11.13 Outlet Protection

11.13.1 Assessment of Erosion Potential

A field investigation of all proposed outlet locations or existing outlets to be used in a drainage design of a proposed project should be conducted to determine the erosion resistance of the soils at the outlet, the character of the downstream flow path, and any other site constraints that must be addressed by the proposed design.

Barring any unusual conditions, as determined during the field investigation, the criteria outlined in this section should be used to determine the level of outlet protection required. When severe conditions are present, it is the responsibility of the designer to provide outlet protection as needed to safeguard against erosion damage.

Pipe outlets are points of critical erosion potential. Stormwater which is transported through closed conveyance systems at design capacity generally reaches a velocity which exceeds the permissible or erosion resistant velocity of the receiving channel or overland area. To prevent scour at stormwater system outlets, a flow transition structure is needed which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or overland area.

11.13.2 Types of Outlet Protection

The most commonly used device for outlet protection is a riprap lined apron. Where practical, they are constructed at a zero grade or minimum slope to slow the outlet velocity. The type and length of the riprap lined apron is related to the outlet flow rate and the tailwater level and whether there is a defined channel downstream.

If the tailwater depth is less than half the outlet pipe rise, it shall be classified as a **Minimum Tailwater Condition**. If the tailwater depth is greater than or equal to half the outlet pipe rise, it shall be classified as a **Maximum Tailwater Condition**.

There are three types of riprap aprons to be used for outlet protection. They are designated as Type A, B and C. Type A riprap aprons would be used under minimum tailwater conditions while Type B riprap aprons would be used for maximum tailwater conditions as defined above, where the pipe outlets overland with no defined channel. Type C riprap aprons would be used when there is a well defined channel downstream of the outlet. The use of a Type C riprap apron on channels that are designated as watercourses or wetlands is discouraged due to potential wetland and fisheries impacts. See Section 11.13.3, Design Criteria, and Section 11.13.5 for the design of riprap aprons.

Where the flow rate proves to be excessive for the economical or practical use of an apron, preformed scour holes may be used. There are two types of preformed scour holes. Type 1 preformed scour holes are depressed one-half the pipe rise and Type 2 preformed scour holes are depressed the full pipe rise. See Section 11.13.3, Design Criteria and Section 11.13.6 for the design of preformed scour holes.

In most cases, a riprap apron or preformed scour hole will provide adequate outlet protection, however where design and site conditions warrant, structurally lined outlet protection or energy dissipators can be investigated. In such instances, coordination with the Hydraulics and Drainage Section early in the design phase is recommended. The design of energy dissipators is presented in HEC-14, "Hydraulic Design of Energy Dissipators For Culverts and Channels."

11.13.3 Design Criteria

The design of riprap outlet protection applies to the immediate area or reach downstream of the pipe outlet and does not apply to continuous rock linings of channels or streams. For pipe outlets at the top of exit slopes or on slopes greater than 10%, the designer should assure that suitable safeguards are provided beyond the limits of the localized outlet protection to counter the highly erosive velocities caused by the reconcentration of flow beyond the initial riprap apron. Outlet protection shall be designed according to the following criteria:

- Riprap outlet protection shall be used at all outlets not flowing over exposed rock or into deep watercourses and ponds.
- In situations not covered by the above noted criteria and where the exit velocity is ≤ 4.27 mps (14 fps), a riprap apron shall also be used. For Type A and B riprap aprons, the type of riprap specified is dependent on the outlet velocity (see Section 11.13.6) and can be determined from Table 11.5. For Type C aprons, the type of riprap specified is determined by the procedures in HEC-15 and HEC-11 depending on the design discharge. See Chapter 7, Channels.
- The type of riprap apron and dimensions are determined by the guidelines outlined in Sections 11.13.2 and 11.13.5, respectively.
- When the outlet velocity is > 4.27 mps (14 fps), the designer should first investigate methods to reduce the outlet velocity. This may be accomplished by any one or combination of the following: increasing the pipe roughness, increasing the pipe size and/or decreasing the culvert slope. When this is not possible or economical, a number of outlet protection or energy dissipation design options are available. These are presented in detail in HEC-14. In most instances, however, a preformed scour hole design should be used, as it generally can provide the necessary degree of protection at an economical cost. The design of a preformed scour hole is presented in Section 11.13.6.

The design criteria of this section should be applicable to most outlet situations. However, recognizing that design and site conditions can vary significantly depending on the project or location on a particular project, it is the responsibility of the designer to ensure that the criteria is suitable to the site or to provide an alternate design which will adequately protect the outlet area from scour and erosion. These situations should be documented in the drainage design report.

Table 11.11 Allowable Outlet Velocities for Type A and B Riprap Aprons

Outlet Velocity - mps (fps)	Riprap Specification
0-2.44 (0-8)	Modified
2.44-3.05 (8-10)	Intermediate
3.05-4.27 (10-14)	Standard

11.13.4 Tailwater Depth

The depth of tailwater immediately at the pipe outlet is required for the design of outlet protection and must be determined for the design flow rate. Manning's equation may be used to determine tailwater depth. See Sections 8.3.5 and 8.3.6 for additional information on how to determine the tailwater depth.

