Riprap–Stabilized Outlet

Definition

A section of stone or crushed concrete protection placed at the outlet end of the culverts, conduits, or channels.

Description and Purpose

The purpose of the rock outlet protection is to reduce the velocity, and energy of water, such that the flow will not erode the receiving downstream reach.

The practice may also be called armoring or an energy dissipater

Pollutant(s) controlled
- Suspended Solids

Advantages and Disadvantages

Advantages
- Permanent low maintenance erosion control

Disadvantages
- Aesthetics

Location

This practice applies where discharge velocities and energies at the outlets of culverts, conduits, or channels are sufficient to erode the downstream reach. This applies to:

- Culvert outlets of all types.
- Pipe conduits from all sediment basins, dry storm water ponds, and permanent type ponds.
- New channels constructed as outlets for culverts and conduits.

General Characteristics

- Riprap structures should be designed by registered professional engineers.
- All work conducted below the ordinary high water mark of a lake or stream, or in a floodplain or wetland will require permits from the DNRE, Land and Water Management Division. This includes placement of riprap. See Figure 1 for an explanation of the ordinary high water mark.

Materials

- Nonwoven geotextile fabric or well-graded gravel or sand-gravel mix for filter blanket
- Crushed or angular aggregate

Design Specifications

General Considerations

The design of rock outlet protection depends entirely on the location. Pipe outlet at the top of cuts or on slopes steeper than 10 percent, cannot be protected by rock aprons or riprap sections due to re-concentration of flows and high velocities encountered after the flow leaves the apron.

Many counties and state agencies have regulations and design procedures already established for dimensions, type and size of materials, and locations where outlet protection is required. Where these requirements exist, they shall be followed.

1. Investigate the downstream channel to assure that nonerosive velocities can be maintained.
2. Determine the tailwater condition at the outlet to establish which design criteria to use.
3. Enter the appropriate chart with the design discharge to determine the riprap size and apron length required. It is noted that references to pipe diameters in the charts are based on full flow. For other than full pipe flow, the parameters of depth of flow and velocity must be used to adjust the design discharges.
4. Calculate apron width at the downstream end if a flare section is to be employed.

Tailwater Depth

The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe.

- If the tailwater depth is less than half the diameter of the outlet pipe, and the receiving stream is wide enough to accept divergence of the flow, it shall be classified as a Minimum Tailwater Condition; see Figure 1 as an example.
- If the tailwater depth is greater than half the pipe diameter and the receiving stream will continue to confine the flow, it shall be classified as a Maximum Tailwater Condition; see Figure 2 as an example.
- Pipes which outlet onto flat areas with no defined channel may be assumed to have a Minimum Tailwater Condition; see Figure 1 as an example.

Apron Size

- The apron length and width shall be determined from the curves according to the tailwater conditions:
    - Minimum Tailwater – Use Figure 1
    - Maximum Tailwater – Use Figure 2
- If the pipe discharges directly into a well defined channel, the apron shall 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.
- The upstream end of the apron, adjacent to the pipe, shall have a width two (2) times the diameter of the outlet pipe, or conform to pipe end section if used.

Bottom Grade

- The outlet protection apron shall be constructed with no slope along its length.
- There shall be no overfall at the end of the apron.
- The elevation of the downstream end of the apron shall be equal to the elevation of the receiving channel or adjacent ground.

Alignment

The outlet protection apron shall be located so that there are no bends in the horizontal alignment.

Materials

- The outlet protection may be done using rock riprap, grouted riprap, or gabions.
- Riprap shall be composed of a well-graded mixture of aggregate size so that 50 percent of the pieces, by weight, shall be larger than the d_{50} size determined by using the charts. A well-graded mixture, as used herein, is defined as a mixture composed primarily of larger aggregate sizes, but with a sufficient mixture of other sizes to fill the smaller voids between the aggregates. The diameter of the largest aggregate size in such a mixture shall be 1.5 times the d50 size.

