refer to Stable Wetland Crossing (Specification BMP C-ENV-06) for temporary wetland crossing design specifications and Temporary Vehicular Stream Crossing (Specification BMP C-ENV-03) for temporary stream crossing design specifications. Construction roads should not be constructed within sinkholes (as defined by a closed topographic depression) or over cave entrances.

Source: AEP 2018, unless otherwise specified.

Table C-SCM-02-2 Sizing and Spacing of Ditch Relief Culverts for Temporary Access Roads

Sizing and Spacing of Ditch Relief Culverts for Temporary Access Roads						
Road Grade (%)	Culvert Spacing[a] (feet)	Length of Upslope Drainage (feet)				
		<300	300 – 400	400 – 500	500 – 600	>600
		Minimum Culvert Size (inches)				
2	300	12	15	15	15	18
3	235	12	15	15	15	18
4	200	12	15	15	15	18
5	180	12	12	15	15	15

Table C-SCM-02-2 Sizing and Spacing of Ditch Relief Culverts for Temporary Access Roads						
Sizing and Spacing of Ditch Relief Culverts for Temporary Access Roads						
6	165	12	12	12	15	15
7	155	12	12	12	12	15
8	150	12	12	12	12	15
9	145	12	12	12	12	15
10	140	12	12	12	12	15
12	135	12	12	12	12	15

Note:

a. Culvert spacing may be adjusted slightly to take advantage of natural drainage courses.

Source: PADEP 2012, Table 3.3, p.31.

Table C-SCM-02-3 Recommended Spacing of Ditch Relief Culverts (18-inch diameter Corrugated Metal Pipe) for Permanent Access Roads					
Recommended Spacing of Ditch Relief Culverts (18-inch diameter Corrugated Metal Pipe) for Permanent Access Roads					
Road Grade (%)	Soil Type in Ditch				
	Gravels, Sandy Gravels, Aggregate Surfacing	Silty Gravels, Clayey Gravels	Plastic and Non-Plastic Inorganic Clays	Inorganic Silts, Silty or Clayey Sands	Sands, Silty Sands, & Gravelly Sands
	Maximum Culvert Spacing Feet[a]				
2	390	315	245	170	95
4	335	275	210	145	85
6	285	230	180	125	75
8	240	195	150	105	65
10	200	160	125	90	55
12	160	130	105	75	45
14	130	110	85	60	35

Note:

a. Culvert spacing may be adjusted slightly to take advantage of natural drainage courses.

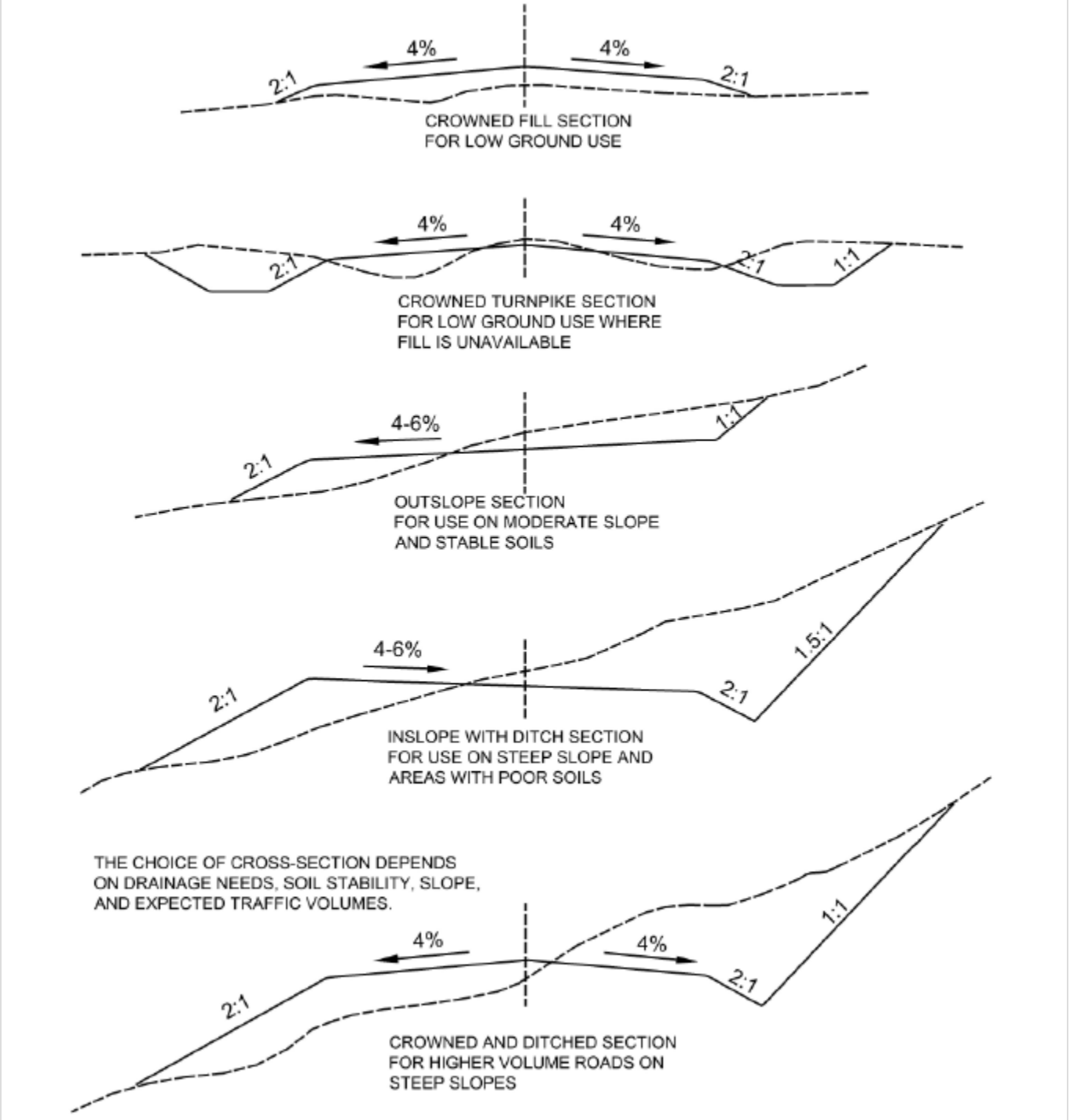
Source: PADEP 2012, Table 3.4, p.32.

6.0 Construction Specifications

Before construction, install the appropriate erosion and sediment controls downgradient of the construction access road grading, including Compost Filter Socks (Specification BMP C-PCM-05), Silt Fence (Specification BMP C-PCM-04), Temporary Sediment Trap (Specification BMP C-SCM-11),

Temporary Sediment Basin (Specification BMP C-SCM-12), and other structures. Upon completion of roadway or parking area grading, immediately stabilize cut and fill slopes.

Figure C-SCM-02-1 Types of Cross Road Sections



Source: AEP 2018, Appendix B. AEP Erosion and Sediment Control Details: West Virginia BMP 3.35 – Access Road/Low Volume Road/Driveway, p.3.35-9.

7.0 Operations and Maintenance Considerations

Inspect roadways and parking areas weekly and after each rainfall event. Inspect roadways and cut/fill slopes for gully or rill erosion or sloughing and scour in the ditches. If temporary right-of-way diversions or broad-based dips are used, ensure that the measures have been maintained and are deep enough to capture road surface runoff. If runoff overruns these measures, repair immediately. Inspect culverts, roadside ditches, and outlets and restore flow capacity as needed (AEP 2018).

Ensure that the proper cross-section is available, and outlets are stable. Fill low areas in travel treads and re-grade, as needed, to maintain road cross-section. Repair or replace surfacing materials as needed (AEP 2018).



Example of Poorly Maintained Vehicular Route Stabilization

Inspect roadside ditches and other drainage structures to ensure that the measures do not become clogged with silt or other debris. Remove accumulated debris as necessary to maintain flow capacity (AEP 2018).

Inspect timber mats to ensure the mats are installed correctly and functioning properly. Remove accumulated sediment as needed to ensure that it is not transported offsite. Immediately replace any severely damaged mats (Wetland Studies and Solutions, Inc. 2020; Dominion Energy 2019).

Inspect seeded areas adjacent to the roads and parking areas to ensure that vegetation is maintained (AEP 2018).

8.0 References

AEP. 2018. FY 2018 General Erosion and Sediment Control and Stormwater Management Specifications for the Construction and Maintenance of Electric Utility Lines. American Electric Power Service Corporation Environmental Services. March, revised. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/bmp-design-specifications.

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Natural Resources Conservation Service. 2020. Conservation Practice Standard: Access Road, Code 560. National Standard 560-CPS-1. United States Department of Agriculture, Natural Resources Conservation Service. September. Available online at: https://www.nrcs.usda.gov/resources/guides-and-instructions/access-road-ft-560-conservation-practice-standard.

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C-SCM-03 Temporary Stone Construction Entrance

1.0 Definition

A temporary stone construction entrance is a pad with a fabric filter liner underneath the stone located at points of vehicular ingress and egress on a construction site. There are several types of track-out controls that minimize the amount of sediment, such as dirt or mud, leaving or being tracked out from the construction site attached to vehicles.

– CAD and PDF files for C-SCM-03 Temporary Stone Construction Entrance

2.0 Purpose and Applicability of Best Management Practices

Construction entrances provide an opportunity for significant removal of mud from construction vehicle tires before they enter a public road, and, just as important, the soil adjacent to the paved surface can be kept intact. Temporary stone construction entrances reduce the tracking of mud onto paved public roads by motor vehicles or runoff and provide a stable entry to or exit from the construction site.

This practice applies where traffic leaves a construction site and moves directly onto a public road or other paved area.

3.0 Planning and Considerations

A fabric filter liner is used as a "separator" to minimize the dissipation of aggregate into the underlying soil due to construction traffic loads. If the action of the vehicles traveling over the gravel pad is not sufficient to remove most of the mud, or there exists an especially sensitive traffic situation on the adjacent paved road, wash the tires before the vehicle enters the public road. If washing is necessary, make provisions to intercept the wash water and trap the sediment so it can be collected and stabilized.



Stone Construction Entrance with Washrack

Use construction entrances in conjunction with stabilization of construction roads (see Construction Road Stabilization [BMP C-SCM-02]) to reduce the amount of mud picked up by construction vehicles and better remove mud. Encourage vehicles (other than construction equipment) to remain in stabilized areas where possible to avoid mud accumulation on vehicles' tires that will regularly enter and leave the site. Other innovative techniques for accomplishing the same purpose (such as a bituminous entrance) can be used, but only after specific plans and details are submitted and approved by the appropriate certified plan reviewer.

4.0 Stormwater Performance Summary

MS-17: VEHICULAR TRACKING AND CONSTRUCTION ENTRANCES – Provisions shall be made to minimize the transport of sediment from the site onto the paved surface.

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

9VAC25-875-560

Erosion Control Efficiency: MODERATE

Sediment Removal Efficiency: MODERATE

5.0 Design Criteria

Table C-SCM-03-1 Design Criteria for Temporary Stone Entrance

Parameter	Notes on Proper Use
Aggregate Size	Use Virginia Department of Transportation (VDOT) #1, #2, or #3 Coarse Aggregate (1.5- to 3.5-inch stone) or American Association of State Highway and Transportation Officials (AASHTO) #1 Course Aggregate (2.5- to 3.5-inch stone).
Entrance Dimensions	Construct the aggregate layer to be a minimum of 6 inches thick and place a minimum 3 inches of aggregate in a cut section to give the entrance added stability and help secure the fabric filter separator. Extend the entrance to the entire width of the vehicular ingress and egress area and have a minimum 12-foot width. Construct the entrance length at a minimum of 70 feet except for smaller construction projects (total disturbance area of less than 1 acre) or sites with entrance constraints. For these project sites, the minimum length is the greater of either 30 feet or a length sufficient for all on-site equipment to make at least two tire revolutions when crossing the trackout surface. Where site conditions warrant that it may be necessary to extend the length or width of the rock to ensure the effectiveness of the entrance.
Mountable Berm & Culvert Pipe	Where access to the site crosses a roadside ditch, stream channel, or natural drainage course, provide a suitable means of conveying the flow past the entrance (e.g., an appropriately sized culvert pipe). Size the pipe to convey the runoff generated by the 2-year, 24-hour frequency storm at a minimum. The minimum permissible pipe size is 6 inches. For such installations, install a mountable berm above the pipe to avoid crushing the pipe. Construct the 3-foot-wide mountable berm centered above the pipe with 5H:1V side slopes and 6 inches higher than the elevation of the rest of the construction entrance.
Filter Fabric	Use filter fabric that is a woven fabric consisting only of continuous-chain polymeric filaments or yarns of polyester. Use filter fabric inert to commonly encountered chemicals and hydrocarbons, mildew and rot-resistant, and conforms to the physical properties noted in Table 1.

Table C-SCM-03-1 Design Criteria for Temporary Stone Entrance	
Parameter	**Notes on Proper Use**
Washing	If most mud is not removed by the vehicles traveling over the stone, wash the vehicles' tires before entering the public road. Carry wash water away from the entrance to an approved settling area or sediment removal device (e.g., sediment basin or trap, silt fence, or compost filter sock) to remove sediment. Prevent all sediment from entering storm drains, ditches, or watercourses. Use a wash rack to make washing more convenient and effective for washing mud from the tires of the work vehicles only. A reinforced concrete or metal wash rack are both viable options to reduce the presence of sediment from work vehicles leaving the construction site (PA DEP 2012). Wash racks are unsuitable for complete truck washing and only apply to washing the vehicle tires. If there is a need for a full wash of vehicles, refer to standard detail Concrete Washout Pit (C-SCM-13). Additionally, ensure that wash racks immediately discharge to a sediment removal device (e.g., sediment basin or trap, silt fence, or compost filter sock) before the water enters waterbodies (PA DEP 2012).
Location	Locate the entrance to provide for maximum use by all construction vehicles. Locate the entrance on level ground at an appropriate site distance. Avoid locating the entrance on steep slopes and ensure the entrance drains transversely to prevent runoff from the entrance flowing into the adjacent roadway. Entrance configurations off the paved road may be modified to allow tractor trailers or longer delivery vehicles adequate area to safely exit the paved road onto the construction entrance and re-enter onto the paved road from the construction entrance.

Table C-SCM-03-2 Construction Specifications for Filter Fabric Liner Under Aggregate Stone			
Fabric Properties[1]	**Light-Duty Entrance[2] (Graded Subgrade)**	**Heavy-Duty Entrance[3] (Rough Graded)**	**Test Method**
Grab Tensile Strength (lbs.)	200	315	ASTM D4632
Grab Tensile Elongation (%)	15	15	ASTM D4632
Trapezoidal Tear (lbs.)	75	113 – 120	ASTM D4533
CBR Puncture Strength (lbs.)	700	900	ASTM D6241
Apparent Opening Size	40	40	ASTM D4751

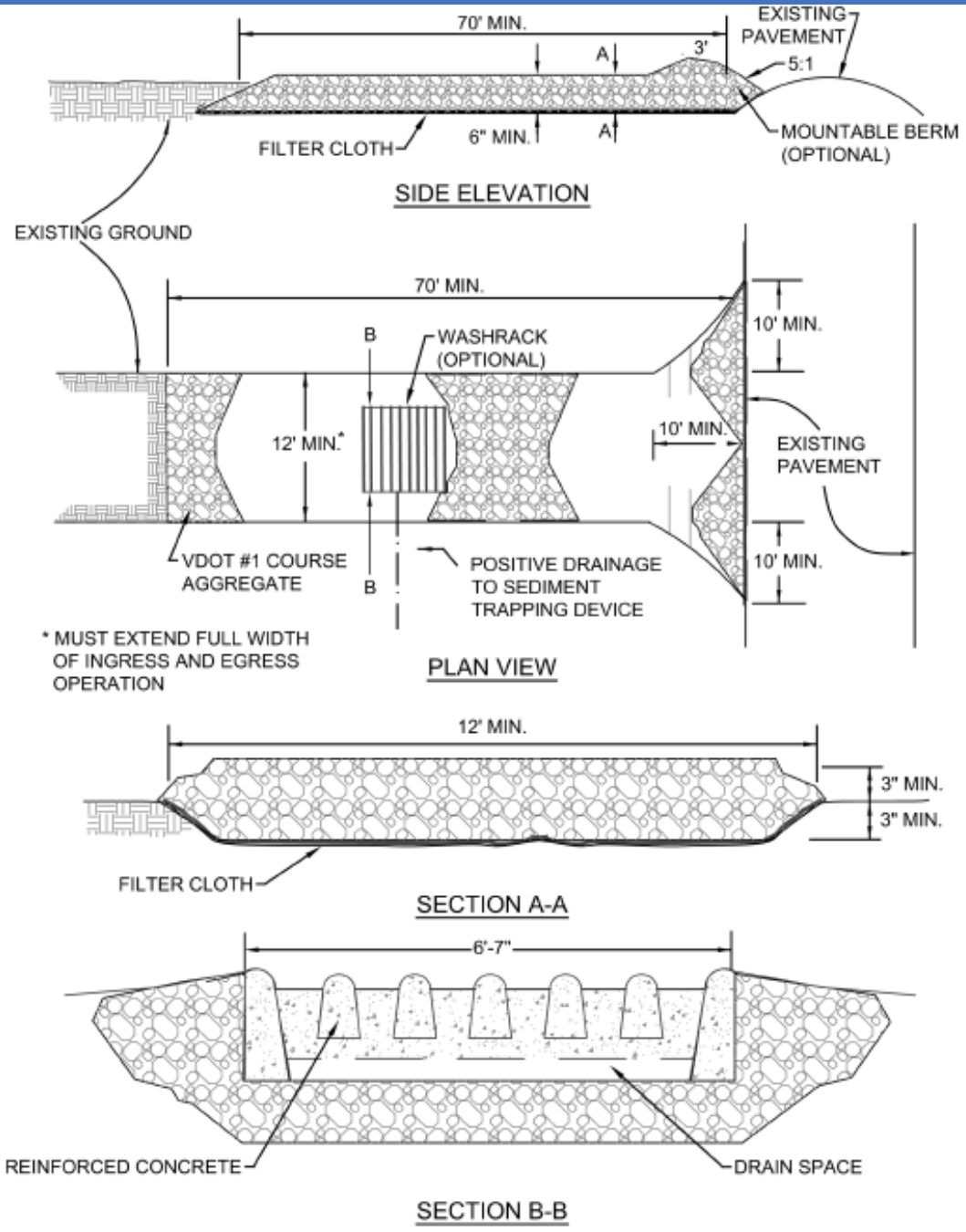
Table C-SCM-03-2 Construction Specifications for Filter Fabric Liner Under Aggregate Stone			
Fabric Properties[1]	Light-Duty Entrance[2] (Graded Subgrade)	Heavy-Duty Entrance[3] (Rough Graded)	Test Method

1. Only use fabrics not meeting these specifications when design procedure and supporting documentation are supplied to determine aggregate depth and fabric strength.
2. **Light-Duty Entrance:** Sites that have been graded to subgrade and where most travel would be by single-axle vehicles and an occasional multi-axle truck. Examples of fabrics that can be used are: Mirafi 500X, Skaps SW200, Geotex 200 ST, or equivalent.
3. **Heavy-Duty Entrance:** Sites with only rough grading and where most travel would be by multi-axle vehicles. Examples of fabrics that can be used are: Mirafi 600X, Skaps SW315, Geotex 315 ST, or the equivalent.

6.0 Construction Specifications

1. Excavate the entrance area to a minimum of 3 inches and clear the area of all vegetation, roots, and other objectionable material.
2. Construct any drainage facilities according to specifications. Provide for the conveyance of surface water under the entrance through culverts.
3. Place the filter fabric underlayment atop the entire width and length of the entrance.
4. Following the filter fabric installation, place the stone to the specified dimensions (including the construction of the mountable berm) as necessary.
5. If wash racks are used, install wash racks according to manufacturer's specifications. Ensure the wash rack can convey sediment-laden water immediately to a sediment control treatment device before entering a water body.
6. Confirm the length and width of the construction entrance before setting up erosion control measures and perimeter control measures.

Figure C-SCM-03-1 Stone Construction Entrance



Source: Maryland Water Resources Administration et al. 1983

7.0 Operations and Maintenance Considerations

Inspect the construction entrance weekly and immediately after each rainfall.

Maintain the entrance to prevent tracking or flow of dirt, mud, or sediment onto public rights-of-way, including periodic top dressing with additional stone and repair or cleanout of structures that trap sediment or both. Maintain a stockpile of rock at the site for top dressing purposes.

Mud and soil particles will eventually clog the voids in the stone and compromise the effectiveness of the construction entrance. When this occurs, top dress the pad with new stone. Complete stone replacement is necessary when the pad becomes wholly clogged with sediment and the topdressing is no longer effective at removing accumulated sediment from tires.



Improperly Maintained Stone Construction Entrance-Stones Dislodged Spilling into Adjoining Roadway

Immediately remove all materials spilled, dropped, washed, or tracked from vehicles onto roadways or storm drains. Do not use water trucks to remove materials dropped, washed, or tracked onto roadways under any circumstances.

Immediately remove stones from the adjoining roadway that construction traffic dislodged from the entrance.

Maintain the area under the wash rack free of accumulated sediment. Repair or replace the wash rack if it becomes damaged.

8.0 References

Maryland Water Resources Administration, Soil Conservation Service, and State Soil Conservation Committee. 1983. Maryland Standards and Specifications for Soil Erosion and Sediment Control. April.

C-SCM-04 Inlet Protection

1.0 Definition

Inlet protection is a sediment filter or an excavated impounding area around a storm drain drop inlet or curb inlet.

– CAD and PDF files for C-SCM-04 Inlet Protection

2.0 Purpose and Applicability of Best Management Practice



Properly Installed Inlet Protection

The purpose of inlet protection is to prevent sediment from entering storm drainage systems before permanent stabilization of the disturbed area. Every storm drain inlet, catch basin, curb inlet, or similar drainage structure receiving sediment-laden runoff should be protected by a combination of upstream erosion control and temporary inlet protection. This practice will significantly reduce sediment loads and will help prevent floatable waste materials and other construction wastes from entering stormwater systems (City of Knoxville 2018).

Inlet protection applies to disturbed tributary areas that have yet to be permanently stabilized and where ponding water will not endanger highways, street traffic, houses, buildings, parks, or other facilities. Small drainage areas, typically smaller than 1 acre, that have impervious surfaces and do not permit the construction of a sediment trap or sediment basin are the most applicable for installing inlet protection.

3.0 Planning and Considerations

Storm sewers made operational before stabilization of the associated drainage areas can convey large amounts of sediment to natural drainageways. In extreme sediment loading, the storm sewer itself may clog and lose a significant portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.



Inlet protection can be accomplished using pre-manufactured proprietary devices or on-site construction. Self-constructed devices generally consist of filtering (geotextile fabric and aggregate) securely anchored and supported against the weight of ponded water by some support (e.g., wood boards, concrete blocks, wire mesh, the inlet structure itself). This can be accomplished in many ways. Inlet protection structures that pond water onto streets, parking lots, or driveways should be designed to have some method for allowing excess water from large storms to bypass or overflow. Inspect the means of filtering (generally clean aggregate or filter fabric) regularly to see if sediments and silt clog the material. Pre-manufactured proprietary devices are compatible with most types of inlets and typically consist of either fabric tubes with aggregate or other filter material or fabric sacks placed underneath an inlet grate to trap sediment. Stormwater runoff may bypass protected inlets on slopes. A berm or other type of wall can capture some of the flow. Design inlets downstream, particularly sump inlets, with an overflow to handle large storms. Best management practice (BMP) selection is site- and inlet type-specific.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

9VAC25-875-560

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

Table C-SCM-04-1 Design Criteria for Materials	
Approach	**Notes on Proper Use**
Drainage Area	No greater than 1 acre per inlet.
Proprietary Devices	Size/order proprietary devices to fit the inlet grate or curb opening.
Construction	Construct the inlet protection device so that: • It will facilitate cleanout and disposal of trapped sediment and minimize interference with construction. • It will not cause excessive inconvenience or damage to adjacent areas or structures.
Stone Filtering	If using stone as the principal ponding/filtering medium, a range of stone sizes is offered; use Virginia Department of Transportation (VDOT) #3, #357, or #5 Coarse Aggregate. Attempt to obtain the greatest amount of filtering action possible using smaller-sized stones while not creating significant ponding problems. In all designs that use stone with a wire mesh support as a filtering mechanism, the stone can be completely wrapped with the wire mesh to improve stability and provide for easier cleaning.
Filter Fabric	Filter fabric may be added to devices that use “coarse aggregate” stone to significantly enhance sediment removal. Secure the filter fabric, meeting the physical requirements noted for “extra strength” provided in Table C-PCM-04-3, between the stones and the inlet (on wire mesh if it is present). As a result of the significant increase in filter efficiency provided by the fabric, a more comprehensive range of stone sizes (VDOT #1, #2, or #3 Coarse Aggregate) may be used with such a configuration. The larger stone will help keep larger sediment masses from clogging the cloth. Notably, significant ponding may occur at the inlet if filter cloth is used in this manner.

6.0 Construction Specifications

Inlet protection can be classified based on the type of inlet on which the protection is being installed. Inlet protection specifications and details are broken down below based on inlet types and whether the protection is to be self-constructed or a pre-manufactured proprietary device. Refer to the manufacturer’s standards, specifications, product materials, and installation details for all proprietary devices so that they are installed and maintained according to the manufacturer’s specifications.

Table C-SCM-04-2 Drop Inlet Self-Constructed Specifications	
Approach	**Notes on Proper Use**
Silt Fence Drop Inlet Sediment Filter	1. Ensure the silt fence conforms to the construction specifications for "extra strength" provided in Table C-PCM-04-3 and is cut from a continuous roll to avoid joints. 2. For stakes, use 2-inch x 4-inch wood (preferred) or equivalent metal at a minimum length of 3 feet. If metal stakes are used, install protective caps. 3. Space stakes evenly around the perimeter of the inlet a maximum of 3 feet apart and securely drive them into the ground approximately 18 inches deep (see Figure C-SCM-04-1). 4. To provide stability to the installation, frame with 2-inch x 4-inch wood strips around the crest of the overflow area at a maximum of 1.5 feet above the drop inlet crest. 5. Place the bottom 12 inches of the fabric in a trench (see Figure C-SCM-04-1) and backfill the trench with 12 inches of compacted soil. 6. Fasten filter fabric securely with staples or wire to the stakes and frame. Joints must be overlapped to the next stake. 7. It may be necessary to build a temporary dike on the downslope side of the structure to prevent bypass flow.  *Failed Silt Fence Inlet Protection (Drop Inlet)*
Gravel and Wire Mesh Drop Inlet Sediment Filter	1. Lay wire mesh over the drop inlet so that the wire extends at least 1 foot beyond each side of the inlet structure. Use wire mesh with 0.5-inch openings. If more than one mesh strip is necessary, the strips should be overlapped by a minimum of 1 foot. 2. Place coarse aggregate atop the wire mesh (see Figure C-SCM-04-2) at a depth of at least 12 inches over the entire inlet opening. Extend the stone beyond the inlet opening at least 18 inches on all sides. 3. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, pull the stones away from the inlet and clean the stone or replace the stone or both. Note: This filtering device has no overflow mechanism; therefore, ponding is likely especially if sediment is not removed regularly. Do not use this device where overflow may endanger an exposed fill slope. Consider the possible effects of ponding on traffic movement, nearby structures, working areas, adjacent property, and other situations.

Table C-SCM-04-2 Drop Inlet Self-Constructed Specifications	
Approach	**Notes on Proper Use**
Block and Gravel Drop Inlet Sediment Filter	1. Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting and holes running horizontally. Depending on design needs, the barrier's height can vary by stacking combinations of 4-inch, 8-inch, and 12-inch-wide blocks. Ensure the barrier of blocks is at least 12 inches high and no greater than 24 inches high. 2. Place wire mesh over the outside vertical face (webbing) of the concrete blocks to prevent the stones from washing through the holes in the blocks. Use wire mesh with 0.5-inch openings. 3. Pile the stones against the wire to the top of the block barrier (see Figure C-SCM-04-3). 4. If the stone filter becomes clogged with sediment so that it no longer performs its function adequately, pull the stones away from the blocks and clean and replace the stones.
Excavated Drop Inlet Sediment Trap	1. Size the excavated trap to provide a minimum storage capacity of 134 cubic yards per acre of drainage area. Construct a trap to be no less than 1 foot and no more than 2 feet deep, measured from the top of the inlet structure. Construct side slopes to be steeper than 2H:1V (see Figure C-SCM-04-4). 2. The slope of the basin may vary to fit the drainage area and terrain. Observe to check trap efficiency and modify as necessary to ensure satisfactory sediment trapping. Where an inlet is located to receive concentrated flows, such as in a highway median, it is recommended that the basin have a rectangular shape in a 2H:1V ratio, with the length oriented in the direction of the flow. 3. Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Deposit removed sediment in a suitable area so that it will not erode.
Trench Drain Inlet Filter	1. For use where existing or proposed slot or trench drain storm inlets will be operational before project completion, and the corresponding drainage area of less than 0.5 acres is permanently stabilized. 2. Place filter fabric underneath the grate system with a minimum of 4 inches of filter fabric extended past the outer edge of the grate. 3. Check for tears and accumulated sediment and perform maintenance or replace fabric as needed.

Table C-SCM-04-2 Drop Inlet Self-Constructed Specifications	
Approach	**Notes on Proper Use**
Yard Drain Inlet Filter	1. For use where existing or proposed yard drain inlets 15 inches in diameter or less will be operational before project completion and permanently stabilize the corresponding drainage area of less than 0.5 acre. 2. Place filter fabric underneath the grate system with a minimum of 4 inches of filter fabric extended past the outer edge of the grate. 3. Remove accumulated sediment and debris from the surface and vicinity of the unit to prevent ponding. 4. Replace the filter fabric immediately if any rips/tears are noticed.

Table C-SCM-04-3 Curb Inlet Self-Constructed Specifications	
Approach	**Notes on Proper Use**
Gravel Curb Inlet Sediment Filter	1. Place wire mesh with 0.5-inch openings over the curb inlet opening so that at least 12 inches of wire extends beyond the inlet opening on both sides, and at least 12 inches of wire extends across the concrete gutter from the inlet opening, as depicted on Figure C-SCM-04-5. 2. Pile the stone against the wire to anchor it against the gutter and inlet opening, cover the inlet opening completely, and extend a minimum of 18 inches beyond the inlet opening on both sides. 3. If the stone filter becomes clogged with sediment so it no longer performs its function adequately, pull the stone away from the block and clean and replace the stone filter.  *Failed Inlet Protection (Curb Inlet)*
Curb Inlet Protection with Wooden Weir	1. Attach a continuous piece of wire mesh (30-inch minimum width x inlet throat length plus 4 feet) to the 2-inch x 4-inch wooden weir (with a total length of throat length plus 2 feet) as shown in Figure C-SCM-04-6. Ensure that the wood is “construction grade” lumber. 2. Place a piece of approved “extra-strength” filter cloth of the same dimensions as the wire mesh over the wire mesh and securely attach it to the 2-inch x 4-inch weir. 3. Securely nail the 2-inch x 4-inch weir to the 9-inch-long vertical spacers between the weir and inlet face at a maximum 6-foot spacing. 4. Place the assembly against the inlet throat, and nail 2-foot (minimum) 2-inch by 4- inch board lengths to the top of the weir at spacer locations. Extend these 2-inch x 4- inch anchors across the inlet tops and hold in place by sandbags or alternate weight. 5. Place the assembly so that the end spacers are a minimum of 1 foot beyond both ends of the throat opening. 6. Form the wire mesh and filter cloth to the concrete gutter and against the face of the curb on both sides of the inlet. Place coarse aggregate atop the wire mesh and filter fabric to prevent water from entering the inlet under or around the filter cloth. 7. Inspect this type of protection frequently and replace the filter cloth and stone when it becomes clogged with sediment. 8. Ensure that storm flow does not bypass the inlet by installing temporary earth or sandbag dikes directing flow into the inlet.

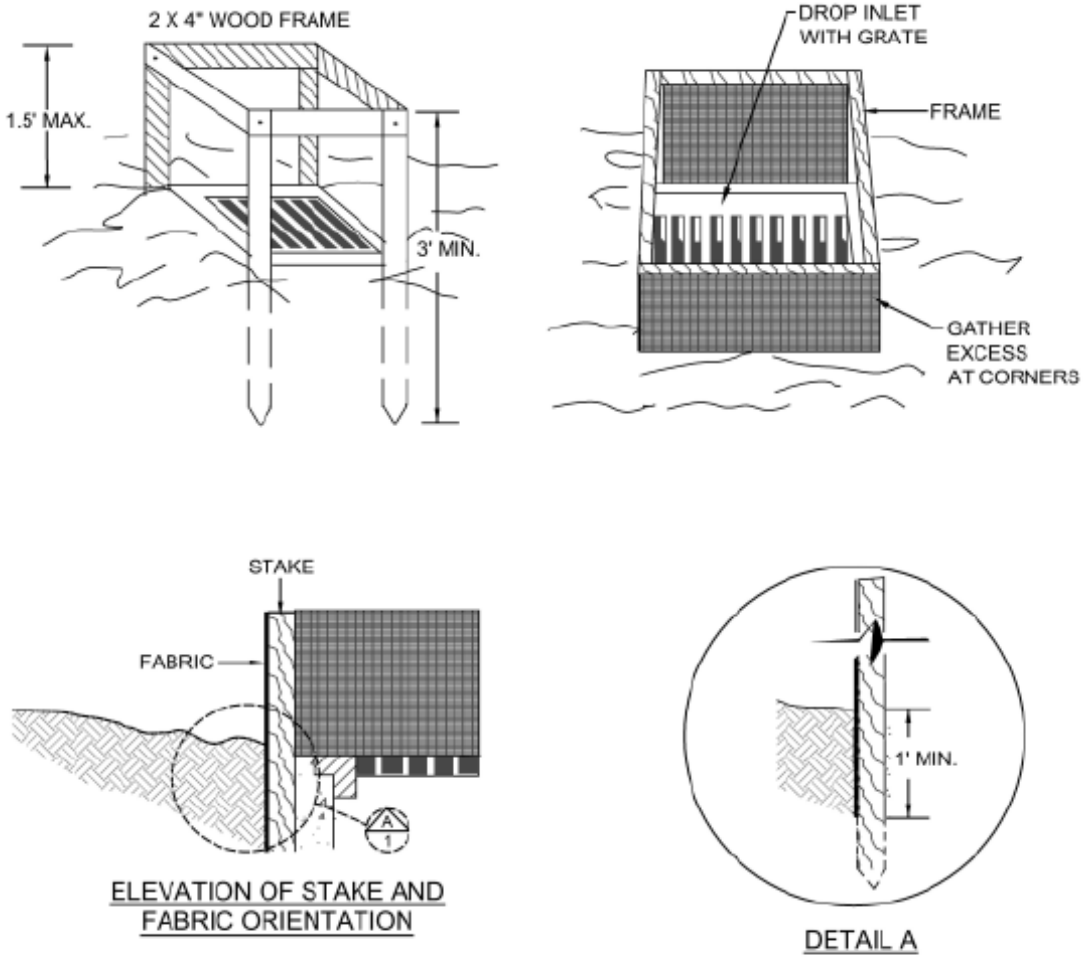
Table C-SCM-04-3 Curb Inlet Self-Constructed Specifications	
Approach	**Notes on Proper Use**
Block and Gravel Curb Inlet Sediment Filter	1. Place two concrete blocks on their sides abutting the curb at either side of the inlet opening. 2. Cut a 2-inch by 4-inch stud and place it through the outer holes of each spacer block to help keep the front blocks in place. 3. Place concrete blocks on their sides across the front of the inlet and abutting the spacer blocks as depicted in Figure C-SCM-04-7. 4. Place wire mesh over the outside vertical face (webbing) of the concrete blocks to prevent the stone from washing through the holes in the blocks. Use wire mesh with 0.5-inch openings. 5. Pile VDOT #3, #357, or #5 coarse aggregate against the wire to the barrier's top, as shown in Figure C-SCM-04-7. 6. If the stone filter becomes clogged with sediment so that it no longer performs its function adequately, pull the stone away from the blocks and clean or replace the stone filter.

7.0 Operations and Maintenance Considerations

Routine inspection and maintenance are critical to ensuring the adequate performance of inlet protection. Include the following activities as part of any maintenance program (Minnesota Pollution Control Agency 2023):

- Inspect all inlet protection devices at least twice weekly (72 hours or more between each inspection) and after every significant rainfall event (0.25 inch or more).
- During extended rainfall events, inspect inlet protection devices at least once every 24 hours.
- Replace clogged aggregate or filter fabric immediately.
- Look for damage or tears to fabric caused by large flows.
- Inspect downstream inlets, pipes, and other infrastructure after severe storms to check for bypassed material.
- Remove sediment from temporary inlet protection methods when sediment reaches depths of 2 or 3 inches. More frequent sediment removal is required from paved areas such as streets or parking lots.
- Remove all inlet protection devices within 30 days after the site is stabilized, or when the inlet protection is no longer needed.
- Bring the disturbed area to final grade and appropriately stabilize all bare areas around the inlet with vegetation.
- Clean storm drainage system of sediment and debris before final inspection.
- In karst areas, inspect excavated drop inlet sediment traps regularly and after each precipitation event for subsidence. Subsidence is a criterion of failure. As such, mitigate subsidence immediately using the appropriate engineering practice.

Figure C-SCM-04-1 Silt Fence Drop Inlet Protection

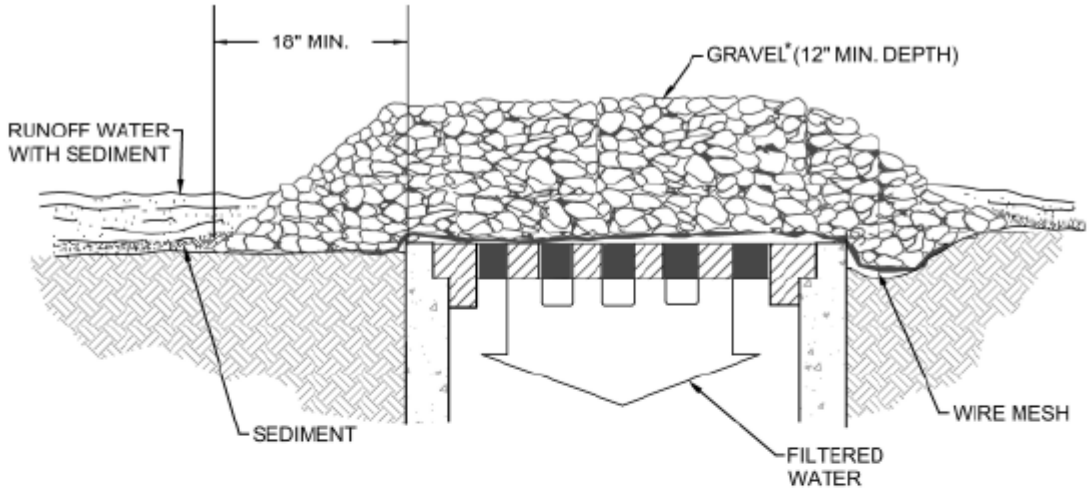


SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE THE INLET DRAINS A RELATIVELY FLAT AREA (SLOPE NO GREATER THAN 5%) WHERE THE INLET SHEET OR OVERLAND FLOWS (NOT EXCEEDING 1 C.F.S.) ARE TYPICAL. THE METHOD SHALL NOT APPLY TO INLETS RECEIVING CONCENTRATED FLOWS, SUCH AS APPLY TO INLETS RECEIVING CONCENTRATED FLOWS, SUCH AS IN STREET OR HIGHWAY MEDIANS.

Source: North Carolina Sediment Control Division et al. 2013

Figure C-SCM-04-2 Gravel and Wire Mesh Drop Inlet Sediment Filter



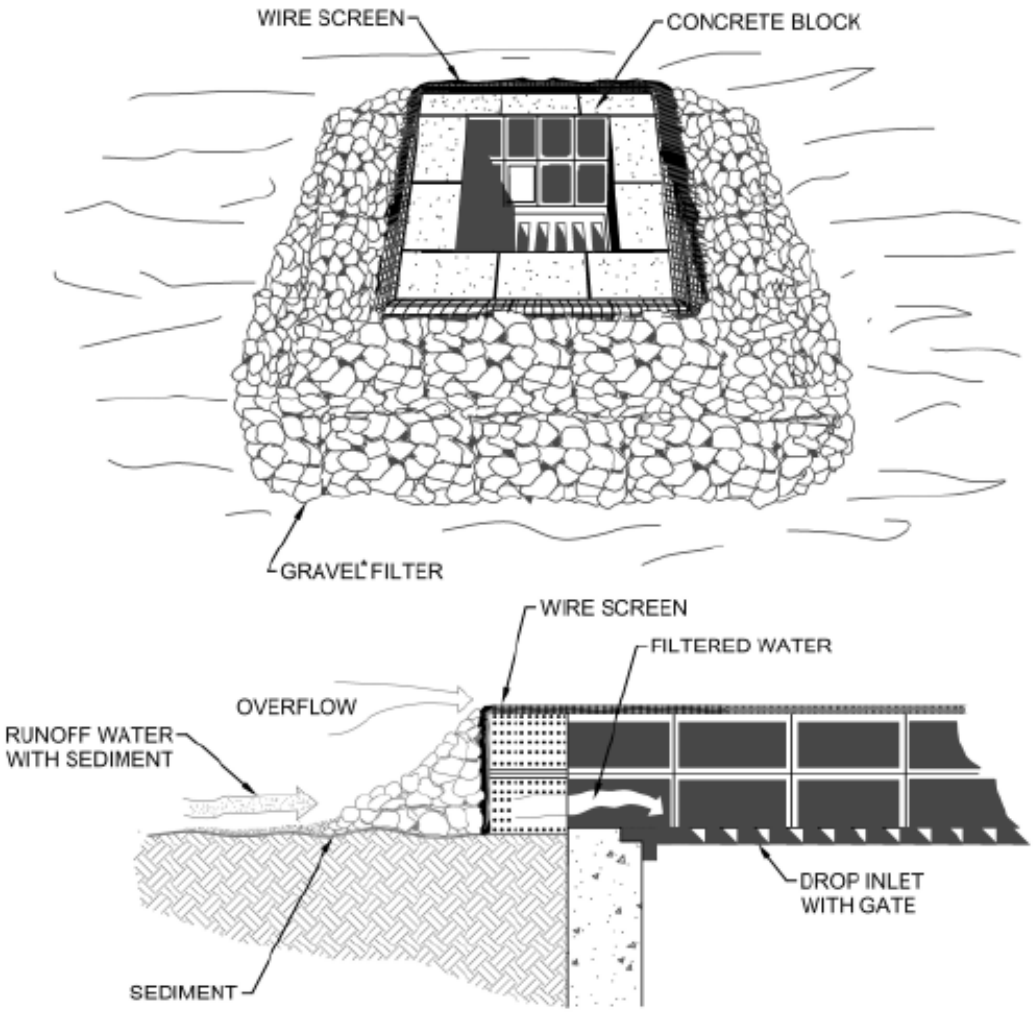
SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY CONCENTRATED FLOWS ARE EXPECTED BUT NOT WHERE PONDING AROUND THE STRUCTURE MIGHT CAUSE EXCESSIVE INCONVENIENCE OR DAMAGE TO ADJACENT STRUCTURES AND UNPROTECTED AREAS.

* GRAVEL SHALL BE VDOT #3, #357 OR #5 COARSE AGGREGATE.

Source: VA DSWC

Figure C-SCM-04-3 Block and Gravel Drop Inlet Sediment Filter



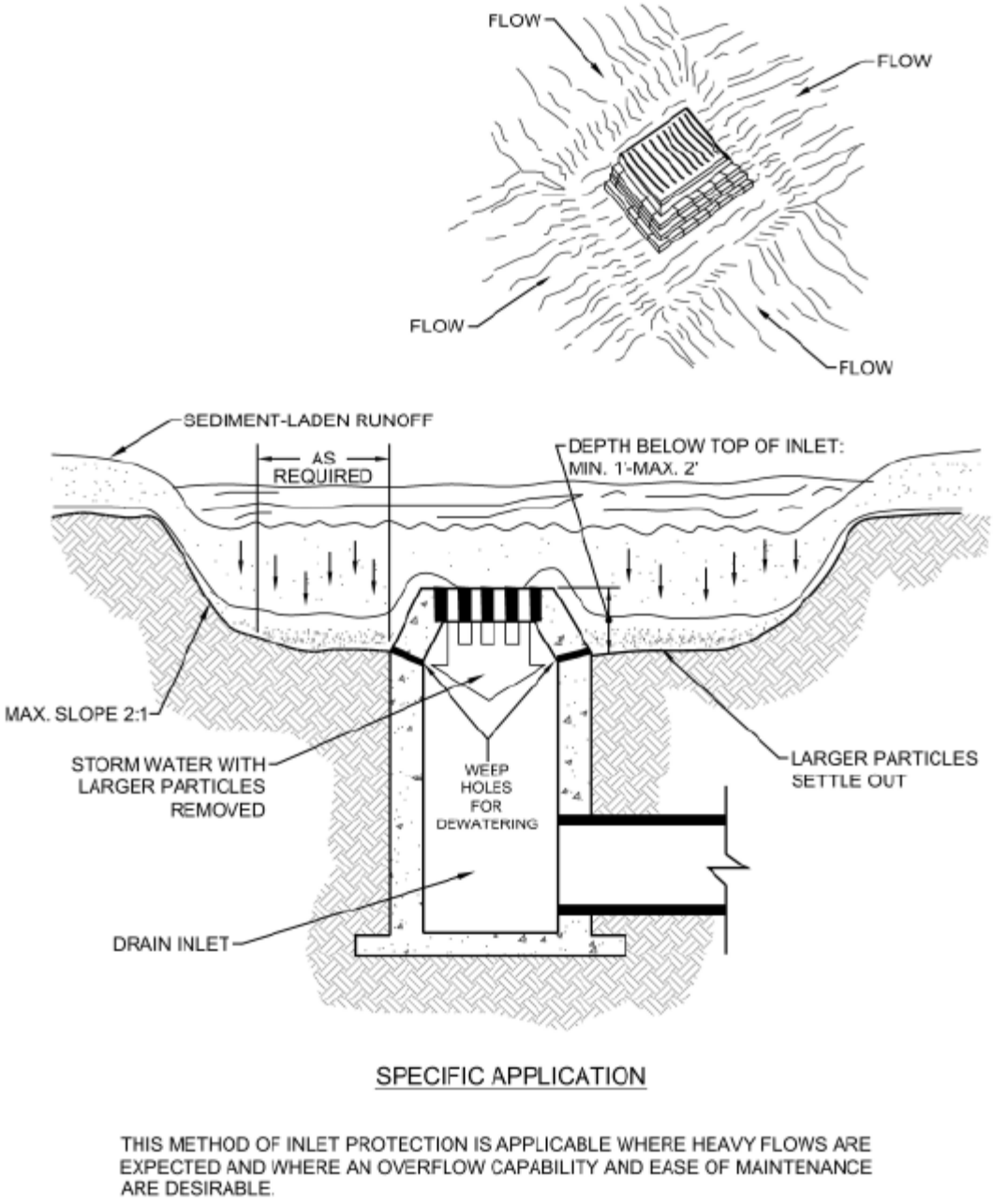
SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY FLOWS ARE EXPECTED AND WHERE AN OVERFLOW CAPACITY IS NECESSARY TO PREVENT EXCESSIVE PONDING AROUND THE STRUCTURE.

* GRAVEL SHALL BE VDOT #3, #357 OR #5 COARSE AGGREGATE.

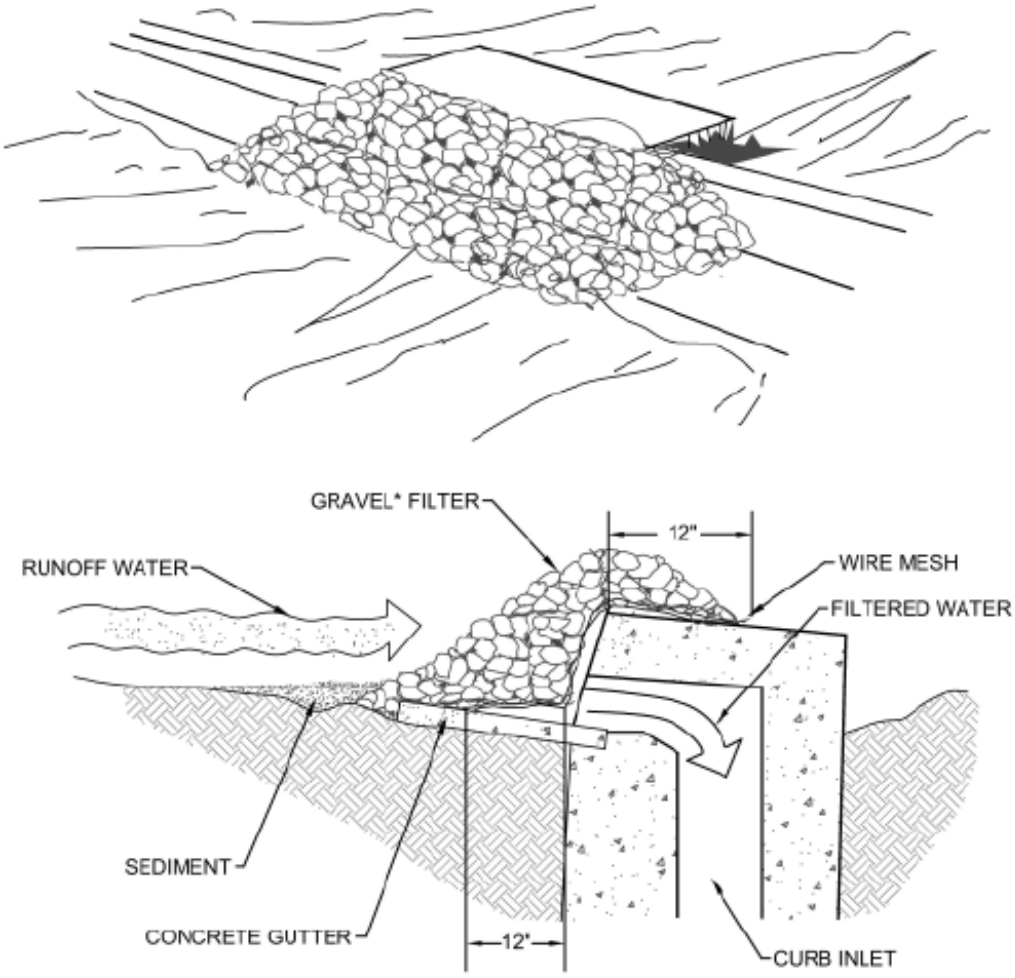
Source: VA DSWC

Figure C-SCM-04-4 Excavated Drop Inlet Sediment Trap



Source: Peterson et al. 1975

Figure C-SCM-04-5 Gravel Curb Inlet Sediment Filter



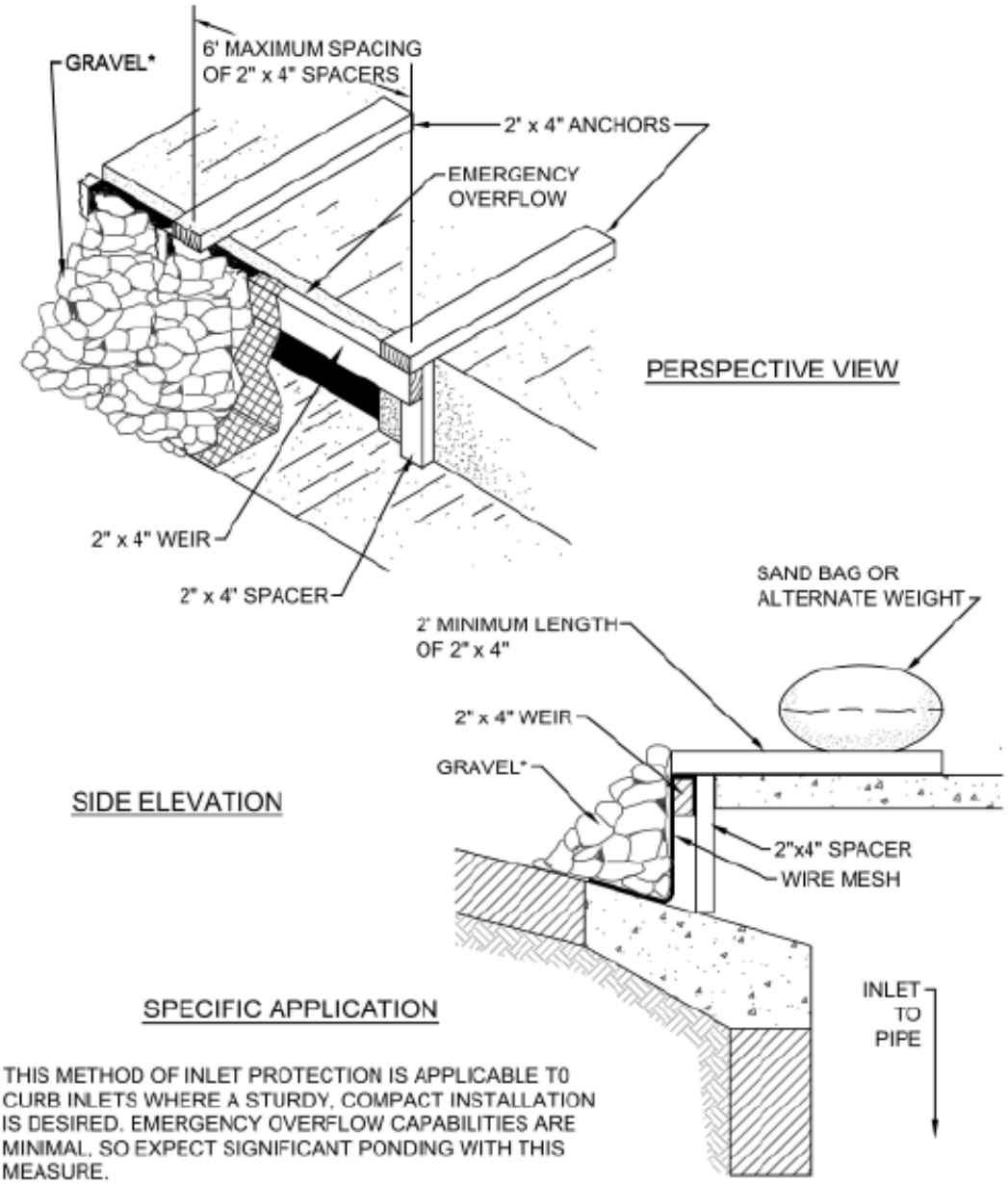
SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE AT CURB INLETS WHERE PONDING IN FRONT OF THE STRUCTURE IS NOT LIKELY TO CAUSE INCONVENIENCE OR DAMAGE TO ADJACENT STRUCTURES AND UNPROTECTED AREAS.

* GRAVEL SHALL BE VDOT #3, #357 OR 5 COARSE AGGREGATE.

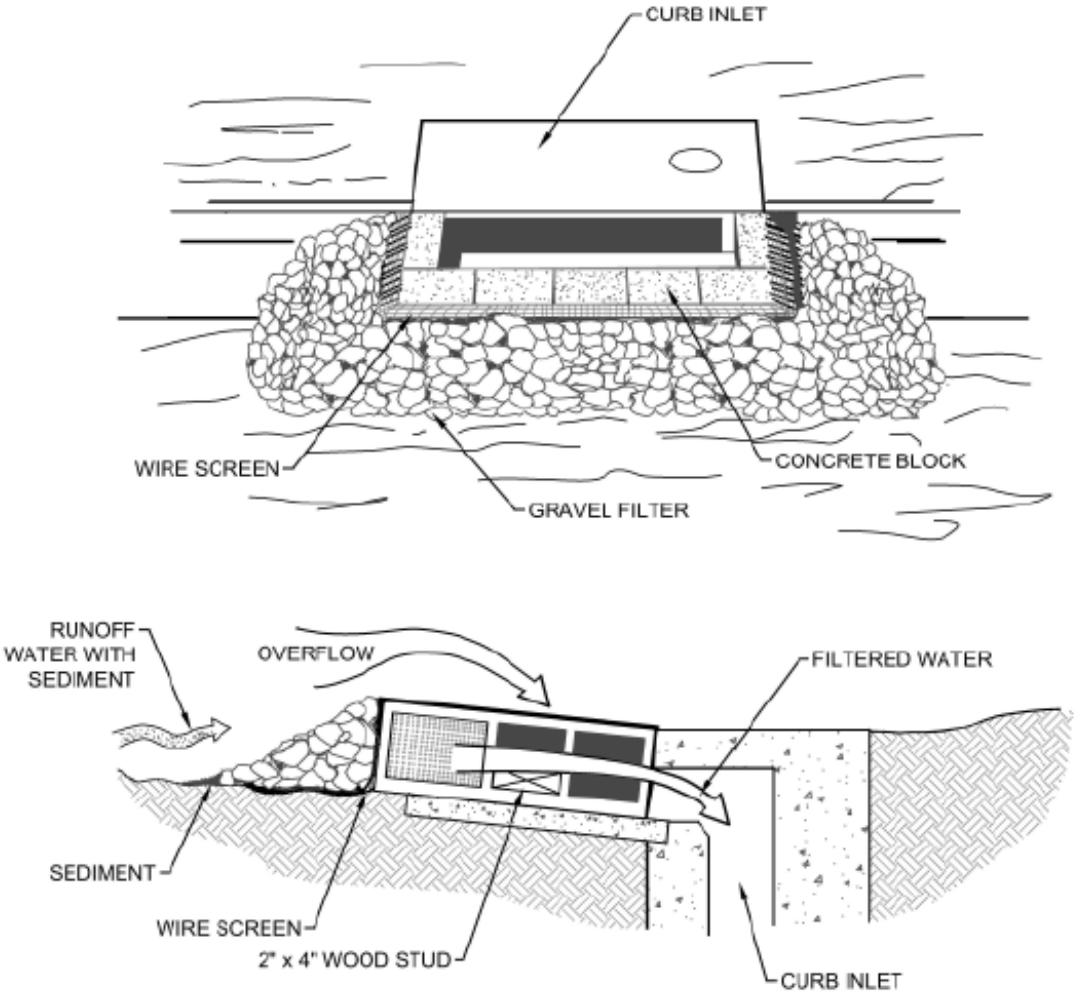
Source: VA DSWC

Figure C-SCM-04-6 Curb Inlet Protection with 2-Inch x 4-Inch Wooden Weir



Source: USDA NRCS

Figure C-SCM-04-7 Block and Gravel Curb Inlet Sediment Filter



Source: VA DSWC

8.0 References

City of Knoxville. 2018. Best Management Practices (BMP) Manual. January.

Minnesota Pollution Control Agency. 2023. Minnesota Stormwater Manual – Sediment Control Practices – Storm Drain Inlet Protection. Located at: https://stormwater.pca.state.mn.us/index.php/Sediment_control_practices_-_Storm_drain_inlet_protection. February 15.

Peterson, A., Reznik, R., Hedin, S., Hendges, M. and D. Dunlap. 1975. Guidebook of Best Management Practices for Michigan Watersheds. Reprinted October 1998.

Virginia Department of Environmental Quality (VDEQ). 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SCM-05 Culvert Inlet Protection

1.0 Definition

Culvert inlet protection is a sediment filter located at the inlets of culverts.

– CAD and PDF files for C-SCM-05 Culvert Inlet Protection

2.0 Purpose and Applicability of Best Management Practice

Culvert inlet protection prevents sediment from entering, accumulating in, and being transported by a culvert and associated drainage system before the permanent stabilization of a disturbed project area.

Culvert inlet protection also controls erosion at culvert inlets during the phase of a project in which elevation and drainage patterns change, causing original control measures to be ineffective or in need of removal.

Use culvert inlet protection where a culvert is to be made operational before permanent stabilization of the disturbed drainage area or to control erosion/remove sediment from water before flowing into an existing culvert.

Different types of structures apply to different conditions (see Figure C-SCM-05-1 and Figure C-SCM-05-2).

3.0 Planning and Considerations

Conduct pre-construction subsurface investigation of culvert inlets to identify any subsurface voids, conduits, or openings in the bedrock.

When construction on a project reaches a stage in which upstream areas are stabilized culverts, other storm sewer appurtenances are installed and many areas are brought to a desired grade, the erosion control measures used in the early stages normally need to be modified or may need to be removed altogether. At that time, there is a need to protect the points at which runoff will leave the area via culverts and drop or curb inlets from sedimentation.

Culverts made operational before stabilization of the associated drainage areas can convey large amounts of sediment to natural drainageways. In case of extreme sediment loading, the pipe or pipe system itself may clog and lose a major portion of its capacity. Use one of the methods noted in this section to prevent sediment from entering the culvert to avoid these problems.

Construct the culvert inlet protection so that:

1. It will facilitate cleanout and disposal of trapped sediment and minimize interference with construction.
2. Any resultant ponding of stormwater will not cause excessive inconvenience or damage to adjacent areas or structures.

See Figure C-SCM-05-1 and Figure C-SCM-05-2 for graphic depictions of inlet protection.

4.0 Stormwater Performance Summary

MS-10: INLET PROTECTION – All storm sewer inlets made operable during construction will be protected so that sediment-laden water cannot enter the conveyance system without first being filtered or otherwise treated to remove sediment.

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

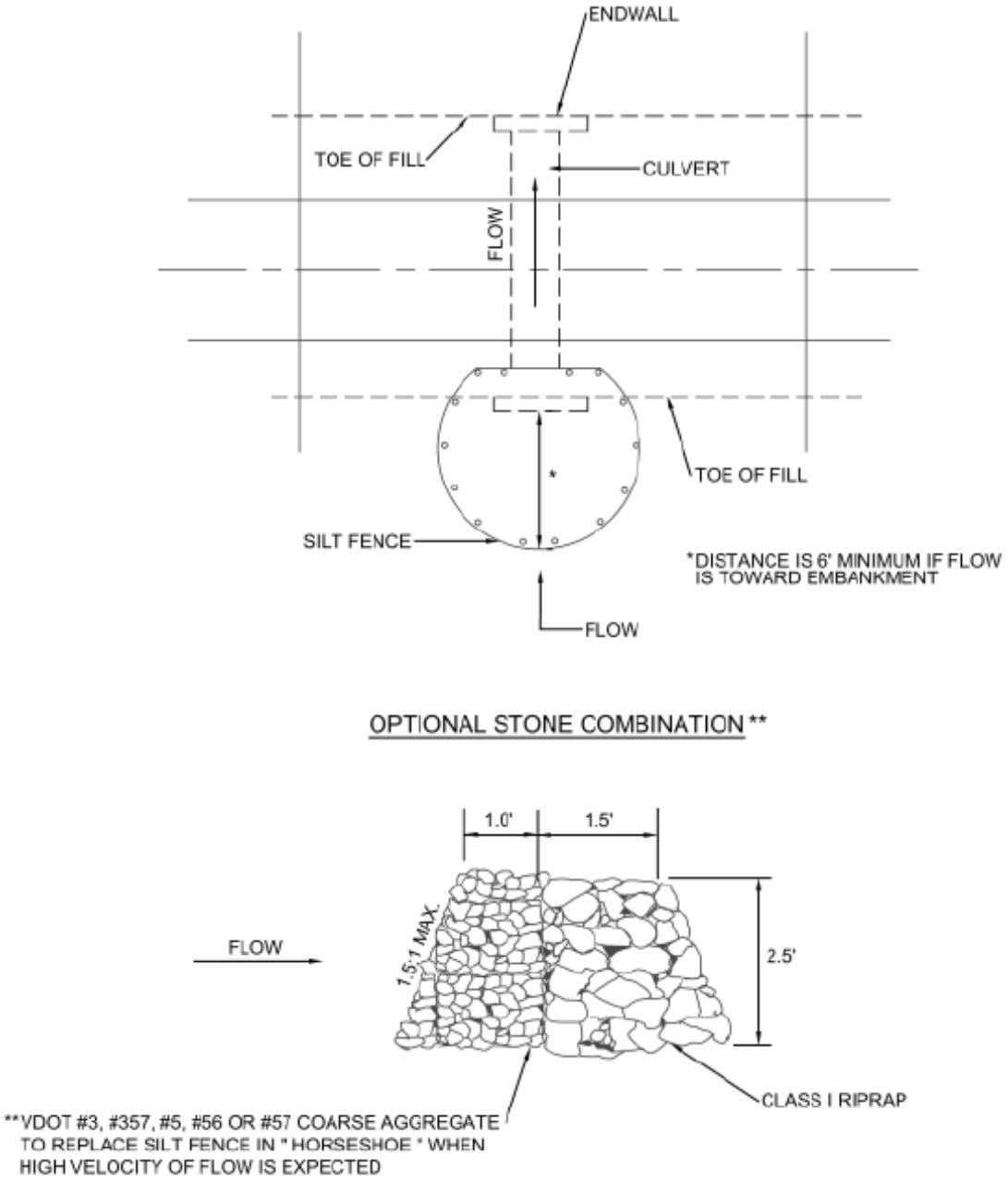
5.1 Silt Fence Culvert Inlet Protection

1. No formal design is required; however, design areas tributary to silt fence culvert inlet protection to comply with slope length and gradient requirements specified in Silt Fence (C-PCM-04).
2. Silt fence culvert inlet protection has an expected maximum usable life of 3 months.
3. Design the maximum area draining to this practice not to exceed 1 acre.

5.2 Culvert Inlet Sediment Trap

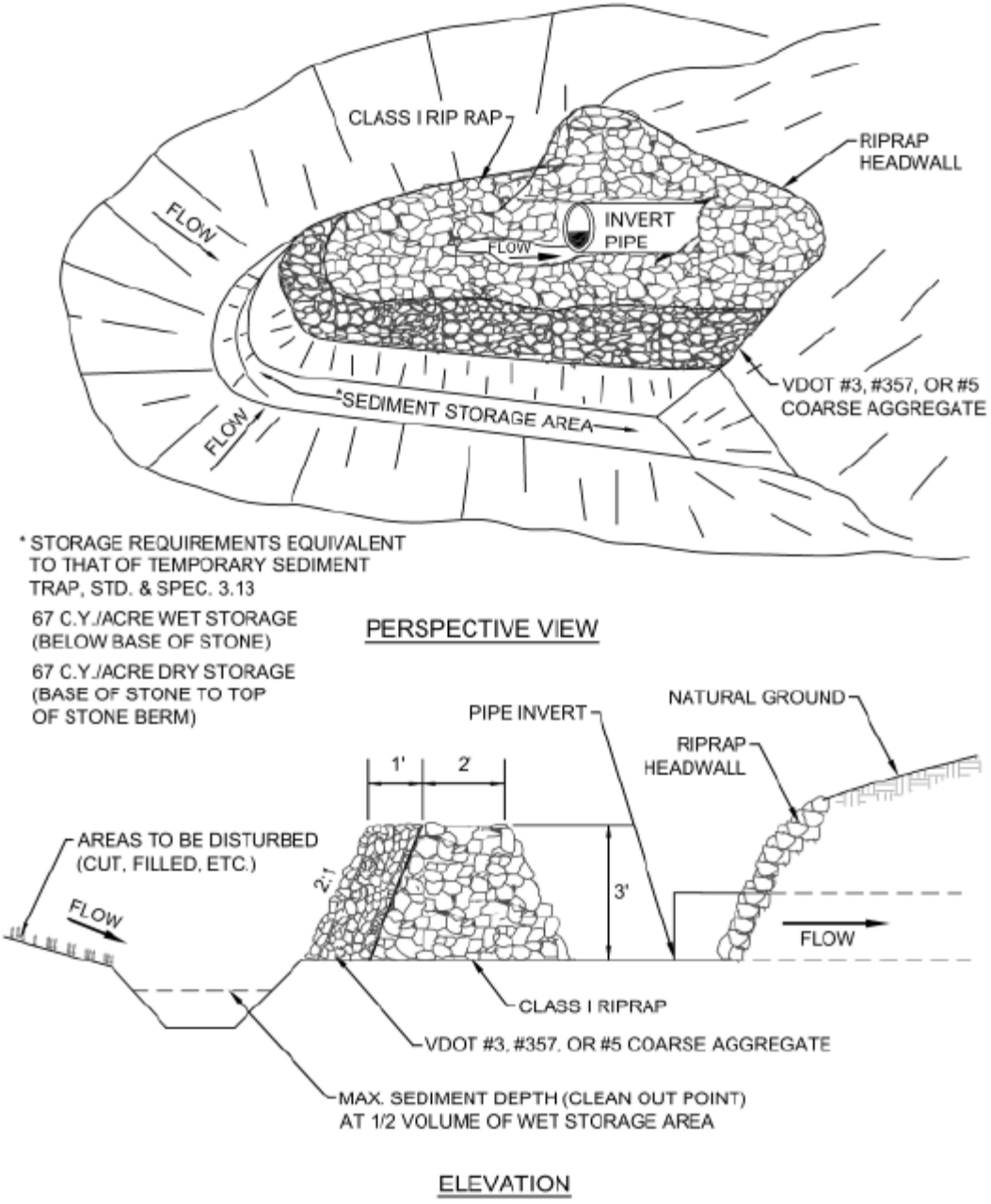
1. Align runoff storage requirements with information outlined under Temporary Sediment Trap (C-SCM-11).
2. Culvert inlet sediment traps have a maximum expected useful life of 18 months.
3. Design the maximum area draining to the trap not to exceed 3 acres.
4. Design the maximum height of the stone berm to be 3 feet.
5. Design the side slopes of the stone berm section not to exceed 2H:1V.
6. Design the side slopes of excavated areas to be no steeper than 1H:1V. Design the maximum depth of excavation within the wet storage area to be 4 feet to facilitate cleanout and for site safety considerations.
7. Design the stone berm to be a combination of coarse aggregate and riprap, with the smaller stone being Virginia Department of Transportation (VDOT) #3, #357, or #5 Coarse Aggregate (smaller stone sizes will enhance filter efficiency) and riprap being Class I. Design the top width of the coarse aggregate to be 1 foot and the top width of the riprap to be 2 feet.
8. Place the filter fabric that meets the physical requirements noted in Riprap (C-ECM-13) at the stone-soil interface to act as a separator.

Figure C-SCM-05-1 Silt Fence Culvert Inlet Protection



Source: Adapted from VDOT Standard Sheets and Va. DSWC

Figure C-SCM-05-2 Culvert Inlet Sediment Trap



Source: North Carolina Sediment Control Commission et al. 2013

6.0 Construction Specifications

6.1 Silt Fence Culvert Inlet Protection



1. Construct the silt fence specifications to comply with Silt Fence (C-PCM-04).
2. Construct the height of the silt fence (in front of the culvert opening) to be a minimum of 16 inches and not to exceed 34 inches.
3. Use extra-strength filter fabric with a maximum stake spacing of 3 feet to construct the measure.
4. Place the silt fence approximately 6 feet from the culvert in the direction of incoming flow, creating a circular shape as shown in Figure C-SCM-05-1. The silt fence should extend above and around the top of the culvert.
5. If the silt fence cannot be installed properly, or the flow or velocity of flow to the culvert protection is excessive and may breach the structure, use the stone combination noted in Figure C-SCM-05-1.
6. Compost filter sock or straw wattles may be used in lieu of a silt fence. Use one row of 18-inch-diameter compost filter sock or smaller compost filter sock or straw wattles stacked to form a minimum height of 16 inches. Stake the stacked compost filter sock or straw wattles in accordance with the Compost Filter Sock Outlet in the Temporary Sediment Trap (C-SCM-11).

6.2 Culvert Inlet Sediment Trap



1. The geometry of the de (sign will be a “horseshoe” shape around the culvert inlet (see Figure C-SCM-05-2).
2. The toe of the riprap (composing the sediment filter dam) should be no closer than 24 inches from the culvert opening to provide an acceptable emergency outlet for flows from larger storm events.
3. All other Construction Specifications documented within the Temporary Sediment Trap (C-SCM-11) also apply to this practice.
4. The proper installation of the culvert inlet sediment trap is a viable substitute for the installation of the temporary sediment trap.

7.0 Operations and Maintenance Considerations

Inspect the structure after each rain event and make repairs as needed.

Replace or clean aggregate when inspection reveals that clogged voids are causing ponding problems that interfere with on-site construction.

Remove sediment and restore the impoundment to its original dimensions when sediment has accumulated to one half the design depth. The deposit removed sediment in a suitable area so that it would not erode and cause further sedimentation problems. In karst areas, sinkholes may form in the vicinity of inlet protection and capture site runoff into groundwater. Inspect inlets for subsidence features and repair any subsidence features identified using the appropriate sinkhole repair BMP.

Remove temporary structures when they have served their useful purpose, but not before the upslope area has been permanently stabilized.

8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

Virginia Department of Environmental Quality (VDEQ). 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SCM-06 Wood Chip Filter Berm

1.0 Definition

A wood chip filter berm is a construction best management practice (BMP) constructed of mounded wood chips placed perpendicular to sheet flow to control erosion by reducing slope length in disturbed areas and retaining sediment. Wood chip berms may be constructed from processed woody material from initial site clearing operations (PA DEP 2012).

– CAD and PDF for C-SCM-06 Wood Chip Filter Berm



Source: MPCA 2023

2.0 Purpose and Applicability of Best Management Practice

Use wood chip filter berms on wooded or rocky slopes where staking and trenching of other BMPs is difficult or impossible.

