



Omaha Regional Stormwater Design Manual

Energy Dissipators

Chapter 7

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City of Omaha Environmental Quality Control Division
www.omahastormwater.org

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7.1 Energy Dissipators Introduction

7.1.1 Overview

The failure or damage of many stormwater system outlet structures can be traced to unchecked erosion. Erosive forces, which are at work in the natural drainage network, are often exacerbated by the construction of a highway or by other urban development. Interception and concentration of overland flow and constriction of natural waterways inevitably results in increased erosion potential. To protect outlets and adjacent areas, it is often necessary to employ an energy dissipator.

7.1.2 Definition

Energy dissipators are any device designed to protect downstream areas from erosion by reducing the velocity of flow to acceptable limits.

7.1.3 Purpose

This chapter provides:

- Design procedures which are based on FHWA Hydraulic Engineering Circular Number 14 (HEC 14) “Hydraulic Design of Energy Dissipators for Culverts and Channels”, September 1983, revised in 1995.
- Results of analysis using the HYDRAIN system and the HY8 software.
- Riprap apron design procedures developed by U.S.D.A. Soil Conservation Service.

7.2 Symbols and Definitions

To provide consistency, the following symbols will be used. These symbols were selected because of their wide use in technical publications. In some cases the same symbol is used in existing publications for more than one definition. Where this occurs in this appendix, the symbol will be defined where it occurs in the text or equations.

Table 7-1 Symbols, Definitions and Units

Symbol	Definition	Units
A	Cross sectional area	ft. ²
A _o	Area of flow at outlet	ft. ²
d _E	Equivalent depth at brink	ft.
d _o	Normal flow depth at brink	ft.
D	Height (or diameter) of pipe outlet	ft.
d ₅₀	Mean diameter of riprap	ft.
Fr	Froude Number	—
g	Acceleration due to gravity	ft./s. ²
h _s	Depth of dissipator pool	ft.
L _B	Overall length of basin	ft.
L _S	Length of dissipator pool	ft.
Q	Rate of discharge	cfs
S _o	Slope of streambed	ft./ft.
TW	Tailwater depth	ft.
V _d	Velocity downstream	ft./s.
V _L	Velocity — (L) feet from brink	ft./s.
V _o	Normal velocity at brink	ft./s.
W _B	Width of basin	ft.
W _o	Width (or diameter) of pipe outlet	ft.

7.3 Design Criteria

7.3.1 Overview

Energy dissipators should be employed whenever the velocity of flow leaving a stormwater management facility exceeds the erosion velocity of the downstream channel system. Several standard energy dissipator designs have been documented by the U.S. Department of Transportation including hydraulic jump, forced hydraulic jump, impact basins, drop structures, stilling wells, and riprap. This chapter will concentrate on those energy dissipators most applicable to urban stormwater management problems.

Erosion problems at storm sewer and culvert outlets are common. Determination of the flow conditions, scour potential, and channel erosion resistance, shall be standard procedure for all designs. The only safe procedure is to design on the basis that erosion protection at such outlets will be necessary.

7.3.2 Dissipator Selection

For many designs, the following outlet protection and energy dissipators provide sufficient protection at a reasonable cost.

- Riprap Apron
- Riprap Basins
- Impact Basin USBR type VI

This chapter will focus on these measures. The reader is referred to the Federal Highway Administration Hydraulic Engineering Circular No. 14 entitled, “Hydraulic Design of Energy Dissipators For Culverts And Channels (HEC 14)”, for the design procedures of other energy dissipators which may be appropriate for project design.

7.3.3 Design Limitations

Ice Buildup

If ice buildup is a factor, it shall be mitigated by:

- sizing the structure to not obstruct the winter low flow, and
- using external dissipators.

Debris Control

Design and installation of debris control, consistent with the guidance of Hydraulic Engineering Circular No. 9, “Debris-Control Structures”, shall be considered:

- where clean-out access is limited, and
- if the dissipator type selected cannot pass debris.

Flood Frequency

The flood frequency used in the design of the energy dissipator device shall be the same flood frequency used for the stormwater conveyance outlet design. The use of a greater frequency is permitted, if justified by:

- low risk of failure of the crossing,
- substantial cost savings,
- limited or no adverse effect on the downstream channel, and
- limited or no adverse effect on downstream development.

Maximum Conveyance Exit Velocity

The exit velocity from a stormwater outlet shall be consistent with the maximum velocity (computed or modeled in accordance with Chapter 5) in the channel that receives flow from the outlet. If the outlet velocity exceeds the receiving channel maximum velocity, or if the outlet velocity exceeds 6 ft. per second, mitigation shall be provided by using:

- channel stabilization (See Chapter 5, Open Channels), and
- energy dissipation.

Tailwater Relationship

The hydraulic conditions downstream shall be evaluated to determine a tailwater depth and the maximum velocity for a range of discharges. Refer to:

- Chapter 5, Open Channels.
- Tailwater depths at a lake, pond, or large water body shall be evaluated using the high water elevations that have the same frequency as the design storms for the conveyance outlet.

7.3.4 Design Options

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.

Pipe Outlet Type

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

- Pipe ends, which 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.
- Aprons do not reduce outlet velocity; if used they shall 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.

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.

Weep Holes

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

7.3.5 Related Designs

Conveyances

Stormwater conveyances 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.

Downstream Channel

Necessary downstream channel protection shall be designed concurrently with dissipator design. A channel that will receive flow from a stormwater outlet or energy dissipator that is to be installed should be analyzed and, if necessary to be stable, designed and stabilized (in accordance with Chapter 5) for the distance that it may be de-stabilized by installation of the outlet.

7.3.6 Computational Methods

Charts

- Charts are required for a manual solution.
- Charts required for the design of riprap basins, USBR type VI impact basins and riprap aprons are included in this chapter. Charts required for the design of other types of energy dissipators are found in HEC 14.

Computer Software

- HY-8 (FHWA Culvert Analysis Software) Version 4.1 or greater, contains an energy dissipator module which can be used to analyze most types of energy dissipators described in HEC 14.

7.4 Design Procedure

7.4.1 Culvert Outlet Conditions

If outlet protection is required, choose an appropriate type. Suggested outlet protection facilities and applicable flow conditions (based on the outlet Froude number and velocity) are described below. When outlet protection facilities are selected, appropriate design flow conditions and site-specific factors affecting erosion and scour potential, construction costs, and long-term durability should be considered.

Recommended outlet protection measures are as follows:

- a. **Riprap Apron** – May be applicable if the outlet Froude number is 2.5 or lower.
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. Stability of the surface at the termination of the apron needs to be considered.
- b. **Riprap Basin** – May be applicable if the outlet Froude number is 2.5 or lower.
They are generally used for transitions from pipe outlets to stable channels. Since riprap outlet basins function by creating a hydraulic jump to dissipate energy, performance is impacted by tailwater conditions.
- c. **Impact Basin USBR Type VI** – May be used for a broad range of design conditions for outlet velocities as high as 30 ft./s.

Practical application typically requires an outlet Froude number between 1 and 9. Baffled outlets may be used at both terminal outlet and channel outlet transitions. They function by dissipating energy through impact and turbulence and are not significantly affected by tailwater conditions.