Thickness

The minimum thickness of the riprap layer shall be 1.5 times the maximum aggregate diameter for d_{50} of 15 inches or less; and 1.2 times the maximum aggregate size for d_{50} greater than 15 inches. The following chart lists some examples:

d_{50} (in)	d_{max} (in)	Minimum Blanket Thickness (in)
4	6	9
6	9	14
9	14	20
12	18	27
15	22	32
18	27	32
21	32	38
24	36	43

Aggregate Quality

- Aggregate for riprap shall consist of field stone, rough unhewn quarry stone, crushed concrete, or other similar material. The aggregate shall be hard and angular and of a quality that will not disintegrate on exposure to water or weathering.
- The specific gravity of the individual aggregates shall be at least 2.5.
- Recycled concrete equivalent may be used provided it has a density of at least 150 pounds per cubic foot, and does not have any exposed steel or reinforcing bars.

Filter Blanket

- A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into and through the riprap. Riprap shall have a filter blanket placed under it in all cases. A filter blanket can be of two general forms: a gravel layer or a nonwoven geotextile filter.
- Gravel filter blanket shall be designed by comparing particle sizes of the overlying material and the base material. Design criteria are available in Standard and Specification for Riprap - Slope Protection.
- A nonwoven geotextile filter (aka. Filter fabric, geotextile liner, filter cloth) should have properties as identified below:

Aggregate Size (in)	**Grab Tensile Strength (min) ASTM D4632 (lbs)**	**Trapezoidal Tear Strength (min) ASTM D4533 (lbs)**	**Puncture Strength (min) ASTM D4833 (lbs)**	**Mullen Burst Strength (min) ASTM D4833 (lbs)**	**Permittivity ASTM D4491 (1/s)**	**Apparent Opening Size (max) ASTM D4751 (mm)**
<16	200	75	75	200	0.5	0.21
16-24	270	100	100	400	0.5	0.21
>24	As directed by engineer					

Gabions

- Gabions shall be made of hexagonal triple twist mesh with heavily galvanized steel wire. The maximum linear dimension of the mesh opening shall not exceed 4 ½ inches and the area of the mesh opening shall not exceed 10 square inches.
- Gabions shall be fabricated in such a manner that the sides, ends, and lid can be assembled at the construction site into a rectangular basket of the specified sizes. Gabions shall be of single unit construction and shall be installed according to manufacturer's recommendations.
- The area on which the gabion is to be installed shall be graded as shown on the drawings. Foundation conditions shall be the same as for placing rock riprap, and filter cloth shall be placed under all gabions. Where necessary, key, or tie, the structure into the bank to prevent undermining of the main gabion structure.

Construction Guidelines

1. The subgrade for the filter, riprap, or gabion shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density of approximately that of the surrounding undisturbed material.

2. The rock or gravel shall conform to the specified grading limits when installed respectively in the riprap or filter.

3. Filter cloth shall be protected from punching, cutting, or tearing. Any damage other than an occasional small hole shall be repaired by placing another piece of cloth over the damaged part or by completely replacing the cloth. All overlaps, whether for repairs or for joining two pieces of cloth shall be a minimum of one foot.

4. Aggregate for the riprap or gabion outlets may be placed by equipment. Both shall each be constructed to the full course thickness in one operation and in such a manner as to avoid displacement of underlying materials. The aggregate for riprap or gabion outlets shall be delivered and placed in a manner that will ensure that it is reasonably homogenous with the smaller aggregates and spalls filling the voids between the larger aggregates. Riprap shall be placed in a manner to prevent damage to the filter blanket or filter cloth. Hand placement will be required to the extent necessary to prevent damage to the permanent works.

Monitoring

- Inspect after high flows for evidence of undermining, scour, and/or dislodged aggregates.

Maintenance

- Once a riprap outlet has been installed, the maintenance needs are very low.