Wood chip filter berms do not require trenching and disturb less soil during installation than silt fence or straw bale barriers.

3.0 Planning and Considerations

Large obstructions (e.g., tree limbs, boulders) should be removed before placement of the wood chips. Once the tributary drainage area is permanently stabilized, the wood chip filter berm may be leveled or left in place.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment will be constructed as a first step in any land-disturbing activity and will be made functional before upslope land disturbance.

Erosion Control Efficiency: LOW

Sediment Removal Efficiency: MODERATE

5.0 Design Criteria

Do not place Wood chip filter berms in areas of concentrated flow. They should be aligned parallel to existing contours and below all disturbed areas.

Typically, the use of wood chip filter berms does not include use within 50 feet of receiving surface waters.

The maximum slope length above a wood chip filter berm should not exceed those identified in Table C-SCM-06-1.

Table C-SCM-06-1 Maximum Slope Length for Wood Chip Filter Berms

Slope - Percent	Maximum Slope Length (ft) Above Barrier
2 (or less)	150
5	100
10	50
15	35
20	25
25	20
30	15
35	15
40	15
45	10
50	10
>50	Not Permitted

Source: PADEP 2012

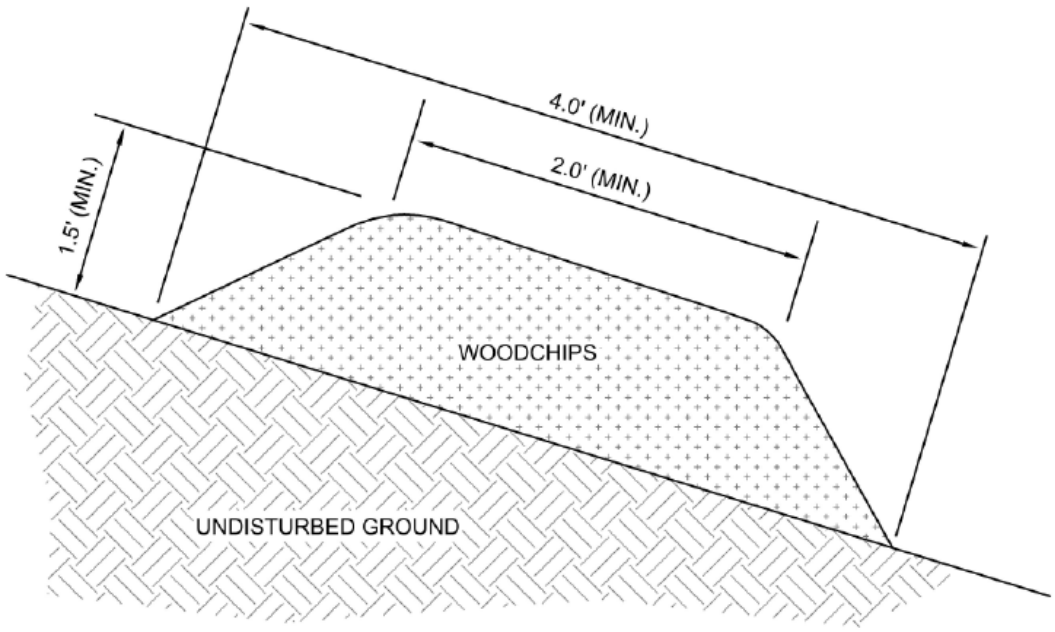
6.0 Construction Specifications

Before placement of the berm, obstructions such as tree limbs and large rocks will be removed.

Wood chip filter berms will be placed at the existing level grade. Both ends of the berm will be extended at least 8 feet upslope to 45 degrees to the main berm alignment.

Wood chip berms will not be located in areas of concentrated flow or used to construct sediment traps or other impoundments.

Figure C-SCM-06-1 Wood Chip Filter Berm Minimum Dimensions



Source: MN Pollution Control Agency 2013

7.0 Operations and Maintenance Considerations

Berms must be inspected weekly and after each runoff event.

Sediment must be removed when accumulations reach half the height of the berm.

Damaged or deteriorated portions of the berm must be replaced immediately upon inspection.

Berms may be leveled when the tributary area has been permanently stabilized or left in place.

8.0 References

Minnesota Pollution Control Agency. 2023. Minnesota Stormwater Manual – Sediment Control Practices – Stabilized Earth/Soil Berm. February 15. Located at: https://stormwater.pca.state.mn.us/index.php?title=Sediment_control_practices_-_Stabilized_earth/soil_berm

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

C-SCM-07 Rock Check Dams

1.0 Definition

Rock check dams are small temporary stone dams constructed across a swale, channel, or drainage ditch.

– CAD and PDF files for C-SCM-07 Rock Check Dam

2.0 Purpose and Applicability of Best Management Practice

Rock check dams minimize the erosion rate of a swale, channel, or ditch by reducing the velocity of concentrated stormwater flows. This practice also traps sediment generated from adjacent areas or the ditch, mainly by ponding the stormwater runoff. Field experience has shown that they perform more effectively than silt fences or straw bales in the effort to stabilize “wet weather” ditches.



A Rock Check Dam Under Dry Conditions
Source: Earth Tek, Inc. 2014.

This sing a combination of stone sizes, is limited to use in small open channels. Do not use rock check dams in a live stream, as the objective is to protect the live watercourse. Some specific applications include:

1. Temporary ditches or swales that, because of their short length of service, cannot receive a non-erodible lining but still need protection to reduce erosion;
2. Either temporary ditches or swales that need protection during the establishment of grass linings; and
3. As an aid in the sediment trapping strategy for a construction site. This practice is not a substitute for major perimeter trapping measures such as a Temporary Sediment Trap (C-SCM-11) or a Temporary Sediment Basin (C-SCM-12).

3.0 Planning and Considerations

It is usually better to establish a protective vegetative lining before flow is confined or to install a structural channel lining than to install check dams; however, where this is not feasible, check dams are useful.

Check dams installed in grass-lined channels may kill the vegetative lining if submergence after rain events is too long and/or silting is excessive.

If check dams are used in grass-lined channels that will be mowed, take care to remove all the stone when the dam is removed including any stone that has washed downstream.

4.0 Stormwater Performance Summary

MS-11: OUTLET PROTECTION – Before any newly constructed stormwater conveyance channel can be made operational, adequate outlet protection and any required temporary or permanent channel lining will be installed in both the conveyance channel and receiving channel.

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: MODERATE

5.0 Design Criteria

There is no formal design required to construct stone check dams; however, there are some general considerations required when proposing the use of check dams for sediment trapping and flow velocity reduction practices.

Table C-SCM-07-1 Design Criteria for Rock Check Dams	
Approach	**Notes on Proper Use**
Drainage Area	Ensure the drainage area of the channel or swale being protected does not exceed: • 2 acres when Virginia Department of Transportation (VDOT) #1 Coarse Aggregate is used alone. • 10 acres when a combination of Class I riprap (added for stability) and VDOT #1 Coarse Aggregate is used. Refer to Figure C-SCM-07-1 for orientation of stone and a cross-sectional view of the measure. Extend the stone to the tops of channel banks.
Spacing	Design the maximum spacing between the dams so that the toe of the upstream dam is at the same elevation as the top of the downstream dam (see Figure C-SCM-07-2). Adjust and compute spacing based on the proposed slope of the channel/swale.
Height/ Weir	Ensure the maximum height of the check dam is 2 feet at the center of the channel/ swale. Design the center of the check dam to be a minimum of 6 inches (0.5 foot) lower than the outer edges at natural ground, providing a weir for open flow over the dam. Compute the depth of flow at the weir for the 2-year, 24-hour storm.
Side Slopes	In the direction of the flow, install the side slopes of the rocks in the rock check dam to be a maximum of 2H:1V (see Figure C-SCM-07-1) to prevent scouring of the material and maximize the efficiency of the control measure.
Filter Fabric	A filter fabric may be used as a separator between the graded stone and the soil base and abutments. The filter fabric will prevent the migration of soil particles from the subgrade into the graded stone. Set the filter fabric into the subgrade soils. Place the filter fabric immediately adjacent to the subgrade without any voids and extend 3 feet beyond the downstream toe of the dam to prevent scour. Refer to Riprap (C-ECM-13) for required physical properties of the filter fabric.

6.0 Construction Specifications

1. For added stability, the base of the check dam can be keyed into the soil approximately 6 inches.
2. Place the stone according to the configuration shown on Figure C-SCM-07-1. Hand or mechanical placement is necessary to achieve complete coverage of the channel or swale and to ensure that the center of the dam is lower than the edges.
3. Alternative proprietary solutions may be used in place of the non-proprietary design included in this Chapter. Refer to the Virginia Department of Transportation List 58, Standard EC-16 Temporary Check Dam list of approved materials.

7.0 Operations and Maintenance Considerations

Inspect the check dam measure every 7 calendar days and within 24 hours after each rainfall event.

Inspect check dams for sediment accumulation after each runoff-producing storm event. Remove sediment when it reaches one half of the original height of the measure.

After removal of sediment, inspect the base of the check Improperly Installed or Maintained Rock Check Dam Failing Under Wet Conditions dam for end run breakthroughs, scouring, end runs, and any removal of rock from higher-velocity flow.

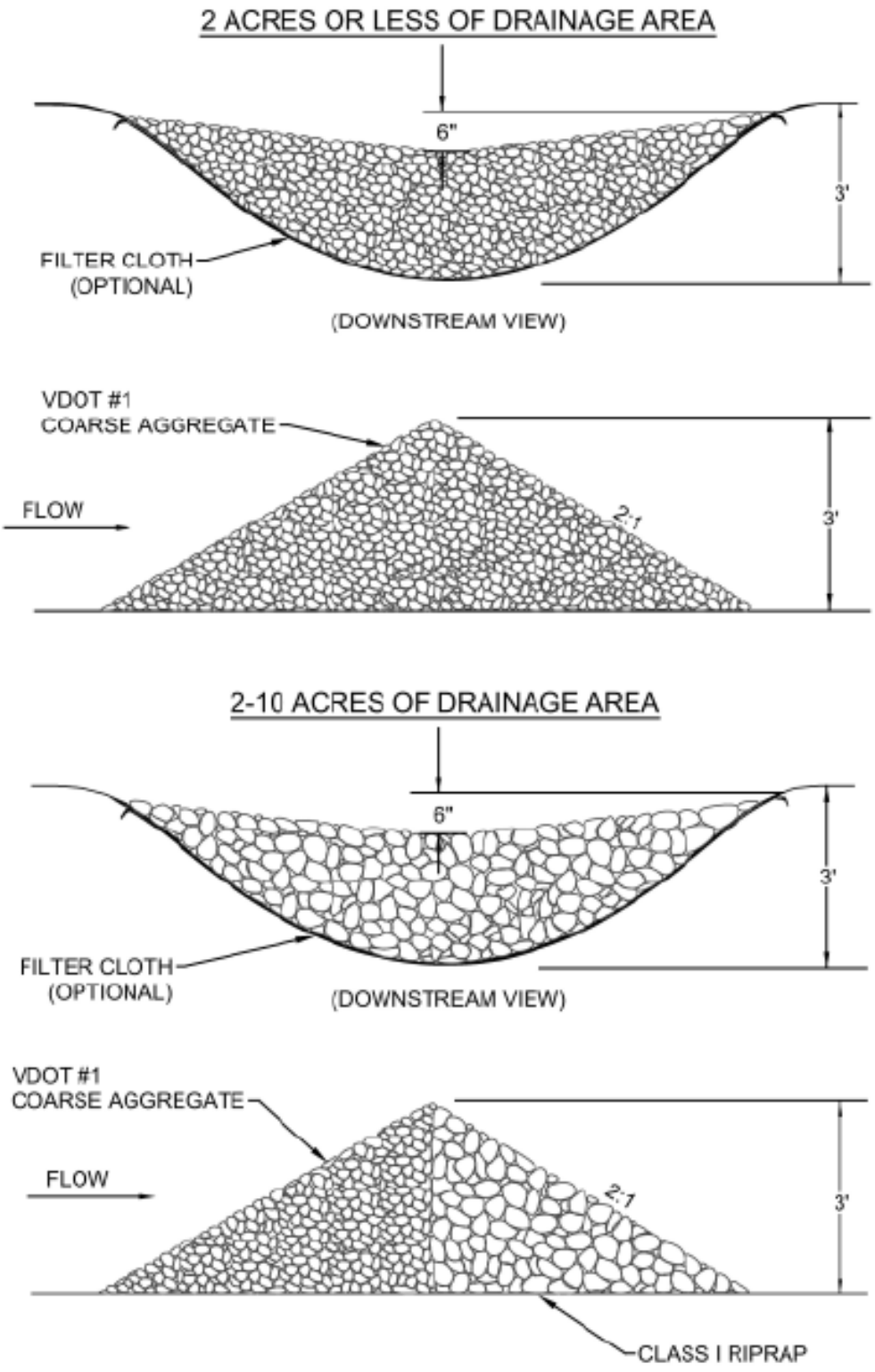
Immediately address any damages to the integrity of the check dam and review and modify the design as necessary to prevent future damages. Remove accumulated trash or other debris that may restrict or divert flow over the center of the check dam.



Improperly Installed or Maintained Rock Check Dam Failing Under Wet Conditions

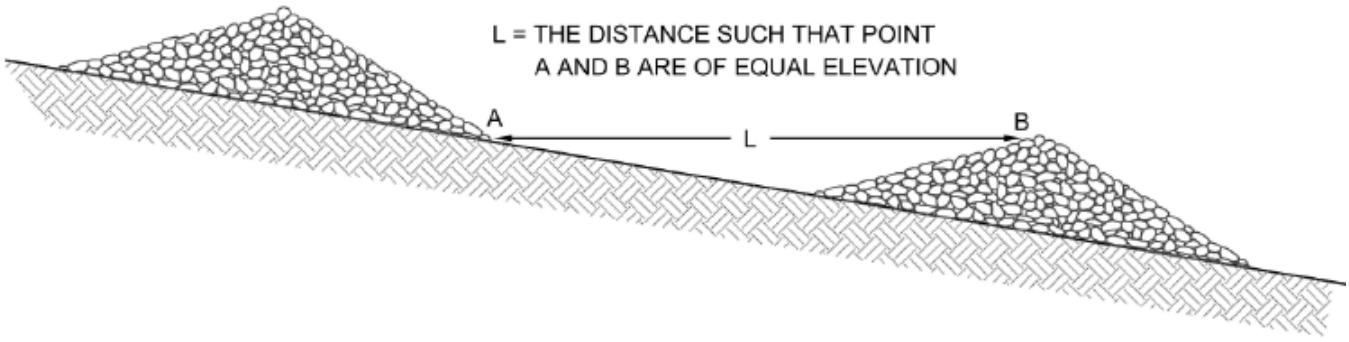
Unless the check dams are designed and constructed to be incorporated into a permanent stormwater management control, remove check dams when their useful life concludes. In temporary ditches and swales, remove check dams and fill in the ditch when they are no longer needed. In permanent structures, remove check dams when all upstream areas are stabilized. In the case of grass-lined ditches, remove check dams after upstream areas are stabilized and when the grass has matured sufficiently to protect the ditch or swale. Repair the area in which the check dam has been removed as needed to provide a continuous flow line in the channel. Seed and mulch the area beneath the check dams immediately after they are removed. The use of filter fabric underneath the stone will make the removal of the stone easier.

Figure C-SCM-07-1 Rock Check Dam



Source: VA DSWC

Figure C-SCM-07-2 Spacing between Rock Check Dams



Source: VA DSWC

8.0 References

Earth Tek, Inc. 2014. Earth Tek Erosion Control Specialists. Located at: http://www.earthtekcos.com/

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SCM-08 Rock Filter Outlet

1.0 Definition

A rock filter outlet is a berm constructed of riprap and stone aggregate where unanticipated concentrated flow to a perimeter control (e.g., silt fence or straw bale barrier) has caused the perimeter control to fail.

– CAD and PDF files for C-SCM-08 Rock Filter Outlet

2.0 Purpose and Applicability of Best Management Practice

Rock filter outlets are an additional perimeter control measure used when silt fence or straw bale barriers have failed due to sheet flow and/or shallow concentrated flow to a common low area along the alignment of the perimeter control, and where a sediment trap may not be warranted.

3.0 Planning and Considerations

If small areas of concentrated flow are identified at the perimeter of the site that may cause perimeter controls to be undermined or overtopped, use rock filter outlets at these concentrated flow points.



Additionally, if a buildup of sediment-laden runoff to a perimeter control is observed after installation, use a rock filter outlet to provide higher flow-through rates.

Rock filter outlets are installed where flow concentrates, typically in combination with silt fence or

straw bale barriers, to prevent spillover or bypass of the perimeter control.

Because rock filter outlets are typically placed at points of failure or compromise in a perimeter control, efforts to break up the area tributary to the failure may result in more optimal performance of the rock filter outlet and the perimeter control to which it is ancillary.

4.0 Stormwater Performance Summary

4.1 MS-4: FIRST-STEP MEASURES

Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment will be constructed as a first step in any land-disturbing activity and will be made functional before upslope land disturbance takes place.

Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: Low

5.0 Design Criteria

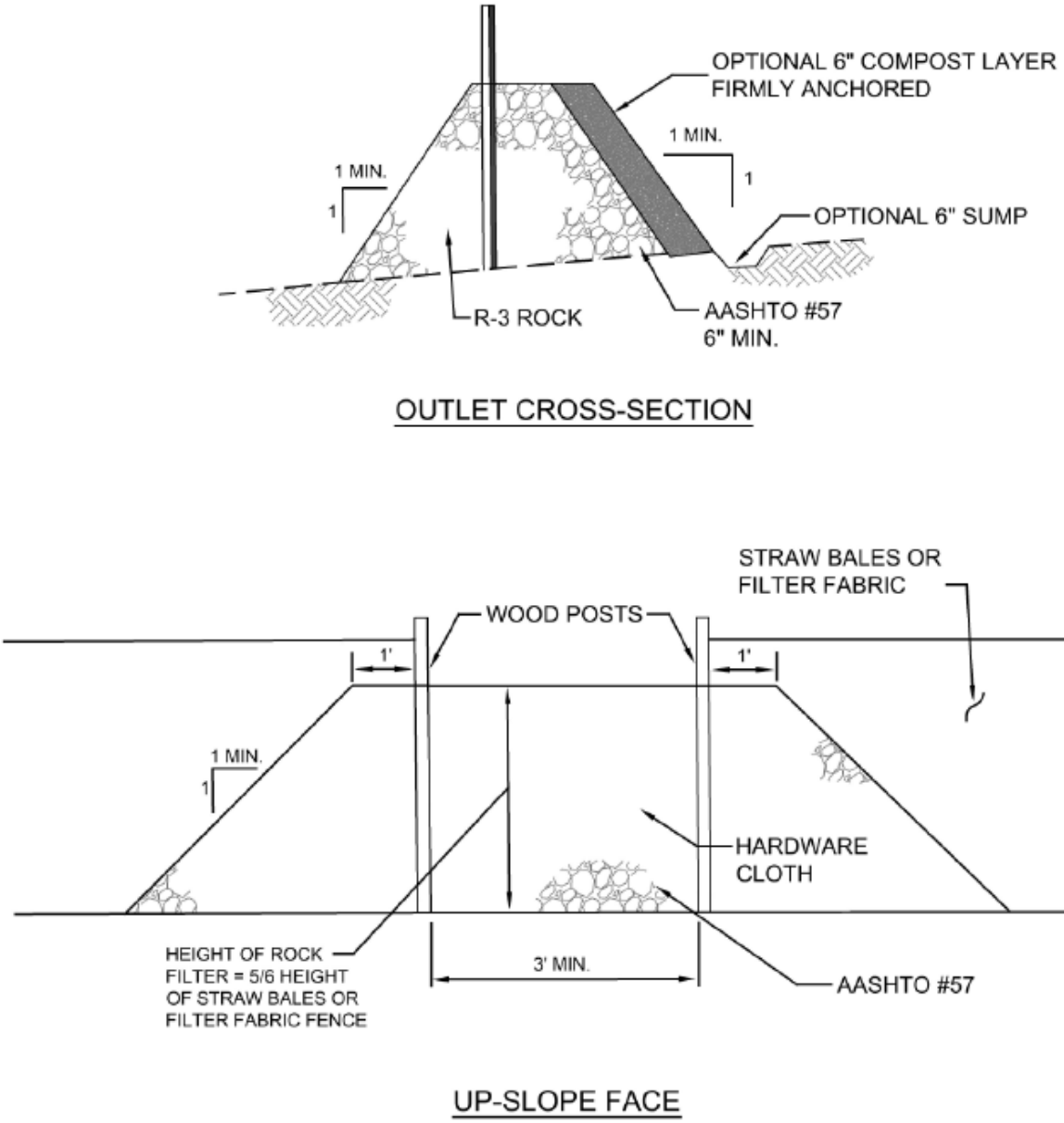
Table C-SCM-08-1 Rock Filter Outlet Design Criteria

Material	Construct the rock filter outlet of Class A1 riprap with a 6-inch-thick layer of Virginia Department of Transportation (VDOT) #3, #357, or #5 coarse aggregate on the upslope face of the rock filter.
Drainage Area	Do not allow more than 0.25 acre of surface area to drain to a rock filter outlet.
Side Slopes	The minimum side slope of the rock filter is 1H:1V.
Top Length	The minimum top width of the rock filter is 5 feet with 1 foot extending beyond the silt fence or straw bale barriers on both sides such that a minimum of 3 feet of the rock filter is between the two sections of silt fence or straw bale barriers.
Top Width	The minimum top width is 1 foot.
Height	Construct the rock filter to be a minimum of five sixths the height of the silt fence filter fabric or straw bale barriers.
Sump	Install an optional 6-inch-deep sump on the upslope side of the rock filter outlet to provide additional sediment removal capacity.

6.0 Construction Specifications

1. Where a silt fence or straw bale barrier has been compromised or a failure has occurred, cut a 3-foot section out of the silt fence or remove a 3-foot section of the straw bale barrier. Install two new posts at each end of the newly cut silt fence and attach the filter fabric to the newly installed support posts. Install support stakes in the remaining portions of the straw bale barrier where a section was removed.
2. Install the riprap portion of the rock filter outlet, and then place the layer of coarse aggregate on the upslope side.

Figure C-SCM-08-1 Rock Filter Outlet Detail



Source: PA DEP

7.0 Operations and Maintenance Considerations

Inspect rock filter outlets immediately after each rainfall and at least daily during prolonged rainfall. Make any required repairs immediately.

Remove sediment when accumulations reach one third the height of the outlet.

Replace clogged riprap and coarse aggregate as necessary to maintain the functionality of the rock filter.

Replace any dislodged or dislocated riprap or coarse aggregate immediately.

Inspect vicinity for subsidence, and repair promptly if found.

Remove and dispose of the rock filter outlet following stabilization of disturbed areas upslope of the outlet.

8.0 References

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SCM-09 Turbidity Curtain

1.0 Definition

A turbidity curtain is a floating geotextile material that minimizes sediment transport from a disturbed area adjacent to or within a body of water.

– CAD and PDF files for C-SCM-09 Turbidity Curtain

2.0 Purpose and Applicability of Best Management Practice

The purpose of a turbidity curtain is to provide sedimentation protection for a watercourse from upslope land disturbance or from dredging or filling within the watercourse.

Turbidity curtains apply to non-tidal and tidal watercourses where intrusion into the watercourse by construction and subsequent sediment movement are unavoidable.

3.0 Planning and Considerations



Soil loss into a watercourse results in long-term suspension of sediment. In time, the suspended sediment may travel long distances and affect widespread areas. A turbidity curtain is designed to deflect and contain sediment and provide enough residence time so that soil particles will fall out of suspension and not travel to other areas.

Select the type of turbidity curtain to be used based on the flow conditions within the water body – whether it be a flowing channel, lake, pond, or a tidal watercourse. The specifications contained herein pertain to minimal and moderate flow conditions in which the velocity of flow may reach 5 feet per second (or a current of approximately 3 knots). Where there are greater flow velocities or currents, consult a qualified engineer and product manufacturer.

Consider the direction of water movement in channel flow situations. Turbidity curtains are not designed to act as water impoundment dams and cannot be expected to stop the flow of a significant volume of water. Turbidity curtains are designed and installed to trap sediment, not to halt the movement of the water itself. For most situations, do not install turbidity curtains across channel flows.

In tidal or moving water conditions, make provisions to allow the volume of water contained within the curtain to change. Take measures to prevent the curtain from submerging because the volume of water contained within the curtain will be much greater at high tide verses low tide due to the bottom of the curtain being weighted and external anchors frequently added. In addition to allowing for slack in the curtain to rise and fall, allow water to flow through the curtain if it is to remain in roughly the same spot and to maintain the same shape. Normally, this is achieved by constructing part of the curtain from a heavy woven filter fabric. The fabric allows the water to pass through the curtain but retains the sediment pollutants. Consider the volume of water that must pass through the fabric and sediment particle size when specifying fabric permeability.

Sediment deflected and settled out by the curtain may be removed if directed by the on-site inspector or the certified plan reviewer. However, consider the probable outcome of removal, as it may create more of a sediment problem by resuspending particles and by accidental dumping of the material by the equipment involved. It is, therefore, recommended that the soil particles trapped by a turbidity curtain only be removed if there has been a significant change in the original contours of the affected area in the watercourse. Regardless of the decision made, allow soil particles to settle for a minimum of 6 hours before their removal by equipment or before removal of a turbidity curtain.

It is imperative that the intended function of the other controls in this chapter, to keep sediment out of the watercourse, be the strategy used in every erosion control plan. However, when proximity to the watercourse precludes successful mitigation of sediment loss, the use of the turbidity curtain during land disturbance is essential.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

MS-12: WATERCOURSE CONSTRUCTION – When work in a live watercourse is performed, precautions shall be taken to minimize encroachment, control sediment transport, and stabilize the work area to the greatest extent possible during construction. Non-erodible material shall be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by non-erodible cover materials.

MS-14: OTHER WATERCOURSE REGULATIONS – All applicable federal, state, and local regulations pertaining to working in or crossing live watercourses shall be met.

9VAC25-875-560

Erosion Control Efficiency: LOW

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

Table C-PCM-09-1 Design Criteria for Turbidity Curtains

Parameter	Notes on Proper Use
Types	Use Type I configuration (see Figure C-SCM-09-1) in areas that are sheltered from wind and waves. Use Type II configuration (see Figure C-SCM-09-1) in areas where there may be small to moderate current running (up to 2 knots or 3.5 feet per second) and/or wind and wave action can affect the curtain. Use Type III configuration (see Figure C-SCM-09-2) in areas where considerable current (up to 3 knots or 5 feet per second) may be present, where tidal action may be present, and/or where the curtain is potentially subject to wind and wave action.
Location	Install turbidity curtains parallel to the direction of flow of a moving body of water. Do not place turbidity curtains across the main flow of a significant body of moving water.
Alignment	Typical alignments of turbidity curtains are illustrated on Figure C-SCM-09-3. The number and spacing of external anchors may vary depending on current velocities and potential wind and wave action; follow manufacturer's recommendations.
Span	Attempt to avoid an excessive number of joints in the curtain; a minimum continuous span of 50 feet between joints is a good “rule of thumb.” For stability reasons, a maximum span of 100 feet between joints (anchor or stake locations) is also a good rule to follow. The ends of the curtain, floating upper, and weighted lower should extend well up into the shoreline, especially if high water conditions are expected. The ends should be secured firmly to the shoreline (preferably to rigid bodies such as trees or piles) to fully enclose the area where sediment may enter the water.

Table C-PCM-09-1 Design Criteria for Turbidity Curtains	
Parameter	**Notes on Proper Use**
Length	Where the watercourse is not subject to tidal action and/or significant wind and wave forces, extend the turbidity curtains the entire depth of the watercourse. In tidal and/or wind and wave action situations, do not allow the curtain to be long enough to touch the bottom. Make sure a minimum 1-foot "gap" exists between the weighted lower end of the skirt and the bottom at "mean" low water. Movement of the lower skirt over the bottom due to tidal reverses or wind and wave action on the floatation system may fan and stir sediments that have already settled out. In tidal and/or wind and wave action situations, it is seldom practical to extend a turbidity curtain depth lower than 12 feet below the surface, even in deep water. Curtains installed deeper will be subject to very large loads with consequent strain on curtain materials and the mooring system. In addition, a curtain installed in such a manner can "billow up" towards the surface under the pressure of the moving water, which will result in an effective depth significantly less than the skirt depth. When sizing the length of the floating curtain, allow an additional 10 to 20 percent variance in the straight-line measurements. This will allow for measuring errors, make installation easier, and reduce stress from potential wave action during high winds. When there is a specific need to extend the curtain to the bottom of the watercourse in tidal or moving water conditions, a heavy woven pervious filter fabric may be substituted for the normally recommended impervious geotextile. This creates a "flow-through" medium, which significantly reduces the pressure on the curtain and will help to keep it in the same relative location and shape during the rise and fall of tidal waters.

6.0 Construction Specifications

Table C-SCM-09-2 Material Specifications for Turbidity Curtains	
Approach	**Notes on Proper Use**
Barriers	Use barriers with a bright color (yellow or "international" orange are recommended) that will attract the attention of nearby boaters.
Floatation	Use floatation devices that are flexible, buoyant units contained in an individual floatation sleeve or collar attached to the curtain (see Figure C-SCM-09-2). Ensure the buoyancy provided by the floatation units is sufficient to support the weight of the curtain and maintain a freeboard of at least 3 inches above the water surface level
Curtain	Ensure the curtain fabric meets the minimum requirements in Table C-SCM-09-3. Ensure seams in the fabric are either vulcanized welded or sewn and develop the full strength of the fabric.

Table C-SCM-09-2 Material Specifications for Turbidity Curtains	
Approach	**Notes on Proper Use**
Load Lines	Use load lines fabricated into the bottoms of all floating turbidity curtains. For Type II and Type III, use load lines fabricated into the top and bottom of the fabric. Use a top load line consisting of woven webbing or vinyl-sheathed steel cable that has a break strength of more than 10,000 pounds. Use a supplemental (bottom) load line consisting of a chain incorporated into the bottom hem of the curtain of sufficient weight to serve as ballast and hold the curtain in a vertical position. Provide additional anchorage as necessary. Ensure the load lines have connecting devices suitable for developing the full breaking strength for connecting to load lines in adjacent sections (see Figure C-SCM-09-1 and Figure C-SCM-09-2, which portray this orientation).
External Anchors	External anchors may consist of wooden or metal stakes (2- x 4-inch or 2.5-inch minimum diameter wood or 1.33 pounds/linear foot steel) when Type I installation is used. When using Type II or Type III installations, use bottom anchors.
Bottom Anchors	Ensure bottom anchors are sufficient to hold the curtain in the same position relative to the bottom of the watercourse without interfering with the action of the curtain. The anchor may dig into the watercourse bottom (grappling hook, plow, or fluke-type) or may be weighted (mushroom type) and attached to a floating anchor buoy via an anchor line. The anchor line would then run from the buoy to the top load line of the curtain. When used with Type III installations, ensure these lines contain enough slack to allow the buoy and curtain to float freely with tidal changes without pulling the buoy or curtain down and check the lines regularly to make sure they do not become entangled with debris. As previously noted, anchor spacing will vary with current velocity and potential wind and wave action; follow manufacturer's recommendations. See orientation of external anchors and anchor buoys for tidal installation on Figure C-SCM-09-2.

Table C-SCM-09-3 Material Specifications for Curtain Fabric	
Physical Property	**Requirement**
Thickness (mils)	45
Weight (oz./sq. yd.)	
Type I	18
Type II	18 or 22
Type III	22
Woven Geotextile Grab Tensile Strength (lbs.)	200
UV Inhibitor	Must be included

6.1 Installation

1. In the calm water of lakes or ponds (Type I installation), it is usually sufficient to merely set the curtain end stakes or anchor points (using anchor buoys if bottom anchors are employed), then tow the curtain in the furled condition out and attach it to the stakes or anchor points. Subsequently, any additional stakes or buoyed anchors required to maintain the desired location of the curtain may be set and these anchor points made fast to the curtain. Cut the furling lines to drop the curtain skirt.
2. In rivers or other moving water (Type II and Type III installations), it is important to set all curtain anchor points. Take care to ensure that anchor points are of sufficient holding power to retain the curtain under the existing current conditions before putting the furled curtain into the water. Again, employ anchor buoys on all anchors to prevent the current from submerging the floatation at the anchor points. If the moving water into which the curtain is being installed is tidal and will subject the curtain to currents in both directions as the tide changes, it is important to provide anchors on both sides of the curtain for two reasons:
    a. Curtain movement will be minimized during tidal current reversals.
    b. The curtain will not overrun the anchors and pull them out when the tide reverses. When the anchors are secure, secure the furled curtain to the upstream anchor point and then sequentially attach to each subsequent downstream anchor point until the entire curtain is in position. At this point, and before unfurling, assess the “lay” of the curtain and make any necessary adjustments to the anchors. Finally, when the location is ascertained to be as desired, cut the furling lines to drop the skirt.
3. Always attach anchor lines to the floatation device, not to the bottom of the curtain. The anchoring line attached to the floatation device on the downstream side will support the curtain. Attaching the anchors to the bottom of the curtain could cause premature failure due to the stresses imparted on the middle section of the curtain.
4. Turbidity curtains may be installed across channel flows when there is a danger of silt buildup in the middle of a watercourse, thereby blocking access or creating a sand bar. Curtains have been used effectively in large areas of moving water by forming a very long-sided, sharp “V” to deflect clean water around a work site, confine a large part of the silt-laden water to the work area inside the “V,” and direct much of the silt toward the shoreline. Take care not to install the curtain perpendicular to the water current.
5. See Figure C-SCM-09-3 for typical installation layouts.

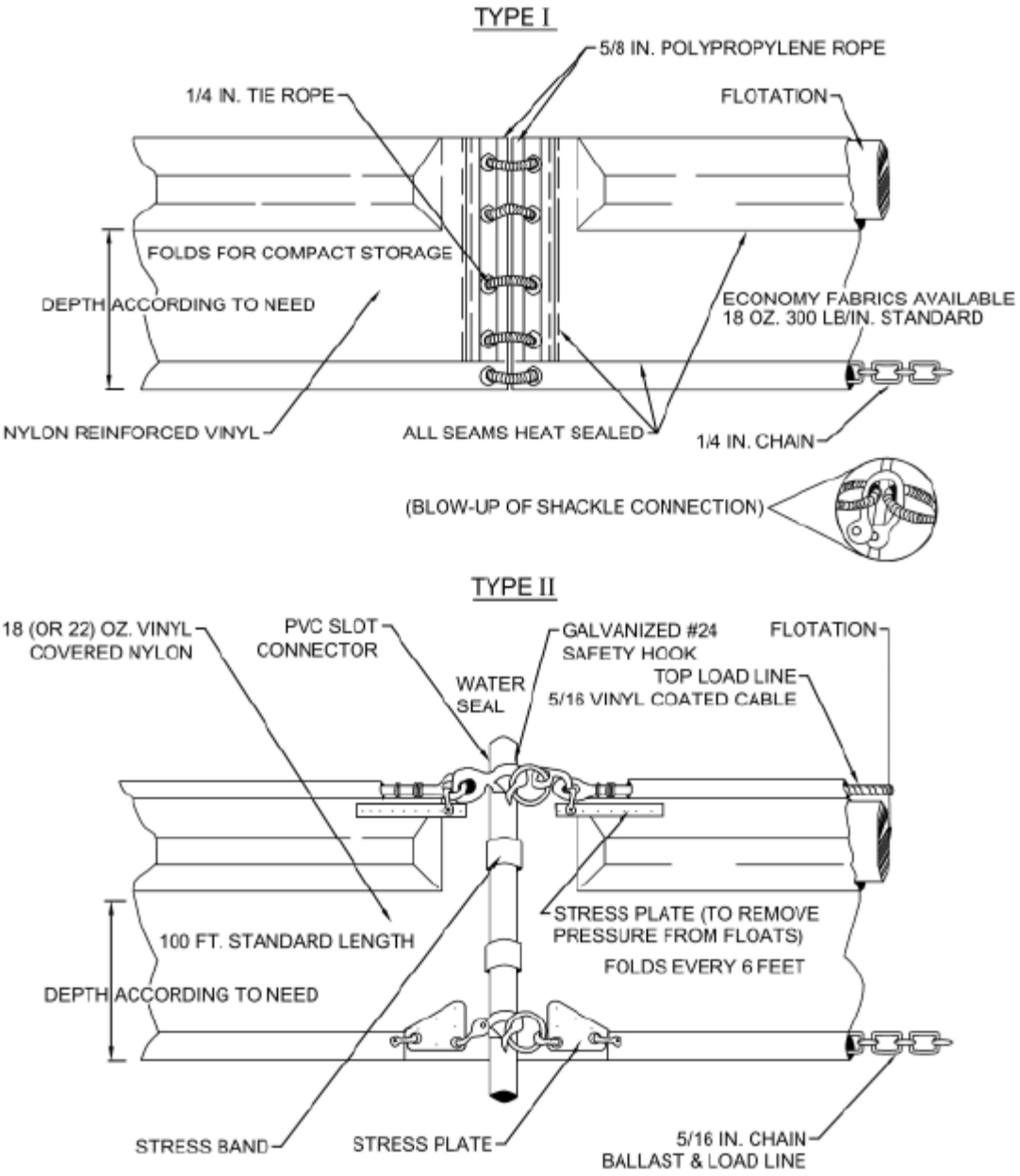
6.2 Removal

1. Take care to protect the skirt from damage as the turbidity curtain is dragged from the water.
2. The site selected to bring the curtain ashore should be free of sharp rocks, broken cement, debris, and other hazards to minimize damage when hauling the curtain over the area.
3. If the curtain has a deep skirt, it can be further protected by running a small boat along its length with a crew installing furling lines before attempting to remove the curtain from the water.

7.0 Operations and Maintenance Considerations

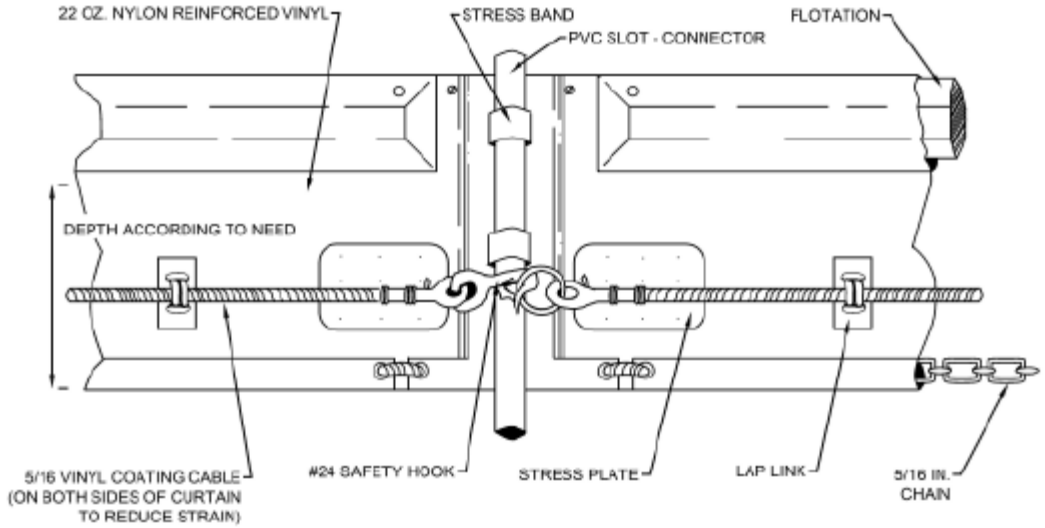
1. Maintain the filter curtain during the project to ensure the continuous protection of the watercourse.
2. Repair the geotextile fabric as necessary using repair kits available from the manufacturer. Follow the manufacturer's instructions to ensure the adequacy of the repair.
3. When the curtain is no longer required, remove the curtain and related components to minimize turbidity. Ensure the remaining sediment is sufficiently settled before removing the curtain. Sediment may be removed and the original watercourse depth (or plan elevation) restored. Transport any spoils to an upland area and stabilize the spoils.

Figure C-SCM-09-1 – Turbidity Curtain Type I & II

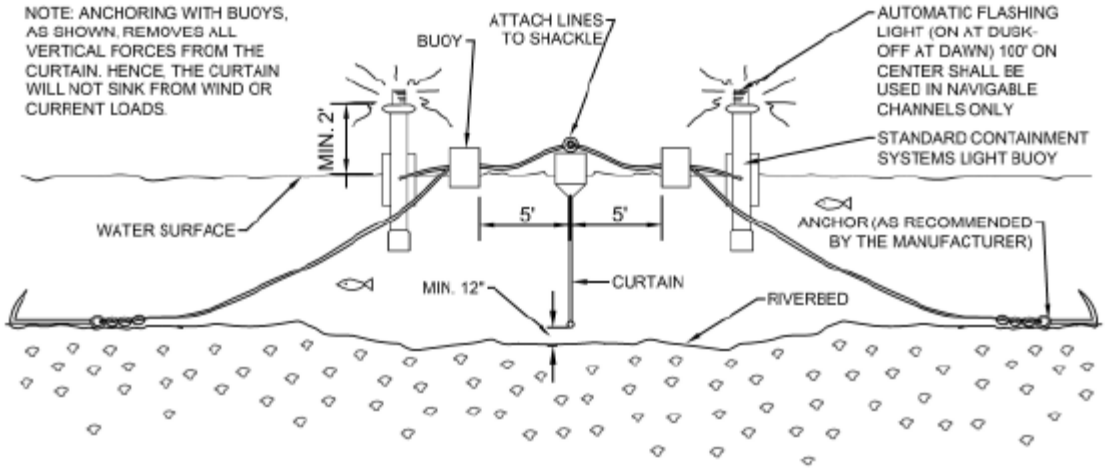


Source: American Boom and Barrier Corp. product literature

Figure C-SCM-09-2 Turbidity Curtain Type III

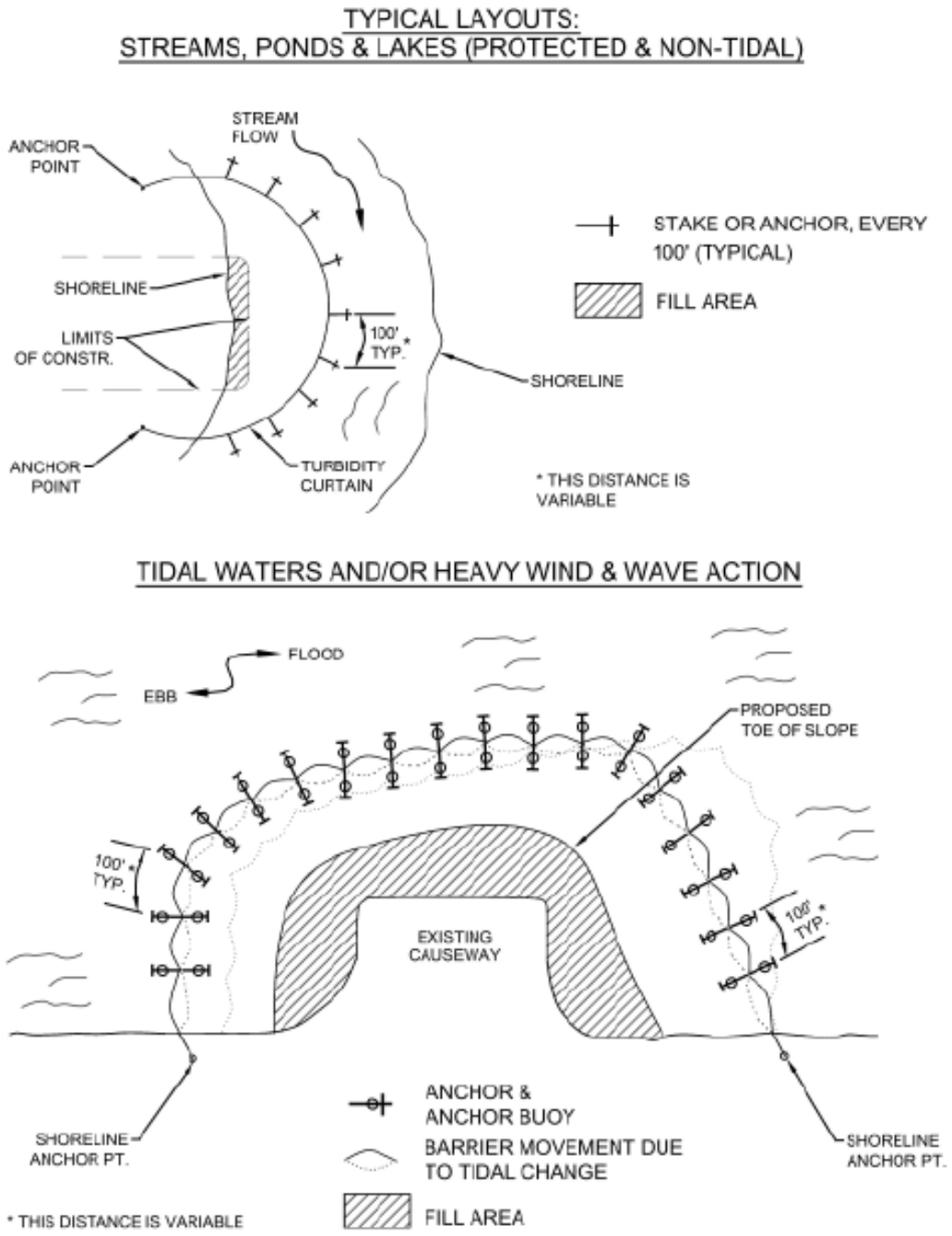


ORIENTATION WHEN INSTALLED (TIDAL SITUATION)



Source: Adapted from American Boom and Barrier Corp. and Virginia Department of Transportation (VDOT) Standard Sheets

Figure C-SCM-09-3 Turbidity Curtain Typical Layouts



Source: Adapted FL DOT Stds

8.0 References

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SCM-10 Dewatering Structure

1.0 Definition

A dewatering structure is a temporary settling and filtering device used to process water discharged from dewatering activities.

– CAD and PDF files for C-SCM-10 Dewatering Structure

2.0 Purpose and Applicability of Best Management Practice

Dewatering structures filter sediment-laden water before the water is discharged off site.

Dewatering structures are appropriate where sediment-laden water needs to be removed from a construction site by means of pumping.

3.0 Planning and Considerations

Water pumped from a construction site usually contains a large amount of sediment. A dewatering structure is designed to remove the sediment before releasing the water off site.

This practice includes several types of dewatering structures that have different applications depending on site conditions and types of operation. Other innovative techniques for accomplishing the same purpose are encouraged, but only after specific plans and details are submitted to and approved by the certified plan reviewer.

A dewatering structure may not be needed if there is a non-sloping, well-stabilized, vegetated area on site to which water may be discharged. A relatively flat, well-stabilized, vegetated area is required so that it can filter sediment and withstand the velocity of the discharged water without eroding.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance.

MS-6: TRAPS AND BASINS – Sediment traps and basins shall be designed and constructed based on the total drainage area they serve.

9VAC25-875-560

Erosion Control Efficiency: LOW

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

Table C-SCM-10-1 Design Criteria for Dewatering Structures

Parameter	Notes on Proper Use
Size	Size and operate a dewatering structure to allow pumped water to flow through the filtering device without overtopping the structure. Use the following formula to determine the storage volume of the dewatering structure: ***Pump discharge (gpm) x 16 = cubic feet of storage required***
Location	Locate dewatering structure away and downhill from stockpiles or excavation spoil piles. Do not place dewatering structure where treated water will be allowed to flow back into the workspace. Ensure a minimum filtering length of 75 feet is available downgradient of the dewatering structure so that the existing well-established vegetated area can adequately filter sediment.
Lining	An excavated basin (applicable to "Straw Bale/Silt Fence Pit") may be lined with filter fabric to help reduce scour and to prevent the inclusion of soil from within the structure.
Additional Criteria	Design criteria more specific to each dewatering device are provided on Figure C-SCM-10-1, Figure C-SCM-10-2, Figure C-SCM-10-3, Figure C-SCM-10-4, and Figure C-SCM-10-5.

gpm = gallons per minute

6.0 Construction Specifications

Table C-SCM-10-2 Material Specifications for Dewatering Structures

Approach	Notes on Proper Use
Portable Sediment Tank (Figure C-SCM-10-1)	Construct the structure with steel drums, sturdy wood, or other material suitable for handling the pressure exerted by the associated volume of water. Use sediment tanks with a minimum depth of 2 feet. Locate the sediment tank for easy cleanout and disposal of the trapped sediment and to minimize interference with construction. Once the water level nears the top of the tank, the pump must be shut off while the tank drains and additional capacity is made available. Design the tank to allow for emergency flow over the top of the tank. Clean out the tank once one third of the original capacity is depleted due to sediment accumulation. Clearly mark the tank showing the cleanout point.
Filter Box (Figure C-SCM-10-2)	Ensure the box selected is made of steel, sturdy wood, or other materials suitable to handle the pressure requirements imposed by the associated volume of water. Fifty-five- gallon drums welded top to bottom are normally readily available and, in most cases, will suffice. Make the bottom of the box porous by drilling holes (or some other method). Place Virginia Department of Transportation (VDOT) #3 Coarse Aggregate over the holes at a minimum depth of 12 inches. Place metal “hardware” cloth between the aggregate and the holes if holes are drilled larger than most of the stone. Due to the fast flow rate of sediment-laden water through the aggregate, direct the effluent over a well-vegetated strip of at least 50 feet after leaving the base of the filter box. Once the water level nears the top of the box, shut off the pump while the box drains and additional capacity is made available. Design/construct the box to allow for emergency flow over the top of the box. Clean out the box once one third of the original capacity is depleted due to sediment accumulation. Clearly mark the box showing the cleanout point. If the stone filter does become clogged with sediment so that it no longer adequately performs its function, pull the stones away from the inlet and clean and replace the stone. Note: Using a filter box only allows for minimal settling time for sediment particles; therefore, it should only be used when site conditions restrict the use of other methods.



Table C-SCM-10-2 Material Specifications for Dewatering Structures	
Approach	**Notes on Proper Use**
	Ensure the pit consists of straw bales, silt fence, a stone outlet (a combination of VDOT Class AI Riprap and VDOT #25 or #26 Aggregate), and a wet storage pit oriented as shown on Figure C-SCM-10-3. For the straw bale pit, use a filter fabric to line the face of the straw bales that conforms to the requirement identified in Riprap (BMP C-ECM-13). In calculating the capacity, include the volume available from the floor of the excavation to the crest of the stone weir. In any case, ensure the excavation is a minimum of 3 feet below the base of the perimeter measures (straw bales or silt fence).
Straw Bale/Silt Fence Pit (Figure C-SCM-10-3)	Install the perimeter measures as per the guidelines in Straw Bale Barrier (C-PCM-02) and Silt Fence (C-PCM-04). Once the water level approaches the crest of the stone weir (emergency overflow), shut off the pump while the structure drains down to the elevation of the wet storage. The wet storage pit may be dewatered only after a minimum of 6 hours of sediment settling time. Pump this effluent across a well-vegetated area or through a silt fence or compost filter sock before allowing it to enter a watercourse. Once the wet storage area becomes filled to one half of the excavated depth, remove and dispose of accumulated sediment. Once the device has been removed, ground contours will be returned to original condition.

Table C-SCM-10-2 Material Specifications for Dewatering Structures	
Approach	**Notes on Proper Use**
Pumped Water Filter Bag (Figure C-SCM-10-4)	Use low-volume filter bags made from non-woven monofilament geotextile material sewn with high-strength, double-stitched “J” type seams. Use filter bags capable of trapping particles larger than 150 microns.  *Source: Cascade Geotecnical 2023.* Use high-volume filter bags made from woven monofilament that meet the requirements included in Table C-SCM-10-3. Provide a suitable means of accessing the bag with machinery required for disposal purposes. Replace filter bags when they become half full of sediment. Keep spare bags available for replacement of those that have failed or are filled. Place bags on straps to facilitate removal unless bags come with lifting straps already attached. Locate bags in a well-vegetated (grassy) area and discharge onto stable, erosion-resistant areas. Where this is not possible, provide a geotextile underlayment and flow path. Bags may be placed on filter stone to increase discharge capacity. Do not place bags on slopes greater than 5%. For slopes exceeding 5%, clean rock or other non-erodible and non-polluting material may be placed under the bag to reduce slope steepness. No downslope sediment barrier is required for most installations. Install Silt Fence (BMP C-PCM-04) or Compost Filter Sock (BMP C-PCM-05) below bags located within 50 feet of any receiving surface water or where a grassy area is not available.

Table C-SCM-10-2 Material Specifications for Dewatering Structures	
Approach	**Notes on Proper Use**
	Locate sump at a low point in the work area and away from construction activity. Where runoff from a work area flows directly to the sump area, attach a pumped water filter bag at the discharge point unless pumping to a sediment basin or sediment trap. Excavate the pit to three times the pipe diameter and a minimum of 4 feet deep. Place a minimum of 6 inches of clean 0.75- to 1.5-inch stone on the bottom of the pit. Use a 12-inch or larger corrugated metal pipe, high-density polyethylene (HPDE) or polyvinyl chloride (PVC) pipe with 1-inch-diameter perforations, 6 inches on center. Cap the bottom of the pipe with a watertight seal.
Sump Pit (Figure C-SCM-10-5)	Wrap pipe with 0.25-inch galvanized hardware cloth and wrap non-woven geotextile over the hardware cloth. Place the pipe vertically into the pit and extend the pipe a minimum of 6 inches above the top of stone. Backfill the pit around the pipe with 0.75- to 1.5-inch stone and extend stone a minimum of 6 inches above the anticipated water surface elevation. Set pump intake inside standpipe. Pump discharge water to a stable area below disturbances from the work zone. If the system clogs, remove perforated pipe and replace geotextile and stone. Keep point of discharge free from erosion.

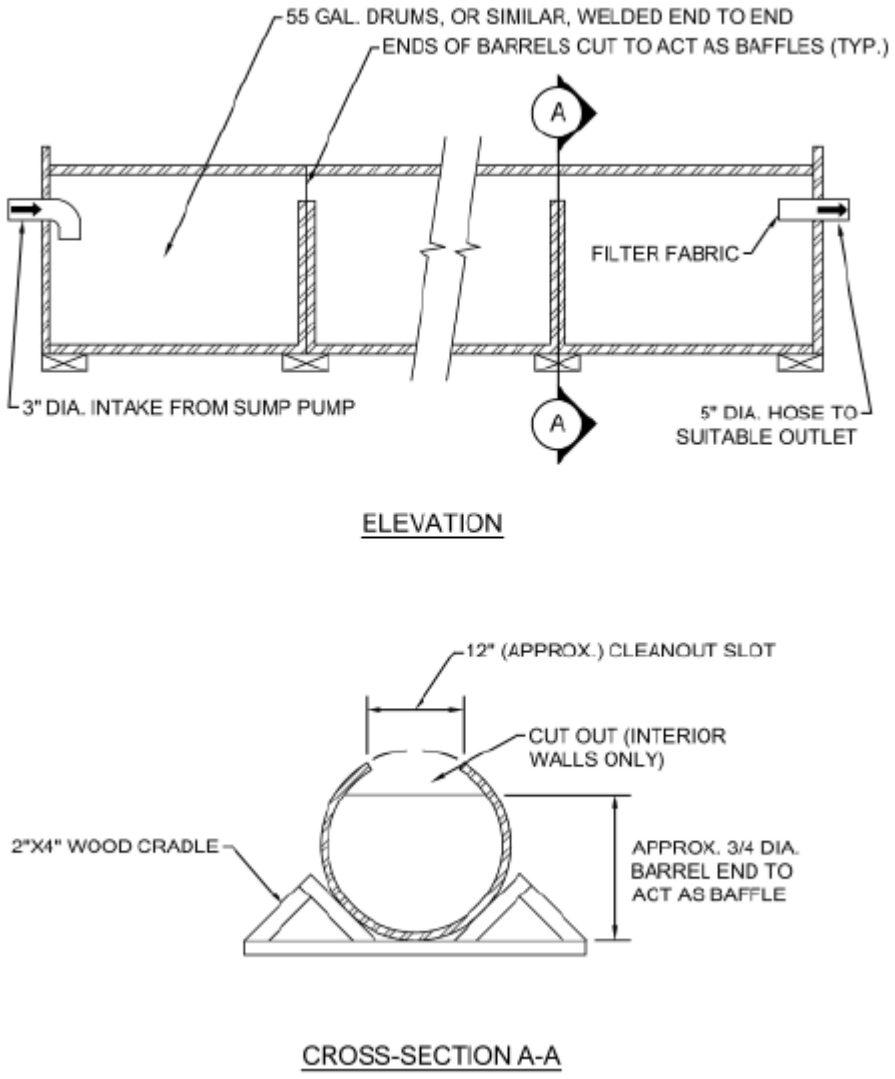
Table C-SCM-10-3 Material Specifications for Pumped Water Filter Bag		
Property	**Test Method**	**Minimum Standard**
Avg. Wide Width Strength	ASTM D-4884	60 lb/in
Grab Tensile	ASTM D-4632	205 lb
Puncture	ASTM D-4833	110 lb
Mullen Burst	ASTM D-3786	350 psi
UV Resistance	ASTM D-4355	70%
AOS % Retained	ASTM D-4751	80 Sieve

7.0 Operations and Maintenance Considerations

1. Inspect the filtering devices daily and repair or replace once the sediment buildup prevents the structure from functioning as designed.
2. Remove the accumulated sediment from the dewatering device, spread on site, and stabilize or dispose of at an approved disposal site as per approved plan.

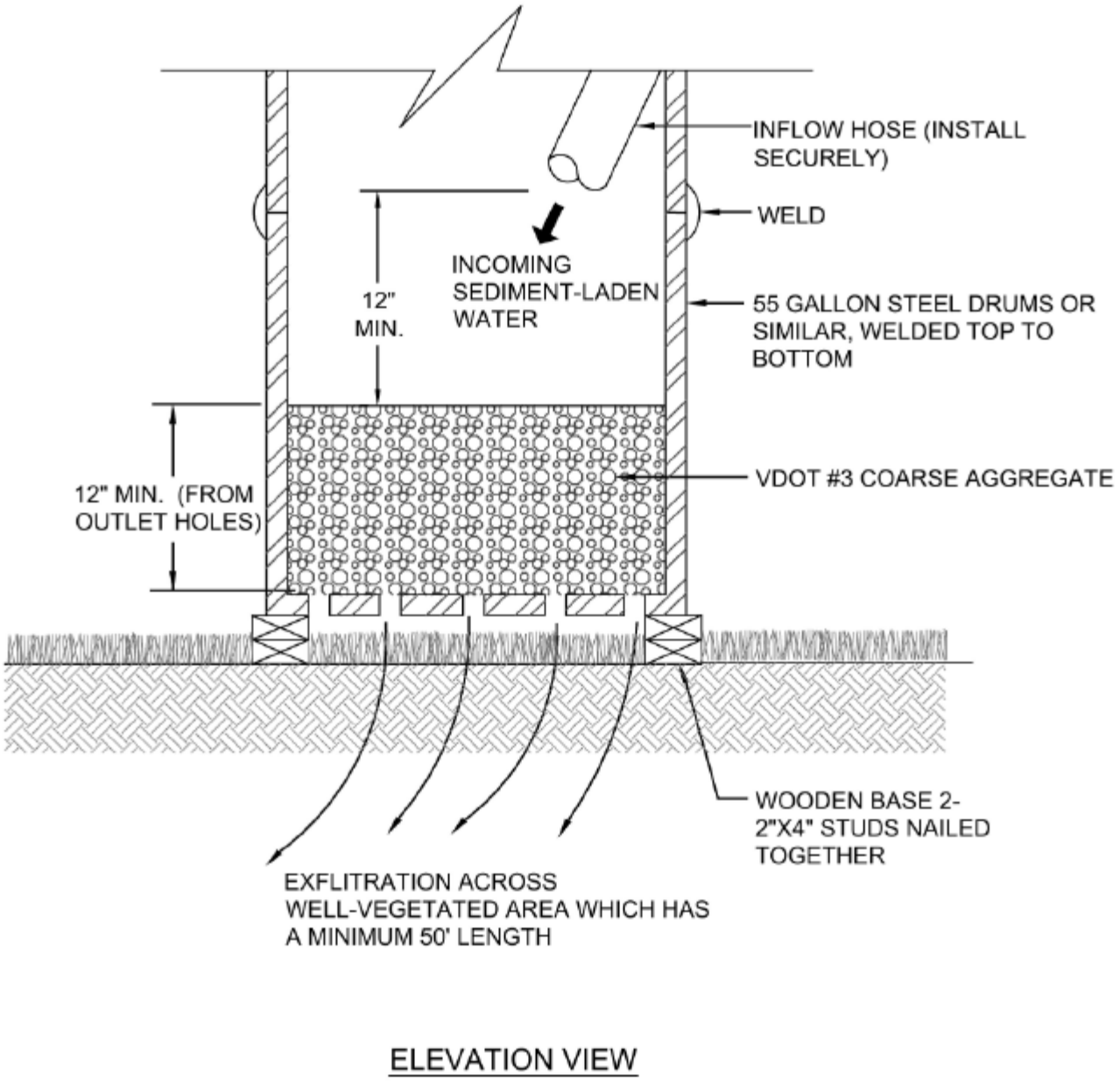
3. Monitor the dewatering structure during operation to ensure that the discharge is not causing erosion. Provide Soil Stabilization Blankets and Matting (BMP C-SSM-05) or Compost Filter Socks (BMP C-PCM-05) as needed to maintain stabilized areas downstream of structure.

Figure C-SCM-10-1 Portable Sediment Tank



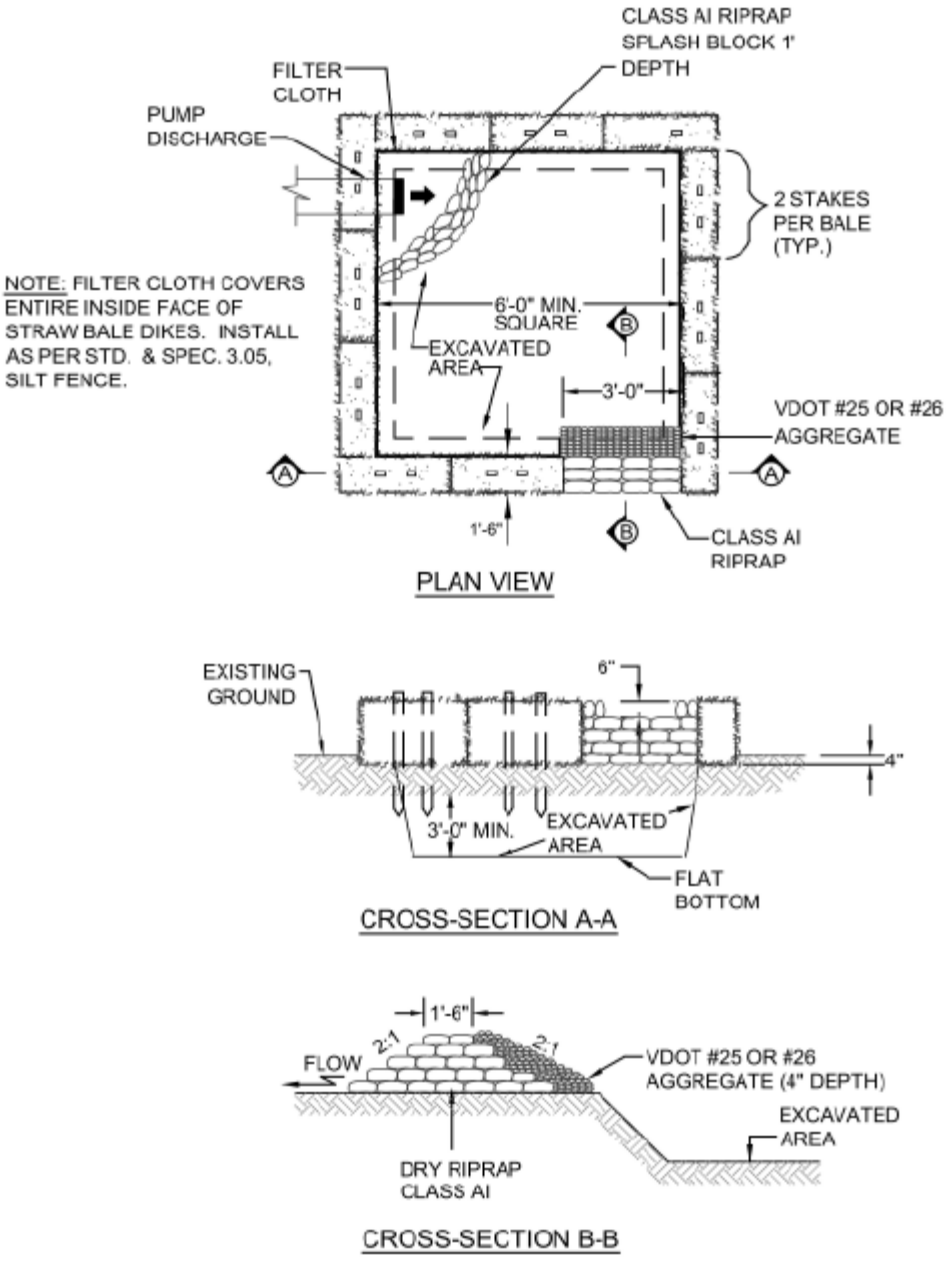
Source: USDA-NRCS

Figure C-SCM-10-2 Filter Box



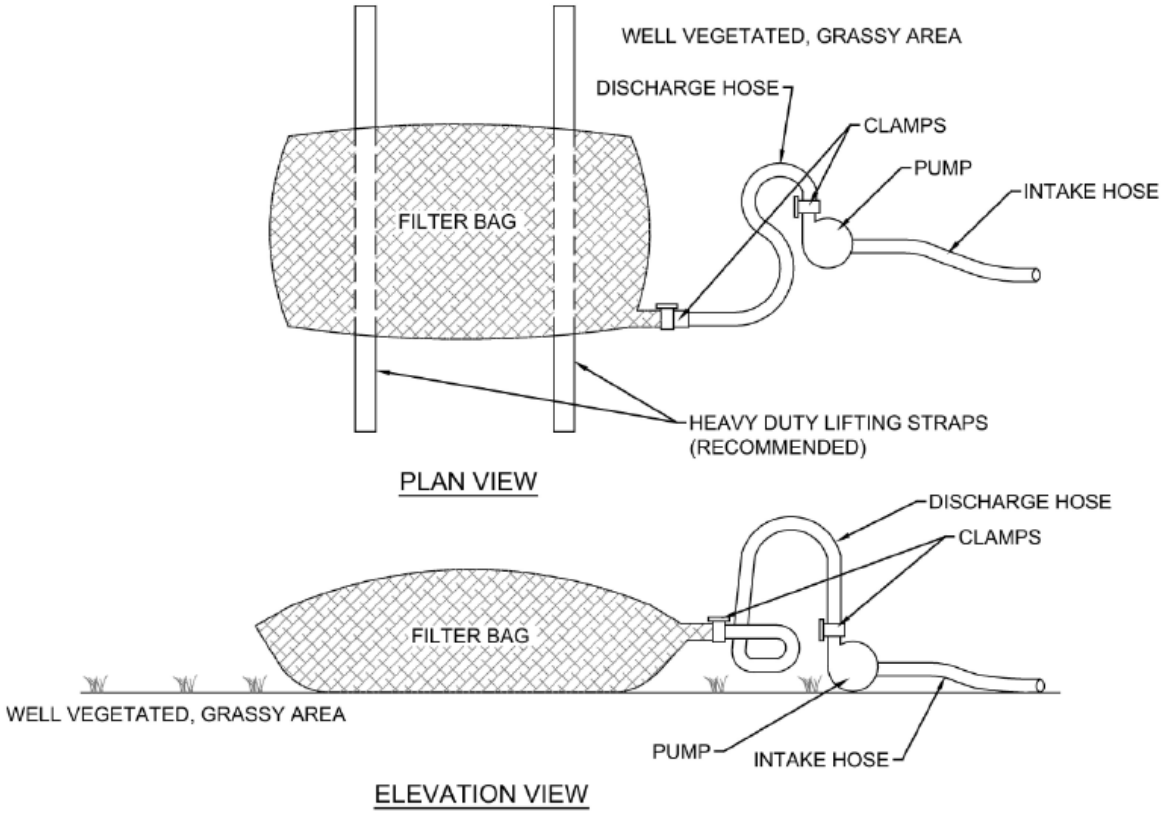
Source: VA DSWC

Figure C-SCM-10-3 Straw Bale/Silt Fence Pit



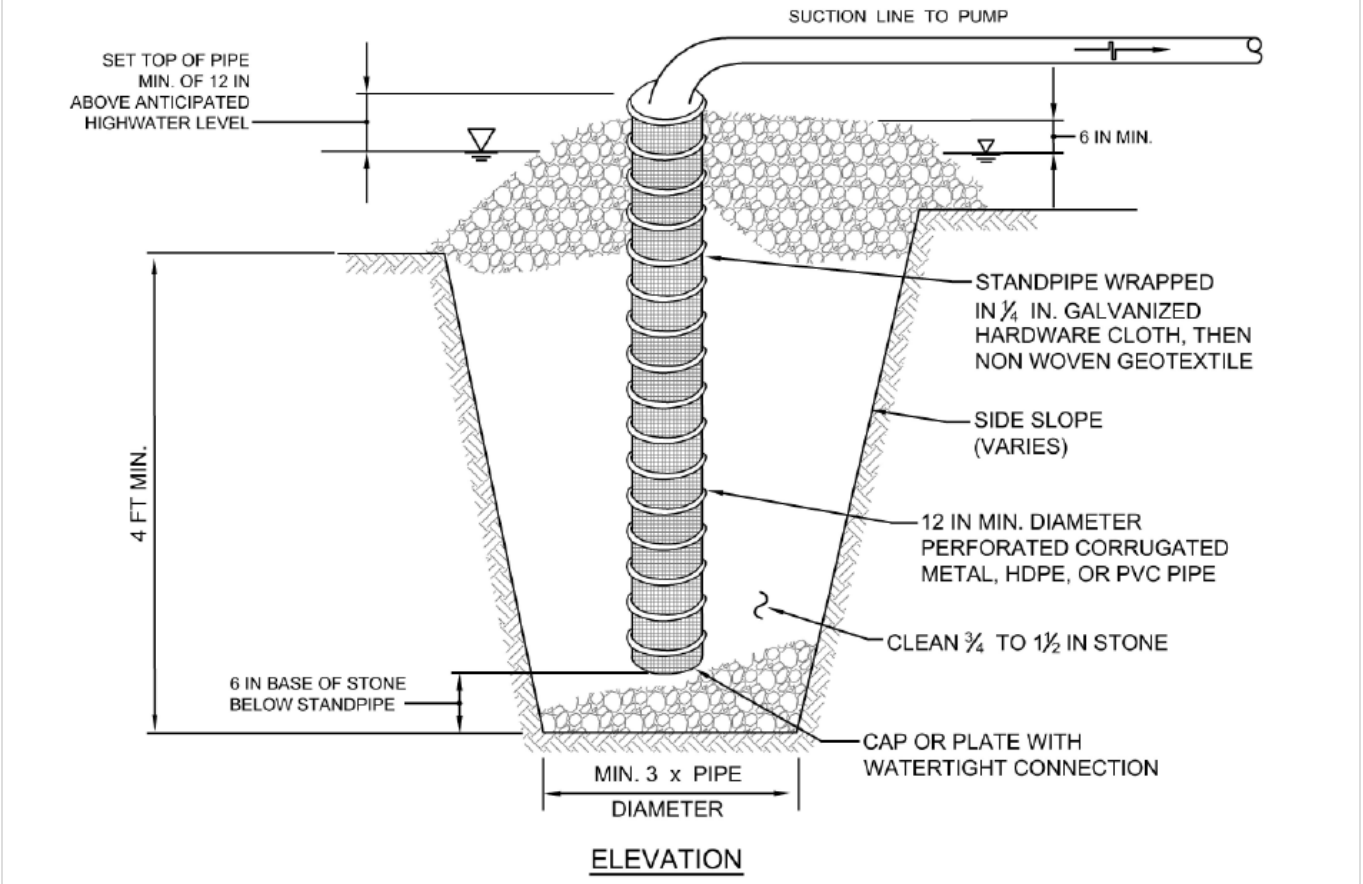
Source: VA DSWC

Figure C-SCM-10-4 Filter Bag



Source: PADEP 2012

Figure C-SCM-10-5 Sump Pit



Source: Maryland Water Management Administration et al. 2011

8.0 References

Cascade Geotechnical Environmental Products. 2023. Silt Bags, Drain Protection, & Water Diversion. Located at: https://cascade.ca/products/silt-bags-sediment-control-drain-protection/.

Maryland Water Management Administration, Natural Resources Conservation Service, and Maryland Association of Soil Conservation Districts. 2011. Maryland Standards and Specifications for Soil Erosion and Sediment Control. December.

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SCM-11 Temporary Sediment Trap

1.0 Definition

A temporary sediment trap is a temporary ponding basin formed by constructing an embankment, often earthen or composed of compost filter sock, with a stone outlet.