- d. **HEC 14** – Contains methods which can be used to analyze most types of energy dissipation.

7.4.2 Scour Hole Estimation

Evaluate the downstream channel stability and provide appropriate erosion protection if channel degradation is expected to occur. Planning for an eroded open scour hole will not be considered an acceptable method of energy dissipation.

7.5 Riprap Aprons

7.5.1 Overview

- Allows dissipation of velocity and energy by expansion of flow on a level, armored surface.
- Often used to prevent erosion at transition from a structural outlet to sheet flow, or to a stable channel.
- May be appropriate in economical practice if the outlet Froude number is ≤ 2.5 .
- Prone to scour at the riprap edges if the apron is not large enough, or is not properly constructed.

7.5.2 Design Procedure

The procedure presented in this section is taken from USDA, SCS (1975). 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 should 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 steps:

Step 1: If possible, determine tailwater conditions for the channel. If tailwater is less than one-half the discharge flow depth (pipe diameter if flowing full), minimum tailwater conditions exist and the curves in [Figure 7-1](#) apply. Otherwise, maximum tailwater conditions exist and the curves in [Figure 7-2](#) should be used.

Step 2: Determine the correct apron length and median riprap diameter, d_{50} , using the appropriate curves from [Figures 7-1](#) and [7-2](#). If tailwater conditions are uncertain, find the values for both minimum and maximum conditions and size the apron as shown in [Figure 7-3](#).

a. For pipes flowing full:

Use the depth of flow, d , which equals the pipe diameter, in in., and design discharge, in cfs, to obtain the apron length, L_a , in ft., and median riprap diameter, d_{50} , in ft., from the appropriate curves.

b. For pipes flowing partially full:

Use the depth of flow, d , in in., and velocity, v , in ft./s. On the lower portion of the appropriate figure, find the intersection of the d and v curves, then find the riprap median diameter, d_{50} , from the scale on the right. From the lower d and v intersection point, move vertically to the upper curves until intersecting the curve for the correct flow depth, d . Find the minimum apron length, L_a , in ft., from the scale on the left.

c. For box culverts:

Use the depth of flow, d , in in., and velocity, v , in ft./s. On the lower portion of the appropriate figure, find the intersection of the d and v curves, then find the riprap median diameter, d_{50} , from the scale on the right. From the lower d and v intersection point, move vertically to the upper curve until intersecting the curve equal to the flow depth, d . Find the minimum apron length, L_a , in ft., using the scale on the left.

Step 3: If tailwater conditions are uncertain, the median riprap diameter should be the larger of the values for minimum and maximum conditions. The dimensions of the apron will be as shown in [Figure 7-3](#). This will provide protection under either of the tailwater conditions.

