APPENDIX B – DESIGN CRITERIA FOR TEMPORARY WATER QUALITY BMPS USED DURING CONSTRUCTION

This Appendix presents design criteria and example calculations for the following temporary water quality BMPs for use on SCDOT projects during the construction process:

Section B.1 Erosion Prevention BMPs

- Section B.1.1 Rolled Erosion Control Products (RECPs)
- Section B.1.2 Riprap for Channel Stabilization
- Section B.1.3 Outlet Protection

Section B.2 Temporary Sediment Control BMPs

When selecting a Standard SCDOT Temporary Sediment Control BMP with an applicable SCDOT Supplemental Technical Specification, SCDOT Standard Drawing, or BMPs included on an applicable SCDOT QPL list, the BMP meets the 80% TSS trapping requirement and the maintenance requirement is already established.

- Section B.2.1 Sediment Dam
- Section B.2.2 Silt Fence
- Section B.2.3 Rock Ditch Check
- Section B.2.4 Sediment Dam for Pipe Inlet

Section B.3 Stormwater Runoff and Ground Control Measures

- Section B.3.1 Pipe Slope Drains
- Section B.3.2 Runoff Diversion Measures
- Section B.3.3 Level Spreaders for Outlet Pipe Discharge

B.1 EROSION PREVENTION BMPS

B.1.1 Rolled Erosion Control Products (RECPs) Design for Conveyance Channels

When designing a permanent conveyance with a grassed or vegetative lining, the design should address the bare condition prior to vegetation being established. A temporary erosion control blanket (ECB) or permanent turf reinforcement mat (TRM) may be applied to protect the conveyance during this period. It is important to use **both** the shear stress and the permissible velocity methods to determine the level of protection that is required.

The design of ECBs and TRMs is based on the anticipated shear stresses and maximum flow velocities the RECP will encounter. Once the design shear stresses and maximum flow velocities are known, an appropriate ECB or TRM may be specified.

B.1.1.1 Maximum Shear Stress

The governing equation for maximum channel shear stress is:

$$\tau = \gamma \ d_n \ S$$

Where:

τ	=	maximum shear stress (lbs/ft^2)
γ	=	unit weight of water = 62.4 lbs/ft^3
d_n	=	maximum normal channel flow depth (ft)
S	=	channel bed slope (ft/ft)

The following variables are required to determine maximum shear stress in a channel:

- Design peak flow rate in cubic feet per second (cfs) for the 10-year, 24-hour storm;
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape;
- Channel bed slope; and
- Maximum normal channel flow depth (feet) based on peak flow rate and channel dimensions. The maximum flow depth expected should be calculated from the following conditions:
    - RECP with no vegetation,
    - RECP with maintained vegetation, and
    - RECP with non-maintained vegetation.

B.1.1.2 Maximum Velocity

The governing equation for maximum velocity is Manning's Equation:

$$V = \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where :

- ***V*** = Maximum velocity (ft/sec)
- ***n*** = Manning's channel roughness coefficient
- ***R*** = Hydraulic radius of the flow based on d_n (ft)
- ***S*** = Channel bed slope (ft/ft)

The following variables are required to determine the maximum velocity in a channel for a 10-year, 24-hour storm event:

- Design peak flow rate value in cfs for the 10-year, 24-hour storm;
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape;
- Channel bed slope;
- Manning's channel roughness coefficient (n) of the TRM or ECB or final vegetation; and
- Normal channel flow depth (d_n) based on peak flow rate, channel dimensions and Manning's "n" value.

<u>Example Calculations for Design of a RECP:</u>

<u>Given:</u>

- Peak flow rate carried by channel: 80 cfs
- Bottom width of design channel, B_o: 4 feet
- Manning's n of RECP: 0.025
- Side slopes of design channel: 2:1
- Channel bed slope (ft/ft): 0.01

<u>Find:</u> A Temporary ECB that will meet the maximum shear stress requirements with no establishment of vegetation.

Solution:

1. Calculate the normal depth of flow in the channel (d_n) using Manning's Equation.
2. Solve for $AR^{2/3}$:

$$AR^{2/3} = \frac{Q * n}{B_o^{8/3} * S^{1/2}} = \frac{80 * 0.025}{4^{8/3} * 0.01^{1/2}} = 0.5$$

Where:

A = *Cross sectional Area of flow*

R = *Hydraulic radius*

Q = *Flow Rate*

S = *Slope of the channel*

B_o= *Bottom width of the channel*

n = *Manning's channel roughness coefficient*

3. For Side Slopes 2:1, Figure B-1 (located at the end of this Appendix) reads:

d_n/B_o = 0.43

4. Solve for d_n = (0.43 * B_o) = (0.43 * 4) = 1.72 feet
5. The maximum shear stress is then calculated:

$\tau = \gamma\, d_n\, S$ = (62.4* 1.72 * .01) = **1.1 (lb / ft^2)**

6. Select an appropriate Temporary ECB for the design conditions: Select an ECB that can handle a maximum shear stress of **1.1 pounds/square foot**.

B.1.2 Riprap for Channel Stabilization

Riprap for channel stabilization should be designed to be stable for the condition of bank-full flow in the reach of channel being stabilized. The Federal Highway Administration (FHWA) design procedure as presented in this section should be used. This method establishes the stability of the rock material relative to the forces exerted upon it.

Refer to Section 804 for Riprap and Slope Protection in the *SCDOT Specifications for Highway Construction*, 2007 Edition, or latest revision.

B.1.2.1 General Design Criteria

- Riprap should extend up the banks of the channel to a height equal to the maximum 10-year flow depth, or to a point where vegetation can be established to adequately protect the channel.

- Riprap placed in channel bends should extend upstream and downstream from the point of curvature at least five times the channel bottom width. The riprap should extend across the bottom and up both sides of the channel.

- A lining of geotextile filter fabric or granular filter material should be placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap.

- Riprap sizes can be designed by the diameter or by the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be angular instead of spherical. Table B.1 lists some typical riprap stones classes and their corresponding dimensions.

Table B.1: Channel Lining Riprap Class Dimensions

Riprap Class	Rock Diameter (Feet)	Percent of Riprap Smaller Than
A	0.75	100
	0.5 (D_{50})	50
	0.2	15
B	1.33	100
	1.0	85
	0.75 (D_{50})	50
	0.42	10
C	1.80	100
	1.30 (D_{50})	50
	0.4	10

B.1.2.2 Design of Riprap Channel Linings

Design of erosion protection within the channel should be accomplished using the FHWA Tangent Flow Method presented below. This method is applicable to both straight and curved channel sections where flows are tangent to channel bank. The Tangent Flow Method determines a stable rock size for straight and curved channel sections using known shape, flow depth, and channel slope dimensions. 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. The final design size will be stable on both the sides and bottom of the channel.

<u>Straight Channel Sections:</u>

1. Enter the graph of Figure B-2 (located at the end of this Appendix) with the maximum flow depth (feet) and channel slope (feet/feet). Where the two lines intersect, choose the D_{50} stone size. Select D_{50} for diagonal line <u>**above**</u> the point of intersection.

2. ***If the channel side slopes are steeper than 3H:1V, continue with Step 3; if not, the*** procedure is complete.

3. Enter the graph in Figure B-3 with the side slope 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 the graph in Figure B-4 the angle of repose for the D_{50} stone size and the channel side slope. (Use an angle of 42 degrees for D_{50} greater than 10 inches. Do not use riprap on slopes steeper than the angle of repose for the stone size.)

5. Enter graph in Figure B-5 with the side slope of the channel and the angle of repose for the D_{50} stone size. Where the two lines intersect, move vertically down to read $\mathbf{K_2}$**.**

6. Compute **(Original $\mathbf{D_{50}}$) * ($\mathbf{K_1/K_2}$) = $\mathbf{D_{50}}$** to determine the correct size stone for the bottom and side slopes of straight sections of channel.

<u>Curved Channel Sections:</u>

1. Enter the graph of Figure B-3 with the maximum flow depth (feet) and channel slope (feet/feet). Where the two lines intersect, choose the D_{50} stone size. Select D_{50} for diagonal line above the point of intersection.

2. Determine the radius of the curved section (R_O) in feet.

3. Calculate the top width of the riprap lined channel at the design water surface in feet (B_S):

$$B_S = B_O + 2(Z*D)$$

B_O = Bottom width of channel (feet)

B_S = Top width of the channel (feet)

Z = Channel sides slopes defined as ZH:1V

D = Depth of riprap (feet)

4. Calculate the Ratio $\mathbf{B_S / R_O}$.
5. Knowing the value of the $\mathbf{B_S / R_O}$ ratio from step 4, use the graph in Figure B-6 and read the corresponding value of $\mathbf{K_3}$.

