APPENDIX C
VEGETATED EMERGENCY SPILLWAY

VERSION 1.0
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[NOTE: Could use a better photo more clearly showing the emergency spillway in the context of the dam.]

SECTION C-1: DESCRIPTION OF PRACTICE

A vegetated emergency spillway is an open channel, usually trapezoidal in cross-section, that is constructed beside an embankment. It consists of an *inlet channel*, a *control section*, and an *exit channel*, and is lined with erosion-resistant vegetation. The purpose of a vegetated emergency spillway is to convey flows that are greater than the principal spillway's design discharge at a non-erosive velocity to an adequate receiving channel.

SECTION C-2: PERFORMANCE CRITERIA

Not applicable.

SECTION C-3: PRACTICE APPLICATIONS AND FEASIBILITY

A vegetated emergency spillway is appropriate to use when the required maximum design flood volume may exceed the capacity of the principal spillway system. A vegetated emergency spillway may also be used as a safety feature to pass flood flows when or if the principal spillway becomes clogged.

SECTION C-4: ENVIRONMENTAL AND COMMUNITY CONSIDERATIONS

The adjacent topography (steepness of the abutments), the existing or proposed land use, and other factors (such as a roadway over the embankment) influence the design and construction of a vegetated emergency spillway.

Vegetated emergency spillways must be built in existing ground or "cut. Even though an emergency spillway helps to extend the life expectancy of an impoundment and lowers the associated downstream hazard conditions, it should *not* be located on any portion of the embankment fill. Therefore, additional land disturbance beside the embankment must be accounted for during the planning stages of a project. Sometimes, an emergency spillway may not be practical due to this or other considerations.

If site topography or other constraints preclude the use of a vegetated emergency spillway in "cut," the principal spillway can be oversized to pass the additional flows or an *armored* emergency spillway may be provided. A cost analysis may be helpful to aid in the selection of the spillway type. If armoring is chosen, then riprap, concrete or any other permanent, nonerodible surface may be used. Note, however, that **an armored emergency spillway over the top of an embankment should be designed by a qualified professional**.

Vegetated emergency spillways should be used only where the soils and topography will permit safe discharge of the peak flow at a point downstream from the embankment and at a velocity that will not cause appreciable erosion. Additional flood storage in the reservoir may be provided to reduce the design flow or the frequency with which the spillway is used.

SECTION C-5: DESIGN APPLICATIONS AND VARIATIONS

(?)

SECTION C-6: SIZING AND TESTING GUIDELINES

Not applicable.

SECTION C-7: DESIGN CRITERIA

A vegetated emergency spillway is designed to convey a pre-determined design flood discharge without excessive velocities and without overtopping the embankment. **The maximum design water surface elevation through the emergency spillway should be at least 1 foot lower than the settled top of the embankment**. **In general, it is recommended that a vegetated emergency spillway be designed to operate during the 100-year frequency storm.**

<u>Layout</u>

Vegetated spillways should be constructed in undisturbed earth in the abutments at one or both ends of an earthen embankment or over a topographic saddle anywhere on the periphery of the basin. **The channel should be excavated into undisturbed earth or rock and the water surface, under maximum design flood discharge, should be confined by undisturbed earth or rock**.

Excavated spillways consist of three elements: (1) an *inlet channel*, (2) a *level section*, and(3) an *exit channel* (see **Figure C-1**). Flow enters the spillway through the inlet channel. The depth of flow, H_p, located upstream from the level section, is controlled in the level section and then discharged through the exit channel. Flow in the inlet channel is *sub-critical*. Flow in the exit channel can be either *critical* or *supercritical*. **The control section is, therefore, the point on the spillway where the flow passes through critical depth**. It is recommended that the control section be installed close to the intersection of the earthen embankment and the emergency spillway centerlines.

The topography must be carefully considered when constructing an emergency spillway. The alignment of the exit channel must be straight to a point far enough below the embankment to insure that any flow escaping the exit channel cannot damage the embankment. This may result in additional clearing and/or grading requirements beside the abutments, property line, etc.

Figure C-1 shows profiles along the centerline of a typical vegetated spillway. To reduce losses through the inlet channel, the cross-sectional area of flow in the inlet channel should be large in comparison to the flow area at the control section. Where the depth of the channel changes to provide for the increased flow area, the bottom width should be altered gradually to avoid abrupt changes in the shape of the sloping channel banks.

The exit channel must have an adequate slope to discharge the peak flow within the channel. However, the slope must be no greater than that which will produce maximum permissible velocities for the soil type or the planned grass cover.

