CHAPTER 7 – OUTLET ENERGY DISSIPATION

Local scour is typified by a scour hole produced at an outlet structure. This is the result of high exit velocities. Coarse material scoured from the circular or elongated hole is deposited immediately downstream, often forming a low bar. Finer material moves farther downstream. The dimensions of the scour hole change due to sedimentation during low flows and the varying erosive effects of storm events.

Localized scour holes may cause degradation of side slopes, as well as undermining and subsequent failure of the outlet structure. There can also be a mosquito vector issue due to shallow standing water that is enough to sustain mosquito larva but no predatory species. Scour holes are also a safety hazard to the public due to degradation and down cutting causing vertical or steep drop offs.

Protection against scour at outlets ranges from relatively simple riprap placement to complex energy dissipation devices. This section addresses energy dissipation and erosion control measures that can be used to minimize or eliminate local scour at a pipe outlet. The following measures are discussed:

- Riprap Apron are flat profile Riprap Aprons typically for smaller sized outlet configurations
- Energy Dissipation Basin are basically pre-formed scour holes (approximating the configuration of naturally formed holes) that dissipate energy while providing a protective lining to the streambed

More extensive protection if needed can be found in more extensive manuals such as Chapter 9 in Volume 2 of Denver's Urban Drainage and Flood Control District criteria manual.

These measures can pose risks to the public due to their rough and uneven nature. Discourage public access and minimize the risk of falls at these structures.

Riprap Apron

This section addresses the use of riprap for erosion protection downstream of an outlet structure. A flat profile Riprap Apron can be used to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. Protection is provided primarily by having sufficient length and flare to dissipate energy by expanding the flow.

Configuration of Riprap Apron

Figures 7-1 through 7-3 illustrate typical riprap protection of streams at outlet structure outfalls.

Dimensions of Riprap Apron

The riprap must extend until the velocity decreases to an acceptable value. Two sets of curves, one for minimum and one for maximum tailwater conditions, are used to determine the apron size and the median riprap diameter (d_{50}). If tailwater conditions are unknown, or if both minimum and maximum conditions may occur, the apron is to be designed to meet criteria for both. Although the design curves are based on round pipes flowing full, they can be used for partially full pipes and box culverts. The design procedure consists of the following symbols that are used in the steps below and related figures:

d_{50} median riprap diameter in feet
D_o pipe diameter in feet
D_w width of box culvert in feet
D_h height of box culvert in feet
d depth of flow in feet
L_a Minimum length of Riprap Apron in feet
W Minimum width of Riprap Apron at downstream end in feet
TW Tailwater

The depth of flow should be calculated as the pipe diameter unless it can be shown that during major storm events that the depth of flow will be less than the pipe diameter. Any such explanations must include any overland flow bypassing the outlet structure and entering the downstream area near the outlet structure.

For box culverts the depth of flow should be calculated as the height of the box culvert.

Design procedures for calculating the median riprap diameter and minimum length of apron are as follows:

1. Determine tailwater conditions for the channel
   - If tailwater is less than one-half of the discharge flow depth, minimum tailwater conditions exist and the curves in Figure 7-2 apply
   - If tailwater is equal or more than one-half of the discharge flow depth, than maximum tailwater conditions exist and the curves in Figure 7-3 apply
   - If unknow than design the Riprap Apron to meet both (use figures 7-1 through 7-3)
2. Using the discharge, draw a line on the appropriate graph (Figure 7-2 and/or 7-3 as appropriate) vertically until it intersects with the lower depth of flow lower curve. Move right horizontally and find the median riprap diameter
3. Using the discharge, draw a line on the appropriate graph (Figure 7-2 and/or 7-3 as appropriate) vertically until it intersects with the upper depth of flow curve. Move left horizontally and find the minimum length of apron
4. If tailwater conditions are uncertain, the median riprap diameter should be the larger of the values for the minimum and maximum tailwater conditions
   - For length of apron regarding minimum tailwater or L_a (Minimum TW) in Figure 7-1 the length of apron calculated from Figure 7-2
   - For length of apron regarding maximum tailwater or L_a (Maximum TW) in Figure 7-1, use length of apron calculated from Figure 7-3
   - This will provide protection under either minimum or maximum tailwater conditions

For multiple outlet structures at a location follow the same design steps shown above using a single hydraulically equivalent hypothetical rectangular conduit.