11.13.5 Apron Dimensions

Length

The length of an apron (L_a) is determined using the following empirical relationships (Equations 11.9 and 11.10) that were developed for the U.S. Environmental Protection Agency (1976) and modified by ConnDOT for use in Connecticut. Tables 11-12 and 11-13 show the various lengths of Type A, B and C riprap aprons based on discharge and pipe size. The tables also show the minimum and maximum lengths of aprons to be computed using Equations 11.31 and 11.32. When the table indicates that the required apron length would exceed the maximum shown, a preformed scour hole should be used in lieu of the riprap apron. As previously stated, the design of a preformed scour hole is presented in Section 11.13.6.

Type A Riprap Apron (Minimum Tailwater Condition) **TW < 0.5 R_p**

$$L_a = \frac{3.26(Q-0.142)}{S_P^{1.5}} + 3.05 \qquad \left(L_a = \frac{1.80(Q-5)}{S_P^{1.5}} + 10 \right) \qquad \textbf{(11.31)}$$

Type B Apron (Maximum Tailwater Condition) **TW ≥ 0.5 R_p**

$$L_a = \frac{5.44(Q-0.142)}{S_P^{1.5}} + 3.05 \qquad \left(L_a = \frac{3.0(Q-5)}{S_P^{1.5}} + 10 \right) \qquad \textbf{(11.32)}$$

Type C Riprap Apron - The length of a Type C Riprap Apron shall be determined using the formula for a Type B Riprap Apron.

L_a = length of apron, m (ft)
S_p = inside diameter for circular sections or maximum inside pipe span for non-circular sections, m (ft)
Q = pipe (design) discharge, cms (cfs)
TW = tailwater depth, m (ft)
R_p = maximum inside pipe rise, m (ft)
Note: $S_p = R_p$ = inside diameter for circular sections

Width

For Type A or B Riprap Aprons, when there is no well defined channel downstream of the apron, the width of the apron at the pipe outlet, W_1, should be at least three times the maximum inside pipe span and the width, W_2 of the outlet end of the apron, as shown in Figure 11-13, should be as follows:

Type A Riprap Apron (Minimum Tailwater Condition)

$W_1 = 3S_p$ (min.)

$W_2 = 3S_p + 0.7L_a$ for TW < 0.5 R_p **(11.33)** and

Type B Riprap Apron (Maximum Tailwater Condition)

$W_1 = 3S_p$ (min.)
$W_2 = 3S_p + 0.4L_a$ for $TW \geq 0.5 R_p$ **(11.34)**

W_1 =width of apron at pipe outlet or upstream apron limit
W_2 =width of apron at terminus or downstream apron limit

Type C Riprap Apron

For a Type C Riprap Apron when there is a well defined channel downstream of the outlet, the bottom width of the apron should be at least equal to the bottom width of the channel and the lining should extend on the channel side slopes at least 0.3m (1 ft) above the tailwater depth (TW) or at least two-thirds of the vertical conduit dimension ($0.7 R_p$) above the invert, whichever is greater. (In all cases, the overall width of the apron shall be a minimum of $3S_p$). See Figure 11-13.

Additional guidelines:

- The type of apron to be used and length should be called out on the construction plans.
- The side slopes of the Type C riprap apron should be 2H:1V or flatter.
- The bottom grade should be level or minimum slope, where practical, for energy dissipation. Where the use of a flat apron is impractical, a preformed scour hole should be considered.
- Granular fill shall be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap. Additionally, an appropriately sized geotextile (separation) can be used when field conditions dictate as determined by the engineer.
- The location of outlets and outlet protection should be carefully considered to minimize rights-of-way and wetland impacts.

11.13.6 Preformed Scour Hole

The preformed scour hole is an excavated hole or depression which is lined with rock riprap of a stable size to prevent scouring. The depression (F) provides both vertical and lateral expansion downstream of the culvert outlet to permit dissipation of excessive energy and turbulence. Equations 11.35 and 11.36 are used to determine the median stone size (d_{50}) required for the lining of the two types of preformed scour holes presented below. The first type, Type 1, represented by Equation 11.35, is depressed one-half the pipe rise and the second type, Type 2, represented by Equation 11.36, is depressed the full pipe rise. A significant reduction in stone size is achieved by the excavation. Therefore, the scour hole depressed the full pipe rise would require a smaller stone size, however the dimensions of the hole would be larger. The type that provides the most economical and practical design given the site conditions should be selected. The dimensions of a preformed scour hole are determined by the set of Equations 11.37 and Figure 11-15.