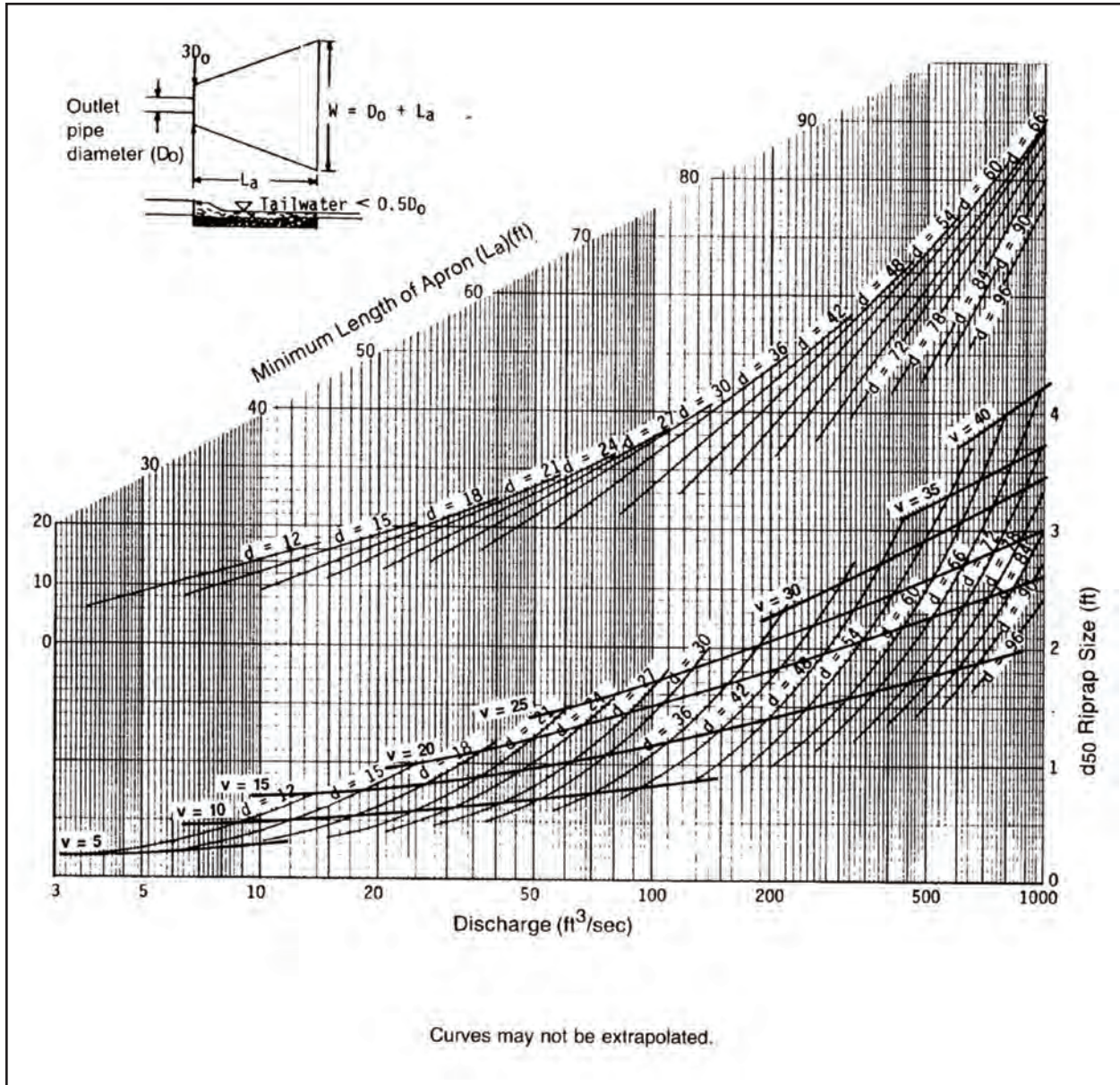


Figure 7-1 Design of Riprap Apron Under Minimum Tailwater Conditions

Source: Dekalb County Manual

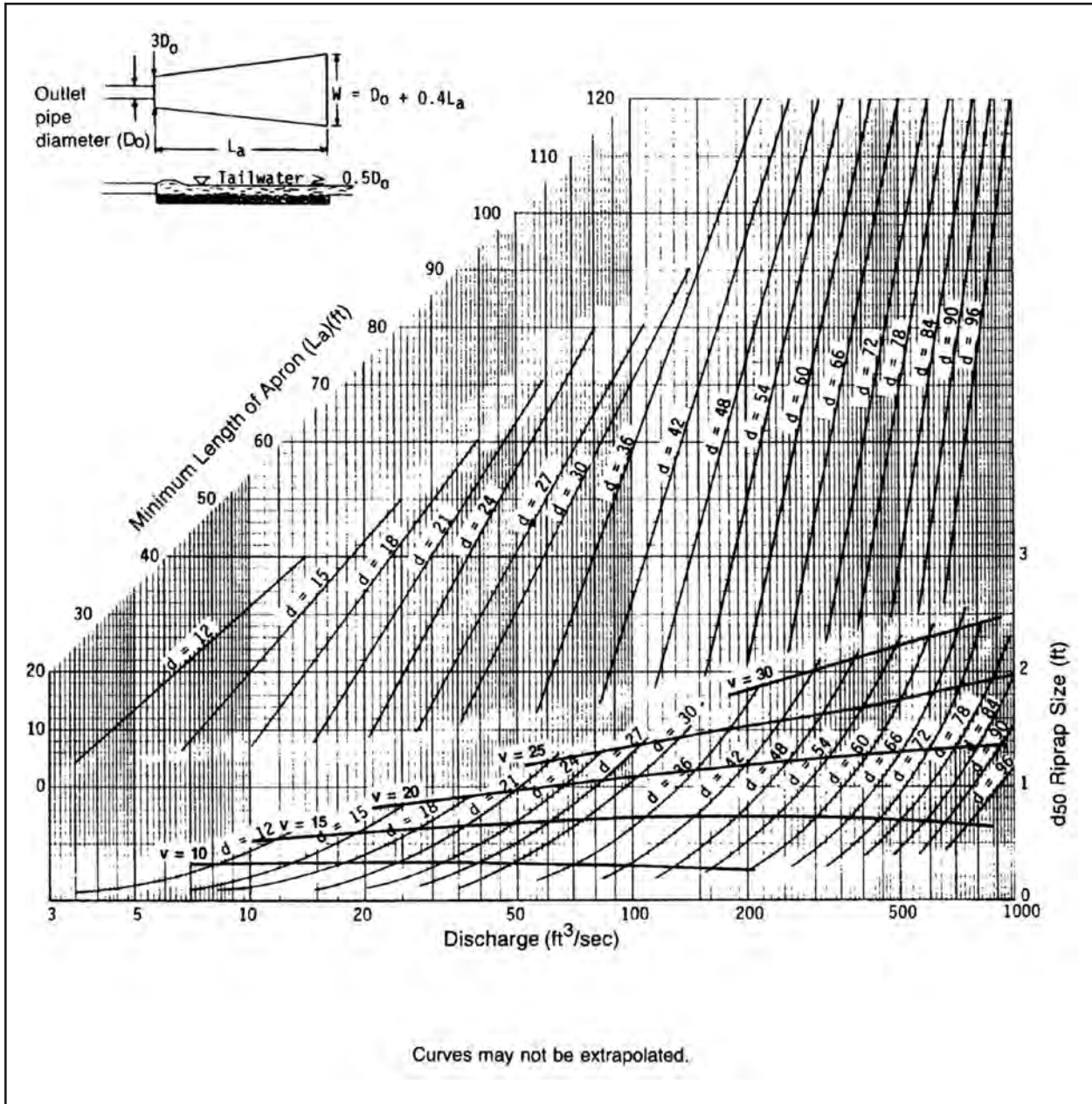


Figure 7-2 Design Of Riprap Apron Under Maximum Tailwater Conditions

Source: Dekalb County Manual

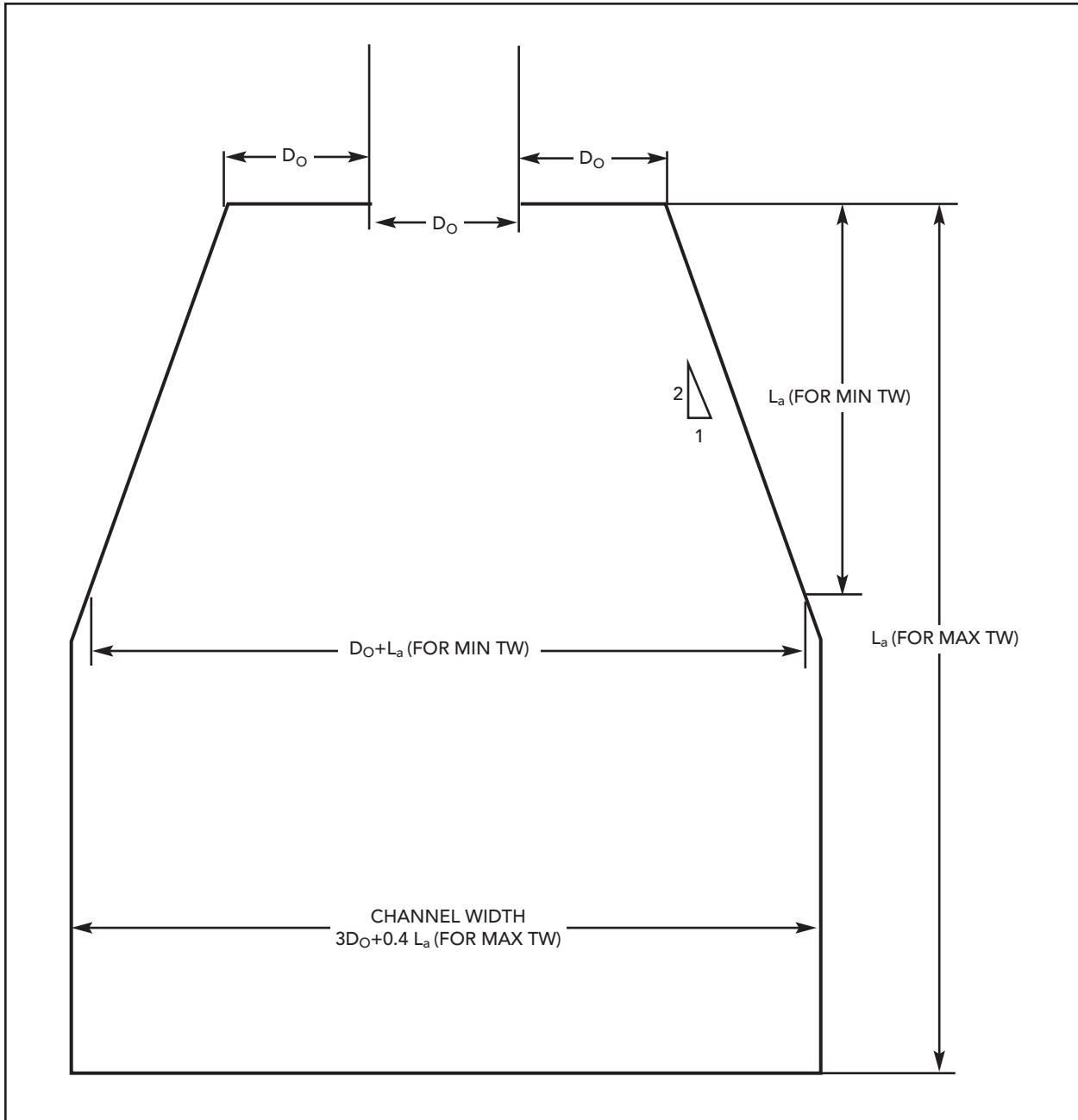


Figure 7-3 Riprap Apron Schematic For Uncertain Tailwater Conditions

7.5.3 Design Considerations

The following items should be considered during riprap apron design:

1. The maximum stone diameter should be 1.5 times the median riprap diameter.

$$d_{\max} = 1.5 \times d_{50}$$

d_{50} = the median stone size in a well-graded riprap apron.