References

New York Standards and Specifications For Erosion and Sediment Control

Figure 1. Outlet Protection Design—Minimum Tailwater Condition
Design of Outlet Protection from a Round Pipe Flowing Full, Minimum Tailwater Condition: Tw < 0.5Do (USDA - NRCS)

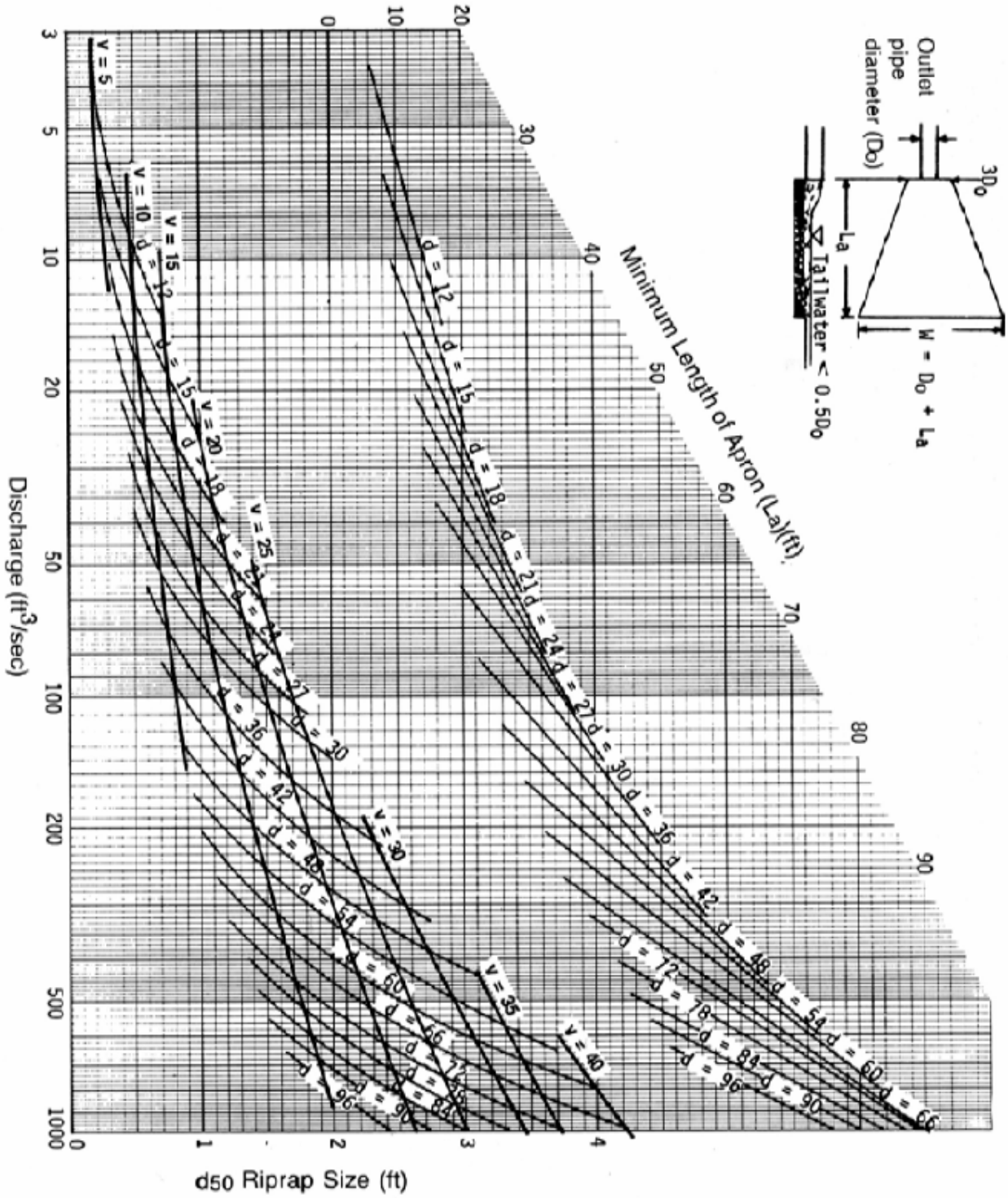


Figure 2. Outlet Protection Design—Maximum Tailwater Condition Design of Outlet Protection from a Round Pipe Flowing Full, Maximum Tailwater Condition: Tw ≥ 0.5Do) (USDA - NRCS)