– CAD and PDF files for C-SCM-11 Temporary Sediment Trap

2.0 Purpose and Applicability of Best Management Practice

Temporary sediment traps are used to detain sediment-laden runoff from small, disturbed areas long enough to allow much of the sediment to settle out to protect water quality in receiving streams, lakes, drainage systems, and adjacent property.

Use a temporary sediment trap:

- Along the contour of the site, below the disturbed areas where the total contributing drainage area per trap is less than 3 acres;
- Where the sediment trap will be used no longer than 18 months (the maximum useful life is 18 months); and
- Where the sediment trap may be constructed either independently or in conjunction with a Temporary Diversion Dike (BMP C-ECM-04).

3.0 Planning and Considerations

Select locations for sediment traps during site evaluation. Note natural drainage divides and select trap sites so that runoff from potential sediment-producing areas can easily be diverted into the traps. Ensure the total contributing drainage area for each trap does not exceed 3 acres.

Construct temporary sediment traps, along with other perimeter controls intended to trap sediment, as a first step in any land-disturbing activity and make it functional before upslope land disturbance.

In most cases, excavation will be required to attain the necessary sediment trap storage volume. Additionally, periodic sediment removal will be necessary to maintain the required sediment trap storage volume. Plans should detail how excavated sediment is to be disposed of, such as by use in fill areas on site or removal to an approved off-site location.

Judiciously consider variations in the design to ensure that the minimum storage requirements and structural integrity noted in this specification are maintained.

Avoid locating traps on steep or unstable slopes where possible. Where not possible, address how failure of the trap will be avoided in the design. Do not locate sediment traps within stream channels or in wetlands.

Avoid placing sediment traps where they will impede active construction. Locate sediment traps to maximize their effective lifespan treating runoff from the construction.

Compost filter sock traps may be used for some locations if the installation procedure for such a trap is followed and the type of sock is suitable for the length of time for which the trap will be in use.

Outlet the sediment trap onto stabilized (preferable undisturbed) ground, into a watercourse, stabilized channel, or into a storm drain system. Maximize the distance between inlet and outlet to the longest length practicable.

Outlet protection must be designed in accordance with Outlet Protection (BMP C-ECM-15). The area below the outlet must not be obstructed to allow free flow from the trap when it is discharging. The drainage path must not be impeded with silt fence or other control measures that do not have the capacity the pass the discharge flows without damage.

4.0 Stormwater Performance Summary

MS-4: FIRST STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

MS-6: TRAPS AND BASINS – Sediment traps and sediment basins shall be designed and constructed based upon the total drainage area to be served by the trap or basin.

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Erosion Control Efficiency: N/A

Sediment Removal Efficiency: High

5.0 Design Criteria

Table C-SCM-11-1 Design Criteria for Temporary Sediment Trap

Drainage Area	Design the sediment trap so that the total contributing drainage area for each trap is less than 3 acres. If the contributing drainage area is 3 acres or greater, refer to Temporary Sediment Basin (BMP C-SCM-12).
Length of Use	A temporary sediment trap must remain in service, through proper upkeep, performance, and maintenance, until the contributing drainage area is stabilized or managed by a replacement best management practice (BMP).
Trap Capacity	Design the sediment trap to have an initial storage volume of 134 cubic yards/acre of drainage area. Where runoff computations are used, use runoff coefficients or curve numbers corresponding to a bare earth condition. Permanent Pool or Wet Storage: Half of the storage volume (67 cubic yards/acre) is reserved for a permanent pool (wet storage volume) to provide a stable settling medium. Measure the wet storage volume from the low point of the excavated area to the base of the stone outlet structure. Calculate the wet storage volume as follows: $V_1 = 0.85 \times A_1 \times D_1$ Where: V_1 = wet storage volume (cubic feet) A_1 = surface area of the flooded area at the base of the stone outlet (square feet) D_1 = maximum depth measured from the low point in the trap to the base of the stone outlet (feet)

Table C-SCM-11-1 Design Criteria for Temporary Sediment Trap

Trap Capacity	Drawdown or Dry Storage: Half of the storage volume (67 cubic yards/acre) provides extended settling time during less frequent, larger storm events. Measure the dry storage volume from the base of the stone outlet to the crest of the stone outlet (overflow mechanism). Calculate the dry storage volume as follows: $V_2 = \frac{A_1+A_2}{2} D_2$ where, V2 = dry storage volume (cubic feet) A1 = surface area of the flooded area at the base of the stone outlet (square feet) A2 = surface area of the flooded area at the crest of the stone outlet (overflow mechanism) (square feet) D2 = depth measured from the base of the stone outlet to the crest of the stone outlet (feet) Remove sediment from the basin when the wet storage volume is reduced by half. Note: Convert cubic feet to cubic yards as follows: number of cubic feet x 0.037 = number of cubic yards
Length to Width Ratio	Provide a storage area with a minimum 2:1 length-to-width ratio measured from point of maximum runoff introduction to outlet.
Excavation	Ensure the side slopes of excavated areas are no steeper than 1H:1V. Design the trap such that the maximum depth of excavation within the wet storage area is 4 feet to facilitate cleanout and for site safety considerations.
Outlet: Design temporary sediment trap outlet configurations in accordance with one or more of the configurations described below.	

Table C-SCM-11-1 Design Criteria for Temporary Sediment Trap	
. 1. *Stone Outlet*	In this configuration, the outlet of the sediment trap consists of a stone section of the embankment set to the top of the wet storage volume. Use a combination of coarse aggregate and riprap to provide for filtering/detention as well as outlet stability. Use Virginia Department of Transportation (VDOT) #3, #357, or #5 Coarse Aggregate (smaller stone sizes will enhance filter efficiency) for the smaller stone and "Class I" for the riprap. Place filter cloth that meets the physical requirements noted in Riprap (BMP C-ECM-13) at the stone-soil interface to act as a "separator." Design the outlet so that the minimum outlet length is 6 feet times the number of acres comprising the total area draining to the trap. The stone outlet crest is at least 1 foot below the top of the embankment to ensure that the flow will travel over the stone and not the embankment. Configure the outlet as noted on Figure C-SCM-11-3. The ends of the stone outlet must extend 1 foot up to the elevation of the embankment to prevent erosion at the stone/soil interface during discharge.
2. *Pipe Outlet*	In this configuration, the outlet for the trap is through a perforated riser and a pipe through the embankment. Use an outlet pipe and riser made of steel, corrugated metal, or other suitable material. Design the top of the embankment to be at least 1.5 feet above the crest of the riser. Dewatering of the sediment trap may be accomplished using a surface skimmer. If the riser alone is used for dewatering, perforate the top two thirds of the riser with 1-inch nominal diameter holes or slits spaced 6 inches vertically and horizontally placed in the concave portion of the corrugated pipe. Do not place holes or slits within 6 inches of the top of the horizontal barrel. Ensure all pipe connections are watertight. Wrap the riser with 0.5- to 0.25-inch hardware cloth wire, then wrap with filter cloth with a sieve size between #40 and #80 and secure with strapping or connecting band at the top and bottom of the cloth. Ensure the cloth covers an area at least 6 inches above the highest hole and 6 inches below the lowest hole. Do not cover the top of the riser pipe with filter cloth. The riser will have a base with sufficient weight to prevent flotation of the riser (see Temporary Sediment Basin, BMP C-SCM-12).Select the riser and barrel diameters from Table C-SCM-11-3.Configure the outlet as noted on Figure C-SSM-11-3. Ensure that riser perforations remain free from clogging and debris.

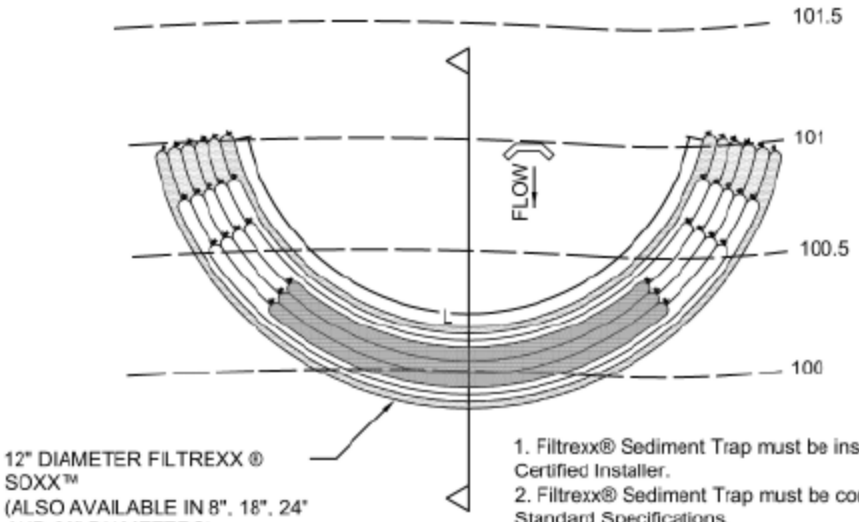
Table C-SCM-11-1 Design Criteria for Temporary Sediment Trap	
3. *Compost Filter Sock Outlet*	Use larger-diameter compost filter socks (18-inch, 24-inch, 32-inch) at the base of the sediment trap system with increasingly smaller-diameter compost filter socks (8-inch, 12-inch, 18-inch) placed on top to form a berm. Construct the compost filter sock berm to have a minimum effective height of 3 feet with a base width equivalent to the height. Additional height and runoff-sediment storage volume can be attained by excavating immediately upslope from the sediment trap. Ensure that excavation does not undermine the compost filter sock berm and integrity of the sediment trap system. Stake the bottom larger-diameter compost filter socks forming the base of the sediment trap berm into the ground using 2-inch by 2-inch by 36-inch-long hardwood stakes placed 10 feet on center. Stake the top layer of smaller-diameter compost filter socks to the bottom layer of socks where the socks overlap using two 2-inch by 2-inch by 48-inch-long (minimum) hardwood stakes wrapped together with 16-gauge wire placed 10 feet on center, starting 5 feet from the bottom stakes. Ensure the angled stakes are placed a minimum of 18 inches into the ground and extend a minimum of 12 inches above the top layer of socks.
4. *Compost Filter Sock Trap*	The compost filter sock embankment must be located to provide, in combination with excavation, a minimum of 134 cubic yards of storage at the design depth. Place compost filter sock sediment traps on low-grade or level contours to maximize runoff- sediment volume containment. The compost filter socks used to form the embankment will be continuous with no gaps or joints. Ensure the flow of water is perpendicular to the sediment trap at impact. Place sediment traps on undisturbed soil to reduce the potential for undermining. Do not place sediment traps on fill soil or slopes. Place compost material behind the bottom layer of compost filter sock to reduce undermining potential. To prevent water flowing around the ends of sediment traps, construct the ends of the compost filter sock sediment trap pointing upslope with the ends a minimum of 1 foot higher in elevation than the lowest point (mid-section) of the sediment trap. Install the mid-section of the sediment trap to be the point of lowest elevation. Configure the outlet as noted on Figure C-SSM-11-3.
Embankment Cross-Section	Design the sediment trap embankment so that the maximum height is 5 feet as measured from the base of the stone outlet. Design the minimum top widths and outlet heights for various embankment heights according to Table C-SCM-11-2. Design the embankment sideslopes to be 2H:1V or flatter.
Removal	Remove sediment traps after the contributing drainage area is stabilized. Ensure that plans identify how the site of the sediment trap is to be graded and stabilized after removal.

Table C-SCM-11-2 Minimum Top Width Required for Sediment Trap Embankments According to Height of Embankment		
Embankment Height (ft)	**Outlet Crest Height (ft)**	**Minimum Embankment Top Width (ft)**
1.5	0.5	2.0
2.0	1.0	2.0
2.5	1.5	2.5
3.0	2.0	2.5
3.5	2.5	3.0
4.0	3.0	3.0
4.5	3.5	4.0
5.0	4.0	4.5

Table C-SCM-11-3 Minimum Riser and Barrel Pipe Outlet Sizes		
Maximum Drainage Area	**Riser Diameter (in.)**	**Barrel Diameter (in.)[1]**
1	15	12
2	18	15
3	21	18

1. Barrel diameter may be same as riser diameter.

Figure C-SCM-11-1 Compost Filter Sock Sediment Trap

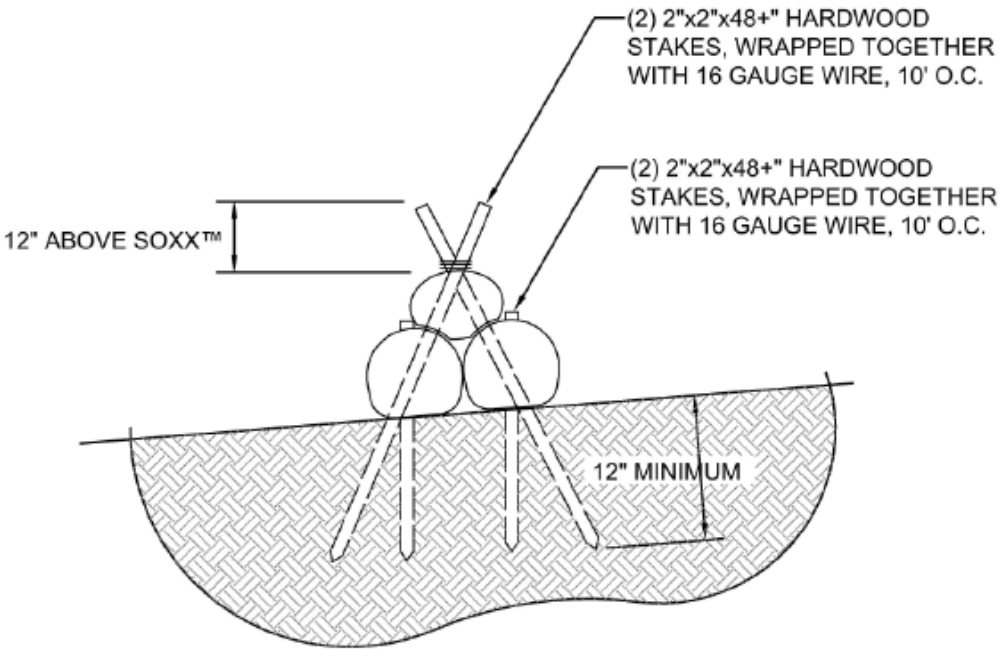


1. Filtrexx® Sediment Trap must be installed by Filtrexx Certified Installer.
2. Filtrexx® Sediment Trap must be comply with all Filtrexx Standard Specifications.
3. Filtrexx® Sediment Trap must use Filtrexx FilterMedia™.
4. Filtrexx® Sediment Trap barrier face sizing shall use Q/0.98cfm(per sf of area face) = A (Q=5L/sec/sq.m)
5. Filtrexx® Sediment Trap barrier face shall be measured as A=L*D.
6. Filtrexx® Sediment Trap shall be constructed so that the minimum base width is equivalent to the height (1H:1V).
7. Sediment accumulation shall not exceed ½ the height of the barrier.
8. Filtrexx® Sediment Trap shall be inspected and maintained after storm events.
9. Soxx™ shall be of larger diameter at the base of the Sediment Tra and decrease in diameter for successive layers.
10. Ends of the Sediment Trap shall be a minimum 1 ft (30 cm) higher in elevation than the mid-section, which shall be at the lowest elevation.
11. Bottom layer of Soxx™ shall be staked with 2x2x36" wooden stakes. Successive layers shall be staked with ½" rebar at a 45 degree angle.



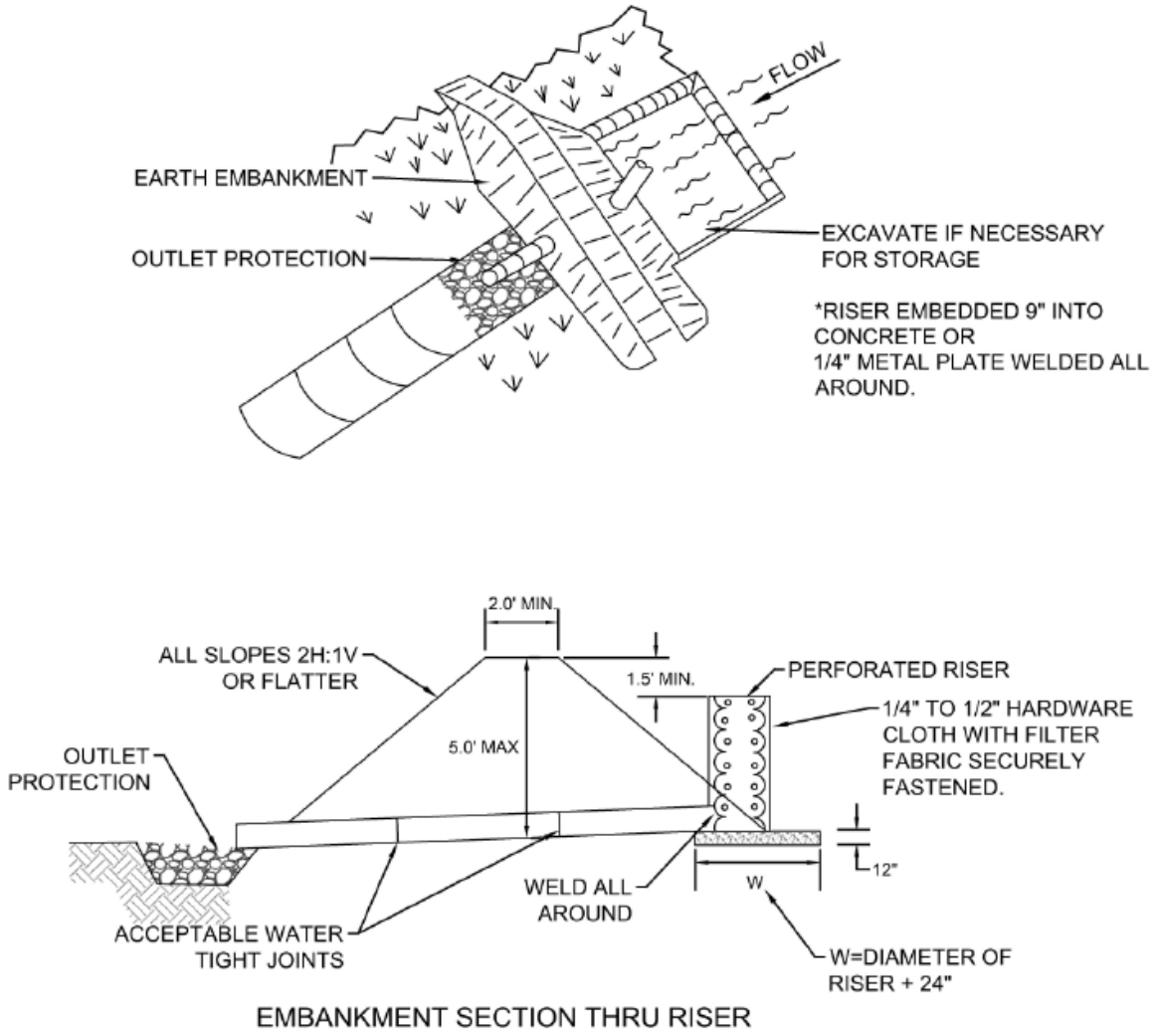
Source: Filtrexx®

Figure C-SCM-11-2 Sediment Trap Staking Detail



Source: Filtrexx® Design Specification 1.9 Sediment Trap – Compost Filter Sock

Figure C-SCM-11-3 Temporary Sediment Trap Embankment Detail



Source: New York State Standards and Specifications for Erosion and Sediment Control

6.0 Construction Specifications

1. Clear, grub, and strip any vegetation and root mat from the area under the embankment.
2. Ensure that fill material for the embankment is free of roots or other woody vegetation, organic material, large stones, and other objectionable material. Construct the embankment in 6-inch layers compacted by traversing with construction equipment.
3. Seed the earthen embankment with Temporary Seeding (BMP C-SCM-09) or Permanent Seeding (BMP C-SCM-10) immediately after installation.
4. Carry out construction operations to minimize erosion and water pollution.
5. Remove the structure and stabilize its area when the upslope drainage area has been stabilized.
6. Ensure that all cut and fill slopes are constructed with 2H:1V side slopes or flatter.

7.0 Operations and Maintenance Considerations

Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to one half the design volume of the wet storage. Deposit sediment removed from the trap in a suitable area so that the placed material will not erode and cause sedimentation.

Regularly check filter stone to ensure that filtration performance is maintained. Remove and clean or replace stone choked with sediment. Replace stone that has been displaced within the embankment or outlet.

Regularly check the structure to ensure that the embankment and outlet are structurally sound and have not been damaged by erosion or construction equipment. Restore damaged embankments and/or outlets to design conditions. Check the height of the stone outlet to ensure that its center is at least 1 foot below the top of the embankment.

Repair or replace any damaged compost filter socks used in the compost filter sock sediment trap.

8.0 References

New York State Department of Environmental Conservation. 2016. New York State Standards and Specifications for Erosion and Sediment Control. November.

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

PADEP. 2012. Erosion and Sediment Pollution Control Program Manual. Final. Technical Guidance Number 363-2134-008. March. Available online at: http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SCM-12 Temporary Sediment Basin

1.0 Definition

A temporary sediment basin is a temporary barrier or dam with a controlled stormwater release structure formed by constructing an embankment of compacted soil across a drainageway.

– CAD and PDF files for C-SCM-12 Temporary Sediment Basin

2.0 Purpose and Applicability of Best Management Practice

A temporary sediment basin is used to detain sediment-laden runoff from disturbed areas in “wet” and “dry” storage long enough for much of the sediment to settle out.

The maximum drainage area that a sediment basin should contain is 100 acres. There must be sufficient space and appropriate topography for the construction of a temporary impoundment. These structures are limited to a useful life of 18 months unless the basins are designed as permanent impoundments. It is recommended that these measures, by virtue of their potential to impound large volumes of water, be designed by a qualified professional.

Temporary sediment basins can be combined with Straw Wattles (BMP C-ECM-01) to capture sediment in a drainageway that leads to a sinkhole outside of the limits of disturbance (LOD).

3.0 Planning and Considerations

3.1 Effectiveness

Sediment basins constructed per this specification are, at best, 60% effective at trapping sediment that flows into them during large storm events (those which cause flow from the outfall pipe) or during periods of minimal vegetative cover at a construction site. Therefore, use sediment basins in conjunction with erosion control practices, such as Temporary Seeding (BMP C-SSM-09), Mulching (BMP C-SSM-11), Temporary Diversion Dike (BMP C-ECM-04) to reduce the amount of sediment flowing into the basin.

To contain most of the sediment that flows to the structure, design and construct the basin to have a permanent pool or wet storage area and a dry storage area that dewaters over time. Sediment trapping efficiency is primarily a function of sediment particle size and the ratio of basin surface area to inflow rate. Therefore, design the basin to have a large surface area for its volume.

Construct sediment basins, along with other perimeter controls intended to trap sediment, as a first step in any land-disturbing activity and make functional before upslope land disturbance (Minimum Standard MS-4).

The use of a floating skimmer may be used to increase the trapping efficiency of the BMP.

3.2 Location

To improve effectiveness, locate the basin to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally low areas and natural drainageways below disturbed areas. Drainage into the basin can be improved using diversion dikes and ditches. Do not locate the basin in a live stream, instead, locate the basin to trap sediment-laden runoff before it enters a stream. Do not locate the basin where its failure would result in the loss of life, interruption of the use or service of public utilities or roads, or major impacts to wetlands and/or streams.

Always consider access for cleanout and disposal of trapped sediment. Locations where a pond can be formed by constructing a low dam across a natural swale are generally preferred to sites that require excavation. Where practical, divert sediment-free runoff away from the basin.

In karst topography, impounded water causes soil saturation and loss of cohesion, and introduces stress from the weight of the water. See Appendix E for additional considerations in karst areas. Differences in hydraulic head and steep hydraulic gradients can result in sinkhole development. To ensure that these facilities are kept small and shallow, it is recommended that drainage areas be kept to 5 acres or less, and that sediment traps be used to the maximum extent practicable so that the total depth is kept below 5 feet. Where a sediment basin cannot be avoided, keep the depth to the minimum (4 feet to the top of the settling volume). At the discretion of the designer, it may be necessary to install an impermeable liner based on geotechnical testing, known occurrences of sinkhole development, and whether the basin will be converted to a permanent stormwater management facility. Emphasize the importance of ensuring the integrity of all pipes in the maintenance instructions. Pipe leakage or sagging can become the focus of soil loss into subsurface voids, leading to subsidence and the development of sinkholes. If sinkholes develop, promptly and properly repair the sinkholes.

It is important for the basin designer to consider the effect that the basin discharge will have on downstream properties and natural resources. During the construction phase of a project, the area draining to a basin location may be greatly increased from the pre-construction condition by way of the use of diversions or temporary or permanent storm sewers. Additionally, the coefficient of runoff from a typically denuded and compacted construction site will be greatly increased even if the drainage area of the basin is unchanged. On very large construction sites, multiple sediment basins may discharge to a single receiving channel, conveying higher volumes of flow for a given storm and for a longer duration.

As a result, the channel or other conveyance downstream from a temporary sediment basin should be analyzed for the construction condition to ensure that the discharge it will receive is not beyond its limits of capacity or stability.

3.3 Multiple Use

Sediment basins may remain in place after construction and final site stabilization to serve as permanent stormwater management structures. Because the most practical location for a sediment basin is often the most practical location for a stormwater management basin, it is often desirable to use these structures for permanent stormwater management purposes. It should be noted, however, that in most cases, a typical structure's outfall system will vary during the construction and post-construction periods. Care must be taken to avoid constructing an outfall system that will achieve the desired post-construction quantity or quality control but will not provide the necessary medium for the containment and settling of sediment-laden construction runoff. Notably, the design for permanent ponds is beyond the scope of these standards and specifications.

When a sediment basin is designed to be converted to a permanent stormwater basin, specific direction must be provided for the process of making that conversion. The timing of the conversion must be coordinated with the sequence of site construction and the stage of stabilization of the basin drainage area to ensure optimal performance in both the temporary and permanent configuration.

4.0 Stormwater Performance Summary

MS-4: FIRST-STEP MEASURES – Sediment basins and traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

MS-6: TRAPS AND BASINS – Sediment traps and basins shall be designed and constructed based on the total drainage area they serve.

MS-19: STORMWATER – Protect properties and waterways downstream of a land-disturbing activity from erosion and sediment deposition due to increases in peak stormwater runoff.

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: HIGH

5.0 Design Criteria

Refer to Appendix A of this specification for design procedures for temporary sediment basins.

Table C-SCM-12-1 Design Criteria Parameters	
Parameter	**Details**
Drainage Area	Below disturbed areas where the total contributing drainage area is up to 100 acres. A hydraulic routing model, or other approved alternative design procedure, must be prepared when the drainage area to any one temporary sediment basin exceeds 25 acres. The design procedures in this standard and specification do not generate hydrographs, use storage volumes or provide a routing of the design storms; for a large drainage area, this may result in an excessively large-diameter riser or an oversized basin. Notably, design considerations that are more accurate and project- specific than those in this specification are acceptable and encouraged with any size basin.
Basin Capacity	Design the basin with a storage capacity of at least 134 cubic yards/acre of **total contributing drainage area**. Half of the design volume (or 67 cubic yards) will be in the form of a permanent pool, and the remaining half as drawdown volume. “Dry” Storage (drawdown volume) = 67 cubic yards/acre (min.) Measure the volume of the drawdown area from the elevation of the permanent pool to the crest of the principal spillway (riser pipe). “Wet” Storage (permanent pool) = 67 cubic yards/acre (min.) Measure the volume of the permanent pool from the low point of the basin to the elevation corresponding to half the total storage volume. Sediment Cleanout Level = 34 cubic yards/acre (min.) bottom of the “Wet” Storage zone Remove sediment from the basin when the volume of the permanent pool has been reduced by half. Do not design the sediment cleanout level to be higher than 1 foot below the bottom of the dewatering device. Calculate the elevation of the sediment cleanout level, and clearly mark on the plans and riser (because this part of the riser normally will be under water, a mark should appear above the permanent pool at a measured distance above the cleanout elevation). While attempting to attain the desired storage capacities, keep embankment heights to a minimum. This precaution takes on added significance when the basin will only serve as a temporary measure or will need substantial retrofitting before functioning as a permanent measure. When site topography permits, consider the use of excavation to obtain the required capacity and to possibly reduce the height of the embankment. This excavation can be performed to create a wet storage forebay area or increase the storage capacity over the entire length of the basin. ***The designer may opt to use a hydraulic routing model in place of the traditional long-hand calculations to determine sediment basin capacity.***

Table C-SCM-12-1 Design Criteria Parameters	
Parameter	**Details**
Length of Use	Do not use for longer than 18 months unless the device is designated as a permanent impoundment.
Basin Shape	To improve sediment trapping efficiency of the basin, design the effective flow length to be twice the effective flow width. This basin shape may be attained by properly selecting the site of the basin, by excavation, or using baffles or berms to develop an effective flow length from entry point to dewatering device/outfall structure.
Embankment Cross-Section	For embankments of less than 10 feet: • Minimum top width of 6 feet • Maximum side slopes of 2H:1V or flatter For embankments 10 to 14 feet in height: • Minimum top width of 8 feet • Maximum side slopes of 2.5H:1V or flatter For 15-foot embankments (maximum allowed under these specifications): • Minimum top width of 10 feet • Maximum of 2.5H:1V side slopes
Spillway Design	Design the outlets for the basin to consist of a combination of principal and emergency spillways that will pass the peak runoff expected from the contributing drainage area for a 25-year storm. Runoff coefficients or curve numbers used in runoff computations should correspond to the soil cover conditions expected throughout the basin's lifetime. If a separate emergency spillway is not feasible due to site conditions and basin geometry, design the principal spillway to pass the entire peak runoff expected from the 25-year storm. However, attempt to provide a separate emergency spillway (refer to Emergency Spillway). Base runoff computations on the soil cover conditions that are expected to prevail during the life of the basin. The spillways designed by the procedures contained in the standard and specification will not necessarily result in any reduction in the peak rate of runoff. If a reduction in peak runoff is desired, generate the appropriate hydrographs/storm routings to choose the basin and outlet sizes.

Table C-SCM-12-1 Design Criteria Parameters	
Parameter	**Details**
Principal Spillway	Design the principal spillway to consist of: • Vertical pipe or box of corrugated metal or reinforced concrete; • Minimum diameter of 15 inches; and • Joined by a watertight connection to a horizontal pipe (barrel) extending through the embankment to outlet beyond the downstream toe of the fill. If the principal spillway is used in conjunction with a separate emergency spillway, design the principal spillway to pass at least the peak flow expected from of 2-year storm. If no emergency spillway is used, design the principal spillway to pass the entire peak flow expected from a 25-year storm.
Design Elevations	Set the crest of the principal spillway to be at the elevation corresponding to the storage volume required (67 cy/ac wet storage + 67 cy/ac dry storage = 134 cy/ac). If the principal spillway is used in conjunction with an emergency spillway, set the crest elevation to be a minimum of 1 foot below the crest of the emergency spillway. In addition, provide a minimum freeboard of 1 foot between the design high water (25-year storm) and the top of the embankment (see Figure C-SCM-12-2). If no emergency spillway is used, set the crest of the principal spillway to be a minimum of 3 feet below the top of the embankment and provide a minimum freeboard of 2 feet between the design high water and the top of the embankment.
Anti-Vortex Device and Trash Rack	Attach an anti-vortex device and trash rack to the top of the principal spillway to improve the flow characteristics of water into the spillway and prevent floating debris from blocking the principal spillway. Use a concentric type of anti-vortex device as shown on Figure C-SCM-12-10.

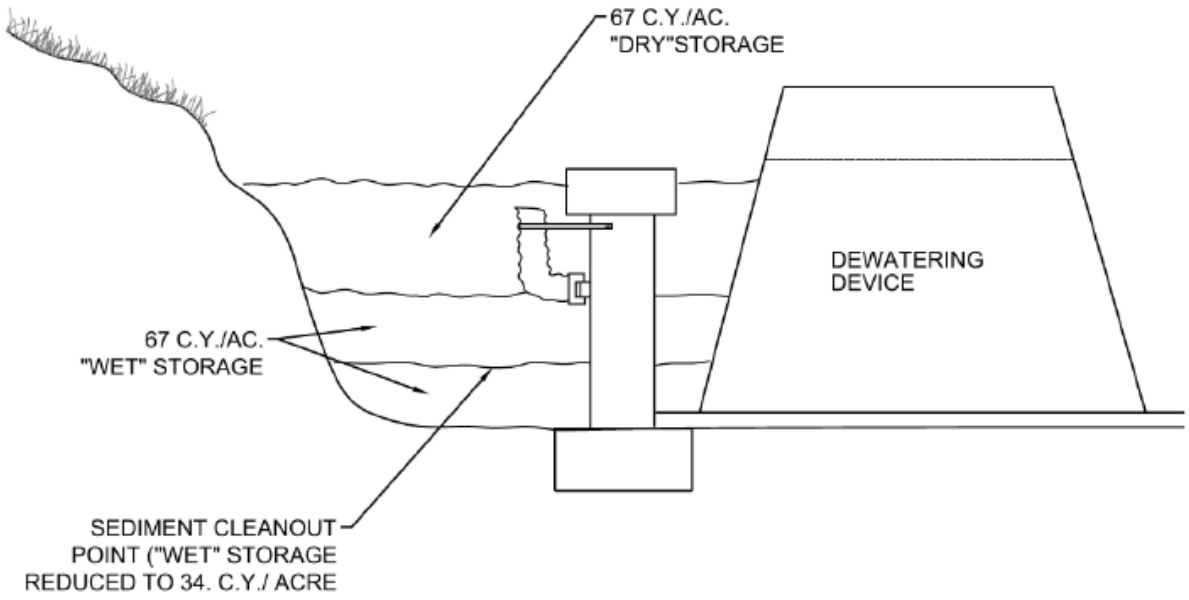
Table C-SCM-12-1 Design Criteria Parameters	
Parameter	**Details**
Dewatering	Make provisions to dewater the basin down to the permanent pool elevation. Sediment basins must not dewater in less than 24 hours, nor take longer than 120 hours. Design the dewatering of the dry storage to remove the “cleaner” water without removing the potentially sediment-laden water found in the wet storage area or any appreciable quantities of floating debris. An economical and efficient device for performing the drawdown is a section of perforated vertical tubing connected to the principal spillway at two locations. By virtue of the potential for the dewatering device or orifice to become clogged, no credit is given for drawdown by the device in the calculation of the principal or emergency spillway locations. Dewatering from the surface provides greater trapping efficiency. One common method is use of a skimmer. A floating skimmer can be attached to the base of the riser. The orifice in the skimmer will control the rate of dewatering. The skimmer should be sized to dewater the basin in 2 to 5 days. The skimmer withdraws temporarily detained water from the top part of the water column to avoid sediment that may be suspended lower in the water column. The skimmer is used to draw down water levels in sedimentation ponds to maintain storage capacity in a way that ensures the cleanest water is discharged in a controlled manner. The quality of the water discharged can be improved using a floating inlet device or “skimmer” attached to a flexible hose attached to the dewatering outlet. The skimmer floats on top of the dry storage pool, discharging the cleanest, least sediment laden water from the surface of the pool.
Barrel	Design the barrel of the principal spillway, which extends through the embankment, to carry the flow provided by the riser of the principal spillway with the water level at the crest of the emergency spillway. The connection between the riser and the barrel must be watertight. Protect the outlet of the barrel to prevent erosion or scour of the downstream area (see Discharge).
Structural Integrity	Analyze the structural integrity of a temporary sediment basin using the 25-year storm event.

Table C-SCM-12-1 Design Criteria Parameters	
Parameter	**Details**
Principal Spillway Base	Firmly anchor the base of the principal spillway to prevent its floating. For spillway risers taller than 10 feet, determine the anchoring requirements using a minimum factor of safety of 1.25 (downward forces = 1.25 x upward forces). For spillway risers 10 feet tall or less, anchor in one of the two following ways: 1. Use a concrete base 18 inches thick, twice the width of riser diameter, and the riser embedded 6 inches into the concrete. See Figure C-SCM-12-3 for design details. 2. Use a square steel plate, a minimum of 0.25 inch thick and having a width equal to twice the diameter of the riser. Cover the plate with 2.5 feet of stone, gravel, or compacted soil to prevent flotation. See Figure C-SCM-12-3 for design details. Note: If the steel base is used, give special attention to compaction so that 95% compaction is achieved over the plate. Also, take added precautions to ensure that material over the plate is not removed accidently during removal of sediment from the basin.
Anti-Seep Collars	Use anti-seep collars on the barrel of the principal spillway within the normal saturation zone of the embankment to increase the seepage length by at least 10% under either of the following two conditions: 1. The settled height of the embankment exceeds 10 feet. 2. The embankment has a low silt-clay content (Unified Soil Classes SM or GM), and the barrel is greater than 10 inches in diameter. Install the anti-seep collars within the saturated zone. Design the maximum spacing between collars to be 14 times the projection of the collars above the barrel. Do not locate collars closer than 2 feet from a pipe joint. Space collars sufficiently to allow passage of hauling and compacting equipment. Ensure that 95% compaction is achieved around the collars. Ensure watertight connections between the collars and the barrel. See Figure C-SCM-12-4 for details.

Table C-SCM-12-1 Design Criteria Parameters	
Parameter	**Details**
Alternatives to Anti-Seep Collars	Anti-seep collars are designed to control seepage and piping along the barrel by increasing the flow length along the barrel. Due to the constraints that collars impose on embankment fill placement and compaction, collars may sometimes be ineffective or result in an increase in seepage and piping. Measures alternative to the use of anti-seep collars have been developed and incorporated into embankment designs. These include a structure known as a "filter diaphragm," or a layer of sand and fine gravel that runs through the dam embankment perpendicular to the barrel. The filter diaphragm is 4 to 5 inches wide, approximately 1 foot tall and is located where the barrel elevation intersects with the upper bounds of the seepage zone. The measure controls the transport of embankment fines, which is the major concern with piping and seepage. The diaphragm channels any undesirable flow through the fine-graded material, which traps embankment material. The flow is then conveyed out of the embankment through a perforated toe drain. The critical design element of the filter diaphragm is the grain-size distribution of the filter material determined by the grain-size distribution of the embankment fill material. Base the use and design of these measures on site-specific geotechnical information, and have the installation supervised by a qualified professional.
Discharge	Release concentrated stormwater flow from a temporary sediment basin into an adequate stormwater conveyance system. 1. Adequacy of all stormwater conveyance systems should be verified in the following manner: a. Demonstrate that the total drainage area at the point of discharge within the stormwater conveyance system is at least 100 times greater than the drainage area served by the temporary sediment basin in question, **OR** b. Analyze the manmade stormwater conveyance systems using the 2-year storm event to demonstrate that stormwater flow will be contained within the system and will not cause erosion of the system, **OR** c. Analyze the manmade stormwater conveyance systems using the 2-year storm event to demonstrate that stormwater flow will be contained within the system and will not cause erosion of the system, **OR** d. Analyze the restored stormwater conveyance systems to demonstrate that stormwater flow, in combination with other stormwater runoff, is consistent with the design parameters of the restored stormwater conveyance system, **OR** e. Analyze the restored stormwater conveyance systems to demonstrate that stormwater flow, in combination with other stormwater runoff, is consistent with the design parameters of the restored stormwater conveyance system, **OR** f. Analyze the natural stormwater conveyance systems using the 2-

Table C-SCM-12-1 Design Criteria Parameters	
Parameter	**Details**
	year storm event to demonstrate that stormwater flow will be contained within the system and will not cause erosion of the system. 2. If an existing manmade stormwater conveyance system is not adequate: a. Improve the manmade stormwater conveyance system to contain the 2-year storm event within the system and does not cause erosion of the system, **OR** b. Develop a temporary sediment basin design that will not cause the pre- development peak runoff rate from a 2-year storm event to increase, **OR** c. Provide a combination of manmade stormwater conveyance system improvement, stormwater detention, or other measures. 3. If an existing restored stormwater conveyance system is not adequate, develop a temporary sediment basin design to ensure that stormwater flow, in combination with other stormwater runoff, is consistent with the design parameters of the restored stormwater conveyance system. 4. If an existing natural stormwater conveyance system is not adequate: a. Improve the natural stormwater conveyance system to contain the 2-year storm event within the system and does not cause erosion of the system, **OR** b. Develop a temporary sediment basin design that will not cause the pre- development peak runoff rate from a 2-year, 24-hour storm event to increase, **OR** c. Provide a combination of natural stormwater conveyance system improvement, stormwater detention, or other measures.

Figure C-SCM-12-1 Minimum Storage Volume

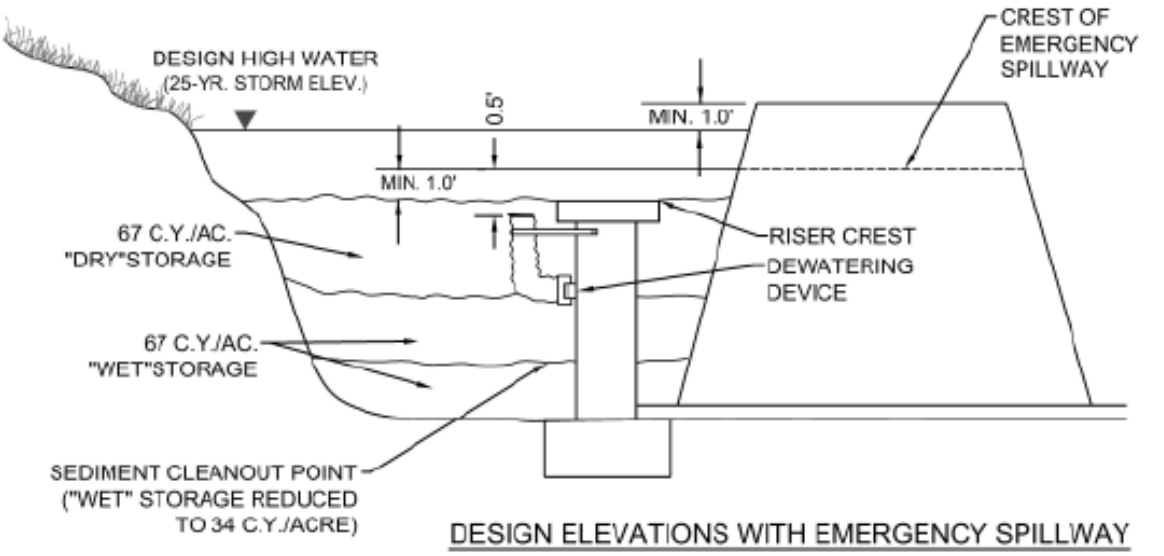


Source: VA DSWC

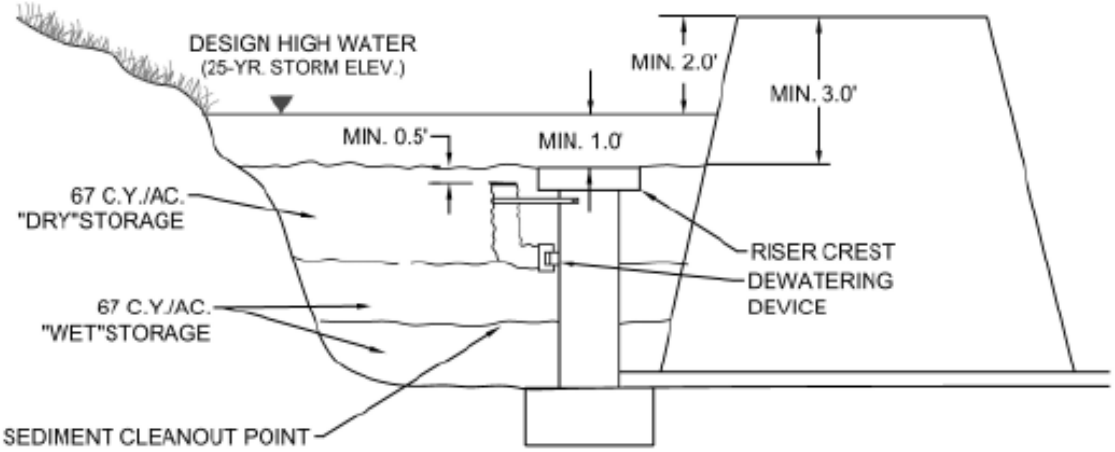
Table C-SCM-12-2 Emergency Spillway Design	
Emergency Spillway	
Design & Construction	The emergency spillway acts as a safety release for a sediment basin, or any impoundment-type structure, by conveying the larger, less frequent storms through the basin without damage to the embankment. The emergency spillway also acts as its name implies – in case of an emergency such as excessive sedimentation or damage to the riser that prevents flow through the principal spillway. Design the emergency spillway to consist of an open channel (earthen and vegetated) constructed adjacent to the embankment over undisturbed material (not fill). Where conditions will not allow the construction of an emergency spillway on undisturbed material, a spillway may be constructed of a non-erodible material such as riprap. Design the spillway to have a control section at least 20 feet long. The control section is a level portion of the spillway channel at the highest elevation in the channel. See Figure C-SCM-12-5 for details. Evaluate site and downstream conditions to determine the feasibility and justification for the incorporation of an emergency spillway. In some cases, the site topography does not allow construction of a spillway to in undisturbed material, and the temporary nature of the facility may not warrant the cost of disturbing more acreage to construct and armor a spillway. In such cases, size the principal spillway to convey all the design storms. If the facility is designed as a permanent facility with downstream restrictions, the added expense of constructing and armoring an emergency spillway may be justified.
Capacity	Design the emergency spillway to carry the portion of the peak rate of runoff expected from a 25-year storm that is not carried by the principal spillway.
Design Elevations	Design the 25-year storm elevation through the emergency spillway to be at least 1 foot below the top of the embankment. Design the crest of the emergency spillway channel to be at least 1 foot above the crest of the principal spillway.
Location	Locate the emergency spillway channel so that it will not be constructed over fill material. Locate the channel to avoid sharp turns or bends. Design the channel to return the flow of water to a defined channel downstream from the embankment.
Maximum Velocities	The maximum allowable velocity in the emergency spillway channel will depend on the type of lining used. For vegetated linings, allowable velocities are listed in Table C-ECM-09-2 in Stormwater Conveyance Channel (BMP C-ECM-09). For non-erodible linings, such as concrete or riprap, design velocities may be increased. However, design the emergency spillway channel to return the flow to the receiving channel at a non-eroding velocity.

Table C-SCM-12-2 Emergency Spillway Design	
Emergency Spillway	
Stabilization	Install temporary or permanent seeding to the spillway channel section of the sediment basin immediately after installation, see Temporary Seeding (BMP C-SSM-09) or Permanent Seeding (BMP C-SSM-10). If excavation is required in the basin, design the side slopes to be no steeper than 1.5H:1V.
Disposal	Remove sediment from the basin when the sediment level is no higher than 1 foot below the bottom of the dewatering orifice, or one half of the permanent pool volume, whichever is lower. On plans for the sediment basin, indicate the methods for disposing of sediment removed from the basin. Possible options are the use of the material in fill areas on site or removal to an approved off-site location. On the sediment basin plans, indicate the final disposition of the sediment basin after stabilization of the upstream drainage area including methods for the removal of excess water lying over the sediment, stabilization of the basin site, and the disposal of any excess material. Where the sediment basin has been designed as a permanent stormwater management basin, on the plans, address the steps necessary for the conversion from sediment basin to a permanent detention or retention facility.
Safety	Sediment basins can be appealing to children and can be dangerous. Install fence around or otherwise make inaccessible sediment basins to persons or animals unless this is deemed unnecessary by the certified plan reviewer due to the remoteness of the site or other circumstances. Install strategically placed signs around the impoundment reading “DANGER- QUICKSAND”. In any case, adhere to local ordinances and regulations regarding health and safety, see Safety Fence (BMP C-PCM-01).

Figure C-SCM-12-2 Sediment Basin Design Elevation



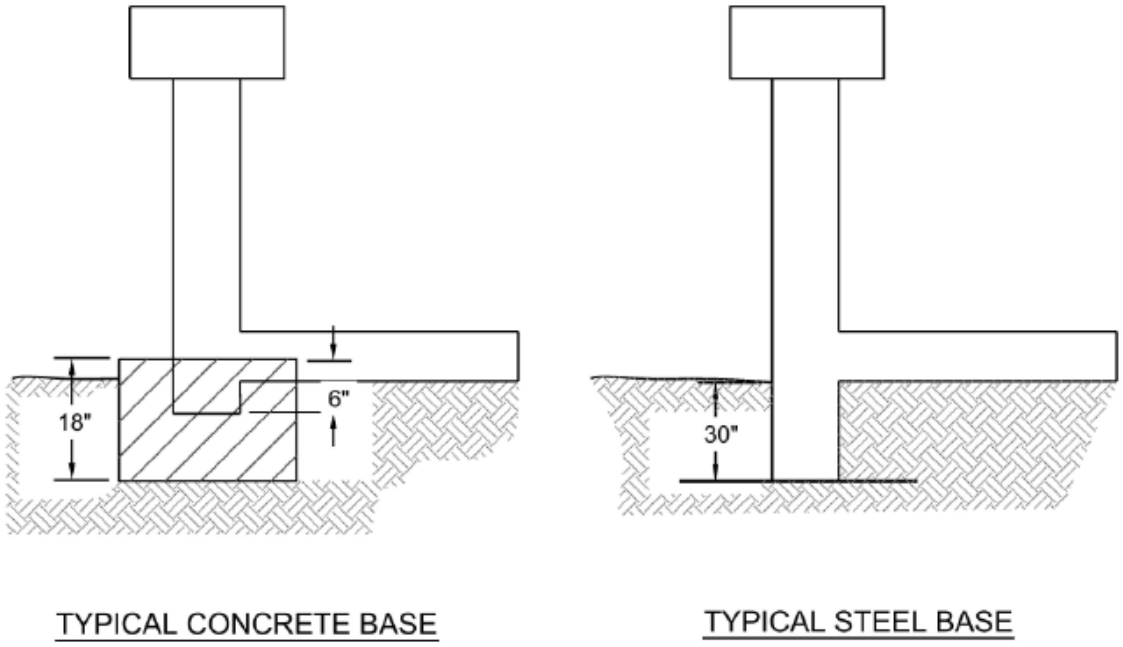
DESIGN ELEVATIONS WITH EMERGENCY SPILLWAY



DESIGN ELEVATIONS WITHOUT EMERGENCY SPILLWAY
(RISER PASSES 25-YEAR EVENT)

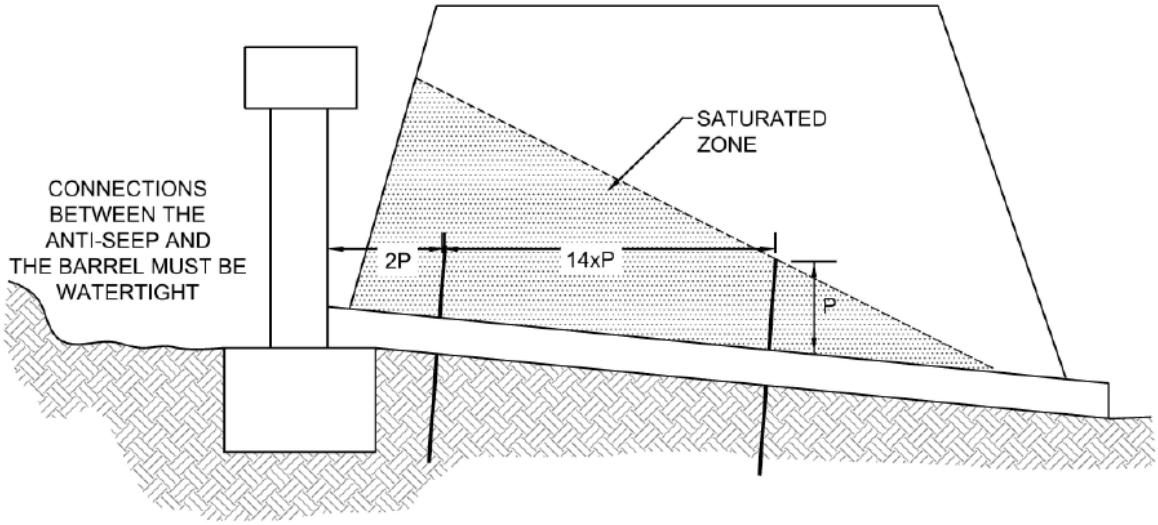
Source: VA DSWC

Figure C-SCM-12-3 Riser Pipe Base Conditions



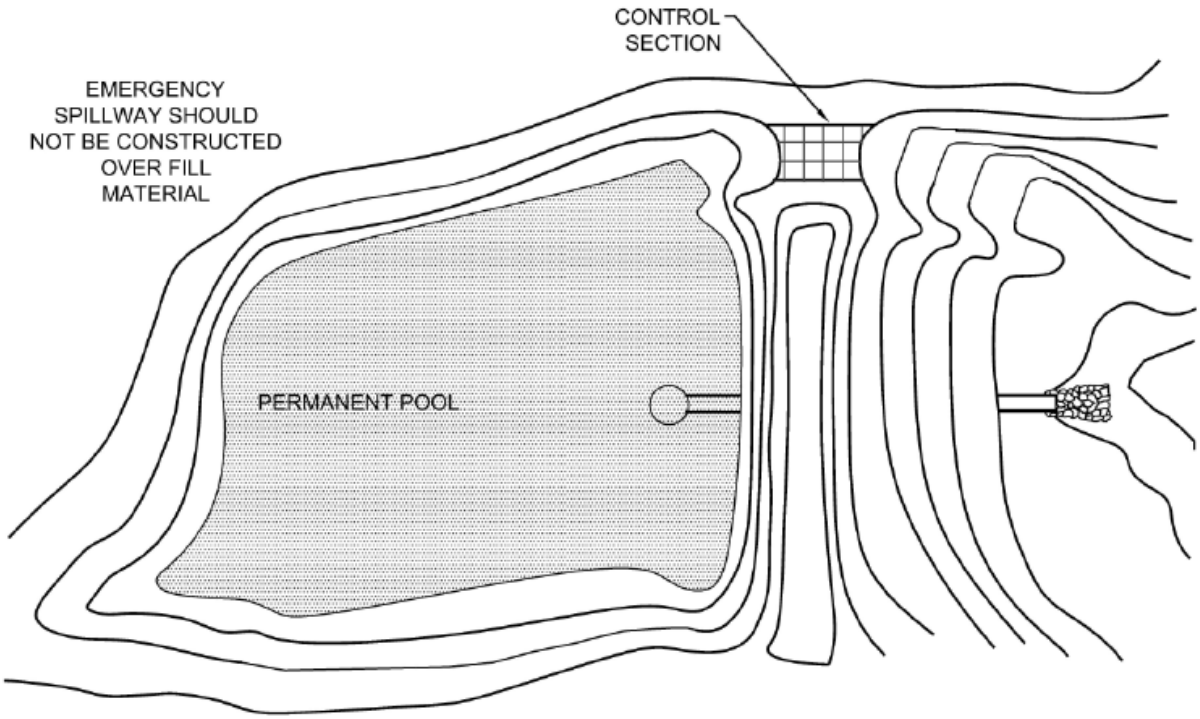
Source: VA DSWC

Figure C-SCM-12-4 Anti-Seep Collar Design



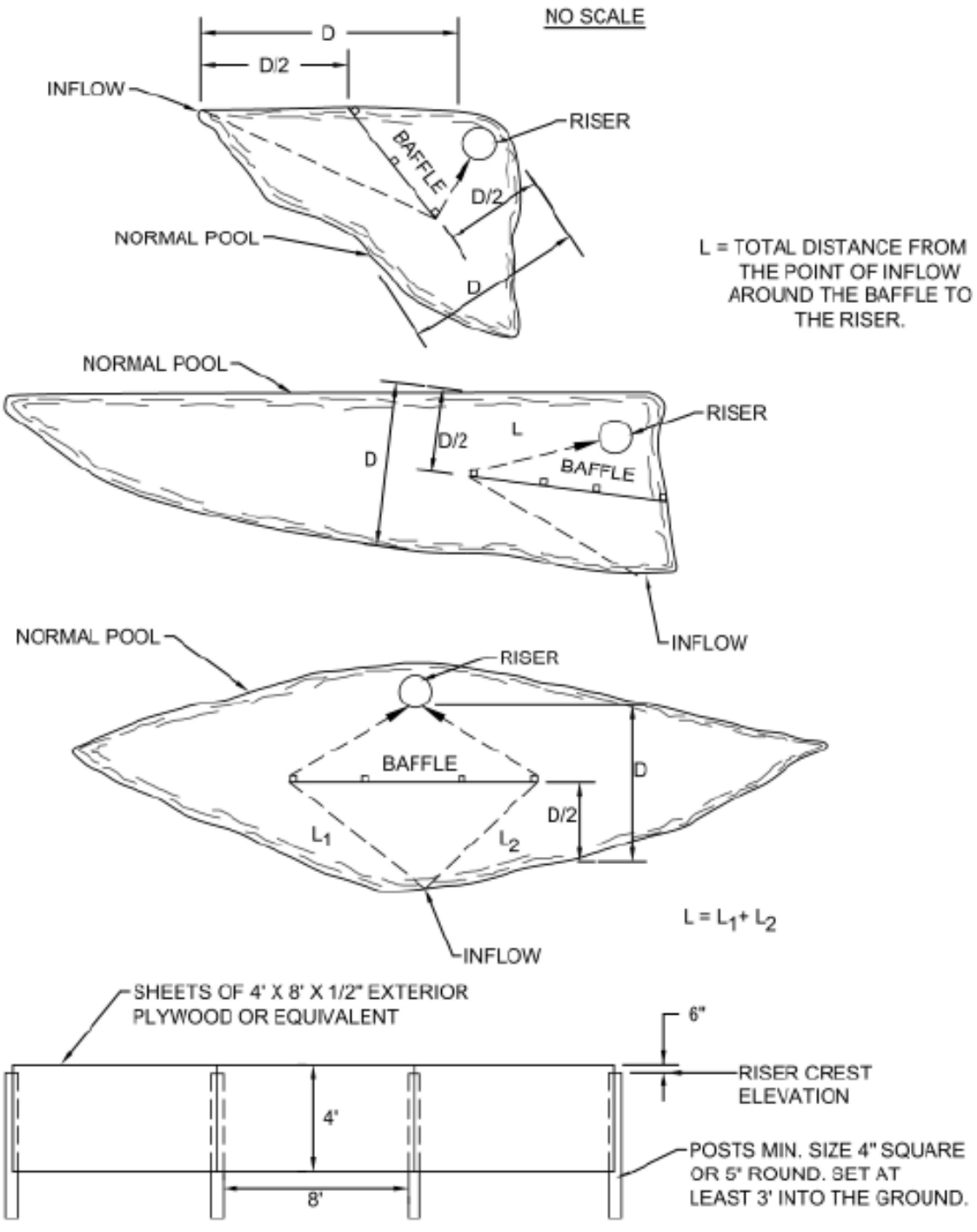
Source: VA DSWC

Figure C-SCM-12-5 Emergency Spillway Design



Source: VA DSWC

Figure C-SCM-12-6 Baffle Board Inclusion Considerations and Design



Source: USDA SCS

6.0 Construction Specifications

Table C-SCM-12-3 Construction Specifications and Criteria

Component	Details
Site Preparation	Clear, grub, and strip the areas under the embankment or any structural works related to the basin of topsoil to remove trees, vegetation, roots, or other objectionable material. To facilitate cleanout and restoration, clear the area of most frequent inundation (measured from the top of the principal spillway) of all brush and trees.
Cutoff Trench	For earth-fill embankments, excavate a cutoff trench along the centerline of the dam. Extend the trench at least 1 foot into a stable, impervious layer of soil and establish a minimum depth of 2 feet. Extend the cutoff trench up both abutments to the riser crest elevation. Construct the cutoff trench with a minimum bottom width of 4 feet, but wide enough to permit operation of compaction equipment. Construct the trench with side slopes no steeper than 1H:1V. Use the same compaction requirements as those for the embankment. Drain the trench during the backfilling/compacting operations.
Embankment	Take the fill material from approved borrow areas. Ensure the material is clean mineral soil, free of roots, woody vegetation, stumps, sod, oversized stones, rocks, or other perishable or objectionable material. Ensure the material selected has enough strength for the dam to remain stable and be tight enough, when properly compacted, to prevent excessive percolation of water through the dam. Fill containing particles ranging from small gravel or coarse sand to fine sand and clay in desired proportions is appropriate. Ensure any embankment material contains approximately 20% clay particles by weight. Using the Unified Soil Classification System, SC (clayey sand), GC (clayey gravel), and CL (low liquid limit clay) are among the preferred types of embankment soils. Scarify areas on which fill is to be placed before placement of fill. Ensure the fill material contains the proper amount of moisture to ensure achievement of 95% compaction. Place fill material in 6-inch continuous layers over the entire length of the fill. Achieve compaction by routing the hauling equipment over the fill so that the entire surface of the fill is traversed by at least one wheel or tread track of the equipment, or by using a compactor. Take special care when compacting around the anti-seep collars (compact by hand, if necessary) to avoid damage and achieve desired compaction. Construct the embankment to an elevation 10% higher than the design height to allow for settlement if compaction is accomplished with hauling equipment. If compactors are used for compaction, reduce the overbuild to not less than 5%.

Table C-SCM-12-3 Construction Specifications and Criteria	
Component	**Details**
Principal Spillway	Securely attach the riser of the principal spillway to the barrel by a watertight connection. Place the barrel and riser on a firmly compacted soil foundation. Firmly anchor the base of the riser according to design criteria to prevent its floating. Do not use pervious materials (such as sand, gravel, or crushed stone) as backfill around the barrel or anti-seep collars. Take special care when compacting around the anti-seep collars (compact by hand, if necessary). Place fill material around the pipe in 4-inch layers and compact until 95% compaction is achieved. Hand-compact a minimum of 2 feet of fill over the barrel before crossing it with construction equipment.
Emergency Spillway	Do not construct vegetated emergency spillways over fill material. Design elevations, widths, and entrance and exit channel slopes are critical to the successful operation of the spillway and should be closely followed during construction.
Inlets	Discharge water into the basin in a manner that prevents erosion. Use diversions with outlet protection to divert sediment-laden water to the upper end of the pool area to improve basin efficiency. To prevent eroding the slope of the basin wall, use a slope drain or a stabilized, lined channel to convey concentrated stormwater flows to the wet storage pool.
Vegetative Stabilization	Stabilize the embankment and emergency spillway of the sediment basin with temporary or permanent vegetation immediately after installation of the basin (see Temporary Seeding (C-SSM-09) or Permanent Seeding (C-SSM-10). Vegetative stabilization of the sediment basin and the areas around it will improve the water quality in the basin and reduce the need for maintenance. Stabilize outside slopes with soil stabilization blankets and matting, refer to Soil Stabilization Blankets and Matting (C-SSM-05). Do not plant trees on any basin embankment because the root systems may compromise the integrity of the berm over time. Trees may be planted in the non- embankment (pool) areas of permanent basins.
Erosion and Sediment Control	Construct the sediment basin in accordance with all the appropriate construction best management practices outlined within, so that the basin itself does not cause a degradation of downstream water quality and habitat.
Safety	Meet all state and local requirements concerning fencing and signs warning the public of the hazards of soft, saturated sediment and flood waters, refer to Safety Fence (C-PCM-01).

Table C-SCM-12-3 Construction Specifications and Criteria	
Component	**Details**
Final Disposal	When temporary structures have served their intended purpose, and the contributing drainage area has been properly stabilized, level or otherwise dispose of the embankment and resulting sediment deposits in accordance with the approved erosion and sediment control plan. The proposed use of a sediment basin site will often dictate final disposition of the basin and any sediment contained therein. If the site is scheduled for future construction, then remove the basin material and trapped sediments, safely dispose of the removed material, and backfill with a structural fill. When the basin area is to remain open space, pump dry, grade, and backfill the basin.

6.1 Temporary to Permanent Basin Conversion

Design permanent basins used temporarily as sediment basins to meet the requirements of the permanent basin (e.g., side slopes, permanent outlet structures, benches, forebays, access ramps, and preservation/remediation of subsoils for infiltration rates). Construct sediment basins that will be converted to post-construction stormwater BMPs that utilize infiltration in the design in accordance with the appropriate specification.

Note that the risk of infiltration failure may increase significantly for infiltration BMPs used as sediment basins during construction. Soil compaction by construction vehicles in these areas may also reduce the intended infiltration capacity in the area.

7.0 Operations and Maintenance Considerations

Inspect the basin embankment regularly to ensure that it is structurally sound and has not been damaged by erosion or construction equipment.

Inspect the emergency spillway regularly to ensure that its lining is well established and erosion-resistant. After every runoff producing rainfall, inspect the principal spillway and dewatering orifice for clogging and remove accumulated debris to maintain free flow from the basin. Inspect the vegetative stabilization, soil stabilization matting, slope drains and baffles if present, and maintain or repair immediately.

Inspect the basin after each runoff-producing rainfall for sediment cleanout. When the sediment reaches the cleanout level, remove and properly dispose of the sediment.

Inspect the basin for sinkhole formation, and if found, repair promptly.

8.0 References

North Carolina Department of Environmental Quality. 2017. *Stormwater Design Manual*.

North Carolina Sedimentation Control Commission, et al. 2013. *Erosion and Sediment Control Planning and Design Manual*.

Pennsylvania Department of Environmental Protection. 2012. *Erosion and Sediment Pollution Control Program Manual*. Final ed.

Washington State Department of Transportation Engineering and Regional Operations, Development Division, Design Office. 2019. *Temporary Erosion and Sediment Control Manual*.

9.0 Appendix A Design Procedure for Temporary Sediment Basins

The following design procedure provides a step-by-step method for designing a temporary sediment basin. The data sheet included in the end of this Appendix should be used in the erosion and sediment control plan to document design values calculated.

Note, if the drainage basin is on karst, review the design considerations listed in Section 3.0 Planning and Considerations.

I. **Basin Volume**

A. Determine the required basin volume. Design the storage capacity of the basin to be at least 134 cubic yards per acre of total contributing drainage area, half of which is in the form of a permanent pool or wet storage, and the remaining half as a "drawdown" area or dry storage.

1. For a natural basin, the wet storage volume may be approximated as follows:

$$V_1 = 0.4 \times A_1 \times D_1$$

where,

V_1 = the wet storage volume (cubic feet)

A_1 = the surface area of the flooded area at the invert of the dewatering outlet (square feet)

D_1 = the maximum depth (feet), measured from the low point in the basin to the invert of the dewatering outlet

2. For a natural basin, the dry storage volume may be approximated as follows:

$$V_2 = \frac{A_1 \times A_2}{2} \times D_2$$

where,

V_2 = the dry storage volume (cubic feet)

A_2 = the surface area of the flooded area at the crest of the principal spillway (square feet)

D_2 = the depth (feet), measured from the invert of the dewatering outlet to the crest of the principal spillway

Note 1: The volumes may be computed from more precise contour information or other suitable data.

Note 2: Convert between cubic feet and cubic yards using the following equation:
number of cubic feet x 0.037 number of cubic yards.

B. If the volume of the basin is inadequate, or embankment height becomes excessive, excavate to obtain the required volume.

II. **Basin Shape**

A. The shape of the basin must align with a length-to-width ratio of at least 2 to 1 according to the following equation:

$$\text{Length-to-width Ratio} = \frac{L}{W_e}$$

where,

W_e = A/L = the effective width

A = the surface area of the normal pool

L = the length of the flow path from the inflow to the outflow. If there is more than one inflow point, any inflow that carries more than 30% of the peak rate of inflow must meet these criteria.

B. The correct basin shape can be obtained by proper site selection, excavation, or the use of baffles. Baffles increase the flow length by deflecting the flow. The baffles should be placed halfway between the inflow point and the outflow. Figure C-SCM-12-6 shows the detail for baffle construction and three situations for which baffles might be used.

III. **Determine whether the basin will have a separate emergency spillway.**

IV. **Determine the elevation of the crest of the principal spillway for the required volume (dewatering orifice at 67 cubic yards per acre and crest of principal spillway 134 cubic yards per acre).**

V. **Estimate the elevation of the design high water and the required height of the dam.**

A. If an emergency spillway is included:

1. Design the crest of the principal spillway to be at least 1 foot below the crest of the emergency spillway.
2. Design the elevation of the peak flow through the emergency spillway (which will be the design high water for the 25-year storm) to be at least 1 foot below the top of embankment.

B. If an emergency spillway is not included:

1. Design the crest of the principal spillway to be at least 3 feet below the top of the embankment.
2. Design the elevation of the design high water for the 25-year storm to be 2 feet below the top of the embankment.

VI. **Determine the peak rate of runoff expected from the drainage area of the basin for a 25-year storm. Derive the "C" factor or "CN" value used in the runoff calculations from analysis of the contributing drainage area at the peak of land disturbance (condition that will create greatest peak runoff).**

VII. **Principal Spillway Design**

A. If an emergency spillway is included, design the principal spillway to at least pass the peak rate of runoff from the basin drainage area for a 2-year storm.

1. Q_p = the 2-year peak rate of runoff

B. If an emergency spillway is not included, design the principal spillway to pass the peak rate of runoff from the basin drainage area for a 25-year storm.

1. Q_p = the 25-year peak rate of runoff

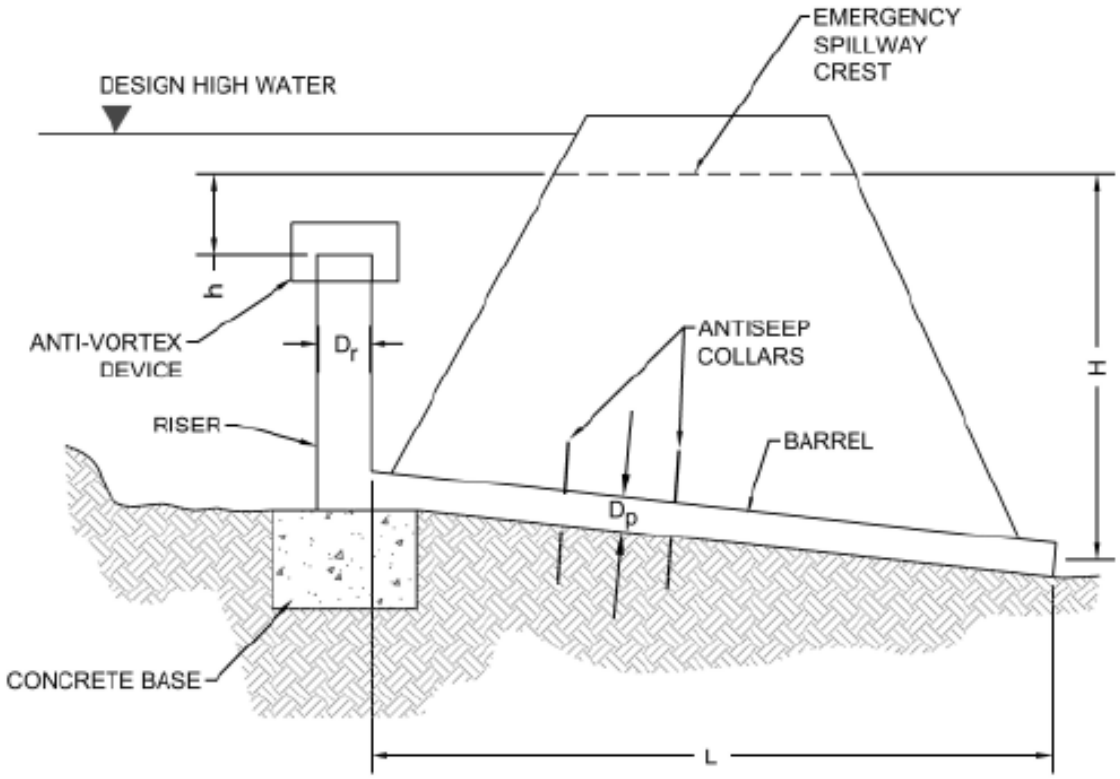
C. Refer to Figure C-SCM-12-7, where h is the difference between the elevation of the crest of the principal spillway and the elevation of the crest of the emergency spillway.

D. Enter Figure C-SCM-12-7 with Q_p. Choose the smallest riser that will pass the required flow with the available head (h).

E. Refer to Figure C-SCM-12-7, where H is the difference in elevation of the centerline of the outlet of the barrel and the crest of the emergency spillway. L is the length of the barrel through the embankment.

F. Enter H in Table C-SCM-12-7. Choose the smallest size barrel that will pass the flow provided by the riser. If L is other than 70 feet, make the necessary correction.