2. The riprap thickness should be 1.5 times the maximum stone diameter or 12 in., whichever is greater.

$$\text{Apron thickness} = 1.5 \times d_{\max}$$

(Apron thickness may be reduced to $1.5 \times d_{50}$ when an appropriate filter fabric is used under the apron.)

3. The apron width at the discharge outlet should be at least equal to the pipe diameter or culvert width, d_w . Riprap should extend up both sides of the apron and around the end of the pipe or culvert at the discharge outlet at a maximum slope of 2:1 and a height not less than the pipe diameter or culvert height, and should taper to the flat surface at the end of the apron.
4. If there is a well-defined channel, the apron length should be extended as necessary so that the downstream apron width is equal to the channel width. The sidewalls of the channel should not be steeper than 2:1.
5. If the ground slope downstream of the apron is steep, channel erosion may occur. The apron should be extended as necessary until the slope is gentle enough to prevent further erosion, or an appropriate alternative energy dissipation method should be utilized.
6. The potential for vandalism should be considered if the rock is easy to carry. If vandalism is a possibility, the rock size must be increased or the rocks held in place using concrete or grout.

7.5.4 Example Problems

Example - Riprap Apron Design for Minimum Tailwater Problem Conditions

A flow of 280 cfs discharges from a 66-in. pipe with a tailwater of 2 ft. above the pipe invert. Find the required design dimensions for a riprap apron.

1. Minimum tailwater conditions = $0.5 d_o = 66 \text{ in.} = 5.5 \text{ ft.}$, therefore, $0.5 d_o = 2.75 \text{ ft.}$
2. Since $TW = 2 \text{ ft.}$, use [Figure 7-1](#) for minimum tailwater conditions.
3. By [Figure 7-1](#), the apron length, L_a , and median stone size, d_{50} , are 38 ft. and 1.2 ft., respectively.
4. The downstream apron width equals the apron length plus the pipe diameter:

$$W = d + L_a = 5.5 + 38 = 43.5 \text{ ft.}$$

- Maximum riprap diameter is 1.5 times the median stone size:

$$1.5 (d_{50}) = 1.5 (1.2) = 1.8 \text{ ft.}$$

- Riprap depth = $1.5 (d_{\text{max}}) = 1.5 (1.8) = 2.7 \text{ ft.}$

Example - Riprap Apron Design for Maximum Tailwater Conditions

A concrete box culvert 5.5 ft. high and 10 ft. wide conveys a flow of 600 cfs at a depth of 5.0 ft. Tailwater depth is 5.0 ft. above the culvert outlet invert. Find the design dimensions for a riprap apron.

- Compute $0.5 d_o = 0.5 (5.0) = 2.5 \text{ ft.}$

- Since TW = 5.0 ft. is greater than 2.5 ft., use [Figure 7-2](#) for maximum tailwater conditions.

$$v = Q/A = [600/(5) (10)] = 12 \text{ ft./s.}$$

- On [Figure 7-2](#), at the intersection of the curve,

$$d_o = 60 \text{ in. and } v = 12 \text{ ft./s., } d_{50} = 0.4 \text{ ft.}$$

Reading up to the intersection with $d = 60 \text{ in.}$, find $L_a = 40 \text{ ft.}$

- Apron width downstream = $d_w + 0.4 L_a = 10 + 0.4 (40) = 26 \text{ ft.}$

- Maximum stone diameter = $1.5 d_{50} = 1.5 (0.4) = 0.6 \text{ ft.}$

- Riprap depth = $1.5 d_{\text{max}} = 1.5 (0.6) = 0.9 \text{ ft.}$

7.6 Riprap Basin

7.6.1 Overview

Following are the principal features of the riprap basin:

- Preshaping and lining with riprap of median size, d_{50} .
- Constructing the floor at a depth of h_S below the invert, where h_S is the depth of scour that would occur in a pad of riprap of size d_{50} .
- Sizing d_{50} so that $2 < h_S/d_{50} < 4$.
- Sizing the length of the dissipating pool to be $10(h_S)$ or $3(W_o)$, whichever is larger, for a single barrel. The overall length of the basin is $15(h_S)$ or $4(W_o)$, which ever is larger.
- Results with angular rock are generally the same as the results with rounded material.
- Layout details are shown on [Figure 7-4](#).

For High Tailwater ($TW/d_o > 0.75$):

- The high velocity water emerging from the pipe outlet retains its jetlike character as it passes through the basin.
- The scour hole would not be as deep as with low tailwater, but would generally be longer.
- Riprap may be required for the channel downstream of the rock lined basin.

7.6.2 Design Procedure

- Step 1:** Determine Input Flow
- d_o or d_E , V_o , Fr at the pipe outlet (d_E = the equivalent depth at the brink = $(A/2)^{0.5}$).
- Step 2:** Check TW
- Determine if $TW/d_o < 0.75$. (See Chapter 5, Open Channels)
- Step 3:** Determine d_{50}
- Use [Figure 7-5](#) ($d_e = y_e$).
 - Select d_{50}/y_E . Satisfactory results will be obtained if $0.25 < d_{50}/y_E < 0.45$.
 - Obtain h_S/y_E using Froude number Fr and [Figure 7-5](#).
 - Check if $2 < h_S/y_{50} < 4$ and repeat until a d_{50} is found within the range.
- Step 4:** Size Basin
- Per [Figure 7-4](#) and using calculation form similar to [Figure 7-6](#).
 - Determine length of the dissipating pool, L_S .
 $L_S = 10h_S$ or $3W_o$ minimum.
 - Determine length of basin, L_B .
 $L_B = 15h_S$ or $4W_o$ minimum.
 - Thickness of riprap:
Approach = $3d_{50}$ or $1.5 d_{max}$
Remainder = $2d_{50}$ or $1.5 d_{max}$

Step 5: Determine V_B

- a. Basin exit depth, d_B = critical depth at basin exit.
- b. Basin exit velocity, $V_B = Q/(W_B)(d_B)$.
- c. Compare V_B with the average normal flow velocity in the natural channel, V_d .

Step 6: High Tailwater Design

- a. Design a basin for low tailwater conditions, Steps 1-5.
- b. Compute equivalent circular diameter D_E for brink area from:
$$A = \pi D_E^2/4 = d_o(W_o)$$
- c. Estimate centerline velocity at a series of downstream cross sections using [Figure 7-7](#).
- d. Size riprap using HEC 11 "Use of Riprap For Bank Protection" or Chapter 5.

Step 7: Design Filter

- a. Unless the streambed material is sufficiently well graded.
- b. Follow instructions in section 4.4, HEC 11.