Outletting to a Channel

Use the same Riprap Apron configuration and median riprap size using the design procedures above. When outletting at the upper end of a channel (outlet pipe outletting in line with channel direction), where the channel width is less than the Riprap Apron configuration, than slope the configuration with the side slope of the channel up to a minimum of the height of the pipe diameter or height of culvert. Minimum side slope for this condition shall be 3:1 or more.

Depth of Riprap

The depth of riprap will be the minimum of two times the median diameter of riprap or 1.5 times the maximum diameter of riprap.

<u>Energy Dissipation Basin</u>

Tailwater basins are to be used for known scour problems, repair of failed or failing existing energy dissipation structures or outlet locations of high velocities. They are for receiving channels, as appropriate, that have little or no flow or tailwater at a time when the outlet structure is in operation. By providing an Energy Dissipation basin at the end of a storm drain outlet, the kinetic energy of the discharge dissipates under controlled conditions without causing scour at the channel bottom.

Rock Size and Depth

The procedure for determining the require riprap size and depth of riprap downstream of the outlet structure is the same as provided in the procedures for the Riprap Apron.

Configuration of Energy Dissipation Basin

Figure 7-4 includes a standard plan and provide view of an Energy Dissipation Basin with the geometry parameters provided. Minimum length of basin (L) and the width of the bottom of the basin (W) are provided in a table at the bottom of Figure 7-4. All slopes in the Energy Dissipation Basin shall be a minimum of 3:1 (three horizontal to one vertical).

Extend riprap up the outlet embankment slope at a minimum to half the depth of the outlet pipe or height of box culvert. Provide pipe end treatment in the form of a pipe headwall with footing or a flared end section headwall with footing.

<u>Other Items</u>

As appropriate, the receiving stream velocity will be calculated and riprap size, depth and configuration will be adjusted accordingly to prevent displacement of riprap.

Other materials (hard armoring such as concrete mats, mattresses, revetments, etc) are encouraged and may be used with proper anchoring as equivalent anchoring. When doing so, provide what is needed using the procedures above for Riprap Apron or Energy Dissipation Basin and demonstrate that what is being provided meets or exceeds those requirements.

Non-hard armoring materials will typically not be allowed.

Submittals

Provide Riprap Apron or Energy Dissipation Basin configuration, riprap size and depth, outlet size(s) as well as minimum length of apron (for Riprap Apron) and riprap size from above procedures. If using other materials provide documentation that it will meet or exceed the calculated requirements for Riprap Apron or Energy Dissipation structures.

If not providing a standard practice from this chapter (e.g. Riprap Apron or Energy Dissipation Basin) provide sufficient engineering details and narrative to show it will provide adequate stream protection from scour.