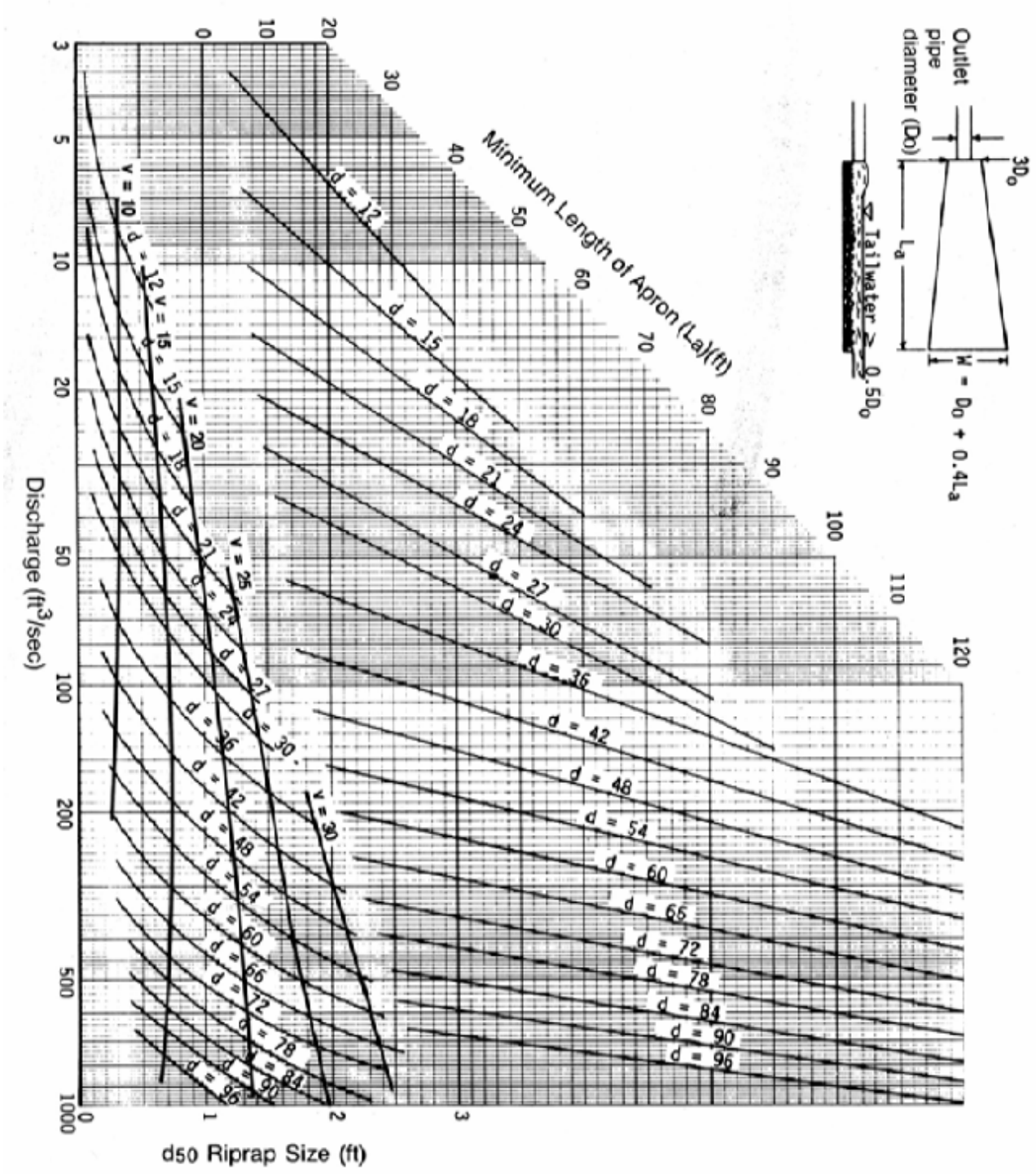


Figure 3. Riprap Outlet Protection Detail—1 of 3

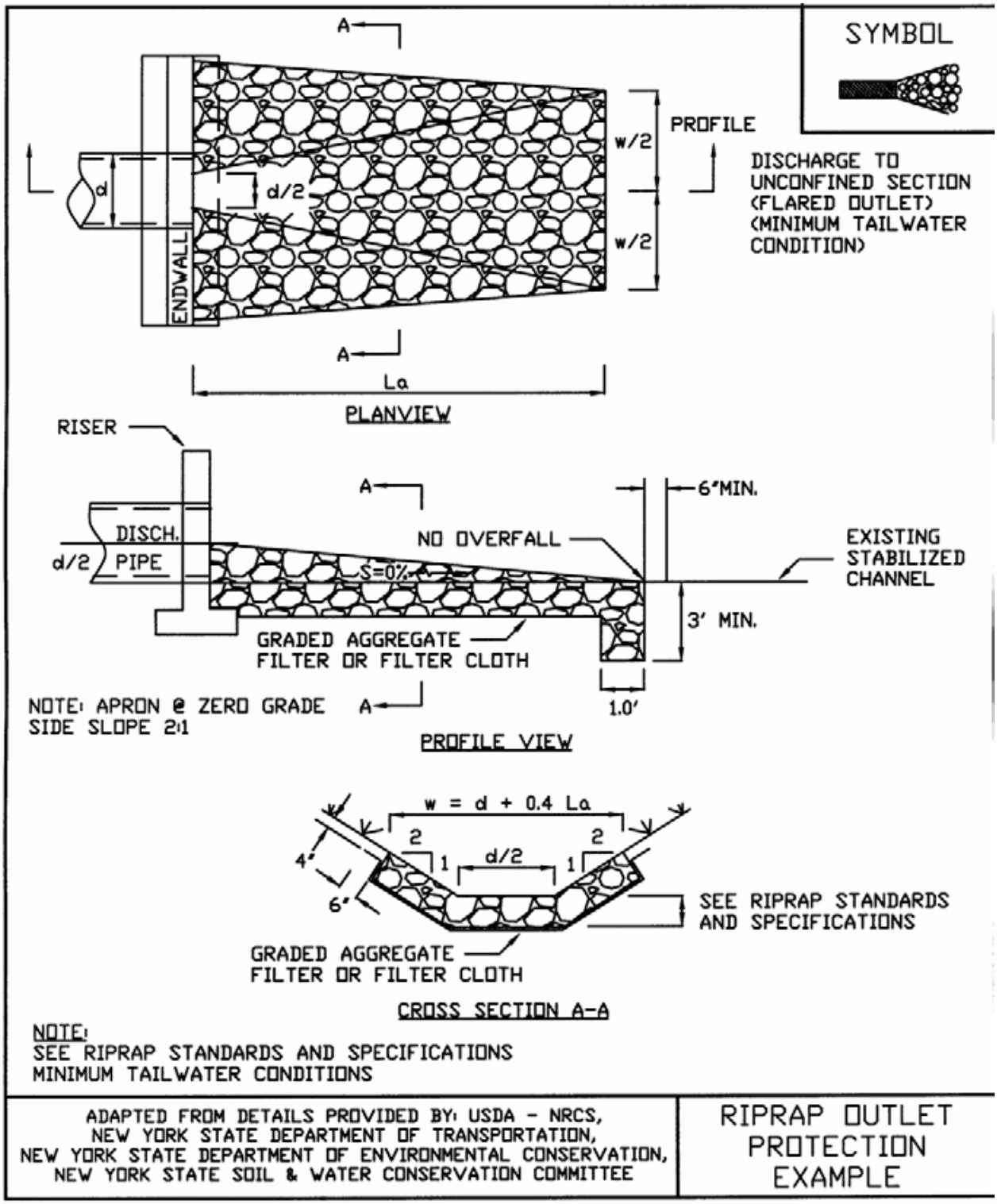


Figure 4. Riprap Outlet Protection Detail—2 of 3

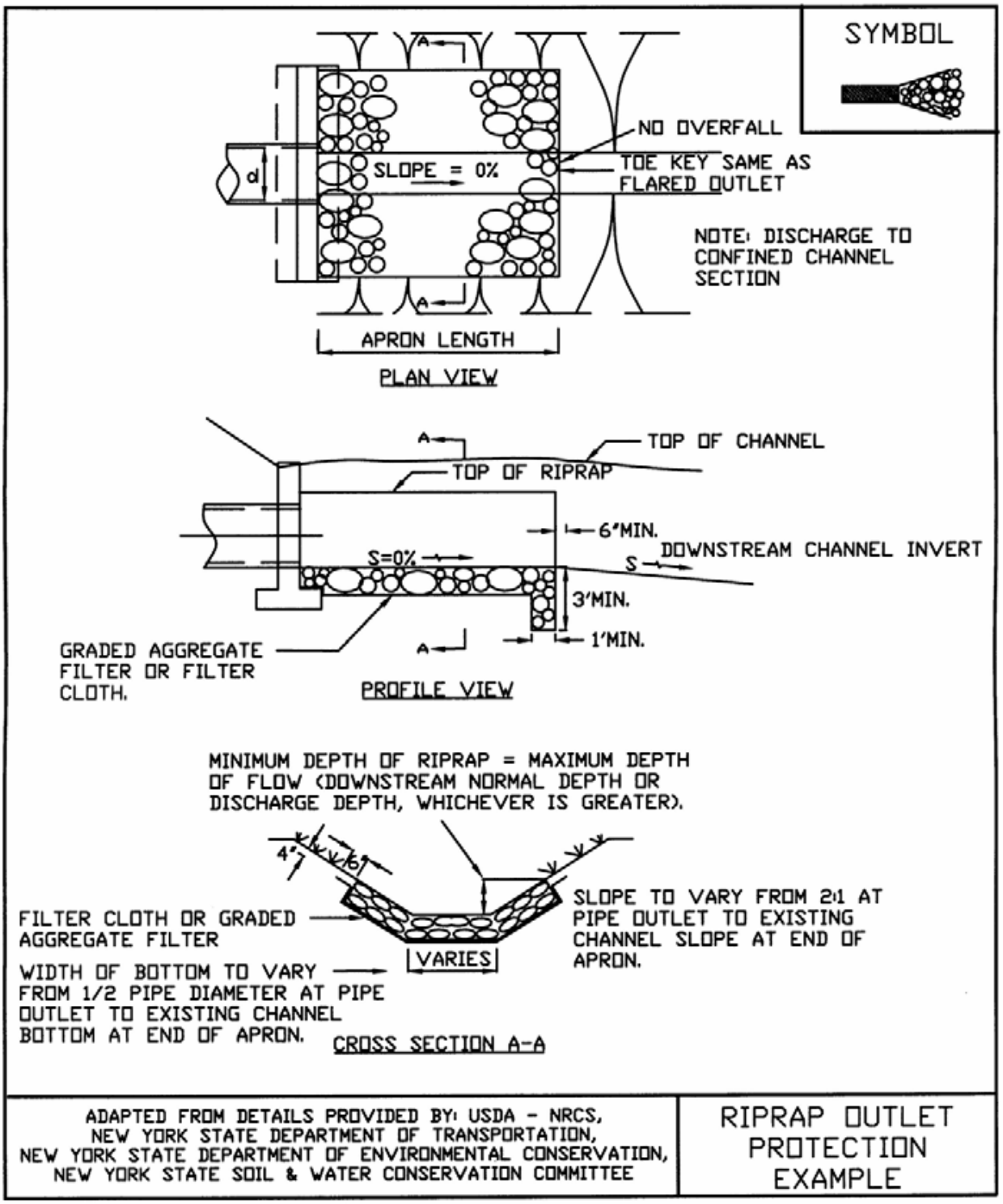