Figure C-SCM-12-7 Principal Spillway Design



H = HEAD ON PIPE THROUGH EMBANKMENT

h = HEAD OVER RISER CREST

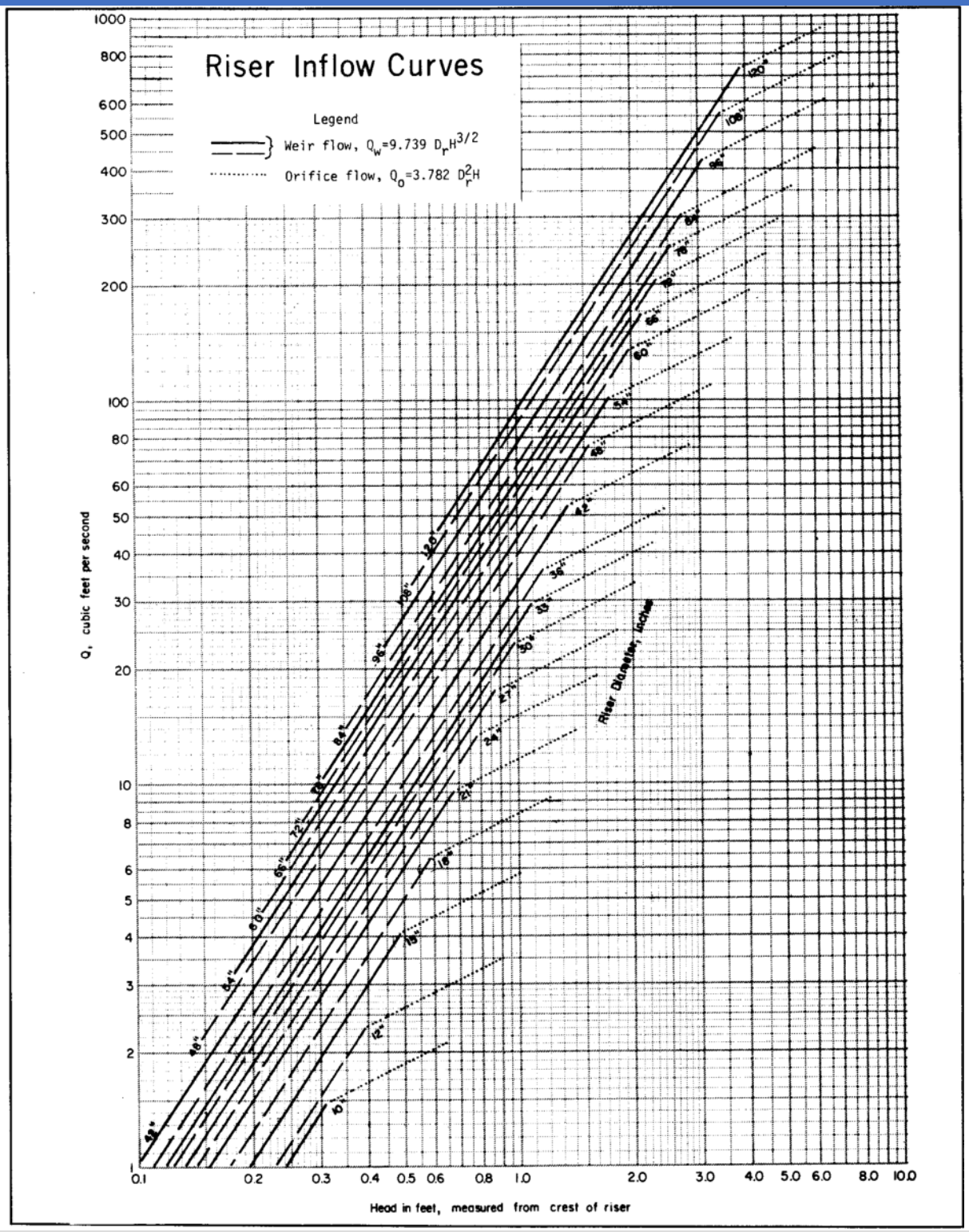
L = LENGTH OF PIPE THROUGH EMBANKMENT

D_p = DIAMETER OF PIPE THROUGH EMBANKMENT

D_r = DIAMETER OF RISER

Source: VA DSWC

Figure C-SCM-12-8 Riser Inflow Curves



Source: USDA-SCS

Table C-SCM-12-4 Pipe Flow Chart, n = 0.025																					
H, in feet	**6"**	**8"**	**10"**	**12"**	**15"**	**18"**	**21"**	**24"**	**30"**	**36"**	**42"**	**48"**	**54"**	**60"**	**66"**	**72"**	**78"**	**84"**	**90"**	**96"**	**102"**
1	0.33	0.7	1.25	1.98	3.48	5.47	7.99	11	18.8	28.8	41.1	55.7	72.6	91.8	113	137	163	191	222	255	290
2	0.47	0.99	1.76	2.8	4.92	7.74	11.3	15.6	26.6	40.8	58.2	78.8	103	130	160	194	231	271	314	360	410
3	0.58	1.22	2.16	3.43	6.02	9.48	13.8	19.1	32.6	49.9	71.2	96.5	126	159	196	237	282	331	384	441	502
4	0.67	1.4	2.49	3.97	6.96	10.9	16	22.1	37.6	57.7	82.3	111	145	184	226	274	326	383	444	510	580
5	0.74	1.57	2.79	4.43	7.78	12.2	17.9	24.7	42.1	64.5	92	125	162	205	253	306	365	428	496	570	648
6	0.82	1.72	3.05	4.86	8.52	13.4	19.6	27	46.1	70.6	101	136	178	225	277	336	399	469	544	624	710
7	0.88	1.86	3.3	5.25	9.2	14.5	21.1	29.2	49.8	76.3	109	147	192	243	300	362	431	506	587	674	767
8	0.94	1.99	3.53	5.61	9.84	15.5	22.6	31.2	53.2	81.5	116	158	205	260	320	388	461	541	628	721	820
9	1.00	2.11	3.74	5.95	10.4	16.4	24	33.1	56.4	86.5	123	167	218	275	340	411	489	574	666	764	870
10	1.05	2.22	3.94	6.27	11	17.3	25.3	34.9	59.5	91.2	130	176	230	290	358	433	516	605	702	806	917
11	1.10	2.33	4.13	6.58	11.5	18.2	26.5	36.6	62.4	95.6	136	185	241	304	376	454	541	635	736	845	962
12	1.15	2.43	4.32	6.87	12.1	19	27.7	38.2	65.2	99.9	142	193	252	318	392	475	565	663	769	883	1004
13	1.20	2.53	4.49	7.15	12.6	19.7	28.8	39.8	67.8	104	148	201	262	331	408	494	588	690	800	919	1045
14	1.25	2.63	4.66	7.42	13	20.5	29.9	41.3	70.4	108	154	208	272	343	424	513	610	716	830	953	1085
15	1.29	2.72	4.83	7.68	13.5	21.2	30.9	42.8	72.8	112	159	216	281	355	439	531	631	741	860	987	1123
16	1.33	2.81	4.99	7.93	13.9	21.9	32	44.2	75.2	115	165	223	290	367	453	548	652	765	888	1019	1160
17	1.37	2.9	5.14	8.18	14.3	22.6	32.9	45.5	77.5	119	170	230	229	378	467	565	672	789	915	1051	1195
18	1.41	2.98	5.29	8.41	14.8	23.2	33.9	46.8	79.8	120	174	236	308	389	480	581	692	812	942	1081	1230
19	1.45	3.06	5.43	8.64	15.2	23.9	34.8	48.1	82	126	179	243	316	400	494	597	711	834	967	1111	1264
20	1.49	3.14	5.57	8.87	15.6	24.5	35.7	49.4	84.1	129	184	249	325	410	506	613	729	856	993	1139	1297
21	1.53	3.22	5.71	9.09	15.9	25.1	36.6	50.6	86.2	132	188	255	333	421	519	628	747	877	1017	1168	1329
22	1.56	3.29	5.85	9.3	16.3	25.7	37.5	51.8	88.2	135	193	261	341	430	531	643	765	898	1041	1195	1360
23	1.60	3.37	5.98	9.51	16.7	26.2	38.3	53	90.2	138	197	267	348	440	543	657	782	918	1064	1222	1390
24	1.63	3.44	6.11	9.72	17	26.8	39.1	54.1	92.1	141	201	273	356	450	555	671	799	937	1087	1248	1420
25	1.66	3.51	6.23	9.92	17.4	27.4	39.9	55.2	94	144	206	279	363	459	566	685	815	957	1110	1274	1450
26	1.7	3.58	6.36	10.1	17.7	27.9	40.7	56.3	95.9	147	210	284	370	468	577	699	831	976	1132	1299	1478
27	1.73	3.65	6.48	10.3	18.1	28.4	41.5	57.4	97.7	150	214	290	377	477	588	712	847	994	1153	1324	1507
28	1.76	3.72	6.6	10.5	18.4	29	42.3	58.4	99.5	153	218	295	384	486	599	725	863	1013	1174	1348	1534
29	1.79	3.78	6.71	10.7	18.7	29.5	43	59.5	101	155	221	300	391	494	610	738	878	1030	1195	1372	1561
30	1.82	3.85	6.83	10.9	19.1	30	43.7	60.5	103	158	225	305	398	503	620	750	893	1048	1216	1396	1588
L, in feet	**Correction Factors for Other Pipe Lengths**																				
20	1.69	1.63	1.58	1.53	1.47	1.42	1.37	1.34	1.28	1.24	1.2	1.18	1.16	1.14	1.13	1.11	1.1	1.1	1.09	1.08	1.08
30	1.44	1.41	1.39	1.36	1.32	1.29	1.27	1.24	1.21	1.18	1.15	1.13	1.12	1.11	1.1	1.09	1.08	1.07	1.07	1.06	1.06
40	1.28	1.27	1.25	1.23	1.21	1.2	1.18	1.17	1.14	1.12	1.11	1.1	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.05	1.04
50	1.16	1.16	1.15	1.14	1.13	1.12	1.11	1.1	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.03
60	1.07	1.07	1.07	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.94	0.94	0.95	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99
90	0.89	0.89	0.9	0.9	0.91	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.94
100	0.85	0.85	0.86	0.86	0.87	0.88	0.89	0.89	0.9	0.91	0.92	0.93	0.93	0.94	0.94	0.95	0.95	0.95	0.96	0.96	0.94
120	0.78	0.79	0.79	0.9	0.81	0.82	0.83	0.83	0.85	0.86	0.87	0.89	0.89	0.9	0.91	0.89	0.92	0.93	0.93	0.94	0.92
140	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.81	0.82	0.84	0.85	0.86	0.87	0.88	0.86	0.89	0.9	0.91	0.91	0.9
160	0.68	0.69	0.69	0.7	0.71	0.73	0.74	0.75	0.77	0.79	0.8	0.82	0.83	0.84	0.85	0.92	0.87	0.88	0.89	0.89	

Notes:

For corrugated metal pipe inlet Km = Kc + Kb = 1.0 and 70 feet of corrugated metal pipe conduit (full flow assumed)

Correction factors for pipe lengths other than 70 feet diameter of pipe in inches

Source: USDA-SCS

Table C-SCM-12-5 Pipe Flow Chart, n = 0.013																		
H, in feet	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
1	3.22	5.44	8.29	11.8	15.9	26.0	38.6	53.8	71.4	91.5	114	139	167	197	229	264	302	342
2	4.55	7.69	11.7	16.7	22.5	36.8	54.6	76	101	129	161	197	236	278	324	374	427	483
3	5.57	9.42	14.4	20.4	27.5	45.0	66.9	931	124	159	198	241	289	341	397	458	523	592
4	6.43	10.9	16.6	23.5	31.8	52.0	77.3	108	143	183	228	278	334	394	459	529	604	683
5	7.19	12.2	18.5	26.3	35.5	58.1	86.4	120	160	205	255	311	373	440	513	591	675	764
6	7.88	13.3	20.3	28.8	38.9	63.7	94.6	132	175	224	280	341	409	482	562	647	739	837
7	8.51	14.4	21.9	31.1	42.0	68.8	102	142	189	242	302	368	441	521	607	699	798	904
8	9.10	15.4	23.5	33.3	44.9	73.5	109	152	202	259	323	394	472	557	685	748	854	966
9	9.65	16.3	24.9	35.3	47.7	78.0	116	161	214	275	342	418	500	590	688	793	905	1025
10	10.20	17.2	26.2	37.2	50.2	82.2	122	170	226	289	361	440	527	622	725	836	954	1080
11	10.70	18.0	27.5	39.0	52.7	86.2	128	178	237	304	379	462	553	653	761	877	1001	1133
12	11.10	18.9	28.7	40.8	55.0	90.1	134	186	247	317	395	482	578	682	794	916	1045	1184
13	11.60	19.6	29.9	42.4	57.3	93.7	139	194	257	330	411	502	601	710	827	953	1088	1232
14	12.00	20.4	31.0	44.1	59.4	97.3	145	201	267	342	427	521	624	736	858	989	1129	1278
15	12.50	21.1	32.1	45.6	61.5	101	150	208	277	354	442	539	646	762	888	1024	1169	1323
16	12.90	21.8	33.2	47.1	63.5	104	155	215	286	366	457	557	667	787	917	1057	1207	1367
17	13.30	22.4	34.2	48.5	65.5	107	159	222	294	377	471	574	688	812	946	1090	1244	1409
18	13.70	23.1	35.2	49.9	67.4	110	164	228	303	388	484	591	708	835	973	1121	1280	1450
19	14.00	23.7	36.1	51.3	69.2	113	168	234	311	399	497	607	727	858	1000	1152	1315	1489
20	14.40	24.3	37.1	52.6	71.0	116	173	240	319	409	510	623	746	880	1026	1182	1350	1528
21	14.70	24.9	38.0	53.9	72.8	119	177	246	327	419	523	638	764	902	1051	1211	1383	1566
22	15.10	25.5	38.9	55.2	74.5	122	181	252	335	429	535	653	782	923	1076	1240	1415	1603
23	15.40	26.1	39.8	56.5	76.2	125	186	258	342	439	547	668	800	944	1100	1268	1447	1639
24	15.80	26.7	40.6	57.7	77.8	127	189	263	350	448	559	682	817	964	1123	1295	1478	1674
25	16.10	27.2	41.5	58.9	79.4	130	193	269	357	458	571	696	834	984	1147	1322	1509	1708
26	16.40	27.7	42.3	60.0	81.0	133	197	274	364	467	582	710	850	1004	1169	1348	1539	1742
27	16.70	28.3	43.1	61.2	82.5	135	201	279	371	476	593	723	867	1023	1192	1373	1568	1775
28	17.00	28.8	43.9	62.3	84.1	138	204	285	378	484	604	737	883	1041	1214	1399	1597	1808
29	17.30	29.3	44.7	63.4	85.5	140	208	290	384	493	615	750	898	1060	1235	1423	1625	1840
30	17.60	29.8	45.4	64.5	87.0	142	212	294	391	501	625	763	913	1078	1256	1448	1653	1871
L, in feet	**Correction Factors for Other Pipe Lengths**																	
20	1.30	1.24	1.21	1.18	1.15	1.12	1.10	1.08	1.07	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.03
30	1.22	1.18	1.15	1.13	1.12	1.09	1.08	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02
40	1.15	1.13	1.11	1.10	1.08	1.07	1.05	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02
50	1.09	1.08	1.07	1.06	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01
60	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
90	0.93	0.94	0.94	0.95	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99
100	0.90	0.91	0.92	0.93	0.93	0.95	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.99
120	0.84	0.86	0.87	0.89	0.90	0.91	0.93	0.94	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.98
140	0.80	0.82	0.83	0.85	0.86	0.88	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.97
160	0.76	0.78	0.80	0.82	0.83	0.86	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95	0.96

Notes:

For reinforced concrete pipe inlet Km = Kc + Kb = 0.65 and 70 feet of corrugated metal pipe conduit (full flow assumed)

Correction factors for pipe lengths other than 70 feet diameter of pipe in inches

Source: USDA-SCS

Table C-SCM-12-6 Design Data for Earth Spillways																		
Stage (Hp) in Feet	Spillway Variables	Bottom Width (b) in Feet																
		8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
0.5	Q	6	7	8	10	11	13	14	15	17	18	20	21	22	24	25	27	28
	V	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	S	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	X	32	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
0.6	Q	8	10	12	14	16	18	20	22	24	26	28	30	32	34	35	37	39
	V	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	S	3.7	3.7	3.7	3.7	3.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	X	36	36	36	36	36	36	37	37	37	37	37	37	37	37	37	37	37
0.7	Q	11	13	16	18	20	23	25	28	30	33	35	38	41	43	44	46	48
	V	3.2	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
	S	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	X	39	40	40	40	41	41	41	41	41	41	41	41	41	41	41	41	41
0.8	Q	13	16	19	22	26	29	32	35	38	42	45	46	48	51	54	57	60
	V	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	S	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	X	44	44	44	44	45	45	45	45	45	45	45	45	45	45	45	45	45
0.9	Q	17	20	24	28	32	35	39	43	47	51	53	57	60	64	68	71	75
	V	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	S	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	X	47	47	48	48	48	48	48	48	48	48	49	49	49	49	49	49	49
1.0	Q	20	24	29	33	38	42	47	51	56	61	63	68	72	77	81	86	90
	V	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	S	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	X	51	51	51	51	52	52	52	52	52	52	52	52	52	52	52	52	52
1.1	Q	23	28	34	39	44	49	54	60	65	70	74	79	84	89	95	100	105
	V	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	S	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	55	55	55	55	55	55	55	56	56	56	56	56	56	56	56	56	56
1.2	Q	28	33	40	45	51	58	64	69	76	80	86	92	98	104	110	116	122
	V	4.4	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	S	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	58	58	59	59	59	59	59	59	60	60	60	60	60	60	60	60	60
1.3	Q	32	38	46	53	58	65	73	80	86	91	99	106	112	119	125	133	140
	V	4.5	4.6	4.6	4.6	4.6	4.6	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
	S	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	X	62	62	62	63	63	63	63	63	63	63	63	64	64	64	64	64	64
1.4	Q	37	44	51	59	66	74	82	90	96	103	111	119	127	134	142	150	158
	V	4.7	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9

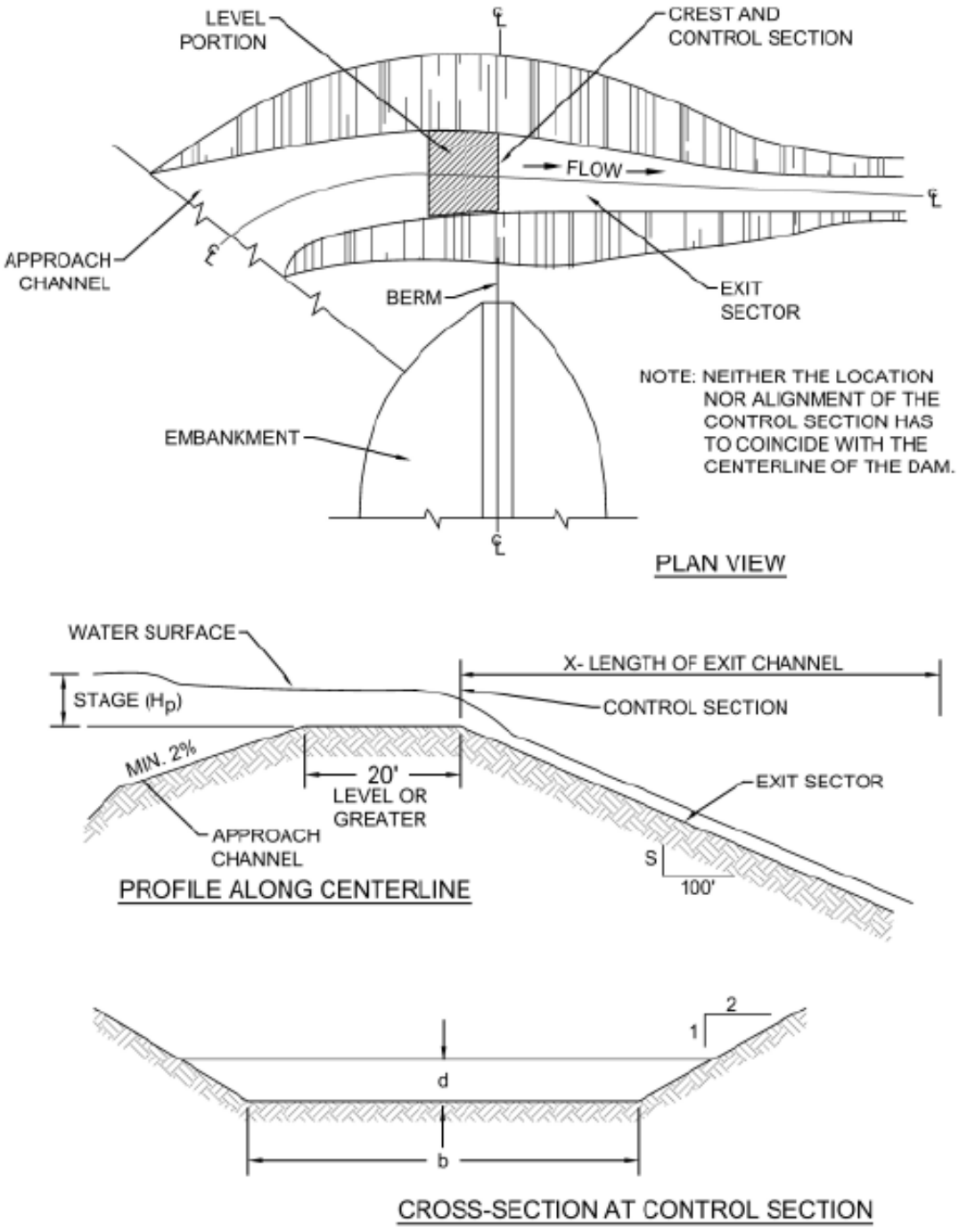
Table C-SCM-12-6 Design Data for Earth Spillways

Stage (Hp) in Feet	Spillway Variables	Bottom Width (b) in Feet																
		8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
	S	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	X	65	66	66	66	66	67	67	67	67	67	67	6.8	6.8	6.8	6.8	6.8	6.9
1.5	Q	41	50	58	66	75	85	92	101	108	116	125	133	142	150	160	169	178
	V	4.8	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	5.1	5.1
	S	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.5	2.5
	X	69	69	70	70	71	71	71	71	71	71	71	72	72	72	72	72	72
1.6	Q	46	56	65	75	84	94	104	112	122	132	142	149	158	168	178	187	197
	V	5.0	5.1	5.1	5.1	5.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
	S S	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	72	74	74	75	75	76	76	76	76	76	76	76	76	76	76	76	76
1.7	Q	52	62	72	83	94	105	115	126	135	145	156	167	175	187	196	206	217
	V	5.2	5.2	5.2	5.3	5.3	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
	S	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	76	78	79	80	80	80	80	80	80	80	80	80	80	80	80	80	80
1.8	Q	58	69	81	93	104	116	127	138	150	160	171	182	194	204	214	226	233
	V	5.3	5.4	5.4	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.6	5.6	5.6	5.6	5.6	5.6
	S	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	80	82	83	84	84	84	84	84	84	84	84	84	84	84	84	84	84
1.9	Q	64	76	88	102	114	127	140	152	164	175	188	201	213	225	235	248	260
	V	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
	S	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	84	85	86	87	88	88	88	88	88	88	88	88	88	88	88	88	88
2.0	Q	71	83	97	111	125	138	153	164	178	193	204	218	232	245	256	269	283
	V	5.6	5.7	5.7	5.7	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.9	5.9	5.9	5.9	5.9
	S	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	88	90	91	91	91	91	92	92	92	92	92	92	92	92	92	92	92
2.1	Q	77	91	107	122	135	149	162	177	192	207	220	234	250	267	276	291	305
	V	5.7	5.8	5.9	5.9	5.9	5.9	5.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	S	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	92	93	95	95	95	95	95	95	95	96	96	96	96	96	96	96	96
2.2	Q	84	100	116	131	146	163	177	194	210	224	238	253	269	288	301	314	330
	V	5.9	5.9	6.0	6.0	6.0	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.2	6.2	6.2	6.2
	S	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	96	98	99	99	99	99	99	100	100	100	100	100	100	100	100	100	100
2.3	Q	90	108	124	140	158	175	193	208	226	243	258	275	292	306	323	341	354
	V	6.0	6.1	6.1	6.1	6.2	6.2	6.2	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	S	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

Table C-SCM-12-6 Design Data for Earth Spillways																		
Stage (Hp) in Feet	Spillway Variables	Bottom Width (b) in Feet																
		8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
	X	100	102	102	103	103	103	104	104	104	105	105	105	105	105	105	105	105
2.4	Q	99	116	136	152	170	189	206	224	241	260	275	294	312	327	346	364	378
	V	6.1	6.2	6.2	6.3	6.3	6.3	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
	S	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
	X	105	105	106	107	107	108	108	108	108	109	109	109	109	109	109	109	109

Source: USDA-SCS

Figure C-SCM-12-9 Excavated Earth Spillway



Source: USDA-SCS

VIII. **Emergency Spillway Design**

A. Design the emergency spillway to pass the remainder of the 25-year peak rate of runoff not carried by the principal spillway.

B. Compute, $Q_e = Q_{25} - Q_P$

C. Refer to Figure C-SCM-12-9 and Table C-SCM-12-6.

D. Determine approximate permissible values for b (the bottom width); s (the slope of the exit channel); and X (minimum length of the exit channel).

E. Enter Table C-SCM-12-6 and choose an exit channel cross-section that passes the required flow and meets the other constraints of the site.

F. Note:

1. Consider the maximum permissible velocity for vegetated waterways when designing an exit channel.
2. For a given Hp, a decrease in the exit slope from S (as given in the table) decreases spillway discharge, but increasing the exit slope from S does not increase discharge. If an exit slope (Se) steeper than S is used, then design procedures detailed in "Open Channel Flow" in Chapter 5 of the 1993 VESCH should be used to verify the adequacy of the exit channel.
3. Use the data to the right of heavy vertical lines with caution, as the resulting sections will be either poorly proportioned or have excessive velocities.

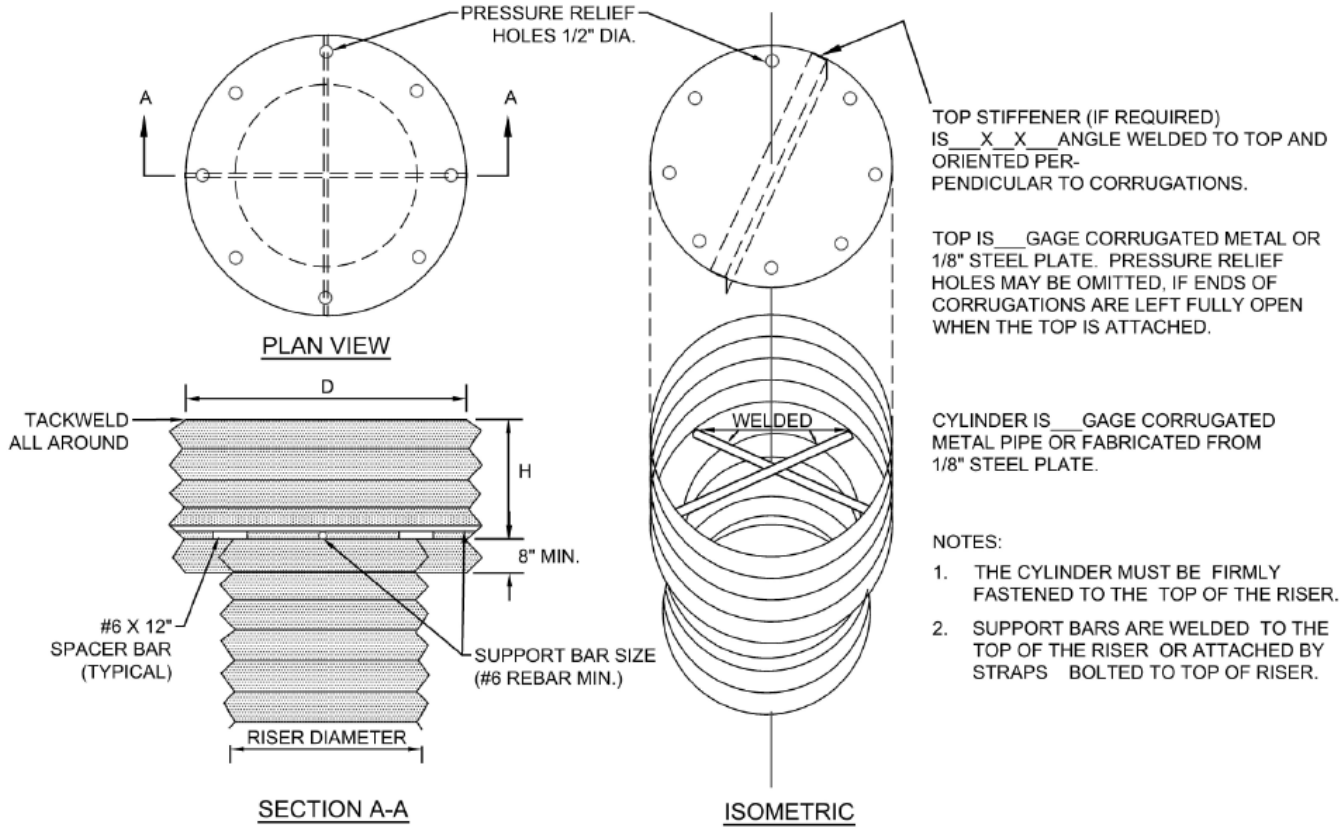
VIII. Re-estimate the elevation of the design high water and the top of the dam based upon the design of the principal spillway and the emergency spillway.

IX. Anti-Vortex Device and Trash Rack

A. This design procedure for the anti-vortex device and trash rack refers only to riser pipes of corrugated metal. There are numerous ways to protect concrete pipe, including hoods, grates, and rebar configurations, which should be a part of project-specific design and will frequently be a part of a permanent structure.

B. Refer to Figure C-SCM-12-10 and Table C-SCM-12-7. Choose cylinder size, support bars, and top requirements from Table C-SCM-12-7 based on the diameter of the riser pipe.

Figure C-SCM-12-10 Anti-Vortex Device Design



Source: USDA-SCS

Table C-SCM-12-7 Anti Vortex Device Design

Riser Dia. (in.)	Cylinder		Height (inches)	Minimum Size Support Bar	Minimum Top	
	Diameter (inches)	Thickness (gage)			Thickness	Stiffener
12	18	16	6	#6 Rebar or 1.5 x 1.5 x 0.1875 angle	16 ga. (F&C)	-
15	21	16	7			-
18	27	16	8			-
21	30	16	11		16 ga.(C), 14 ga.(F)	-
24	36	16	13			-
27	42	16	15			-
36	54	14	17	#8 Rebar	14 ga.(C), 12 ga.(F)	-
42	60	16	19			-
48	72	16	21	1.25” pipe or 1.25 x 1.25 x 0.25 angle	14 ga.(C), 10 ga.(F)	-
54	78	16	25			
60	90	14	29	1.5” pipe or 1.5 x 1.5 x 0.5 angle	12 ga.(C), 8 ga.(F)	-
66	96	14	33	2” pipe or 2 x 2 x 0.1875 angle	12 ga.(C), 8 ga.(F) w/stiffener	2 x 2 x 0.25 angle

Table C-SCM-12-7 Anti Vortex Device Design

Riser Dia. (in.)	Cylinder		Height (inches)	Minimum Size Support Bar	Minimum Top	
	Diameter (inches)	Thickness (gage)			Thickness	Stiffener
72	102	14	36	25” pipe or 2 x 2 x 0.25 angle		2.5 x 2.5 x 0.25 angle
78	114	14	39			
84	120	12	42	2.5” pipe or 2.5 x 2.5 x 0.25 angle		2.5 x 2.5 x 0.3125 angle

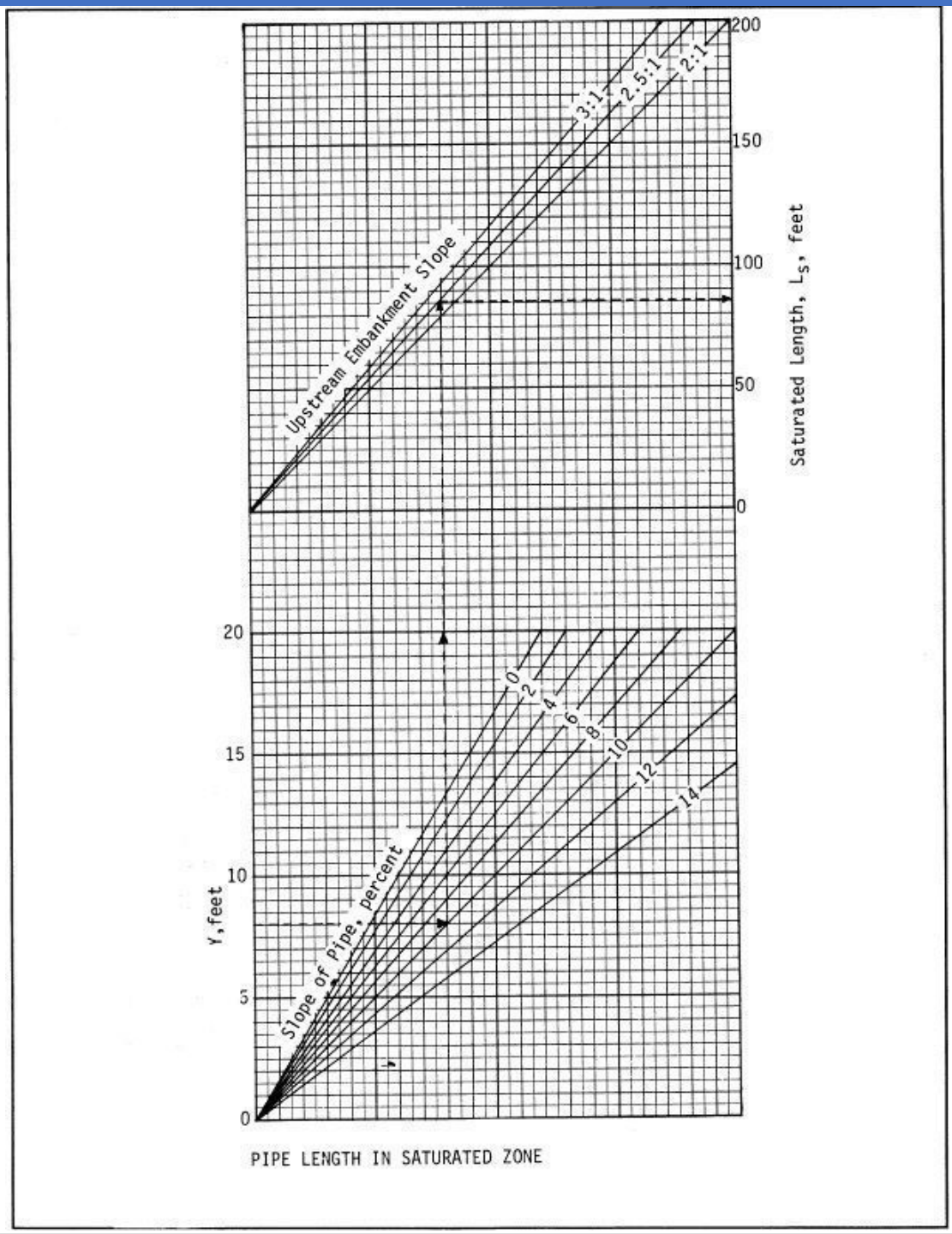
Notes:

1. The criterion for sizing the cylinder is that the area between the inside of the cylinder and the outside of the riser is equal to or greater than the area inside the riser. Therefore, this table is invalid for use with concrete pipe risers.
2. Corrugation for 12” to 36” pipe measures 2.7” x 0.5”; for 42” to 84” the corrugation measures 5” x 1” or 8” x 1”.

C = corrugated; F = flat.

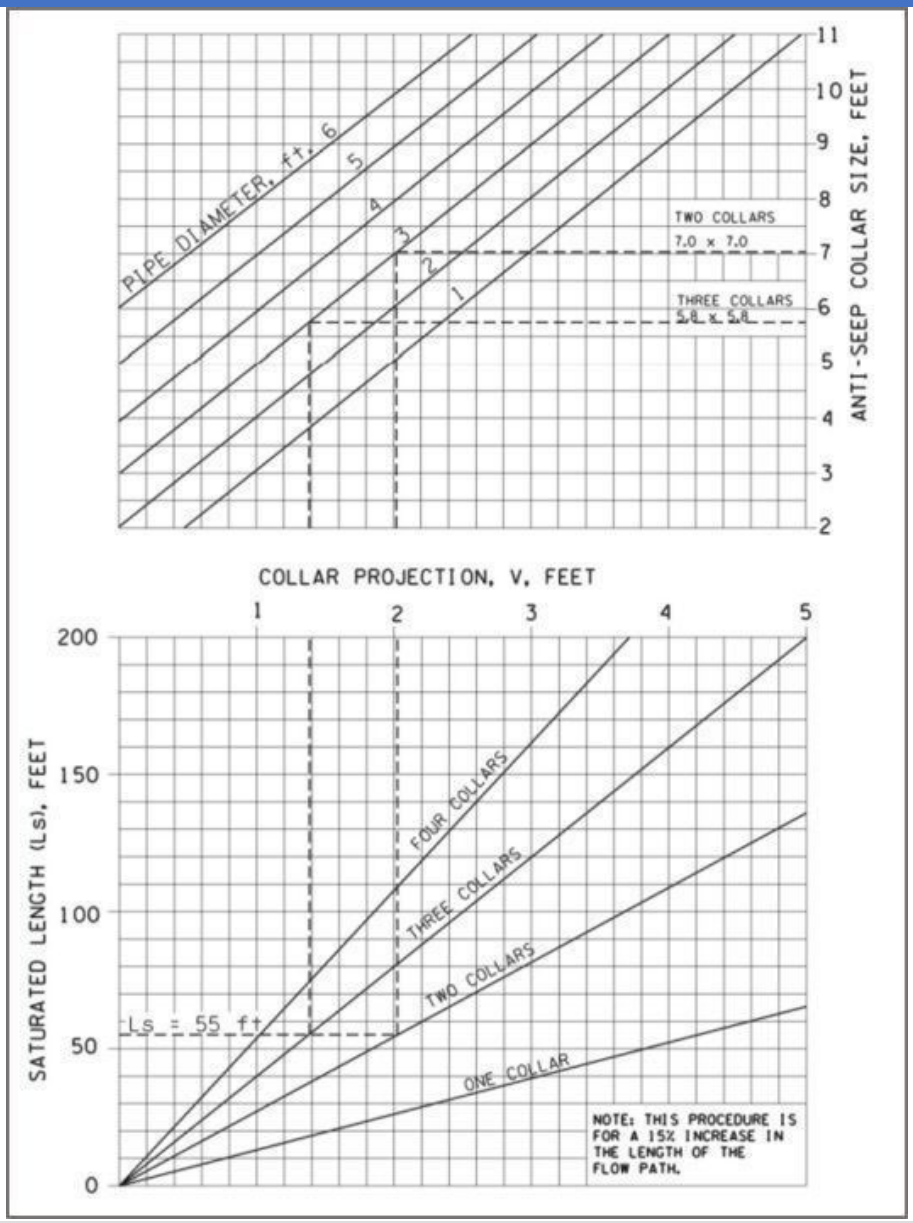
Source: Adapted from USDA-SCS and Carl M. Henshaw Drainage Products Information.

Figure C-SCM-12-11 Pipe Length in Saturated Zone



Source: USDA-SCS

Figure C-SCM-12-12 Anti-Steep Collar Design Chart



Source: OHIO DOT (2004)

XI. Anti-Seep Collars

A. Use anti-seep collars under the conditions specified in the Design Criteria.

B. Use anti-seep collars to increase the seepage length along the barrel by 10%.

C. Determine the length of the barrel within the saturated zone graphically (as in Figure C-SCM-12-11) or by solving the following equation:

$$L_s = Y\ (Z + 4)\left[1 + \frac{S}{0.25 - S}\right]$$

where:

L_s = length of barrel in the saturated zone, in feet

Y = the depth of water at the principal spillway crest, in feet

Z = slope of the upstream face of embankment in Z feet horizontal to one vertical

S = slope of the barrel in feet per foot

D. Enter Figure C-SCM-12-12 with L_s. Move horizontally right until one of the lines is intersected. Move vertically until the correct line for barrel diameter is intersected. Move horizontally right to read P, the size of the anti-seep collar.

E. If more than one collar is used, design the spacing between collars to be 14 times the projection of the collar above the barrel.

F. Do not locate collars closer than 2 feet from a pipe joint.

G. See Figure C-SCM-12-13 for details of the anti-seep collar.

XII. Anchoring the Principal Spillway

A. Firmly anchor the principal spillway to prevent its floating.

B. If the riser is taller than 10 feet, calculate the forces acting on the spillway. Anchor the spillway to provide a safety factor of 1.25 (downward forces = 1.25 x upward forces).

C. If the riser is shorter than 10 feet, choose one of the two methods illustrated on Figure C-SCM-12-14 to anchor the principal spillway.

XIII. Dewatering

A. Refer to Figure C-SCM-12-15 for details and orientation.

B. Calculate the diameter of the dewatering orifice:

Use a modified version of the discharge equation for a vertical orifice and a basic equation for the area of a circular orifice.

Naming the variables:

A = flow area of orifice (square feet)

D = diameter of circular orifice (feet)

H = average driving head (maximum possible head measured from radius of orifice to crest of principal spillway divided by 2) (feet)

Q = volumetric flowrate through orifice needed to achieve approximate 6-hour drawdown (cubic feet per second)

S = total storage available in the dry storage area (cubic feet)

Q = S / 21,600 seconds

Use S for basin and find Q. Then substitute in calculated Q and find A:

$$A = \frac{Q}{(64.32 \times h)^{1/2} (0.6)}$$

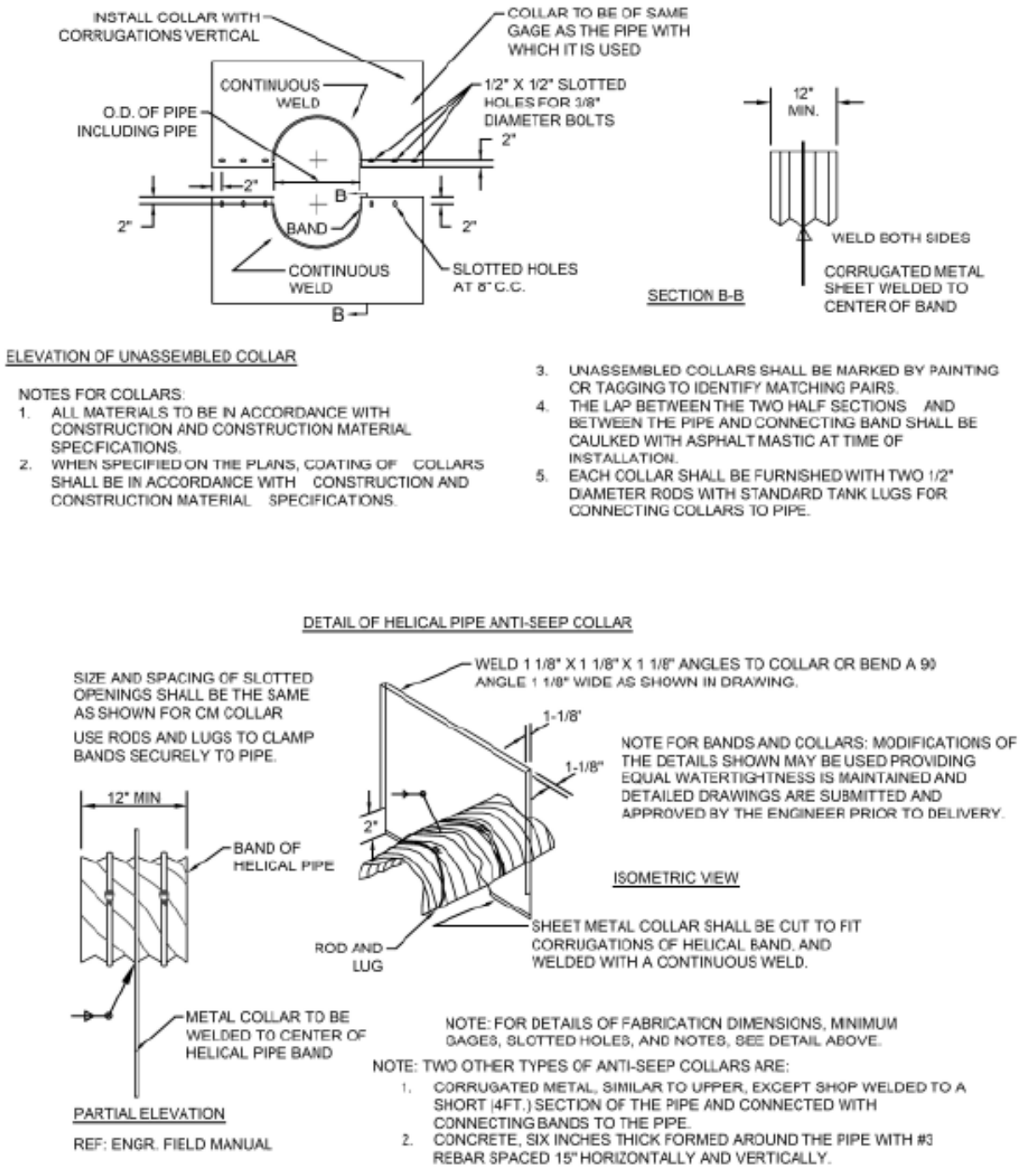
Then, substitute in calculated A and find d:

$$d^* = 2 \times \left[\frac{A}{3.14}\right]^{1/2}$$

*Do not use a diameter of dewatering orifice less than 3 inches to help prevent clogging by soil or debris.

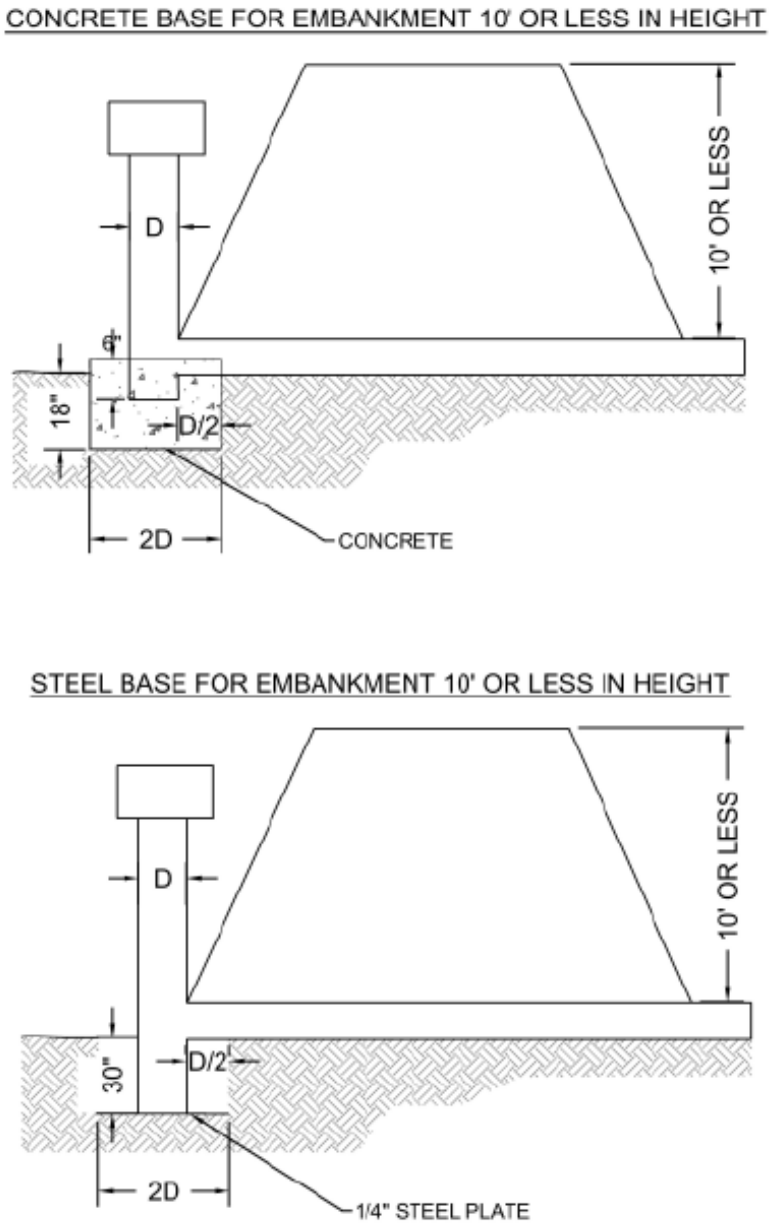
Note: Use perforated flexible tubing at least 2 inches larger in diameter than the calculated orifice to improve flow.

Figure C-SCM-12-13 Anti-Seep Collar Details



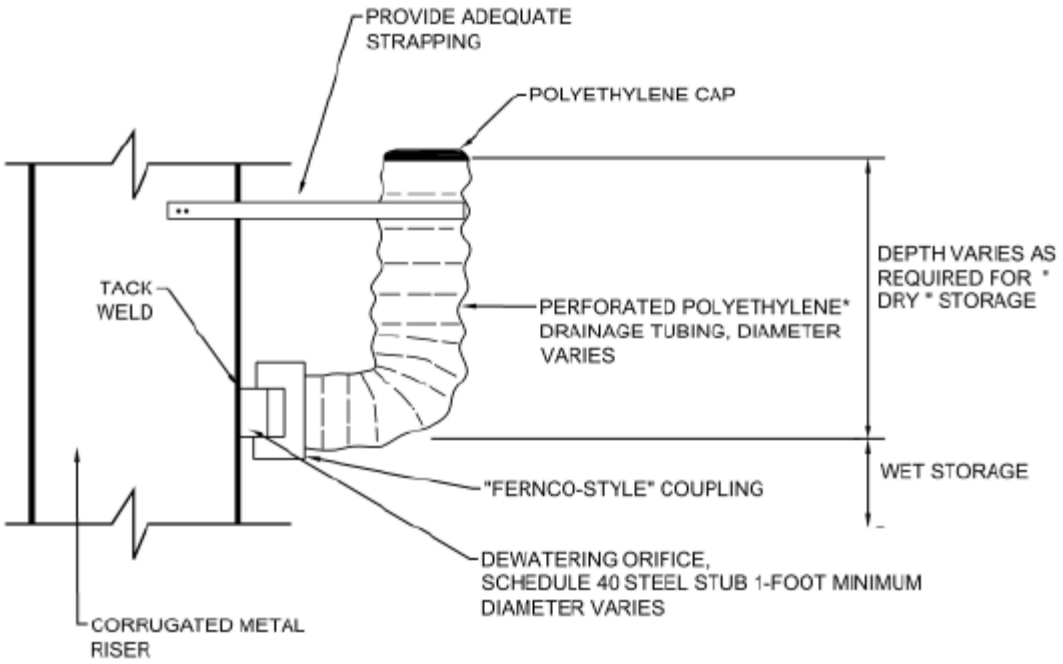
Source: USDA-SCS

Figure C-SCM-12-14 Riser Bank Conditions for Embankments Less Than 10' High



Source: USDA-SCS

Figure C-SCM-12-15 Dewatering System for Sediment Basins



NOTE: WITH CONCRETE RISER, USE PVC SCHEDULE 40 STUB FOR DEWATERING ORIFICE

* DRAINAGE TUBING SHALL COMPLY WITH ASTM F667 AND AASHTO M294

Temporary Sediment Basin Design Data Sheet

Project:	
Basin No.:	
Location:	
Total Area Draining to Basin:	acres

Basin Volume Design	
Wet Storage:	
Minimum Required Volume [1]	cy
Available Basin Volume at Elevation [2]	cy
Excavation Volume to Obtain Required Volume [3]	cy
Available Volume before Cleanout Required [4]	cy
Cleanout Level Elevation [2]	ft
Distance From Invert of the Dewatering Orifice to Cleanout Level [5]	ft
Dry Storage:	
Minimum Required Volume [1]	cy
Available Basin Volume at Crest of Riser Elevation [2,6]	cy
Diameter of Dewatering Orifice	in
Diameter of Flexible Tubing [7]	in
Preliminary Design Elevations:	
Crest of Riser	ft
Top of Dam	ft
Design High Water	ft
Upstream Toe of Dam	ft
Basin Shape	
Length of Flow to Effective Width Ratio	L:W_e
If > 2, baffles are not required	
If < 2, baffles are required	
Runoff	
2-year peak rate of runoff, Q2	cfs
25-year peak rate of runoff, Q25	cfs
Principal Spillway Design	
With Emergency Spillway, Required Spillway Capacity Qp = Q2	cfs
Without Emergency Spillway, Required Spillway Capacity Qp = Q25	cfs
With Emergency Spillway, Assumed Available Head (h) (using Q2) [8]	ft
Without Emergency Spillway, Assumed Available Head (h) (using Q25) [8]	ft
Riser Diameter (Dr)	in
Actual Head [9]	ft
Barrel Length (l)	ft
Head (H) on Barrel Through Embankment [10]	ft
Barrel Diameter [11]	in
Trash Rack and Anti-Vortex Device Diameter [12]	in

Temporary Sediment Basin Design Data Sheet	
Trash Rack and Anti-Vortex Device Height [12]	in
Emergency Spillway Design	
Required Spillway Capacity Qe = Q25 – Qp	cfs
Bottom Width (b)	ft
Slope of the Exit Channel (s)	ft/ft
Minimum Length of the Exit Channel (x) [13]	ft
Anti-Seep Collar Design	
Depth of Water at Principal Spillway Crest (Y)	ft
Slope of Upstream Face of Embankment (Z)	Z:1
Slope of Principal Spillway Barrel (Sb)	%
Length of Barrel in Saturated Zone (Ls)	ft
Number of Collars Required	
Collar Dimensions [14]	
Final Design Elevations	
Top of Dam	ft
Design High Water	ft
Emergency Spillway Crest	ft
Principal Spillway Crest	ft
Dewatering Orifice Invert	ft
Cleanout	ft
Upstream Toe of Dam or Excavated Bottom of “Wet Storage Area” (If excavation was performed)	ft

Notes:

1. Minimum of 67 cubic yards per acre of total drainage area.
2. Obtain elevations from the storage – elevation curve.
3. Elevation corresponding to required volume = invert of the dewatering orifice.
4. Minimum of 33 cubic yards per acre of total drainage area.
5. Minimum of 10 feet.
6. Minimum of 134 cubic yards per acre of total drainage area.
7. Diameter of dewatering orifice plus 2 inches.
8. h = Crest of Emergency Spillway Elevation minus Crest of Riser Elevation.
9. From Figure C-SCM-12-8. Avoid orifice flow conditions.
10. From Figure C-SCM-12-7.
11. From Table C-SCM-12-4 [Corrugated Metal Pipe] or Table C-SCM-12-5 [Reinforced Concrete Pipe].
12. From Table C-SCM-12-7.
13. From Table C-SCM-12-7.
14. From Figure C-SCM-12-12.

C-SCM-13 Concrete Washout Pit

1.0 Definition

A concrete washout pit is a temporary excavated or above-ground lined constructed pit or a prefabricated or fabricated container in which concrete truck mixers and equipment can be washed after their loads have been discharged to prevent highly alkaline runoff from entering storm drainage systems or leaching into soil.

2.0 Purpose and Applicability of Best Management Practice

A concrete washout pit is used for containing wash water from rinsing out concrete trucks, drums, pumps, chutes, equipment, and concrete truck exteriors. Provide washout facilities for every project for which concrete will be poured or otherwise formed on the site.

A concrete washout pit promotes proper disposal of waste concrete and wash water by containing it on site, thereby preventing contamination of waterways, groundwater, and storm drains.

Concrete washout structures are used when concrete equipment is cleaned on-site.

3.0 Planning and Considerations

Provide proper signage to alert drivers of the presence of the washout facilities.

Do not place washout facilities near storm drains, open ditches, or surface waters.

Place washout facilities in a convenient location for the trucks, preferably near the location where the concrete is being poured, but distant enough from other vehicular traffic to minimize the potential for accidental damage or spills. Ensure placement follows local setback requirements.

Locate excavated washout structures so that the structures do not intercept surface runoff. If runoff drains toward an excavated structure, provide a diversion around the structure.

If a sinkhole is found on-site, precautions must be taken to ensure that the proposed location of a Concrete Washout Pit is not located within 150 feet of the outer edge of the sinkhole.

Prefabricated containers are an acceptable alternative to fabricated washout structures provided the volume is adequate to contain all wash water and solids while maintaining a minimum 12-inch freeboard.



Source: Alexis Sidari, PE

Concrete washout water (or wash water) is a slurry containing toxic metals that are also caustic and corrosive, having a pH near 12. The wash water is retained on-site in the washout facility and allowed to evaporate, leaving only the hardened cementitious solids to be recycled or taken off-site for disposal.

4.0 Stormwater Performance Summary

MS-2: Stockpiles, Waste, and Borrow Areas – During construction of the project, soil stockpiles and borrow areas shall be stabilized or protected with sediment trapping measures. The applicant is

responsible for the temporary protection and permanent stabilization of all soil stockpiles on site as well as borrow areas and soil intentionally transported from the project site.

Erosion Control Efficiency: N/A

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Table C-SCM-13-1 Concrete Washout Pit Design Criteria

Parameter	Details
Capacity	Size the washout facility to contain solids, wash water, and rainfall and to allow for the evaporation of the wash water and rainfall. Estimate wash water at 7 gallons per chute and 50 gallons per hopper of the concrete pump truck and/or discharging drum.
Dimensions	The minimum size of the structure is 10 feet by 10 feet at the bottom.
Freeboard	Provide a minimum of 12 inches of freeboard above the liquid and solid waste anticipated between cleanout intervals.
Side Slopes	If excavated, the side slopes are a maximum of 1H:1V.
Location	Locate the facility a minimum of 100 feet from drainage swales, storm drain inlets, wetlands, streams, and other surface waters. Prevent surface water from entering the structure. Design and location of Concrete Washout Pit to adhere to the standards and setbacks of the local municipalities, if special consideration/location must be used, receive prior approval before the installation of the measure. Sinkhole, cave entrances, or other similar natural earthen cavities should be searched for during initial inspection of site, if found, Concrete Washout Pit should not be within 150- feet of said natural landscape feature. Coordinate location of Concrete Washout Pit with local municipality before installation. Provide appropriate access with a gravel access road sloped down to the structure. Place signs to direct drivers to the facility after their load is discharged. Wherever possible, locate washout facilities on slopes not exceeding a 2% grade
Liner	Line all washout facilities to prevent leaching of liquids into the ground. Use plastic sheeting with a minimum thickness of 10 mils with no holes or tears and anchored beyond the top of the pit with an earthen berm, sandbags, stone, or other structural appurtenance. Ensure that pre-fabricated washouts can capture and contain the concrete wash and are sized based on the expected frequency of concrete pours.

Table C-SCM-13-1 Concrete Washout Pit Design Criteria	
Parameter	**Details**
Removal	After the pit is used to wash down the chutes of multiple ready-mixed trucks, and the wash water has evaporated or has been vacuumed off, the remaining hardened solids can be broken up and removed from the pit. This process may damage the plastic lining and support structure (hay bales, sandbags, or wood planks). If damage occurs, repair and reline the pit with new plastic. When the hardened solids are removed, bind the solids with the plastic lining and send to a landfill or recycling center. If the pit is going to be emptied and repaired frequently, the plastic lining, hay bales, sandbags, and wood planks will generate additional solid waste.

6.0 Construction Specifications

Table C-SCM-13-2 Construction Specifications	
Component	**Details**
Compost Sock Washout	Where compost sock washouts are used, place a suitable impervious geomembrane at the location of the washout before installing the socks. Stake 24-inch-diameter compost socks with 2-inch by 2-inch by 36-inch-long wood stakes placed 5 feet on center around perimeter of the geomembrane to form a ring with the ends of the sock located at the upslope corner. Overlap the ends of the compost sock by a minimum of 4 feet on the upslope side of the filter ring. Ensure continuous contact of the sock with the geomembrane at all locations. Where necessary, a double row of 24-inch-diameter socks may be stacked and then an 18-inch- diameter sock staked on top to form a triangular cross-section.
Hay Bale and Plastic Washout Pit	A washout pit made with hay bales and a plastic lining can be dug into the ground or built above grade. Construct the hay bale washout pit using hay bales placed to a minimum height of 3 feet to form a 10-foot by 10-foot inside area. Stake the bales using two wood or metal stakes per bale. Place the plastic lining over the inside area and the top and sides of the hay bales. Staple the lining to the top of the hay bales using 2-inch-wide by 4-inch-long by 0.125- inch-diameter steel wire staples. Use two staples per hay bale. The washout pit can be constructed using two stacked bales or can be partially excavated to reach the 3-foot depth.
Excavated Washout Pit	Excavate the washout area to a minimum depth of 3 feet with a 1H:1V (maximum) side slope to form a 10-foot by 10-foot bottom area. Place the liner over the bottom and side slopes of the excavated area and extend the liner a minimum of 3 feet at the top of the side slopes. Place sandbags around the perimeter of the washout pit at the tops of the side slopes to secure the liner in place. Staple the lining to the top of the wood frame using 2-inch-wide by 4-inch-long by 0.125-inch-diameter steel wire staples.

Table C-SCM-13-2 Construction Specifications	
Component	**Details**
Wood Plank and Plastic Washout Pit	Construct the 10-foot by 10-foot washout pit using three 2-inch by 12-inch wood frames stacked to form a 3-foot-high wooden frame above the ground surface. Install two stakes on either side of the wooden frame and fasten to the wooden frame. Install four stakes on each 10-foot side of the wooden frame (16 stakes total). Place the plastic liner over the inside area and top sides of the wood plank frame. Staple the lining to the top of the wood frame using 2- inch wide by 4-inch long by ⅛-inch diameter steel wire staples.
Vinyl Washout Container	The vinyl washout container is portable, reusable, and easier to install than a hay bale washout pit. The biodegradable filter bag assists in extracting the concrete solids and prolongs the life of the vinyl container. When the bag is lifted, the water is filtered out, and the remaining concrete solids and the bag can be disposed of together in a landfill, or the hardened concrete can be delivered to a recycler. After the solids have been removed several times and the container is full of wash water, the wash water can be allowed to evaporate so that the container can be reused. The wash water can be removed more quickly by placing another filter bag in the container and spreading water gelling granules evenly across the water. In about 5 minutes, the water in the filter bag will turn into a gel that can be removed with the bag. The gel and filter bag can then be disposed of together.
Metal Washout Container	The metal roll-off bin is designed to securely contain concrete wash water and solids and is portable and reusable. It also has a ramp that allows concrete pump trucks to wash out their hoppers. Roll-off providers offer recycling services such as picking up the roll-off bins after the wash water has evaporated and the solids have hardened, replacing them with empty washout bins, and delivering the hardened concrete to a recycler rather than a landfill. Some providers will vacuum off the wash water, treat it to remove metals and reduce the pH, and deliver it to a wastewater treatment plant for additional treatment and subsequent discharge to a surface water. Everything is recycled or treated sufficiently to be returned to a natural surface water.

7.0 Operations and Maintenance Considerations

Inspect all concrete washout facilities daily. Deactivate and repair or replace damaged or leaking facilities immediately. Pump excess rainwater that has accumulated over hardened concrete to a stabilized area such as a grass filter strip. Remove accumulated hardened material when 75% of the storage capacity of the structure is filled. Pump any excess wash water into a containment vessel and properly disposed of off-site.

Dispose of the hardened material off site in a construction/demolition landfill. The hardened concrete may be recycled by crushing and reusing the crushed concrete as construction material. The crushed concrete material makes an excellent aggregate for road base and can be used as fill at the construction site in accordance with state and local regulations or delivered to a recycler. Concrete recyclers can be found at municipal solid waste disposal facilities, private recycling plants, or large construction sites.

Replace the plastic liner with each cleaning of the washout facility. Inspect the project site frequently to ensure that concrete is not being discharged in non-designated areas. Before forecasted rainstorms, remove liquids or cover the structure to prevent overflows.



Poorly Maintained Concrete Washout Station



Properly Installed and maintained Concrete Washout Station

8.0 References

Maryland Department of the Environment Water Management Administration, Natural Resources Conservation Service, and Maryland Association of Soil Conservation Districts. 2011. *2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control*.

New York Department of Environmental Conservation. 2016. *New York State Standards and Specifications for Erosion and Sediment Control*.

Pennsylvania Department of Environmental Protection. 2012. *Erosion and Sediment Pollution Control Program Manual*. Final ed.

Town of Bluffton, SC. Www.townofbluffton.sc.gov/447/Sediment-Erosion-Control. Accessed 8 Feb. 2023.

C-SSM-01 Tree Preservation and Protection

1.0 Definition

Tree preservation and protection is the protection of desirable trees from mechanical and other types of injury during land disturbance and construction.

– CAD and PDF files for C-SSM-01 Tree Preservation and Protection

2.0 Purpose and Applicability of Best Management Practice

Tree preservation and protection is implemented to ensure the survival of desirable trees and their root zones where the trees will be effective for erosion and sediment control, watershed protection, landscape beautification, dust and pollution control, noise reduction, shade, and other environmental benefits while the land is being converted from forest to urban setting. Tree protection may also be used on previously developed lands where there are existing trees or other plant materials needing protection from damage by construction equipment or soil compaction by vehicular traffic.

Tree preservation and protection should be used where tree-inhabited areas are subject to land-disturbing activities.

3.0 Planning and Considerations

Stands of trees and individual trees selected for preservation should be accurately located on the Erosion & Sediment Control Plan and designated as “TREE(S) TO BE SAVED” or equivalent.

New development often takes place on tracts of forested land. In fact, building sites are often selected because of the presence of mature trees. However, unless sufficient care is implemented and planning conducted in the interval between buying the property and completing construction, much of this resource is likely to be destroyed. The property owner is ultimately responsible for protecting as many trees (including their understory and ground cover) as possible. This responsibility is usually exercised by agents, planners, designers, and contractors. Newly planted trees require approximately 20 to 30 years to provide the benefits for which they are so highly valued. Trees perform the following functions on a site:

1. Assist in stabilizing the soil and preventing erosion;
2. Help to decrease stormwater runoff through canopy interception and root zone absorption;
3. Moderate temperature changes and provide shade;
4. Moderate the effects of sun and wind;
5. Provide buffers and screens against noise and undesirable views;
6. Filter pollutants from the air;
7. Help to remove carbon dioxide from the air and release oxygen;
8. Provide a haven for animals and birds, which help to control insect populations;
9. Conserve and increase property values;
10. Provide psychological and aesthetic counterpoints to the man-made urban setting; and
11. Provide definition of outdoor spaces and pathways.

3.1 Stresses of Construction

Trees are living organisms that are constantly involved in the process of respiration, food processing, and growth. Construction exposes trees to a variety of stresses resulting in injury ranging from superficial wounds to death.

An understanding of these stresses is helpful in planning for tree protection.

1. **Surface Impacts:** Natural and man-related forces exerted on the tree above the ground can cause significant damage to trees. Table C-SSM-01-1 identifies some of the common surface impacts to which trees are subjected during construction.

Table C-SSM-01-1 Surface Impacts from Construction	
Surface Impacts from Construction	
Wind Damage	Removal of some trees from groups will expose those remaining to greater wind velocities. Trees tend to develop anchorage where it is most needed. Isolated trees develop anchorage rather equally all around, with stronger root development on the side of the prevailing winds. The more a tree is protected from the wind, the less secure its anchorage. The result of improper thinning is often wind-thrown trees. Selective removal in favor of a single tall tree may also create a lightning hazard.
Excessive Pruning	Unprotected trees are often "topped" or carelessly pruned to prevent interference with utility wires or buildings. If too many branches are cut, the tree may not be able to sustain itself. If the tree is pruned without considering the growth habit, the tree may lose all visual appeal. If the branches are not pruned correctly, decay may set in.
Trunk Damage	Tree trunks are often nicked or scarred by trucks and construction equipment. Such superficial wounds provide access to insects and disease.

2. **Root Zone Impacts:** Disturbing the delicate relationship between soil, roots, and the rest of the tree can damage or kill a tree. The roots of an existing tree are established in an area where they can access essential materials (water, oxygen, and nutrients). The mass of the root system is the correct size to balance the intake of water from the soil with the transpiration of water from the leaves. In general, a tree's root system extends about the same distance from the trunk as its branches.
   a. Raising the grade as little as 6 inches can impact the normal exchange of air and gases. Roots may suffocate due to lack of oxygen or be damaged by toxic gases and chemicals released by soil bacteria.
   b. Raising the grade may also elevate the water table. This can cause drowning of the deeper roots.
   c. Even shallow cuts of 6 to 8 inches will remove most of the topsoil, removing some feeder roots and exposing the rest to drying and freezing.
   d. Deep cuts may sever a large portion of the root system, depriving the tree of water and increasing the chance of wind-throw.
   e. Lowering the grade may lower the water table, inducing drought. This is a problem in large roadway cuts or underdrain installations.
   f. Trenching or excavating through the root zone of a tree can eliminate as much as 40 percent of the root system.
   g. Compaction of the soil within the drip line (even a few feet beyond the drip line) of a tree by equipment operation, materials storage, or paving can block off air and water from roots.
   h. Construction chemicals or refuse disposed of in the soil can change soil chemistry or be toxic to trees. Most damage to trees from construction is due to the invisible root zone stresses.

4.0 Stormwater Performance Summary

MS-1: STABILIZATION – Permanent or temporary soil stabilization shall be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization shall be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer

than 14 days. Permanent stabilization shall be applied to areas that are to be left dormant for more than 1 year.

9VAC25-875-560.

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: LOW

5.0 Design Criteria

No formal design is required. However, when planning for the development of a wooded site, where some trees will be preserved, consider the following criteria:

5.1 Selecting Trees to be Retained

The proper development of a wooded site requires completion of a plan for tree preservation before clearing and construction begins. Trees should be identified by species and located on a topographical map, either as stands or as individuals, depending on the density and value of the trees. Decide which trees to save based on the considerations identified in Table C-SSM-01-2.

Table C-SSM-01-2 Design Criteria for Tree Preservation and Protection

Design Criteria for Tree Preservation and Protection	
Life expectancy and present age	Preference should be afforded to trees with a long life span such as white oak, beech, and maple. Long-lived specimens that are past their prime may succumb to the stresses of construction; therefore, smaller, younger trees of desirable species are preferred because the younger trees are more resilient and will last longer. However, if the cost of preservation is greater than the cost of replacement with a specimen of the same age and size, replacement may be preferred.
Health and disease susceptibility	Check for scarring caused by fire or lightning, insect, or disease damage and rotted or broken trunks or limbs. Pest- and pollution-resistant trees are preferred.
Structure	Check for structural defects that indicate weakness or reduce the aesthetic value of a tree such as trees growing from old stumps; large trees with overhanging limbs that endanger property; and trees with brittle wood (such as silver maple), misshapen trunks or crowns, and small crowns at the tops of tall trunks. Open grown trees often have better form than those grown in the woods. Trees with strong tap or fibrous root systems are preferred to trees with weak rooting habits.
Cleanliness	Some trees (such as elm and black locust) are maintenance-intensive, dropping twigs, bark, fruit, or plant exudates. Trees that seed prolifically or sucker profusely are generally less desirable in urban areas. Thornless varieties are preferred.
Aesthetic values	Handsome bark and leaves, neat growth habit, fine fall color, and attractive flowers and fruit are desirable characteristics. Trees that provide interest during several seasons of the year enhance the value of the site.

Table C-SSM-01-2 Design Criteria for Tree Preservation and Protection	
Design Criteria for Tree Preservation and Protection	
Comfort	Trees help relieve the heat of summer and buffer strong winds throughout the year. Summer temperatures may be 10 degrees cooler under hardwoods than under conifers. Deciduous trees drop their leaves in winter, allowing the sun to warm buildings and soil. Evergreens are more effective wind buffers.
Wildlife	Preference should be given to locally native trees that provide food, cover, and nesting sites for birds and game.
Adaptability to the proposed development	1. Consider the mature height and spread of trees, as these features may interfere with proposed structures and overhead utilities. Roots may interfere with walls; walks; driveways; patios; and other paved surfaces or water lines, septic tanks, and underground drainage. 2. Trees must be appropriate to the proposed use of the development; select trees that are pollution-tolerant for high-traffic and industrial areas, screen and buffer trees for noise or objectionable views, and salt-tolerant species for areas exposed to de-icing salts or ocean spray. 3. Consider locations of landfills. Gases generated within can travel long distances underground, injuring distant trees. Choose species tolerant of anaerobic soil conditions. 4. Determine the effect of proposed grading on the water table. Grading should not take place within the drip line of any tree to be saved.
Survival needs of the tree	Chosen trees must have enough room to develop naturally. Trees will be subject to injury from increased exposure to sunlight, heat radiated from buildings and pavement, and wind. It is best to retain groups of trees rather than individuals. Gradually thin trees as they mature and only when necessary.
Relationship to other trees	Individual species should be evaluated in relation to other species on the site. A species with low value when growing among hardwoods will increase in value if it is the only species present. Trees standing alone generally have higher landscape value than those in a wooded situation. However, tree groups are much more effective at preventing erosion and excess stormwater runoff.

Table C-SSM-01-2 Design Criteria for Tree Preservation and Protection	
Design Criteria for Tree Preservation and Protection	
Ecological Cores	The Virginia Natural Heritage Program (VNHP) in the Department of Conservation and Recreation has developed a network of natural lands for the commonwealth of Virginia. This project, named the Virginia Natural Landscape Assessment (VaNLA), is a landscape-scale geospatial analysis for identifying, prioritizing, and linking natural lands in Virginia. Using land cover data derived from satellite imagery, the VaNLA identifies large patches of natural land with at least one hundred acres of interior cover. This interior cover, known as core area, begins one hundred meters from patch edges. Small patches with ten to ninety-nine acres of interior cover are included as habitat fragments that support landscape corridors and that may be important in localities with few large patches of natural land. Core areas and habitat fragments are referred to collectively as "ecological cores." Although the VaNLA is predominantly an analysis of forests, ecological cores include marshes, dunes, and beaches where these covers are abundant and exceed minimum size requirements. Tree removal should be avoided if any trees on site are determined to be ecological cores.
Virginia Native Species	Any Virginia Native Species should be saved to the fullest extent possible and can be identified with the Virginia Native Plant Finder.