Empirical Preformed Scour Hole Equations:

Type 1: Scour Hole Depression = one-half pipe rise, m (ft)

$$d_{50} = (0.0276\, R_p^2 / TW)\, (Q/R_p^{2.5})^{1.333} \qquad (d_{50} = (0.0125 R_p^2/TW)\, (Q/R_p^{2.5})^{1.333}) \qquad \textbf{(11.35)}$$

Type 2: Scour Hole Depression = full pipe rise, m (ft)

$$d_{50} = (0.0181\, R_p^2 / TW)\, (Q/R_p^{2.5})^{1.333} \qquad (d_{50} = (0.0082 R_p^2/TW)\, (Q/R_p^{2.5})^{1.333}) \qquad \textbf{(11.36)}$$

d_{50} = median stone size required, m (ft)

For variables S_p, R_p, TW and Q, see Section 11.13.5.

Type 1 and 2 preformed scour hole dimensions (See Figure 11-15)

$C = 3S_p + 6F$ Basin Length m (ft)
$B = 2S_p + 6F$ Basin Inlet and Outlet Width m (ft) **(11.37)**
$F = 0.5R_p$ (Type 1) or R_p (Type 2) Basin Depression m (ft)

Table 11-14 solves the above set of equations for Type 1 and 2 preformed scour holes for various pipe sizes.

The type of riprap required is as follows:

Modified	d_{50} < 0.13m (0.42 ft)
Intermediate	0.13m (0.42 ft) < d_{50} < 0.20m (0.67 ft)
Standard	0.20m (0.67 ft) < d_{50} < 0.38m (1.25 ft)
Special Design	0.38m (1.25 ft) < d_{50}

Reference: Report No. FHWA-RD-75-508 ("Culvert Outlet Protection Design: Computer Program Documentation")

OUTLET PROTECTION - OUTLET VELOCITY ≤ 4.27 meters/sec

	OUTLET PIPE DIAMETER OR SPAN (mm)									
DISCHARGE	300	375	450	600	750	900	1050	1200	1350	1500
(cms)										
0-0.142	***3.0***	***3.0***		***USE***						
0.170	3.6	3.4								
0.180		3.6	***3.5***							
0.190		3.7	3.6			***MINIMUM***				
0.210		4.0	3.8	***3.5***						
0.250		4.5	4.2	3.8						
0.275			4.5	4.0						
0.300			4.7	4.1				***LENGTH***		
0.325			5.0	4.3						
0.340				4.4	***4.0***					
0.350				4.5	4.1					
0.400		***USE***		4.8	4.3	***4.0***			***OUTLINED***	
0.450				5.2	4.6	4.2	***4.0***			
0.500				5.5	4.8	4.4	4.1			
0.550					5.0	4.6	4.3	***4.0***		
0.600					5.3	4.8	4.4	4.2		
0.650					5.5	4.9	4.6	4.3		
0.800				***PREFORMED***		5.5	5.0	4.6		
0.940						6.0	5.4	5.0		
1.000							5.6	5.1		
1.100							5.9	5.4	***5.0***	
1.250							6.3	5.7	5.3	***5.0***
1.300							6.5	5.9	5.4	5.1
1.500					***SCOUR***			6.3	5.8	5.4
1.700								6.8	6.2	5.7
1.900								7.3	6.6	6.1
2.200								8.0	7.2	6.6
2.500									7.8	7.1
2.850									8.5	7.7
3.250							***HOLE***			8.4
3.600										9.0

Table 11-12 - Length - L_a (meters)
Type A Riprap Apron

Notes: 1. Bold face outlined boxes indicate minimum L_a to be used for a given pipe diameter or span.
2. Rounding and interpolating are acceptable.

OUTLET PROTECTION - OUTLET VELOCITY ≤ 14 feet/sec

DISCHARGE (cfs)	OUTLET PIPE DIAMETER OR SPAN (in)									
	12	15	18	24	30	36	42	48	54	60
0-5	***10***	***10***		***USE***						
6	12	11								
7		13	***12***							
8		14	13	***12***		***MINIMUM***				
9			14	13						
10			15	13						
11			16	14				***LENGTH***		
12				14						
14				16	***14***					
16				17	15	***14***			***OUTLINED***	
18				18	16	15				
20					17	15	***14***			
22		***USE***			18	16	15			
24						17	15	***14***		
26						17	16	15		
28						18	16	15		
30						19	17	16		
35						20	18	17	***16***	
40				***PREFORMED***			20	18	17	***16***
45							21	19	18	16
50							22	20	18	17
55								21	19	18
60								22	20	19
65								24	21	20
70					***SCOUR***			25	22	20
75								26	23	21
80									24	22
90									26	24
100									28	25
110										27
125							***HOLE***			29
130										30

Table 11-12.1 - Length - L_a (feet)
Type A Riprap Apron

Notes: 1. Bold face outlined boxes indicate minimum L_a to be used for a given pipe diameter or span.
2. Rounding and interpolating are acceptable.