   $\mathbf{R_O}$ **=** Radius of the curved section

6. Compute **(Original $\mathbf{D_{50}}$) * $\mathbf{K_3 = D_{50}}$** to determine the correct size stone for the bottom and side slopes of curved channel sections.

Example Calculations for Design of Riprap Lined Channel Sections:

Straight Channel Section:

Given: A trapezoidal channel has a depth (D) of 3 feet, a bottom width (B_O) of 8 feet, side slopes (Z) of 2:1, and a 2 percent slope.

Find: A stable riprap size for the bottom and side slopes of the channel.

Solution:

1. From Figure B-2, for a 3 foot deep channel over a 2 percent grade, read D_{50} = 0.75 feet (or 9 inches)
2. Since the side slopes are steeper than 3:1, continue with Step 3 (If side slopes were less than 3:1, the process would be complete.)
3. From Figure B-3, for B_O /d = 8/3 = 2.67 and side slopes (Z) = 2, read K_1 = 0.82
4. From Figure B-4, for D_{50} = 9 inches, read Angle of Repose = 41
5. From Figure B-5, for side slopes Z = 2, and Angle of Repose = 41, read K_2 = 0.73
6. Stable Riprap = D_{50} * (K_1/K_2) = 0.75 * (0.82/0.73) = **0.84 feet** (10 inches)

Curved Channel Section:

Given: The preceding straight channel example has a curved section with a radius of 50 feet.

Find: A stable riprap size for the bottom and side slopes of the curved channel section.

Solution:

1. R_O = 50 feet
2. Calculate channel top width of water surface, $B_S = B_O + 2(Z*D) = 8 + 2(2*3) = 20$ feet
3. Calculate the ratio B_S / R_O = 20/50 = 0.40

4. From Figure B-6, for B_S / R_O = 0.40, read K_3 = 1.1

5. D_{50} * K_3 = (0.84 feet * 1.1) = **0.92 feet** (11 inches)

B.1.3 Outlet Protection

Refer to *SCDOT Standard Drawings 804-205-00, 804-305-01, 804-305-02, and 804-310-00* or latest revisions. The design of outlets for pipes and channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous lining and protection of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10 percent should not be protected using just outlet protection. This causes re-concentration of the flow that result in large velocities when the flow leaves the protection area.

Outlet protection should:

- Have a minimum width three times the diameter of the outlet pipe ($3D_o$) at the upstream end of the protection, adjacent to the pipe outlet.
- Advance up the slope a minimum of one (1) foot above the pipe invert.
- Extend across the channel bottom and up the channel banks to the top of the bank.
- Be constructed with no slope along its length (0.5 percent grade) where applicable. The downstream invert elevation of the protection should be equal to the elevation of the invert of the receiving channel. There should be no overfalling at the end of the protection.
- Be located so there are no bends in the horizontal alignment.

If the outlet discharges into a well-defined channel, the receiving side slopes of the channel should be as shown on the design plans. A non-woven geotextile filter fabric must be place under all riprap outlet protection installations.

Outlet protection may be designed according to the following criteria for ***a round pipe flowing full:***

- The flow velocity at the outlet flowing at design capacity shall not exceed the permissible velocity of receiving unprotected grass-lined channels as provided in Table B.2.
- Tailwater Depth and Condition: The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. If the tailwater depth is less than half the diameter of the outlet pipe, it should be classified as a "minimum tailwater condition". If the tailwater depth is greater than half the pipe diameter, it should be classified as a "maximum tailwater condition". Pipes which discharge onto flat areas with no defined channel may be assumed to have a minimum tailwater condition.
- Protection Length: The required protection length, $\boldsymbol{L_a}$, according to the tailwater condition, should be determined from the appropriate graphs provided in Figure B-7 for minimum tailwater condition and in Figure B-8 for maximum tailwater condition.

Table B.2: Maximum Permissible Velocities for Unprotected Grass Lined Channels

Cover	Maximum Permissible Velocity* (ft/sec)					
	Erosion-Resistant (*Clay, Sandy Clay, Sandy Clay Loam, Clay Loam, Silty Clay, Silty Clay Loam*) Soils % Slope			**Easily Eroded (*Sand, Loamy Sand, Sandy Loam, Loam, Silty Loam, Silt*) Soils % Slope**		
	0-5	**5-10**	**> 10**	**0-5**	**5-10**	**> 10**
Common Bermudagrass	8	7	6	6	5	4
Bahia Carpet Grass Centipede Grass Tall Fescue	7	6	5	5	4	3
Grass-legume Mixture	5	4	NR**	4	3	NR**
Small Grains / Temporary Vegetation	3.5	NR**	NR**	2.5	NR**	NR**

Allow velocities over 5 ft/sec* ***only* *where good cover and proper maintenance will be provided. If poor vegetation exists due to shade, climate, soils or other factors, reduce the permissible velocity.*
***NR = Not Recommended (Source: Elementary Soil and Water Engineering, Shwab et. al.)*

- Protection Width: When the pipe discharges directly into a well-defined channel, the protection should extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less).
- If the outlet discharges onto a flat area with no defined channel, the width of the protection should be determined as follows:
  - The upstream end of the protection, adjacent to the outlet, should have a minimum width three times the diameter of the outlet pipe ($3D_o$).
  - For a minimum tailwater condition, the downstream end of the protection should have a minimum width equal to the pipe diameter plus the length of the apron ($D_o + L_a$).
  - For a maximum tailwater condition, the downstream end of the protection should have a minimum width equal to the pipe diameter plus 0.4 times the length of the apron ($D_o + 0.4 * L_a$).

Bottom Grade: The protection shall be constructed with no slope along its length (0 percent grade) where applicable. The downstream invert elevation of the protection should be equal to the elevation of the invert of the receiving channel. There shall be no overfalling at the end of the protection.

Side Slopes: If the outlet discharges into a well-defined channel, the receiving side slopes of the channel should be as shown on the design plans.

Alignment: The protection should be located so there are no bends in the horizontal alignment.

Materials:

- The preferred protection lining is with an appropriate permanent TRM. The shear stress and maximum velocity should be calculated to determine which type of TRM is applicable for the situation (see Section B.1.1).
- When conditions are too severe for TRMs, the outlet protection may be riprap, grouted riprap, concrete, or gabion baskets. The median-sized stone for riprap may be determined from the curves in Figure B-7 and Figure B-8 (located at the end of this Appendix) according to the tailwater condition. The gradation, quality, and placement of riprap should conform to the requirements presented in Section B.1.2.
- In all cases, a Class 2 non-woven geotextile filter cloth should be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the physical properties for filter cloth found in the requirements presented in Section 804.2.11 of the *SCDOT Specifications for Highway Construction*, 2007 Edition, or latest revision.

<u>Example Calculations for the Design of Outlet Protection:</u>

<u>Given:</u> An 18-inch pipe discharges 24 cfs at design capacity onto a grassy slope (no defined channel).

<u>Find:</u> The required length, width, and median stone size (D_{50}) for riprap outlet protection.

<u>Solution:</u>

1. Since the pipe discharges onto a grassy slope with no defined channel, a <u>minimum tailwater</u> condition is assumed.
2. From Figure B-7, the intersection of a discharge of 24 cfs and a pipe diameter (d) of 18 inches, gives a protection length (L_a) of <u>20 feet</u>.
3. From Figure B-7, the intersection of a discharge of 24 cfs and a pipe diameter (d) of 18 inches, gives a median stone size (D_{50}) of <u>0.8 feet</u>, or <u>Class B riprap</u>.
4. The upstream protection width equals 3 times the pipe diameter ($3D_o$) = 3 x 1.5 feet = **<u>4.5 feet</u>**.
5. The downstream protection width equals the apron length + the pipe diameter = 20 feet + 1.5 feet = **<u>21.5 feet</u>**.

B.2 TEMPORARY SEDIMENT CONTROL BMPS

When selecting a Standard SCDOT Temporary Sediment Control BMP with an applicable SCDOT Supplemental Technical Specification, SCDOT Standard Drawing, or BMPs included on an applicable SCDOT QPL list, the BMP meets the 80% TSS trapping requirement and the maintenance requirement is already established.