5.2 Site Planning for Tree Protection

1. If lot size allows, select trees to be saved before siting the building. No tree should be destroyed or altered until the design of buildings and utility systems is final.
2. Critical areas, such as floodplains, steep slopes, and wetlands, should be left in their natural condition or only partially developed as open space.
3. Locate roadways to cause the least damage to valuable stands. Follow original contours, where feasible, to minimize cuts and fills.
4. Minimize trenching by locating several utilities in the same trench. Excavations for basements and utilities should be kept away from the drip lines of trees.
5. Construction material storage areas, soil stockpiles, and worker parking should be identified on the site plan and located where they will not cause compaction over roots.
6. When retaining existing trees in parking areas, leave enough ground ungraded beyond the drip line of the tree to allow for its survival.
7. Locate erosion and sediment control measures at the limits of clearing (not in wooded areas) to prevent deposition of sediment within the drip lines of trees being preserved. Sediment basins should be constructed in the natural terrain, if possible, rather than where extensive grading and tree removal will be required.

6.0 Construction Specifications

1. Groups of trees and individual trees selected for retention should be accurately located on the plan and designated as "TREE(S) TO BE SAVED." Individual specimens that are not part of a tree group should also be identified by species and diameter on the plan. The boundary of the tree protection zone for both groups and individual trees should be clearly and conspicuously depicted on the grading and E&S plans. Tree protection zones should always be outside of the limits of grading.

2. At a minimum, the limits of clearing should be located outside the drip line of any tree to be retained and, in no case, closer than 5 feet to the trunk of any tree (see Figure C-SSM-01-1).
3. **Marking:** Before the pre-construction conference, individual trees and stands of trees to be retained within the limits of clearing should be marked at a height visible to equipment operators. According to the Virginia Department of Forestry, a diagonal slash of brightly colored paint approximately 8 to 10 inches long is a common practice where an accidental or purposeful alteration of the proper markings is a concern. In most situations, such as in an area designated for formal landscaping, a surveyor's ribbon or a similar material applied at a reasonable height encircling the tree will suffice.

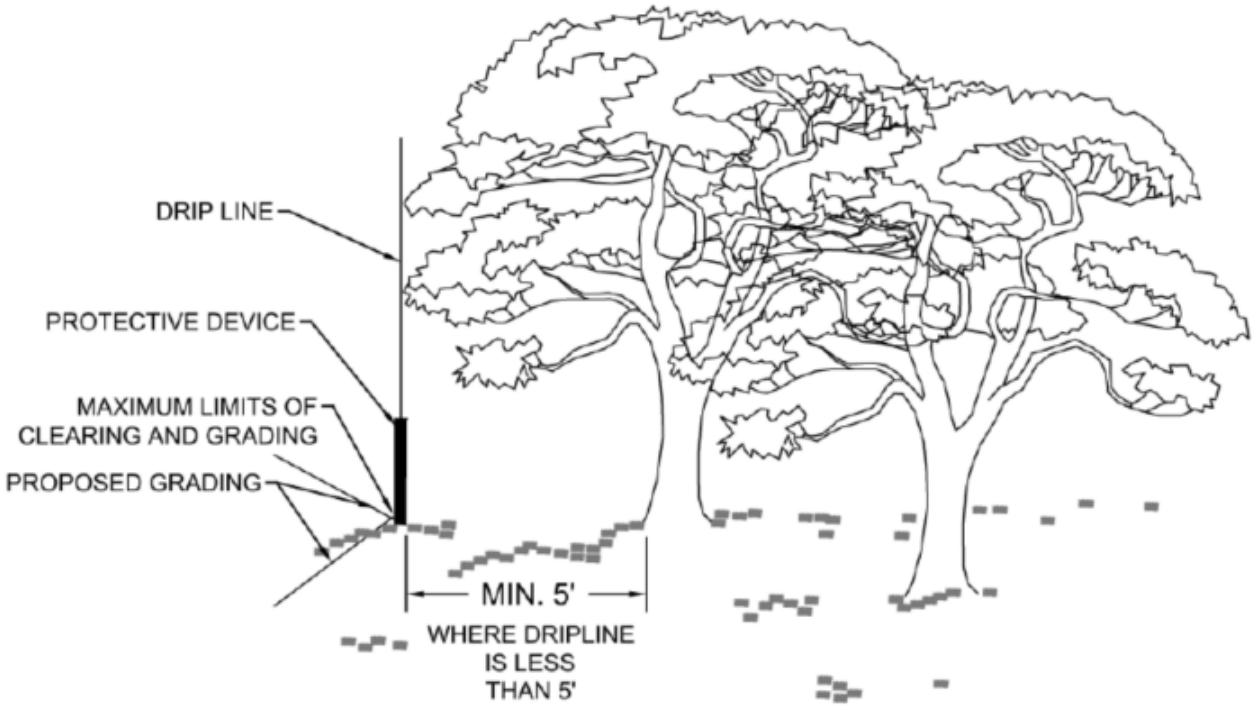


Metal Tree Protection Surrounding Steeper Grade Around Tree

4. **Pre-Construction Conference:** During any pre-construction conference, tree preservation and protection measures should be reviewed with the contractor as they apply to that specific project.
5. **Equipment Operation and Storage:** Heavy equipment, vehicular traffic, or stockpiles of any construction materials (including topsoil) should not be permitted within the drip line of any tree to be retained. Trees being removed should not be felled, pushed, or pulled into trees being retained.

   Equipment operators should not clean any part of their equipment by slamming it against the trunks of trees to be retained.
6. **Fires:** Fires should not be permitted within 100 feet from the drip lines of any trees to be retained. Fires should be limited in size to prevent adverse effects on trees and kept under surveillance.

Figure C-SSM-01-1 Construction Operations Relative to Protected Tree Location



Source: Fairfax County 1976

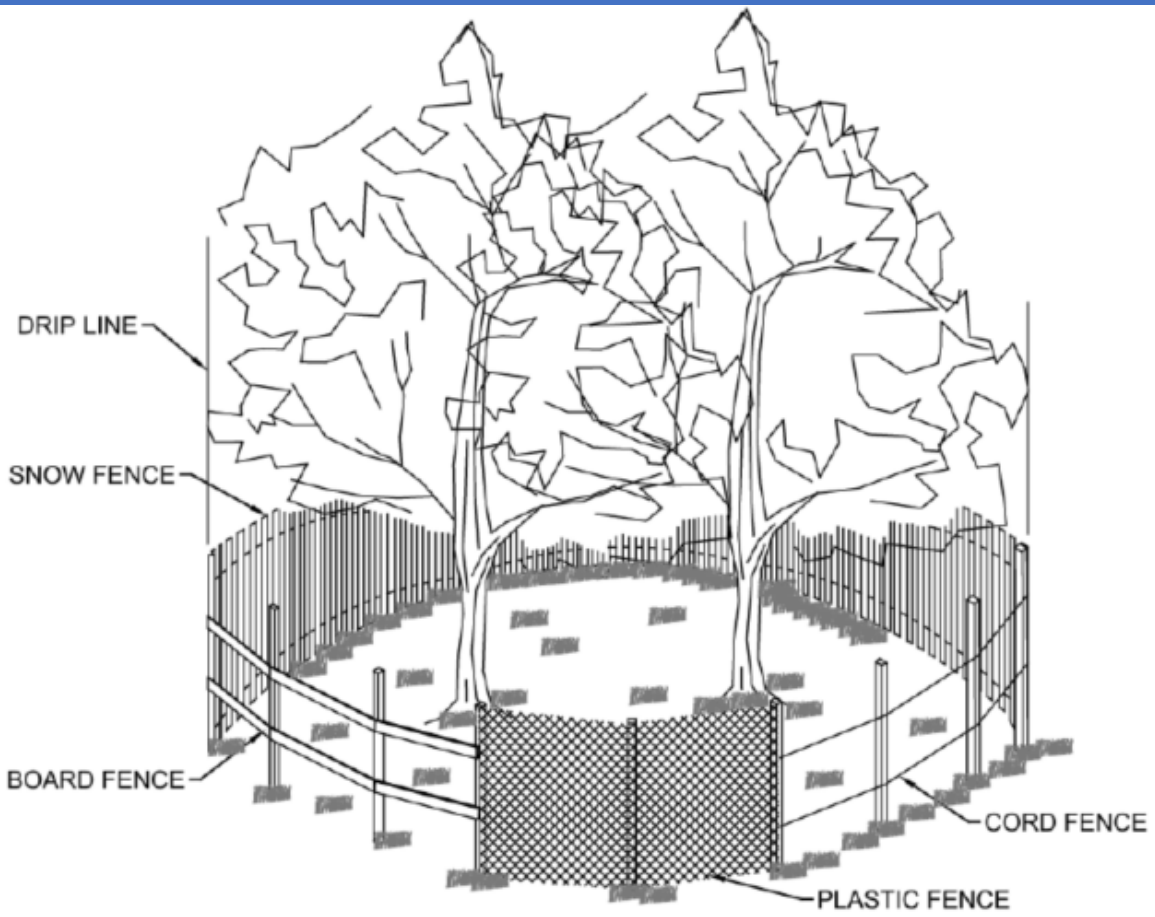
7. **Storage and Disposal of Toxic Materials:** No toxic materials should be stored closer than 100 feet to the drip lines of any trees to be retained. Paint, acid, nails, gypsum board, wire, chemicals, fuels, and lubricants should not be disposed of in such a way as to injure vegetation.
8. **Fencing and Armoring (Figure C-SSM-01-2):** Any device may be used that will effectively protect the roots, trunks, and tops of trees retained on the site. However, trees to be retained within 40 feet of a proposed building or excavation should be protected by fencing. Personnel should be instructed to honor protective devices. The devices described are suggested only and are not intended to exclude the use of other devices that will protect the trees to be retained.

Table C-SSM-01-3 Fencing and Armoring Specifications

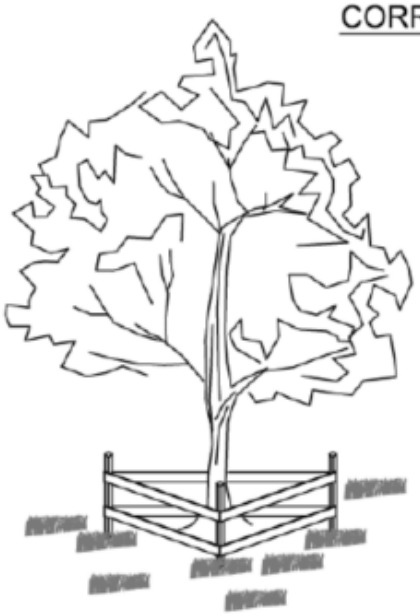
Fencing and Armoring Specifications	
Snow Fence	Standard 40-inch-high snow fence should be placed at the limits of clearing on standard steel posts set 6 feet apart.
Board Fence	Board fencing consisting of 4-inch-square posts set securely in the ground and protruding at least 4 feet above the ground should be placed at the limits of clearing with a minimum of two horizontal boards between posts. If it is not practical to erect a fence at the drip line, construct a triangular fence nearer the trunk. The limits of clearing will still be located at the drip line because the root zone within the drip line will still require protection.
Cord Fence	Posts with a minimum size of 2 inches square or 2 inches in diameter set securely in the ground and protruding at least 4 feet above the ground should be placed at the limits of clearing with two rows of cord 0.25 inch or thicker at least 2 feet apart running between posts with strips of colored surveyor's flagging tied securely to the string at intervals no greater than 3 feet.
Plastic Fencing	40-inch-high “international orange” plastic (polyethylene) web fencing secured to 60-inch-high minimum nominal 2-inch by 2-inch oak posts driven to a minimum depth of 18 inches on 6-foot minimum centers should be installed at the limits of clearing. The fence should have the following minimum physical qualities: Tensile yield: Average 2,000 lbs. per 4-foot width (ASTM D638) Ultimate tensile yield: Average 2,900 lbs. per 4-foot width (ASTM D638) Elongation at break (%): Greater than 1,000% (ASTM D638) Chemical resistance: Inert to most chemicals and acids
Earth Berms	Temporary earth berms should be constructed according to specifications for a Temporary Diversion Dike (BMP C-ECM-04) with the base of the berm on the tree side located along the limits of clearing. Earth berms may not be used for this purpose if their presence will conflict with drainage patterns.
Additional Trees	Additional trees may be left standing as protection between the trunks of the trees to be retained and the limits of clearing. However, for this alternative to be used, the trunks of the trees in the buffer should be no more than 6 feet apart to prevent passage of equipment and material through the buffer. These additional trees should be reexamined before completing construction and either given sufficient treatment to ensure survival or be removed.

Table C-SSM-01-3 Fencing and Armoring Specifications	
Fencing and Armoring Specifications	
Trunk Armoring	As a last resort, a tree trunk can be armored with burlap wrapping and 2-inch studs wired vertically no more than 2 inches apart to a height of 5 feet encircling the trunk. If this alternative is used, the root zone within the drip line will still require protection. Nothing should ever be nailed to a tree.

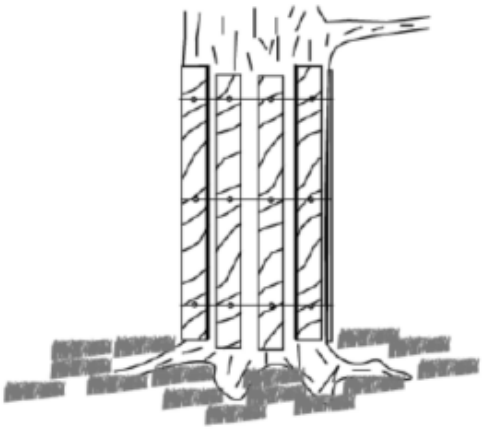
Figure C-SSM-01-2 Fencing and Armoring



CORRECT METHODS OF TREE FENCING



TRIANGULAR BOARD FENCE



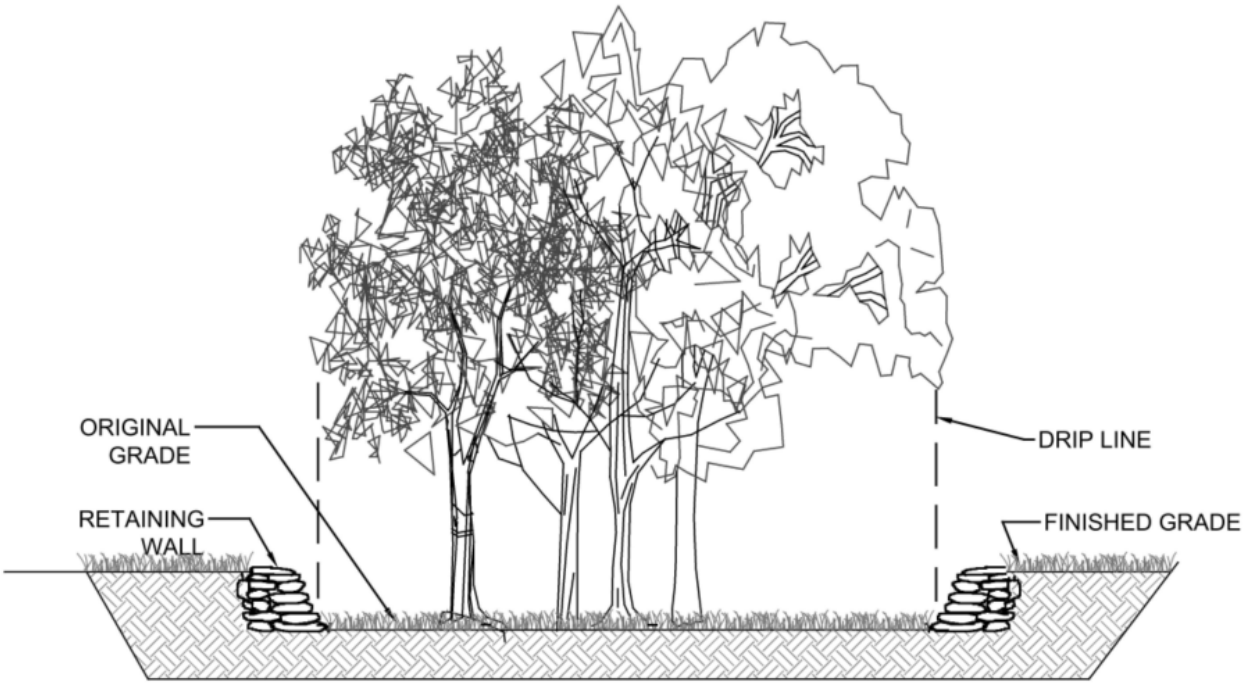
CORRECT TRUNK ARMORING

Source: Va. DSWC

Fencing and armoring devices should be in place before any excavation or grading begins, should be kept in good repair during construction, and should be the last items removed during the final cleanup after the completion of the project.

Raising the grade: When the ground level must be raised around an existing tree or tree group, the following should be considered and steps taken to adequately care for the affected tree.

Figure C-SSM-01-3 Tree Well



Source: Va. DSWC

a. A well may be created around the tree(s) slightly beyond the drip line to retain the natural soil around the feeder roots (Plate 3).

b. In the case of an individual tree, when the alternative described in item a is not practical or desirable, the following method is recommended to ensure survival of the tree (Figure C-SSM-01-4):

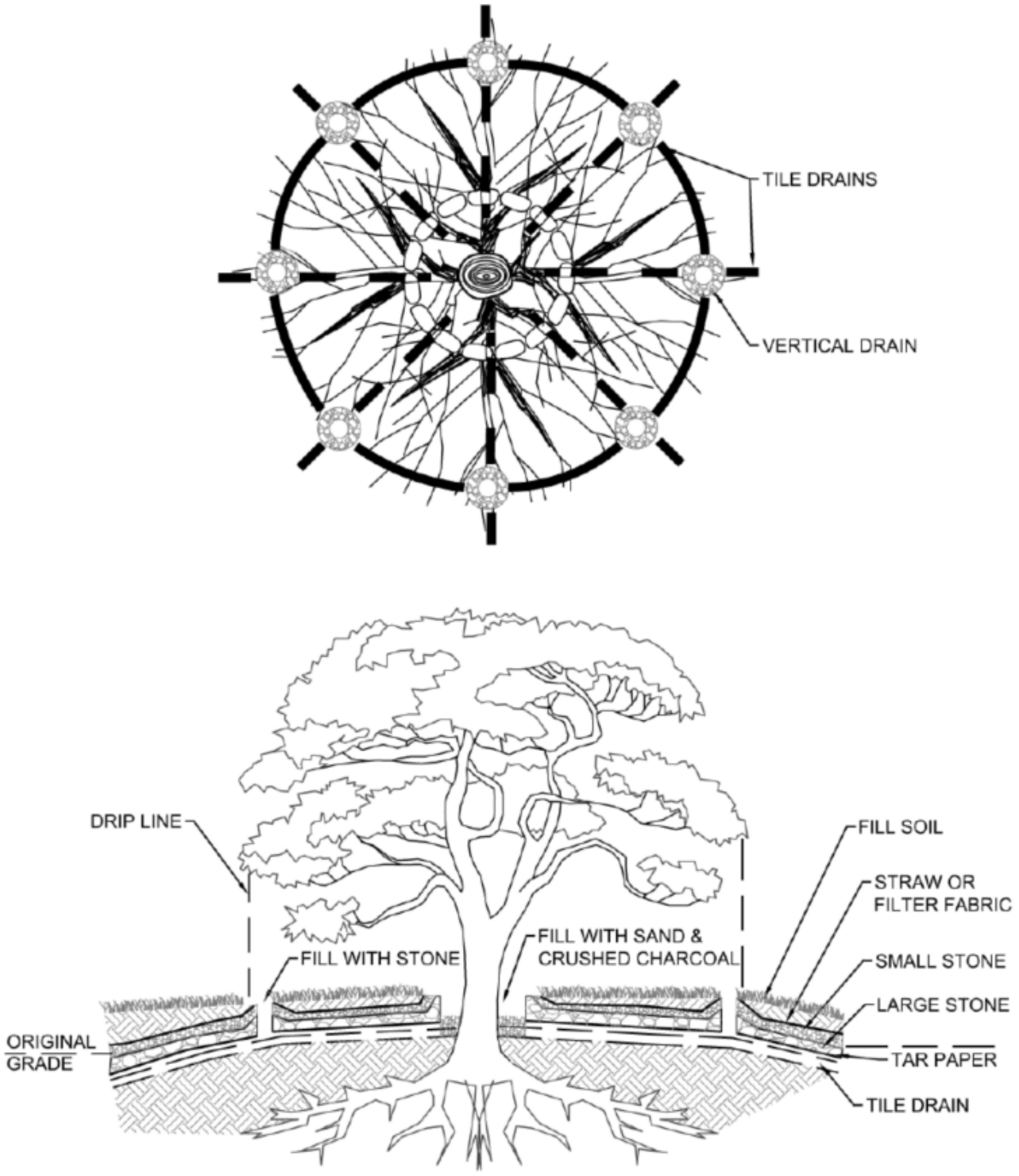
   1) Before making the fill, remove the green vegetation, sod, leaf litter, and other organic matter from beneath the tree or trees to 3 feet beyond the drip line and loosen the surface soil to a depth of approximately 3 inches without damaging the roots.

   2) Apply fertilizer in the root area of the tree to be retained. Fertilizer formulations, application rates, and methods should conform to the guidelines provided in Table C-SSM-01-4.

   3) The dry well should be constructed to allow for tree trunk diameter growth. A space of at least 1 foot between the tree trunk and the well wall is adequate for large, old, slow-growing trees.

      Clearance for younger trees should be at least 2 feet.

Figure C-SSM-01-4 Tree Well Detail 1



Source: Pirone 1978.

Table C-SSM-01-4 Tree Fertilization for Protection from Construction				
Tree Type	**Special Conditions**	**Application Rate & Method**		**Formulation**
Broad-Leaf Deciduous	Greater than 6 inches dbh* except American beeches and crabapples	Normal	2 to 4 lbs. per inch dbh; broadcast	Commercial 10-8-6 or 10-6-4
		Grade Change	4 to 5 lbs. per inch dbh; broadcast	Commercial 10-6-4
	Smaller than 6 inches dbh including all American beeches and crabapples	Normal	1 to 2 lbs. per inch dbh; broadcast	Commercial 10-8-6 or 10-6-4
		Grade Change	2 to 3 lbs. per inch dbh; broadcast	Commercial 10-6-4
Narrow-Leaf Evergreen	Greater than 6 inches dbh, located in groups	2 to 4 lbs. per 100 sq. ft. of bed area; broadcast		Commercial 10-6-4
	Greater than 6 inches dbh, single specimens in open area	2 lbs. per inch dbh; broadcast		
	Smaller than 6 inches dbh	5 lbs. per 100 sq. ft. of bed area; incorporated into soil		Tankage or Cottonseed Meal
Broad-Leaf Evergreen	Where nitrogen in soil is sufficient	Liberal quantities incorporated into soil and applied as mulch		Acid Peat Moss or Rotted Oak Leaf Mold
	Where additional nitrogen is necessary	Also add 5 lbs. per 100 sq. ft. of bed area incorporated into soil		Tankage or Cottonseed Meal
*dbh = Diameter at breast height (4.5 feet above ground level).				
Source: Pirone 1978.				

4) The well should be high enough to bring its top just above the level of the proposed fill. The well wall should taper slightly away from the tree trunk at a rate of 1 inch per foot of wall height.

5) The well wall should be constructed of large stones, brick, building tile, concrete blocks, or cinder blocks. Ensure that ample openings are left through the wall of the well to allow for free movement of air and water. Mortar should only be used near the top of the well and only above the porous fill.

6) Drain lines composed of 4-inch, high-quality drain tiles should begin at the lowest point inside the well and extend outward from the tree trunk in a wheel-and-spoke pattern with the trunk as the hub. These radial drain lines should slope away from the well at a rate of 0.125 inch per foot. The circumferential line of tiles should be located beneath the drip line of the tree.

   Vertical tiles or pipes should be placed over the intersections of the two tile systems if a fill of more than 2 feet is planned. These vertical tiles should be held in place with stone fill. Tile joints should be tight. Some radial tiles should extend beyond each intersection and slope sharply downward to ensure good drainage.

7) Tar paper or its approved equivalent should be placed over the tile and/or pipe joints to prevent clogging, and large stone should be placed around and over drain tiles and/or pipes for protection.

8) A layer of 2 to 6 inches of stone should be placed over the entire area under the tree from the well outward at least as far as the drip line. For fills up to 2 feet deep, a layer of stone 8 to 12 inches thick should be adequate. A thicker layer of this stone, not to exceed 30 inches, will be needed for deeper fills.

9) A layer of 0.75-inch to 1-inch stone covered by straw, fiberglass mat, or a manufactured filter fabric should be used to prevent soil from clogging the spaces between stones. Cinders should not be used as fill material.

10) Filling should be completed with porous soil, such as topsoil, until the desired grade is reached. This soil should be suitable to sustain specified vegetation.

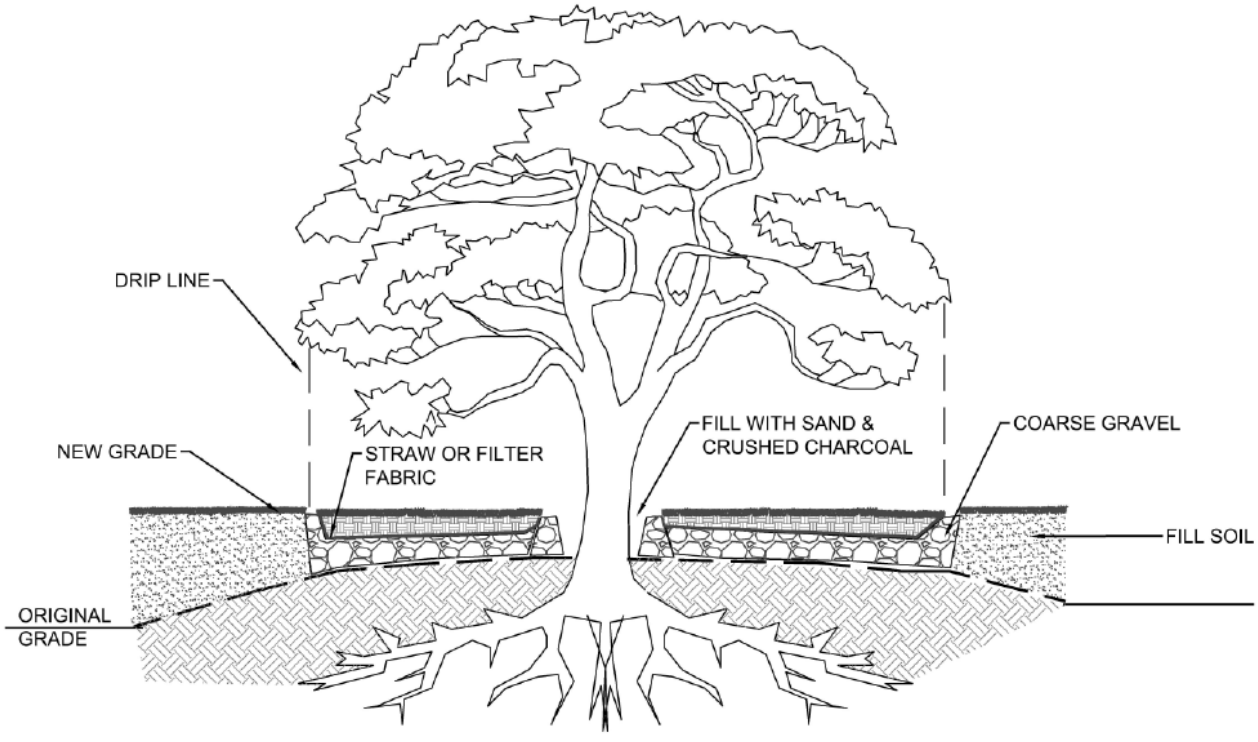
11) To prevent clogging of the drain lines, crushed stone should be placed inside the dry well over the openings of the radial tiles. Vertical tiles should also be filled with crushed rock and may also be covered with a screen.

12) To prevent falls into the dry well and leaves and accumulation of debris, the area between the trunk and the well wall should either be covered by an iron grate or filled with a 50-50 mixture of crushed charcoal and sand (this will also prevent rodent infestation and mosquito breeding).

c. Where water drainage through the soil is adequate, coarse gravel in the fill may be substituted for the tile. This material has sufficient porosity to ensure air drainage. Instead of the vertical tiles or pipes in the system, stones, crushed rock, and gravel may be added so that the upper level of these porous materials slants toward the surface in the vicinity below the drip line (Figure C-SSM-01-5).

d. Raising the grade on only one side of a tree or group of trees may be accomplished by constructing only half of one of these systems.

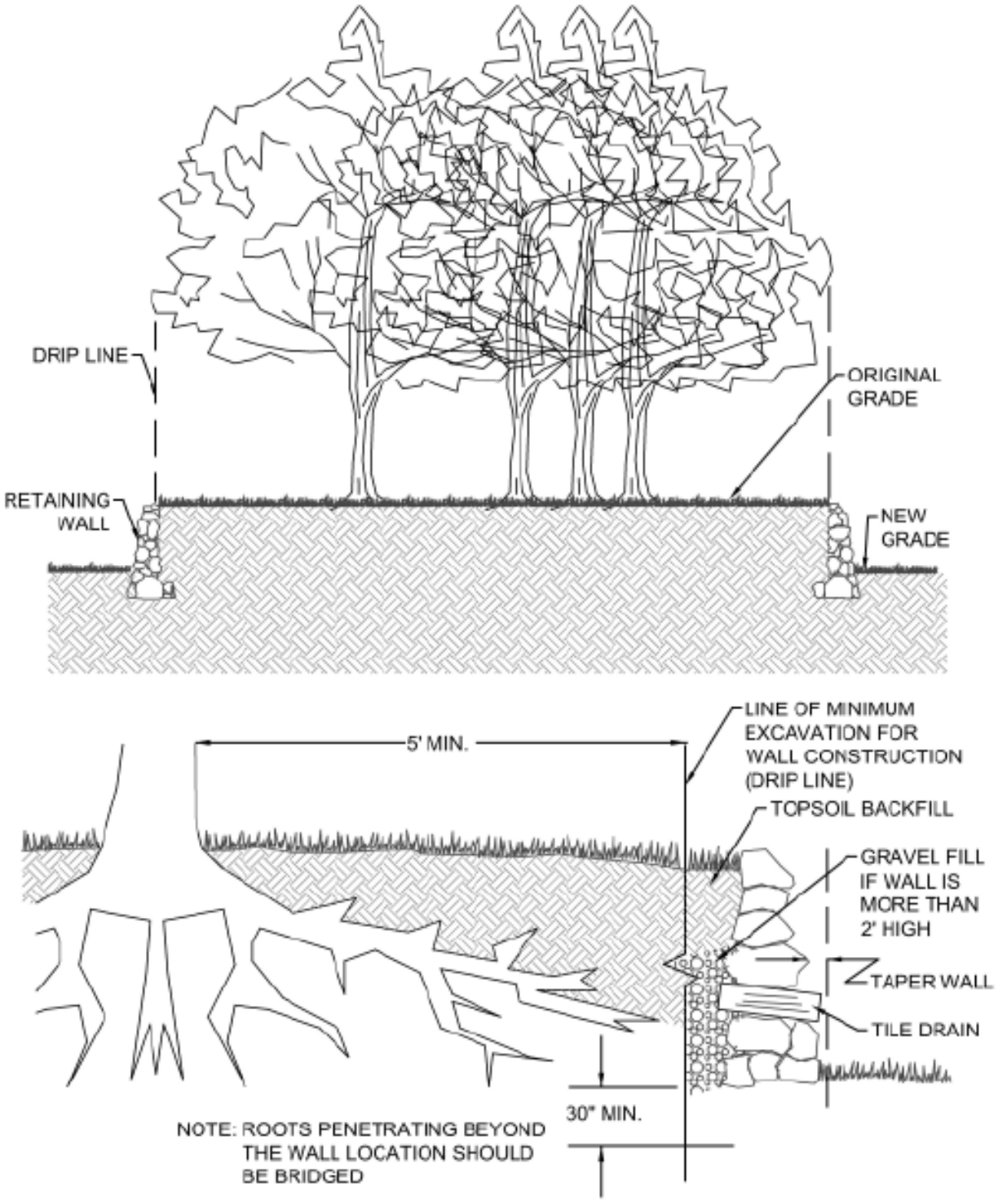
Figure C-SSM-01-5 Tree Well without Drain Tiles



Source: VA DSWC

2. **Lowering the grade:** Trees should be protected from harmful grade cuts by the construction of a tree wall (Figure C-SSM-01-6).
   a. Following excavation, all tree roots that are exposed and/or damaged should be trimmed clean; painted with tree paint; and covered with moist peat moss, burlap, or other suitable material to keep them from drying out.
   b. The wall should be constructed of large stones, brick, building tile, or concrete or cinder block in accordance with the detail on Figure C-SSM-01-6.
   c. Backfill with peat moss, other organic material, or with topsoil to retain moisture and aid in root development.
   d. Apply fertilizer and water thoroughly. Fertilizer formulations, application rates, and methods will conform to the guidelines provided in Table C-SSM-01-4.
   e. Prune the tree crown, reducing the leaf surface in proportion to the amount of root loss.
   f. Provide drainage through the wall so water will not accumulate behind the wall.
   g. The grade may be lowered on only one side of a tree or group of trees by constructing only half of this system.

Figure C-SSM-01-6 Tree Well Detail 2



Source: Zion 1968.

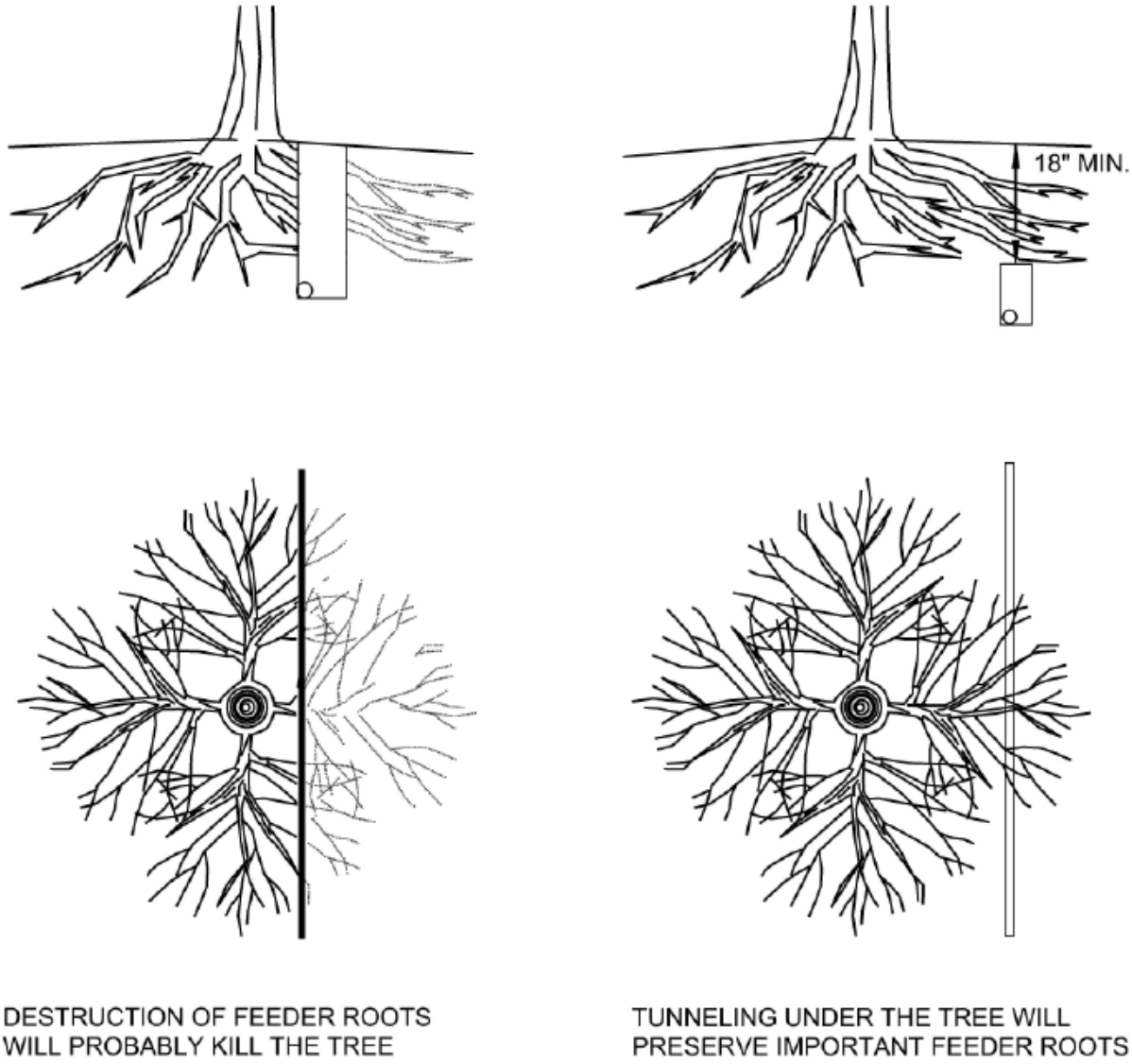
3. **Trenching and Tunnelling:**

a. Trenching should be conducted as far away from the trunks of trees as possible, preferably outside the reach of branches or crown spreads of trees, to reduce the amount of root area damaged or killed by trenching.

b. Wherever possible, trenches should avoid large roots or root concentrations. This can be accomplished by curving the trench or by tunnelling under large roots and areas of heavy root concentration.

c. Tunnelling is more expensive initially, but it usually causes less soil disturbance and physiological impact on the root system (Figure C-SSM-01-7). The extra cost may offset the potential cost of Tunnelling is almost always preferred over trenching. The tunnel should be 18 inches or deeper below the ground surface and should not be located under the center of the tree (an off-center tunnel has the smallest impact on the roots).

Figure C-SSM-01-7 Trenching vs. Tunneling



Source: Pirone 1979.

d. Roots should not be left exposed to the air. The roots should be covered with soil as soon as possible or protected and kept moistened with wet burlap or peat moss until the trench or tunnel can be filled.

e. The ends of damaged and cut roots should be cut off smoothly and protected by painting promptly with a tree wound dressing.

f. Trenches and tunnels should be filled as soon as possible. Air spaces in the soil will be avoided by careful filling and tamping.

g. Peat moss or other suitable material should be added to the fill material as an aid to inducing and developing new root growth.

h. The tree should be mulched and fertilized to conserve moisture, stimulate new root growth, and enhance general tree vigor.

i. If a large portion of the root system has been damaged or killed, the crown leaf surface should be proportionately reduced to balance the reduced root system. This may be accomplished by pruning 20 to 30 percent of the crown foliage. If roots are cut during the winter, the tree should be pruned before the next growing season. If roots are cut during the growing season, the tree should be pruned immediately.

4. **Removal and Replacement of Damaged Trees:** Should a tree intended and marked for retention be damaged seriously enough that survival and normal growth are not possible, the tree should be removed. If replacement is desirable and/or required, the replacement tree should be of the same or similar species, 2-inch to 2.5-inch (minimum) caliper balled and burlapped nursery stock. However, today, with the aid of a “tree spade,” the same caliper tree may be required as a replacement. Trees being removed should not be felled, pushed, or pulled into any tree being preserved.

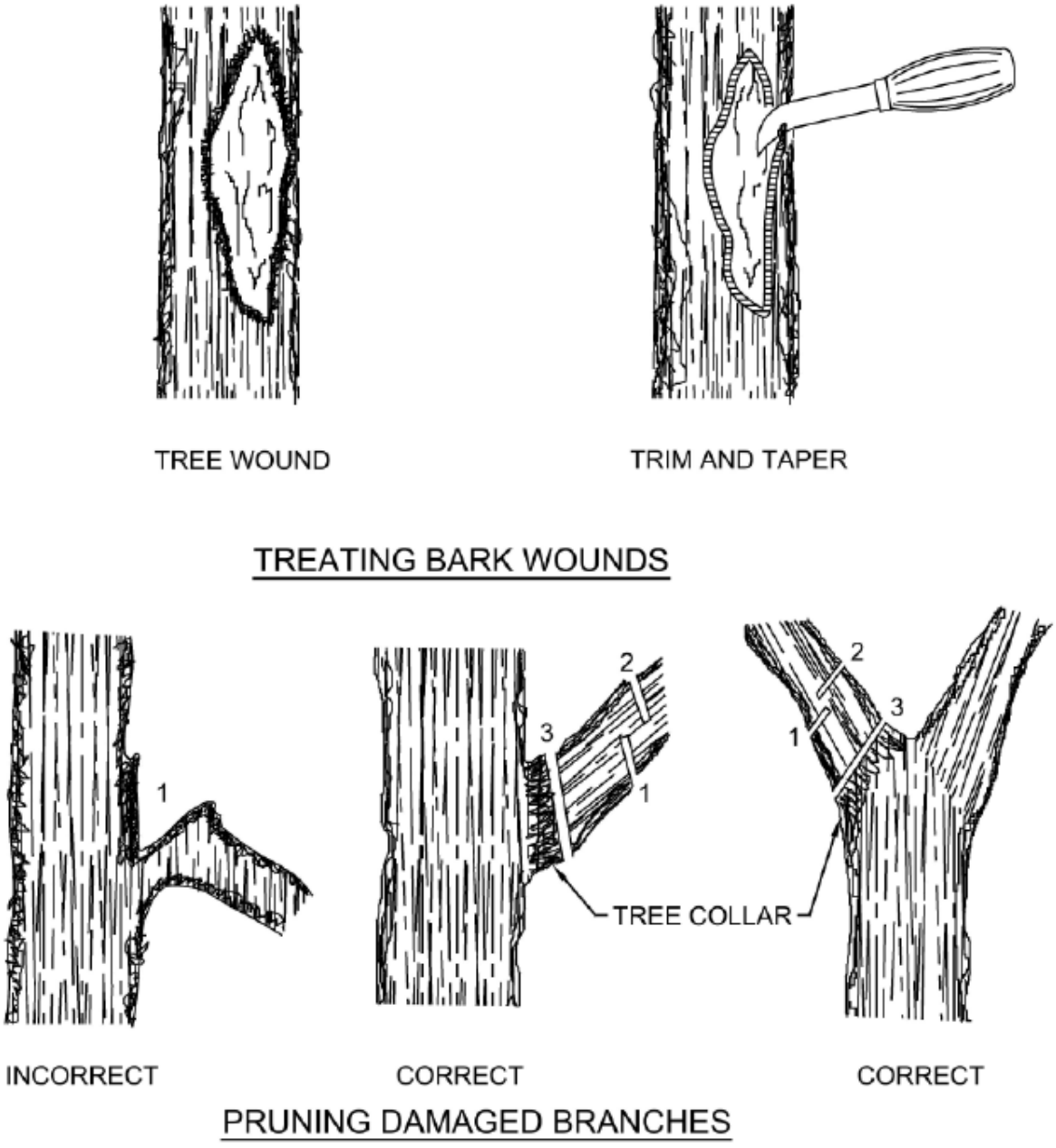
5. **Cleanup:** Cleanup after a construction project can be a critical time for tree damage. Trees protected during development are often destroyed by carelessness during the final cleanup and landscaping. Fences and barriers should be removed last, after everything else is cleaned up and carried away. Equipment operators should not clean any part of their equipment by slamming it against the trunk of any tree to be preserved.

7.0 Operations and Maintenance Considerations

Despite precautions, some protected trees may suffer damage. In such cases, the maintenance guidelines identified in Table C-SSM-01-5 should be implemented:

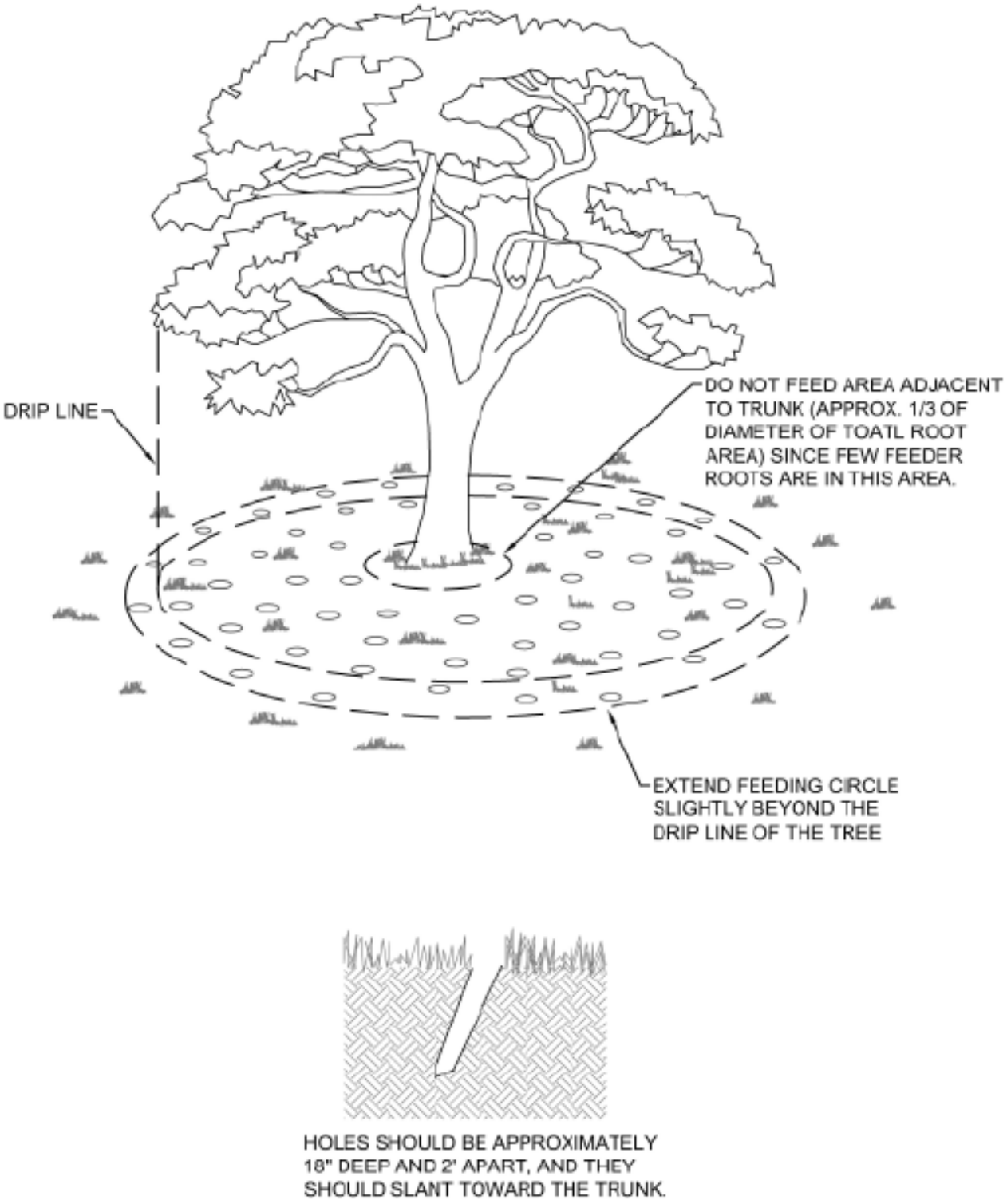
Table C-SSM-01-5 Operation and Maintenance	
Operation and Maintenance Considerations	
Soil Aeration	If the soil has become compacted over the root zone of any tree, the ground should be aerated by punching holes with an iron bar. The bar should be driven 1 foot deep and then moved back and forth until the soil is loosened. This procedure should be repeated every 18 inches until all the compacted soil beneath the crown of the tree has been loosened.
Repair of Damage	1. Any damage to the crown, trunk, or root system of any tree retained on the site should be repaired immediately. 2. When major root or bark damage occurs, remove some foliage to reduce the demand for water and nutrients. 3. Damaged roots should immediately be cut off cleanly inside the exposed or damaged area. Paint cut surfaces with approved tree paint and spread moist peat moss, burlap, or topsoil over the exposed area. 4. To treat bark damage, carefully cut away all loosened bark back into the undamaged area, taper the cut at the top and bottom, and provide drainage at the base of the wound (Figure C-SSM-01-8). 5. All tree limbs damaged during construction or removed for any other reason should be cut off above the collar at the preceding branch junction (Figure C-SSM-01-8). 6. Care for serious injuries should be prescribed by a forester or a tree specialist.
Fertilization	Broadleaf trees that have been stressed or damaged should receive a heavy application of fertilizer to aid their recovery. 1. Trees should be fertilized in the late fall (after October 1) or the early spring (from the time frost is out of the ground until May 1). Fall applications are preferred, as the nutrients will be made available over a longer period. 2. Fertilizer should be applied to the soil over the feeder roots (see Figure C-SSM-01-9). In no case should it be applied closer than 3 feet from the trunk. The root systems of conifers extend some distance beyond the drip line. Increase the area to be fertilized by one fourth the area of the crown. 3. Fertilizer should be applied using approved fertilization methods and equipment. 4. Formulations and application rates should conform to the guidelines provided in Table C-SSM-01-4. Maintain a ground cover of organic mulch around trees sufficient to prevent erosion, protect roots, and hold water.

Figure C-SSM-01-8 Tree Care



Source: Fairfax County 1976.

Figure C-SSM-01-9 Tree Fertilization



Source: Pirone 1979.

8.0 References

ASTM. 2022. D638-14 – Standard Test Method for Tensile Properties of Plastics. July 21.

Fairfax County. 1976. Fairfax County's Public Facilities Manual. Land Development Services. Volume III.

Georgia Soil and Water Conservation Commission.2016. Manual for Erosion and Sediment Control in Georgia. Vegetative & Structural BMPs for Land-Disturbing Activities. 2016.

Pirone, P.P. 1978 Tree Maintenance. Fifth Edition.

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C-SSM-02 Topsoiling

1.0 Definition

Topsoil is defined as the A and E horizons of the existing mineral soil profile. Well humified litter layer (O horizon) material may also be included but not fresh or partially decomposed litter. Topsoiling as a construction best management practice (BMP) entails preserving and using the surface layer of undisturbed soil, often enriched in organic matter, to obtain a more desirable planting and growth medium and enhance final site stabilization.



Source: Wetlands Inc. 2021

2.0 Purpose and Applicability of Best Management Practice

Topsoiling provides a suitable growth medium for final site-stabilizing vegetation.

Topsoiling applies where:

1. The preservation or importation of topsoil is determined to be the most effective method of providing a suitable growth medium.
2. High-quality turf is desirable to withstand intense use or meet aesthetic requirements.
3. Permanent vegetation will be established.
4. Slopes are 2H:1V or flatter unless other measures are taken to prevent erosion and sloughing.

Topsoiling is necessary when the subsoil or existing soil presents the following problems:

1. The texture, rockiness, pH, or nutrient balance of the available soil cannot be modified by reasonable means to provide an adequate growth medium (which would contain a high volume of air-void space [approximately 20 percent by volume]), moderate water-holding capacity with a high percent of the contained water readily available for plant uptake, stability against compaction and decomposition that would alter the air-water balance, low concentrations of soluble salts, freedom from pests and toxins, and uniformity.
2. The soil material is too shallow (less than 20 inches depth of solum) to provide an adequate root zone and to supply necessary moisture and nutrients for plant growth.
3. The existing soil contains pollutants that are potentially toxic to plant growth.

3.0 Planning and Considerations

Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of humified organic matter. It is the major zone of root development, carrying many of the nutrients available to plants and supplying a large share of the water used by plants. Topsoil can usually be differentiated from subsoil by texture as well as color. Clay content usually increases in the subsoil. The depth of topsoil may vary widely. On severely eroded sites, it may be gone entirely (North Carolina Sediment and Control Commission et al. 2013).

Advantages of topsoil include its high organic matter content and friable consistence, water-holding capacity, and nutrient content. The texture and friability of topsoil are usually much more conducive to seedling emergence and root growth. In addition to being a better growth medium, topsoil is often less erodible than subsoils, and the coarser texture of topsoil vs subsoil increases infiltration capacity and reduces runoff.

Although topsoil serves as an excellent growth medium, there are disadvantages to its use:

- Stripping, stockpiling, and reapplying topsoil, or importing topsoil, may not always be cost-effective vs amending existing soil.
- Topsoiling can delay seeding or sodding, increasing the exposure time of denuded areas.
- Topsoil may contain undesirable weed species seeds that may compete with intended vegetation.

In site planning, the option of topsoiling should be compared with that of preparing a seedbed into properly amended subsoil. Some clay content in subsoils provides high moisture availability and deters leaching of nutrients and, when properly limed and fertilized and/or organically amended, subsoils may serve as a good growth medium that is generally free of weed seeds. In many cases, topsoiling may not be required for the establishment of less demanding, lower-maintenance plant material. **Topsoiling is strongly recommended where permanent vegetation is to be established.** Topsoiling is necessary when establishing vegetation on shallow (< 6 inches to rock) soils, soils containing potentially toxic materials, and soils of critically low pH (highly acidic; < pH 5.5 unless limed) levels.

If topsoiling is to be conducted, the following items should be considered:

- Topsoil will be spread at a settled depth of 4 inches on grades less than 3:1 (VDEQ 2022).
- Topsoil stockpiles should be located on disturbed areas, away from concentrated runoff, that do not interfere with work on the site.
- Allow sufficient scheduling for topsoil to be spread and stabilized before seeding, sodding, or planting.
- Care must be taken not to apply topsoil to subsoil if the two soils have strongly contrasting textures. Clayey topsoil over sandy subsoil is a particularly poor combination, as water may creep along the junction between the soil layers, causing the topsoil to saturate and slough. Sandy topsoil over a clay subsoil is equally likely to fail.
- The returned topsoil layer must adhere sufficiently to the underlying subsoil to ensure stability and resist planar slippage failure. It may be necessary to roughen the surface of the underlying subsoil (see Surface Roughening [C-SSM-03]), particularly materials with high clay content, which may smear when cut and manipulated when moist. Alternatives to topsoiling, including use of soil amendments and roughening of slopes, should be considered for steep slopes.
- Use of manufactured soils that meet the design criteria outlined below (Section 5.0) should be considered when natural topsoil materials are not available.

4.0 Stormwater Performance Summary

MS-1: STABILIZATION – Permanent or temporary soil stabilization shall be applied to denuded areas within 7 days after reaching final grade on any portion of the site. Temporary soil stabilization shall be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization shall be applied to areas that can be left dormant for more than 1 year.

MS-2: STOCKPILES, WASTE, AND BORROW AREAS – During construction of the project, soil stockpiles and borrow areas shall be stabilized or protected with sediment trapping measures. The applicant is responsible for the temporary protection and permanent stabilization of all soil stockpiles on site as well as borrow areas and soil intentionally transported from the project site.

9VAC25-875-560.

5.0 Design Criteria

The site should be evaluated in the field to determine if there is sufficient topsoil of good quality to justify stripping. Topsoil should be friable and Natural Resources Conservation Service (NRCS) texture class loam (loam, sandy loam, silt loam, sandy clay loam, clay loam). Heavy loads of debris, trash, stumps, rocks, roots, and noxious weeds should not be present, and the soil should demonstrate the ability to support healthy vegetation.

All topsoil should be tested by a qualified laboratory for the following criteria:

1. Organic matter as humus content should be not less than 1.5% by weight.
2. pH range should be from 6.0 to 7.5. If pH is less than 6.0, lime should be added in accordance with soil test results or in accordance with the recommendations of the vegetative establishment practice being used.
3. Soluble salts concentrations should not exceed 500 parts per million (ppm).

If additional off-site or manufactured topsoil is needed, or if the topsoil is modified, it should meet these standards.

6.0 Construction Specifications

6.1 Stripping

Topsoiling should not be performed when the soil is wet or frozen. Stripping should be confined to the immediate construction area. A 4- to 6-inch stripping depth is common, but depth may vary depending on the soil. All perimeter dikes, basins, and other sediment controls should be in place before stripping.

6.2 Stockpiling

Select the stockpile location to avoid slopes, natural drainageways, and traffic routes. On large sites, respreading is easier and more economical when topsoil is stockpiled in small piles located near where the topsoil will be used.

Stabilize or protect stockpiles in accordance with Minimum Standard 2.

Sideslopes of the stockpile should not exceed 2H:1V (VDEQ 2022).

Perimeter control measures must be placed around the stockpile immediately to retain sediment, see Silt Fence (C-PCM-04) and Temporary Seeding (C-SSM-09) if the stockpile is to remain dormant for longer than 30 days (refer to Minimum Standards MS-1 and MS-2). 109

6.3 Site Preparation for Topsoiling

Before topsoiling, establish necessary erosion and sediment control practices such as diversions, grade stabilization structures, berms, dikes, level spreaders, waterways, and sediment basins. These practices must be maintained during topsoiling.

1. Grading: Previously established grades on the areas to be topsoiled should be maintained according to the approved plan.
2. Liming: Where the pH of the subsoil is 6.0 or lower, agricultural limestone should be spread in accordance with results of the soil test or the vegetative establishment practice being used.
3. Bonding: After the areas to be topsoiled have been brought to grade, and immediately before dumping and spreading the topsoil, the subgrade should be loosened by discing or scarifying to a depth of at least 2 inches to encourage adhesion of the topsoil to subsoil and limit slippage.

6.4 Applying Topsoil

Topsoil should not be placed during frozen or muddy conditions; when topsoil or subgrade is excessively wet; or in a condition that may otherwise be detrimental to proper grading, proposed sodding, or seeding.

After areas to be topsoiled have been brought to grade, and immediately before dumping and spreading the topsoil, the subgrade (subsoil) should be loosened by discing or scarifying to a depth of at least 2 inches to ensure bonding of the topsoil and subsoil.

The topsoil should be uniformly graded and distributed to a minimum settled depth of 2 inches on 3H:1V or steeper slopes and 4 inches on flatter slopes. See Table C-SSM-02-1 to determine volume of topsoil required for application to various depths.

Any irregularities in the surface resulting from topsoiling or other operations should be corrected to prevent the formation of depressions or water pockets.

It is necessary to grade and smooth the topsoil sufficiently to ensure good contact with the underlying mineral soil and to obtain a level seedbed, particularly for the establishment of high-maintenance turf.



Topsoiling Application Failed
Source: Environment Canterbury Regional Council 2017

Compaction is to be avoided, as it increases runoff velocity and volume and deters seed germination.

Surfaces that are not going to be mowed should be left rough in accordance with Surface Roughening (C-SSM-03).

Table C-SSM-02-1 Volume (cubic yards) of Topsoil Required for Various Depths

Depth (inches)	Per 1,000 Square Feet	Per Acre
1	3.1	134
2	6.2	268
3	9.3	403
4	12.4	537
5	15.5	672
6	18.6	806

7.0 Operations and Maintenance Considerations

Slopes and areas that will not be mowed may be left rough after spreading topsoil. A disc may be used to promote bonding at the interface between topsoil and subsoil.

After topsoil application, follow procedures for seedbed preparation, taking care to avoid excessive mixing of topsoil into the subsoil. Apply stabilization to areas that remain dormant for 7 days after topsoil has been spread.

8.0 References

Environment Canterbury Regional Council. 2017. Erosion and Sediment Control Toolbox for Canterbury. located at: www.esccanterbury.co.nz.

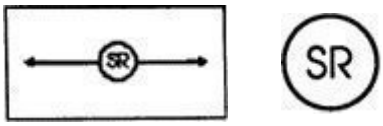
North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual.

Virginia Department of Environmental Quality (VDEQ). 1992. Virginia Erosion and Sediment Control Handbook. Third edition.

VDEQ. 2022. Guidance Memo No. 22-2012 – Stormwater Management and Erosion & Sediment Control Design Guide. July 1.

Wetlands, Inc. 2021. Topsoiling. Located at: www.wetlandsincorporated.com/services/topsoiling.

C-SSM-03 Surface Roughening



1.0 Definition

Surface roughening is the practice of providing a rough soil surface with horizontal depressions to reduce runoff velocity, increase infiltration, aid the establishment of vegetation, and reduce erosion. For roughened surfaces within 50 feet of a surface water, and where blanketing of seeded areas is proposed as the means to achieving permanent stabilization, spray-on type blankets are recommended. Details for stair stepping, grooving, and tracking are provided in subsequent sections.



Effective and Proper Surface Roughening
Source: USEPA 2021

Surface roughening is also providing a rough soil surface with horizontal depressions created by operating a tillage or other suitable implement on the contour or leaving slopes in a roughened condition by not fine grading them.

– CAD and PDF files for C-SSM-03 Surface Roughening

2.0 Purpose and Applicability of Best Management Practice

Use surface roughening to:

1. Aid the establishment of vegetative cover from seed.
2. Reduce runoff velocity and increase infiltration.

3. Reduce erosion and provide for sediment trapping.

This practice is recommended under the following conditions:

1. Surface roughening should be applied to slopes 3H:1V or steeper unless a stable rock face is provided or it can be shown that there is not a potential for sediment pollution to enter surface waters.
2. When slopes are steeper than 3H:1V, use stair-step grading, grooving, furrowing, or tracking if the slopes are to be stabilized with vegetation.
3. Areas with grades shallower than 3H:1V should have the soil surface lightly roughened and loose to a depth of 2 to 4 inches before seeding.
4. Areas that have been graded and will not be stabilized immediately may be roughened to reduce runoff velocity until seeding takes place.

Slopes with a stable rock face do not require roughening or stabilization.

3.0 Planning and Considerations

It is difficult to establish vegetation on smooth, hard surfaces due to reduced water infiltration and the potential for erosion. Although rough slope surfaces with uneven soil and rocks left in place may appear unattractive or unfinished at first, such conditions encourage water infiltration, speed the establishment of vegetation, and decrease runoff velocity.

Rough and loose soil surfaces give lime, fertilizer, and seed some natural coverage. Niches in the surface provide microclimates, which generally provide a cooler and more favorable moisture level than hard, flat surfaces and aid seed germination.

There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends on the type of slope. ***Roughening methods include stair-step grading, grooving, and tracking.*** Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

1. Disturbed areas that will not require mowing may be stair-step graded, grooved, or left rough after filling.
2. Stair-step grading is particularly appropriate in soils containing large amounts of soft rock. Each "step" catches material that sloughs from above and provides a level site where vegetation can become established.
3. Areas that will be mowed (these areas should have slopes less steep than 3H:1V) may have small furrows left by discing, harrowing, raking, or seed-planting machinery operated on the contour.
4. It is important to avoid excessive compacting of the soil surface when scarifying. Tracking with bulldozer treads is preferable to not roughening at all but is not as effective as other forms of roughening, as the soil surface is severely compacted and runoff is increased.

4.0 Stormwater Performance Summary

MS-1: STABILIZATION – Permanent or temporary soil stabilization shall be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization shall be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization shall be applied to areas that are to be left dormant for more than 1 year.

MS-7: CUT AND FILL SLOPES – Cut and fill slopes shall be designed and constructed to minimize erosion. Slopes found to be eroding excessively within 1 year of permanent stabilization shall be provided with additional slope stabilizing measures until the problem is corrected.

5.0 Design Criteria

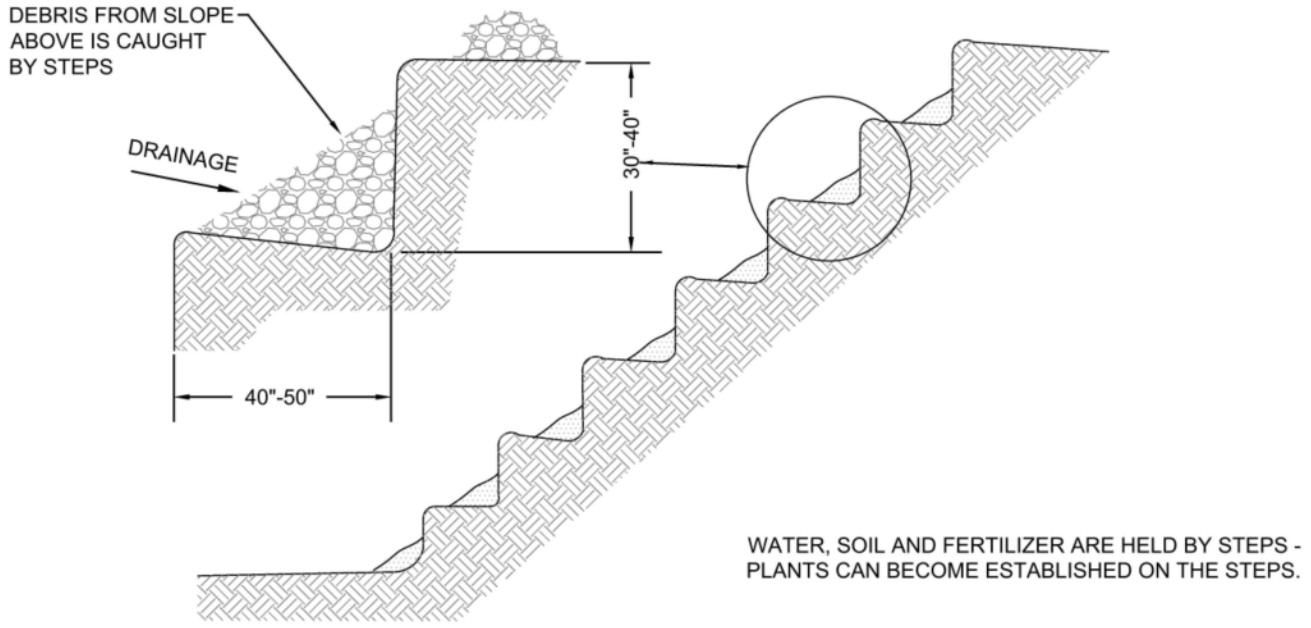
No formal design is required.

6.0 Construction Specifications

6.1 For Cut Slope Applications for Areas that Will Not Be Mowed

Cut slopes with a gradient steeper than 3H:1V should be stair-step graded or grooved.

Figure C-SSM-03-1 Stair Stepping Cut Slopes



1. Stair-step grading may be carried out on any material soft enough to be ripped with a bulldozer. Slopes consisting of soft rock with some subsoil are particularly suited to stair-step grading (Figure C-SSM-03-1).

   The ratio of the vertical cut distance to the horizontal distance should be less than 1H:1V, and the horizontal portion of the "step" should slope toward the vertical wall.

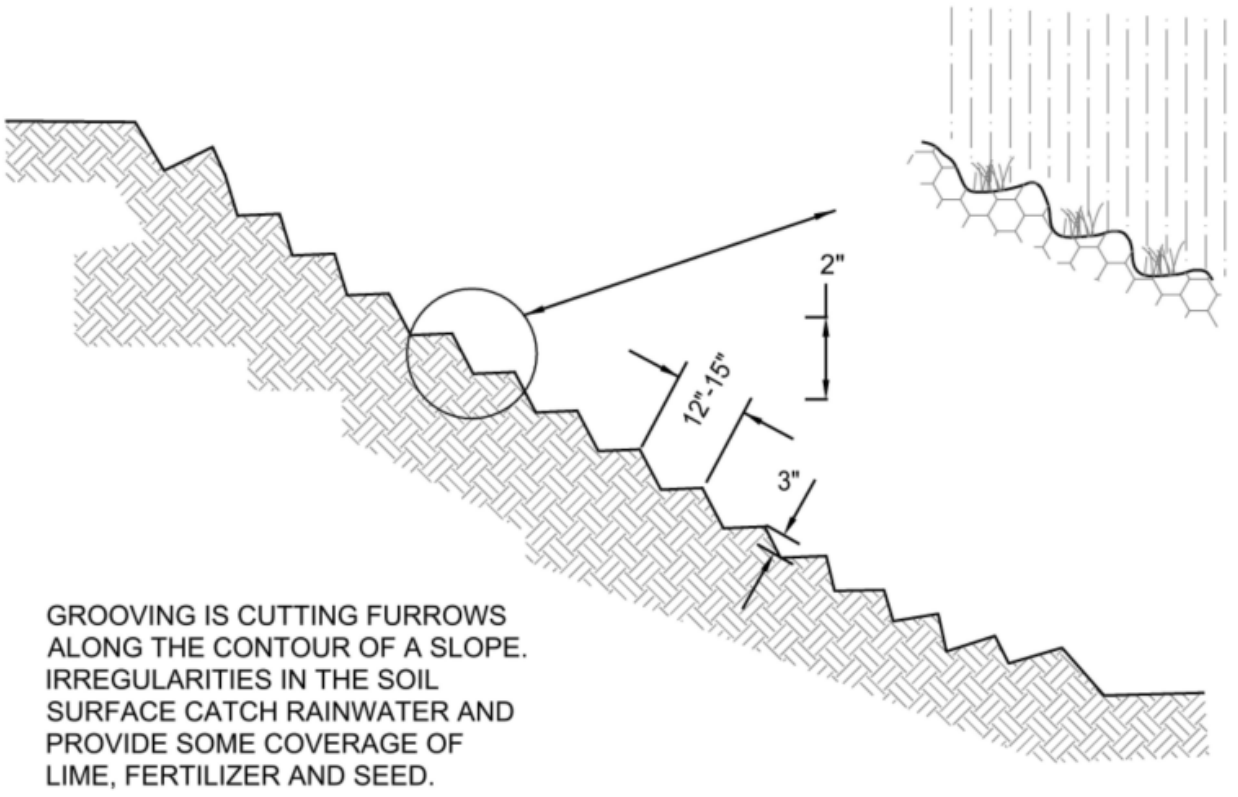
   Individual vertical cuts should not be more than 30 inches on soft soil materials and not more than 40 inches in rocky materials.

2. Grooving or tracking consists of using machinery to create a series of ridges and depressions that run perpendicular to the slope (on the contour).

   Grooves may be made with any appropriate implement that can be safely operated on the slope and that will not cause undue compaction.

3. Suggested implements include discs, tillers, spring harrows, and the teeth on a front-end loader bucket. Such grooves should not be less than 3 inches deep or further than 15 inches apart.

Figure C-SSM-03-2 Grooving Slopes



6.2 For Fill Slope Applications for Areas that Will Not Be Mowed

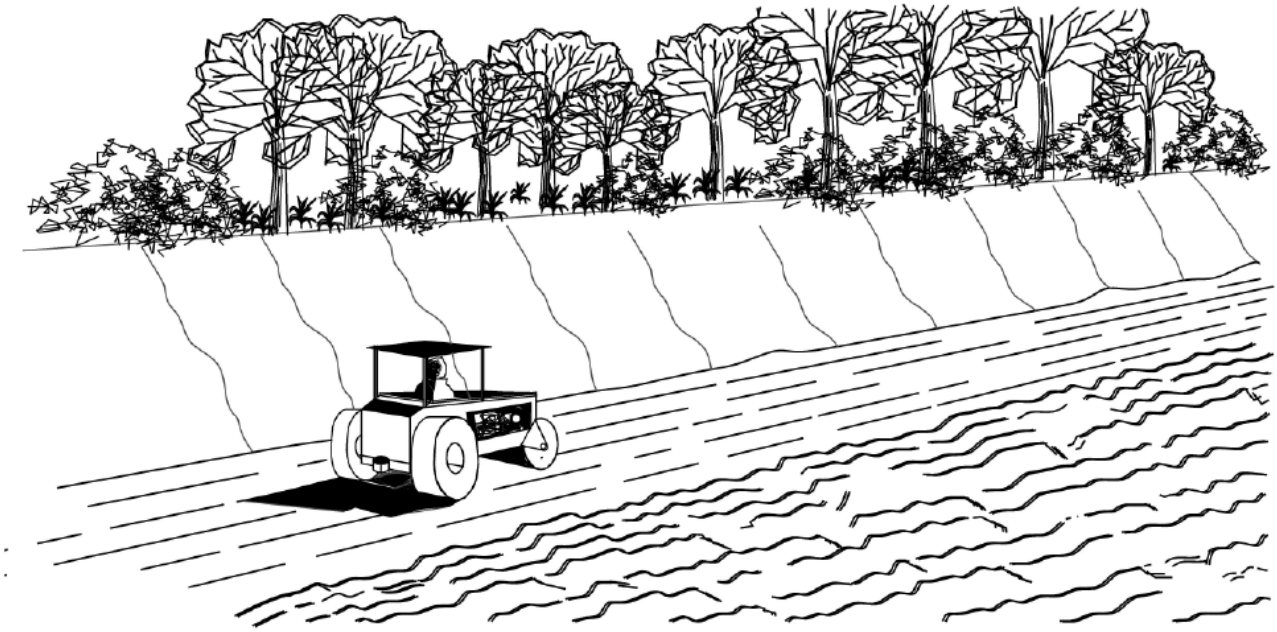
1. Fill slopes with a gradient steeper than 3H:1V should be grooved or allowed to remain rough as the slopes are constructed. Method (1) or (2) may be used.
2. Groove according to #2 in the previous section. As lifts of the fill are constructed, soil and rock materials may be allowed to fall naturally onto the slope surface. See Figure C-SSM-03-3.

   Colluvial materials (soil deposits at the bases of slopes or from old stream beds) should not be used in fills, as the materials flow when saturated. At no time should slopes be bladed or scraped to produce a smooth, hard surface.