Soil Types and Vegetative Cover

The type of soil and vegetative cover used in an emergency spillway can be used to establish the spillway design dimensions. Soil types are classified as *erosion resistant* and *easily erodible*. ***Erosion resistant soils*** are those with a high clay content and high plasticity. Typical soil textures for erosion resistant soils are silty clay, sandy clay, and clay. ***Easily erodible soils*** are those with a high content of fine sand or silt, and a low plasticity or non-plastic. Typical soil textures for easily erodible soils are fine sand, silt, sandy loam, and silty loam. **Table C-1** provides permissible velocities for a vegetated spillway based on its soil type, vegetated cover, and exit channel slope. The maximum permissible velocity may be increased by 25% when the anticipated average use is less than once in 10 years.

Table C-1. Permissible Velocities for Vegetated Spillways [1]

Vegetative Cover	Permissible Velocity [2] (ft./sec.)			
	Erosion Resistant Soils [3]		Easy Erodible Soils [4]	
	Slope of Exit Channel		Slope of Exit Channel	
	0 - 5%	5 – 10%	0 – 5%	5 – 10%
Bermuda Grass Bahiagrass	8	7	6	5
Buffalograss Kentucky Bluegrass Smooth Bromegrass Tall Fescue Reed Canary Grass	7	6	5	4
Sod Forming Grass-Legume Mixtures	5	4	4	3
Lespedeza Weeping Lovegrass Yellow Bluestem Native Grass Mixtures	3.5	3.5	2.5	2.5

[1] USDA-NRCS TP-61
[2] Increase values 25 percent when the anticipated average use of the spillway is not more frequent than once in 10 years.
[3] Those with a high clay content and high plasticity. Typical soil textures are silty clay, sandy clay, and clay
[4] Those with a high content of fine sand or silt and lower plasticity or non-plastic. Typical soil textures are fine sand, silt, sandy loam, and silty loam.

Source: USDA-NRCS Engineering Field Manual

The *type* and *length of vegetative cover* affect the design of a vegetated spillway. Vegetation provides a *degree of retardance* to the flow through the spillway. **Table C-2** gives retardance values for various heights of vegetative cover. Retardance for a given spillway will depend mostly upon the *height* and *density* of the cover chosen. Generally, after the cover is selected, "retardance with a good, uncut condition" should be used to find the capacity. Since a condition offering less protection and less retardance exists during the establishment period and after mowing, a lower degree of retardance should be used when designing for stability. Refer to the sample exercises for the design of vegetated spillways found in **Chapter 13** of the *Virginia Stormwater Management Handbook* (2009). **[NOTE: Be sure this chapter reference is correct.]**

Table C-2. Retardance Classifications for Vegetative Channel Linings

Retardance	Vegetative Cover	Stand	Condition
B	Tall Fescue	Good	Unmowed – 18”
	Sericea Lespedeza	Good	Unmowed – 18”
	Grass-Legume Mixture	Good	Unmowed – 20”
	Small Grains, Mature	Good	Uncut – 19”
	Bermuda Grass	Good	Tall – 12”
	Reed Canary Grass	Good	Mowed – 14”
C	Bermuda Grass	Good	Mowed – 6”
	Redtop	Good	Headed – 18”
	Grass-Legume Mixture – Summer	Good	Unmowed – 7”
	Kentucky Bluegrass	Good	Headed – 9”
	Small Grains, Mixture	Poor	Uncut – 19”
	Tall Fescue	Good	Mowed – 6”
D	Bermuda Grass	Good	Mowed – 2.5”
	Red Fescue	Good	Headed – 15”
	Grass-Legume Mixture – Spring and Fall	Good	Mowed – 2”
	Sericea Lespedeza	Good	Mowed – 2”

Source: USDA-NRCS

Hydraulic Design

The hydraulic design of earthen spillways can be simplified if the effects of *spillway storage* are ignored. Stormwater facilities designed for compliance with state or local stormwater management regulations are typically small, resulting in minimal storage effects on the flood routing.

Two design calculation procedures are presented in **Chapters 16 and 17** of the *Virginia Stormwater Management Handbook* (2009) **[NOTE: Be sure these chapter references are correct.]**. The first (Procedure 1) is a conservative design procedure which is also found in the *Virginia Erosion & Sediment Control Handbook* (VESCH) 1992 edition, (Std., & Spec. 3.14). This procedure is typically acceptable for stormwater management basins. The second method (Procedure 2) utilizes the roughness, or retardance, and durability of the vegetation and soils within the vegetated spillway. This second design is appropriate for larger or regional stormwater facilities where the construction inspection and permanent maintenance are more readily enforced. These larger facilities typically control relatively large watersheds and are located such that the stability of the emergency spillway is essential to safeguard downstream features.