B.2.1 Sediment Dams

B.2.1.1 Description

Sediment dams are temporary BMPs used to remove sediment from construction runoff where the total drainage area is less than 10 acres. Sediment dams are typically located inside the right-of-way in a cut ditch or along the toe-of-fill.

Construct temporary sediment dams in accordance with the Plans and the *SCDOT Standard Drawings for Sediment Dams 815-405-01 and 815-405-02* (or most recent revision) at locations shown on the Plans or as directed by the RCE. Once the construction areas are fully stabilized, the sediment dams are removed.

B.2.1.2 Materials

The main components of a sediment dam are the Class A or B rock dam, rock spillway, Aggregate No. 5 filter stone, Class 2 non-woven geotextile, and outfall channel.

B.2.1.3 Design Requirements

There are two general sediment dam designs for South Carolina – the correct design is chosen according to the Project location. Figure A-1 (Appendix A) shows the line dividing the upper and lower portions of the state. In the upper portion of the state, correct design is dependent on the percent of disturbed area in the watershed. This is shown in Table B.3.

B.2.1.3.1 Sediment Dam Storage Volume

The sediment dam overall storage volume is composed of two volumes - sediment storage volume and runoff storage volume.

<u>Sediment Storage Volume</u>

The design sediment storage volume is calculated based on the disturbed area draining to the sediment dam. The sediment storage volume for sediment dams is 415 ft^3 per disturbed acre (15.4 CY) in the Upper State and 450 ft^3 per disturbed acre (16.7 CY) in the Lower State. Select the sediment storage volume as shown in Table B.3.

<u>Runoff Storage Volume</u>

The runoff storage volume is provided between the top of the sediment storage volume and the crest of the rock dam spillway. Select the runoff storage volume as shown in Table B.3.

Determine the sediment dam width, length, side slopes and height of the rock dam to obtain the required overall sediment dam storage volume. Design the spillway to safely pass the 10-year, 24-hour storm event.

The minimum dimensions shown in Table B.3 are designed to safely pass the 10-year, 24-hour storm event and achieve 80% TSS removal.

Table B.3: Sediment Dam Design Guidelines

Total Drainage Area (acres)	Lower State Total Storage Volume (ft^3)	Upper State Total Storage Volume (ft^3)			Min Rock Dam Height (to bottom of spillway) (ft)	Min Rock Dam Bottom Width (ft)	Sediment Storage Height (ft)	Spillway Bottom Width (ft)
		75-100% Total Drainage Areas Disturbed	25-75% Total Drainage Areas Disturbed	0-25% Total Drainage Areas Disturbed				
1	1,450	2,815	2,115	1,505	3	3	0.5	9
2	2,900	5,630	4,225	3,010	3	3	0.5	9
3	4,350	8,445	6,335	4,510	4	3	0.75	11
4	5,800	11,260	8,445	6,015	4	4	0.75	12
5	7,250	14,075	10,560	7,520	4	4	0.75	12
6	8,700	16,890	12,670	9,025	4	4	0.75	12
7	10,150	19,705	14,780	10,530	4	6	0.75	14
8	11,600	22,520	16,890	12,030	4	6	0.75	14
9	13,050	25,335	19,000	13,535	4	6	0.75	14
10	14,500	28,150	21,115	15,040	4	6	0.75	14

B.2.1.3.2 General Design Criteria

- The maximum drainage area to a single sediment dam is less than 10 acres.
- Sediment storage volume is 415 cubic feet per disturbed acre (15.4 CY) in the Upper State and 450 cubic feet per disturbed acre (16.7 CY) in Lower State for all soils types.
- Sediment dam riprap is Class A riprap for Sediment Dams with drainage areas of 3 acres or less.
- Sediment dam riprap is Class B riprap for Sediment Dams with drainage areas greater than 3 acres.
- Riprap should be mechanically placed and shaped.
- The maximum upstream and downstream slope of the placed riprap is 2H:1V.
- The bottom of the sediment dam has a slope of 0.5%.
- Place a Class 2 non-woven Geotextile for erosion control under the riprap.
- Place a 6-inch layer of Aggregate No. 5 on the upstream face of the riprap.
- Top of dam to spillway crest (spillway depth) is one (1) foot.
- Side slopes of the spillway are 1H:1V.

- The top of the rock dam has a minimum width (parallel to flow) of 24 inches.
- Temporarily seed and stabilize all areas of the sediment dam except for the bottom.
- When site constraints do not allow a sediment dam design according to this section, the design aids located in Appendix I of this manual may be used to design sediment dams for 80% trapping efficiency.

B.2.1.4 Inspection and Maintenance

The key to a functional sediment dam is continual monitoring, regular maintenance, and regular sediment removal. Attention to sediment accumulations within the sediment dam is extremely important.

Inspect sediment dams at the inspection frequency required by the latest version of the SCDHEC Construction General Permit. When repairs or maintenance are necessary, perform them immediately.

- Inspect the spillway for erosion and damage.
- Remove trapped sediment from the sediment dam when 50% of the sediment storage volume is occupied with sediment (half full). Clean trapped sediment when sediment accumulations reach the clean-out mark on the sediment clean out stake.
- Trapped sediment should be removed from the site or stabilized on site.
- Repair and seed side slope areas that have eroded or have become damaged by equipment during silt cleanout or other operations.

B.2.2 Silt Fence

Refer to *SCDOT Supplemental Technical Specification for Silt Fence Systems* (SC-M-815-2 or most recent revision).

B.2.2.1 General Design Criteria

- Maximum slope length to the fence: 100 feet
- Maximum slope gradient normal [perpendicular] to fence line: 2H:1V
- The suggested allowable land slope based on allowable flow length is shown in Table B.4.

Table B.4: Silt Fence Land Slope to Allowable Sheet Flow Relationship

Land Slope (%)	Maximum Sheet Flow Slope Distance to Fence (ft)
3 - 5	100
5 - 10	75
10 - 20	50
20 - 50	25

- Silt fencing shall not receive concentrated flows greater than 0.5 cfs and shall not be placed across channels.
- Sheet flow should have no more than 0.25 cfs per 100 feet of silt fence and the maximum fill slope protected by the fence musts not exceed 2:1.
- Design removal efficiency goal for TSS: 80%
- Minimum installed fence fabric height: 24 inches

B.2.3 Rock Ditch Check

Refer to *SCDOT Standard Drawing for Ditch Checks 815-105-00* (or most recent revision).

B.2.3.1 General Design Criteria

- The center section of the rock ditch check should be lower than the edges.
- Spacing varies with the bed slope of the ditch. The maximum spacing between the rock checks should be such that the toe of the upstream check is at the same elevation as the top of the downstream check.
- In the case of grass-lined ditches and swales, ditch checks should be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than four (4) percent. The newly exposed area beneath the ditch checks should be seeded and mulched immediately after dam removal.
- The body of the rock ditch check should be composed of Class A Riprap.
- The upstream face of the rock ditch check should be composed of a 6-inch thick layer of Aggregate No. 5 or No. 57 stone.
- Rock ditch checks should not exceed a height of two (2) feet at the centerline of the channel.
- Rock ditch checks should have a minimum top flow length (parallel to flow) of two (2) feet.
- Design removal efficiency goal for TSS: 80%.
- Maximum drainage area: two (2) acres
- Maximum height: two (2) feet
- If the rock ditch check is not properly sized, the flow will overtop the structure and the trapping efficiency is assumed to be 0 percent when this failure takes place.
- Never place rock check dams in USGS blue line streams.
- A non-woven geotextile fabric meeting AASHTO M288 Class 2 should be installed over the soil surface where the rock ditch check is placed.
- The upstream and downstream slopes of the ditch check should not be steeper than 2H:1V, but may be flattened due to traffic safety as directed by the RCE.
- Stone should be placed up the conveyance banks to prevent water from cutting around the ditch check.

B.2.4 Sediment Dam for Pipe Inlets

B.2.4.1 Description

Sediment dams for pipe inlets are temporary BMPs used to remove sediment from construction runoff where the total disturbed area is less than or equal to 2 acres and drains to a pipe inlet. Sediment dams for pipe inlets are typically located inside the right-of-way.

Construct temporary sediment dams for pipe inlets in accordance with the Plans and the *SCDOT Standard Drawings for Sediment Dam for Pipe Inlet 815-406-00* (or most recent revision) at locations shown on the Plans or as directed by the RCE. Once the construction areas are fully stabilized, sediment dams for pipe inlets are removed.