Figure 7- /: Riprap Apron Schematic For Uncertain Tailwater Conditions

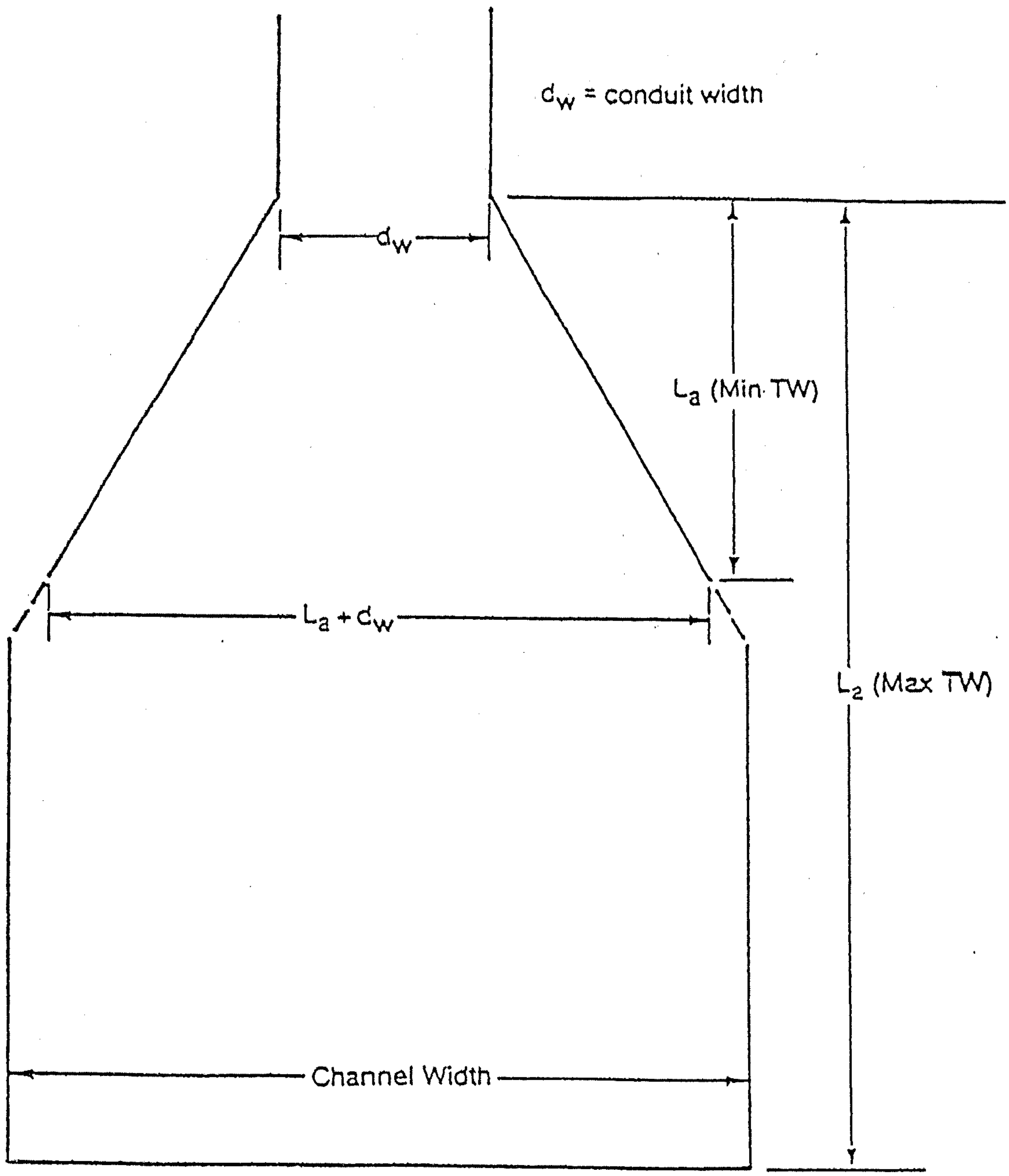