If the inflow is known (from the post-developed condition hydrology) and either the desired maximum water surface elevation, or the approximate width of the proposed emergency spillway (established by the embankment geometry and the adjacent topography), then the relationship between H_p, the depth of flow through the emergency spillway, and b, the emergency spillway bottom width, can be established using design Procedure 1 (**Chapters 16 and 17**) **[NOTE: Be sure these chapter references are correct.]** and **Table 16-12**. **[NOTE: This note refers to a table on page 5-77 in the "Engineering Calculations" Chapter of the 1999 Virginia Stormwater Management Handbook. Be sure to update this reference to the new Table numbers in the revised Handbook (2009).]**

If the required discharge capacity, Q, permissible velocity, V (see **Table C-1**), degree of retardance, C (see **Table C-2**), and the natural slope of the exit channel, s_o , are known, then the bottom width, b, of the level and exit sections and the depth of flow, H_p , may be computed using design Procedure 2 (**Chapters 16 and 17**) and **Table 16-13**. However, Tables 16-13(a-d) is not appropriate for bottom widths less than 8 feet. **[NOTE: This note refers to the tables on page 5-78 through 5-80 in the "Engineering Calculations" Chapter of the 1999 Virginia Stormwater Management Handbook. Be sure to update this reference to the new Table numbers in the revised Handbook (2009).]**

The hydraulic design of a vegetated emergency spillway should comply with the following:

1. The maximum permissible velocity for vegetated spillways should be selected using **Table C-1**.

2. The slope range of the exit channel provided in **Table 16-11 (Chapter 16)** **[NOTE: This note refers to a table on page 5-62 in the "Engineering Calculations" Chapter of the 1999 Virginia Stormwater Management Handbook. Be sure to update this reference to the new Table numbers in the revised Handbook (2009).]**, is a minimum slope range needed to insure ***supercritical*** flow in the exit channel.

3. Spillway side slopes should be no steeper than 3H:1V unless the spillway is excavated into rock.

4. For a given H_p , a decrease in the exit slope from s_o, as given in **Table 16-11 (Chapter 16)**, decreases the spillway discharge, but increasing the exit slope from s_o does not increase discharge.

5. The exit channel should have a straight alignment and grade and, at a minimum, the same cross-section as the control section.

6. The inlet channel should have a straight alignment and grade.

7. The selected bottom width of the spillway should not exceed 35 times the design depth of flow. Where this ratio of bottom width to depth is exceeded, the spillway is likely to be damaged by meandering flow and accumulated debris. Whenever the required bottom width of the spillway is excessive, consideration should be given to the use of a spillway at each end of the dam. The two spillways do not need to be of equal width if their total capacity meets design requirements. If the required discharge capacity exceeds the ranges shown in the referenced tables, or topographic conditions preclude the construction of the exit channel

bottom using a slope that falls within the designated ranges, alternate design procedures should be used.

8. Vegetated emergency spillways should be designed for use with the 100-year frequency storm or greater.

SECTION C-8: REGIONAL AND CLIMATE DESIGN VARIATIONS

Not applicable.