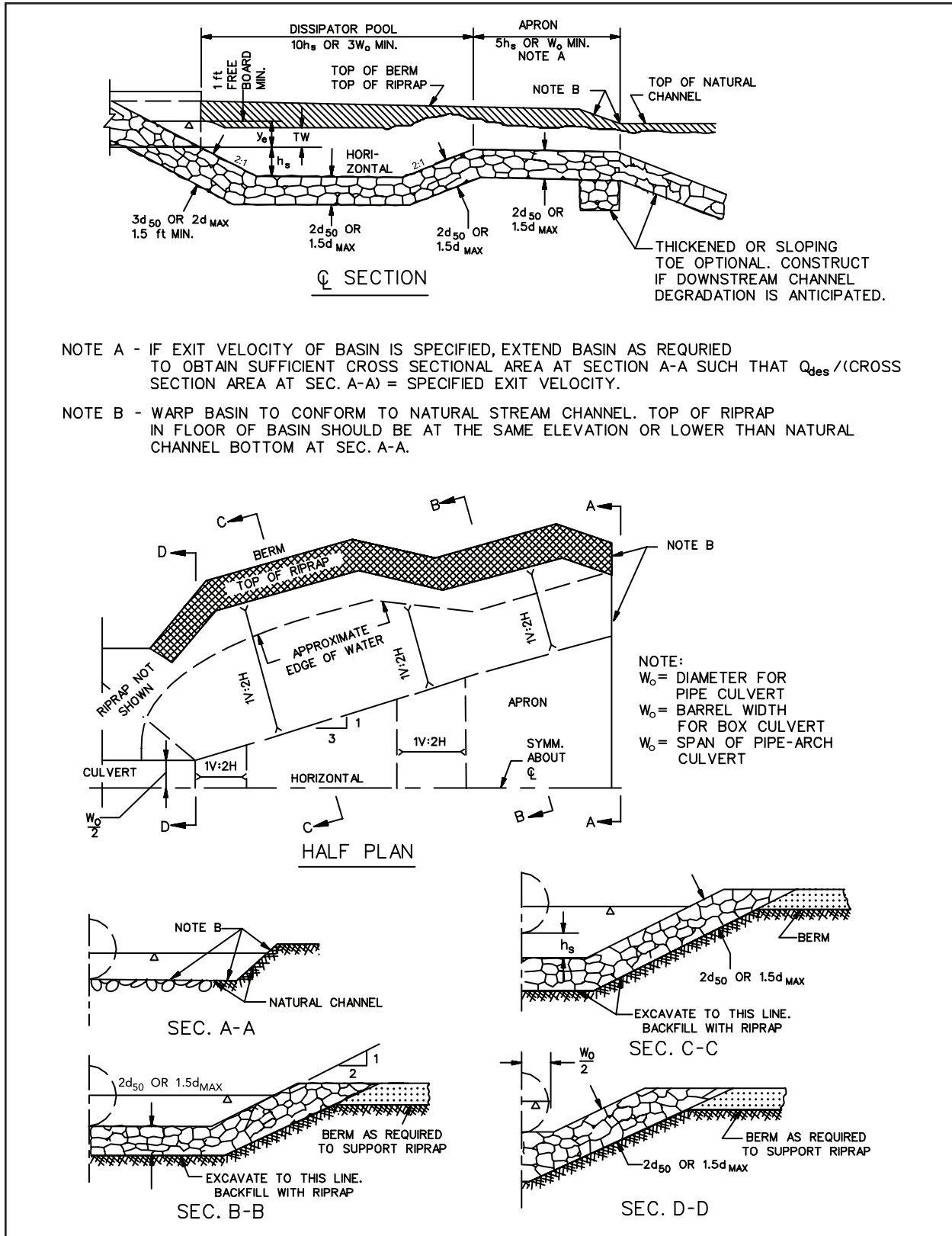


Figure 7-4 Details Of Riprap Basin Energy Dissipator

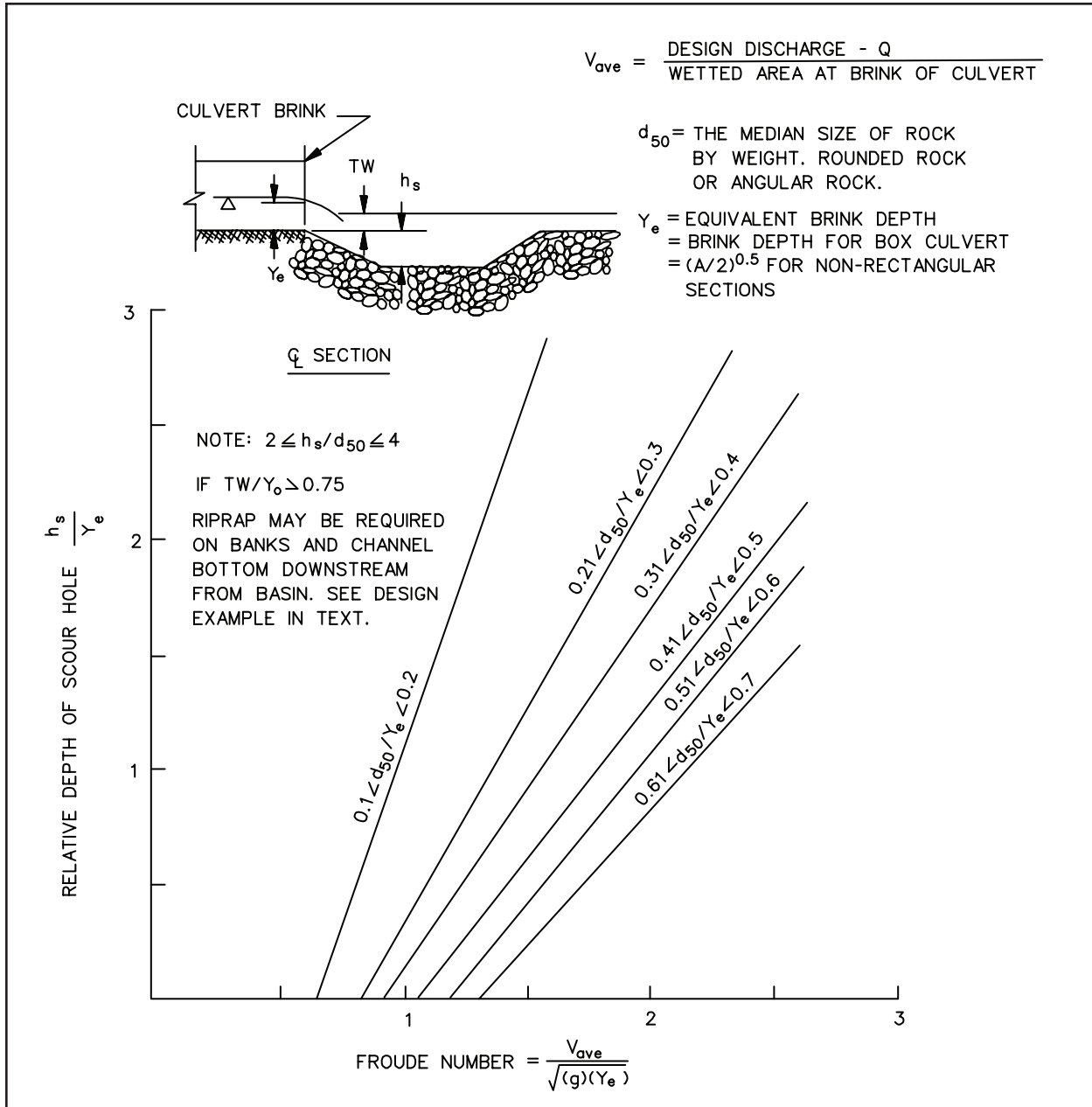
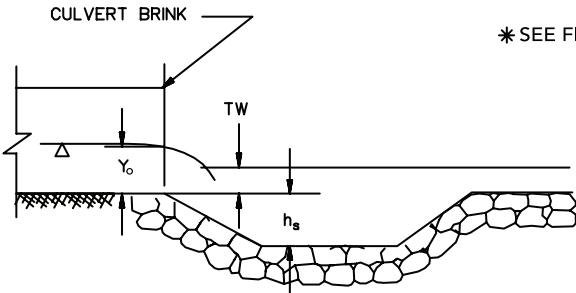