Surface Roughening Ignored on Side Slopes of Access Road

Figure C-SSM-03-3 Fill Slope Treatment



EACH LIFT OF THE FILL IS COMPACTED, BUT THE OUTER FACE OF THE SLOPE IS ALLOWED TO REMAIN LOOSE SO THAT THE ROCKS, CLODS, ETC. REACH THE NATURAL ANGLE OF REPOSE.

Source: VA DSWC

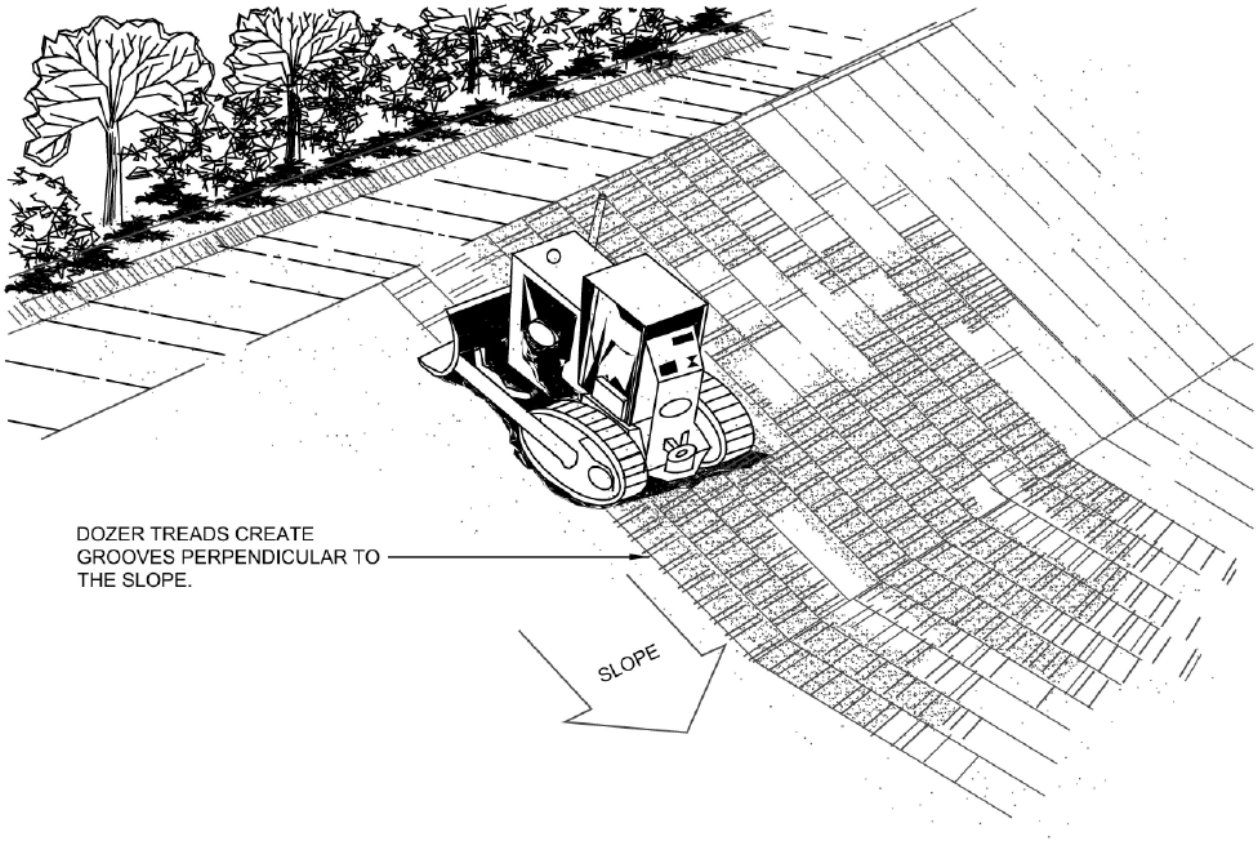
6.3 Cuts, Fills, and Graded Areas that Will Be Mowed

Mowed slopes should not be steeper than 3H:1V. Excessive roughness is undesirable where mowing is planned. These areas may be roughened with shallow grooves such as those that remain after tilling, discing, harrowing, raking, or use of a cultipacker-seeder. The final pass of any such tillage implement should be on the contour (perpendicular to the slope).

Grooves formed by such implements should be no less than 1 inch deep and not farther than 12 inches apart. Fill slopes that are left rough as constructed may be smoothed with a dragline or pick chain to facilitate mowing.

6.4 Roughening with Tracked Machinery

Figure C-SSM-03-4 Tracking



Source: MI Soil Erosion & Sedimentation Guide

Roughening with tracked machinery on clayey soils is not recommended unless no alternatives are available. Undue compaction of surface soil results from this practice. Sandy soils do not compact severely and may be tracked. In no case is tracking as effective as the other roughening methods described.

When tracking is the chosen surface roughening technique (Figure C-SSM-03-4), it should be accomplished by operating tracked machinery up and down the slope to leave horizontal depressions in the soil. As few passes of the machinery should be made as possible to minimize compaction.

6.5 Seeding

Roughened areas should be seeded and mulched as soon as possible to obtain optimum seed germination and seedling growth. See Temporary Seeding (C-SSM-09), Permanent Seeding (C-SSM-10), and Mulching (C-SSM-11). Fill diversions and slope drains can be used to prevent concentrated flow over slopes while waiting for vegetative stabilization.

7.0 Operations and Maintenance Considerations

Periodically check the seeded slopes for rills and washes. Fill these areas slightly above the original grade, then reseed and mulch as soon as possible (North Carolina Sedimentation Control Commission et al. 2013).

Seeded slopes should be inspected after every recordable rain event. Seed should be reapplied in areas where it may have washed away during the previous rain event.

8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

United States Environmental Protection Agency (USEPA). 2021. Stormwater Best Management Practice: Soil Roughening. EPA-832-F-21-028JJ. December.

Virginia Department of Environmental Quality. 1992. Virginia Erosion and Sediment Control Handbook. Third edition.

C-SSM-04 Compost Blankets

1.0 Definition

A compost blanket is a layer of loosely applied composted material placed on the soil in disturbed areas to reduce stormwater runoff and erosion.

2.0 Purpose and Applicability of Best Management Practice

A compost blanket is a slope stabilization, erosion control, and vegetation establishment practice used on construction sites to stabilize bare, disturbed, or erodible soils. The compost material fills in small rills and voids to limit channelized flow, provides a more permeable surface to facilitate stormwater infiltration, and promotes revegetation.



Example Compost Blanket Source: Full Circle Mushroom Compost, Inc. n.d.

Compost blankets function as mulch, cover 100% of the soil surface, and therefore provide the beneficial effects characteristic to mulches including: reduced raindrop impact and splash erosion, reduced runoff energy and sheet erosion, buffered soil temperature for plants, decreased moisture evaporation, increased moisture holding capacity at the soil surface, reduced runoff volume and velocity, and increased infiltration.

Where planned and applied correctly to a properly prepared subgrade, compost blankets can aid in amending the soil. This can provide benefits to the soil's structure; increased aggregation, aeration, infiltration and percolation, activity of beneficial microbes, and availability of nutrients; increased plant health; and long-term site sustainability.

Seeds can be mixed into the compost before the blanket is applied to the surface.

Compost blankets may be used for temporary erosion control and in support of providing permanent vegetative cover. When the blanket is specified for permanent stabilization, incorporate vegetative cover with the compost at rates shown in the seeding specification on the approved plan and maintained until the permanent cover is established. Use Virginia native seed for incorporation into compost blankets for permanent stabilization. Where specified for temporary stabilization, install and maintain the blanket as

specified in the construction sequence on the approved plan. Incorporate a temporary vegetative cover or nurse crop with temporary compost blankets.

3.0 Planning and Considerations

- Consider compost blankets when soil is poor. Compost blankets can be placed on any soil surface: flat, steep, rocky, or frozen.
- Only use compost blankets to control sheet flow from rainfall and not in areas of concentrated runoff.
- Take care not to apply compost where it can raise the nutrient level of streams.
- Do not place compost blankets in locations that receive concentrated or channeled flows either as runoff or a point source discharge.
- Do not use compost blankets in areas subject to vehicular traffic and use by heavy equipment.
- Avoid very coarse compost if the slope is to be landscaped or seeded, as it will make planting and crop establishment more difficult.

4.0 Stormwater Performance Summary

MS-1: STABILIZATION – Permanent or temporary soil stabilization shall be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization shall be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days.

Permanent stabilization shall be applied to areas that are to be left dormant for more than 1 year.

9VAC25-870-560

Erosion Control Efficiency: HIGH

Sediment Removal Efficiency: LOW

5.0 Design Criteria

The application of compost blankets is appropriate for erosion and sediment control on slopes up to a 2H:1V grade and for use in areas that have sheet flow drainage patterns.

Slopes steeper than 2H:1V may require special installation techniques such as additional blanket thickness, soil stabilization blankets or matting, and/or slope interruption devices (compost filter socks and berms).

The chemical, physical, and biological parameters of compost blankets recommended for use in this application are described in Table C-SSM-04-1.

Table C-SSM-04-1 Design Criteria for Compost

Compost Parameters for Compost Blanket Use				
Parameter[a]	**Unit**	**Acceptable Vegetative**	**Acceptable Non-Vegetative**	**Test Method**
Stability	mg CO2-C per g OM per day	<4	<4	TMECC 05.08-B
Maturity	% seed emergence & vigor	>80	N/A	TMECC 05.05-A

Table C-SSM-04-1 Design Criteria for Compost				
Compost Parameters for Compost Blanket Use				
Moisture Content	% wet weight basis	30-60	30-60	TMECC 03.09-A
Organic Matter Content	% dry weight basis	25-65	25-100	TMECC 05.07-A
Particle Size	Screen size to pass through	99% passing 3”; 90-100% pass 1”; 65-100% pass 0.75”; 0-75% pass 0.25”. Maximum particle size length 6” (152mm)	99% passing 3”; 90-100% pass 1”; 65-100% pass ¾”; 0-75% pass ¼”. Maximum particle size length 6” (152mm)	TMECC 02.12-B
pH	pH units	6.0-8.5	N/A	TMECC 04.11-A
Soluble Salts (Electrical Conductivity)	dS/m (mmhos/cm) dry weight basis	<5	N/A	TMECC 04.10-A
Physical Contaminants	% dry weight basis	<0.25	<0.25	Biological Assays

Notes:

Source: US Composting Council n.d.

a Recommended test methodologies are provided in Test Methods for the Examination of Composting and Compost (TMECC; US Composting Council n.d.).

% = percent

“ = inch

dS/m = deciSiemens per meter

mg CO2-C per g OM per day = milligram of carbon dioxide mineralization per gram of Organic Matter per day

mm = millimeter

mmhos/cm = millimhos per centimeter

N/A = not applicable

6.0 Construction Specifications

Perform the following steps to install compost blankets for erosion and sediment control. Include this information in the construction sequence on the approved erosion and sediment control plan. Modifications to the construction sequence are subject to the approval of the certified plan reviewer.

1. Prepare the soil by removing all large rocks, dirt clods, stumps, roots, grass clumps, trash, and other obstructions from the soil surface to allow for direct contact between the soil surface and the compost blanket.
2. Select the method to apply the compost blanket. The compost blanket can be applied by hand, conveyor system, compost spreader, or pneumatic delivery (blower) system. A pneumatic blower is most cost-effective and most adaptive in applying compost to steep, rough terrain, and hard-to-reach locations.
3. Apply the compost blanket to 100% of the area as required on the approved plan. Cover 100% of the bare or disturbed area with the blanket such that no native soil is visible in or through the compost blanket. Apply the compost blanket at the application rates specified in Table C-SSM-04-2.

Mix seed thoroughly with the compost before application or apply to the compost blanket at time of application at the appropriate rates prescribed by the approved plan.

4. Install compost blankets at least 10 feet over and beyond the shoulder of the slope and/or into the edge of existing vegetation to ensure that runoff does not undercut the blanket. Ensure that the existing root mat is not disturbed when installing compost blankets into the edge of existing vegetation.
5. Design and specify compost blanket application rates based on specific site (e.g., soil characteristics, existing vegetation) and climatic conditions, as well as project-related requirements and calculated stormwater runoff.
6. Track compost blankets installed on slopes greater than or equal to 4H:1V. Secure compost blankets placed on slopes greater than or equal to 3H:1V with adequate soil stabilization blankets and matting. Install soil stabilization blankets or matting over the compost blanket where high winds and wind erosion are expected, regardless of slope. All other installation procedures and specifications will be as shown on the approved plan and described in the approved construction sequence. Uniformly apply the compost as described in the approved construction sequence with the appropriate equipment. If required, thorough watering may be used to improve settling of the blanket.
7. The compost blanket should extend at least 3 feet over the shoulder of the slope to ensure that stormwater runoff does not flow under the blanket.
8. If the slope is steep (>2H:1V), apply soil stabilization blankets or matting over the compost blanket. Then place compost filter socks across the slope to reduce the runoff velocity. Compost berms may be placed at the top of the slope to divert or diffuse concentrated runoff before it reaches the compost blanket.



Improperly Installed Compost Blanket on Steep Slope
Source: ?

Table C-SSM-04-2 Compost Blanket Application Rates

Compost Blanket Application Rates			
Annual Rainfall/ Flow Rate	**Total Precipitation & Rainfall Erosivity Index**	**Application Rate for Vegetated[a] Compost Surface Mulch**	**Application Rate for Unvegetated Compost Surface Mulch**
Low	1”-25”; 20-90	1”-1.5” (25mm-37.5mm)	1”-1.5” (25mm-37.5mm
Average	26”-50”; 91-200	1”-1.5” (25mm-37.5mm)	1.5”-2” (37mm-50mm)
High	>51”; >201	1”-2” (25mm-50mm)	2”-4” (25mm-50mm)

Notes:

Source: North Carolina Sediment Control Division et al. 2013, Chapter 6 Practice Standards and Specifications, Section 6.18 Compost Blankets.

[a] Only use the lower application rates in conjunction with seeding and for compost blankets applied during the prescribed planting season for the region.

“ = inch

mm = millimeter

7.0 Operations and Maintenance Considerations

- Inspect compost blankets weekly and after each runoff event. If failure or damage to the blanket occurs, or if vegetation does not establish within the expected germination time of the selected seed type, reapply compost and seed to the affected area to return it to the original condition.
- Take additional measures as necessary to establish permanent ground cover.
- Inspect compost blankets until permanent vegetation is established.
- Repair soil stabilization blankets or matting placed over the compost blanket if the blankets or matting have been moved or damaged by wind or stormwater runoff and/or if part of or the whole blanket is not in contact with the soil surface.

8.0 References

Full Circle Mushroom Compost, Inc. n.d. Compost Blanket. Web page. Available online at: https://www.fullcirclemushroomcompost.com/projects/mushroom-compost-blanket-pa/.

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

US Composting Council. n.d. Compost – Erosion Control Uses: Compost Blanket Class Specific Guide. Available online at: www.compostingcouncil.org/page/CompostErosionControlUses.

United States Environmental Protection Agency. 2012. Stormwater Best Management Practice: Compost Blankets. EPA 833-F-11-007. United States Environmental Protection Agency, Office of Water, 4203M. March. Available online at: https://www3.epa.gov/npdes/pubs/compostblankets.pdf or https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater-construction.

C-SSM-05 Soil Stabilization Blankets and Matting

1.0 Definition

Soil stabilization blankets and matting are a form of protective blanket (Treatment 1 or soil stabilization matting (Treatment II) on a prepared planting area of a steep slope, channel, or shoreline.

– CAD and PDF files for C-SSM-05 Soil Stabilization Blanket and Matting

2.0 Purpose and Applicability of Best Management Practice

Soil stabilization blankets and matting aid in controlling erosion on critical areas by providing a microclimate that protects young vegetation and promotes its establishment. In addition, some types of soil stabilization mats are also used to raise the maximum permissible velocity of turf grass stands in channelized areas by “reinforcing the turf” to resist the forces of erosion during storm events.

Soil stabilization blankets and matting are applicable to short, steep slopes where erosion hazard is high, and planting is likely to be too slow to provide adequate protective cover; in vegetated channels where the velocity of design flow exceeds "allowable" velocity; on streambanks or tidal shorelines where moving water is likely to wash out new plantings; or where the forces of wind prevent standard mulching from remaining in place until vegetation becomes established.



Source: East Coast Erosion Control

Another application of this best management practice (BMP) is the stabilization of the slopes within sinkholes and slopes along ephemeral drainageways that terminate in sinkholes or other karst features.

Soil stabilization blankets and matting do not effectively prevent slope failures. Where slope stability problems are anticipated or encountered, consider appropriate measures such as reducing slope steepness, diverting upslope runoff, reducing soil moisture, loading the toe of the slope, or buttressing the slope.

3.0 Planning and Considerations

Soil stabilization blankets and mats can be applied to disturbed areas to supplement nature's erosion control system (vegetation) in its initial establishment and provide a safe and "natural" conveyance for high-velocity stormwater runoff.

Soil stabilization blankets and mats are being used today in many applications where previously a structural lining would have been required.

Designers should choose the type of blanket or matting most appropriate for the specific needs of a project.

Table C-SSM-05-1 Design Considerations for Soil Stabilization	
Type	**Notes on Proper Use**
Treatment 1	*Treatment 1 is a degradable soil stabilization blanket* that includes "combination" blankets consisting of a plastic netting, which covers and intertwines with a natural organic or man-made mulch, or a jute mesh, which is typically homogeneous in design and can act alone as a soil stabilization blanket. Use Treatment 1 soil stabilization blankets to help establish vegetation on previously disturbed slopes of 3H:1V or greater. Because the materials that comprise the soil stabilization blankets will deteriorate over time, use the blankets in permanent conveyance channels understanding that the system's resistance to erosion is based on the type of vegetation planted and the existing soil characteristics. During the establishment of vegetation, ensure that Treatment 1 blankets are not subjected to shallow or deep concentrated flows moving at rates greater than 4 feet per second (fps) or a shear stress over 2.25 lb/ft^2. Treatment 1 provides the following benefits in the achievement of vegetative stabilization when properly applied over seed and required amendments: • Protection of the seed and soil from raindrop impact and subsequent displacement; • Thermal consistency and moisture retention for seedbed area; • Stronger and faster germination of grasses and legumes; • Leveling off excess stormwater runoff; and • Prevention of sloughing of topsoil added to steeper slopes.

Table C-SSM-05-1 Design Considerations for Soil Stabilization	
Type	**Notes on Proper Use**
Treatment 2	*Treatment 2 is a soil stabilization matting,* which consists of a non-degradable, three- dimensional plastic structure that can be filled with soil prior to planting. This configuration provides a matrix for root growth in which the matting becomes entangled and penetrated by roots, forming continuous anchorage for surface growth and promoting enhanced energy dissipation. Use Treatment 2 matting on steep slopes (normally 3H:1V or greater) and in stormwater conveyance channels. In addition to the benefits noted for Treatment 1, Treatment 2 provides the following benefits in the achievement of vegetative stabilization and in the replacement of more traditional channel linings such as concrete and riprap: • Causes soil to drop out of stormwater and fill matrix with fine soils, which become the growth medium for the development of roots; • When embedded in the soil within stormwater channels, acts with the vegetative root system to form an erosion-resistant cover that resists hydraulic lift and shear forces; • Because Treatment 2 is non-degradable, the matting can be used in permanent conveyance channels and can withstand higher velocities of flow than the vegetation and soil would normally allow; and • However, ensure that where Treatment 2 matting is used within a conveyance system, the matting is not subjected to a flow velocity greater than 10 fps or shear stress over 8 lb/ft^2.

3.1 VDOT Nomenclature

Designers are cautioned that inclusion on the VDOT "Approved Products List" does not indicate compliance with the specifications in this Handbook or approval for use by VDEQ.

Designers should also note that these relationships are provided for informational purposes only. The specifications within this handbook apply to all projects outside of the VDOT right-of-way.

The following relationship exists between the two methods of naming the practice:

Table C-SSM-05-2 VESCH to VDOT Equivalency	
Virginia Erosion and Sediment Control Handbook (VESCH)	**VDOT Specifications**
Treatment 1 (is equivalent to)	Standard EC-2 (Temporary Rolled Erosion Control Product [RECP])
Treatment 2 (is equivalent to)	Standard EC-3 (Permanent RECP)

4.0 Stormwater Performance Summary

4.1 MS-1: Stabilization

Permanent or temporary soil stabilization will be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization will be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization will be applied in areas to be left dormant for more than 1 year.

4.2 MS-3: Permanent Vegetation

A permanent vegetative cover will be established on denuded areas not otherwise permanently stabilized. Permanent vegetation will not be considered established until achievement of a ground cover that is uniform, mature enough to survive, and will inhibit erosion.

Sediment Removal Efficiency: N/A

Erosion Control Efficiency: High

5.0 Design Criteria

Table C-SSM-05-3 Design Criteria for Soil Stabilization Blankets

Treatment 1 – Soil Stabilization Blanket	
Parameter	**Notes on Proper Use**
Allowable Velocity and Shear Stress	Refer to Table C-SSM-05-5 for allowable velocity and shear stress values for linings.
Combination Blanket	Use combination blankets that consist of a photo-degradable plastic netting, which covers and is entwined in a natural organic or man-made mulching material. Use a blanket with a mulching material that consists of wood fibers, wood excelsior, straw, coconut fiber, man-made fibers, or a combination of the same. Use a blanket that is a consistent thickness, with the mulching material/fibers evenly distributed over its entire length. Use a blanket that has the mulching material/fibers interlocked or entwined to form a dense layer, which not only resists raindrop impact but will allow vegetation to penetrate the blanket. Use a blanket that is non-toxic to vegetation and to the germination of seed and is not injurious to the unprotected skin of humans. At a minimum, ensure the plastic netting covers the top side of the blanket and possess a high web strength. Ensure the netting is entwined with the mulching material/fiber to maximize strength and provide for ease of handling.

Table C-SSM-05-3 Design Criteria for Soil Stabilization Blankets	
Treatment 1 – Soil Stabilization Blanket	
Jute Mesh	Use a jute mesh material that is a uniform, open, plain weave of undyed and unbleached single jute yarn. Use a yarn that has a loosely twisted construction and does not vary in thickness by more than one half of its normal diameter. Use a jute mesh material that is new and conforms to the following criteria. • Length of jute mesh is marked on each roll. • There are 0.60-inch openings (± 25%) between strands, lengthwise. • There are 0.90-inch openings (± 25%) between strands, lengthwise. • Weight is an average 0.90 pound per square yard with a tolerance of 5%. As previously noted, jute mesh provides such good coverage (large surface area of strands) and contains such small openings that it can be used alone as a blanket.
Other Treatment 1 Products	Use other Treatment 1 products that conform to manufacturer's specifications and are approved by the certified plan reviewer prior to being specified for a particular application. Install these products in accordance with manufacturer's recommendations, provided those recommendations are at least as stringent as this specification. Where used, ensure that these products cover more than 30% of the soil surface.
Staples	Use staples for anchoring Treatment 1 blankets that are No. 11-gauge wire or heavier with a minimum length of 6 inches. Use a larger staple with a length of up to 12 inches on loose, sandy, or unstable soils.

Table C-SSM-05-4 Design Criteria for Soil Stabilization Matting	
Treatment 2 – Soil Stabilization Matting	
Parameter	**Notes on Proper Use**
Allowable Velocity and Shear Stress	Refer to Table C-SSM-05-5 for allowable velocity and shear stress values for linings.

Table C-SSM-05-4 Design Criteria for Soil Stabilization Matting	
Treatment 2 – Soil Stabilization Matting	
Matting	Most of the Treatment 2 products provide a three-dimensional geo-matrix of nylon, polyethylene, or randomly oriented monofilaments, forming a mat. These products contain ultraviolet (UV) inhibiting stabilizers added to the compounds to ensure endurance and provide "permanent root reinforcement." The three-dimensional feature creates an open space that is allowed to fill with soil. The roots of the grass plant become established within the mat itself, forming a synergistic root and mat system. As the grass becomes established, the two "reinforce" each other, preventing movement or damage to the soil. Allowable velocities and shear stress values are increased considerably over natural turf stands. Selection of the appropriate matting materials, along with proper installation, become critical factors in the success of this practice. It is recommended that any velocities that exceed 10 fps or 8 lb/ft^2 be properly protected with some form of structural lining in accordance with Stormwater Conveyance Channel (C-ECM-09).
Staples	Staples or anchoring methods and recommendations vary by manufacturers. The expectation of high velocities will dictate the use of more substantial anchoring. Some of the typically recommended stakes, staples, and pins are depicted on Figure C-SSM-05-3.

Table C-SSM-05-5 Allowable Velocity and Shear Stress – Lined Ditches			
Type of Lining		**Maximum Allowable**	**Maximum Allowable Shear**
VESCH	**VDOT Standard**	**Velocity (fps)**	**Stress (lb/ft^2)**
Treatment 1	EC-2 (Type 1)	4.0	1.50
	EC-2 (Type 2)		1.75
	EC-2 (Type 3)		2.0
	EC-2 (Type 4)		2.25
Treatment 2	EC-3 (Type 1)	7.0	6.0
	EC-3 (Type 2)	10.0	8.0
	EC-3 (Type 3)	N/A	10.0
Source: VDOT Drainage Manual			

6.0 Construction Specifications

Table C-SSM-05-6 Material Specifications for Soil Stabilization Blankets	
Treatment 1 Soil Stabilization Blanket Installation	
Activity	**Notes**
Site Preparation	After the site has been shaped and graded to approved design, prepare a friable seedbed relatively free from clods, rocks more than 1.5 inches in diameter, and any foreign material that will prevent uniform contact of the protective covering with the soil surface. If necessary, redirect runoff away from the channel or slope during installation.
Planting	Lime, fertilize, and seed in accordance with Temporary Seeding BMP C-SSM-09 or Permanent Seeding BMP C-SSM-10, MS#1, and the approved plan. When using jute mesh on a seeded area, apply approximately one half the seed after laying the mat. The protective covering can be laid over sprigged areas in which small grass plants have been inserted into the soil. Where ground covers are to be planted, lay the protective covering first and then plant through the material as per planting design. When open-weave nets are used, apply lime, fertilizer, seed, and mulch before laying the net. When a combination blanket (such as an "excelsior" blanket) is used, apply seed and soil amendments before the blanket is laid.
Orientation	Refer to Figure C-SSM-05-1 for orientation of Treatment 1 for different topographic conditions.
Laying and Stapling	If instructions have been followed, all needed check slots will have been installed, and the protective covering will be laid on a friable seedbed free from clods, rocks, roots, or other large matter that might impede good contact. Start laying the protective covering from the top of the channel or top of slope and unroll down-grade. Allow to the blanket lay loosely on soil; do not stretch. Bury the upslope ends of the protective covering in an anchor slot no less than 6 inches deep. Tamp earth firmly over the material. Staple the material at a minimum of every 12 inches across the top end. Staple the edges of the material every 3 feet. Where multiple widths are laid side-by- side, overlap the adjacent edges a minimum of 2 inches and staple together. Place staples down the center, staggered with the edges at 3-foot intervals. Refer to Figure C-SSM-05-1 for laying and stapling arrangement.

Table C-SSM-05-6 Material Specifications for Soil Stabilization Blankets	
Treatment 1 Soil Stabilization Blanket Installation	
Activity	**Notes**
Check Slots	On highly erodible soils and on slopes steeper than 4H:1V, make erosion check slots every 50 feet (see Figure C-SSM-05-2). Insert a fold of the material (separate piece) into a 6-inch trench and tamp firmly. Staple fold to "main" blanket at minimum 12-inch intervals across the upstream and downstream portions of the blanket. Note: Many combination blankets are designed and manufactured to resist movement and uplift to a point at which check slots may not be required. Designers and plan reviewers should review manufacturers' specifications before installation.
Joining Protective Coverings	Insert a new roll of material into an anchor slot, as with upslope ends. Overlap the end of the previous roll a minimum of 12 inches and staple across the end of the roll just below the anchor slot and across the material every 12 inches.
Terminal End	Where the material is discontinued, or at which time the protective covering meets a structure of some type, fold 4 inches of the material underneath and staple a minimum of every 12 inches.
At Bottom of Slopes	Lead net out onto a level area before anchoring. Turn ends under 4 inches, and staple across end a minimum of every 12 inches.
Final Check	After installation, check to ensure that the following installation conditions are in place: • Protective blanket is in uniform contact with the soil. • All lap joints are secure. • All staples are driven flush with the ground. • All disturbed areas have been seeded.

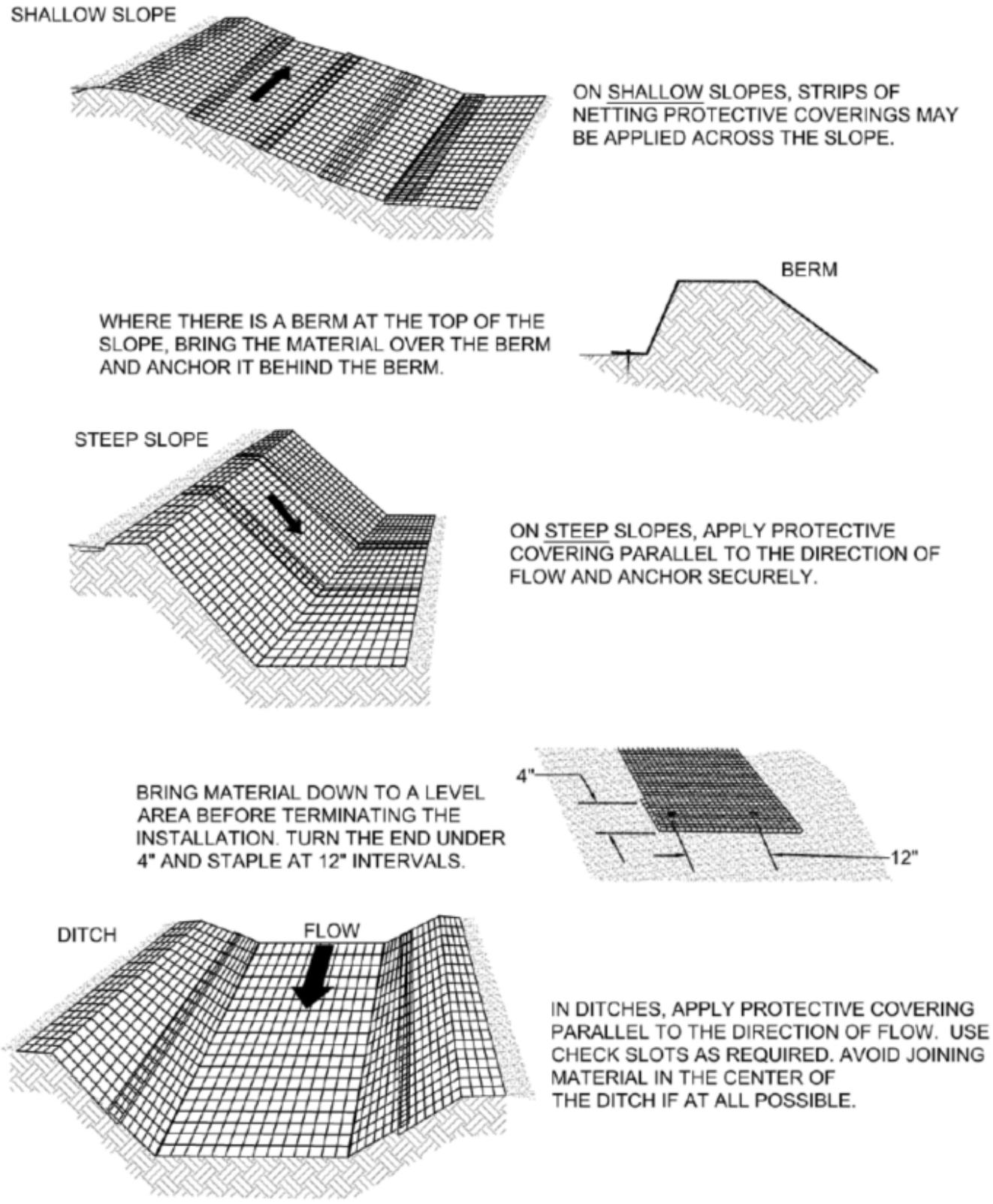
Table C-SSM-05-7 Material Specifications for Soil Stabilization Matting	
Treatment 2 Soil Stabilization Matting Installation	
Activity	**Notes**
Site Preparation	After the site has been shaped and graded to approved design, prepare a friable seedbed relatively free from clods, rocks more than 1 inch in diameter, and any foreign material that will prevent uniform contact of the protective covering with the soil surface. If necessary, redirect runoff away from the channel or slope during installation.
Planting	Lime, fertilize, and seed in accordance with seeding (Temporary Seeding BMP C-SSM-09 or Permanent Seeding BMP C-SSM-10), MS#1, and the approved plan paying special attention to the plant selection that may have been chosen for the matted area. If the area has been seeded prior to installing the mat, make sure and reseed all areas disturbed during installation.

Table C-SSM-05-7 Material Specifications for Soil Stabilization Matting	
Treatment 2 Soil Stabilization Matting Installation	
Mulching	Apply mulch (normally straw) following installation of Treatment 2 matting at rates noted in Mulching (BMP C-SSM-11).
Laying and Stapling	Refer to Figure C-SSM-05-4, Figure C-SSM-05-5, and Figure C-SSM-05-6 for laying and stapling arrangements. The key to achieving desired performance is proper installation.
Check Slots	Refer to Figure C-SSM-05-4 for check slot installation for matting. Matting manufacturers vary significantly in their check slot requirements. Like the installation of Treatment 1, a check slot may be required when laying Treatment 2 to "correct" the flow of water if runoff has the potential to undermine the matting. Most authorities (including VDOT) require that the sides of the matting also be entrenched, creating a slope shelf for the material to rest on, preventing water from entering under the mat on the sides.
Securing the Material and Joining Mats	Again, product specifications vary – upstream and downstream terminal slots, new roll overlaps, and multiple width installations differ by product and manufacturer.
Final Check	After installation, check to ensure that the following installation conditions are in place: • Soil stabilization mat is in uniform contact with the soil. • All required slots and lapped joints are in place. • The material is properly anchored. • All disturbed areas are seeded.

7.0 Operations and Maintenance Considerations

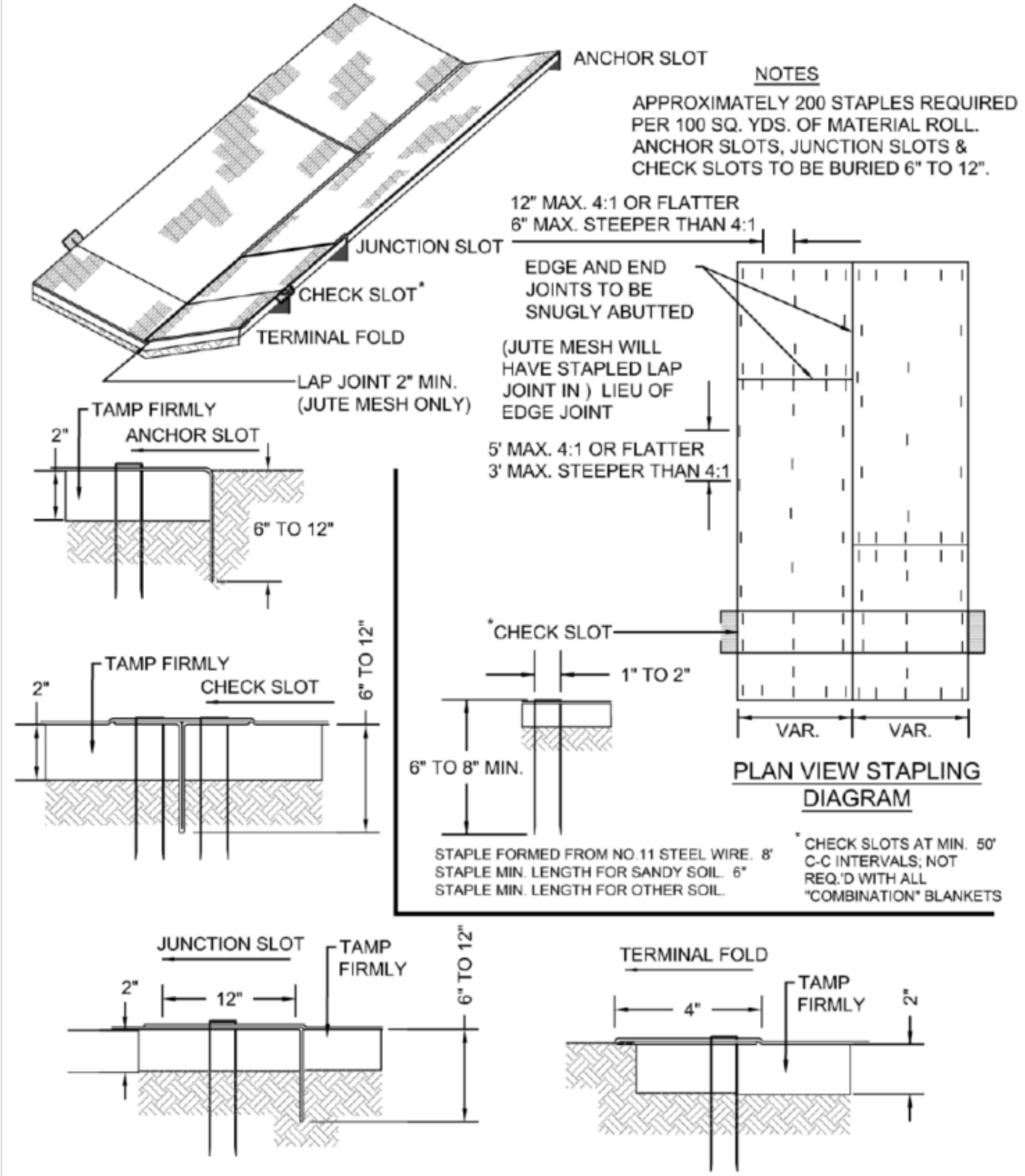
Inspect all soil stabilization blankets and matting periodically following installation, particularly after rainstorms, to check for erosion and undermining. Repair any dislocation or failure immediately. If washouts or breakage occurs, reinstall the material after repairing damage to the slope or channel. Continue to monitor these areas until they become permanently stabilized; at that time, an annual inspection is adequate.

Figure C-SSM-05-1 Typical Orientation of Treatment (Soil Stabilization Blanket)



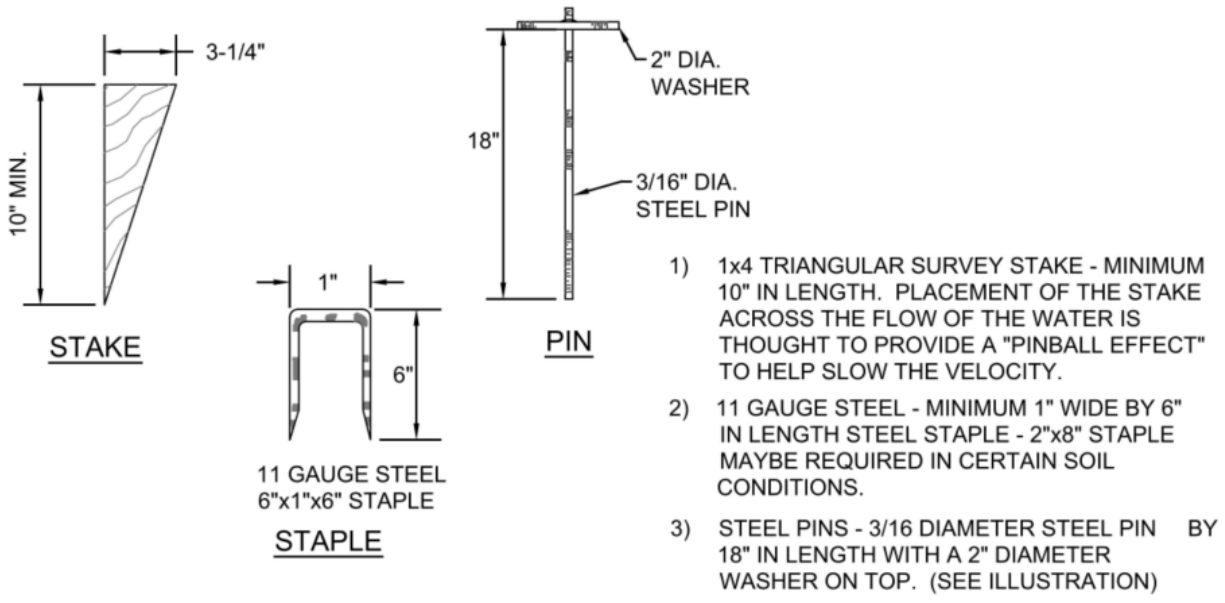
Source: Adapted from Ludlow Products Brochure

Figure C-SSM-05-2 Typical Treatment Installation Criteria (Soil Stabilization Blanket)



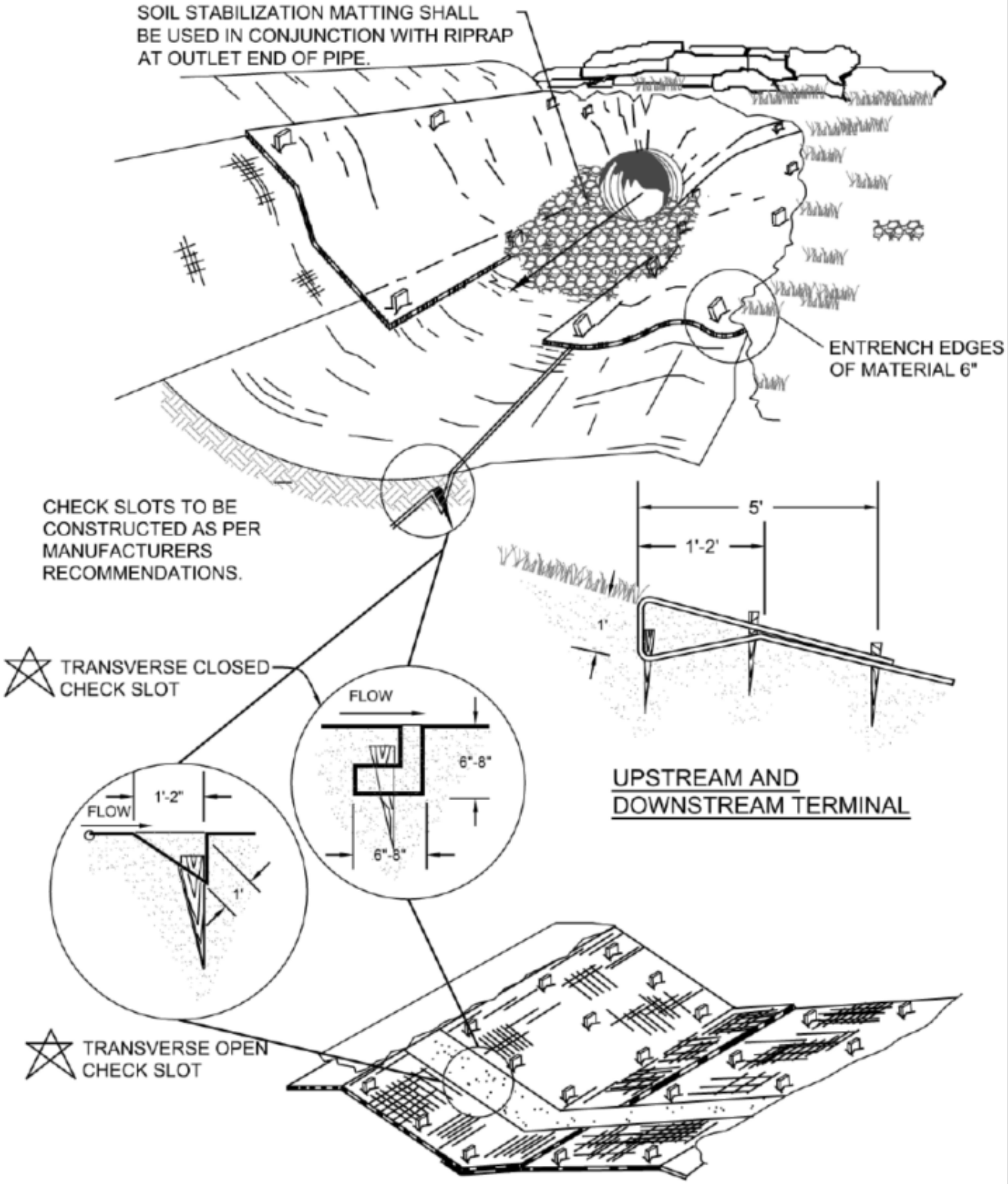
Source: VDOT Road & Bridge Stds

Figure C-SSM-05-3 Stakes, Staples, & Pins for Installation of Treatment (Soil Stabilization Matting)



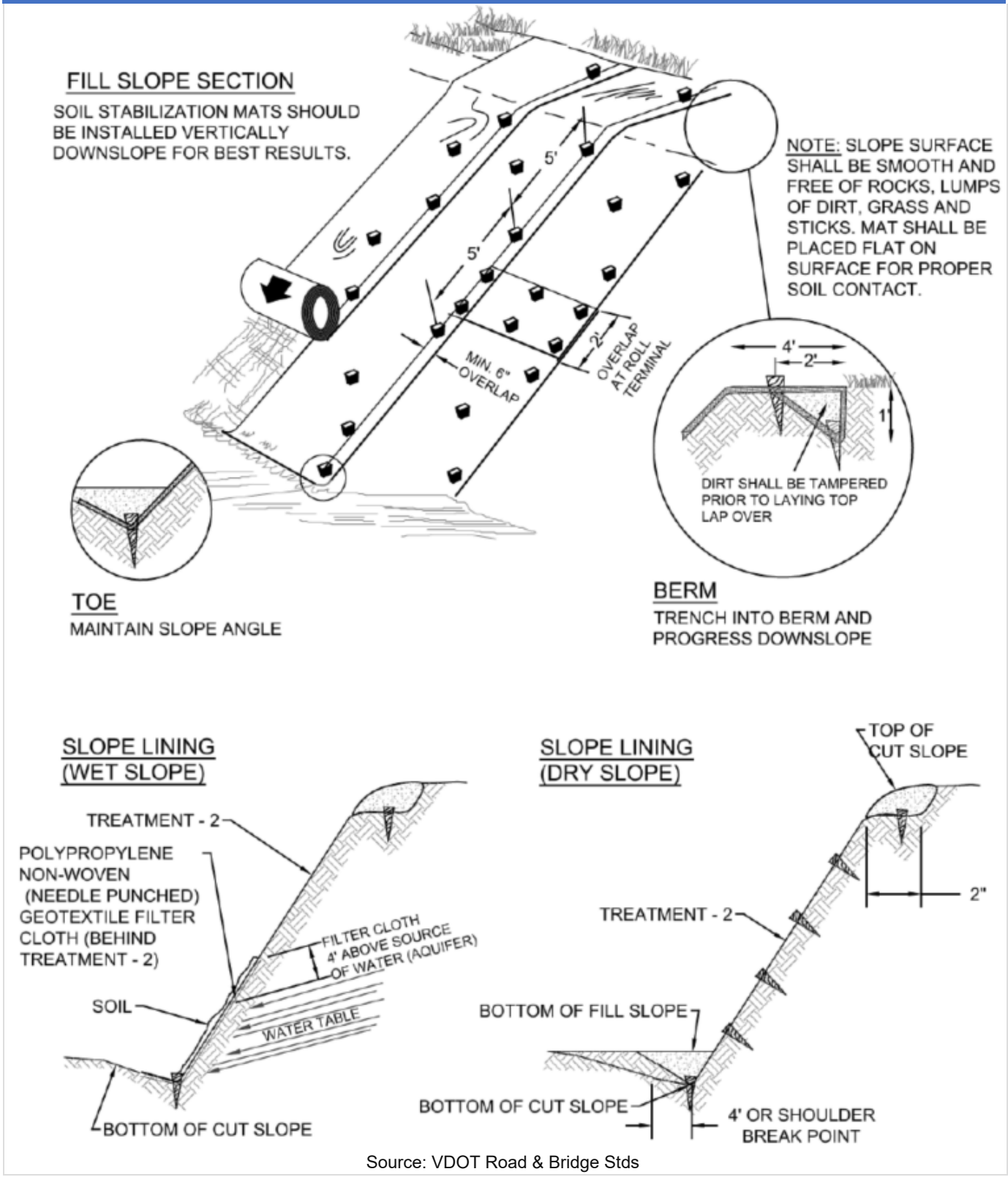
Source: Product Literature from Greenstreat, Inc.

Figure C-SSM-05-4 Typical Treatment Soil Stabilization Matting Installation



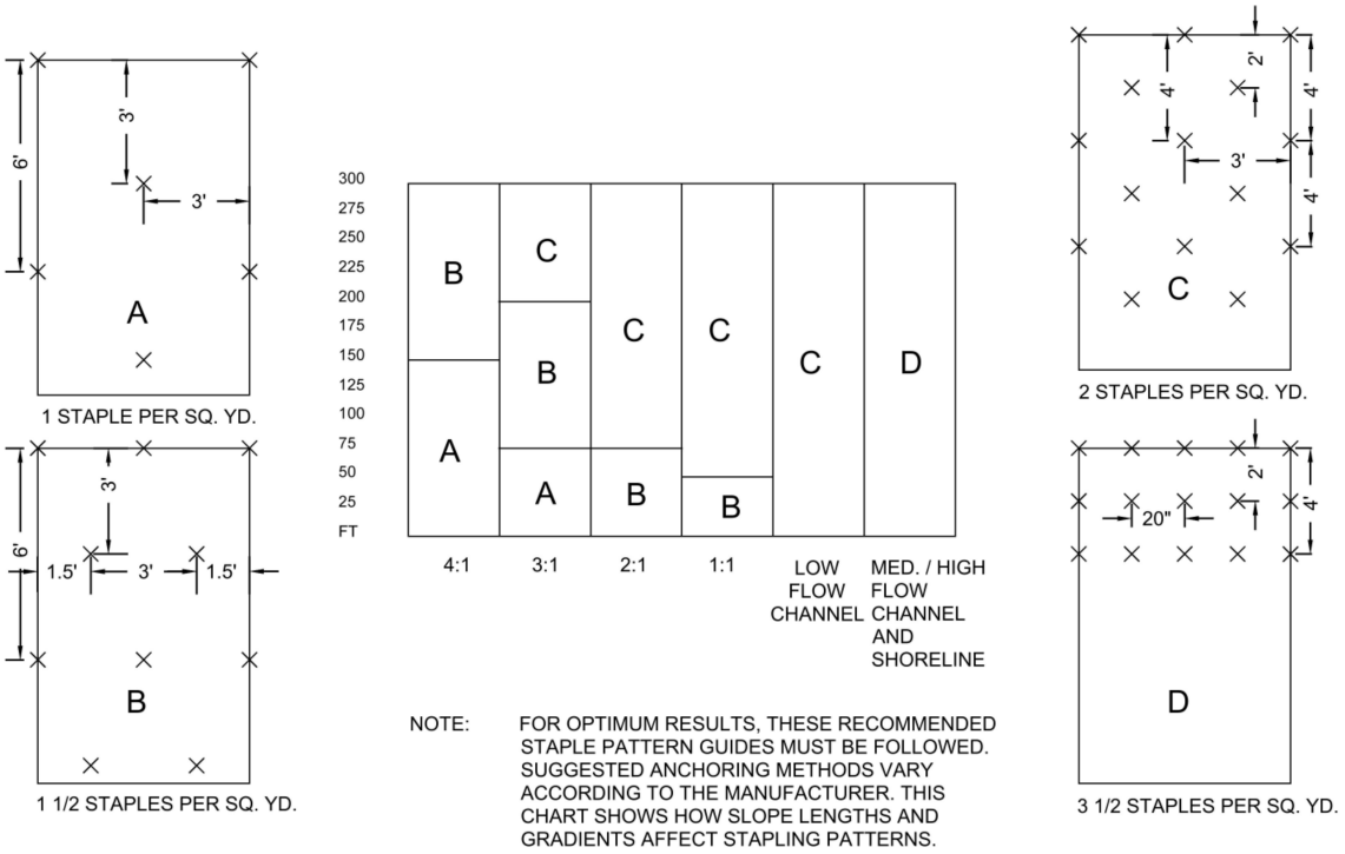
Source: VDOT Road & Bridge Stds

Figure C-SSM-05-5 Typical Treatment Soil Stabilization Matting Slope Installation



Source: VDOT Road & Bridge Stds

Figure C-SSM-05-6 General Staple Pattern Guide for Treatment 2



Source: Product Literature from North American Green



Photo Credit: eastcoasterosion.com



Photo Credit: Michael D. DeVuono, PE

8.0 References

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C-SSM-06 Sodding

1.0 Definition

Sodding is permanent stabilization of areas by laying a continuous cover of grass sod over exposed soils (North Carolina Sediment Control Division et al. 2013).

– CAD AND PDF files for C-SSM-06 Sodding

2.0 Purpose and Applicability of Best Management Practice

Sodding is used to:

- Establish permanent turf immediately.
- Prevent erosion and damage from sediment and runoff by stabilizing the soil surface.
- Reduce the production of dust and mud associated with bare soil surfaces.
- Stabilize drainageways where concentrated overland flow will occur.
- Serve as a filtering device for sediments before achieving permanent stabilization.

Sodding should be practiced in areas that require immediate vegetative cover to stabilize the surface or where sodding is preferred to other means of grass establishment.

Locations particularly suited to stabilization with sod are:

- Waterways carrying intermittent flow;
- Areas around drop inlets or in grassed swales;
- Steep slopes (up to 2H:1V if not mowed, 3H:1V if mowed); and
- Residential or commercial lawns where quick use and/or aesthetics are factors.

3.0 Planning and Considerations

The successful establishment of quality turfgrass is difficult in Virginia. Extremes in temperature and moisture availability create severe stresses on both cool- and warm-season grasses. The selection of appropriate turf establishment methods requires a great deal of forethought.

A quality turf containing the recommended mixtures and species can be established with either seed or sod. Soil preparation for the two methods is the same. The advantages of properly installed sod include:

1. Immediate erosion and dust control;
2. An instant green surface with no dust or mud;
3. Nearly year-round establishment capability;
4. Less chance of failure than seed;
5. Freedom from weeds;
6. Rapid stabilization of surfaces for traffic areas, channel linings, or critical areas; and
7. The option of buying a quality-controlled product with predictable results.

It is initially more costly to install sod than to seed. However, this cost is justified where sod can perform better than seed in controlling erosion. In swales and waterways, where concentrated flow will occur, properly pegged sod is preferable to seed because there is no lag time between installation and the time at which the channel is protected by vegetation. Drop inlets that will be placed in grassed areas can be kept free of sediments, and the grade immediately around the inlet can be maintained by framing the inlet with sod strips. Sod can be laid during times of the year when seeded grass may fail, so long as

there is adequate water available for irrigation in the early weeks. Cold temperatures are not favorable conditions for sodding. When correctly installed, sod can provide immediate permanent vegetative stabilization.

Ground preparation and proper maintenance are as important with sod as with seed. Sod is composed of living plants, and those plants must receive adequate care in order to stabilize a disturbed area. Irrigation is essential at all times of the year to install sod. Because sod is composed of living plants that must receive adequate care, final grading and soil preparation should be completed before sod is delivered. If left rolled or stacked, heat can build up inside the sod, causing severe damage and loss of costly plant material (North Carolina Sediment Control Division 2013).

4.0 Stormwater Performance Summary

MS-1: STABILIZATION – Permanent or temporary soil stabilization shall be applied to denuded areas within seven days after final grade is reached on any portion of the site. Temporary soil stabilization shall be applied within seven days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization shall be applied to areas that are to be left dormant for more than one year.

MS-3: PERMANENT VEGETATION – A permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized. Permanent vegetation shall not be considered established until a ground cover is achieved that is uniform, mature enough to survive, and will inhibit erosion.

9VAC25-75-560

Erosion Control Efficiency: High

Sediment Removal Efficiency: Low

5.0 Design Criteria

Table C-SSM-06-1 Material Specifications	
Design Criteria for Materials	
Choosing Appropriate Types of Sod	The type of sod selected should be composed of plants adapted to both the site and the intended purpose. Species selection is primarily determined by region, availability, and intended use. Availability varies across the state and from year to year. New varieties are continually being developed and tested. A complete and current listing of sod recommendations can be obtained from suppliers. Sod composed of a mixture of varieties may be preferred because of its broader range of adaptability (North Carolina Sediment Control Division et al. 2013). Use Table C-SSM-06-2 to select the type of sod best suited to your area.
Quality of Sod	• **VCIA Certified Sod**: If possible, sod used should be state-certified. Certified turfgrass sod is grown from certified seed inspected and certified by the Virginia Crop Improvement Association (VCIA) or the certifying agency in other states. • **Non-VCIA Certified Sod:** High-quality sod is also available outside of the VCIA-certified sod program. High-quality sod will be free of serious disease, insect, or weeds. It will be dense, have good color, and hold together well. • Sod should be machine-cut at a uniform soil thickness of 0.75 inch (±0.25 inch) at the time of cutting. This thickness should exclude shoot growth and thatch. • Pieces of sod should be cut to the supplier's standard width and length, with a maximum allowable deviation in any dimension of 5%. Torn or uneven pads should not be accepted. • Standard size sections of sod should be strong enough to support their own weight and retain their size and shape when suspended from a firm grasp on one end of the section.

Table C-SSM-06-2 Virginia Grasses for Sodding

Types of Sod Available in Virginia and Recommended Uses

Kentucky Bluegrass	Adapted to the Northern Piedmont and Mountain Regions. Individual varieties selected must make up not less than 10% or more than 35% of the total mixture by weight. All varieties must be certified. Selections can be made from Category I alone or various combinations of Categories I, II, and III as noted. **Category I** – Recommended Kentucky bluegrass varieties 65% - 100% A-34, Abbey, Aspen, Asset, Baron, Blacksburg, Bristol, Cheri, Chateau, Classic, Coventry, Georgetown, Glade, Haga, Julia, Liberty, Loft's 1757, Merit, Midnight, Monopoly, Plush, Princeton 104, Rugby, Suffolk, Victa **Category II** – Special use varieties. If used, must contain at least 65% Category I varieties <u>Shade Tolerant</u> 10-35% Bristol, Columbia, Georgetown, Glade, Midnight <u>Low-Maintenance Tolerant</u> 10-35% Bristol, Columbia, Georgetown, Glade, Midnight **Category III** – Promising Kentucky bluegrass – Limited performance data or seed availability 10-35% Dawn, Estate, Freedom, Kelly
Tall Fescue	Adapted to the entire state. <u>Recommended tall fescue varieties</u> 90-100% Amigo, Apache, Bonanza, Chieftain, Finelawn 5GL, Mesa, Rebel II, Shenandoah, Tribute <u>Promising tall fescues</u> Certified Arriba, Austin, Avanti, Aztec, Cochise, Crossfire, Eldorado, Hubbard 87, Jaguar II, Maverick II, Monarch, Olympic II, Phoenix, Safari, Shortstop, Sundance, Taurus, Thoroughbred, Titan, Tradition, Vegas, Winchester, Wrangler 0-10% Kentucky bluegrass: Baron, Cheri, Columbia, Monopoly, Nassau, Ram I, Victa
Bermudagrass	Tufcote is adapted to the Richmond-Danville-Newport News triangle. Midiron may be used east of Roanoke and south of Charlottesville. Tifgreen and Tifway may be used to the east and south of Richmond. Vamont may be used east of Roanoke and at lower elevations in southwestern Virginia. Certified Midiron, Tifgreen#, Tifway, Tifway II, Tufcote and Vamont

Table C-SSM-06-2 Virginia Grasses for Sodding	
Types of Sod Available in Virginia and Recommended Uses	
Zoysiagrass	This sod performs best in southeastern Virginia. Meyer, Emerald#

Note: Common Bermudagrass is not recommended for sod production.

Only recommended in southeastern Virginia.

6.0 Construction Specifications

6.1 Soil Preparation

1. Before soil preparation, bring areas to be sodded to final grade in accordance with the approved plan.
2. Determine the exact requirements for lime and fertilizer using soil tests conducted by the State Laboratory at Virginia Polytechnic Institute and State University or a reputable commercial laboratory. Information on state soil tests is available from county or city agricultural extension agents.
3. Before laying sod, clear the soil surface of trash, debris, large roots, branches, stones, and clods more than 1 inch in length or diameter. Sod should not be applied to gravel or other non-soil surfaces.
4. Fill or level any irregularities in the soil surface resulting from topsoiling or other operations to prevent the formation of depressions or water pockets.
5. Areas to be topsoiled and topsoil used should fulfill the requirements of Topsoiling (C-SSM-02). No sod should be spread on soil that has been treated with soil sterilant or any other toxic herbicides until enough time has elapsed to permit dissipation of toxic materials.

6.2 Sod Installation (See Table C-SSM-06-1)

1. Frozen soil surfaces are not suitable for sodding. When presented with frozen soil or other unfavorable sodding conditions, the contractor should establish perimeter control measures (if not already installed) and delay final surface stabilization until thaw.
2. Sod should not be cut or laid in excessively wet or dry weather.
3. Sod should be harvested, delivered, and installed within 36 hours.
4. Moistening the sod after it is unrolled helps maintain its viability. Store it in the shade during installation (North Carolina Sediment Control Division et al. 2013).

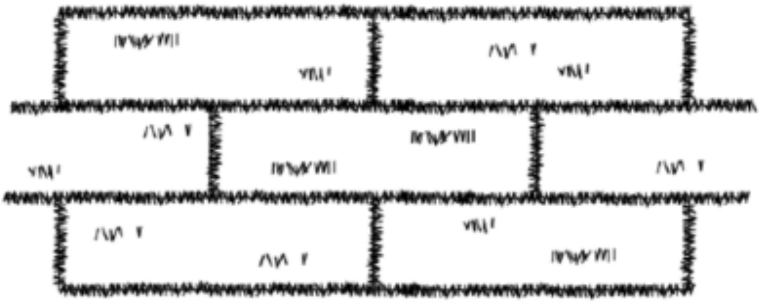


Unclean and Poor Sod Installation

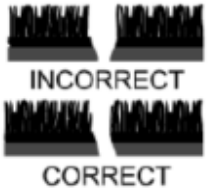
5. Rake/till the soil surface to loosen and break the crust just before laying sod. During periods of high temperature, the soil should be lightly irrigated immediately before laying the sod to cool the soil and reduce root burning and dieback.
6. The first row of sod should be laid in a straight line, with subsequent rows placed parallel to and butting tightly against each other. Lateral joints should be staggered to promote more uniform growth and strength. Care should be exercised to ensure that sod is not stretched or overlapped and that all joints are butted tight to prevent voids, which would cause drying of the roots.
7. On slopes 3H:1V or greater, or where erosion may be a problem, sod should be laid with staggered joints and secured by stapling or other approved methods. Sod should be installed with the length perpendicular to the slope (on the contour).

8. As sodding of clearly defined areas is completed, sod should be rolled or tamped to provide firm contact between roots and soil.
9. Fill any spaces between sod match edges with topsoil.
10. After rolling, sod should be irrigated to a depth sufficient that the underside of the sod pad and the soil 4 inches below the sod are thoroughly wet.
11. Until a good root system develops, in the absence of adequate rainfall, watering should be performed as often as necessary to maintain moist soil to a depth of at least 4 inches.
12. The first mowing should not be attempted until the sod is firmly rooted, usually after 2 to 3 weeks. Not more than one third of the grass leaf should be removed in a single cutting.

Figure C-SSM-06-1 Sodding



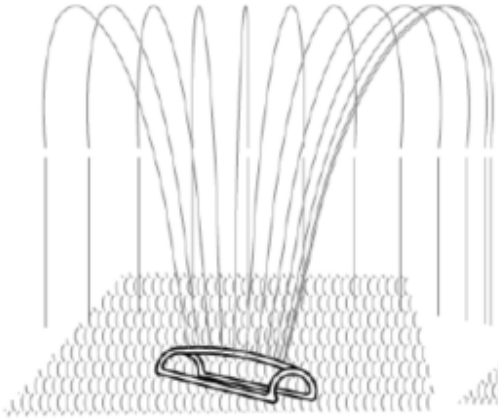
LAY SOD IN A STAGGERED PATTERN. BUTT THE STRIPS TIGHTLY AGAINST EACH OTHER. DO NOT LEAVE SPACES AND DO NOT OVERLAP. A SHARPENED MASON'S TROWEL IS A HANDY TOOL FOR TUCKING DOWN THE ENDS AND TRIMMING PIECES.



BUTTING - ANGLED ENDS CAUSED BY THE AUTO-MATIC SOD CUTTER MUST BE MATCHED CORRECTLY.



ROLL SOD IMMEDIATELY TO ACHIEVE FIRM CONTACT WITH THE SOIL.

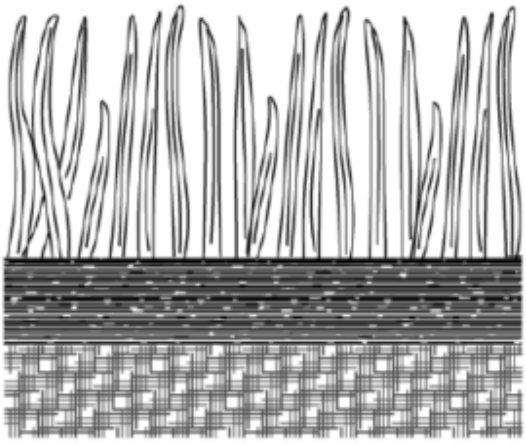


WATER TO A DEPTH OF 4" AS NEEDED. WATER WELL AS SOON AS THE SOD IS LAID.



MOW WHEN THE SOD IS ESTABLISHED - IN 2-3 WEEKS. SET THE MOWER HIGH (2"-3").

APPEARANCE OF GOOD SOD



SHOOTS OR GRASS BLADES. GRASS SHOULD BE GREEN AND HEALTHY, MOWED AT A 2"-3" CUTTING HEIGHT.

THATCH - GRASS CLIPPINGS AND DEAD LEAVES, UP TO 1/2" THICK.

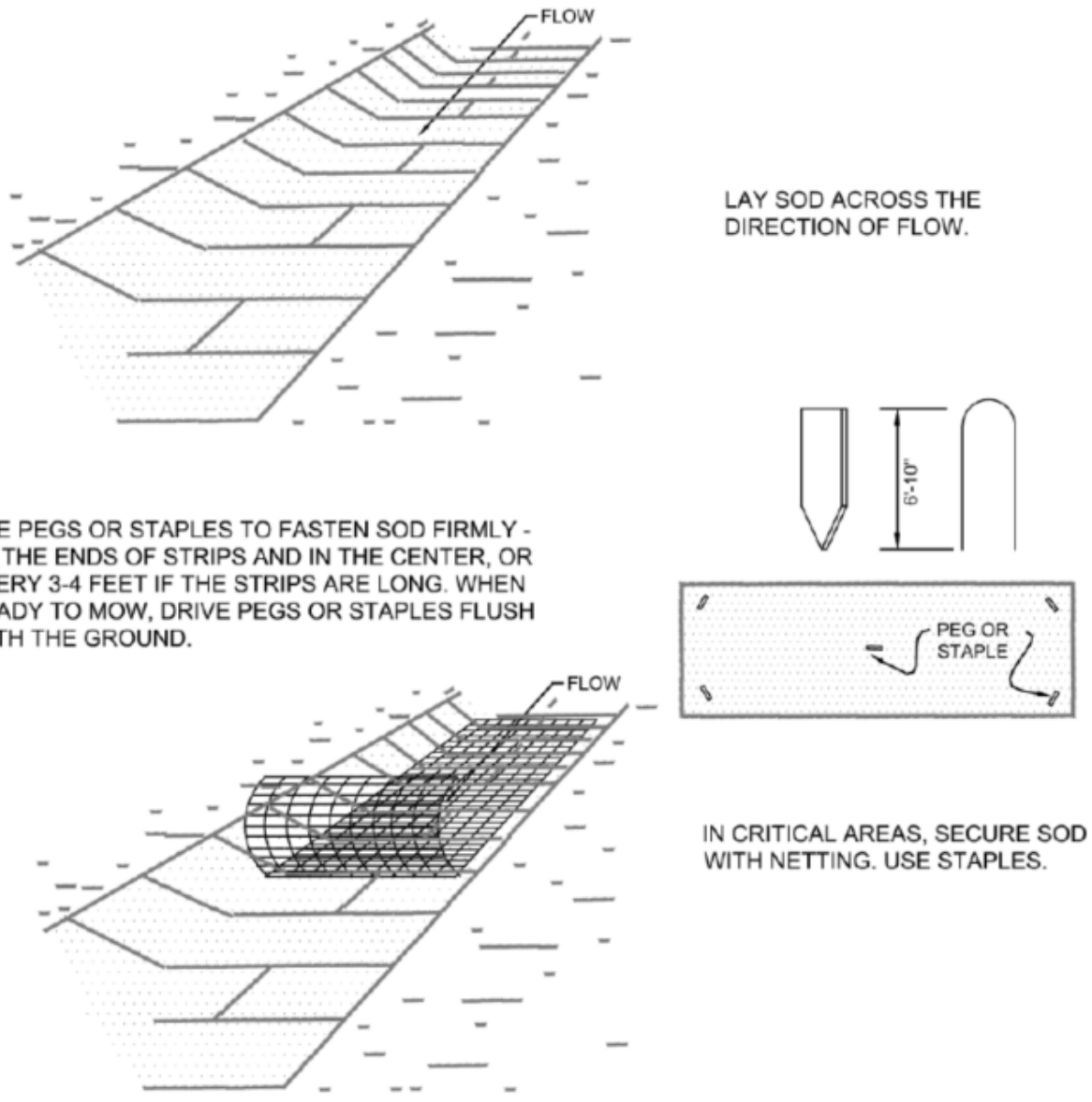
ROOT ZONE - SOIL AND ROOTS. SHOULD BE 1/2"-3/4" THICK, WITH DENSE ROOT MAT FOR STRENGTH.

Source: VA DSWC

6.3 Sodded Waterways (See Figure C-SS-06-2)

1. Care should be taken to prepare the soil adequately in accordance with this specification. The sod type should consist of plant materials able to withstand the designed velocity; see Stormwater Conveyance Channels (C-ECM-09).
2. Sod strips in waterways should be laid perpendicular to the direction of flow. Care should be taken to butt ends of strips tightly.
3. After rolling or tamping, sod should be pegged or stapled to resist washout during establishment.
4. All other specifications for this practice should be adhered to when sodding a waterway.

Figure C-SSM-06-2 Sodded Waterways



Source: VA DSWC

7.0 Operations and Maintenance Considerations

1. During the 2- to 3-week establishment stage, sod should be watered as necessary to maintain adequate moisture in the root zone and prevent dormancy of sod.
2. No more than one third of the shoot (grass leaf) should be removed in any mowing. Grass height should be maintained between 2 and 3 inches unless otherwise specified.
3. After the first growing season, established sod will require fertilization and may require lime. Follow soil test recommendations when possible or apply maintenance levels as outlined in Table C-SSM-06-3.

Table C-SSM-06-3 Sodding Maintenance
Maintenance Fertilization of Established Sod
Cool-Season Grasses
4 lbs. nitrogen per 1,000 ft^2/year
1 lb. phosphorus per 1,000 ft^2/year
2 lbs. potash per 1,000 ft^2/year
75% of the total requirements should be applied between September 1 and December 31. The balance should be applied during the remainder of the year.
Warm-Season Grasses
Apply 4 to 5 lbs. nitrogen per 1,000 ft^2 per year (between May 1 and August 15).
Phosphorus and potash should only be applied according to soil test results.
Maintenance fertilization should use slow-release fertilizers, which reduce the number of applications per year and subsequently reduce adverse impacts on groundwater.

8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and-sediment-control/erosion-and-sediment-control-planning-and-design-manual.

Virginia Crop Improvement Association. Virginia Turfgrass Variety Recommendations. 1991.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Specification 3.33. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SSM-07 Bermudagrass and Zoysiagrass Establishment

1.0 Definition

Bermudagrass and Zoysiagrass establishment is the establishment of vegetative cover with hybrid Bermudagrass or Zoysiagrass by planting sprigs, stolons, or plugs of these types of grasses.

2.0 Purpose and Applicability of Best Management Practice

The purposes of Bermudagrass and Zoysiagrass establishment are as follow:

1. To reduce erosion and decrease sediment yield from disturbed areas;
2. To stabilize disturbed areas with a specific plant material suited to the site at a cost lower than would be incurred by installing sod; and
3. To establish vegetative cover more rapidly than would be possible using seed.

Conditions for which Bermudagrass and Zoysiagrass establishment applies:

1. Where hybrid Bermudagrass or Zoysiagrass is the desired plant material and establishment with sod is not preferred;

2. Droughty, sandy sites or situations in which high salt content is a problem. The grasses should not be used in shaded areas or on poorly drained sites; and
3. Where irrigation can be made available during establishment.

3.0 Planning and Considerations

Bermuda and Zoysia are warm-season, permanent grasses that are well-suited to erosion control, as the grasses have vigorous rhizomes and stolons (runners). There are two types of Bermudagrass grown in Virginia: common and hybrid. Whenever possible, the design engineer (in coordination with the contractor) should make all efforts possible to use Virginia native species of grass for all applicable erosion and sediment control measures.