OUTLET PROTECTION - OUTLET VELOCITY ≤ 4.27 meters/sec

	OUTLET PIPE DIAMETER OR SPAN (mm)									
DISCHARGE (cms)	300	375	450	600	750	900	1050	1200	1350	1500
0-0.142	***3.0***	***3.0***			***USE***					
0.170	4.0	3.7	***3.5***							
0.180		3.9	3.7	***3.5***		***MINIMUM***				
0.190		4.2	3.9	3.6						
0.200		4.4	4.1	3.7	**3.5**					
0.205		4.5	4.2	3.8	3.6					
0.227			4.5	4.0	3.7			***LENGTH***		
0.250			5.0	4.3	3.9					
0.275				4.6	4.1					
0.300				4.9	4.3	***4.0***				
0.320				5.1	4.5	4.2			***OUTLINED***	
0.340				5.3	4.7	4.3	***4.0***			
0.360		***USE***		5.5	4.8	4.4	4.1			
0.380					5.0	4.5	4.2	***4.0***		
0.410					5.2	4.7	4.4	4.1		
0.440					5.5	4.9	4.5	4.3		
0.500						5.3	4.8	4.5		
0.560						5.7	5.1	4.7		
0.620				***PREFORMED***		6.0	5.4	5.0		
0.660							5.6	5.1		
0.730							6.0	5.4	***5.0***	
0.800							6.3	5.7	5.3	***5.0***
0.850							6.5	5.9	5.4	5.1
1.000								6.5	6.0	5.5
1.120					***SCOUR***			7.0	6.4	5.9
1.250								7.5	6.8	6.3
1.370								8.0	7.2	6.6
1.500									7.6	7.0
1.630									8.1	7.4
1.750									8.5	7.7
1.975							***HOLE***			8.4
2.200										9.0

Table 11-13 - Length - L_a (meters)
Type B or C Riprap Apron

Notes: 1. Bold face outlined boxes indicate minimum L_a to be used for a given pipe diameter or span.
2. Rounding and interpolating are acceptable.

OUTLET PROTECTION - OUTLET VELOCITY ≤ 14 feet/sec

DISCHARGE (cfs)	OUTLET PIPE DIAMETER OR SPAN (in)									
	12	15	18	24	30	36	42	48	54	60
0-5	***10***	***10***		***USE***						
5.5	12	11								
6		12	***12***			***MINIMUM***				
7		14	13	**12**						
8			15	13						
8.5			16	14				***LENGTH***		
9				14						
10				15	***14***					
11				16	15					
12				17	15	***14***			***OUTLINED***	
13				18	16	15				
14					17	15	***14***			
16		***USE***			18	16	15	***14***		
18						18	16	15		
20						19	17	16		
22						20	18	16		
24							19	17	***16***	
26							20	18	17	***16***
28				***PREFORMED***			21	19	17	16
30							21	19	18	17
32							22	20	18	17
35								21	19	18
40								23	21	19
45								25	23	21
48					***SCOUR***			26	24	22
50									24	22
55									26	23
60									27	25
63									28	26
65										26
75							***HOLE***			29
80										30

Table 11-13.1 - Length - L_a (feet)
Type B or C Riprap Apron

Notes: 1. Bold face outlined boxes indicate minimum L_a to be used for a given pipe diameter or span.
2. Rounding and interpolating are acceptable.

OUTLET PROTECTION
OUTLET VELOCITY > 4.27 meters/sec or Length of Apron exceeds limits shown on Tables 11-12 and 11-13

Preformed Scour Hole										
(See Figure 11-15)	PIPE DIAMETER OR SPAN (mm)									
	300	375	450	600	750	900	1050	1200	1350	1500
Type 1										
B	1.5	1.9	2.3	3.0	3.8	4.6	5.3	6.1	6.9	7.6
C	1.8	2.3	2.7	3.7	4.6	5.5	6.4	7.3	8.2	9.1
d	Depends on riprap type (see Figure 11-15)									
$2S_p$	0.6	0.8	1.0	1.2	1.6	1.8	2.2	2.4	2.8	3.0
$F = 0.5 S_p$	0.2	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8
$3S_p$	0.9	1.2	1.5	1.8	2.4	2.7	3.3	3.6	4.2	4.5
Type 2										
B	2.4	3.0	3.7	4.9	6.1	7.3	8.5	9.8	11.0	12.2
C	2.7	3.4	4.1	5.5	6.9	8.2	9.6	11.0	12.3	13.7
d	Depends on riprap type (see Figure 11-15)									
$2S_p$	0.6	0.8	1.0	1.2	1.6	1.8	2.2	2.4	2.8	3.0
$F = S_p$	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.5
$3S_p$	0.9	1.2	1.5	1.8	2.4	2.7	3.3	3.6	4.2	4.5

Table 11-14 - Dimensions of Preformed Scour Hole (Meters)

OUTLET PROTECTION
OUTLET VELOCITY > 14 feet/sec or Length of Apron exceeds limits shown on Tables 11-12.1 and 11-13.1