Figure 7-5 Riprap Basin Depth Of Scour

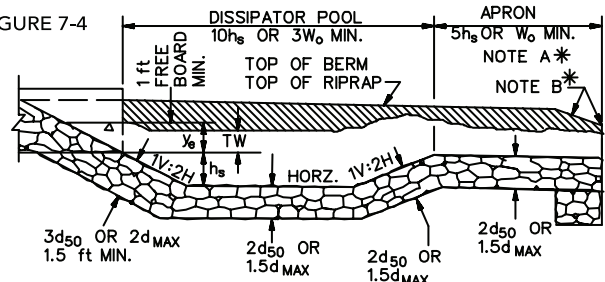
USER TYPE VI DISSIPATOR COMPUTATION FORM

PROJECT: _____ PLAN SHEET NO. _____ DATE _____
 _____ DESIGNER _____ REVIEWER _____



CULVERT BRINK

* SEE FIGURE 7-4



DESIGN VALUES	TRIALS		
	1	2	3
D50/de			
D50			
Fr			
hs/de			
hs			
hs/D50			
2 < hs/D50 < 4			

BASIC DIMENSIONS		FEET	
POOL LENGTH IS THE LARGER OF:	10hs		
	3Wo		
BASIN LENGTH IS THE LARGER OF:	15hs		
	4Wo		
THICKNESS APPROACH	3D50		
THICKNESS APPROACH	2D50		

TAILWATER CHECK	
TW	
de	
TW/de	
IF TW/de > 0.75 CALCULATE DOWNSTREAM RIPRAP LENGTH (L)	

CALCULATE DOWNSTREAM RIPRAP LENGTH (L)				
L/De*	L	VL/VO	VL	D50

*De = (4Ac/π)⁵

Figure 7-6 Riprap Basin Design Checklist

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7.6.3 Design Example - Low Tailwater

Box culvert — 8 ft. × 6 ft.

Design Discharge $Q = 800$ cfs

Supercritical flow in culvert

Normal flow depth $d_o =$ brink depth $d_E = 4$ ft.

Tailwater depth, $TW = 2.8$ ft.

Step 1: Determine Input Flow

- a. $d_o = d_E$ for rectangular section
 $d_o = d_E = 4$ ft.
 $V_o = Q/A = 800/(4)8 = 25$ ft./s.
 $Fr = V/(g d_E)^{0.5} = 25/[(32.2)4]^{0.5} = 2.20 < 3.0$, O.K.

Step 2: Check TW

- a. Determine if $TW/d_o < 0.75$
 $TW/d_E = 2.8/4.0 = 0.7$
 Therefore $TW/d_E < 0.75$, O.K.

Step 3: Determine d_{50}

- a. Use [Figure 7-5](#)
- b. Select $d_{50}/d_E = 0.45$
 $d_{50} = 0.45(4) = 1.8$ ft.
- c. Obtain h_S/d_E using $Fr = 2.2$
 $h_S/d_E = 1.6$
- d. Check if $2 < h_S/d_{50} < 4$
 $h_S = 4(1.6) = 6.4$ ft.
 $h_S/d_{50} = 6.4/1.8 = 3.6$ ft.
 $2 < 3.6 < 4$, O.K.

Step 4: Size Basin

- a. As shown in [Figure 7-4](#)
- b. Determine length of dissipating pool, L_S
 $L_S = 10h_S = 10(6.4) = 64$ ft.,
 $\text{min} = 3W_o = 3(8) = 24$ ft.,
 Therefore, use $L_S = 64$ ft.
- c. Determine length of basin, L_B
 $L_B = 15h_S = 15(6.4) = 96$ ft.,
 $\text{min} = 4W_o = 4(8) = 32$ ft.,
 Therefore use $L_B = 96$ ft.
- d. Thickness of riprap:
 Approach = $3d_{50} = 3(1.8) = 5.4$ ft.,
 Remainder = $2d_{50} = 2(1.8) = 3.6$ ft.

Step 5: Determine V_B

- a. $d_B =$ critical depth at basin exit = 3.3 ft. (Assuming a rectangular cross section with width $W_B = 24$ ft.)
- b. $V_B = Q/(W_B d_B) = 800/(24 \times 3.3) = 10$ ft./s.
- c. $V_B = 10$ ft./s. $< V_d = 18$ ft./s.

7.6.4 Design Example - High Tailwater

Data on the channel and the culvert are the same as for the low tailwater example, except the new tailwater depth, $TW = 4.2$ ft.

$$TW/d_o = 4.2/1.05 = 1.05 > 0.75$$

Downstream channel can tolerate only 7 ft./s.

Steps 1 through 5 are the same as in the previous low tailwater example.

Step 6:

- a. From Steps 1-4
 $d_{50} = 1.8$ ft., $h_S = 6.4$ ft.
 $L_S = 64$ ft., $L_B = 96$ ft.
- b. Compute equivalent circular diameter, D_E , for brink area from:
 $A = \pi D_E^2/4 = d_o(W_o) = 4(8) = 32$ ft.²
 $D_E = [32(4)/\pi]^{0.5} = 6.4$ ft.
 $V_o = 25$ ft./s.
- c. Estimate centerline velocity at a series of downstream cross sections using [Figure 7-7](#).

L/D_E^1	L	V_L/V_o	V_L	d_{50}^2
10	64	0.59	14.7	1.4
15 ³	96	0.37	9.0	0.6
20	128	0.30	7.5	0.4
21	135	0.28	7.0	0.4

¹ Use $W_o = D_E$ in [Figure 7-7](#)

² from [Figure 7-8](#)

³ is on a logarithmic scale so interpolations must be made logarithmically

- d. Size riprap using HEC 11. The channel can be lined with the same size rock used for the basin. Protection must extend at least 135 ft. downstream.
- e. [Figure 7-9](#) shows a summary of the design example calculations based on the form provided in [Figure 7-6](#).