B.2.4.2 Materials

The main components of a sediment dam for pipe inlets are Class B riprap rock dam, rock spillway, Aggregate No. 5 filter stone, and Class 2 non-woven geotextile.

B.2.4.3 Design Requirements

These minimum design requirements are conservatively designed to safely pass the peak flow rate for the specific pipe size. Sediment dams for pipe inlets are capable of achieving 80% TSS removal efficiency based on the soil specific eroded particle size distribution located in Appendix G. Qualifying soils for the design of sediment dams for pipe inlets are defined as soils that have the eroded particle size distribution percent finer distribution range as shown in Table B.5 and B.6.

Table B.5: Disturbed Area ≤ 0.5 Acres Qualifying Soil Guidelines

Hydrologic Soil Group (HSG)	Eroded Particle Sizes (mm)	0.044	0.038	0.004	0.003
A, B, C, D	Soil Specific Percent Finer Range	***0-25***	***0-25***	***0-4***	***0-3***

Table B.6: Disturbed Area > 0.5 and ≤ 1.0 Acres Qualifying Soil Selection Guidelines

Hydrologic Soil Group (HSG)	Eroded Particle Sizes (mm)	0.044	0.038	0.004	0.003
A	Soil Specific Percent Finer Range	***0-15***	***0-15***	***0-4***	***0-3***

Use other sediment control BMPs to obtain 80% TSS removal efficiency for drainage areas greater than 1 acre or soils that do not meet the requirements of Table B.6. Sediment dams for pipe inlets may also be used as part of a treatment train for all soils, where sediment control BMPs capable of achieving 80% TSS removal efficiency are used downstream.

B.2.4.3.1 Sediment Storage Volume

The design sediment storage volume is calculated based on the disturbed area draining to the sediment dam for pipe inlets. The sediment storage volume for sediment dams is 450 cubic feet per disturbed acre (16.7 CY) for all soils types.

B.2.4.3.2 Sediment Dam for Pipe Inlet Dimensions

Determine the sediment dam for pipe inlets dimensions using Table B.7.

Table B.7: Sediment Dam for Pipe Inlet Design Guidelines

Pipe Size (in)	Rock Dam Height (ft)	Sediment Storage Width (ft) based on disturbed area in acres				Sediment Dam Inside L_1 (ft)	Sediment Dam Inside L_2 (ft)
		0.5 acres	1.0 acre	1.5 acres	2.0 acres		
18	1.5	4.0	7.0	11.0	14.0	3.5	1.75
24	2.0	3.0	6.0	9.0	12.0	4.0	2.0
30	2.5	2.5	5.5	8.0	10.5	4.5	2.25
36	3.0	2.5	4.5	7.0	9.5	5.0	2.5
42	3.5	2.0	4.0	6.0	7.5	7.5	3.75
48	4.0	2.0	3.5	5.5	7.0	8.0	4.0

B.2.4.3.3 General Design Criteria

- The maximum disturbed area to a single sediment dam for pipe inlet is ≤ 2 acres.
- Sediment storage volume is 450 cubic feet per disturbed acre (16.7) for all soils types.
- Sediment storage height is one (1) foot for all pipe sizes.
- Rock dam height for sediment dam for pipe inlet is equal to the outer diameter of the pipe.
- Sediment dam for pipe inlets riprap is Class B.
- Riprap should be mechanically placed and shaped.
- The maximum upstream and downstream slope of the placed riprap is 1H:1V.
- Place a Class 2 non-woven Geotextile for erosion control under the riprap.
- Place a 6-inch layer of Aggregate No. 5 on the upstream face of the riprap.
- The top of the rock dam has a minimum width (parallel to flow) of 24 inches.

B.2.4.4 Inspection and Maintenance

The key to a functional sediment dam for pipe inlet is continual monitoring, regular maintenance, and regular sediment removal. Attention to sediment accumulation behind the sediment dam is extremely important.

Inspect sediment dams for pipe inlets at the inspection frequency required by the latest version of the SCDHEC Construction General Permit. When repairs or maintenance are necessary, perform them immediately.

- Inspect the dam for erosion and damage.

- Remove trapped sediment from the sediment dam for pipe inlet when 50% of the sediment storage volume is occupied with sediment (half full). Clean trapped sediment when sediment accumulations reach the clean-out mark on the sediment clean out stake.

- The design clean out schedule for sediment dam for pipe inlets is 1-month, therefore these structures will require routine maintenance and will fill with sediment faster than sediment basins and sediment dams.

- Trapped sediment should be removed from the site or stabilized on site.

- Repair and seed areas that have eroded or have become damaged by equipment during silt cleanout or other operations.

B.3 STORMWATER RUNOFF AND GROUND WATER CONTROL MEASURES

B.3.1 Pipe Slope Drains

Refer to Section 803 Pipe Slope Drains of the *SCDOT Specifications for Highway Construction*, 2007 Edition (or most recent revision).

B.3.1.1 General Design Criteria

- Typical pipe slope drains are made of non-perforated corrugated plastic pipe designed to pass the peak flow rates for the 10-year, 24-hour storm event.
- The maximum drainage area allowed per pipe is two acres.
- Diversion berms or dikes should direct runoff to slope drains. The minimum height of these dikes or berms should be 1.5 feet. The height of the berm around the pipe inlet should be a minimum of 1.5 feet high and at least 0.5 feet higher than the top of the pipe. The berm at the pipe inlet shall be compacted around the pipe.
- Permanent slope drains should be buried beneath the soil surface a minimum of 1.5 feet.
- If the pipe slope drain will be conveying sediment-laden water, all flows should be directed into a sediment trapping facility.

B.3.2 Runoff Diversion Measures

Refer to *SCDOT Standard Drawing for Temporary Erosion & Sedimentation Control 815-605-00* (or most recent revision)

B.3.2.1 Diversion Dike and Berm Design Criteria

- Top width: two (2) feet minimum.
- Bottom width at ground level is typically six (6) feet.
- Height of dike or berm: 1.5 feet minimum measured from upslope toe.
- Side slopes: 2H:1V or flatter.
- Grade: Limited to grades between 0.5 percent and 1.0 percent.
- Spacing:

Percent Slope	**<5%**	**5% - 10%**	**10% - 40%**
Horizontal Spacing (feet)	300	200	100

- Stabilization: Slopes shall be stabilized immediately using vegetation, sod, and/or erosion control blankets or turf reinforcement mats to prevent erosion.
- Outlet: Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping facility.
- Other: Minimize construction traffic over diversion dikes and berms.

B.3.2.2 Diversion Swale Design Criteria

- Bottom Width: 2-foot minimum, with a level bottom.
- Depth: 1.5-foot minimum.
- Side Slope: 2H:1V or flatter.
- Grade: Maximum five (5) percent, with positive drainage to a suitable outlet.
- Stabilization: Stabilize with RECPs immediately.
- Spacing:

Percent Slope	**< 5%**	**5% - 10%**	**10% - 40%**
Horizontal Spacing (feet)	300	200	100

- Outlet: Level spreader or riprap to stabilize outlet/sedimentation pond.

- The top width of earthen diversion dikes should be at least two (2) feet wide. The bottom width at ground level is typically eight (8) feet.
- The minimum height for earthen dikes should be 18 inches, with side slopes no steeper than 2H:1V.
- Construction traffic over diversion dikes and berms should be minimized. However, for points where vehicles must cross the dike, the slope should be no steeper than 3H:1V and the mound should be constructed of gravel rather than soil.
- Provide energy dissipation measures as necessary. Sediment laden runoff must be released through a sediment trapping BMP.

B.3.3 Level Spreaders for Outlet Pipe Discharges

B.3.3.1 Description

Use Level Spreaders for Outlet Pipe Discharges as an energy dissipater to disperse concentrated runoff uniformly. Use level spreaders for peak design flow rates up to 30 cubic feet per second (cfs). Level spreaders are constructed at virtually zero percent grade across a slope, and consist of a permanent structure used to disperse or "spread" concentrated flow thinly over the level spreader lip. The main purpose is to spread potentially erosive concentrated flow over a wide area to reduce erosion at the outlet.

B.3.3.2 Design

Use level spreaders for outlet pipe discharges to convey runoff from pipe outfalls uniformly onto downstream areas. Level Spreaders are applicable:

- As outlets for diversion structures.
- Only where uniform sheet flow can be achieved down slope of level spreaders.
- As a segment of a stormwater BMP treatment series.
- Where runoff from an impervious surface is uneven and/or runoff is released as concentrated flow, such as through curb cuts or slope drains.

