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Hydraulic Structures - Conduit Outlets

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Module 3: Conduit Outlet Structures

Learning Objectives

By the end of this section, you will be able to:

- **Select** the most effective energy dissipation structure based on hydraulic exit conditions, tailwater control, and site-specific constraints.
- **Calculate** critical design dimensions and hydraulic parameters for USBR Type VI impact stilling basins and low tailwater riprap basins.
- **Identify** requirements for culvert outlet protection to mitigate local scour and general stream degradation.

Executive Summary: Energy dissipation or stilling basin structures are mandatory to minimize scour damages caused by high exit velocities and turbulence at conduit and culvert outlets. This chapter provides design criteria for concrete impact basins, baffle chute rundowns, and low tailwater riprap basins. Engineers must analyze tailwater ranges and bed conditions, including degradation and local scour, to match structure selection to the receiving stream. While rock protection is common, reinforced concrete structures are often more economical for high-energy settings or space-limited sites.

Design Fundamentals

Energy dissipation structures are required to minimize scour damages at conduit and culvert outlets. Reinforced concrete structures are suitable for a wide variety of site conditions and can be more economical than large rock basins when considering long-term costs.

Criteria for Conduit Outlet Structure Selection

Selection should include a concrete structure if any of the following conditions exist:

- High-energy dissipation efficiency is required where conditions approach or exceed limits for alternate designs.
- Low tailwater control is anticipated.
- Site conditions involve public use areas where plunge pools or standing water are unacceptable for safety and appearance.
- Space limitations necessitate a compact concrete structure.

Large cross-sectional conduits with high discharges require spillway terminal technology, such as Type II, III, or IV stilling basins.

Riprap Size

The appropriate riprap size and type (L, M, H, or B18) are determined using the design velocity and Figure HS-20c. The initial step involves calculating the riprap sizing design parameter, **Pd**:

Equation 3-5:

$$P_d = \frac{V}{(g \cdot d)^{0.5}}$$

Where:

- **Pd** = riprap sizing design parameter
- **V** = design flow velocity at pipe outlet (ft/sec)
- **g** = acceleration due to gravity = 32.2 ft/sec²
- **d** = design depth of flow at pipe outlet (ft)



Photograph HS-12. Upstream and downstream views of a low tailwater basin in Douglas County protecting downstream wetland area. Burying and revegetation of the rock would blend the structure better with the adjacent terrain.

If the calculated **Pd** falls above the Type H riprap line in Figure HS-20c, engineers must use **B18** or larger grouted boulders, or consider a USBR Impact Basin VI.

Once the size is selected, determine the minimum thickness (**T**) of the riprap layer:

Equation 3-6 (HS-17):

$$T = 1.75 \cdot D_{50}$$

Where:

- **T** = minimum thickness of the riprap layer
- **D50** = median size of the riprap from Table HS-9

Table HS-9. Median (i.e., D50) Size of District's Riprap/Boulder

Riprap Type	D_{50} —Median Rock Size (inches)
L	9
M	12
H	18
B18	18 (minimum dimension of grouted boulders)

Basin Length

The minimum basin length (**L**) is the greater value derived from the following calculations:

For Circular Pipe: (Equation HS-18)

$$L = 4D \text{ or } L = D^{0.5} \cdot \left(\frac{V}{2}\right)$$

Where:

- **L** = basin length (the greater value derived from the calculations)
- **D** = diameter of circular conduit
- **V** = design flow velocity at outlet

For Rectangular Pipe:

$$L = 4H \text{ or } L = H^{0.5} \cdot \left(\frac{V}{2}\right)$$

Where:

- **L** = basin length (the greater value derived from the calculations)
- **H** = height of rectangular conduit
- **V** = design flow velocity at outlet

Basin Width

Determine the minimum width (**W**) of the basin downstream of the flared end section as follows:

For Circular Pipes: Equation 3-7 (HS-20):

$$W = 4D$$

For Rectangular Pipes: Equation 3-8 (HS-21):

$$W = w + 4H$$

Where:

- **W** = basin width
- **D** = diameter of circular conduit
- **w** = width of rectangular conduit
- **H** = height of rectangular conduit

Other Design Requirements

- **Slopes:** All slopes within the pre-shaped riprap basin must be **2H to 1V**.
- **Fasteners and Cutoff Walls:** Provide pipe joint fasteners and a structural concrete cutoff wall at the end of the flared section or headwall.
- **Cutoff Wall Depth (B): Equation 3-9 (HS-22):**

$$B = \frac{D}{2} + T \text{ or } B = \frac{H}{2} + T$$

Where:

- **B** = cutoff wall depth
- **D** = diameter of circular conduit
- **H** = height of rectangular conduit
- **T** = minimum thickness of the riprap layer
- **Embankment Protection:** Riprap must extend up the outlet embankment slope to the **mid-pipe level**.

Culvert Outlets



Photograph HS-13. Culvert outlets when left unprotected cause downstream erosion. The designer’s job is not complete until provisions are made to protect the outlet. Use of vegetated soil-riprap would blend this structure better into the natural landscape.



Culvert design is incomplete without dedicated attention to outlet hydraulics and discharge stilling. Concentrated discharges and turbulence often require special structures to limit local scour and stream degradation.

Hydraulic Challenges

- **Local Scour:** High exit velocities create a scour hole at the outlet. This hole is generally deepest during passage of flow when tailwater depth is **minimal**, rather than during peak flow.
- **Stream Degradation:** Natural streambed lowering (head cutting) can occur independently or be accelerated by high-energy culvert discharges.

Available Control Measures (HEC No. 14)

1. Colorado State University rigid boundary basin
2. Tumbling flow rectangular section
3. Increased resistance—box culverts
4. Roughness elements—circular culverts
5. USBR Type II, III, and IV basins
6. Contra Costa and Hook-type energy dissipators
7. Straight drop structures and riprap basins
8. Properly anchored flared end sections (Figure HS-19a)

Impact Stilling Basin

Design standards are based on the **USBR Type VI basin**, which is a relatively small structure that is highly efficient in dissipating energy without requiring tailwater. Dissipation is achieved through turbulence created by the loss of momentum as flow impacts a large overhanging baffle.



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