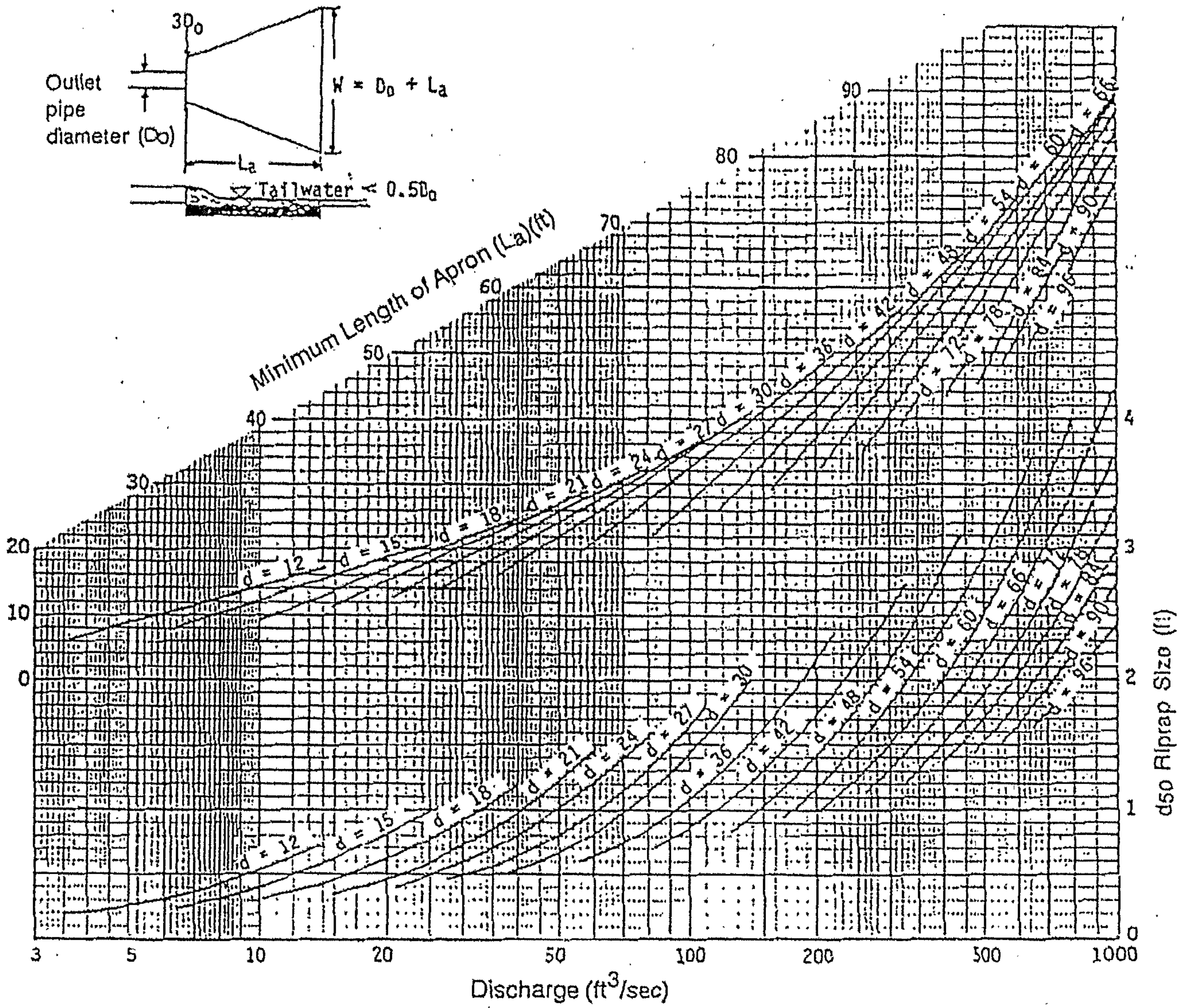
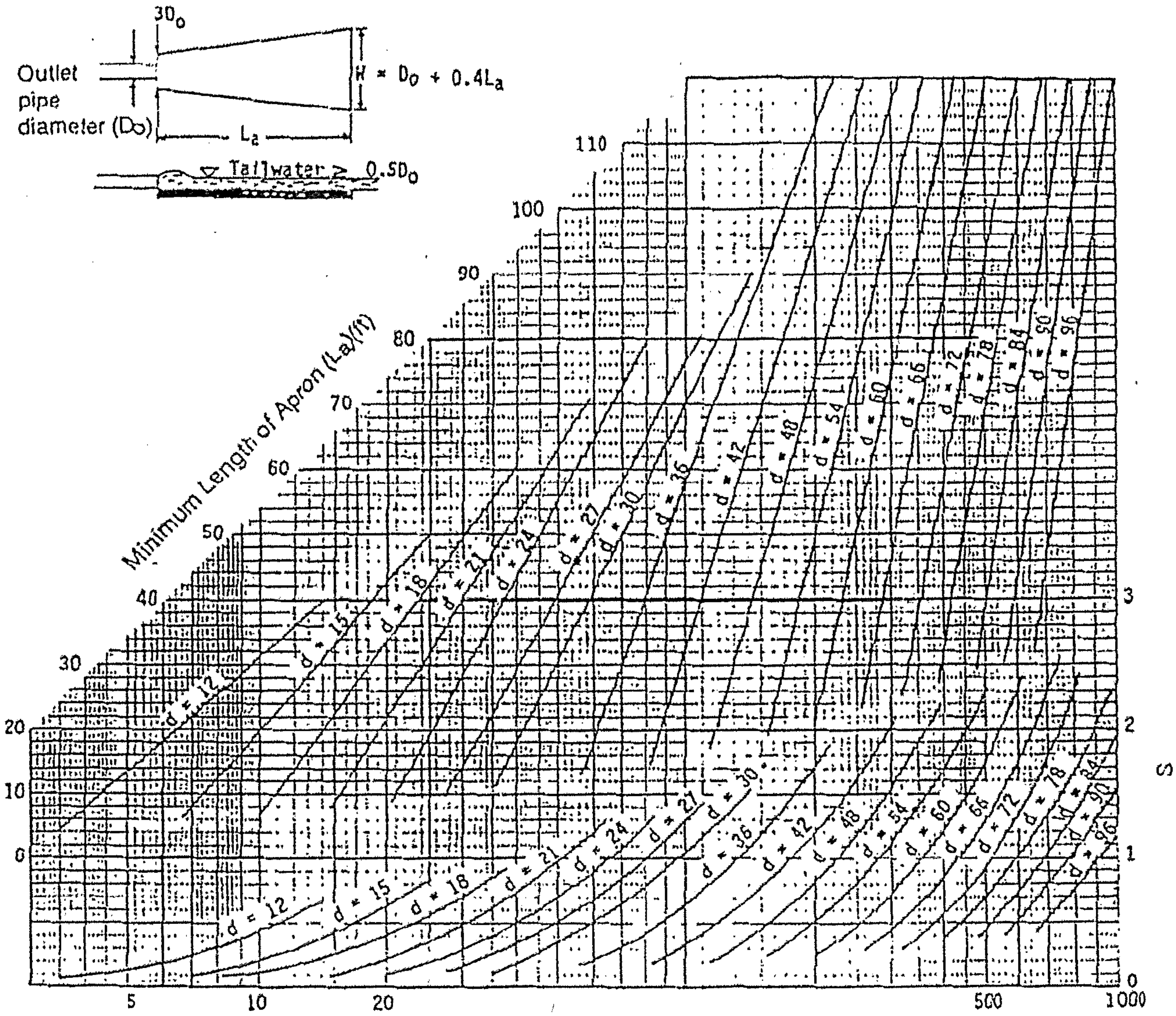