<u>Do Not Use Level Spreaders</u>:

- Where discharge slopes exceed 6% for wooded/forested areas or 8% for thick ground cover/grass areas.
- Where there are draws or concentrated flow channels located within the down slope area of a proposed level spreader.
- Where the runoff water will re-concentrate after release from the level spreader before reaching an outlet designed for concentrated flow.
- Where there will be traffic over the level spreader.

Depending on the use, level spreader elements may include a forebay, level spreader lip, pipe drain, and turf reinforcement matting (TRM) or Class A or B riprap. Ensure level spreaders not discharging to a specific stormwater BMP or designed stormwater conveyance system discharge to a stabilized area.

Level spreader dimensions are derived from the design peak flow rates (cfs). Table B.8 shows the minimum depth and minimum length of the level spreader lip based on the discharge pipe size.

Table B.8: Level Spreader Dimensions

Pipe Size (inches)	Minimum Depth (feet)	Minimum Lip Length (feet)
12	1.0	11.0
18	1.5	16.5
24	2.0	22.0
30	2.5	27.5
36	3.0	33.0

B.3.3.3 Materials

Forebay/Excavated Swale

Use a forebay or excavated swale for the preliminary treatment of stormwater. Excavate the forebay as a bowl-shaped feature to slow the influent before it reaches the level spreader lip. Reinforce the forebay with a turf reinforcement matting (TRM), Class A or B riprap, or transition mats.

Level Spreader Lip

User a level spreader lip made of earth, gravel, or concrete. When the lip is constructed of earth or gravel, reinforce the level spreader lip with turf reinforcement matting. The level spreader lip is the main body of the level spreader that receives water from the forebay, directly from a BMP, or directly from a pipe outlet. Construct the lip so it is level along the entire length.

Drainage Pipe

Use a level spreader drainage pipe when the underlying soil has an infiltration rate less than two (2) inches/hour or when water detained within the level spreader does not drain. Use a non-perforated PVC drainage pipe with a minimum diameter of four (4) inches.

Turf Reinforcement Matting (TRM)

Stabilize the level spreader with turf reinforcement matting.

B.3.3.4 Construction Requirements

Construct Level Spreaders on undisturbed soil whenever possible. If the use of fill is unavoidable, compact each layer to not less than 95.0% of maximum density before successive layers are applied unless otherwise provided. Accomplish the compaction by using suitable construction procedures while the material is at suitable moisture content. SC-T-29 is used to determine the maximum densities. Protect the level spreader and downstream vegetated area from sediment and stormwater flows during construction.

Site Preparation

Before level spreader construction, ensure the ground contours are parallel to the level spreader location, slopes are less than 6% to 8%, and no draws are located downstream of the level spreader. Assess the downstream area and ensure the area is stabilized prior to the construction of the level spreader. Ensure level spreader is actually level.

Installation

Install the level spreader with no greater than 0.05 percent grade on the spreader lip to ensure a uniform distribution of flow. A temporary stormwater diversion may be necessary until the level spreader is fully stabilized.

Forebay/Excavated Swale

Construct an excavation upstream of the level spreader lip acting as a stilling basin for runoff to pond. Excavate the forebay to the dimensions, side slopes, and elevations shown on the contract plans or as directed by the RCE. The minimum depth of the forebay ranges from one (1) to three (3) feet. Do not operate heavy equipment for the excavation of the level spreader. Remove excavated materials from the level spreader and forebay and dispose of them properly.

Level Spreader Lip

Install the level spreader lip with a minimum top width of six (6) inches. Install the level spreader lip with a minimum 6-inch drop to the existing downstream ground allowing water to pass over the lip without interference from vegetation. Extend a TRM a minimum of three (3) feet downstream of the level spreader lip, then anchor and trench the TRM into place as required. The TRM limits erosion as water discharges from the top of the level spreader to the downstream vegetated area.

B.3.3.5 Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of level spreaders. During the first year after construction, inspect level spreaders for proper distribution of flows and signs of erosion during and after all major rainfall events. After the first year, inspect level spreaders annually.

Summary of maintenance requirements:

- Maintain level spreaders annually and after all major storm events.
- Check the level spreader and downstream areas for signs of erosion.
- Address erosion that is discovered in downstream areas through re-grading if necessary, re-seeding, and the application of turf reinforcement matting (TRM) if necessary.
- Remove sediment and debris from the forebay and from behind the level spreader lip when it reaches a depth of 50% of the storage volume or depth.
- As needed, mow the grass in the forebay and around the level spreader to a height of approximately three (3) to six (6) inches.

Other required maintenance includes, but is not limited to:

- Replacing or replenishing vegetation as needed.

- Removing trash and debris periodically as needed.
- Re-grade and re-seed level spreader upslope edges and the forebay as a result of deposited sediment. (Depositing sediment may kill grass and change the level spreader elevation.)

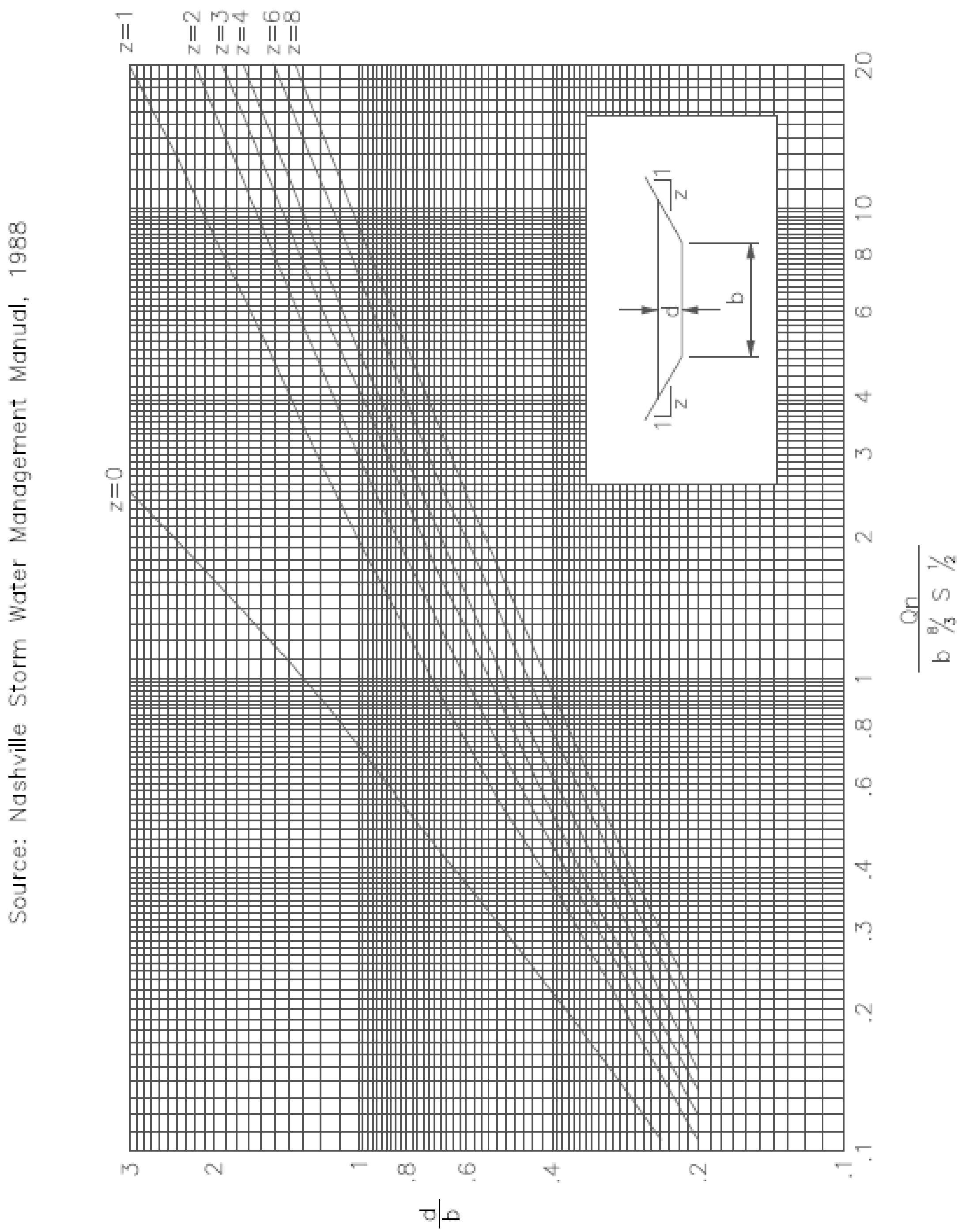
B.3.3.6 Acceptance

Obtain RCE acceptance and approval for all level spreader installations.