Table C-SSM-07-1 Grass Types

Grass Types	
Common Bermudagrass	Produces seed and may be established with seed. However, it has the potential to become a weed problem because it spreads vigorously; it is also coarse and not suitable for fine turf. Common Bermudagrass has little cold tolerance and winterkills frequently.
Hybrid Bermudagrasses and Zoysiagrass	Established mainly by sodding, sprigging, or plugging. Recent developments in the turf industry have allowed hybrid Bermudagrass stands to establish from seed; however, the technology is relatively new. These grasses produce a fine, tight turf; do not spread as vigorously as common Bermudagrass; exhibit good cold tolerance; and can withstand many adverse conditions. For these reasons, hybrid Bermudagrass and Zoysiagrass are the warm-season permanent turf grasses of choice for Virginia.
Sprigging	A sprig is a small section of rhizome (underground stem) 3 to 5 inches long, with at least one node or joint. Leaves should be present at the nodes. Stolons (runners) are aboveground stems that spread by creeping on the soil surface. A mixture of sprigs and stolons is usually used in “sprigging.” Sprigs may be planted by machine or hand.
Plugging	Plugs are small sections of sod pressed into precut holes in the soil so that top growth is flush to the surface and leaves are exposed. Plugs are usually planted by hand; however, plugging machines are also available.

Notably, where speed is essential and cost is not an overriding constraint, sod should be used; see Sodding (BMP C-SSM-06).

Both Zoysia and Bermuda are particularly suited for use in grass-lined waterways. Depending on the soil type, an established stand can tolerate intermittent concentrated flows of water on slopes up to 10 percent. It is important to divert runoff from the waterway during the first 3 weeks of establishment to permit the grass to take root. If this cannot be accomplished, the center of the waterway should be sodded to prevent washout.

Bermudagrass is drought-tolerant, salt-tolerant, and tolerates floods of short duration. It prefers a pH range of 6.0 to 7.0 with high nitrogen fertilization during the growing season. Most Bermudagrasses are adapted to the warmer climates in Southeastern Virginia; however, turf research has developed several varieties that continue to perform very well in the western part of the state. Currently, all varieties of Bermudagrass will be dormant in winter and will turn brown at that time.

The Bermudagrass hybrids most frequently used in Virginia differ in appearance, cold tolerance, and suitability for turf use. The following varieties are suggested for rough- and fine-turf areas:

Table C-SSM-07-2 Varieties for Rough-Turf Areas	
Varieties for Rough-Turf Areas	
Midland	A cold-hardy variety adapted in all areas of the state at medium to low elevations. Adapted for forage production, this is a tall-growing Bermuda (12 to 18 inches) and should be used in low- maintenance areas.
Coastal	Also a forage type for low-maintenance areas. Can be used as far west and north as Chatham, Charlotte Courthouse, and Warsaw, but will winterkill during severe winters at these locations.

Table C-SSM-07-3 Varieties for Fine-Turf Areas	
Varieties for Fine-Turf Areas	
Midiron	A fine-turf type. Has a good chance of surviving most winters as far west and north as Blacksburg and Charlottesville.
Vamont	Similar cold tolerance and texture to Midiron but far more aggressive.
Tufcote	A fine-turf type. Less cold hardy than Midiron.
Tifway	A fine-textured turf type. Good survival east and south of Richmond in most years. Not as cold- hardy as Tufcote.

Research continues on successful establishment of Zoysiagrass in Virginia. It has been determined that Zoysia has limited potential for use in athletic field development due to recovery problems and slow establishment. Establishment is commonly achieved by sprigs or plugs and seeds pre-treated with potassium hydroxide. The following Zoysiagrass varieties are presently listed on the Virginia Crop Improvement Association (VCIA) recommended list:

Table C-SSM-07-4 Zoysiagrass Types	
Zoysiagrass Types	
Meyer	A broad blade is prevalent. This variety is considered more winter-hardy than others.
Emerald	A fine-turf type. A much finer blade than that found on Meyer. This variety is also much less winter-hardy.

4.0 Stormwater Performance Summary

MS-1: STABILIZATION – Permanent or temporary soil stabilization shall be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization shall be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization shall be applied in areas to be left dormant for more than 1 year.

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Erosion Control Efficiency: High

Sediment Removal Efficiency: High

5.0 Design Criteria

No formal design is required.

6.0 Construction Specifications

6.1 Soil Preparation

Procedures for preparing the soil are the same for sprigging and plugging.

1. Bermuda and Zoysia require soils that are well drained, loose enough for root penetration, have a pH range between 6.0 and 7.0, and are free of toxic amounts of materials harmful to plant growth. If any of these criteria cannot be met, topsoil should be applied in accordance with Topsoiling (BMP C-SSM-02).
2. Necessary erosion and sediment control practices will be installed before establishment of Bermudagrass. Final grading will be carried out according to the approved plan.
3. Surfaces will be roughened in accordance with Surface Roughening (BMP C-SSM-03).
4. The soil should be free of debris, trash, large roots, and weeds.

6.2 Lime and Fertilizer

Soil should be tested to determine the exact requirements for lime and fertilizer. Soil tests may be conducted by the State Laboratory at Virginia Polytechnic Institute and State University or a reputable commercial laboratory. Information on state soil tests is available from county or city agricultural extension agents.

Under difficult circumstances, where it is not possible to obtain a soil test, the following soil amendments will be made:

Table C-SSM-07-5 Lime and Fertilizer Specifications

Lime and Fertilizer Specifications	
Pulverized agricultural limestone	Apply 90 lbs./1,000 sq. ft. (2 tons/acre) of an agricultural grade of limestone.
Fertilizer	Apply **10-10-10** fertilizer at a rate of **500** lbs. /acre or **12** lbs. / 1,000 ft^2. Apply additional phosphorus and potassium 30 to 60 days later based on the results of a soil test. Apply an additional equivalent of 1 lb./1,000 ft^2 of nitrogen when the phosphorus and potassium are applied. Never apply more than 1 pound of water-soluble nitrogen per 1,000 ft^2 within a 30- day period and no more than 2 yearly lbs. N/1,000 ft^2.

These amendments should be spread evenly over the area to be sprigged and incorporated into the top 3 to 6 inches of the soil by discing, harrowing, or other acceptable means. Any irregularities in the soil surface resulting from topsoiling or other operations should be filled or leveled to prevent the formation of water pockets.

Soil preparation, liming, and fertilizing should be completed before requesting delivery of sprigs or sod. This material is perishable and should not remain on a pallet or in crates longer than 36 hours from the time of digging. The presence of mildew or distinct yellowing of the leaves usually indicates damage to turf.

6.3 Sprigging and Plugging

6.3.1 Sources

Sprigs can be purchased as sod and then shredded or can often be purchased by the bushel. For turf-type Bermudagrasses, certified or approved sod sources (bearing the label of the VCIA) should be used. Plugs may be cut from sod as needed or purchased pre-cut. Coastal and midland Bermudagrasses may be available through agricultural sources. Interested persons should contact the county or city agricultural extension agent or the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) district office for information on where these materials may be obtained. Sprigs should be 3 to 5 inches long, having several nodes (joints). Plugs should have a minimum diameter of 2 inches.

Table C-SSM-07-6 Quantities of Material Needed

	Quantities of Material Needed
Sprigging	Eight to 12 bushels/1,000 ft^2 or 350 to 500 bushels/acre. One bushel of sprigs is approximately equal to 1 square yard (yd^2) of sod (with soil removed).
Plugging	Approximately 12 yd^2 of sod/1,000 ft^2, or 530 yd^2 of sod/acre.

6.3.2 When to Plant

To establish quickly, many feel that Bermudagrass should not be in a dormant state (leaves should be green). However, research shows some success with dormant installations. Nonetheless, so that plants may develop adequate root structure before cold weather begins, they should be planted no later than midsummer. May 1 through July 15 is the optimum season for Bermudagrass establishment. Some cultivars may be established as late as mid-August in the southeastern part of the state.

6.3.3 How to Plant

Table C-SSM-07-7 How to Plant

	How to Plant
Sprigging	Sprigs may be broadcast over the surface by hand, planted in rows by machine, or applied with a hydro-sprigger. Machines are available that will insert sprigs properly and firm the soil over them. When sprigs are broadcast or hydro-sprigged, the sprigs should be partially covered with soil by light discing or topdressing with good soil. Ideally, half of the sprig should be covered with soil, and half (including some leaves) should be exposed. Soil should be firmed over the sprigs using a cultipacker or by rolling or tamping. When planted in rows, sprigs should be placed no more than 12 inches apart in rows that are 12 to 18 inches apart. Closer spacing is recommended for slopes, waterways, and highly erodible soils.
Plugging	Plugs should be inserted in the soil surface so that leaf tips are above the surrounding soil and tamped firmly in place. Plugs should be placed in a grid pattern on 12- to 18-inch centers. Closer spacing is recommended on critical areas. Plugs are usually placed by hand, but machines are available that can plug automatically.

6.3.4 Ideal Conditions

The following are essential for good Bermudagrass or Zoysiagrass growth:

1. Adequate moisture – water immediately after planting, and water enough to keep soil moist to a depth of 4 inches during the first 4 weeks and as needed thereafter to sustain growth.
2. Sunlight – do not permit mulches, other plantings, or structures to shade new Bermudagrass stands.
3. Freedom from erosive forces – keep concentrated flows of water off new plantings for 2 weeks to 1 month.

6.3.5 Weed Control

To become effectively established, Bermudagrass must not have to compete with weeds for sunlight, water, or space. Cultivating is impractical, as growing stolons may be injured.

Oxadiazon or equivalent, applied immediately following sprigging at a rate of 100 to 150 lbs./acre (depending on time of year), provides excellent control of most broadleaf and grassy weeds; use 2 to 3 lbs. of active ingredient/acre. For control of broadleaf weeds only, apply Dicamba (0.25 to 0.5 lb. active ingredient/acre) and 2,4-D (1 lb. active ingredient/acre). Use these herbicides when weeds are 2 to 3 inches tall, but not before grass is well-rooted.

7.0 Operations and Maintenance Considerations

Bermudagrass and Zoysiagrass sprigs and plugs can be expected to root in 5 to 10 days under optimum conditions. Full coverage of the soil by spreading plants can be obtained in 8 to 12 weeks with good growing conditions and proper maintenance.

Stands may be mowed when growth requires. Coastal and midland growths may be left un-mowed except for annual trimming to 6 inches. Turf-type Bermudagrasses may be cut at 1 to 1.5 inches.

For maintenance purposes, apply 1 lb. actual nitrogen/1,000 sq. ft. at 30- to 45-day intervals after initial installation until August 15. Nitrogen in fertilizer should be 50 percent or more water insoluble.

8.0 References

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SSM-08 Trees, Shrubs, Vines, and Ground Cover

1.0 Definition

Stabilizing disturbed areas by establishing vegetative cover with trees, shrubs, vines, or ground covers.

– CAD and PDF files for C-SSM-08 Trees, Shrubs, Vines, and Ground Cover

2.0 Purpose and Applicability of Best Management Practice

1. To stabilize the soil where vegetation other than turf, grass, or legumes are preferred;
2. To provide food and shelter for wildlife where wildlife habitat is desirable; and
3. To provide windbreaks or screens.

This practice applies:

1. Where turf establishment is difficult;
2. On steep or rocky slopes, where mowing is not feasible;
3. Where native, non-invasive ornamental plants are desirable for landscaping purposes; and
4. Where woody plants are desirable for soil conservation or to establish wildlife habitat.

5. Conserved Open Spaces and Riparian Buffer areas that will be reforested.

3.0 Planning and Considerations

Disturbed areas may be stabilized in many ways. Most frequently, a permanent vegetative cover of grasses and legumes is established. There are locations, however, where other types of vegetation are preferred. The following situations are examples of ways in which trees, shrubs, vines, and ground covers may be used.

1. On cut and fill slopes adjacent to paved areas of shopping centers, schools, industrial parks, or other non-residential projects, woody plants, and ground cover can be used to control erosion. They will also help to control foot traffic, will not require as much maintenance as mowed lawns, and will be more attractive than un-mowed grass cover.
2. In residential areas, slopes too steep to be mowed and areas along rights-of-ways or easements may be planted in trees, shrubs, vines, or ground covers to reduce maintenance needs and improve appearance.
3. The interested homeowner or small project developer may use ornamental plants in problem areas – shade, steep slopes, inaccessible places – as alternatives to grass. Ground cover may be used to reduce or eliminate the need for mowing grass on level areas.

Many different plants may be used for these purposes. The plants discussed in this practice are those known to be adapted to Virginia, easy to grow, and commonly available from commercial nurseries. Many plants suitable for use are not mentioned here. Information on such plants can be obtained from local nurseries, landscape architects, and extension agents. To the extent that site planners and designers specify native species for a site, they should refer to the DCR invasive species list as part of the process of selecting plant materials. (See DCR 2022). This serves two purposes: to avoid use of invasive species to the extent possible; and to ensure plant selection is based on the most current information available.

Because many types of woody plants and ground cover are discussed, and site conditions and land use vary so widely, it is not practical to give specific requirements for the establishment of every plant mentioned. However, this practice does provide a set of general guidelines for growing trees, shrubs, vines, and ground covers on disturbed land.

3.1 Zones of Adaptation

Zones of climatic adaptation of landscape plants are referred to as “Plant Hardiness Zones.” Table C-SSM-08-5 provides a detailed list of trees suitable for planting in Virginia. The table provides information such as: appropriate zone, mature tree height, pH range, and other factors that should be considered by a landscape architect or similar person choosing a tree for a specific site.

4.0 Stormwater Performance Summary

4.1 MS-1: STABILIZATION

Permanent or temporary soil stabilization will be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization will be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization will be applied to areas that are to be left dormant for more than 1 year.

MS-5: EARTHEN STRUCTURE STABILIZATION - Stabilization measures shall be applied to earthen structures such as dams, dikes and diversions immediately after installation.

MS-7: CUT AND FILL SLOPES - Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. Slopes that are found to be eroding excessively within one year of permanent stabilization shall be provided with additional slope stabilizing measures until the problem is corrected.

Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: N/A

5.0 Design Criteria

Consider the spacing of trees from structures and properly provide necessary coverage through mature canopy size. Refer to BMP Figure C-SSM-08-3 for spacing of trees away from homes/structures.

5.1Critical Root Zone, Structural Root Zone, and Diameter at Breast Height

Determine the critical root zone (CRZ) of a tree when planting near aboveground or underground structures. The CRZ, along with the structural root zone (SRZ), are essential for the health and stability of the tree. Determine the root zone radius from the diameter at breast height (DBH) of the tree using the following equations.

DBH = Tree trunk diameter at 4.5 feet above grade

CRZ = Radius protection of 1.5 feet per inch of DBH

SRZ = Radius protection of 0.5 foot per inch of DBH

Planting a tree in areas with underground utilities and structures within the CRZ may cause health issues for the tree and cause root growth within the utility or structure.

For further information on proper planting and protection, refer to Tree Preservation and Protection (BMP C-SSM-01).

6.0 Construction Specifications

As noted in MS-1, disturbed soil between trees and shrubs must be mulched or planted with permanent vegetation to prevent erosion. Refer to the other vegetative practices to select a method for stabilizing these areas.

Table C-SSM-08-1 Construction Specifications for Trees	
Activity	**Notes on Proper Execution**
Selecting the Right Trees	In urban and suburban environments, trees may be exposed to insufficient light and water; high-velocity winds; salt from highway ice control programs; heat radiation from roads and buildings; pollutants from cars and industry; root amputation for water, sewer, and gas lines; topping to prevent interference with power lines; and covering of roots by pavement. New species and varieties of trees are being selected for the modern environment based on their ability to withstand those difficult conditions and still provide the benefits associated with having trees (see Table C-SSM-08-1). While trees are being selected, evaluate the site where the trees will be planted. Consider the previous use of the land; adverse soil conditions such as poor drainage or acidity; exposure to wind; temperature extremes; locations of utilities, paved areas, and security lighting; and traffic patterns.
Tree Characteristics	Selection of trees depends on the desired function of the tree, whether it be shade, privacy screening, noise screening, appearance, enhancement of wildlife habitat, or a combination of these. Consider the following characteristics of the tree when making choices. Some of these characteristics are identified in Table C-SSM-08-6 for trees commonly grown in Virginia. Hardiness – "Hardiness zones" are based on average annual minimum temperature. Trees are adapted to the various zones in Virginia (Figure C-SSM-10-2). Mature Height and Spread – Consider the eventual height of a tree in relation to planting location to avoid future problems with power lines and buildings (see Figure C-SSM-08-3). Growth Rate – Some trees attain mature height at an early age, while others take many years. If "instant shade" is desired, rapid growth is needed. Slow-growing trees are usually less brittle and live longer. Root System – Some trees obstruct underground pipelines with fibrous roots. Cleanliness – Maintenance problems can be avoided by not selecting trees that drop seedpods, flowers, or twigs in large amounts. Moisture and Fertility Requirements – If good soil and drainage are not available, select trees tolerant of poor growing conditions. Ornamental Effects – If a tree is unusually attractive, some other shortcomings may be overlooked. Evergreen vs. Deciduous – Evergreens retain their leaves throughout the year and are useful for privacy screens and noise screens. Deciduous trees drop their leaves in fall and are preferable for shade trees.

Table C-SSM-08-1 Construction Specifications for Trees	
Activity	**Notes on Proper Execution**
	Container-grown trees can be planted at any time of year in which the ground is not frozen if sufficient water is provided. Purchase and plant trees when quite young (less than 2-inch diameter trunk) to avoid dealing with root-bound plants. Balled and burlapped trees are usually larger; check to be sure that soil around roots was dug with the tree and not just packed around bare roots. Keep the soil around the roots moist.
Sources of Trees and How They May Be Bought	Tree seedlings are available commercially and are also sold in lots of 50, 100, 500, or 1,000 by the state forest nurseries. State nurseries are located in New Kent, Augusta, and Cumberland. About 20 species of trees are usually available during the height of the planting season at nominal prices. These seedlings are not to be used as ornamentals or for fine landscaping and are intended to be used as conservation plantings for erosion control, reforestation, and development of wildlife habitat. Because 50 seedlings will only plant an area of 3,000 square feet, small areas can be planted if the purpose is conservation. More information about this program is available through the Virginia Department of Forestry (https://dof.virginia.gov).
Planting Bare-Rooted Tree Seedlings	Handle trees to be planted as bare-rooted seedlings only while dormant in spring or after leaf fall in autumn. Refer to Figure C-SSM-08-4 for planting instructions. When stabilizing the disturbed area between tree plantings, do not use grasses or legumes, which will overshade the new seedlings. Where possible, a circle of mulch around seedlings will help them to compete successfully with herbaceous plants.
Transplanting Trees	Transplanting trees refers to planting balled, burlapped, and container-grown trees. Hardwoods should be transplanted in the late fall following their leaf drop. There is a single exception to this rule: “Willow” oaks seem to survive at a greater rate when the trees are transplanted in the spring. Evergreens may be transplanted beginning with the fall cooldown period (normally September) and may continue into spring before elongation of the new growth.
Tree Preparation	Proper digging of a tree includes the conservation of as much of the root system as possible, particularly the fine roots. Ensure the soil adhering to the roots is damp when tree is dug and kept moist until planting. Ensure the soil (or “root”) ball is 12 inches in diameter for each inch of diameter of the trunk. Carefully excavate the tree, wrap the soil ball in burlap, and tie with rope. Use of a mechanical tree spade is also acceptable. Bind the branches of evergreens or any trees to be transported for a distance with soft rope to prevent damage.
Site Preparation	Rather than digging a planting hole, rototill or loosen with a shovel a shallow area the depth (height) of the soil ball and the width of five times the diameter of the soil ball or container. Organic material can be added to the loosened soil as long as the new material is used uniformly throughout the area. Heavy or poorly drained soils are not good growth media for trees. When it is necessary to transplant trees into such soils, take extra care. Properly installed drain tile will improve drainage; refer to Subsurface Drain (BMP C-ECM-09).

Table C-SSM-08-1 Construction Specifications for Trees	
Activity	**Notes on Proper Execution**
Setting the Tree	At the center of the prepared area, dig a shallow hole to set the tree. Ensure the hole allows the root ball to sit on solid ground rather than loose soil. Ensure the upper surface of the root ball is level with the existing soil. The tree may be set just a few inches higher than its former location, especially if soil is poorly drained. Do not set the tree lower than it was previously positioned. Ensure the soil to be placed around the root ball is moist but not wet (see Figure C-SSM-08-5). Set the tree in the hole and remove the rope that holds the burlap. Cut away the burlap or, at a minimum, push it back into the bottom of the excavation. Do not break the soil of the root ball. Fill the hole with soil halfway and tamp firmly around the root ball. Add water to settle the soil and eliminate air pockets. When the water has drained off, fill the hole the remainder of the way and tamp as before. Use extra soil to form a shallow basin around the tree, somewhat smaller than the diameter of the root ball (Figure C-SSM-08-5). The shallow basin will be for holding water when the tree is irrigated. Level the ground and eliminate these basins when winter sets in, as ice forming in the basin might injure the trunk.
Supporting the Tree	Newly planted trees may need artificial support, especially in windy areas, to prevent excessive swaying. Use stakes or guy wires as shown on Figure C-SSM-08-4. Use rubber hose and allow some slack in the guy to encourage strengthening of the plant. Remove all supports within 6 months of planting.
Watering	Thoroughly water the soil around the tree after the tree is set in place. When the soil becomes dry, water the tree deeply but not too often. Mulching around the base of the tree is helpful in preventing roots from drying out.
Maintenance of Tree Plantings	Like all plants, trees require water and fertilizer to grow. Water young trees with an inch of water each week for the first 2 years after planting. When rain does not supply this need, water the tree deeply but not any more frequently than once per week. Fertilize transplanted trees 1 year or so after planting. Simple methods of fertilizing are adequate (application of the fertilizer to the surface of the soil or mulch around the tree). The best material for small trees is well-rotted stable manure. Add the manure as a 2-inch layer of mulch around the tree annually. If chemical fertilizers are used, a formulation such as 10-8-6 or 10-6-4 (NPK) is preferred. Use about 2 pounds per inch of trunk diameter measured 4 feet from the ground. Thus, if the trunk diameter at 4 feet was 5 inches, then 10 pounds of fertilizer would be applied. For evergreens, use one half the recommended amount of chemical fertilizer or use only organic fertilizers such as cottonseed meal, bone meal, or manure. Fertilizer must contact the roots to benefit the tree. A straightforward way to ensure contact is to make holes in the tree's root area with a punch bar, crowbar, or augur. Ensure holes are 18 inches deep, spaced about 2 feet apart, and located around the drip line of the tree. Distribute the necessary fertilizer evenly into these holes and close the holes with the heel of the shoe or by filling with topsoil or peat moss. Fertilize trees in late fall or in early spring before leaves emerge.

Table C-SSM-08-2 Construction Specifications for Shrubs	
Activity	**Notes on Proper Execution**
Shrubs	Much of what has been said about trees also applies to shrubs. A shrub is a solid, woody plant less than 15 feet tall, usually with several trunks rising from a common base. Some shrubs have the appearance of small trees, and some lie close to the ground.
Selecting Appropriate Shrubs	There are so many ornamental shrubs available that advising on the choice of any one is difficult. Table C-SSM-08-6 provides the basic characteristics of shrubs commonly available at commercial nurseries in Virginia, which are recommended for conservation planting because they enrich or hold the soil or encourage development of wildlife habitat. Information on other shrubs is available from nurserymen and extension agents.
Planting Shrubs	Follow the general procedure for tree planting when planting shrubs.

Table C-SSM-08-3 Construction Specifications for Vines and Ground Cover	
Activity	**Notes on Proper Execution**
Vine and Ground Cover Selection	Low-growing plants that sprawl, trail, spread, or send out runners come in many leaf types, colors, and growth habits. Some are suitable only as part of a maintained landscape, and some can stabilize large areas with little care. In addition to stabilizing disturbed soil, vines and ground covers can perform the following functions: • Maintain cover in areas where turf will not thrive. • Provide attractive cover that does not need mowing. • Help to define traffic areas and control pedestrian movement. People are more likely to walk on the grass than to walk on a prickly planting of juniper. Table C-SSM-08-7 provides the characteristics of some commonly used vines and ground covers suitable for Virginia. Information on others is available from nurserymen.
Site Preparation	Ground covers are plants that naturally grow close together, causing severe competition for space, nutrients, and water. Well prepared soil for ground covers is essential. A well-drained soil high in organic matter is best. If the area to be planted is so large that adding amendments to the soil as a whole would be impractical, organic matter may be added only to each planting hole. Lime and fertilize the ground according to soil test or add 5 pounds of 10-10-10 (N-P-K) and 10 pounds of ground agricultural limestone to every 100 square feet. Incorporate into the top 4 to 6 inches of the soil. Add organic matter up to one third of the total soil volume, either over the whole area (a layer 2 inches deep mixed into the top 6 inches) or in each planting hole if the area is large.
Planting	Most ground covers perform best when planted in the spring. Container-grown plants can be planted throughout the growing season if adequate water is provided. Plant vines and ground cover such as pachysandra on 1-foot centers; large plants, such as juniper, can be spaced on 3-foot centers. Most ground covers are planted from container-grown nursery stock. Transplant to the prepared seedbed using a small trowel or a spade. Make a hole large enough to accommodate the roots and soil. Backfill and firm the soil around the plant, water immediately, and keep well-watered until established.

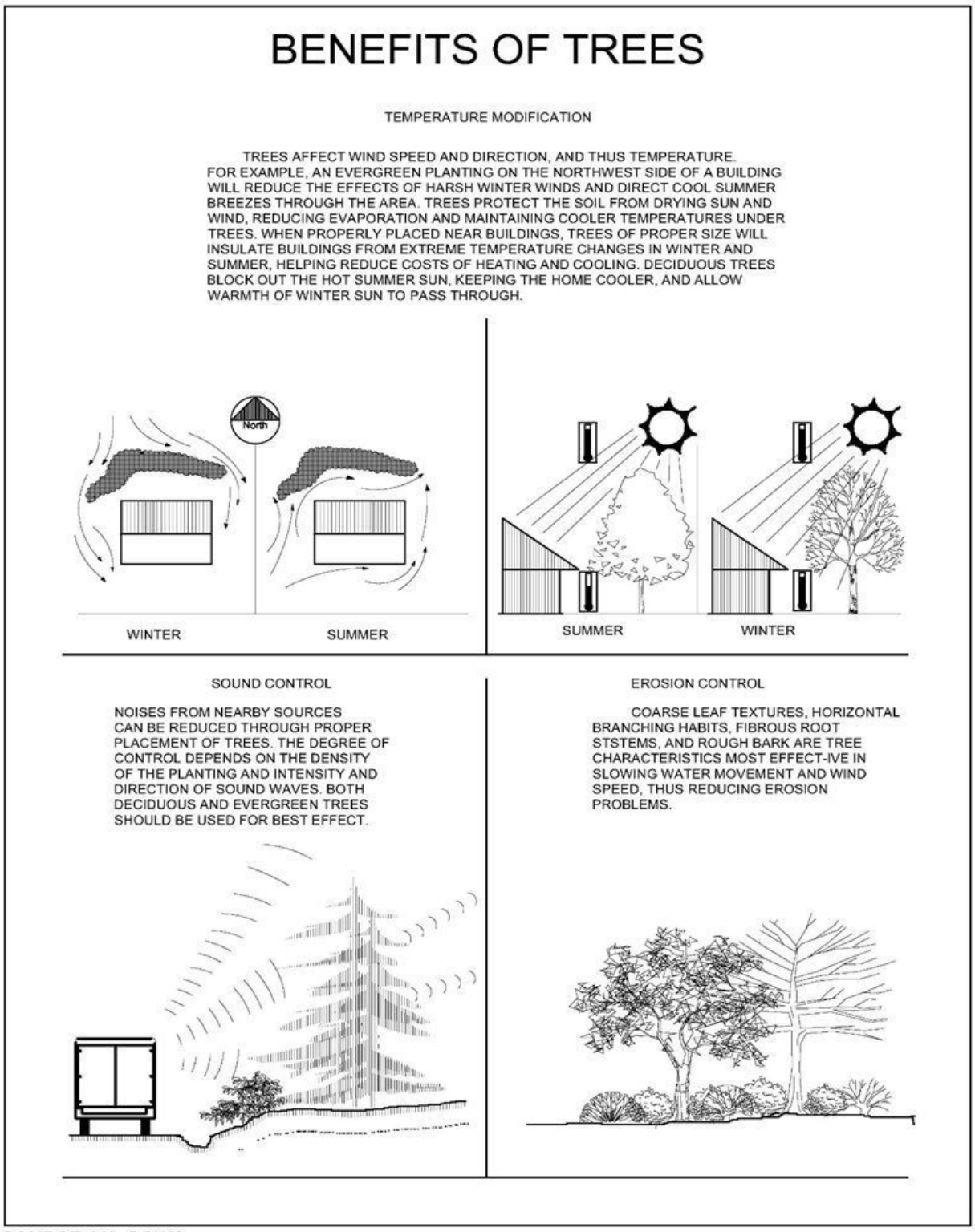
Table C-SSM-08-4 Construction Specifications for Mulching	
Activity	**Notes on Proper Execution**
Mulching	Plant the soil between trees and shrubs with cover vegetation or install mulch. When establishing ground covers, it is not desirable to plant species that will compete strongly with the ground cover or will make maintenance difficult. To prevent erosion and reduce weed problems, install a thick, durable mulch such as shredded bark or wood chips. Pre-emergent herbicides may be necessary where weeding is not practical. On slopes where erosion may be a problem, Soil Stabilization Blankets and Matting (BMP C-SSM-05) may be installed before planting, and plants can be tucked into the soil through slits in the net. Install such plants in a staggered pattern to minimize erosion.

7.0 Operations and Maintenance Considerations

Proper pruning, watering, and application of fertilizer every 3 or 4 years will keep shrubs healthy. Maintain the mulch cover or turf cover surrounding the shrubs. A heavy layer of mulch reduces weeds and retains moisture.

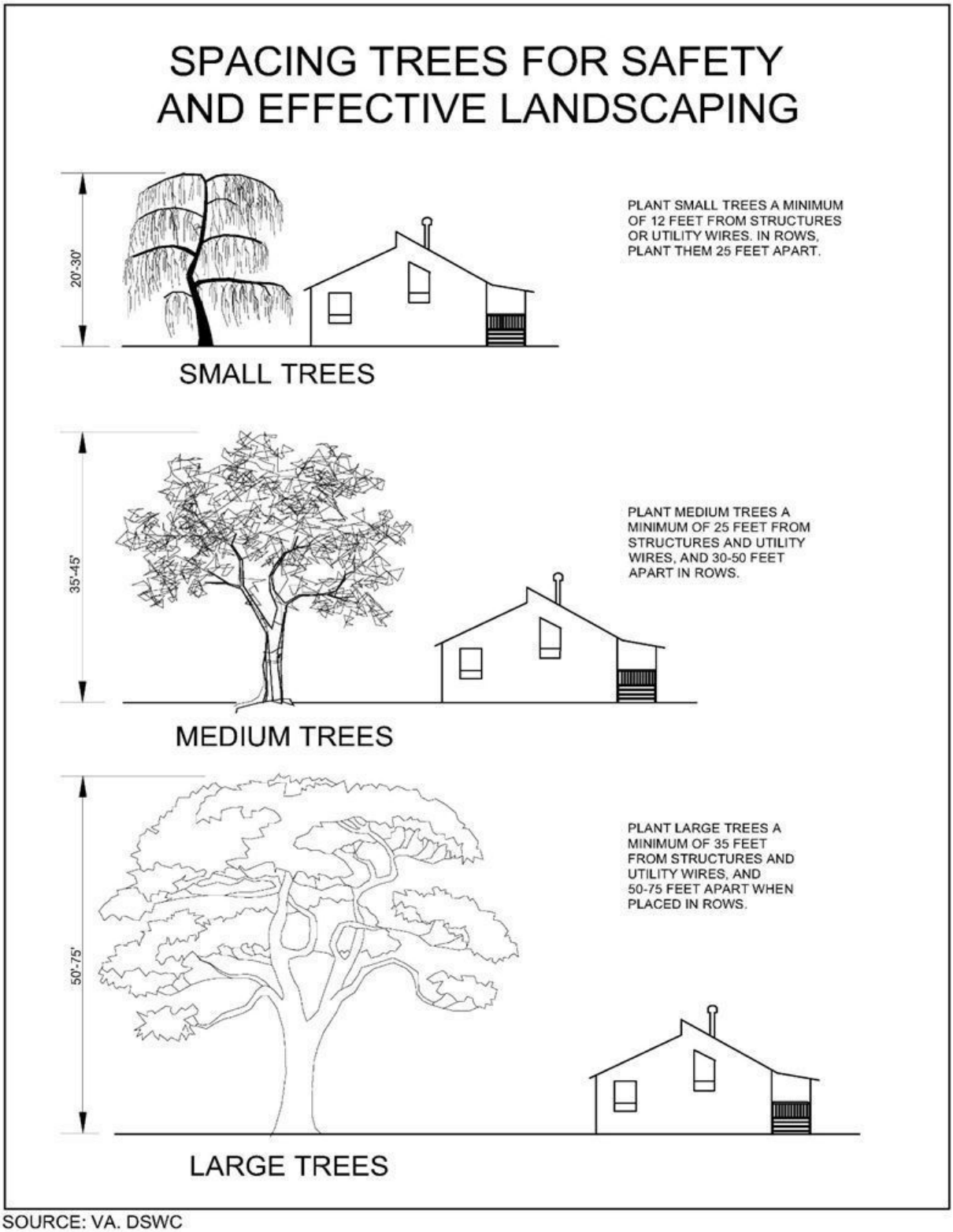
Trim old growth as needed to improve the appearance of ground covers. Most covers need annual trimming to promote growth. Maintain mulch cover with additions of mulch where needed. Fertilize as described above every 3 to 4 years.

Figure C-SSM-08-1 Benefits of Trees



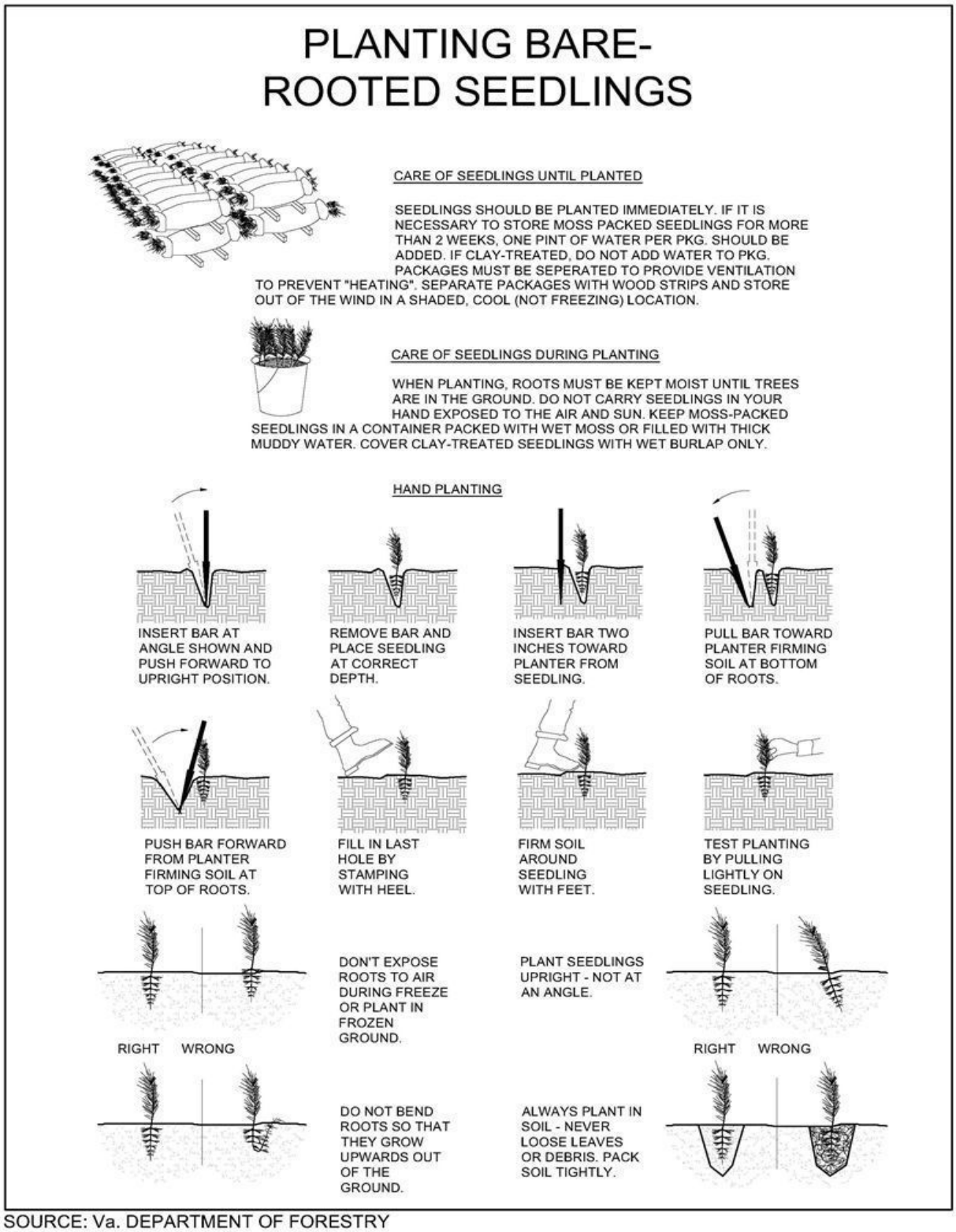
SOURCE: VA. DSWC

Figure C-SSM-08-3 Spacing Trees for Safe and Effective Landscaping



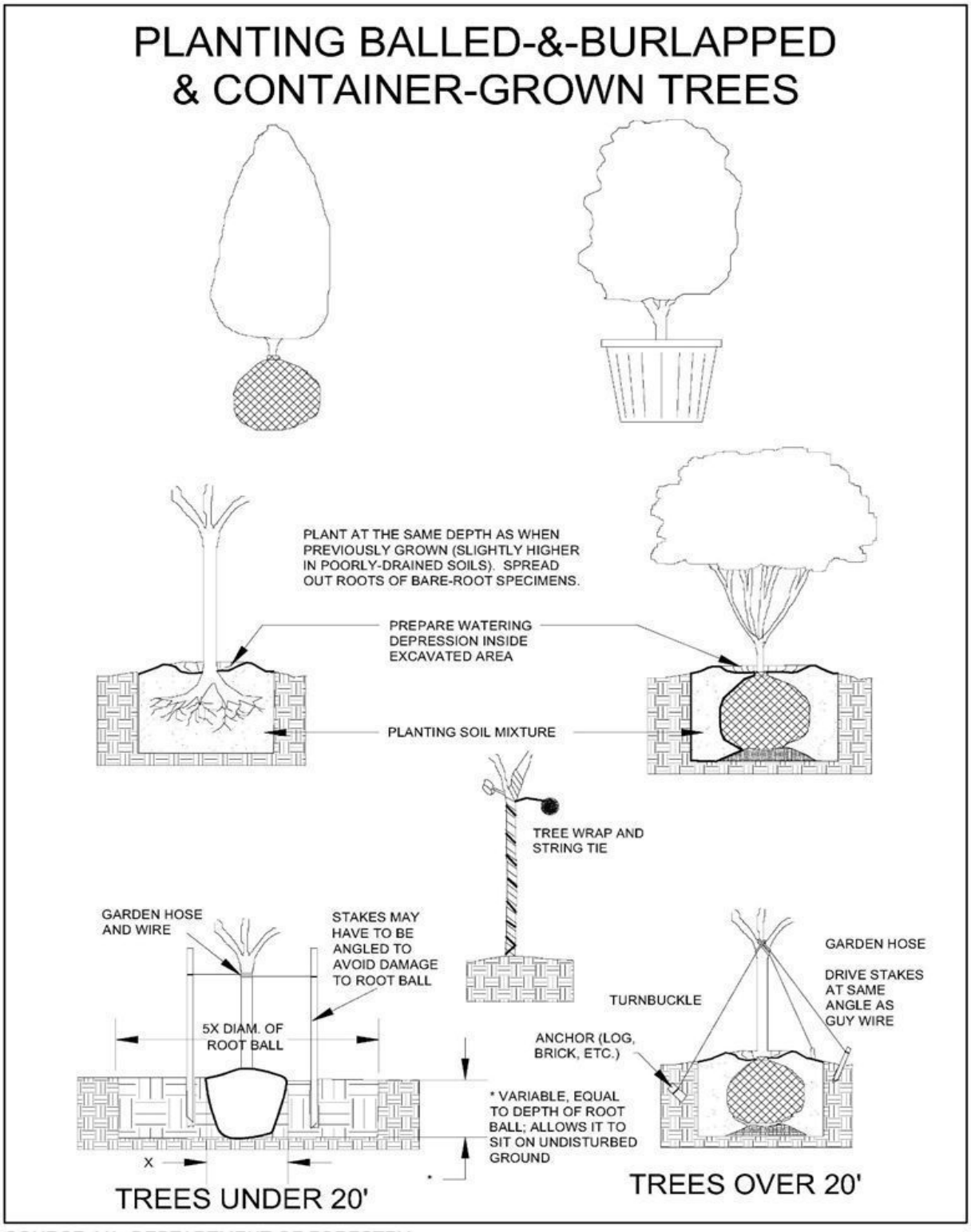
SOURCE: VA. DSWC

Figure C-SSM-08-4 Planting Bare Rooted Seedlings



SOURCE: Va. DEPARTMENT OF FORESTRY

Figure C-SSM-08-5 Planting Bald/Burlapped/Container-Grown Trees



SOURCE: VA. DEPTARTMENT OF FORESTRY

Table C-SSM-08-5 Tree Selection																	
Trees for Landscaping, Erosion Control and Soil Conservation in Virginia																	
Common Name (Botanical Name)	Leaf Type	Zones in VA	Mature Size (ft)	Soil Moisture Preferred			pH Range	Uses			Disease/Pest Resistance	Salt Tolerance	Pollution Tolerance			Remarks (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	
Beech (*Fagus grandifolia*)	D	6 7 8	70 - 120		X		6.5 - 7.5	X			fair	S	-	S	-	Long-lived. Has edible nuts. Needs lots of space.
Birch, River (*Betula nigra)*	D	7 8	50 - 80	X	X		4.0 - 5.0	X			good	-	S	S	-	Prefers deep, moist soils such as streambanks. Graceful form.
Cedar, Eastern Red (*Juniperus virginiana*)	E	7 8	20 - 50	X	X	X	6.0 - 6.5	X			good	-	T	T	T	Long-lived.
Chickasaw Plum, (*Prunus angustifolia*)	D	6 7 8	15 - 20		X	X	6.0 - 8.0	X	X		good	-	-	-	T	Mildly poisonous if seeds are ground up and consumed. [1]
Crabapple (*Malus angustifolia*)	D	6 7 8	15 - 20		X		4.5 - 8.0	X	X	X	fair	I	S	S	-	White or pink flowers, edible fruit. [2]
Cucumber Tree (*Magnolia acuminata*)	D	6 7	50 - 80	X	X		4.0 - 7.0	X			good	-	-	-	-	Grows rapidly. Green flowers; scarlet fruits in fall.
Dogwood, Flowering (*Comus florida*)	D	6 7 8	30 - 40		X		5.0 - 6.5	X	X		good	-	T	T	T	Ideal street tree. White or pink flowers. Has poor drought resistance.
Ginkgo (*Ginkgo biloba*)	D	6 7 8	to 100		X	X	6.0 - 6.5	X	X		very good	-	T	T	T	Plant male trees only - fruit has an offensive odor.
Hackberry, Dwarf (*Celtis tenuifolia*)	D	6 7 8	80 - 90	X	X	X	6.5 - 7.5	X	X		good	T	T	T	-	Tolerant of parking lot conditions. [3]
Hawthorne (*Crataegus spp.*)	D	6 7 8	15 - 25		X		6.0 - 7.5	X	X		good	I	-	S	-	Thorny, Washington, and Lavalle types are good ornamentals. Tolerant of parking lot conditions.
Holly (*Ilex opaca*)	E	6 7 8	40 - 50	X	X	X	4.0 - 6.	X	X	X	good	I	-	T	T	Slow-growing. Shade-tolerant. Red berries appear only on female trees.
Hornbeam (Ironwood) (*Carpinus caroliniana*)	D	6 7 8	10 - 30	X	X	X	6.5 - 7.5	X	X		good	S	-	T	I	Prefers low, moist bottomlands. Will tolerate shade. Yeddo hornbeam and European hornbeam preferred.
Locust, Black (*Robinia pseudo-acacia*)	D	6 7 8	30 - 50		X	X	5.0 - 7.5			X	fair	I	S	T	I	Suited only to erosion control on seriously disturbed areas.
Maple, Striped (*Acer pensylvanicum*)	D	6 7	15 - 35		X	X	4.5 - 6.0	X			fair	-	T	T	I	Prefers well drained, deep, fertile soil. May be used in clipped hedges. [4]
Maple, Red (*Acer rubrum*)	D	6 7 8	50 - 80	X	X		4.5 - 7.5	X	X	X	good	S	T	T	-	Grows rapidly when young. Good tree for suburbs, but not city (Gerling, Tilford).
Maple, Sugar (*Acer saccharum*)	D	6	50 - 70	X	X	X	6.5 - 7.5	X			fair	I	T	T	-	Outstanding fall foliage. Suburban, but not city, tree. Slow-growing and shapely (Green Mountain).

Table C-SSM-08-5 Tree Selection																
Trees for Landscaping, Erosion Control and Soil Conservation in Virginia																
Common Name (Botanical Name)	Leaf Type	Zones in VA	Mature Size (ft)	Soil Moisture Preferred			pH Range	Uses			Disease/Pest Resistance	Salt Tolerance	Pollution Tolerance			Remarks (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O^3	SO^2	F	
Oak, Chestnut (*Quercus montana*)	D	6	60 - 70		X	X	6.0 - 6.5	X			good	T	S	TI		Grows well in sandy, gravelly, or rocky soils.
Oak, Pin (*Quercus palustris*)	D	6 7 8	60 - 80	X	X	X	5.5 - 6.5	X	X		good	T	S	S	I	Most easily transplanted of the oaks (Sovereign).
Oak, Red, Northern (*Quercus rubra borealis*)	D	6 7 8	70 - 90		X	X	4.5 - 6.0	X	X	X	good	T	T	T	I	Most rapid-growing oak. Needs plenty of space.
Oak, Red, Southern (*Quercus falcata*)	D	7 8	70 - 80			X	4.0 - 5.0			X	good	-	T	T	I	Characteristically an upland tree. Prefers dry, infertile soils.
Oak, Scarlet (*Quercus coccinea*)	D	6 7	60 - 80			X	6.0 - 6.5	X	X		good	T	S	TI		Prefers sandy or gravelly soils.
Oak, White (*Quercus alba*)	D	6 7 8	60 - 80		X	X	6.5 - 7.5	X	X	X	fair	T	S	S	I	Long-lived, stately tree. Grows slowly.
Oak, Willow (*Quercus phellos*)	D	7 8	40 - 50	X	X	X	4.0 - 6.5	X			good	T	S	TI		Long-lived, but grows quickly. Easy to transplant. Prefers fertile, acid soil.
Pine, Table Mountain (*Pinus pungens*)	E	6 7	20 - 40	X	X		4.0 - 8.0	X			good	T	-	-	-	Very hardy and rapid growing. Will tolerate shallow soil and drought. [5]
Pine, Loblolly (*Pinus taeda*)	E	7 8	90 - 120	X	X		4.0 - 6.5			X	good	-	-	S	S	Use only for conservation plantings, not as an ornamental.
Pine, Shortleaf (*Pinus echinate Miller*)	E	6 7	80 - 100		X	8 X	4.0 - 6.5	X			good	-	-	-	-	Attractive shape. Prefers well drained, sandy or gravelly soil.
Pine, Marsh (*Pinus serotina*)	E	6 7	60 - 90			X	4.0 - 6.5	X			fair	I	S	S	S	Resistant to fire but susceptible to wind damage due to their height. [6]
Pine, Virginia (*Pinus virginiana*)	E	7 8	30 - 40		X	X	4.0 - 6.5	X			good	I	S	S	-	Tolerates poor soil. Use for conservation plantings, not as an ornamental. Shallow-rooted.
Pine, White (*Pinus strobus*)	E	6	80 - 100			X	4.0 - 6.5	X			fair	S	S	S	S	Very attractive, rapid-growing tree. Prefers deep, sandy loam. Subject to white pine blister rust.
Sycamore, American (*Platanus occidentalis*)	D	6 7 8	75 - 100		X	X	4.5 - 9.5	X	X	X	good	-	-	T	T	Good city tree.[7]
Eastern Redcedar (*Juniperus virginiana*)	E	6 7 8	30-40	X	X	X	4.0-9.0	X	X	X	fair	T	-	-	-	Mildly toxic if consumed. [10]
Tupelo (Blackgum) (*Nyssa sylvatica*)	D	6 7 8	60 - 80	X	X		5.0 - 6.0	X		X	good	I	T	T	-	Scarlet fall foliage. Suitable for swampy areas.

Table C-SSM-08-5 Tree Selection													
Trees for Landscaping, Erosion Control and Soil Conservation in Virginia													
Common Name (Botanical Name)	Leaf Type	Zones in VA	Mature Size (ft)	Soil Moisture Preferred			pH Range	Uses			Disease/Pest Resistance	Salt Tolerance	Pollution Tolerance			Remarks (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	

Notes:

For hardiness zones in Virginia, see Figure C-SSM-08-2.

Leaf Type: “E” = Evergreen; “D” = Deciduous.

Pollution Tolerance: “S” = Sensitive, will show physical damage; “T” = Tolerant; “I” = Intermediate, damage depends on growing conditions; “-” = No information at this time.

Table C-SSM-08-6 Shrub Selection													
Shrubs for Vegetating Disturbed Areas													
Common Name (Botanical Name)	Leaf Type	Drainage Tolerance						Shade Tolerance	pH Range	Mature Height (ft)	Flowers	Fruit	Uses
		Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained							
Arrowwood Vibrurnum (*Viburnum denatum*)	D		X	X	X			fair	4.5 - 8.0	5 - 10	white clusters	navy berries	Hedges and borders. Winter food for birds and wildlife. [8]
California Privet (*Ligustrum ovalifolium*)	E		X	X				fair	6.0 - 7.0	12 - 18	--	--	Hedges and windbreaks. Grows rapidly. Do not use in Mountain Region.
Bayberry (*Myrica pennsylvanica*)	E	X	X	X				poor	5.0 - 6.0	6 - 8	--	waxy, gray berries	Revegetating sand dunes; ornamental for droughty areas; fixes nitrogen in soil.
Beach Plum (*Prunus maritima*)	D	X	X	X				fair	6.0 - 8.0	7	white	edible, purple plum-like fruits	Revegetating sand dunes/ droughty areas. Fruit used for jelly and baking, also favored by wildlife.
Bristly Locust (*Robinia hispida*)	D	X	X	X				poor	5.0 - 7.5	10	pink	Bristly pods	Steep slopes, Resistant to drought. Spreads by sprouting from roots. [9]
Elderberry (*Sambucus canadensis*)	D		X	X	X	X		fair	6.0 - 7.5	12	white	edible purple berries	Provides food for birds and deer. Fruit in 4 to 5 yrs.
Ground Juniper (*Juniperus communis var. depressa*)	E		X	X	X			good	5.0 - 6.0	3 - 4	--	--	Used as ground cover or ornamental. Set plants 2 feet apart for cover in 2 to 3 years. [11]
American Yew (*Taxus canadensis*)	E		X	X	X			good	6.0 - 7.0	– 3 - 5	--	red berries	Used in riparian buffers and along steep slopes. [12]
Virginia Rose (*Rosa virginiana*)	D		X	X				poor	4.5 - 8.0	4 - 6	yellow, pink	red hips in 1-2 yrs.	Stabilizing sand dunes and landscaping. Food and cover for songbirds and rabbits. Sprawling growth habit, but not aggressive. [13]
Sweet Fern (*Comptonia peregrina*)	D	X	X					poor	5.0 - 6.0	2 - 4	--	--	Pleasantly scented. Fixes nitrogen. Spreads by underground stems. Stabilizes droughty areas. Do not use in Coastal Plain.
Red Honeysuckle (*Lonicera dioica)*	D		X	X	X			good	6.0 - 8.0	3 - 6	red	Orange or burgundy berries	Woody, twining vine that is found in moist areas as well as sandy or rocky ground. [14]

Table C-SSM-08-6 Shrub Selection												
Shrubs for Vegetating Disturbed Areas												
		Drainage Tolerance										
Common Name (Botanical Name)	Leaf Type	Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained	Shade Tolerance	pH Range	Mature Height (ft)	Flowers	Fruit	Uses
Winterberry (*Ilex verticillata*)	D		X	X	X	X	fair	5.0 - 6.0	10	--	red berries in 3-4 years	Ornamental screens. Winter food for songbirds.

Notes:

E = Evergreen

D = Deciduous

* = Where no comment is made, fruit or flowers are inconspicuous.

Table C-SSM-08-7 Ground Cover and Vine Selection										
Ground Covers and Vines for Erosion Control										
		Drainage Tolerance								
Common Name (Botanical Name)	Leaf Type	Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained	Shade Tolerance	pH Range	Flowers	Characteristics
Bearberry (*Arctostaphylos uva-ursi*)	E	X	X				good	4.5 - 6.0	--*	Trailing shrub. Low-fertility sandy areas, dunes. Set plants 18 in. apart for cover in 2 to 4 years.
Blazing Star (*Liatris spicata*)	D	X	X	X	X	X	poor	4.0 - 8.0	purple, pink, or white, stacked in a cylindrical shape	Narrow leaves up to a foot long. Can be planted up to 3' apart. Highly attractive to pollinators.[15]
Smooth Purple Coneflower (*Echinacea laevigata*)	D		X	X	X		fair	6.0 - 9.5	pink or purple with large centers	Pest and disease resistant. Used by bees for nectar and birds in the winter if seed heads are left intact. [16]
Lily-Of-The-Valley (*Convallaria pseudomajalis*)	E	X	X	X	X		good	4.5 - 6.0	fragrant white bells on short stalks	Highly toxic to humans if consumed. [20]
Sea Oats *(Uniola paniculata)*	E	X	X	X			poor	4.5 - 9.5	--	Slow-growing and long-lived plant with deep taproots and lateral rhizomes that work to hold soil in place. [19]
Thimbleweed (*Anemone virginiana*)	D		X	X	X		excellent	4.5- 8.0	Small yellow or white flowers	Sap may cause skin irritation. Highly resistant to pests and diseases. [18]
Virginia Creeper (*Parthenocissus quinquefolia*)	D	X	X				fair	5.0 - 7.5	--*	Ground cover for dunes and other dry areas; will climb trees. Attractive crimson foliage in fall. Berries eaten by songbirds. Set plants 18 in. apart for cover in 1-2 years.
Virginia Heartleaf *(Asarum virginicum)*	E		X	X			excellent	4.0- 6.0	--	Low growing plant spreads via a creeping rhizome. [17]

Notes:

E = Evergreen

D = Deciduous

* = Where no comment is made, fruit or flowers are inconspicuous.

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For new plant types:

[1] https://plants.ces.ncsu.edu/plants/prunus-angustifolia/

[2] https://plants.ces.ncsu.edu/plants/malus-angustifolia/

[3] https://plants.ces.ncsu.edu/plants/celtis-tenuifolia/

[4] https://plants.ces.ncsu.edu/plants/acer-pensylvanicum/

[5] https://plants.ces.ncsu.edu/plants/pinus-pungens/

[6] https://plants.ces.ncsu.edu/plants/pinus-serotina/

[7] https://plants.ces.ncsu.edu/plants/platanus-occidentalis/

[8] https://plants.ces.ncsu.edu/plants/viburnum-dentatum/

[9] https://plants.ces.ncsu.edu/plants/robinia-hispida/

[10] https://plants.ces.ncsu.edu/plants/juniperus-virginiana/

[11] https://plants.ces.ncsu.edu/plants/juniperus-communis-var-depressa/

[12] https://plants.ces.ncsu.edu/plants/taxus-canadensis/

[13] https://plants.ces.ncsu.edu/plants/rosa-virginiana/

[14] https://plants.ces.ncsu.edu/plants/lonicera-dioica/

[15] https://plants.ces.ncsu.edu/plants/liatris-spicata/

[16] https://plants.ces.ncsu.edu/plants/echinacea-laevigata/

[17] https://plants.ces.ncsu.edu/plants/asarum-virginicum/

[18] https://plants.ces.ncsu.edu/plants/anemone-virginiana/

[19] https://plants.ces.ncsu.edu/plants/uniola-paniculata/

[20] https://plants.ces.ncsu.edu/plants/convallaria-pseudomajalis/

C-SSM-09 Temporary Seeding

1.0 Definition

The establishment of a temporary vegetative cover on disturbed areas by seeding with appropriate rapidly growing annual plants.

2.0 Purpose and Applicability of Best Management Practice

1. To reduce erosion and sedimentation by stabilizing disturbed areas that will not be brought to final grade for a period of more than 14 days.
2. To reduce damage from sediment and runoff to downstream or offsite areas, and to protect bare soils exposed during construction until permanent vegetation or other erosion control measures can be established.

Conditions Where Practice Applies:

This best management practice (BMP) applies where exposed soil surfaces are not to be fine-graded for periods longer than 14 days. Such areas include bare areas, soil stockpiles, dikes, dams, sides of sediment basins, temporary road banks, non-vegetated cuts and fills, and diversions (see MS #1 and MS #2).

Apply a permanent vegetative cover to areas that will be left dormant for a period of more than 1 year.

3.0 Planning and Considerations

Sheet erosion, caused by the impact of rain on bare soil, is the source of most fine particles in sediment. To reduce this sediment load in runoff, protection of the soil surface is necessary. The most efficient and economical means of controlling sheet and rill erosion is to establish vegetative cover with at least 75 percent living vegetative cover with a maximum contiguous bare area of less than 500 square feet. Annual plants that sprout rapidly and survive for only one growing season are suitable for establishing initial or temporary vegetative cover. Temporary seeding is encouraged when possible to aid in controlling sediment losses and sheet flow from construction sites and other partially disturbed and non-vegetated areas.

Temporary seeding is essential to preserve the integrity of earthen structures used to control sediment such as dikes, diversions, and the banks and dams of sediment basins. Temporary seeding also prevents costly maintenance operations on other erosion control systems. For example, sediment basin cleanouts will be reduced if the drainage area of the basin is seeded where active grading and construction are not taking place. Perimeter dikes will be more effective if not choked with sediment.

Proper seedbed preparation and the use of quality seed are important in this practice, as with permanent seeding. Failure to carefully follow sound agronomic practices, such as beginning with well-conditioned soil and on a well-prepared seedbed, will often result in an inadequate stand of vegetation that provides little or no erosion control.

Temporary seeding provides protection for no more than 1 year, during which time permanent stabilization is initiated. Multiple temporary seeding efforts may be necessary for extended durations (> 6 months) that involve both cool and warm seasons.

4.0 Stormwater Performance Summary

4.1 MS-1: Stabilization

Permanent or temporary soil stabilization will be applied to bare soil within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization will be applied within 7 days to bare soil

areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization will be applied to areas to be left dormant for more than 1 year.

4.2 MS-2: Stockpiles, Waste, and Borrow Areas

During construction of the project, soil stockpiles and borrow areas will be stabilized or protected with sediment trapping measures. The applicant is responsible for the temporary protection and permanent stabilization of all soil stockpiles onsite as well as borrow areas and soil intentionally transported from the project site.

Sediment Removal Efficiency: N/A

Erosion Control Efficiency: High

5.0 Design Criteria

No formal design criteria.

6.0 Construction Specifications

Prior to seeding, complete grading and install necessary erosion control practices such as dikes, waterways, and basins.

Table C-SSM-09-1 Construction Specifications for Temporary Seeding

Activity	Notes on Proper Performance
Plant Selection	Select plants appropriate to the season and site conditions from Table C-SSM-09-3 and Table C-SSM-09-4. Note that Table C-SSM-09-3 presents plants that can be used without extensive evaluation of site conditions; Table C-SSM-09-4 presents more in- depth information on the plant materials.
Seedbed Preparation	To control erosion on bare soil surfaces, plants must be able to germinate and grow. Good seedbed preparation is essential to successful plant establishment. A good seedbed is loose and uniform, with at least 35 percent soil-sized particles (<2mm). Where hydroseeding methods are used, the surface may be left with a more irregular surface of large clods and stones. Minimize steep slopes because steep slopes challenge seedbed preparation and increase the erosion hazard.

Table C-SSM-09-1 Construction Specifications for Temporary Seeding	
Activity	**Notes on Proper Performance**
Liming	Determine if lime is necessary for temporary seeding. In most soils, it may take several months for a pH adjustments to fully occur following the application of lime. Therefore, it may be difficult to justify the cost of liming a temporary site, especially when the soil will later be moved and regraded. Table C-SSM-09-2 may be used to determine the actual need along with suggested application rates if the soil pH is known. If the pH of the soil is not known, an application of ground agricultural limestone at the rate of 1 to 1.5 tons per acre on coarse-textured soils and 2 to 3 tons per acre on fine- textured soils is usually sufficient. Apply limestone uniformly and incorporate into the top 4 to 6 inches of soil. Soils with a pH of 6 or higher need not be limed. However, any soil with a pH of 5.5 should receive lime application. All liming materials should be Virginia Department of Agriculture and Consumer Services (VDACS) certified agricultural limestone or other approved liming products based on their calcium carbonate equivalent.
Fertilizer	Apply fertilizer at a rate of 600 pounds per acre (14 pounds per 1,000 square feet) using 10-20-10 fertilizer or equivalent nutrients. Incorporate lime and fertilizer into the top 4 to 6 inches of the soil if possible. If a hydraulic seeder is used, do not mix seed and fertilizer more than 30 minutes before application.
Surface Roughening	If the area has been recently loosened or disturbed, no further roughening is required. When the area is compacted, crusted, or hardened, loosen the soil surface by discing, raking, harrowing, or other acceptable means according to Surface Roughening (BMP C-SSM-03).
Tracking	Tracking with bulldozer cleats is most effective on sandy soils. This practice often causes undue compaction of the soil surface, especially in clayey soils, and does not aid plant growth as effectively as other methods of surface roughening.
Seeding	Evenly apply seed with a broadcast seeder, drill, cultipacker seeder, or hydroseeder. Plant small grains no more than 1.5 inches deep. Plant small seeds, such as Kentucky Bluegrass, no more than 0.25 inch deep. Plant other grasses and legumes between 0.25 inch to 0.5 inch deep.
Mulching	Mulch seedings made in fall for winter cover and during hot and dry summer months according to Mulching (BMP C-SSM-11) except those of hydro-mulch (fiber mulch), which are not considered adequate (>70% vegetative cover) for mid-winter or mid- summer seedings. Use straw mulch during these periods. Temporary seedings made under favorable soil and site conditions during optimum spring and fall seeding dates may not require mulch.
Reseeding	Areas that fail to establish vegetative cover adequate to prevent rill erosion will be reseeded as soon as such areas are identified. Do not mow. Protect from traffic as much as possible.

Table C-SSM-09-2 Liming

Liming Requirements for Temporary Sites

pH Test	Recommended Application of Agricultural Limestone
below 4.2	3 tons per acre
4.2 to 5.2	2 tons per acre
5.2 to 6	1 ton per acre

Source: Va. DSWC

Table C-SSM-09-3 Plant Material for Temporary Seeding

Acceptable Temporary Seeding Plant Materials "Quick Reference for all Regions"

Planting Dates	Species	Rate (pounds per acre)
Sept. 1 – Feb. 15	50/50 Mix of annual ryegrass (*Lolium multi-florum*) & cereal (winter) rye (*Secale cereale*)	50 – 100
Feb. 16 – Apr. 30*	Annual ryegrass (*Lolium multi-florum*)	60 – 100
May 1* – Aug. 31	German millet (*Setaria italica*)	50

* The shift date for annual rye to German millet should be April 15 for the Piedmont and Coastal Plain, rather than May 1.

Table C-SSM-09-4 Temporary Seeding Applications

Temporary Seeding Plant Materials, Seeding Rates, and Dates

Species	Seeding Rate		North[a]			South[b]			Plant Characteristics
	lbs./ acre	lbs./ 1,000 ft²	3/1 - 4/30	5/1 - 8/15	8/15 - 11/1	2/15 - 4/30	5/1 - 9/1	9/1 - 11/15	
Oats (*Avena sativa*)	50 – 100	2.0	X	-	--	X	-	-	Use spring varieties (e.g., Noble).
Rye[d] (*Secale cereale*)	50 – 110	2.5	X	-	X	X	-	X	Use for late fall seedings, winter cover. Tolerates cold and low moisture.
German millet (*Setaria italica*)	50	1.0	-	X*	-	-	X*	-	Warm-season annual. Dies at first frost. May be added to summer mixes.
Annual ryegrass[c] (*Lolium multi-florum*)	60	1.5	X*	-	X	X*	-	X	May be added in mixes. Will mow out of most stands.

Table C-SSM-09-4 Temporary Seeding Applications									
Temporary Seeding Plant Materials, Seeding Rates, and Dates									
Korean Lespedeza[c] (*Lespedeza stipulacea*)	25	1.5	X	X	-	X	X	-	Warm-season annual legume. Tolerates acid soils. May only be used in a mix with another grass (e.g., annual or cereal rye); it is not suitable as a pure seeding for this purpose.

a. Northern Piedmont and Mountain regions. See Figure C-ENV-01-1 and Figure C-ENV-01-2.
b. Southern Piedmont and Coastal Plain.
c. May be used as a cover crop with spring seeding.
d. May be used as a cover crop with fall seeding.
Xe. May not be planted between these dates.
-f May be planted between these dates.

*** The shift date for annual rye to German millet should be April 15 for the Piedmont and Coastal Plain, rather than May 1.**

7.0 Operations and Maintenance Considerations

Inspect seeded areas every 7 calendar days and within 24 hours after each rainfall event that produces 0.5 inch or more of precipitation. Reseed any bare areas > 500 square feet.

Cover seeded area with straw or mulch to moderate soil moisture and temperature during the initial germination period.

Supply temporary seeding with adequate moisture. Supply water as needed, especially in abnormally hot or dry weather or on adverse sites. Control water application rates to prevent runoff.

8.0 References

North Carolina Sediment Control Division, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. 2013. Erosion and Sediment Control Planning and Design Manual. North Carolina Department of Environmental Quality, Division of Energy, Mineral, and Land Resources in partnership with the North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extension Service. Available online at: https://www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/erosion-and- sediment-control/erosion-and-sediment-control-planning-and-design-manual.

South Carolina DHEC. 2005. Storm Water Management BMP Handbook. Located at: https://scdhec.gov/bow/stormwater/best-management-practices-bmps/bmp-handbook.

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

C-SSM-10 Permanent Seeding

1.0 Definition

Permanent seeding is the establishment of perennial vegetative cover on disturbed areas by planting seed.

2.0 Purpose and Applicability of Best Management Practice

The purposes of permanent seeding are:

1. To reduce erosion and decrease sediment yield from disturbed areas;
2. To permanently stabilize disturbed areas in a manner that is economical, adaptable to site conditions, and allows selection of the most appropriate plant materials;
3. To improve wildlife habitat; and
4. To enhance natural beauty.

Permanent seeding applies in:

1. Disturbed areas where permanent, long-lived vegetative cover is needed to stabilize the soil; and
2. Rough-graded areas that will not be brought to final grade for 1 year or more.

3.0 Planning and Considerations

Vegetation controls erosion by reducing the velocity and volume of overland flow and protecting the bare soil surface from raindrop impact.

Areas that must be stabilized after the land has been disturbed require vegetative cover. The most common and economical means of establishing this cover is by seeding grasses and legumes. Permanent vegetative covers must meet the requirements of Minimum Standard #3.

Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.

Disadvantages include the potential for erosion during establishment, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, the potential need for weed control during establishment, and a need for water and appropriate climatic conditions during germination.

There are so many variables in plant growth that an ideal outcome cannot be guaranteed. Much can be done in the planning stages to increase the chances for successful seeding. Selection of the right plant materials for the site, good seedbed preparation, and conscientious maintenance are important.

An establishment and persistence of 75 percent or more living overall perennial vegetation of the intended species mix and a maximum contiguous bare area of < 500 square feet is required to effectively limit sheet and rill erosion and permanently stabilize the soil surface.

Table C-SSM-10-1 Design Considerations for Permanent Seeding	
Parameter	**Notes on Proper Design**
Selecting Plant Materials	The factors affecting plant growth are climate, soils, and topography. In Virginia, there are three major physiographic regions that reflect changes in soil and topography. When selecting appropriate plant materials, the characteristics of the physiographic region in which the project is located should be considered (see Figure C-SSM-10-1).
Physiographic Regions	Coastal Plain: Soils on the Coastal Plain are deeply weathered, stratified deposits of sand and clay that are generally acidic and low in plant nutrients. The sandy soils are hot and droughty in summer. This region receives more rain and is warmer than the other regions of the state. The land is fairly level, and many areas are poorly drained. Warm-season grasses traditionally perform well in these areas. Piedmont: Soil characteristics on the Piedmont Plateau vary widely. These soils tend to be shallow with clayey subsoils. Piedmont soils are usually low in pH and P unless in active agricultural production and are often highly eroded to expose red/yellow highly acidic clayey subsoil materials. Soils derived from mica schist are highly erodible. Topography is rolling and hilly. The southern Piedmont has much the same climate as the Coastal Plain and is often referred to as the "transition zone" in planting. This region contains areas that will support both warm- and cool-season grasses. Appalachian and Blue Ridge Region: This region is divided into mountains, valleys and dissected plateaus. Soils on mountain ridges and dissected plateaus tend to be shallow, acidic, and may erode rapidly on steep slopes. Shaley intermediate slopes are often unstable and droughty. Soils in limestone valleys generally occur on more rolling landforms and are usually much deeper. This area is cooler and often drier than the rest of the state. The rugged to rolling topography complicates plant establishment. Cool-season grasses and legumes are normally recommended in this region.
Soils	Overall, soils in Virginia always require some nitrogen fertilization to establish plants. Phosphorus and potassium are usually needed. Except for some small pockets of shallow limestone soils, lime is universally needed. Soils can be modified with lime and fertilizer, but climate cannot be controlled. For this reason, the State of Virginia has been divided into two major climatic regions (referred to as the Northern Piedmont and Mountain Region and the Southern Piedmont and Coastal Plain Region) for grass and legume selection (see map on Figure C-SSM-10-2). Microclimate, or localized climate conditions, can affect plant growth. A south-facing slope is drier and hotter than a north-facing slope and may require drought-tolerant plants. Consider that shaded areas require shade-tolerant plants, the windward side of a ridge will be drier than the leeward, and other conditions.

Table C-SSM-10-1 Design Considerations for Permanent Seeding	
Parameter	**Notes on Proper Design**
Land Use	A prime consideration in selecting plants to establish is the intended use of the land. All these uses – residential, industrial, commercial, recreational – can be separated into two major categories: high-maintenance and low-maintenance. High-Maintenance Areas – will be mowed frequently, limed, and fertilized regularly, and will either be subject to intense use (e.g., athletics) or require maintaining to an aesthetic standard (home lawns). Use grasses for these areas that are fine-leaved and visually appealing, able to form tight sod, and be long-lived perennials. The grasses must be well-adapted to the geographic area in which they are planted because constant mowing puts turf under great stress. Sites where high- maintenance vegetative cover is desirable include homes, industrial parks, schools, churches, athletic playing surfaces, and some recreational areas. Low-Maintenance Areas – will be mowed infrequently or not at all, lime and fertilizer may not be applied regularly, and the areas will not be subjected to intense use or required to have a uniform appearance. These plants must be able to persist with little maintenance over long periods of time. Grass and legume mixtures are preferred for these sites because legumes are capable of fixing nitrogen from the air for their own use and the use of the plants around them. Such mixed stands are better able to withstand adverse conditions. Sites that would be suitable for low- maintenance vegetation include steep slopes, stream or channel banks, some commercial properties, and “utility turf” areas such as road banks.
Seedbed Preparation	Modification of the soil on a disturbed site provides the optimum environment for seed germination and seedling growth. For water infiltration and root penetration to occur, the surface soil needs to be loose and non-compacted to at least six inches. Deeper loosening (de-compaction) may be required on compacted fill or smeared cut slopes. To ensure that soil pH (balance of acidity vs. alkalinity) is adequate and reduce root toxicities, VDACS approved liming materials should be applied to adjust the pH to between 6.0 and 7.5. Sufficient N-P-K will need to be added as fertilizers or other approved soil amendments (e.g. compost). After the seed is in place, protect the new seedlings with mulch, applied over or with seeding, to retain moisture and moderate temperature extremes. Mulch also helps to stabilize the disturbed site against sediment losses until the vegetation establishes.