SECTION C-9: TYPICAL GRAPHICAL DETAILS

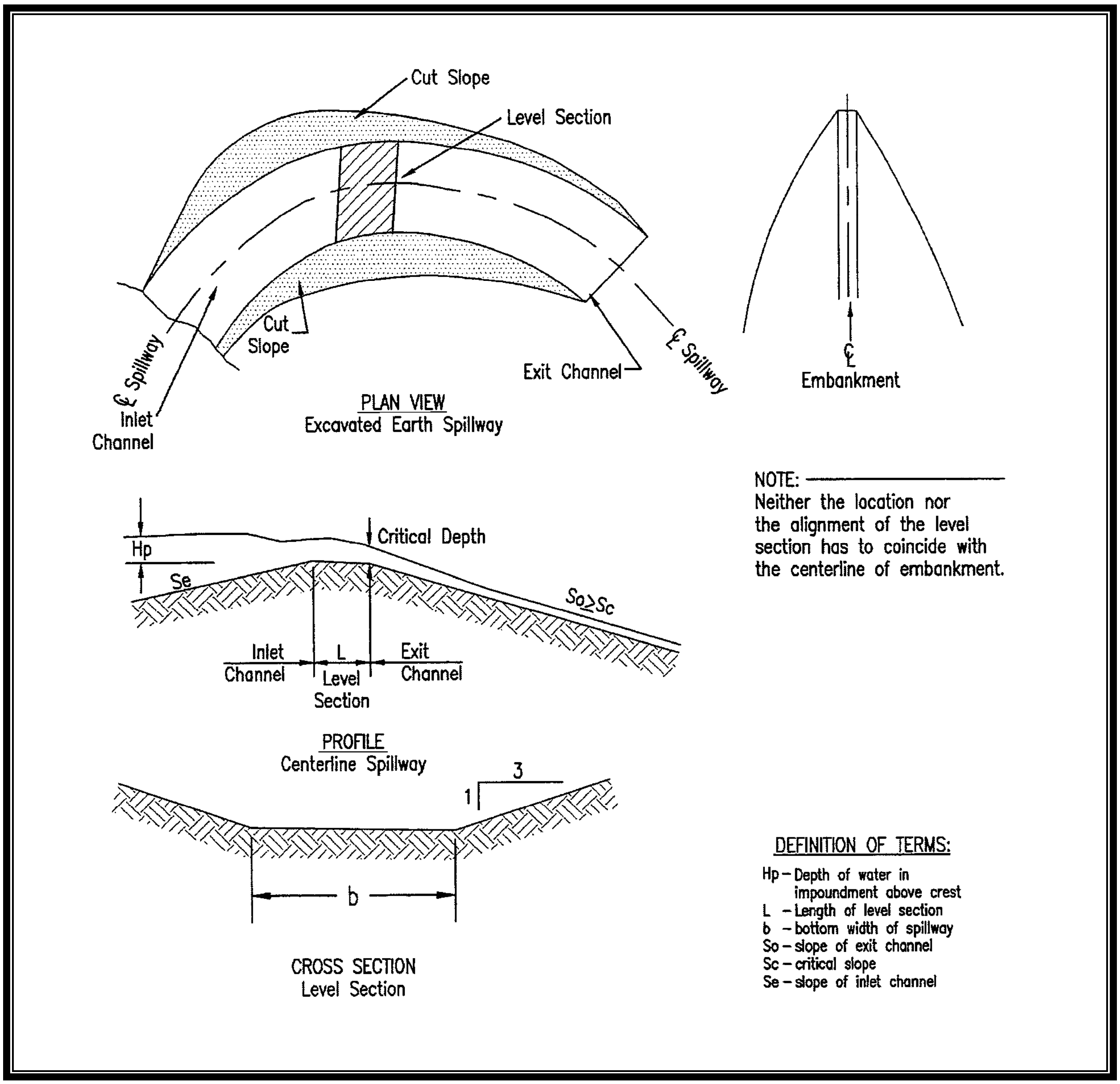

Figure C-1. Typical Plan and Profiles Along the Centerline of an Earth Spillway

Figure C-2. Emergency Spillway Draining into a Concrete Channel

[NOTE: Not sure how appropriate this photo is, since this Appendix focuses on *vegetated* emergency spillways and does not address this type of design. Perhaps we should delete this photo?]

SECTION C-10: MATERIAL SPECIFICATIONS

Not applicable. (?)

SECTION C-11: CONSTRUCTION SEQUENCE AND INSPECTION

Overall, widely acceptable construction standards and specifications for a vegetated emergency spillway on an embankment, such as those developed by the USDA-Natural Resource Conservation Service or the U. S. Army Corps of Engineers, should be followed. Further guidance can be found in the USDA-NRCS *Engineering Field Manual* and the *National Engineering Handbook*. Specifications for all earthwork and any other related work should conform to the methods and procedures that apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

Installation of a vegetated emergency spillway consists of the following: (a) excavating the proper bottom width and side slopes according to the approved plan; (b) backfilling with 12 inches of topsoil (minimum); and (c) stabilizing the area following the *Virginia Erosion and Sediment Control Handbook (*VESCH, 1992).

SECTION C-12: OPERATION AND MAINTENANCE

The following maintenance and inspection guidelines are recommendations. The engineer must decide if additional criteria are needed based upon the size and scope of the facility.

1. Vegetated emergency spillway channels should be mowed concurrently with the embankment and should not be cut to less than 6 to 8 inches in height.

2. The emergency spillway approach and discharge channels should be cleared of brush and other woody growth periodically.

3. After any flow has passed through the emergency spillway, the spillway crest (control section) and exit channel should be inspected for erosion. All eroded areas should be repaired and stabilized.

SECTION C-13: REFERENCES

USDA Natural Resource Conservation Service. *Engineering Field Manual*.

USDA Natural Resource Conservation Service. *National Engineering Handbook*.

USDA Natural Resource Conservation Service. *Technical Release No. 60: Earth Dams and Reservoirs*.

U. S. Department of the Interior. *Design of Small Dams*. 1987.

Virginia Erosion and Sediment Control Handbook (VESCH), 1992.