Figure 5. Riprap Outlet Protection Detail—3 of 3

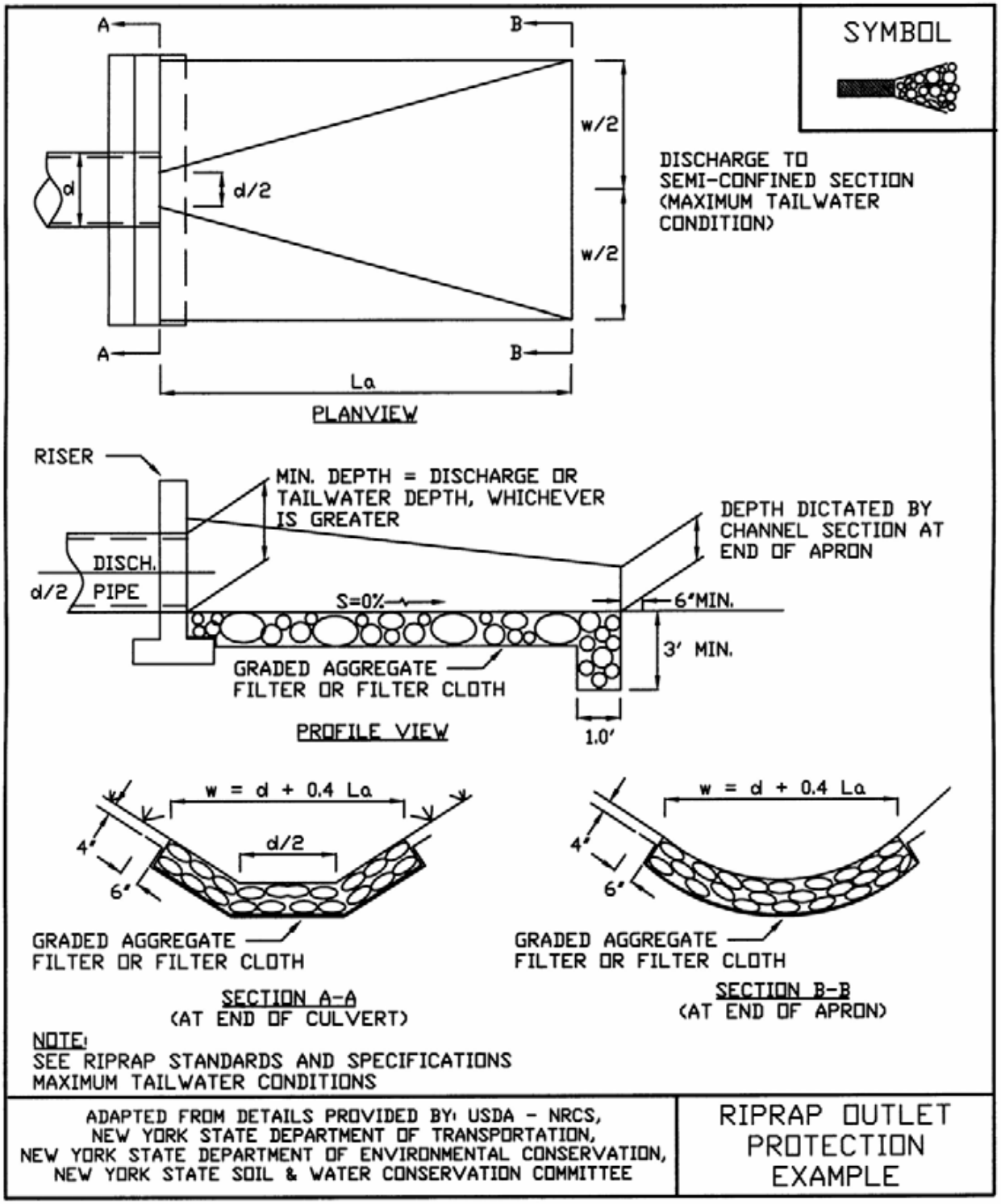
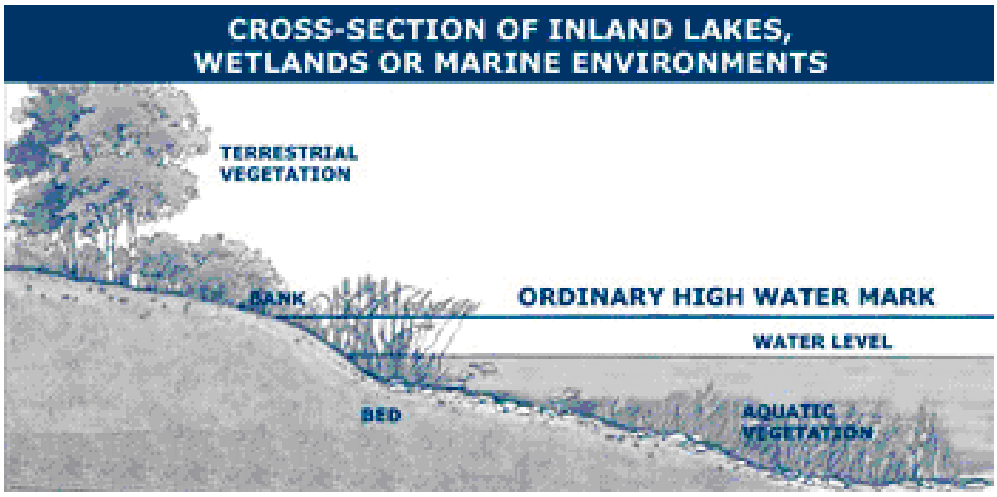
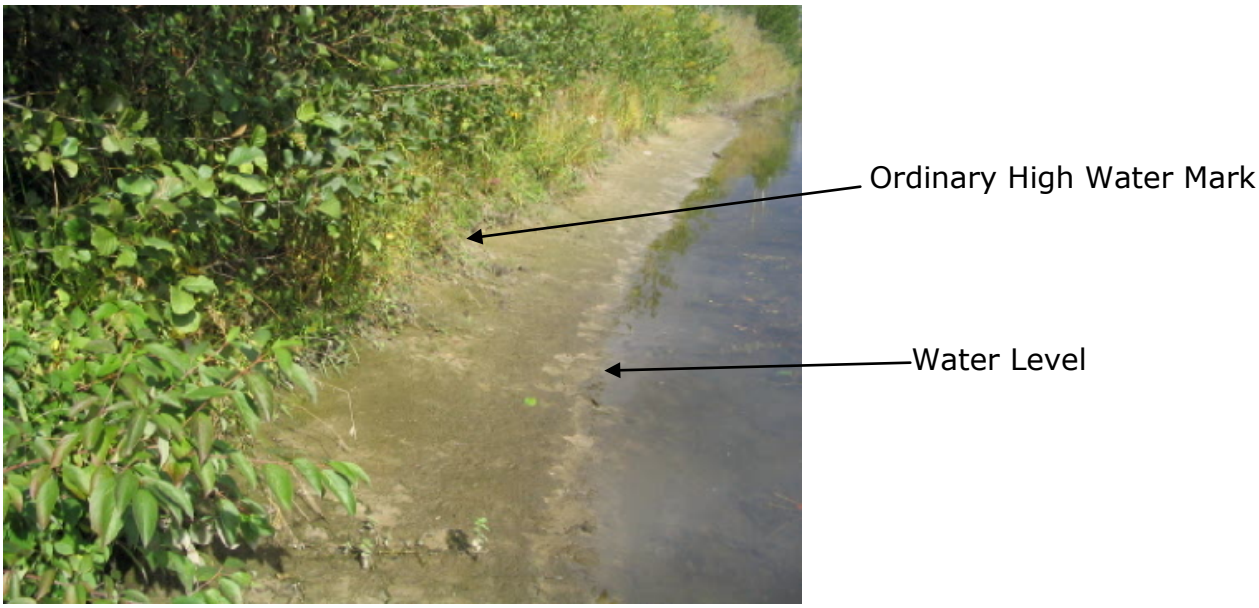


Figure 6. Ordinary High Water Mark



"Ordinary High Water Mark" means the line between upland and bottomland that persists through successive changes in water levels, below which the presence and action of the water is so common or recurrent that the character of the land is marked distinctly form the upland and is apparent in the soil itself, the configuration of the surface of the soil, and the vegetation. On a lake that has a level established by law, it means the high established level. Where water returns to its natural level as the result of the permanent removal or abandonment of a dam, it means the natural ordinary high-water mark.