Preformed Scour Hole										
(See Figure 11-15)	PIPE DIAMETER OR SPAN (in)									
	12	**15**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**
Type 1										
B	5	6	8	10	13	15	18	20	23	25
C	6	8	9	12	15	18	21	24	27	30
d	Depends on riprap type(see Figure 11-15)									
$2S_p$	2.0	2.6	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
$3S_p$	3.0	3.9	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0
$F = 0.5\ S_p$	0.5	0.625	0.75	1	1.25	1.5	1.75	2	2.25	2.5
Type 2										
B	8	10	12	16	20	24	28	32	36	40
C	9	11	14	18	23	27	32	36	41	45
d	Depends on riprap size (see Figure 11-15)									
$2S_p$	2.0	2.6	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
$3S_p$	3.0	3.9	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0
$F = S_p$	1.0	1.3	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0

Table 11-14.1 - Dimensions of Preformed Scour Hole (Feet)

11.13.7 Design Procedure for Riprap Outlet Protection

Outlet protection consists of the construction of an erosion resistant section between a conduit outlet and a stable downstream channel. Erosion at an outlet is chiefly a function of soil type and the velocity of the conduit discharge. Therefore, in order to mitigate erosion, an adequate design must stabilize the area at the conduit outlet and reduce the outlet velocity to a velocity consistent with a stable condition in the downstream channel.

This section presents a generalized procedure for the design of riprap outlet protection. Although each project will be unique, the design outlined below will normally be applicable.

Step 1. Assess the Erosion Potential at the Outlet and other Critical Site Factors

For all proposed outlet locations including existing outlet locations to be used on the project:

A. A field investigation should be conducted to determine the erosion resistance of the soils at the outlet, the character of the downstream flow path, and any other site constraints that must be addressed by the proposed design.

B. Prepare a site description and a sketch (channel cross section, where appropriate) for the outlet location.

C. Ensure that field survey limits extend far enough to adequately show the proposed outlet protection design, downstream flow path, drainage right-of-way and any other important topographic features on the design plans

Step 2. Determine Tailwater Conditions at the Outlet

A. See Section 11.13.4 and Sections 8.3.5 and 8.3.6 for further information on how to determine the tailwater depth.

B. If the pipe outlet discharges into a well-defined channel, estimate the existing velocity in the receiving channel using Manning's Equation (Equation 7.6, Section 7.4.11). See Section 8.3.8 regarding Maximum Velocity.

Step 3. Calculate the Outlet Velocity for the Design Discharge

Culvert outlet velocity is one of the primary indicators of erosion potential and will serve in most instances to define the outlet protection required.

The continuity equation Q=AV (Equation 7.5, Section 7.4.11) can be utilized in all situations to compute the average velocity at any point within a conduit. For conduits flowing partly full, however, the location of the water surface and consequently the area of flow cannot always be easily determined.

The following procedure for the calculation of outlet velocity will produce results, which, though approximate, will be adequate for most design purposes.

A. Determine the design discharge for the conduit based on the design return frequency.

B. See Step 2 A. for the tailwater (TW) acting at the outlet pipe.

C. Calculate the outlet velocity.

Step 4. Evaluate the Outlet Velocity

If the outlet velocity is considered excessive for site conditions or exceeds 4.27 mps (14 fps), the designer should investigate methods to reduce the outlet velocity. These may include any one or combination of the following:

- increasing the pipe roughness
- increasing the pipe size
- decreasing the culvert slope

It should also be noted that the above methods may be employed at velocities less than 4.27 mps (14 fps) when it desired to reduce the size of riprap required at the outlet.

For instance, a 450-mm (18-inch) pipe has a design discharge of 0.3 cms (10 cfs) and an outlet velocity of 3.66 mps (12 fps). Table 11.11 indicates that standard riprap would be required at the outlet, however, it may be more practical to employ the above methods for reducing the exit velocity, so that modified or intermediate riprap can be used in lieu of standard riprap.

Step 5. Select an Appropriate Type of Outlet Protection Design

Review Section 11.13.2 describing the Types of Outlet Protection and the Design Criteria in Section 11.13.3, which will be used in the selection of the type and size of the outlet protection. The type of outlet protection and design criteria presented in these Sections are summarized below:

TYPE	OUTLET VELOCITY mps (fps)	TAILWATER DEPTH	COMMENT
Type A Riprap Apron	≤ 4.27 (14)	≤ ½ pipe rise (minimum condition)	Outlet has no well-defined channel downstream
Type B Riprap Apron	≤ 4.27 (14)	≥ ½ pipe rise (maximum condition)	Outlet has no well-defined channel downstream
Type C Riprap Apron	≤ 4.27 (14)	all	Outlet has a well-defined channel downstream
Preformed Scour Hole	≥ 4.27 (14)	all	May be used for lower exit velocities as dictated by Tables 8-6 and 8-7
Structurally Lined Energy Dissipaters	≥ 4.27 (14)	all	See HEC-14 To be used only with prior approval from Hydraulics and Drainage Section.

Table 11-15 Summary of Outlet Protection Types and Selection Criteria

A. If the outlet velocity, tailwater depth and site conditions indicate that a Type A, B or C Riprap Apron may be used, check Tables 11-12 and 11-13 to see if a Riprap Apron can be used based on the pipe size and discharge.

B. If a Riprap Apron is adequate, Tables 11-12 and 11-13 will specify the length of apron required. Proceed to **Step 6**.