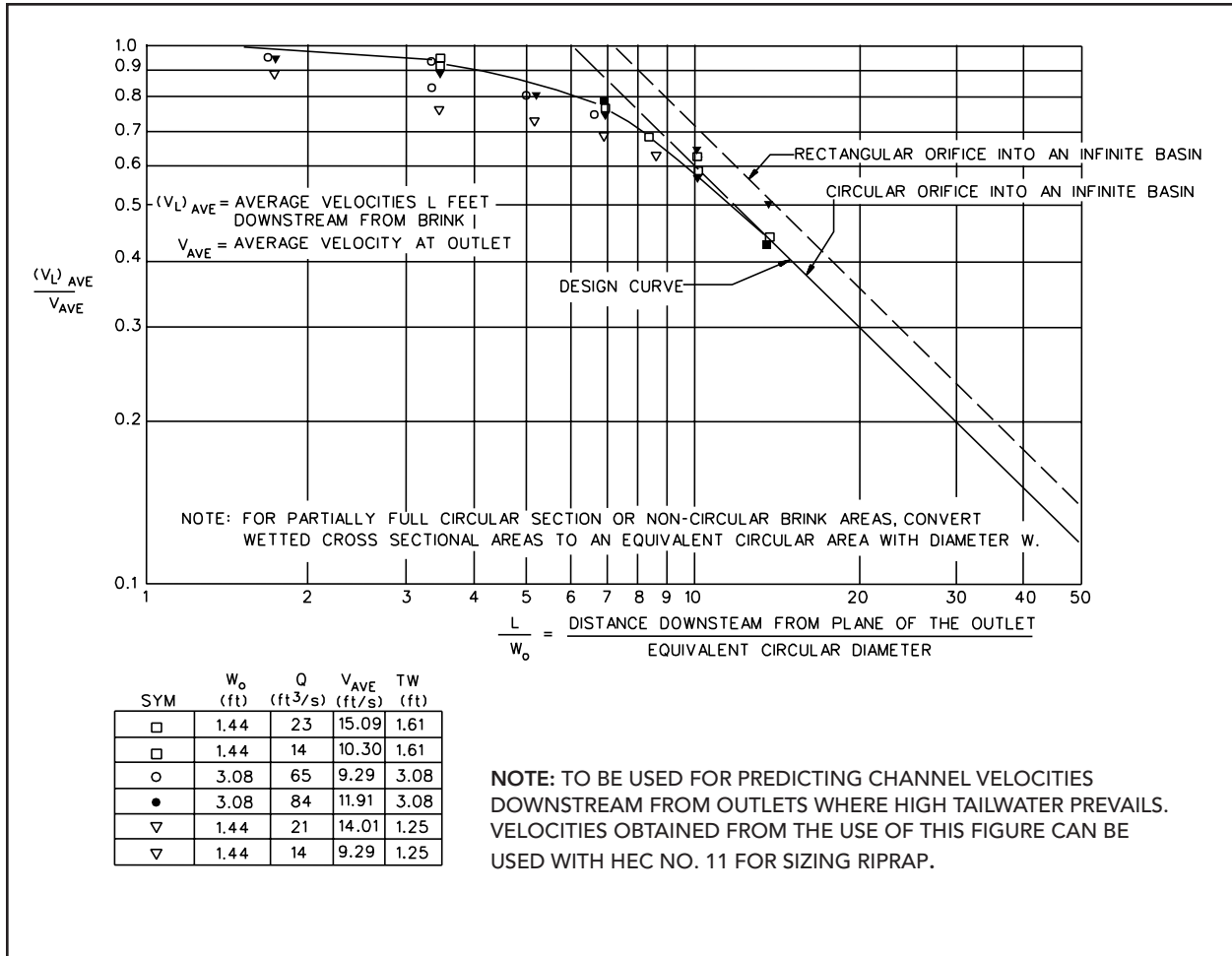


Figure 7-7 Distribution Of Centerline Velocity For Flow From Submerged Outlet

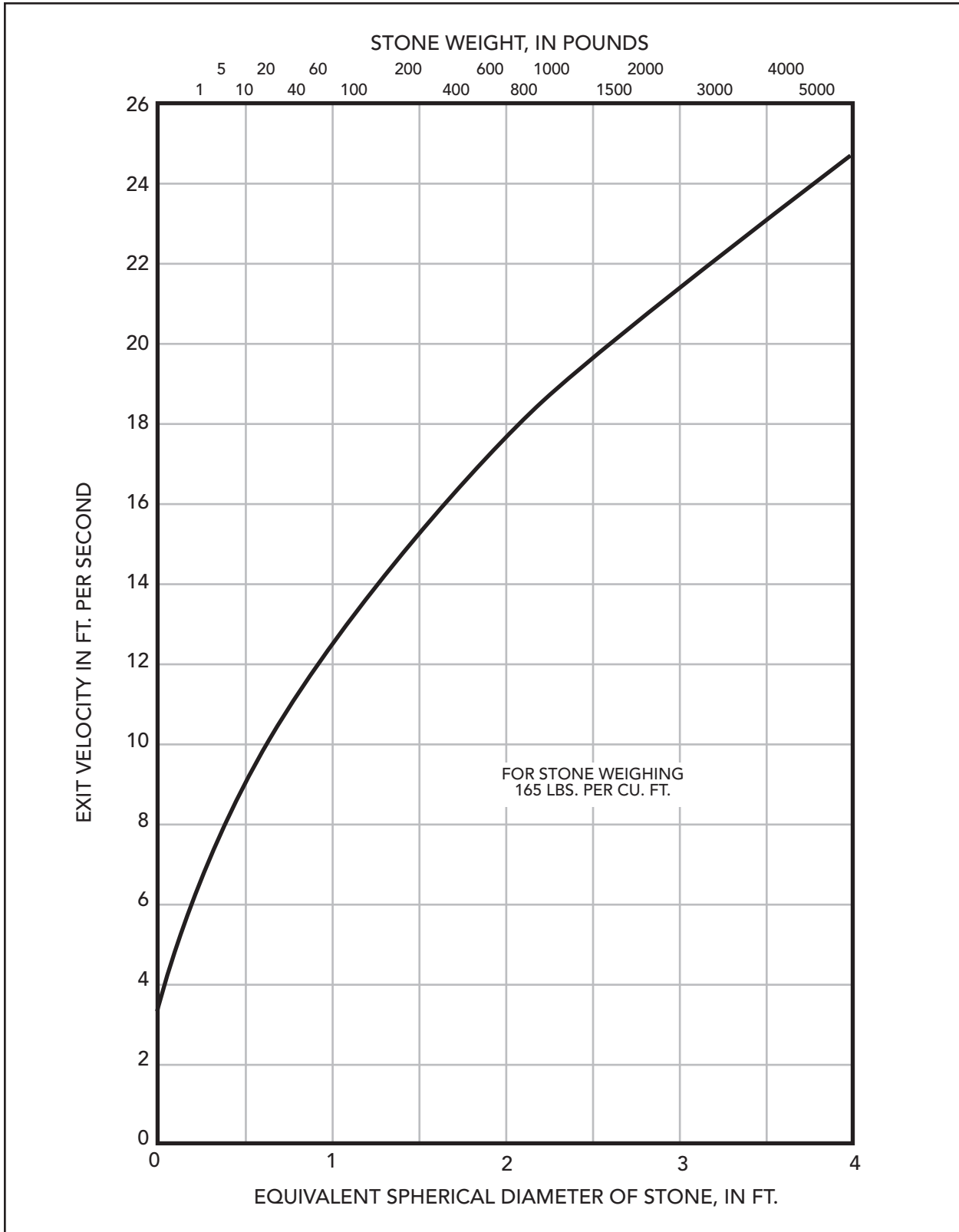


Figure 7-8 Riprap Size Versus Exit Velocity (after HEC 14)

