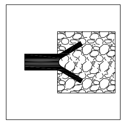
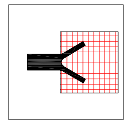
Outlet Protection

Plan Symbol



RipRap



ECB or TRM

Description

Outlet protection dissipates the energy of concentrated storm water flows reducing erosion or scouring at storm water outlets. In addition, outlet protection lowers the potential for downstream erosion. Outlet protection is achieved through a variety of techniques, including turf reinforcement mats (TRMs), riprap, concrete aprons, paved sections and other structural measures.

The techniques outlined in this section are not the only techniques that may be used for outlet protection design. This section shows one method for outlet protection design as an example of the variables that need to be considered in the design. Other methods utilized that are not discussed in this Handbook should include all graphs, charts, and calculations verifying that the protection will handle the peak flow velocity, flow depths, and shear stress.

Outlet Protection Design Criteria

The design of outlets for pipes and channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous lining and protection of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10 percent should not be protected using just outlet protection. This causes re-concentration of the flow resulting in increased velocities when the flow leaves the protection area. Outlet protection may be designed according to the following criteria:

1. The design flow velocity exiting the outlet at design capacity **should not** exceed the permissible velocity of receiving area.

2. Tailwater Depth:
   Tailwater is the water depth at the downstream end or outfall of the culvert. The depth of tailwater immediately below the outlet protection must be determined for the design capacity of the pipe.

   Minimum Tailwater Condition is defined as a tailwater depth less than ½ the diameter of the outlet pipe. Pipes that outlet onto flat areas with no defined channel have a minimum tailwater condition.

   Maximum Tailwater Condition is defined as a tailwater depth greater than ½ the pipe diameter.

3. Protection Length:
   The required protection length, L_a, according to the tailwater condition, should be determined from Figure OP1(minimum tailwater condition) or Figure OP2 (maximum tailwater condition).

4. Protection Width: When the pipe discharges directly into a well-defined channel, the protection should extend across the channel bottom and up the channel banks to an elevation one foot above the Maximum Tailwater depth or to the top of the bank (whichever is less).

- If the outlet discharges onto a flat area with no defined channel, the width of the protection should be determined with a Minimum Tailwater Condition:

  Design the upstream end of the protection, adjacent to the outlet, with a width three times the diameter of the outlet pipe (3D). Design the downstream end of the protection with a width equal to the pipe diameter plus the length of the apron ($D + L_a$).

- For a Maximum Tailwater Condition, design the downstream end of the protection with a width equal to the pipe diameter plus 0.4 times the length of the apron ($D + 0.4 * L_a$).

5. Bottom Grade: Construct the protection with no slope along its length (0 percent grade) where applicable. The downstream invert elevation of the protection is equal to the elevation of the invert of the receiving channel. There is no overfalling at the end of the protection.

6. Side Slopes: If the outlet discharges into a well-defined channel, the receiving side slopes of the channel should not be steeper than 3H: 1V.

7. Alignment: Locate the protection so there are no bends in the horizontal alignment.

8. Materials:

- The preferred protection lining is an appropriate permanent turf reinforcement matting (TRM). Calculate the shear stress and maximum velocity to determine the applicable TRM.
- When conditions are too severe for TRMs the protection may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median-sized stone for riprap may be determined from design figures according to the tailwater condition.
- In all cases, place a non-woven geotextile filter cloth between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the required physical properties for filter cloth.

Installation

- Do not protect pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% with only outlet protection. This causes re-concentration of the flow that results in large velocities when the flow leaves the protection area.
- Follow specific standards for installation of the selected materials used for outlet protection.
- Follow all Manufacturer's installation procedures for TRMs and other manufactured products.
- A Manufacturer's Representative may be required to oversee all installation procedures and officially approve the installation of manufactured products used for outlet protection.

Inspection and Maintenance

- Periodically check all outlet protection, aprons, plunge pools, and structural outlets for damage. Immediately make all needed repairs to prevent further damage.
- If any evidence of erosion or scouring is apparent, modify the design as needed to provide long term protection (keeping in mind fish passage requirements if applicable).
- Inspect outlet structures after heavy rains to see if any erosion has taken place around or below the structure.

Outlet Protection Design Example

Given: An 18-inch pipe discharges 24 cfs at design capacity onto a grassy slope (no defined channel).
Find: The required length, width, and median stone size **(d_{50})** for riprap lined protection.
Solution:

1. The pipe discharges onto a grassy slope with no defined channel, a **Minimum Tailwater Condition**.

2. From Figure OP1, the intersection of a discharge of 24 cfs and a pipe diameter **(d)** of 18-inches, Gives a protection length **(L_a)** of 20-feet.

3. From Figure OP1, the intersection of a discharge of 24 cfs and a pipe diameter **(d)** of 18-inches. Gives a median stone size **(d_{50})** of 0.8-ft.

4. The upstream protection width equals 3 times the pipe diameter **($3D_o$)** = 3 x 1.5-feet = 4.5-feet

5. The downstream protection width equals apron length **(L_a)**+ pipe diameter **(d)** ; = 20-feet + 1.5-feet = **21.5-feet**

The table below provides general information for sizing rock and outlet aprons for various sized pipes

Pipe Size (inches)	Average Rock Diameter (inches)	Apron Width (feet)	Apron Length for Low Flow (feet)	Apron Length for High Flow (feet)
8	3	2-3	3-5	5-7
12	5	3-4	4-6	8-12
18	8	4-6	6-8	12-18
24	10	6-8	8-12	18-22
30	12	8-10	12-14	22-28
36	14	10-12	14-16	28-32
42	16	12-14	16-18	32-38
48	20	14-16	18-25	38-44

Riprap Outlet Protection

Riprap Outlet Protection

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Riprap washes away.	Replace riprap with a larger diameter stone based on the pipe diameter and discharge velocity.
Apron is displaced.	Align apron with receiving water and keep it straight throughout its length. Repair damaged fabric and/or replace riprap that has washed away.
Scour occurs around apron or riprap.	Remove damaged TRM or riprap, fill in scoured areas, and repair damage to slopes channels or underlying filter fabric. Reinstall outlet protection.
Outlet erodes.	Stabilize TRM outlets with vegetation, replace eroded riprap; grout riprap.