C. If the Tables do not show an apron length, this indicates that the designer should proceed to **Step 7,** using a preformed scour hole design instead of a riprap apron.

   For example, a project has two outlets.

   Outlet No.1 is a 450-mm (18-inch) RCP with an outlet velocity of 2.74 mps (9 fps) and a design discharge of 0.275 cms (9.7 cfs) that outlets onto a flat area with a tailwater depth (TW) less than 200 mm (8 in).

Outlet No.2 is a 600-mm (24-inch) RCP with an outlet velocity of 3.35 mps (11 fps) and a design discharge of 0.500 cms (17.7 cfs) that outlets into a drainage channel with a tailwater depth (TW) of 500 mm (20 in).

Initially, the design parameters indicate that a Type A Riprap Apron and a Type C Riprap Apron would be appropriate for Outlet No. 1 and 2, respectively.

Next, Table 11-12 is checked for Outlet No. 1 with the design discharge and shows that a Type A Riprap Apron could be used with a required length of 4.5-m (15-ft.). Table 11-13 is checked for Outlet No. 2 and shows that the design discharge falls outside the limit for the use of a Type C Riprap Apron and that a preformed scour hole design should be used.

Step 6. Riprap Apron Dimensions

The designer has determined in **Step 5** that a riprap apron is appropriate at the outlet location. Riprap apron dimensions are discussed in Section 11.13.5 and are determined as follows:

A. The length of apron (L_a) is determined from Tables 11-12 and 11-13 or Equations 11.31 and 11.32. **It should be noted, however, that the Tables are required to determine the minimum and maximum length of apron that can be used for a given pipe size and discharge.** The length of apron is shown on Figures 11-13 and 11-14.

B. The width of the upstream (W_1) and downstream W_2) apron limit for the Type A and B Riprap Apron are computed using Equations 11.33 and 11.34, respectively, or as shown on Figure 11-13. The width of a Type C Riprap Apron (W_3) is determined as described in Section 11.13.5 or as shown on Figure 11-14.

Step 7. Preformed Scour Hole Design

The designer has determined in **Step 5** that the outlet velocity, Tables 11-12 and 11-13 or site conditions dictate that a preformed scour hole is required for outlet protection. The design is discussed in Section 11.13.6 and summarized as follows:

A. Compute the median stone size (d_{50}) required for both the Type 1 and 2 Preformed Scour Holes using Equations 11.35 and 11.36, respectively.

B. Compute the scour hole dimensions for both types using the set of equations labeled 11.37 or Figure 11-15.

C. Compare the values computed in Steps 7A and 7B for the two preformed scour hole types and select the one that provides the most economical and practical design given the site conditions.

Step 8. Special Design

In unusual cases where neither a riprap apron nor preformed scour hole can be used, and a special design is required, HEC-14 can be used to design an alternative energy dissipater. These designs, however, require prior approval from the Hydraulics and Drainage Section.

Step 9. Prepare Outlet Protection Computation Form

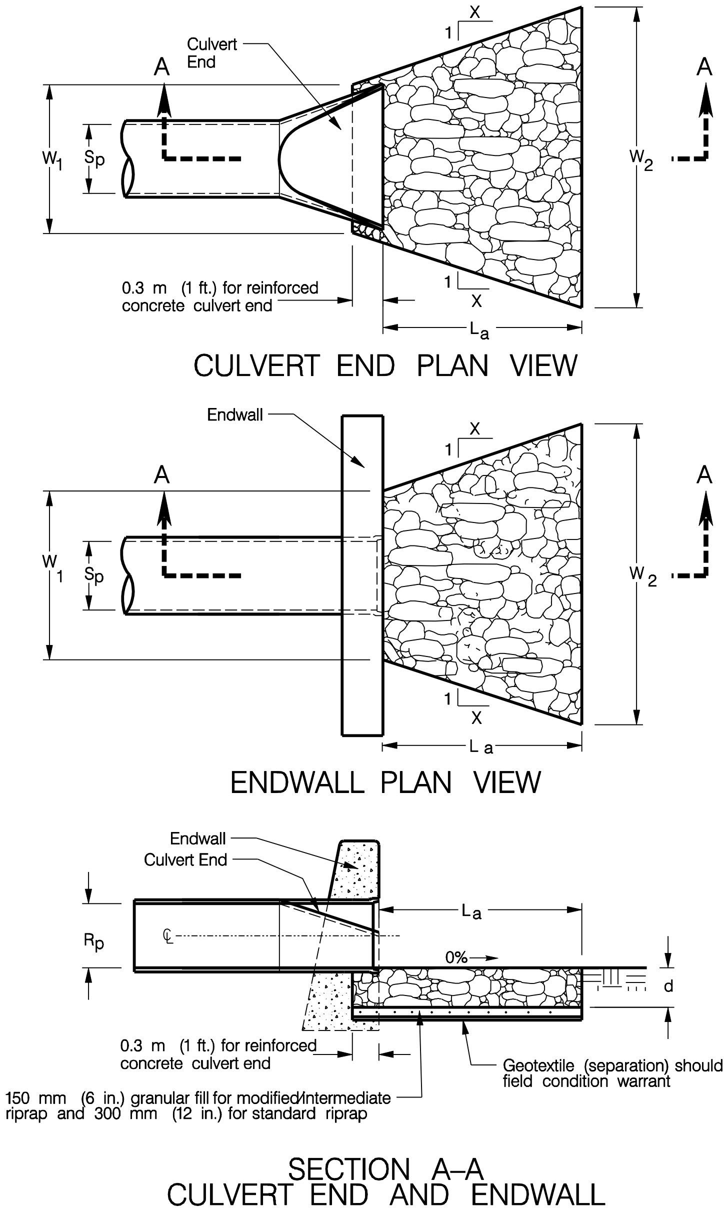
See Appendix A for form.

