6. ENERGY DISSIPATION

6.1 Overview

The failure or damage of many culverts, storm sewer outfalls, and detention basin outlet structures can be traced to unchecked erosion and scour. When the outlet velocity from a culvert or storm sewer outfall cannot be reduced to acceptable levels by other means, the flow energy should be dissipated before the discharge is returned to the downstream channel. Prior to designing an energy dissipator, the designer should try to reduce outlet velocity of the culvert by:

- Choosing gentler slopes, if possible.
- Installing a "soil saver" or depressed inlet end section at the inlet and lowering the slope of the culvert.
- Designing a broken back culvert with a flat outlet section (See Chapter 5: Design of Culverts for more information on culvert design).
- Installing a drop manhole at the last manhole upstream of the storm sewer outfall.

6.2 Design Criteria

An energy dissipator should be constructed when the outlet velocity of a culvert exceeds the values shown in Table 6-1. The flood frequency used in the design of the energy dissipator shall be the same flood frequency used for the culvert or storm sewer design.

Table 6-1. Requirements for Energy Dissipation

Design Flow Outlet Velocity	Energy Dissipation Requirement
Less than 8 ft/sec	Not Required
8 to 10 ft/sec	Evaluate on a Case-by-Case Basis
Greater than 10 ft/sec	Required

6.2.1 Dissipator Type Selection

The dissipator type selected for a site must be appropriate to the location. In this chapter, the terms "internal" and "external" are used to indicate the location of the dissipator in relationship to the culvert. An internal dissipator is located within the culvert barrel, and an external dissipator is located outside the culvert. For internal energy dissipation, the hydraulic jump occurs within the culvert barrel; for external energy dissipation, the hydraulic jump occurs outside the barrel.

For many designs, the following external energy dissipators provide sufficient protection at a reasonable cost and can be used when the following outlet conditions exist. Design procedures for these and other energy dissipators can be found in the most recent edition of Hydraulic Engineering Circular No. 14: Hydraulic Design of Energy Dissipators for Culverts and Channels (HEC 14).

- Riprap Apron
  - A riprap apron consists of riprap placed at the outlet of a drainage structure and reduces velocity by increasing the roughness of the outlet channel. Riprap aprons may be applicable if the outlet Froude number is 2.5 or lower. Refer to Chapter 4 Open Channels for a discussion of the Froude number. In general, riprap aprons prove economical for transitions from stormwater conveyance facilities to overland sheet flow at terminal outlets but may also be used for transitions from conveyance outlets to stable channel sections. Riprap aprons are typically used for storm sewer or culverts up to 60 inches in diameter. Stability of the surface at the termination of the apron needs to be considered.

- Riprap Basin (or Pre-formed Scour Hole)
  - A riprap basin or preformed scour hole is an excavated hole or depression that is lined with riprap of a stable size and designed to prevent scouring at a culvert outlet. The depression provides both a vertical and lateral expansion of the flow and a temporary stilling pool at the culvert outlet. The depth of the depression for the preformed scour hole is based on the flow velocity and depth at the culvert outlet, and the size of the riprap used to line the depression. A riprap basin may be applicable if the outlet Froude number is 3.0 or lower. Refer to Chapter 4 Open Channels for a discussion of the Froude number. Riprap basins are generally used for transitions from pipe outlets to stable channels. Since they function by creating a hydraulic jump to dissipate energy, their design is impacted by tailwater conditions.
- USBR Type VI Impact Basin
  - The U.S. Bureau of Reclamation (USBR) Type VI impact basin is contained in a relatively small box-like structure that dissipates energy through impact and turbulence and requires no tailwater for successful performance. Although the emphasis in this manual is on its use at culvert outlets, the structure may also be used in open channels. Type VI Impact Basins may be used for outlet flow rates as high as 400 cubic feet per second and velocities as high as 50 feet per second. Impact basins may be used at both terminal outlet and channel outlet transitions.

6.2.2 Design Limitations

6.2.2.1 Ice Buildup

If ice buildup within a culvert pipe or a box culvert is a factor, it shall be mitigated by sizing the structure to not obstruct the winter low flow and by using external dissipators.

6.2.2.2 Debris Control

Design and installation of debris control, consistent with the guidance of the most recent edition of Hydraulic Engineering Circular No. 9: Debris Control Structures (HEC 9), shall be considered where clean-out access is limited and if the dissipator type selected cannot pass debris.

6.2.2.3 Tailwater Relationship

The hydraulic conditions downstream shall be evaluated to determine a tailwater depth and the maximum velocity for a range of discharges according to Chapter 4: Open Channels. Tailwater depths at a lake, a pond or a large water body shall be evaluated using the high-water elevations that have the same frequency as the design storms for the conveyance outlet.

6.2.3 Design Options

6.2.3.1 Material Selection

The material selected for the dissipator shall be based on a comparison of the total cost over the design life of alternate materials and shall not be made using first cost as the only criteria. This comparison shall consider replacement cost and the difficulty of construction as well as traffic delay.

6.2.3.2 Pipe Outlet Type

In choosing a dissipator, the selected pipe end treatment has the following implications:

- Pipe ends that are projecting or mitered to the fill slope offer no outlet protection.
- Headwalls provide embankment stability and erosion protection. They provide protection from buoyancy and reduce damage to the culvert.
- Commercial end sections add little cost and may require less maintenance, retard embankment erosion, and incur less damage from maintenance.
- Concrete aprons do not reduce outlet velocity; if used, they should not protrude above the normal streambed elevation.
- Wingwalls are used where the side slopes of the channel are unstable, where an outlet is skewed to the normal channel flow, to redirect outlet velocity or to retain fill.

6.2.3.3 Safety Considerations.

Traffic shall be protected from external energy dissipators by locating them outside the appropriate "clear zone" distance per the AASHTO Roadside Design Guide or shielding them with a traffic barrier. Protection of the general public (children, bicyclists, skaters, etc.) should also be carefully considered whenever energy dissipators are located in or near parks or other public places.

6.2.3.4 Weep Holes

If weep holes are used to relieve uplift pressure, they shall be designed in a manner similar to underdrain systems.

6.2.4 Related Designs

6.2.4.1 Culverts and Storm Sewer

Culverts and storm sewer shall be designed independently of the dissipator design. The design shall be completed before the outlet protection is designed and shall include computation of outlet velocity.

6.2.4.2 Downstream Channel

Necessary downstream channel protection shall be designed concurrently with dissipator design. A channel that will receive flow from a stormwater outfall or energy dissipator that is to be installed should be analyzed and, if necessary to be stable, designed and stabilized for the distance that it may be affected by the installation of the outfall.

6.3 Design Procedures

Design procedures for energy dissipators described in this chapter, as well as additional energy dissipators, can be found in the most recent edition of HEC 14: Hydraulic Design of Energy Dissipators for Culverts and Channels.

The computer software HY-8 from the Federal Highway Administration contains an energy dissipator module that can be used to analyze most types of energy dissipators described in HEC 14.

6.4 References

- City of Lincoln Public Works and Utilities Department, 2004. *Drainage Criteria Manual.*
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual.*
- Federal Highway Administration, 2005. *Hydraulic Engineering Circular No. 9, Third Edition, Debris Control Structures Evaluation and Countermeasures.*
- Federal Highway Administration, 2006. *Hydraulic Engineering Circular No. 14, Third Edition, Hydraulic Design of Energy Dissipators for Culverts and Channels.*
- Nebraska Department of Transportation, 2006. *Drainage and Erosion Control Manual.*