South Carolina Department of Transportation

FIGURE B-1
NORMAL DEPTH FOR TRAPEZOIDAL CHANNELS

EFFECTIVE DATE: OCTOBER, 2013

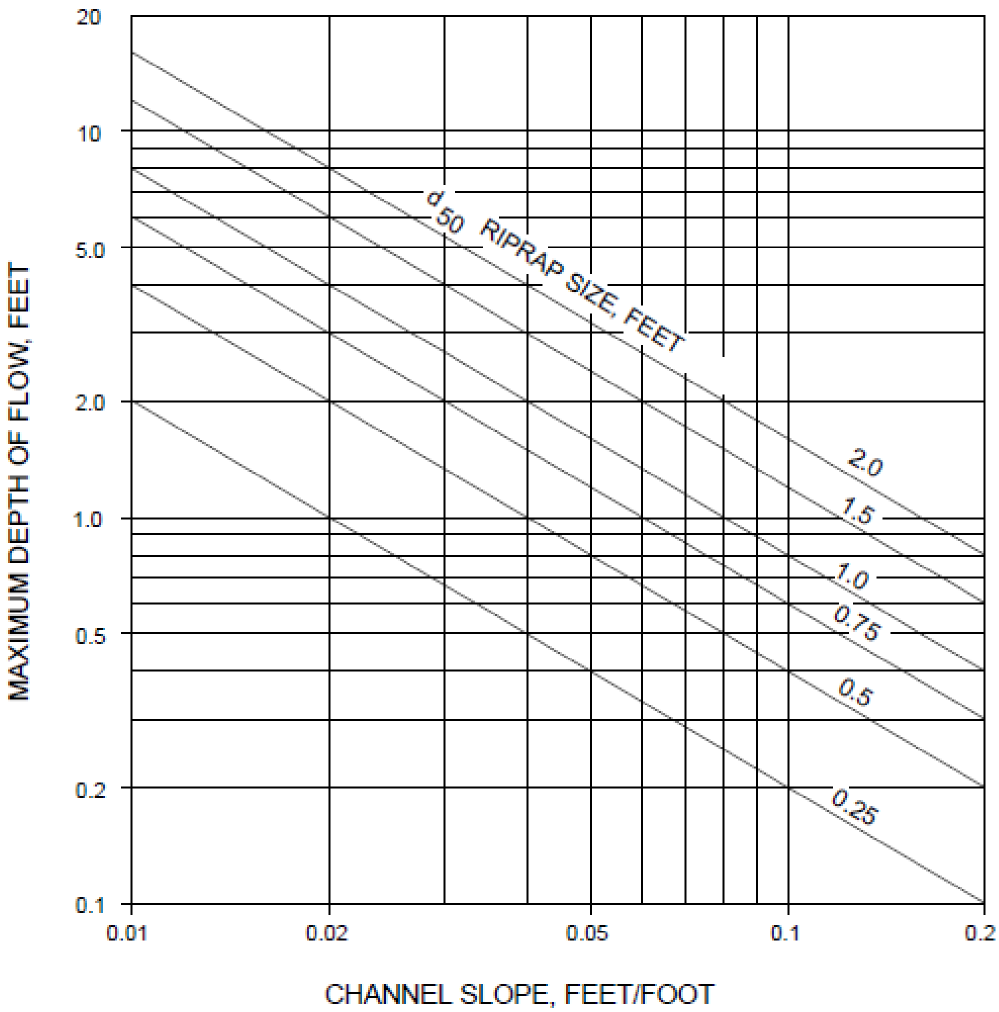


NORMAL DEPTH FOR TRAPEZOIDAL CHANNELS

South Carolina Department of Transportation

FIGURE B-2
MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

EFFECTIVE DATE: OCTOBER, 2013

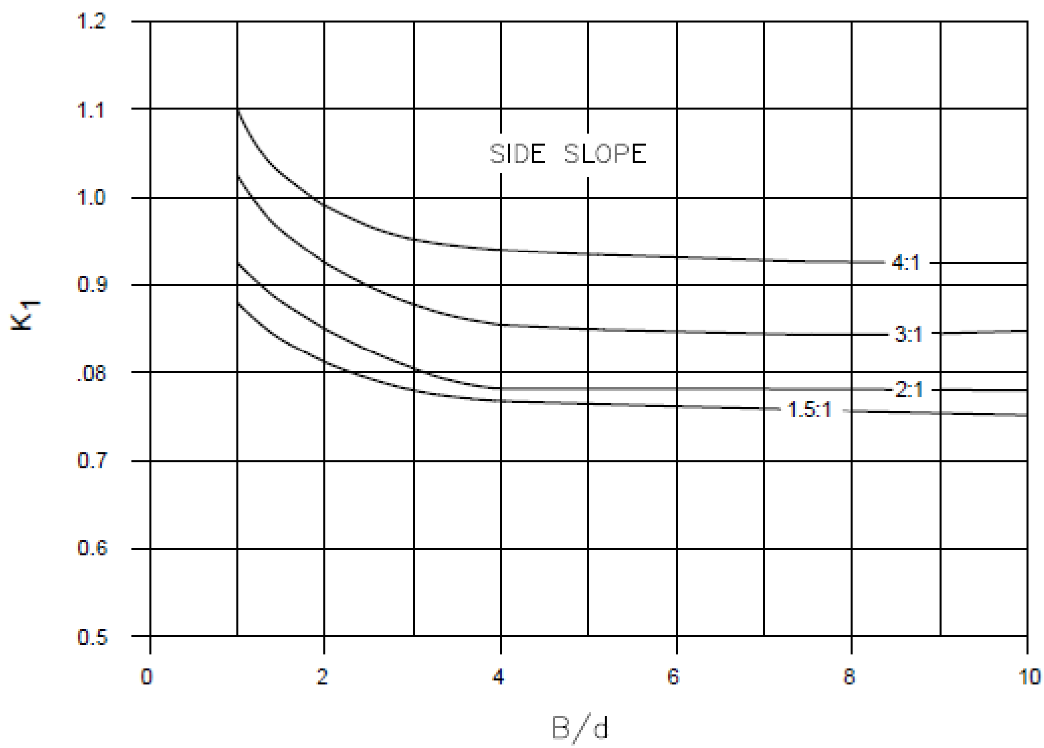


SOURCE: SCDHEC, 2005

MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

FIGURE B-3
DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPEZOIDAL CHANNEL

EFFECTIVE DATE: OCTOBER, 2013



SOURCE: SCDHEC, 2005

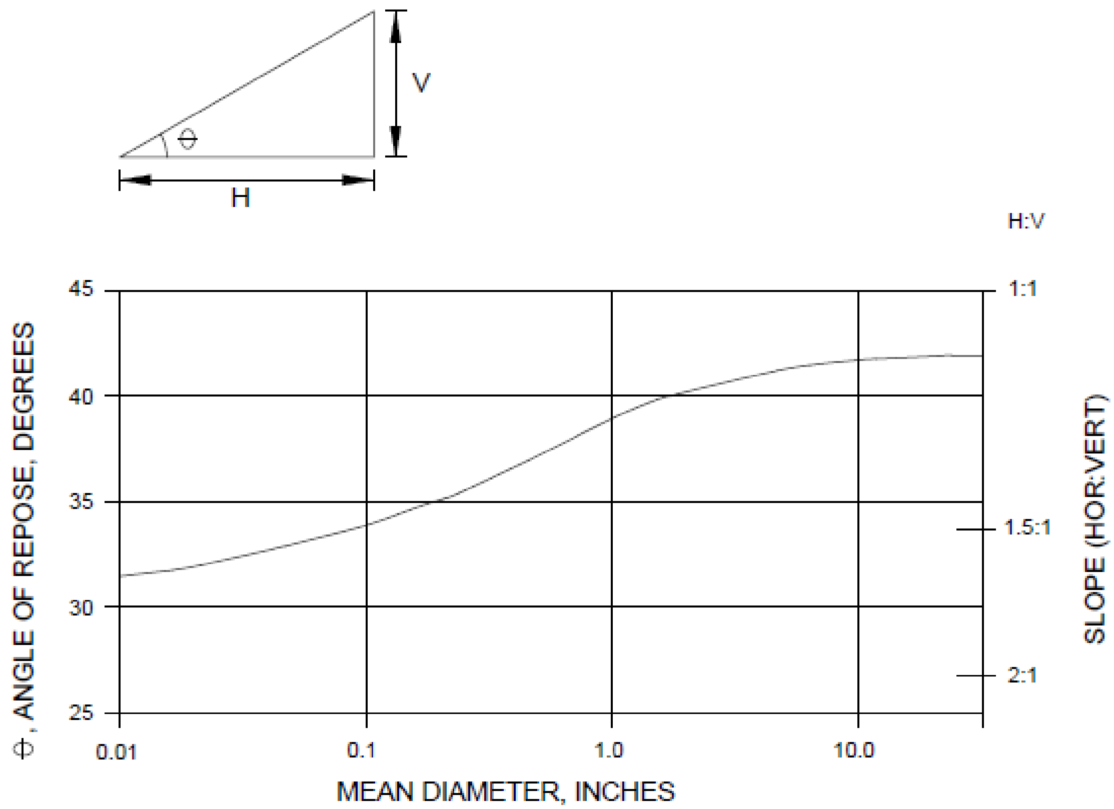
DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPEZOIDAL CHANNEL