Step 10. Project Plans

The following information is required on the project plans for outlet protection:

TYPE	**PLANS**	**DETAILS**
Type A, B & C Riprap Apron	Call out apron type (A,B,C), riprap type & length of apron (L_a). Show apron limits.	Include detail(s) similar to Figures 11-13 & 11-14
Preformed Scour Hole Type 1 & Type 2	Call out type & riprap size. Show limits.	Include a detail similar to Figure 11-15.

Table 11-16 Outlet Protection Plan Requirements



LEGEND

S_p = Max. inside pipe span (non–circular sections); Inside pipe diameter (circular sections)

R_p = Max. inside pipe rise (non–circular sections); Inside pipe diameter (circular sections)

L_a = Length of riprap apron measured from the end of culvert end section or face of endwall

d = 300 mm (12 in.) Modified Riprap; 450 mm (18 in.) Intermediate Riprap; 900 mm (36 in.) Standard Riprap

	X	W_1	W_2
Type A Riprap Apron	3	$3S_p$	$3S_p + 0.7$ La
Type B Riprap Apron	5	$3S_p$	$3S_p + 0.4$ La

Figure 11-13 Type A and B Riprap Apron
(to be used where there is no defined channel downstream of the outlet)

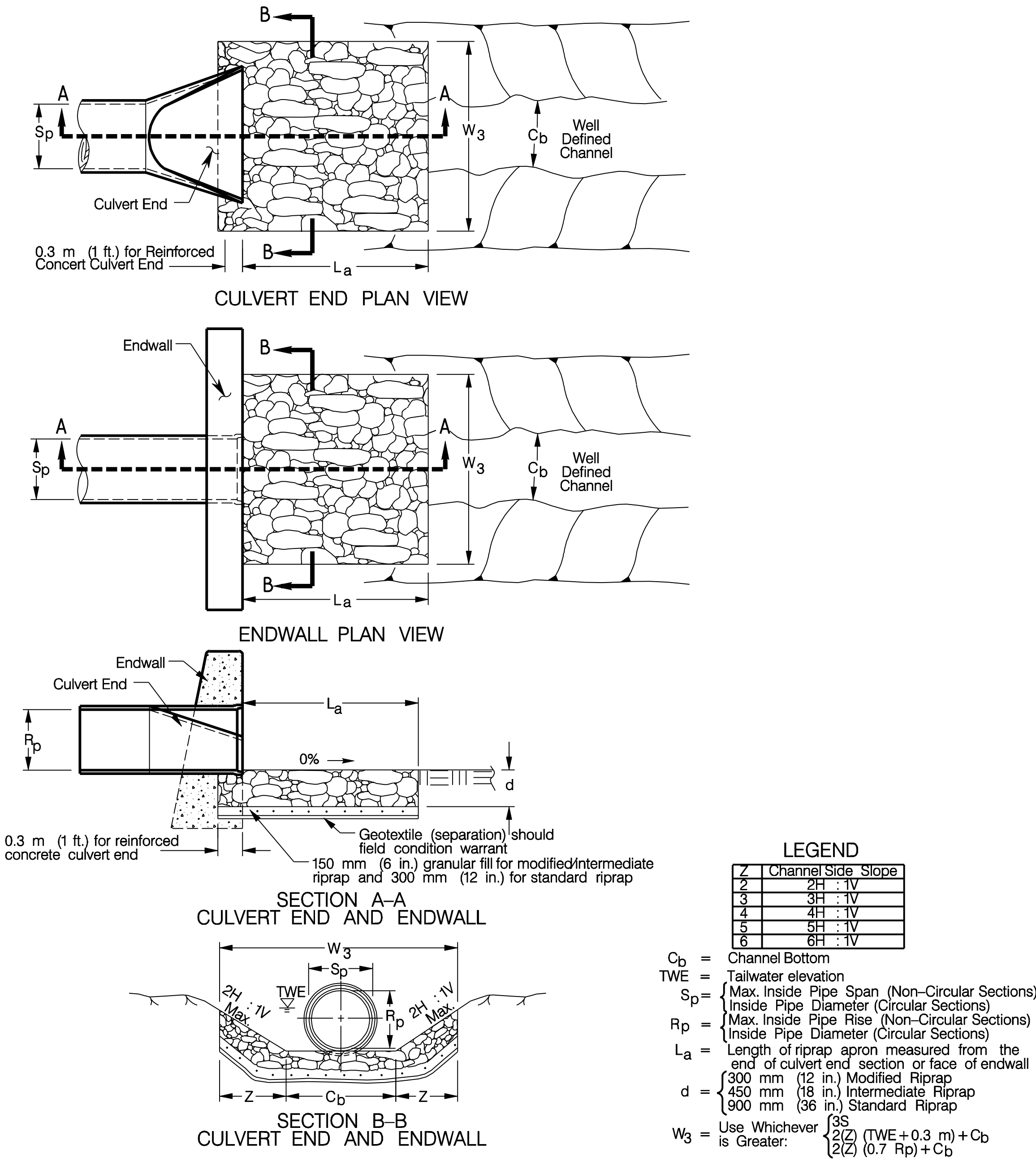


Figure 11-14 Type C Riprap Apron
(to be used where there is a well defined channel downstream of the outlet)

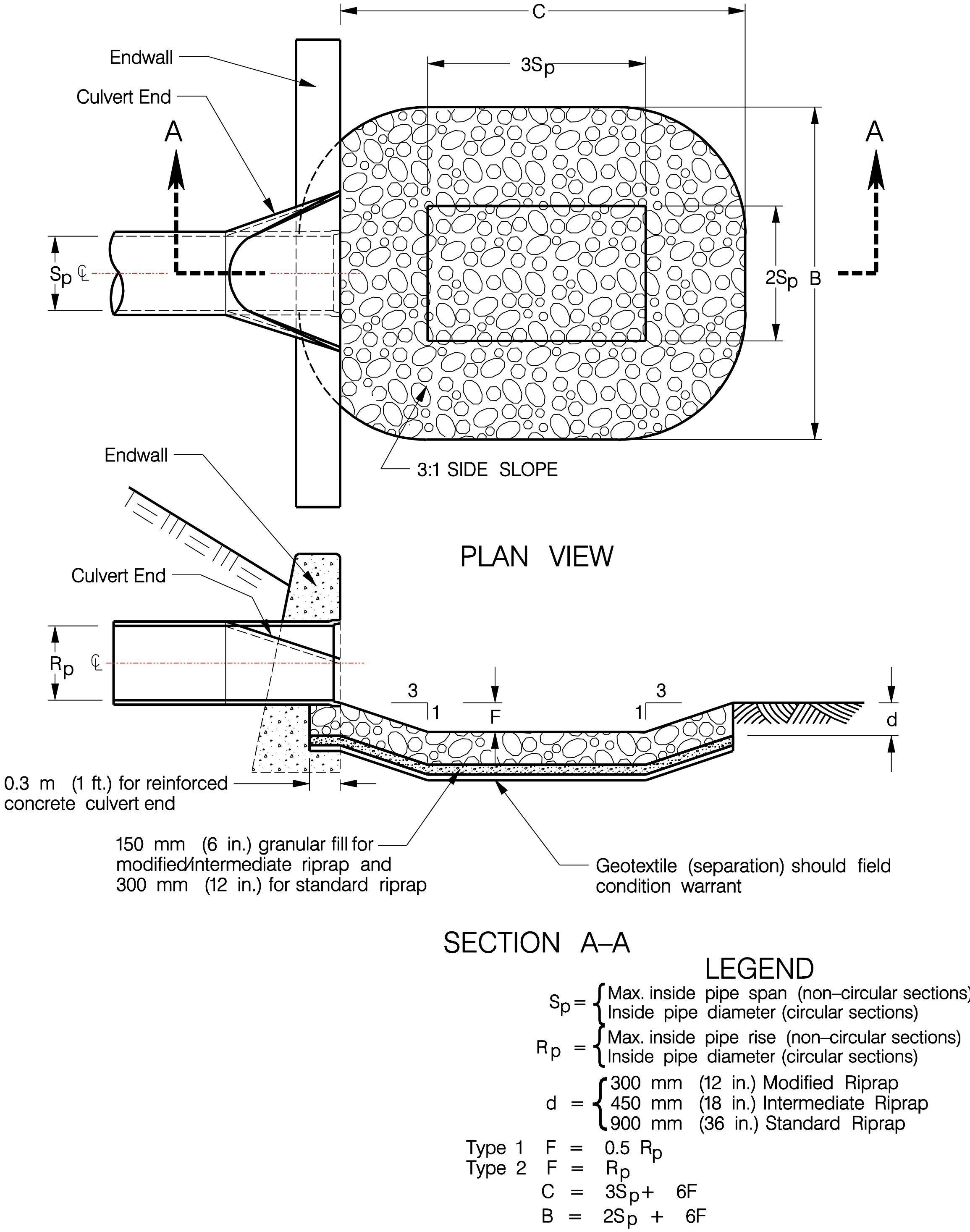


Figure 11-15 Preformed Scour Hole Type 1 and Type 2