Figure 7-1: Design of Riprap Apron Under Minimum Tailwater Conditions

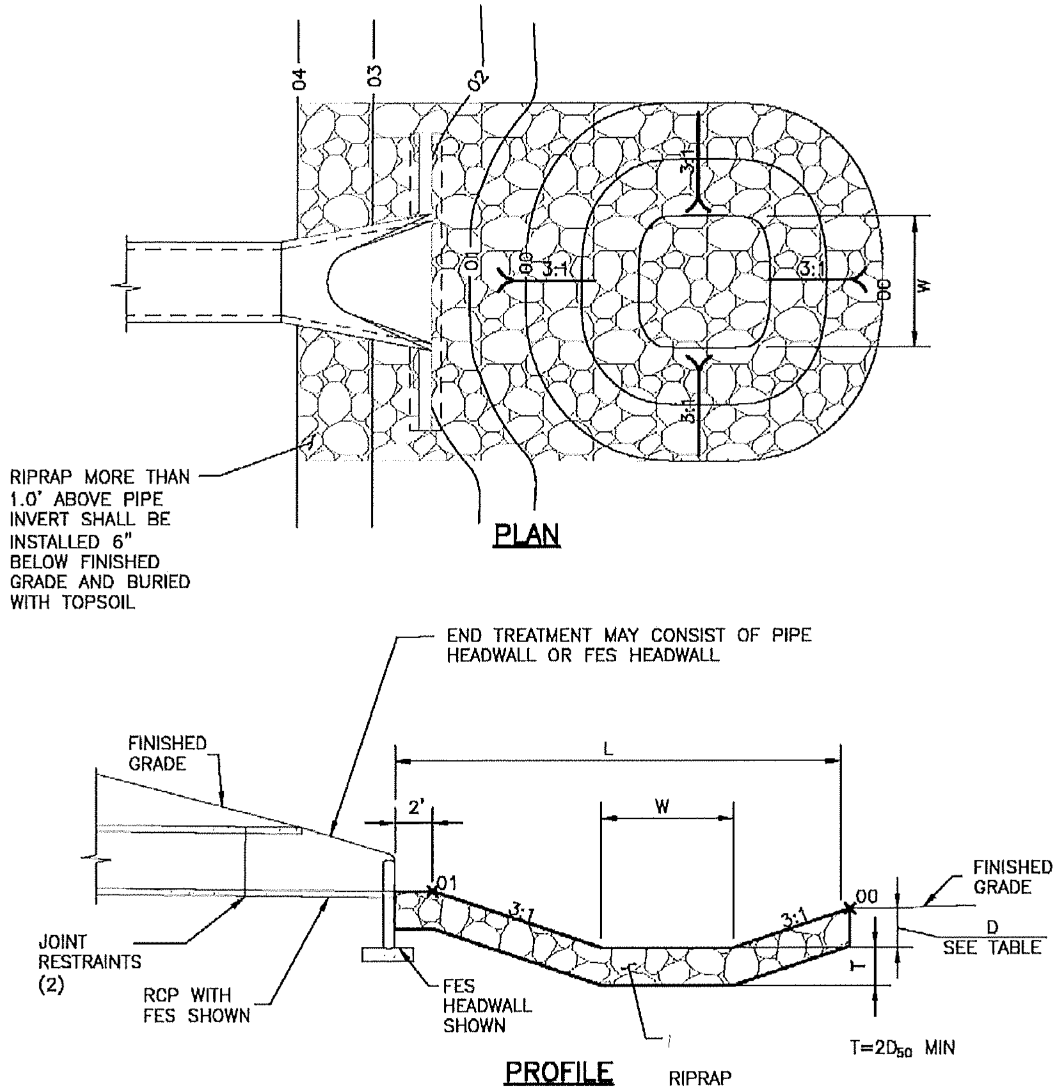


Curves may not be extrapolated.

Figure 7-3: Design of Riprap Apron Under Maximum Tailwater Conditions



Curves may not be extrapolated.



PIPE SIZE OR BOX HEIGHT	D	W*	L
18" – 24"	1'–0"	4'	15'
30" – 36"	1'–6"	6'	20'
42" – 48"	2'–0"	7'	24'
54" – 60"	2'–6"	8'	28'
66" – 72"	3'–0"	9'	32'

* IF OUTLET PIPE IS A BOX CULVERT WITH A WIDTH GREATER THAN W, THEN W = CULVERT WIDTH

Figure 7.4 Energy Dissipation **basin**