South Carolina Department of Transportation

FIGURE B-4

ANGLE OF REPOSE FOR RIPRAP STONES

EFFECTIVE DATE: OCTOBER, 2013

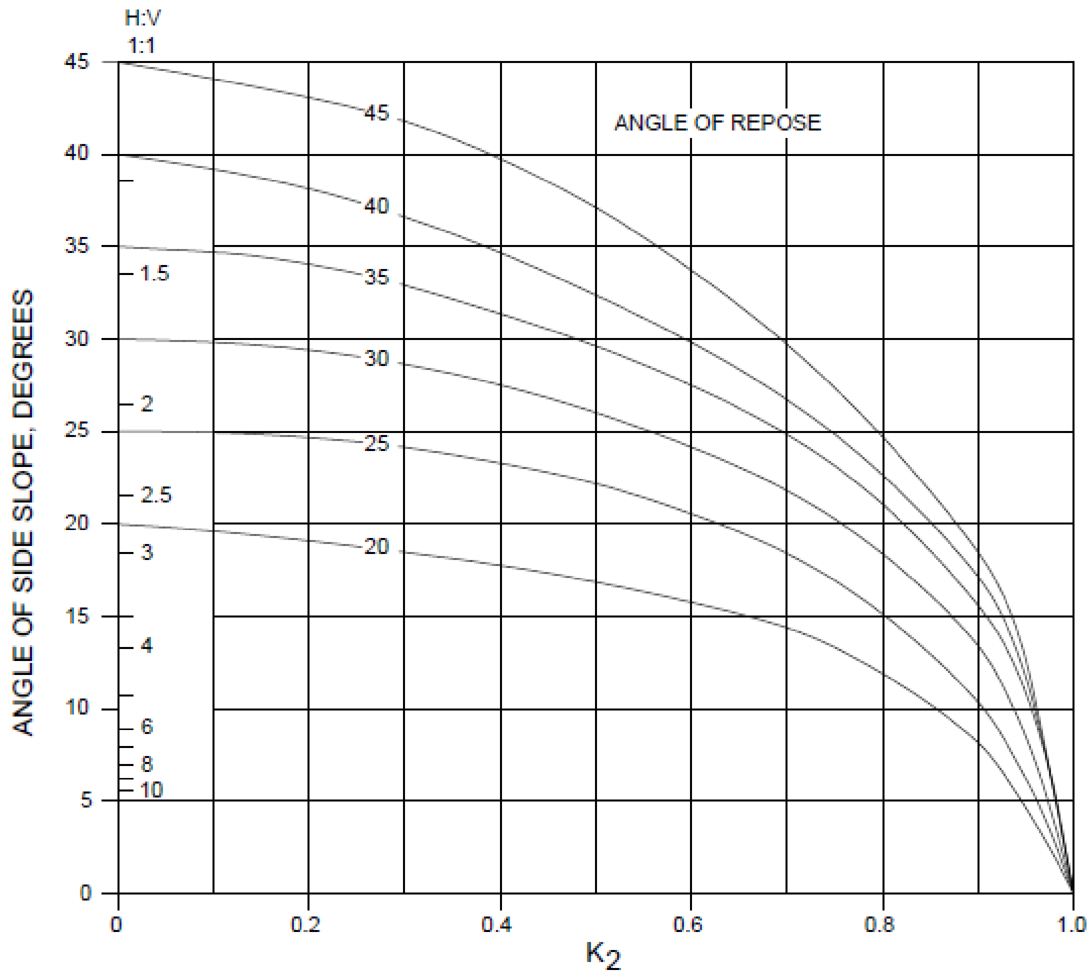


SOURCE: SCDHEC, 2005

ANGLE OF REPOSE FOR RIPRAP

FIGURE B-5
RATIO OF CRITICAL SHEAR STRESS ON SIDES TO CRITICAL SHEAR STRESS ON BOTTOM

EFFECTIVE DATE: OCTOBER, 2013



SOURCE: SCDHEC, 2005

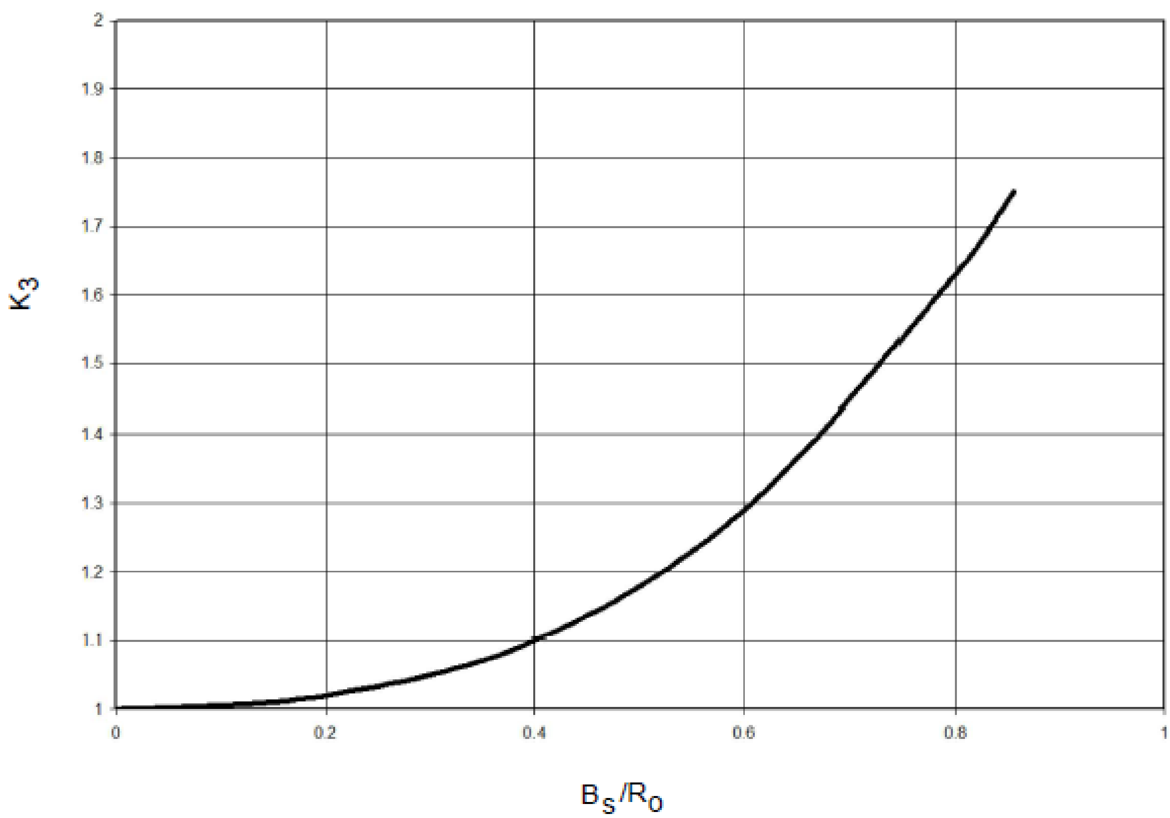
RATIO OF CRITICAL SHEAR STRESS ON SIDES TO CRITICAL SHEAR STRESS ON BOTTOM

FIGURE B-6
RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACHES

EFFECTIVE DATE: OCTOBER, 2013

B_s = SURFACE WIDTH

R_o = MEAN RADIUS OF BENDS



