***Objective:*** Determine rip-rap outfall apron size, gradation and thickness that will decrease discharge velocities and prevent downstream erosion.

***Methodology:*** U.S. Federal Highway Administration, 2006, Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Center Circular No. 14. (section 10.2 Riprap Apron)

***Design Criteria:***

| Location | | Pipe Diameter (ft) | *Design Flow Q (cfs) | |
|---|---|---|---|---|
| (Point Discharge) | HW-1 | 1.25 | 6.40 | 25-yr, 24-hr, type III |
| | | | | |

*Refer to HydroCAD 25-year storm for determination of Q (cfs)

| Location | | **Velocity (ft/sec) | **TW (ft) |
|---|---|---|---|
| (Point Discharge) | HW-1 | 8.1 | 0.8 |
| | | | |

**Refer to HydroCAD 25-year storm for determination of V (fps) and TW

***Calculations:*** **Riprap Apron Stone Sizing** (Use Fractured Stone Only w/ S.G of 2.65 or similar)

**d50 = 0.2 * Dia * (Q/√g*Dia^2.5)^4/3 * (Dia/TW)**

Where:
d50 = Median Stone Diameter
TW = Tailwater Height (ft)
Dia = Pipe Diameter (ft)
Q = Flow (cfs)
g = acceleration due to gravity (32.2 ft/sec^2)

Tailwater Check: Min TW is 0.4D

| | | | |
|---|---|---|---|
| Min. TW | 0.4 (1.25ft) | 0.50 | ft |

**Use TW = 0.5 ft**

| Location | | D50 (ft) | D50 (in) |
|---|---|---|---|
| (Point Discharge) | HW-1 | 0.188 | 2.256 |
| | | | |

**Use d50 = 6.0 in**

**Use d50 = 6.0 in** (Min. Size) Apron Depth (in): Min. 3x(d50) **Use d = 18.0 in**

**Apron Dimensions:** L=1.8Q/Dia1.5 + 7Dia Apron Length (ft): 14.89 **Use L = 16.0 ft**

Where:
Dia = Pipe Diameter (ft)
L = Apron Length
W = Apron Width
d= Apron Depth

W = Dia + 0.4L
Min 3x(Dia.)

Apron Width (ft): 7.21 **Use W = 8.0 ft**

| Gadation Summary: d50 = 6.0 inch | |
|---|---|
| % Passing | Stone Size |
| 100 | 9.0 |
| 50-70 | 8.0 |
| 35-50 | 6.0 |
| 0 - 35 | 3.0 |

***Design Summary:***

| Location | | Apron Dimensions | | | |
|---|---|---|---|---|---|
| | | Length (ft) | Width (ft) | Depth (in) | d50 (in) |
| **(Point Discharge)** | **HW-1** | **16.0** | **8.0** | **18.0** | **6.0** |
| | | | | | |

***Project Disclaimer:***
The design information, figures, calculations, results and engineering judgement contained on this spreadsheet are project specific and are intended to generate riprap outlet protection specifications, based on hydraulic analysis. The results contained hereon may not be re-used, duplicated or revised, without prior review and written approval from the design engineer of record.