Table C-SSM-10-1 Design Considerations for Permanent Seeding	
Parameter	**Notes on Proper Design**
Non-Native, Invasive & Pollinator Friendly Plant Considerations	Many of the plant species commonly utilized for permanent seedings are not native to Virginia and are considered by Virginia DCR (2022) to be invasive with respect to their ability to move into adjacent relatively natural areas. This is primarily due to their higher probability of success for establishing and persisting in highly disturbed environments vs. available native grasses and forbs. Therefore, revegetation planners and practitioners should take these concerns into account when determining seed mixtures for a given site. Greater emphasis is also being placed upon establishment of "pollinator friendly" flowering species into revegetation protocols for disturbed sites. In general, establishment and maintenance of native grasses and pollinator friendly species mixes requires a higher level of establishment and management inputs than the more conventional seeding mixtures described later in this guidance.

4.0 Stormwater Performance Summary

4.1 MS-1: Stabilization

Permanent or temporary soil stabilization will be applied to bare soil areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization will be applied within 7 days to bare soil areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization will be applied in areas to be left dormant for more than 1 year.

4.2 MS-3: Permanent Vegetation

A permanent vegetative cover will be established on bare soil areas not otherwise permanently stabilized. Permanent vegetation will not be considered established until achievement of a ground cover that is uniform, mature enough to survive, and will inhibit erosion.

Sediment Removal Efficiency: N/A

Erosion Control Efficiency: High

5.0 Design Criteria

No formal design criteria.

6.0 Construction Specifications

Table C-SSM-10-2 Construction Specifications for Permanent Seeding	
Parameter	**Notes on Execution**
Selection of Plant Materials	Selection of plant materials is based on climate, topography, soils, land use, and planting season. To determine which plant materials are best adapted to a specific site, use Table C-SSM-10-4 and Table C-SSM-10-5, which describe plant characteristics and list recommended varieties. The species listed in Table C-SSM-10-4 to C-SSM-10-8 are not exclusive and other species and varieties may be suitable for use in Virginia based on emerging research by VDOT and the revegetation industry. However, use of aggressive or invasive species as identified by VA DCR where viable native substitutes are available is discouraged. Information about invasive species is available on the DCR website. (See DCR 2022) Suggested basic seeding mixtures for site conditions in Virginia are provided in Tables C-SSM-10-6, C-SSM-10-7, and C-SSM-10-8. These mixtures are designed for general use and have proven to be successful over time on typical sites. See Tables CSSM- 10-4 and C-SSM-10-5 for recommended varieties. However, it is strongly suggested that all low maintenance seed mixtures contain at least two different species of both grasses and legumes in addition to an appropriate seasonal cover species. More extensive descriptions of plant materials (grasses and legumes), their usage, and pictorial representations are provided in Table C-SSM-10-1. When using some varieties of turf grasses, the Virginia Crop Improvement Association (VCIA) recommends that turf grass mixtures may also be used. Consumer protection programs have been devised to identify quality seed of the varieties recommended by the Virginia Cooperative Extension Service. These will bear a label indicating that they are approved by the Association. Mixtures may be designed for a specific physiographic region or based on intended use. Special consideration is given to plant characteristics, performance, and other attributes. Site planners and designers should refer to the DCR invasive species list as part of the process of selecting plant materials for a site. (See DCR 2022). This serves two purposes: to avoid use of invasive species to the extent possible; and to ensure plant selection is based on the most current information available.

Table C-SSM-10-2 Construction Specifications for Permanent Seeding	
Parameter	**Notes on Execution**
Seed Quality Criteria	Where certified seed is not available, use grass and legume seed in vegetative establishment that meets the minimum requirements as provided below. Ensure all tags on containers of seed are labeled to meet the requirements of the state seed law. Ensure all seed is subject to re-testing by a recognized seed laboratory that employs a registered seed technologist or by a state seed lab. Ensure all seed used has been tested within 12 months. Ensure the inoculant added to legume seed in the seed mixtures is a pure culture of nitrogen-fixing bacteria prepared for the species. Do not use inoculants after the date indicated on the container. Use twice the supplier's recommended rate of inoculant on dry seedings; five times the recommended rate if hydroseeded. Delay addition of the inoculant until no more than 30 minutes prior to hydroseeding to avoid loss of viability Ensure the quality of the seed used is shown on the bag tags to conform to the guidelines documented in Table C-SSM-10-9. All seeding rates shown in Tables C-SSM-10-4 to C-SSM-10-9 should be applied on a "pure live seed" (PLS) basis calculated as the sum of readily germinable and hard seed, but not inert matter or other weedy species.

Table C-SSM-10-2 Construction Specifications for Permanent Seeding	
Parameter	**Notes on Execution**
Seedbed Requirements	Do not establish vegetation on slopes that are unsuitable due to inappropriate soil texture, poor internal structure or internal drainage, volume of overland flow, or excessive steepness until these problems have been corrected. To maintain a good stand of vegetation, ensure the soil meets the following minimum requirements as a growth medium: • Sufficient fine grained soil material (> 25% < 2 mm) to maintain adequate soil moisture and nutrient supply. Areas that do not meet this requirement will require topsoiling (C-SSM-02) or application of compost and/or manufactured soil materials to be viable; • Sufficient pore space to permit root penetration. An in situ surface soil bulk density of between 1.35 g/cm3 (clayey soils) and 1.75 g/cm3 (sandy soils) following site preparation and soil amendment indicates sufficient pore space for water holding and enhanced infiltration.; • Sufficient soil depth to provide an adequate root zone. Ensure the depth to rock or impermeable layers (such as hardpans) is a minimum of 12 inches, except on slopes steeper than 2H:1V, where the addition of soil is not feasible; • A favorable pH range for plant growth. If the soil is so acidic that a pH range of 6.0 to 7.0 cannot be attained by addition of pH-modifying materials, then the soil is considered an unsuitable environment for plant roots, and further soil modification is required; • Free from toxic amounts of materials harmful to plant growth; and • Free from excessive quantities of roots, branches, large stones, large clods of earth, or trash of any kind. Clods and stones may be left on slopes steeper than 3H:1V if they do not significantly impede good seed-to-soil contact. If any of these criteria cannot be met (i.e., if the existing soil is too coarse, dense, shallow, acidic, or contaminated to foster vegetation), apply topsoil in accordance with Topsoiling (C-SSM-02). Install the necessary structural erosion and sediment control practices before seeding. Carry out grading according to the approved plan. Roughen surfaces in accordance with Surface Roughening (C-SSM-03).

Table C-SSM-10-2 Construction Specifications for Permanent Seeding	
Parameter	**Notes on Execution**
Soil Conditioners and Amendments at Seeding	To modify the texture, structure, or drainage characteristics of a soil, the following materials may be added. Any product labeled as a soil conditioner, horticultural growing medium, liming material or fertilizer in VA must be approved by VDACS. Peat: Peat is a very costly conditioner but works well. If added, use sphagnum moss peat, hypnum moss peat, reed-sedge peat, or peat humus from freshwater sources. Shred and condition peat in storage piles for at least 6 months after excavation. Use a wetting agent unless aged peat is available. Sand: Use sand that is clean and free of toxic materials. Sand modification is ineffective unless added at a rate of 80 to 90 percent by volume, which is extremely difficult to achieve onsite. If this practice is considered, consult a professional authority to ensure that it is conducted properly. Animal Manure: Any application of animal manures must follow applicable VDEQ waste management regulations and may be subject to VA DCR nutrient management planning (NMP) guidance. Fully composted (per criteria in C-SSM-04) manure products can be utilized as soil conditioners with input from a waste management professional. Rotted Sawdust or Wood Waste Materials: Thoroughly rotted sawdust or stabilized wood waste materials that is free of sticks, stones and toxic materials may be used as a soil conditioner, but may require additional N fertilizer to offset high C:N ratio limitations based on input from a waste management professional. Biosolids: Utilization of biosolids (treated sewage sludge) is a proven beneficial practice for a wide range of agricultural and disturbed land remediation and revegetation practices. All land application of biosolids is regulated by VDEQ on a producer x site-specific application basis in conformance with USEPA Part 503 regulations. Conformance with DCR Nutrient Management Planning (NMP) criteria is also generally required. Certain biosolids products (Class A; EQ) have been treated, processed and tested to an extent that they are available for general use without a site-specific permit. Biosolids are an effective soil amendment that can supply organic matter and essential macro/micronutrients when applied and utilized properly. Application rates may vary from < 5 to 35 dry tons per acre per depending on site-specific soil conditions and nutrient management/loss considerations. Certain composted products also contain biosolids and are available for use as a revegetation soil amendment.

Table C-SSM-10-2 Construction Specifications for Permanent Seeding	
Parameter	**Notes on Execution**
Lime	Determine lime needs by soil tests, which may be performed by the Cooperative Extension Service Soil Testing Laboratory at Virginia Polytechnic Institute and State University (VPI&SU) or by a reputable commercial laboratory. Information concerning the State Soil Testing Laboratory is available from county extension agents. Reference Table C-SSM-10-10 for liming applications needed to correct undesirable pH for various soil types. Under unusual conditions, where it is not possible to obtain a soil test, apply an agricultural grade of limestone at the following rates. Coastal Plain — 2 tons/acre (90 lbs./1,000 ft2) Piedmont and Appalachian Region — 2 tons/acre (90 lbs./1,000 ft2) Liming materials should be labeled and approved by VDACS.
Fertilizer	Determine fertilizer needs by soil tests, which may be performed by the Cooperative Extension Service Soil Testing Laboratory at VPI&SU (https://www.soiltest.vt.edu/) or by a reputable commercial laboratory. Information concerning the Soil Testing Laboratory is available from county extension agents. All fertilizer materials should be VDACS approved and labeled. Under unusual conditions, where it is not possible to obtain a soil test, apply a fertilizer at the following rates. Mixed Grasses & Legumes: 1,000 lbs./acre (23 lbs./1,000 ft^2) of 10-20-10 (N-P_2O_5-K_2O) or equal. These rates apply to establishment needs only and subsequent post-establishment fertilization with N will be required for pure grass stands or stands where at least a 25% legume component does not persist. Follow-up applications of P2O5 may also be required for exposed fine-textured, acidic and high clay subsoil materials. These subsoils are typically red to reddish yellow in color. Additional K2O is also required for frequently mowed stands or on very sandy soils. All fertilizer application should be based on soil testing by the Virginia Tech Soil Testing Laboratory or another DCR approved laboratory. Legume Stands Only: 1,000 lbs./acre (23 lbs./ 1,000 ft^2) of 5-20-10 is preferred 1,000 lbs./acre (23 lbs./ 1,000 ft^2) of 10-20-10 or equal Grass Stands Only: 1,000 lbs./acre (23 lbs./1,000 ft^2) of 10-20-10 or equal Use other fertilizer formulations, including slow-release sources of nitrogen (preferred from a water quality standpoint), provided these fertilizers can supply the same amounts and proportions of plant nutrients.
Incorporation	Incorporate lime and fertilizer into the top 4 to 6 inches of the soil by discing or other means whenever possible. For erosion control, when applying lime and fertilizer with a hydroseeder, apply to a rough, loose surface.

Table C-SSM-10-2 Construction Specifications for Permanent Seeding	
Parameter	**Notes on Execution**
Seeding	Certified Seed: use certified seed for all permanent seeding whenever possible. Certified seed is inspected by the VCIA or the certifying agency in other states. Use seed that meets the published state standards and bears an official “Certified Seed” label (see Seed Quality Criteria in row 2 of this table). Legume Seed: Use legume seed inoculated with the inoculant appropriate to the species. Scarify seed of the lespedezas and the clovers species to promote uniform germination. Application: Apply seed uniformly with a broadcast seeder, drill, culti-packer seeder, or hydroseeder on a firm, friable seedbed. Ensure the seeding depth is between 0.25 to 0.5 inch. Hydroseeding: To avoid poor germination rates because of seed damage during hydroseeding, add 50 percent more seed to the tank if machinery breaks down for 30 minutes to 2 hours based on the proportion of the slurry remaining in the tank. Beyond 2 hours, a full rate of new seed may be necessary. Often, hydroseeding contractors prefer not to apply lime in their rigs, as it is abrasive. In inaccessible areas, apply lime separately in pelletized or liquid form. Surface roughening is particularly important when hydroseeding, as a roughened slope will provide some natural coverage of lime, fertilizer, and seed. Apply inoculants at five times the recommended rate when inoculant is included in the hydroseeder slurry.
Mulching	Mulch all permanent seeding immediately upon completion of seed application in accordance with Mulching (C-SSM-11).
Maintenance of New Seedings	In general, a stand of vegetation cannot be determined to be fully established until it has been maintained for 1 full year after planting.
Irrigation	Supply new seedings with adequate moisture. Supply water as needed, especially late in the season, in abnormally hot or dry weather, or on adverse sites. Control water application rates to prevent excessive runoff. Inadequate amounts of water may be more harmful than no water.
Reseeding	Inspect seeded areas for failure and make necessary repairs and reseedings within the same season if possible. If vegetative cover is inadequate to prevent rill erosion, over-seed and fertilize in accordance with soil test results. If a stand has less than 40 percent cover, re-evaluate choice of plant materials and quantities of lime and fertilizer. Test the soil to determine if acidity or nutrient imbalances are responsible. Re-establish the stand following seedbed preparation and seeding recommendations.

Table C-SSM-10-2 Construction Specifications for Permanent Seeding	
Parameter	**Notes on Execution**
Post-Establishment Fertilization	Begin fertilization of intensively managed/mowed cool-season grasses 90 days after planting to ensure proper stand and density. Begin fertilization of intensively managed/mowed warm-season grasses at 30 days after planting. Apply maintenance levels of fertilizer as determined by soil test. In the absence of a soil test, conduct fertilization as follows: Cool-Season Grasses 4 lbs. nitrogen per 1,000 ft^2 per year 1 lb. phosphorus per 1,000 ft^2 per year 2 lbs. potash per 1,000 ft^2 per year Apply 75 percent of the total requirements between September 1 and December 31. Apply the balance during the remainder of the year. Do not apply more than 1 lb. of soluble nitrogen per 1,000 ft^2 at any one time. Warm-Season Grasses Apply 4 to 5 lbs. nitrogen per 1,000 ft^2 per year between May 1 and August 15. Apply phosphorus and potash according to soil test. Note: The use of slow-release fertilizer formulations for maintenance of turf is encouraged to reduce the number of applications and the impact on groundwater. Less intensive post-establishment fertilizer applications may be required for low-intensity un-mowed stands, particularly when at least 25% legumes are present. However, stand density and vigor should be evaluated periodically if lower fertilization rates are employed. Soil testing should be utilized for routine P and K prescriptions over time, but not for N recommendations. Maintenance of pH > 5.5 is essential for both grass and legume persistence in permanent seedings.
Other Additives	A wide range of other soil amendments including byproduct limes, digestates, biochar, and various processed animal manure products are available for utilization in permanent seeding applications. However, users should ensure that any soil bulk soil amendment has been approved for such use by VDACS, VDEQ or DCR and that application complies with appropriate labeling or NMP limitations.

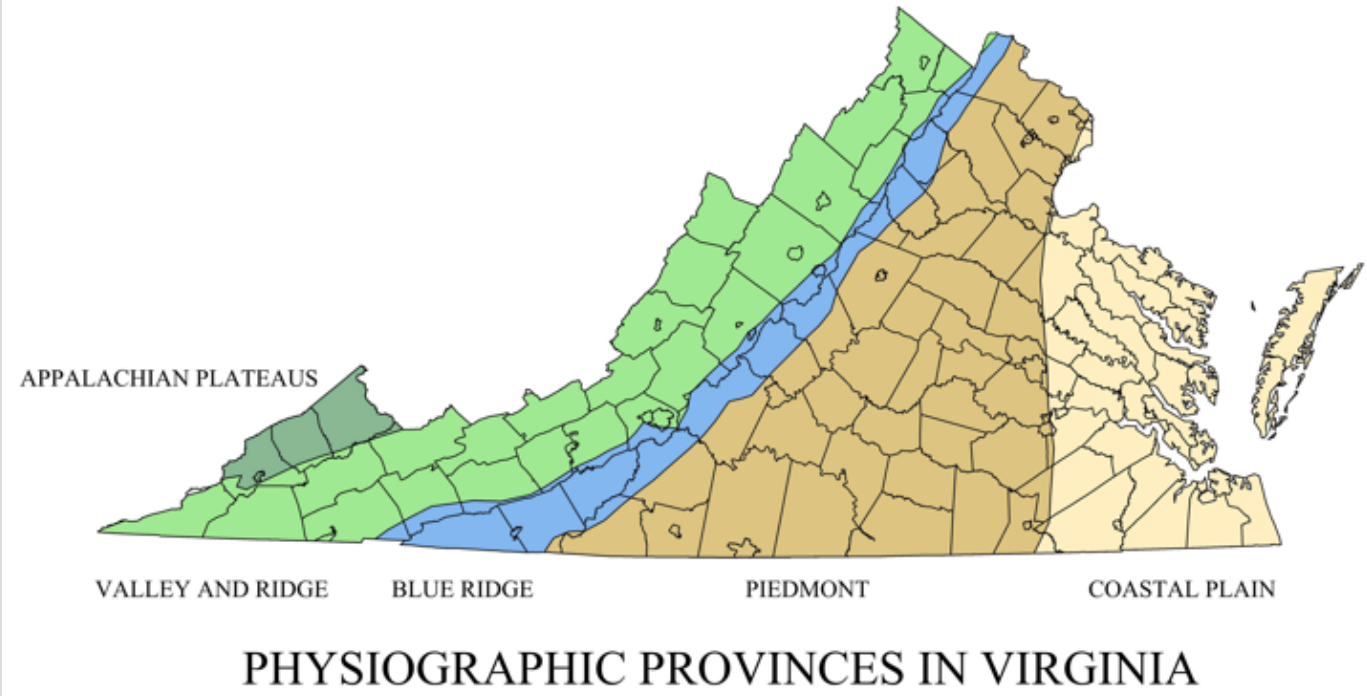
Table C-SSM-10-3 Keys to Successful Establishment of Grasses and Legumes	
Activity	**Notes on Proper Execution**
Planning	Where feasible, plan grading around optimal seeding dates for the region. The most effective times for establishing perennial grasses and legumes in Virginia generally extend from March through May and from August through October. Outside these dates, the probability of failure is much higher. If the time of year is not suitable for seeding a permanent cover (perennial species), plant a temporary cover crop. Temporary seeding of annual species (small grains, ryegrasses, or millets) often succeeds during periods that are unsuitable for seeding permanent (perennial) species. Variations in weather and local site conditions can modify the effects of regional climate on seeding success. For this reason, mixtures including both cool- and warm-season species are preferred for low-maintenance cover, particularly in the Coastal Plain. Such mixtures promote cover that can adapt to a range of conditions. Many of these mixtures are not desirable, however, for high-quality lawns, in which variation in texture of the turf is inappropriate. It is important to note that, in Virginia, the successful establishment of 100 percent warm-season grasses in a high-quality lawn is limited to the extreme eastern portions of the Coastal Plain.
Selection	Consider species selection early in the preparation of an erosion and sediment control plan. A variety of vegetation can be established in Virginia due to the diversity in both soils and climate. However, for practical and economic stabilization and long-term protection of disturbed sites, select species judiciously. Consider seasonality when selecting species. Grasses and legumes are usually classified as warm- or cool-season in reference to their season of growth. Cool-season plants realize most of their growth during the spring and fall and are relatively inactive or dormant during the hot summer months. Therefore, fall is the most favorable time in which to plant them. Warm-season plants “green up” late in the spring, grow most actively during the summer, and go dormant at the time of the first frost in fall. Spring and early summer are preferred planting times for warm-season plants.

Table C-SSM-10-3 Keys to Successful Establishment of Grasses and Legumes	
Activity	**Notes on Proper Execution**
Seed Mixtures	As previously noted, the establishment of high-quality turf frequently involves planting a single species. However, in seedings for erosion control purposes, consider the inclusion of more than one species. Mixtures need not be excessive in poundage or seed count. The addition of a quick-growing annual provides early protection and facilitates establishment of one or two perennials in a mix. More complex mixtures might include a quick-growing annual, one or two legumes, and more than one perennial grass. The fast-growing nurse crop provides shade and temperature buffering for the establishing perennials and also takes up soluble N-P-K from soil solution to limit leaching/runoff losses which is then recycled over time to the established perennial stand via litterfall and root turnover. The addition of a “nurse” crop (quick-growing annuals added to permanent mixtures) is a sound practice for soil stabilization, particularly on difficult sites (those with steep slopes; poor, rocky, erosive soils; those seeded outside the optimum seeding periods) or where the development of permanent cover is likely to be slow. The nurse crop germinates and grows rapidly, holding the soil until the slower-growing perennial seedlings become established. Utilization of diverse seed mixes, particularly use of two or more perennial grasses and legumes (each) is strongly recommended for extensively disturbed and regraded cut/fill sites and areas with strongly contrasting aspects and slope/topographic positions. Consideration should be given to use of native grasses and flowering species when compatible with short-term, site-specific erosion control and longer-term management needs.

7.0 Operations and Maintenance Considerations

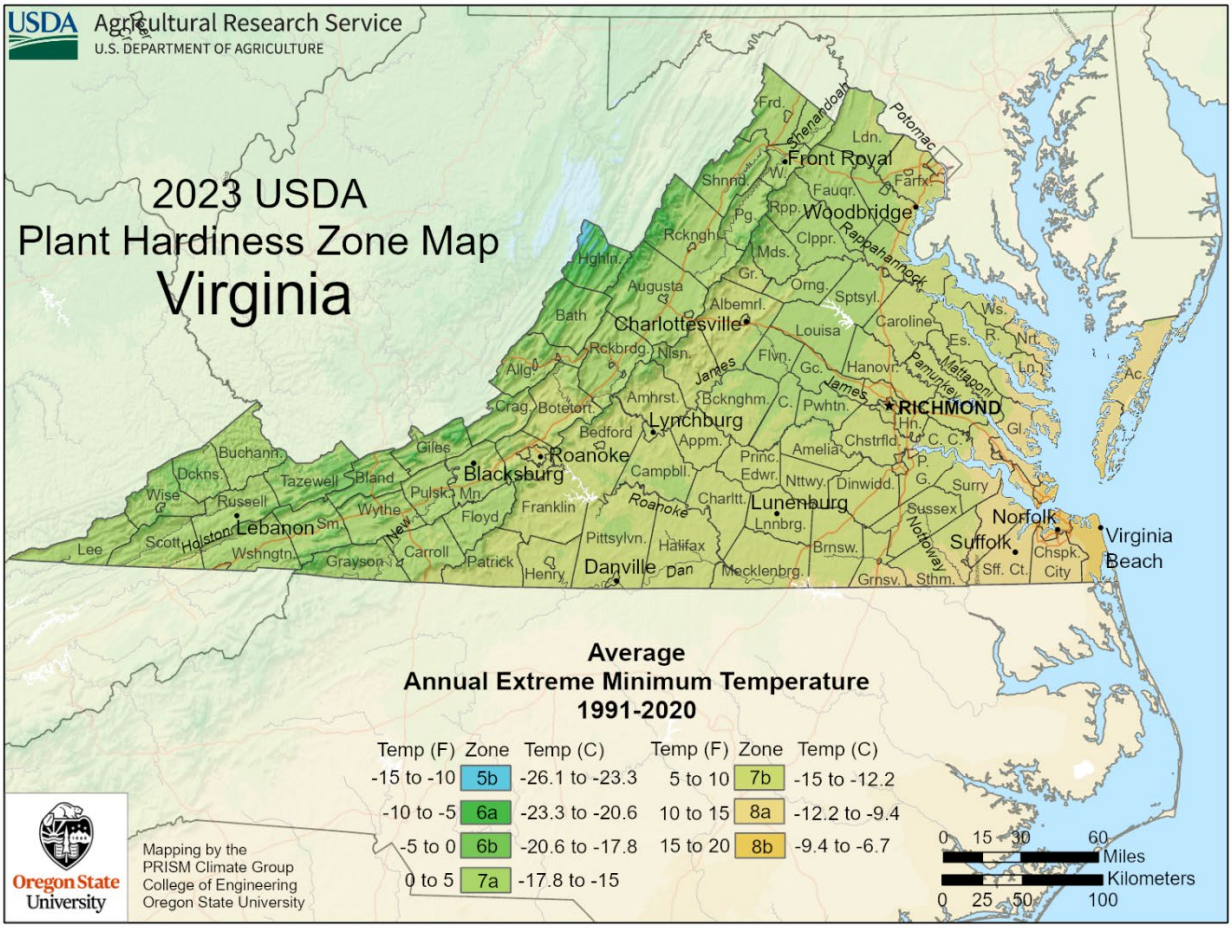
Even with careful, well-planned seeding operations, failures can occur. When plants have not germinated on an area or have died, reseed these areas immediately to prevent erosion damage. However, it is extremely important to determine why germination failed and take any corrective action necessary before reseeding the area. Healthy vegetation is the most effective erosion control available.

Figure C-SSM-10-1 Physiographic Provinces of Virginia



Source: Va. DSWC

Figure C-SSM-10-2 Plant Hardiness Zones in Virginia



Source: Adapted from Virginia Climate Advisory 1979.

Table C-SSM-10-4 Characteristics of Commonly Selected Grasses												
Common Name (Botanical Name)	Life Cycle	Season	pH Range	Germi-nation Time (days)	Optimum Germi-nation Temp-erature (˚ F)	Winter Hardi-ness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeding Rate (lbs/acre) PLS	Maintenance Requirements	Remarks	Suggested Varieties for Virginia
Tall fescue (*Festuca arundinacea*) (*Schedonorus arundinaceus*)	P	C	5.5 - 6.2	10 - 14	60 - 85	F	F	M	SPD	75*	Low when used for erosion control; high when used in lawn	Better suited for erosion control and rough turf application.	Ky 31
Tall fescues (Improved)	P	C	5.5 - 6.2	10 - 14	60 - 85	F	G	M	SPD	50	Responds well to high maintenance.	Excellent for lawn and fine turf.	See current VCIA list.**
Kentucky bluegrass (*Poa pratense*)	P	C	6.0 - 6.5	14	60 - 75	G	P	M	SPD	35	Needs fertile soil, favorable moisture. Requires several years to become well established.	Excellent for fine turfs. Takes traffic, mowing. Poor drought/heat tolerance.	See current VCIA list.
Perennial ryegrass (*Lolium perenne*)	P	C	5.8 - 6.2	7 - 10	60 - 75	F	F	M-H	SPD	30	Will tolerate traffic.	May be added to mixes. Improved varieties will perform well all year.	See current VCIA list.

Table C-SSM-10-4 Characteristics of Commonly Selected Grasses												
Common Name (Botanical Name)	Life Cycle	Season	pH Range	Germi-nation Time (days)	Optimum Germi-nation Temp-erature (˚ F)	Winter Hardi-ness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeding Rate (lbs/acre) PLS	Maintenance Requirements	Remarks	Suggested Varieties for Virginia
Hard fescue (*Festuca Longifolia or Festuca ovina or Festuca brevipila)*	P	C	5.0 - 6.2	10 - 14	60 - 80	VG	G	L	MWD	50	Grows well in sun or shade and will tolerate infertile soils; improved disease resistance.	Exceeds all fine fescues in most tests. Excellent for low-maintenance situations.	See Current VCIA list.
Chewings fescue (F. rubra)	P	C	5.0 - 6.2	10 - 14	60 - 80	VG	G	L	MWD	50	Tolerates shade; dry, infertile soils.	Poor traffic tolerance, less thatch than other fine fescues.	See Current VCIA list.
Red fescue (others) (*Festuca rubra*)	P	C	5.0 - 6.2	10 - 14	60 - 80	VG	G	L	MWD	50	Low to medium fertility requirements. Requires well-drained soil.	Spreads by rhizomes, tillers, and stolons. Will not take traffic – very shade-tolerant.	Long-fellow, Victory
Redtop (*Agrostis gigantea*)	P	C	5.8 - 6.2	10	65 - 85	G	F	L	PD	25	Will tolerate poor, infertile soils; deep- rooted.	Does well in erosion control mixes - not for lawns.	No named varieties.

Table C-SSM-10-4 Characteristics of Commonly Selected Grasses													
Common Name (Botanical Name)	Life Cycle	Season	pH Range	Germi-nation Time (days)	Optimum Germi-nation Temp-erature (˚ F)	Winter Hardi-ness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeding Rate (lbs/acre) PLS	Maintenance Requirements	Remarks	Suggested Varieties for Virginia
Weeping lovegrass (*Evagrostis curvula*)	P	W	4.5 - 6.2	14	65 - 85	F-P	G	L-M	SPD	25	Low fertility requirements; excellent drought tolerance.	Fast-growing, warm-season bunchgrass. Excellent cover for erosion control.	Common
Bermudagrass (*Cynodon dactylon*)	P	W	5.8 - 6.2	21	70 - 95	P	G	M-H	SPD	15	High nitrogen utilization, excellent drought tolerance. Some varieties adapted to western VA.	Common varieties used for erosion control. Hybrids used for fine turf.	See current VCIA list.
Orchardgrass (*Dactylis glomerata*)	P	C	5.8 - 6.2	18	60 - 75	F	F	M	SPD	50	Does best on well- drained, loamy soil.	Good pasture selection; may be grazed.	Take na Potomac
Annual ryegrass (*Lolium multiflorum*)	A	C	5.8 - 6.2	7	60 - 70	G	P	M-H	SPD	15	Will grow on most Virginia soils. Do not use in fine-turf areas.	May be added into mixes or established alone as temporary cover in spring and fall.	Common

Table C-SSM-10-4 Characteristics of Commonly Selected Grasses													
Common Name (Botanical Name)	Life Cycle	Season	pH Range	Germi-nation Time (days)	Optimum Germi-nation Temp-erature (˚ F)	Winter Hardi-ness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeding Rate (lbs/acre) PLS	Maintenance Requirements	Remarks	Suggested Varieties for Virginia
Cereal Rye (*Secale cereale*)	A	C	5.8 - 6.2	7	55 - 70	VG	G	L-M	SPD	40	Will establish in most all Virginia soils. Do not use in fine-turf areas.	May be added into mixes or established alone for late fall/ winter cover.	Abruzzi, Balboa
German/Foxtail millet (*Setaria italica*)	A	W	5.8 - 6.2	10	65 - 85	VP	G	M	MWD	40	Establishes well during summer. Very low moisture requirements.	May be added to erosion control mixes or established alone.	Common, German
Spring Oats (Avena sativa)	A	C	5.8 - 6.5	7	55-70	G	G	L-M	MWD-WD	50	Will establish in most all Virginia soils. Do not use in fine-turf are	May be added into mixes or established alone for late fall/ winter cover.	Noble, Otee, Ogle

Table C-SSM-10-4 Characteristics of Commonly Selected Grasses													
Common Name (Botanical Name)	Life Cycle	Season	pH Range	Germi-nation Time (days)	Optimum Germi-nation Temp-erature (˚ F)	Winter Hardi-ness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeding Rate (lbs/acre) PLS	Maintenance Requirements	Remarks	Suggested Varieties for Virginia

Key:

A = Annual

P = Perennial

C = Cool-Season Plant

W = Warm-Season Plant

G = Good

F = Fair

P = Poor

VP = Very Poor

H = High

M = Medium

L = Low

SPD = Somewhat Poorly Drained

MPD = Moderately Poorly Drained

PD = Poorly Drained

VPD = Very Poorly Drained

* Rate for mixed stands, increase by 2X for pure high maintenance stands.

**VCIA/VDOT Green Tab List: https://www.virginiacrop.org/vdot-green-tag-program.html

Table C-SSM-10-5 Characteristics of Legumes Appropriate for Erosion Control													
Common Name (Botanical Name)	Life Cycle	Season	pH Range	Germi-nation Time (days)	Optimum Germi-nation Temp-erature (˚ F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeding Rate (lbs/acre) PLS*	Maintenance Requirements	Remarks	Suggested Varieties for Virginia
Flatpea (*Lathyrus silvestrus*)	P	C	5.0 - 7.0	14 - 28	65 - 75	G	G	L	PD	10-15	Needs lime and high phosphorus. Good shade tolerance.	Tolerates acidic and wetter soils better than other legumes.	Lathco
Birdsfoot trefoil (*Lotus corniculatus*)	P	C	6.0 - 6.5	7	65 - 70	G	F	M	SPD	15-25	Inoculation is essential. Grows in medium-fertile, slightly acid soils.	Grows better on poorly drained soils than most legumes. Moderate heat tolerance.	Audewey Empire Fergus Norcean

Table C-SSM-10-5 Characteristics of Legumes Appropriate for Erosion Control													
Common Name (Botanical Name)	Life Cycle	Season	pH Range	Germi-nation Time (days)	Optimum Germi-nation Temp-erature (˚ F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeding Rate (lbs/acre) PLS*	Maintenance Requirements	Remarks	Suggested Varieties for Virginia
Annual Lespedezas (*Lespedeza striata, L. stipulacea*)	A	W	5.8 - 6.2	14	70 - 85	F	VG	L	MWD	20-30	Will grow on almost any well-drained soil.	Choose Kobe for southeastern VA; needs almost no nitrogen to survive.	Kobe, Korean
Red clover (*Trifolium pratense*)	P	C	6.0 - 6.5	7 - 14	70	*G*	F	M	SPD	15-20	Needs high levels of phosphorus and potassium.	Acts as a biennial. Can be added to low-maintenance mixes.	Kenstar, Kenland
White clover (*Trifolium repens*)	P	C	6.0 - 6.5	10	70	G	P	M	PD	10-15	Requires favorable moisture, fertile soils, high pH.	Spreads by soil surface stolons, white flowers.	Common, White Dutch
Partridge Pea	A	Warm	5.5 - 7.0	10-14	70	G	G	L	MWD	10-15	Good for initial restoration; can reseed; tolerates sandy soils	Native; high pollinator value	Lark, Riley Comanche

Key:

A = Annual

P = Perennial

C = Cool-Season Plant

W = Warm-Season Plant

G = Good

F = Fair

P = Poor

VP = Very Poor

H = High

M = Medium

L = Low

SPD = Somewhat Poorly Drained

MPD = Moderately Poorly Drained

PD = Poorly Drained

VPD = Very Poorly Drained

Note: All legumes must be inoculated with specific Rhizobia immediately before seeding.

* Seeding rates assuming legumes used in a mixed stand with grasses to achieve > 25% legume cover in final perennial stand.

Table C-SSM-10-6 Suggested and Example Site-Specific Seeding Mixtures for Appalachian/Mountain Area

Site Condition	Seed Mix		Application Rate (pounds per acre)
Minimum-Care Lawn Commercial or Residential	Turf-Type Tall Fescue	90-100%	150 – 200
	Improved Perennial Ryegrass*	0-10%	
	Kentucky Bluegrass	0-10%	
High-Maintenance Lawn	Bluegrass – minimum of three to five varieties from VCIA list for use in Virginia		125
	Improved VCIA Turf-Type Tall Fescue		150 – 200
General Slope (3H:1V or less)	Tall Fescue****		50 – 75
	Red Top and/or Hard Fescue		10 – 20
	White Clover and/or Birdsfoot Trefoil***		10 – 20
	Seasonal Nurse Crop **		30 – 40
Low-Maintenance Slope (> 3:1) or Inaccessible Area***	Tall Fescue****		50 – 75
	Red Top or Hard Fescue		10 – 20
	Annual Lespedeza		10 – 15
	White Clover and/or Birdsfoot Trefoil***		10 – 20
	Seasonal Nurse/Cover Crop**		30 – 40

* Perennial ryegrass will germinate faster and at lower soil temperatures than fescue, thereby providing cover and erosion resistance for seedbed.

** Use seasonal nurse crop in accordance with seeding dates as stated below:

March 1 through May 15 – annual/cereal rye

May 16 through August 15 – foxtail/German millet

August 16 through February 28 – annual/cereal rye

*** All legume seed must be properly inoculated. Legumes recommended unless periodic N fertilization maintenance intended.

Flatpea at 20 lbs/acre may be utilized where warranted. All legume seed must be properly inoculated. Weeping lovegrass may also be included in any slope or low-maintenance mixture during warmer seeding periods; add 10 to 20 lbs/acre in mixes.

**** Increase seeding rate if Kentucky 31 is used rather than VCIA/VDOT improved varieties.

Note: Seed mixes are suggested and subject to modification based on site-specific conditions by an agronomist or other qualified revegetation professionals. All seed rates expressed as PLS (Pure Live Seed; see Table C-SSM-10-9).

Table C-SSM-10-7 Site-Specific Seeding Mixtures for Piedmont Area

Site Condition	Seed Mix		Application Rate (pounds per acre)
Minimum-Care Lawn Commercial or Residential	Turf-Type Tall Fescue	95-100%	150 – 200
	Improved Perennial Ryegrass	0-5%	
	Kentucky Bluegrass	0-5%	
High-Maintenance Lawn	Improved (VCIA) Turf-Type Tall Fescue	100%	150 – 200
General Slope (3H:1V or	Tall Fescue***		50 – 75

Table C-SSM-10-7 Site-Specific Seeding Mixtures for Piedmont Area		
Site Condition	**Seed Mix**	**Application Rate (pounds per acre)**
less)	Red Top or Red/Hard Fescue	10 – 20
	White Clover and/or Birdsfoot Trefoil**	10 – 20
	Seasonal Nurse Crop*	30 – 40
Low-Maintenance Slope (> 3:1) or Inaccessible Area***	Tall Fescue	50 – 75
	Red Top and/or Hard Fescue	5 – 10
	White Clover and/or Birdsfoot Trefoil**	15 – 20
	Annual Lespedeza**	10 – 15
	Seasonal Nurse/Cover Crop	20-30

* Use seasonal nurse crop in accordance with seeding dates as stated below: February 16 through April annual rye

February 16 through April – annual/cereal rye

May 1 through August 15 – foxtail/German millet

August 16 through February 15 – annual/cereal rye

** Use legume seed that is properly inoculated with specified Rhizobia. Legumes recommended unless periodic N fertilization is intended. Weeping lovegrass may be added to any slope or low-maintenance mix during warmer seeding periods; add 10 to 20 lbs/acre in mixes.

*** Increase seeding rate if KY-31 is used rather than VCIA/VDOT improved varieties.

Bermudagrass can be added to substitute for Tall or Hard Fescue in the Low Maintenance mixes for the Southern Piedmont, particularly on sandy soils or hot (S and W) facing slopes. May through October, use hulled seed. All other seeding periods, use un-hulled seed.

Note: Seed mixes are suggested and subject to modification based on site-specific conditions by an agronomist or other qualified revegetation professionals. All seed rates expressed as PLS (Pure Live Seed; see Table C-SSM-10-9).

Table C-SSM-10-8 Site-Specific Seeding Mixtures for Coastal Plain Area		
Site Condition	**Seed Mix**	**Application Rate (pounds per acre)**
Minimum-Care Lawn Commercial or Residential	Kentucky 31* or VCIA approved Turf-Type Tall Fescue	150 – 200
	or Common Bermudagrass	75
High-Maintenance Lawn	Kentucky 31 or VCIA approved Turf-Type Tall Fescue	150 – 200
	Hybrid Bermudagrass (seed) **	40 (unhulled)
	Hybrid Bermudagrass (by other vegetative establishment method refer to Bermudagrass & Zoysiagrass Establishment [C-SSM-07])	30 (hulled)
General Slope (3H:1V or less)	Tall Fescue and/or Hard Fescue	50 – 75
	Red Top Grass	5 – 10
	Annual Lespedeza and/or White Clover***	10 – 20
	Seasonal Nurse Crop ****	30 – 40
Low-Maintenance Slope	Tall Fescue and/or Red/Hard Fescue	75 – 100

Table C-SSM-10-8 Site-Specific Seeding Mixtures for Coastal Plain Area		
Site Condition	**Seed Mix**	**Application Rate (pounds per acre)**
(Steeper than 3H:1V)	Common Bermudagrass **	0 – 15
	Redtop Grass	5 – 10
	Annual Lespedeza and/or White Clover***	10 – 20
	Seasonal Nurse Crop ****	30 – 40

* Increase seed rate if only KY-31 is used.

** May through October, use hulled seed. All other seeding periods, use unhulled see. Weeping lovegrass may be added to any slope or low-maintenance mix during warmer seeding periods; add 10 - 20 pounds per acre in mixes.

*** Use legume seed that is properly inoculated with specified Rhizobia. Legumes recommended unless periodic N fertilization is intended. Weeping lovegrass may be added to any slope or low-maintenance mix during warmer seeding periods; add 10 to 20 lbs/acre in mixes.

***** Use seasonal nurse crop in accordance with seeding dates as stated below:

March 15 through August, foxtail/German millet

September, October through November 15 annual/cereal rye

November 16 through March 15, annual/cereal rye

Note: Seed mixes are suggested and subject to modification based on site-specific conditions by an agronomist or other qualified revegetation professionals. All seed rates expressed as PLS (Pure Live Seed; see Table C-SSM-10-9).

Table C-SSM-10-9 Examples of Seed Purity Expectations for PLS Calculations		
Seed Type	**Minimum Seed Purity (%)**	**Minimum Germination (%)**
Legumes		
Lespedeza, Korean	97	85**
Grasses		
Bluegrass, Kentucky	97	85
Fescue, tall (Improved, Turf-Type Cultivars)	98	85
Fescue, tall (Ky-31)	97	85
Fescue, red	98	85
Redtop	94	80
Perennial ryegrass	98	90
Perennials		
Weeping lovegrass	98	87
Annuals		
Annual ryegrass	97	90

Table C-SSM-10-9 Examples of Seed Purity Expectations for PLS Calculations		
Seed Type	**Minimum Seed Purity (%)**	**Minimum Germination (%)**
German millet	98	85
Oats	98	80
Cereal rye	98	85

* Do not accept seed containing prohibited or restricted noxious weeds. Do not use seed containing more than 0.5 percent weed seed. To calculate percent pure, live seed, multiply germination times purity and divide by 100. Use seed certified by VCIA and/or recommended by VDOT Green Tag program.

Example: VCIA/VDOT Green Tag Tall Fescue with a germination of 85% and a purity of 98%:

100 lbs of VCIA certified seed would contain 98 lbs of pure tall fescue seed.

The same 100 lbs of VCIA certified seed would contain 98 x 0.85 = 83.3 lbs on a Pure Live Seed (PLS) basis.

If the prescribed rate for field application is 75 lbs/per acre, this would need to be applied at 90 lbs/acre.

** Includes “hard seed” that is presumed to germinate within one growing season.

Table C-SSM-10-10 Ground Agricultural Limestone* (lbs./1,000 ft²) needed to Correct pH Level of Acid Soils to 6.5			
Existing pH	**Soil Texture**		
	Sandy Loam	**Loam**	**Clay Loam**
6.2	20	35	40
6.0	40	55	70
5.8	55	65	85
5.6	70	80	105
5.4	90	100	125
5.2	105	120	140
5.0	120	140	160
4.8	125	180	205
4.6	155	210	230
4.0	200	250	300

* Apply lime in accordance with the results of a soil test, such as may be obtained through the soil testing laboratory at Virginia Tech or through a reputable commercial laboratory.

8.0 References

VDEQ. 1992. Virginia Erosion and Sediment Control Handbook. Third ed. Available online at: https://www.deq.virginia.gov/our-programs/water/stormwater/stormwater-construction/handbooks.

Virginia Department of Conservation and Recreation (DCR). 2022. Virginia Invasive Plant Species List. https://www.dcr.virginia.gov/natural-heritage/invsppdflist (accessed August 16, 2023).

9.0 Appendix A Plant Information Sheets

Plant Information Sheets

Contents:

- Annual Grasses and Grains
  - Oats
  - Rye
  - Foxtail millet
  - Annual ryegrass
- Perennials
  - Tall fescue
  - Kentucky bluegrass
  - Perennial ryegrass
  - Fine fescues Bermudagrass
- Miscellaneous Erosion Control Grasses
  - Weeping lovegrass
  - Redtop
- Legumes
  - Flatpea
  - White clover

Annual Grasses and Grains

Small grains are cool-season annual grasses primarily grown for animal feed and human consumption. In Virginia, the grains used for soil stabilization are primarily rye and oats. Foxtail millet, which is sometimes considered a small grain, is becoming a very popular and successful planting for soil stabilization.

Oats (*Avena sativa*)

A cool-season annual grass primarily grown for animal feed and human consumption but also used for soil stabilization. Oats are seeded in early spring in the western part of the state (winter oats may be sown in the Coastal Plain). Seeding rates are three bushels (100 lbs) per acre bare ground or 2.5 lbs per 1,000 ft^2.



Rye (*Secale cereale*)

Often referred to as winter rye because of its winter hardiness, rye is the most common small grain used for soil stabilization. It is also the most productive grain on dry, infertile, acid, or sandy soils. It may be seeded in the fall for winter ground cover. By maturing early, it offers less competition during late spring, a critical time in the establishment of perennial species. Rye grain germinates quickly and is tolerant of poor soils. Including rye grain in fall-seeded mixtures is almost always advantageous, but it is particularly helpful on difficult and erodible soils, erodible slopes, or when seeding is late. Rates up to 100 lbs for bare ground. Overly thick stands of rye grain will suppress the growth of perennial seedlings. Approximately 50 lbs per acre is the maximum for this purpose and, where lush growth is expected, that rate should either be cut in half or rye grain should be eliminated from the mixture.



Rye (Secale cereale)

Foxtail millet (*Setaria italica*)

A warm-season annual grass that may be used for temporary cover. German millet (variety commonly used in Virginia) germinates quickly and goes to seed quickly. These features make it an excellent companion grass for summer seedlings. It dies at first frost. Seeding rates are up to 50 lbs per acre for temporary cover. Use 10 to 20 lbs per acre in mixes.



Foxtail Millet (Setaria italica)

Annual rye (*Lolium multiflorum*)

A cool-season annual grass used for temporary cover or as a nurse grass to allow for germination of permanent stands. Most used in mixes for erosion control. Performs well throughout the state in neutral to slightly acid soils. Rates up to 100 lbs per acre for temporary cover. Use 10 to 20 lbs per acre in mixes



Annual Rye (Lolium multiflorum)

Perennials

Tall fescue (*Festuca arundinacea*)	
Uses	Pasture; hay; recreation areas; lawns; and stabilization of waterways, banks, slopes, cuts, fills, and spoils. It is the most widely used grass at this time for stabilizing large, disturbed areas.
Description	A robust, cool-season, long-lived, deep-rooted bunchy grass that may have short rhizomes (underground stems). Kentucky 31 is the best-known variety. New varieties of tall fescue are becoming available for lawn and other fine turf uses, and several offer definite improvements. However, their higher cost over the standard (Ky 31) is seldom justified when used for stabilization and erosion control. Tall fescue tolerates a wide range of seeding dates; however, except at high mountain elevations, it is most dependable when planted in fall.
Adaptation	Adapts well to both high- and low-maintenance uses throughout Virginia. Adapted to a wide range of climatic conditions. Optimum pH range is 6.0 to 7.0; will tolerate from 3.0 to 8.0. Will grow on shallow and claypan soils if they are moist. Growth is limited more by moisture than by temperature extremes, but it will tolerate drought, infertile soils, and moderate shade.
Establishment	Requires a firm seedbed. Hydroseeding is successful. Seeding rates vary from 100 lbs per acre for erosion control to 250 lbs per acre for lawns. Plant in early spring or from the middle of August through September. Legumes may not thrive in fescue stands due to the aggressive growth habits of this grass. Mowing is desirable on critical areas at least once every 2 years; lack of periodic mowing will encourage clumping of grass.
Sources	Readily available as seed and sod.



Tall Fescue (Festuca arundinacea)

Kentucky bluegrass (*Poa pratense*)	
Uses	Pasture, turf for lawns, athletic fields, golf courses, and playgrounds. Also used to stabilize waterways, slopes, cuts, and fills. Choice food for grouse, turkeys, deer, and rabbits.
Description	Long-lived, cool-season perennial grass that forms a dense sod. Becomes dormant in the heat of summer because its growing season is spring and fall.
Adaptation	Best adapted to well-drained, fertile soils of limestone origin and the climate of northern and western Virginia. Optimum pH range is 6.0 to 7.0. Bluegrasses are better suited to high-maintenance situations in the transition zone. Essentially dormant during dry or hot weather; however, bluegrass will normally survive severe drought.
Establishment	Requires a firm, weed-free seedbed, and adequate fertilization (liberal phosphorus) and lime are important. Can be used with tall fescues at low rates. Minimum mowing height is 1.5 inches. Critical erosion areas may be mowed only once per year, if desired. This grass is usually seeded with a mixture of other grasses or legumes. Use several varieties of bluegrass together to ensure good stand survival. Bare ground rates are 120 lbs per acre. Overseed 1 to 1.5 lbs per 1,000 ft^2.
Sources	Readily available as seed and sod.



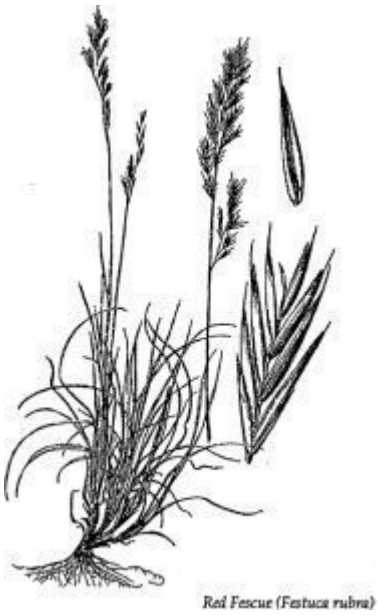
Kentucky Bluegrass (Poa pratense)

Perennial ryegrass (*Lolium perrenne*)	
Uses	Erosion control, soil improvement, lawns, pasture, and hay; newer varieties are excellent for high-traffic areas.
Description	Perennial ryegrasses are an excellent selection where rapid establishment is desired. Cool-season grass. Ryegrasses cross-pollinate freely, so “common ryegrass” may be a mixture of annual and perennial species. Certified seed of perennial ryegrass varieties is produced: Blaser, Palmer, Goalie, Fiesta II, Ranger, Regal, and Pennfine may be used in Virginia.
Adaptation	Throughout Virginia. Grows best on dark, rich soils in mild climates. Newer varieties have good drought tolerance but may require irrigation if under drought stress or heavy traffic. Will tolerate wet soils with good surface drainage.
Establishment	A firm, mellow surface over compact subsoils will provide good results. Seed in fall or spring. Perennial ryegrass may also be seeded in mid-August to early September. For turf, use a rate of 5 to 8 lbs per 1,000 ft^2. If seeded alone; lesser amounts are suitable in mixtures depending on the characteristics of the companion species. Generally, not seeded alone except on athletic fields subject to intensive use. Perennial ryegrass does best when used with bluegrass as 20 percent or less of the mixture. Ryegrasses germinate rapidly, which makes them particularly suited to disturbed-area stabilization and temporary seeding. Ryegrasses will tend to dominate stands in mixtures if the percentage is too high.
Sources	Readily available commercially. Take care to buy seed appropriate to the needs of the project.



Perennial Ryegrass (Lolium perrenne)

Fine fescues (red fescue, hard fescue, Chewings fescue)	
Uses	Excellent for shady, low-maintenance areas and north-facing slopes. May be used to stabilize waterways, slopes, banks, cuts, fills, and as a cover crop in orchards.
Description	Red fescue is a cool-season perennial that occurs in two forms: bunch type and creeping. Creeping red fescue forms a tight sod. The leaves of red fescue are narrow and wiry. Hard fescues are slow growing with excellent shade tolerance.
Adaptation	Shade-tolerant and somewhat drought-resistant once established. Grows well in sandy and acidic soils. Optimum pH range is 4.5 to 6.0. Prefers well-drained soils but requires adequate moisture for establishment. In areas of high temperature and humidity (such as southeastern Virginia), some fine fescues may turn brown or deteriorate during the summer. Newer varieties of hard fescue are more drought tolerant.
Establishment	Rarely seeded in pure stands. Seedbed preparation and fertility adjustments are usually dictated by the other grasses in the mixture. Red fescues may comprise 25 to 60 percent by weight of a seeding mixture. In shaded areas, red fescue may be the key grass in the mixture. Do not mow consistently below 1.5 inches.
Sources	Readily available commercially. New hard fescues may be in short supply.



Red Fescue (Festuca rubra)

Bermudagrass (*Cynodon dactylion*)	
Uses	Soil and water conservation, pasture, hay, silage, lawns, both high-maintenance and general-purpose turf, and stabilization of grassed waterways.
Description	A long-lived, warm-season perennial that spreads by stolons and rhizomes (runners and underground stems). Height of stems of common Bermudagrass may be 12 inches. The stems are short-jointed and the leaves flat and spreading. Common Bermudagrass may be established vegetatively with sprigs (sections of stems) or from seeds; however, this grass has the potential to develop into a weed problem because it spreads vigorously. Cold-tolerant hybrids are usually specified. These are traditionally established from sprigs or sod, but seed is now available.
Adaptation	Southern Piedmont and Coastal Plain in Virginia and some southern Appalachian ridges and valleys. Refer to Bermudagrass and Zoysiagrass Establishment (C-SSM-07) for regional adaptations of varieties. Makes its best growth when average daily temperatures are above 75 degrees Fahrenheit. Grows on a wide range of soils from heavy clays to deep sands. Optimum pH is 6.0 to 6.5. It is drought- resistant and salt-tolerant. Tolerates floods of short duration but will not thrive on waterlogged soils; does not persist under heavy shade. For rough areas, the varieties Midland (a forage hybrid) and Coastal are recommended. For fine-turf areas, Tufcote (a fine-leaved turf hybrid), Midiron, Tifway, and Vamont are used in Virginia.
Establishment	By sodding or planting sprigs. Plant sprigs (by hand or machine) when soil is warm in a well-prepared, moist seedbed. Extend one end of the sprig aboveground, and cover the other end with firmly packed soil.
Sources	Readily available as seed, sprigs, and sod.



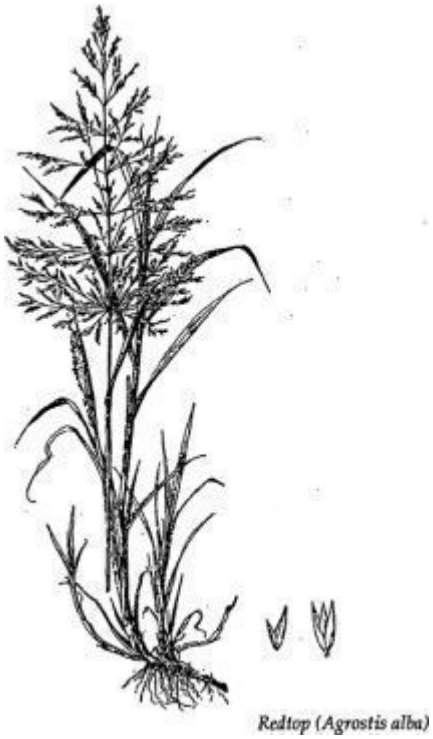
Bermudagrass (Cynodon dactylion)

Miscellaneous Erosion Control Grasses

Weeping lovegrass (*Eragrostis curvula*)	
Uses	Fast-growing cover for erosion control. In the northeast, weeping lovegrass acts as a summer annual. The normal life of 3 to 5 years may be foreshortened by low winter temperatures. May provide permanent cover on southern exposure.
Description	A rapid-growing, warm-season bunchgrass introduced from East Africa. The long, narrow leaves are numerous, very fine, and droop over to the ground, hence the name. Leaf height is rarely above 12 inches.
Adaptation	Prefers light-textured, well-drained soil; will thrive on soil of low fertility. Low winter temperatures may deplete stand.
Establishment	Easy to establish by seed; germinates rapidly and grows quickly. Lime and fertilizer needs are similar to those of tall fescue and ryegrass. Requires pH of 5.5 or higher. May be planted any time after danger of frost and throughout the summer. Very fine seed, commonly added to erosion control seed mixtures. Use of hydroseeders is successful if the seeding rate is increased to compensate for the lack of a firm seedbed. Normal seeding rates are 5 to 20 lbs per acre in mixes.
Sources	Readily available from large seed companies.



Weeping Lovegrass (Eragrostis curvula)

Redtop (*Agrostis alba*)		
Uses	Erosion control, pasture, companion grass in turf seedings and stabilizing ditch and channel banks, grassed waterways, and other disturbed areas.	 Redtop (*Agrostis alba*)
Description	A coarse, cool-season perennial grass with rhizomes (underground stems). Grows to 30 to 40 inches.	
Adaptation	Throughout Virginia; does better in the cool, humid areas. Will grow under a wide variety of soil and moisture conditions. Grows on very acid soils (pH 4.0 to 7.5) and poor, clay soils of low fertility. While drought-resistant, it is also a useful wetland grass.	
Establishment	Has very small seed and requires a compact seedbed. May be sown in early spring or late summer. Seldom seeded alone except as temporary turf. Adequate fertilization is essential on critical areas to obtain good cover rapidly. Mostly added to mixes, usually 2 to 3 lbs per acre. Redtop will disappear from a stand under frequent low mowing.	
Sources	Available from commercial sources.	

Flatpea (*Lathyrus sylvestris*)	
Uses	Flatpea is an erosion control plant that provides a thick mat of vegetative cover, fixes nitrogen in the soil, and can be maintained with a minimum of management. It is useful on road banks, dams, borrow area, gravel pits, surface mine spoil, and industrial waste areas. It is an ideal plant for stabilizing logging roads and utility rights-of-way because it will restrict the invasion of many woody species. It also provides good wildlife cover and food.
Description	A cool-season perennial legume. It will climb to a height of 6 to 7 feet if support is available, but the normal height is 2 to 3 feet.
Adaptation	Flatpea is adaptable to a wide variety of soil conditions. It is drought-tolerant; cold-hardy; and does well on low-fertility sites such as sands, gravels, and soils from acidic sandstones. It is not adapted to wet sites, but it will grow on somewhat poorly drained soils. It will tolerate minor shade and a minor degree of flooding. The optimum pH range is from 6.0 to 6.5. The only available variety is Lathco, developed by the USDA Soil Conservation Service.
Establishment	Use only inoculated seed. Scarify the seedbed if possible. The seed is normally drilled or band seeded, but on rough sites or steep slopes, it can be broadcast and then worked into the soil by light dragging. Where possible, install a light application of mulch, properly anchored, to ensure a good stand. Lime application is essential if the soil pH is below 5.0. Fertilize according to a soil test or apply 400 lbs per acre of 10-20-10 fertilizer. Work lime and fertilizer into soil when preparing the seedbed. For a primary stand, use a seeding rate of 30 to 40 lbs in a mixture with 8 to 10 lbs of perennial ryegrass or 10 to 15 lbs of tall fescue. Flatpea is slow to germinate, so plant grasses to provide quick cover. Early spring seedings in April or May are best; June seedings are less desirable. Grass seedings may be overseeded with flatpea from November through March. Flatpea is usually not winter-hardy if seeded in mid or late summer; therefore, dormant seedings are recommended. Mulch with straw at a minimum rate of 1.5 tons per acre on all critical sites and anchor. Little management is required. Remove woody vegetation if the site is invaded. Mowing is acceptable once the stand is established. Mow after full bloom at a 6-inch minimum height.



Flatpea (*Lathyrus sylvestris*)

Sources	Lathco is commercially available.

White clover (*Trifolium repens*)	
Uses	Common white clover is used mostly for pastures. Ladino clover, a giant white clover, is also used for hay and silage in mixtures with a grass. The thick growing, spreading characteristics of the common type make it ideal for erosion control.
Description	A cool-season perennial legume. The common type has a prostrate type of growth, while the Ladino is more upright. Both spread by stolons (horizontal branches along ground) and by roots at the nodes. Representative common varieties used in Virginia are Tillman, common, and white Dutch. Ladino is the only cultivar for the large type.
Adaptation	Thrives in cool climates and on moist, rich soils with full sun. Will not tolerate extremes of cold or drought. Where soil moisture is not adequate, Ladino is short-lived. Optimum soil pH is 6.5, but it will grow in a range of 5.0 to 7.5. Common white clover volunteers readily in bluegrass mixtures where moderate to high fertility is maintained. Stands are persistent.
Establishment	Ladino clover requires inoculation, fertilizing, and liming for successful growth. Phosphorus and potash are the key fertilizer elements required. Ladino makes a good companion crop with grasses such as orchardgrass, bromegrass, and tall fescue. These grasses will normally crowd out the Ladino after 2 to 3 years. Plant seed (drilled or broadcast) at shallow depths, and a firm seedbed is desirable.
Sources	Available commercially.



White Clover (Trifolium repens)

C-SSM-11 Mulching

1.0 Definition

Mulching is the application of a protective blanket of straw or other plant residues/materials to the soil surface during the establishment of temporary and permanent seeding.

2.0 Purpose and Applicability of Best Management Practice

The purposes of mulching are:

1. To prevent erosion by protecting the soil surface from raindrop impact and reducing the velocity of overland water flow.
2. To foster the growth of vegetation by increasing available moisture levels and providing insulation against extreme heat and cold.

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination.



Source: James Madison University

Mulching applies in the following conditions:

1. Mulch areas that have been permanently seeded (see Permanent Seeding, BMP C-SSM-10) immediately following seeding.
2. Mulch areas that cannot be seeded because of the season to provide some protection to the soil surface. Use an organic mulch, and then seed the area as soon as weather or seasonal conditions permit. Do not use fiber mulch alone for this practice, as at normal application rates, it does not provide adequate protection.
3. Mulch may be used together with plantings of trees, shrubs, or certain ground covers that do not provide adequate soil stabilization by themselves.
4. Use mulch in conjunction with temporary seeding operations as specified in Temporary Seeding (BMP C-SSM-09).

3.0 Planning and Considerations

Mulches are applied to the soil surface to conserve a desirable soil property or to promote plant growth. A surface mulch is one of the most effective means of controlling runoff and erosion on disturbed land.

Organic mulch materials, such as straw, wood chips, bark, and fiber mulch, have been found to be the most effective.

Do not use chemical soil stabilizers or soil binders alone for mulch. These materials are useful to bind organic mulches together to prevent displacement.

Multiple manufactured Soil Stabilization Blankets and Matting (BMP C-SSM-05) have been developed for erosion control in recent years. Some of these products can be used as mulches, particularly in critical areas such as waterways. Soil stabilization blankets may be used to hold other mulches to the soil surface.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season, and economics. It is especially important to mulch liberally in midsummer, before winter, and on cut slopes and southern slope exposures.



Source: Iowa DNR

Table C-SSM-11-1 Design Considerations for Organic Mulches

Mulch	Notes on Proper Use
Straw	Straw is most used in conjunction with seeding. Use straw that comes from wheat or oats (free of troublesome weed seeds) and spread by hand or machine. Anchor down straw by an acceptable method, as the straw can be windblown.
Hay	Hay may be used in lieu of straw where volunteer germination will not present a problem and may be spread by hand or machine. Anchor or tack down hay that can be windblown.
Corn Stalks	Shred corn stalks into 4- to 6-inch lengths. Stalks decompose slowly and are resistant to displacement.
Wood Chips	Wood chips are suitable for areas that will not be closely mowed and around ornamental plantings. Place wood chips at 2 to 7 inches of depth. Chips decompose slowly and do not require tacking. Treat wood chips with 12 pounds of nitrogen per ton to prevent nutrient deficiency in plants; however, wood chips can be a very inexpensive mulch if obtained from trees cleared on the site.
Bark Chips, Shredded Bark	Bark chips and shredded bark are by-products of timber processing used in landscaped plantings. Bark is also a suitable mulch for areas planted with grasses and not closely mowed. Bark may be applied by hand or mechanically and is not usually toxic to grasses or legumes; additional nitrogen fertilizer is not required. Place bark at a rate of 35 cubic yards per acre.

Table C-SSM-11-1 Design Considerations for Organic Mulches	
Mulch	**Notes on Proper Use**
Fiber Mulch	Fiber mulch is used in hydroseeding operations and applied as part of the slurry. It creates the best seed-soil contact when applied atop (as a separate operation) newly seeded areas. These fibers do not require tacking, although tacking agents or binders are sometimes used in conjunction with the application of fiber mulch. This form of mulch does not sufficiently protect highly erodible soils. Additionally, fiber mulch is not adequate when used during the dry summer months or when used for late fall mulch cover. Use straw mulch during these periods. Fiber mulch may be used to tack (anchor) straw mulch. This treatment is well suited for steep slopes, critical areas, and areas susceptible to displacement. Apply fiber at a maximum of rate 2,000 pounds per acre.
Other Organic Materials	There are other organic materials that make excellent mulches but are only available locally or seasonally. Creative use of these materials can reduce costs.
Chemical Mulches and Soil Binders	A wide range of synthetic, spray-on materials is marketed to stabilize and protect the soil surface. These include emulsions or dispersions of vinyl compounds, rubber, or other substances mixed with water and applied to the soil. These materials may be used alone in some cases as temporary stabilizers or in conjunction with fiber mulches or straw. When used alone, chemical mulches are not capable of insulating the soil or retaining soil moisture like organic mulches and do not have good characteristics for an aid in seeding establishment. This soil protection is also easily damaged by traffic. Application of these mulches is usually more expensive than organic mulching, and the mulches decompose in 60 to 90 days. Check labels on chemical mulches and binders for environmental concerns. Take precautions to avoid damage to fish, wildlife, and water resources.

Table C-SSM-11-1 Design Considerations for Organic Mulches	
Mulch	**Notes on Proper Use**
Netting, Blankets, and Mats	Netting is very effective at holding mulch in place on waterways and slopes before grass can be established. Field experience has shown that plastic netting, when used alone, does not retain soil moisture or modify soil temperature. In some cases, netting may stabilize the soil surface while grasses are establishing but is primarily used in grassed waterways and on slopes to hold straw or similar mulch in place. Jute mesh and other soil stabilization blankets are good choices for mulching on difficult slopes and in minor drainage swales. Most of the soil stabilization mattings (used to create a permanent matrix for root growth within the soil) must be mulched to properly stabilize an area. Notably, some manufacturers have recently developed permanent mattings that include self-contained, temporary mulching materials; however, these measures will have to meet the requirements noted in Soil Stabilization Blankets and Matting (BMP C-SSM-05) before they can be recommended for use on steep slopes and in channel flow situations. The most critical aspect of installing blankets and mats is obtaining firm, continuous contact between the material and the soil. Without such contact, the material may fail and allow erosion to occur. It is important to use an adequate number of staples and make sure the material is installed properly to maximize soil protection. These products are discussed in more detail in Soil Stabilization Blankets and Matting (BMP C-SSM-05).

4.0 Stormwater Performance Summary

4.1 MS-1: Stabilization

Permanent or temporary soil stabilization should be applied to denuded areas within 7 days after final grade is reached on any portion of the site. Temporary soil stabilization should be applied within 7 days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization should be applied to areas to be left dormant for more than 1 year.

Erosion Control Efficiency: Moderate

Sediment Removal Efficiency: Low

5.0 Design Criteria

Be aware of the slope, soil, and water availability in the specific location proposed for the use of mulching. Consult with the design engineer before making any assumptions/modifications to the specifications in the approved plan.

6.0 Construction Specifications

Table C-SSM-11-2 Construction Specifications for Organic Mulches	
Parameter	**Instructions**
Criteria	Organic mulches may be used in any area where mulch is required, subject to the restrictions noted in Table C-SSM-11-5. Organic mulches are effective where they can be tacked securely to the surface of the soil.
Materials	Select materials based on site requirements, availability of materials, and availability of labor and equipment. Table C-SSM-11-5 lists the most used organic mulches. Other materials, such as peanut hulls and cotton burs, may be used with the permission of the certified plan reviewer.
Prior to Mulching	Before mulching, complete the required grading and install necessary sediment control practices. Apply lime and fertilizer seed and complete surface roughening as needed before mulching except in the following circumstances. Seed is applied as part of a hydroseeder slurry containing wood fiber mulch. A hydroseeder slurry is applied over straw.
Application	Spread mulch materials uniformly by hand or machine. When spreading straw mulch by hand, divide the area to be mulched into approximately 1,000-square-foot sections and place 70 to 90 pounds (1.5 to 2 bales) of straw in each section to facilitate uniform distribution. After spreading mulch, ensure no more than 25% of the ground is visible. When using a hydroseeder, confirm the use of a green dye to ensure the seed is spread uniformly across the ground.

Straw mulch must be anchored immediately after spreading to prevent displacement. Other organic mulches listed in Table C-SSM-11-5 do not require anchoring. Use the following methods of anchoring straw.

Table C-SSM-11-3 Mulch Anchoring Specifications	
Method	**Notes on Proper Use**
Mulch Anchoring Tool	A tractor-drawn implement designed to punch mulch into the soil surface, often referred to as a Krimper or Krimper tool. This method provides good erosion control with straw. It is limited to use on slopes no steeper than 3H:1V, where equipment can operate safely. Operate machinery along the contour.
Fiber Mulch	A very common practice with widespread use today. Apply fiber mulch by means of a hydroseeder at a rate of 500 to 750 pounds per acre atop straw mulch or hay. Fiber mulch has an added benefit of providing additional mulch to the newly seeded area.
Mulch Nettings	Lightweight plastic, cotton, or paper nets may be stapled over the mulch according to manufacturer's recommendations.

Table C-SSM-11-3 Mulch Anchoring Specifications	
Method	**Notes on Proper Use**
Peg and Twine	Because it is labor-intensive, this method is feasible only in small areas where other methods cannot be used. Drive 8- to 10-inch wooden pegs 3 inches into the soil surface every 4 feet in all directions. Stakes may be driven before or after straw is spread. Secure mulch by stretching twine between pegs in a crisscross-within-a square pattern. Turn twine two or more times around each peg.
Vegetation	Rye (grain) may be used to anchor the mulch in fall plantings and German millet in the spring. Broadcast at 15 pounds per acre before applying mulch.
Liquid Mulch Binders	Ensure application of liquid mulch binders and tackifiers is heaviest at edges of mulched areas and at crests of ridges and banks to prevent displacement. Uniformly apply the binder to the remainder of the area. Binders may be applied after mulch is spread or may be sprayed into the mulch as it is being blown onto the soil. Straw and binder together are noted as the most effective method. The following types of binders may be used: **Synthetic Binders:** Formulated binders or organically formulated products may be used as recommended by the manufacturer to anchor mulch. **Asphalt:** Any type of asphalt thin enough to be blown from spray equipment is satisfactory. Use rapid-curing (RC-70, RC-250, RC-800), medium-curing (MC-250, MC- 800), and emulsified asphalt (SS-1, CSS-1, CMS-2, MS-2, RS-1, RS-2, CRS-1, and CRS-2). Apply asphalt at 0.1 gallon per square yard (10 gal./1000 sq. ft. or 430 gal./acre). Do not use heavier applications, as it may cause the straw to "perch" over rills. All asphalt designations are from the Asphalt Institute Specifications. In traffic areas, uncured asphalt can be picked up on shoes and cause damage to the indoors of buildings/houses. Use RS or CRS types to minimize any potential risk. *Note: This method is not used as commonly as it once was. The development of hydraulic seeding equipment has encouraged the industry to turn to synthetic or organically based binders and tackifiers. When this method is used, environmental concerns should be addressed to ensure that petroleum-based products do not enter water supplies. Avoid applications into waterways or channels.

Table C-SSM-11-4 Chemical Mulch Specifications	
Mulch Type	**Notes on Proper Use**
Chemical Mulches	Chemical mulches* may be used alone only in the following situations: Where no other mulching material is available. In conjunction with temporary seeding when mulch is not required for that practice. From March 15 to May 1 and August 15 to September 30, provided they are used on areas with slopes no steeper than 4H:1V that have been roughened in accordance with Surface Roughening (C-SSM-03). If rill erosion occurs, another mulch material will be applied immediately. *Note: Chemical mulches may be used to bind other mulches or with fiber mulch in a hydroseeded slurry at any time. Manufacturer's recommendations for application of chemical mulches will be followed.

Table C-SSM-11-5 Organic Mulch Materials and Application Rates			
Mulches	**Rates**		**Notes**
	Per Acre	**Per 1,000 ft²**	
Straw or Hay	1.5 to 2 tons	70 to 90 lbs.	Free from weeds and coarse matter. Must be anchored. Spread with mulch blower or by hand. Use a minimum of 2 tons per acre for winter cover.
Fiber Mulch	1,500 lbs.	35 lbs.	Do not use as mulch for winter cover or during hot, dry periods. Apply as slurry. When fiber mulch is the only available mulch during periods when straw should be used, apply at a minimum rate of 2000 lbs./acre or 45 lbs./1,000 ft².
Corn Stalks	4 to 6 tons	185 to 275 lbs.	Cut or shredded in 4- to 6-inch lengths. Air-dried. Do not use in fine turf areas. Apply with mulch blower or by hand.
Wood Chips	4 to 6 tons	185 to 275 lbs.	Free of coarse matter. Air-dried. Treat with 12 lbs. nitrogen per ton. Do not use in fine turf areas. Apply with mulch blower, chip handler, or by hand.
Bark Chips or Shredded Bark	50 to 70 cy	1 to 2 cy	Free of coarse matter. Air-dried. Do not use in fine turf areas. Apply with mulch blower, chip handler, or by hand.

Source: Va. DSWC

7.0 Operations and Maintenance Considerations

Inspect all mulches and soil coverings periodically and after rainstorm events to check for erosion. Where erosion is observed in mulched areas, apply additional mulch. Inspect nets and mats after rainstorms for

dislocation or failure. If washouts or breakage occur, reinstall netting or matting as necessary after repairing damage to the slope or ditch. Inspect mulches until grasses are firmly established.

Where mulch is used in conjunction with ornamental plantings, inspect periodically throughout the year (approximately every 3 months) to determine if mulch is maintaining coverage of the soil surface; repair as needed.

8.0 References

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