SOURCE: SCDHEC, 2005

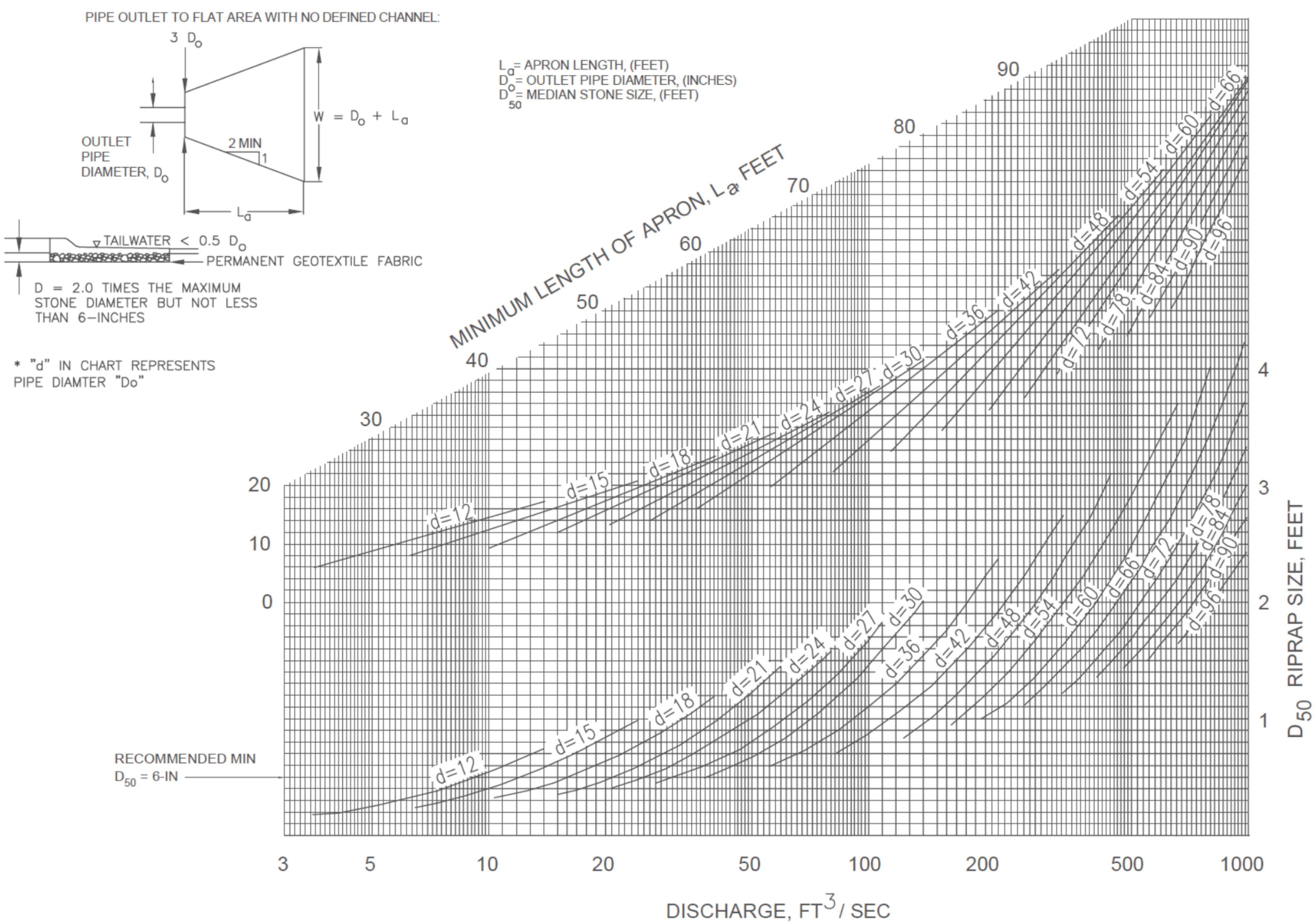
RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACHES

South Carolina Department of Transportation

FIGURE B-7

MINIMUM TAIL WATER CONDITION

EFFECTIVE DATE: OCTOBER, 2013



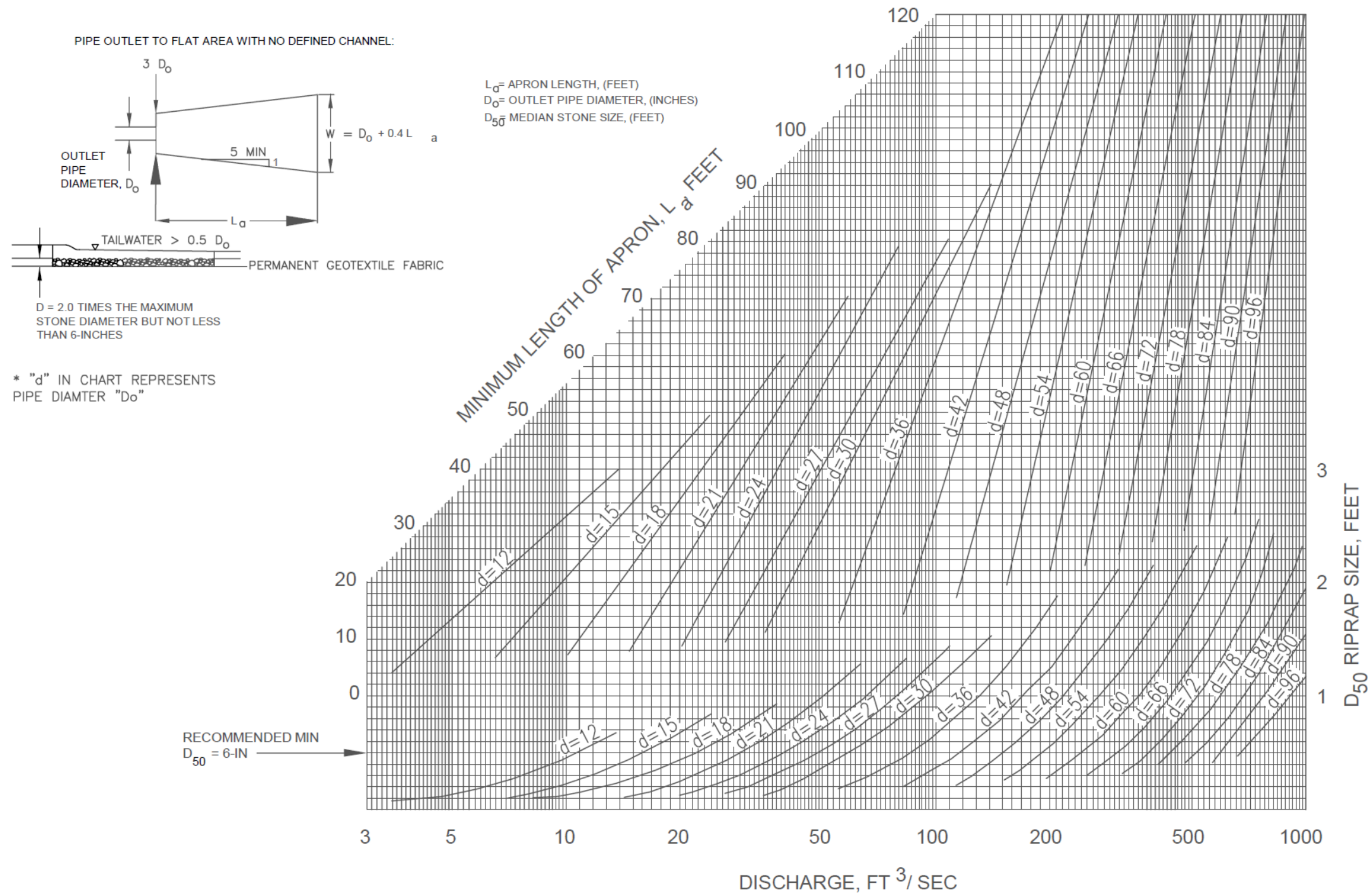
SOURCE: USDA-NRCS

DESIGN OF RIPRAP OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MINIMUM TAILWATER CONDITION (T_w < 0.5 DIAMETER)

FIGURE B-8

MAXIMUM TAIL WATER CONDITION

EFFECTIVE DATE: OCTOBER, 2013



SOURCE: USDA-NRCS

DESIGN OF RIPRAP OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MAXIMUM TAILWATER CONDITION (T_w > 0.5 DIAMETER)