OP

Outlet Protection

Description

Outlet protection for culverts, storm drains, steep ditches, and flumes is essential to preventing major erosion from damaging downstream channels and drainage structures. Outlet protection can be a channel lining, structure, or flow barrier designed to lower excessive flow velocities from pipes and culverts, prevent scour, and dissipate energy. However, effective outlet protection must begin with efficient storm drainage system design that uses adequately sized pipes, culverts, ditches and channels placed at the most efficient slopes and grades. Good outlet protection will significantly reduce erosion and sediment by reducing flow velocities.

Selection Criteria

Outlet protection is needed wherever discharge velocities and energies at the outlets of culverts, pipes, conduits, channels, or ditches have potential to erode downstream reach.

Design Considerations

The design and analysis of riprap protection, stilling basins, impact barriers, and other types of culvert outlets is very important for stormwater system stability. The first step is to look for ways to reduce the need for outlet protection by efficient storm drainage system design. The last section of pipe (prior to the outlet of a culvert or storm drain) should not be placed at a steeper grade than necessary to adequately convey the design storm. This may require a deeper-than-usual manhole or inlet for the last section of pipe, but any additional costs are usually offset by reduced erosion and better stability due to lower outlet velocities.

Most common temporary or permanent outlet protection is riprap. Permanent riprap protection should be sized by a professional engineer as part of the storm drainage design, using guidelines in the Riprap BMP section of this manual to specify sound and durable crushed rock. Riprap outlet protection is usually less expensive and easier to install than concrete aprons or other energy dissipaters. A riprap channel lining is flexible and adjusts to settlement; it also serves to trap sediment and reduce flow velocities.

Outlet Velocity

The primary factor in selecting the type of outlet protection is determining the outlet velocity for culverts, which is dependent upon the type of flow profile associated with the design storm. The culvert flow may be controlled by the type of inlet, the throat section, the pipe capacity, or by the type of outlet. The type of control may change from outlet control to inlet control, for example, depending on the flow value. Culvert design is fully described in FHWA Hydraulic Design Series No. 5, Hydraulic Design of Highway Culverts (see reference). For inlet control (including throat section), the outlet velocity is assumed to be normal depth as computed by Manning's equation. For outlet control, the outlet velocity is found by using Manning's equation with the computed tailwater depth or the critical flow depth of culvert, whichever is greater. The entire culvert cross-sectional area is used if the tailwater depth is higher than the top of the culvert opening.

Riprap Aprons

Riprap aprons should not be used to change the direction of outlet flow, for which an impact-type energy dissipater would be more effective. Riprap aprons rely primarily upon a higher Manning's roughness coefficient to slow water velocity into proportions, which are manageable by a properly designed channel.

Place a heavy-duty geotextile filter fabric (see 5.3 Geotextile) upon prepared subgrade, and carefully anchor to avoid damage or movement. Place riprap without excessive drop heights, avoiding damage by equipment tracks or blades. Dumped rock riprap generally has a higher Manning's roughness coefficient than grouted riprap, and is, therefore more effective at slowing stormwater down. However, grouted riprap may be more useful in certain instances. Riprap is generally not adequate at the base of concrete flumes or chutes, and a concrete outlet protection structure is greatly preferred in these instances.

Construct riprap apron at zero percent grade for the specified length L_A and width W_A by using the appropriate D_{50} size of stones interpolated from Table 1. If a curve is needed within the riprap apron, place within the lower reach of apron and use larger riprap sizes in the curved section. The basic design procedure is:

Compute tailwater depth (using normal flow with Manning's equation) for the downstream receiving channel. Select conditions as being Low Tailwater (typically for an undefined channel or greatly oversized channel) or as being High Tailwater (most defined channel shapes). If conditions are unknown, then compute parameters from both sections of table and use the most conservative value.

Compute depth of flow in culvert based upon the particular type of culvert flow control. For inlet control, the outlet velocity is assumed to be normal depth as computed by Manning's equation. For outlet control, the outlet velocity is found by using Manning's equation with the computed tailwater depth or the critical flow depth of culvert, whichever value is greater. The entire culvert cross-sectional area is used if the tailwater depth is higher than the top of the culvert opening.

Interpolate values for riprap apron length (L_A) and riprap median size (D_{50}) from the appropriate portion of Table 1. If the culvert is not flowing full, then adjust these values upwards by the following factors. The median riprap size D_{50} is more sensitive than the apron length L_A. The minimum riprap size D_{50} is 6 inches, which may be specified as TDOT machined Class A-1 riprap as described in the Riprap BMP section of this manual.

Table 1
Rip-Rap Aprons

Flow Depth / Diameter	Increase D_{50} by:	Increase L_A by:
1.00	-----	-----
.90	-----	-----
.80	1.10	-----
.70	1.20	1.05
.60	1.30	1.10
.55	1.40	1.15
.50	1.50	1.20

Energy Dissipaters and Stilling Basins

Structural controls, generally made from precast concrete or from pour-in-place concrete, should be used whenever riprap aprons are inadequate. The design of the energy dissipaters and stilling basins shown in Figure 2 are discussed in the FHWA publication HEC-14, Hydraulic Design of Energy Dissipaters for Culverts and Channels (see reference), which can be downloaded at:

http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm

Stilling basins are used to convert flows from supercritical to subcritical depths by allowing a hydraulic jump to occur. The stilling basin allows a controlled hydraulic jump to occur within the structure over a wide range of flow conditions and depths. Energy dissipaters and stilling basins must be designed by a professional engineer using hydraulic computations. A primary concern for both energy dissipaters and stilling basins is whether sediment and trash can accumulate.

Maintenance

Inspect outlet protection on a regular basis for erosion, sedimentation, scour, or undercutting. Repair or replace riprap, geotextile or concrete structures as necessary to handle design flows. Remove trash, debris, grass, sediment, or burrowing animals as needed. Maintenance may be more extensive if smaller riprap sizes are used, as children may tempt to throw or otherwise displace stones and small rocks.

Limitations

Riprap outlet protection may occupy a large area. The specified grade for a riprap apron is zero percent. It may be difficult to handle large amounts of riprap, given that designed outlet protection is usually at or near the project boundary or property line. An easement may be necessary to maintain riprap outlet protection.

Grouted riprap and concrete structures are subject to upheaval from freeze/thaw action. Weepholes and adequately drained foundations are necessary for these types of outlet protection.

Photo 1 – 2
Outlet Protection

References

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