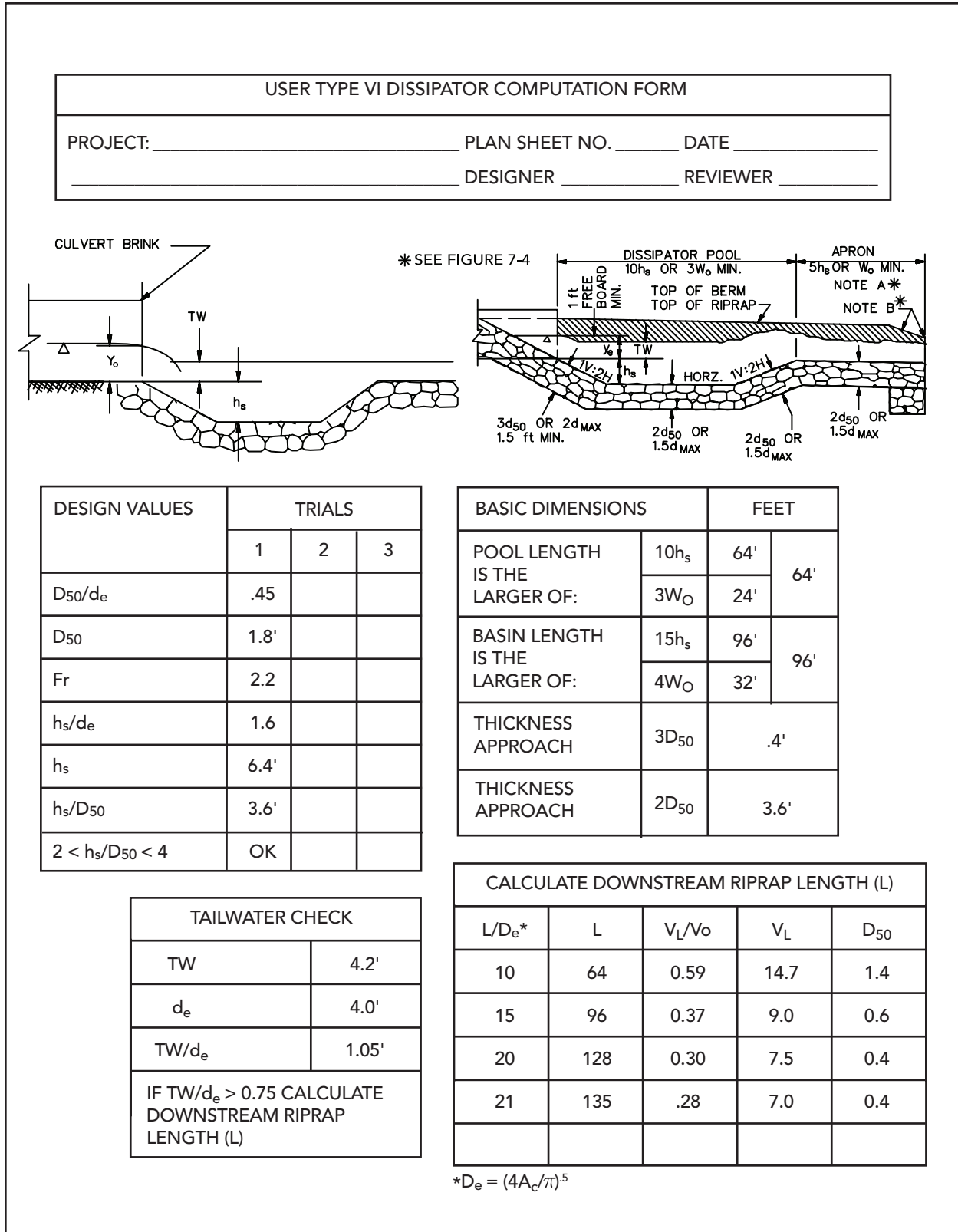


Figure 7-9 Riprap Basin Design Example

7.6.5 Computer Output

The riprap basin dissipator geometry can be computed using the “Energy Dissipator” module which is available in microcomputer program HY-8, Culvert Analysis. For an example similar to those of [Sections 7.6.3](#) and [7.6.4](#), the output of the culvert and channel input data, and computed geometry using the “Energy Dissipator” module, are shown below.

FHWA CULVERT ANALYSIS, HY 8, VERSION 4.5			
CURRENT DATE	CURRENT TIME	FILE NAME	FILE DATE
CULVERT AND CHANNEL DATA			
CULVERT NO. 1		DOWNSTREAM CHANNEL	
CULVERT TYPE: 8 ft. × 6 ft. BOX		CHANNEL TYPE : IRREGULAR	
CULVERT LENGTH = 300 ft.		BOTTOM WIDTH = 8.0 ft.	
NO. OF BARRELS = 1.0		TAILWATER DEPTH = 3.7 ft.	
FLOW PER BARREL = 800 cfs		TOTAL DESIGN FLOW = 800 cfs	
INVERT ELEVATION = 172.5 ft.		BOTTOM ELEVATION = 172.5 ft.	
OUTLET VELOCITY = 25 ft./s.		NORMAL VELOCITY = 21.8 ft./s.	
RIPRAP STILLING BASIN — FINAL DESIGN			
THE LENGTH OF THE BASIN		= 93.4 ft.	
THE LENGTH OF THE POOL		= 62.2 ft.	
THE LENGTH OF THE APRON		= 31.1 ft.	
THE WIDTH OF THE BASIN AT THE OUTLET		= 8.0 ft.	
THE DEPTH OF POOL BELOW CULVERT INVERT		= 6.2 ft.	
THE THICKNESS OF THE RIPRAP ON THE APRON		= 5.4 ft.	
THE THICKNESS OF THE RIPRAP ON THE REST OF THE BASIN		= 3.6 ft.	
THE BASIN OUTLET VELOCITY		= 10 ft./s.	
THE DEPTH OF FLOW AT BASIN OUTLET		= 4.4 ft.	

7.7 Impact Basin USBR Type VI

7.7.1 Overview

The USBR Type VI basin, [Figure 7-10](#), developed by the U.S. Bureau of Reclamation (USBR):

- is referred to as the USBR Type VI basin or hanging baffle,
- is contained in a relatively small box like structure,
- requires no tailwater for successful performance,
- may be used in open channels, as well, and
- is not recommended where debris or ice buildup may cause substantial clogging.

Hanging Baffle

Energy dissipation is initiated by flow striking the vertical hanging baffle and being deflected upstream by the horizontal portion of the baffle and by the floor, creating horizontal eddies.

Notches in Baffle

Notches are provided to aid in cleaning the basin. The notches provide concentrated jets of water for cleaning. The basin is designed to carry the full discharge over the top of the baffle if the space beneath the baffle becomes completely clogged.

Equivalent Depth

This depth must be calculated for a pipe or irregular shaped conduit. The cross section flow area in the pipe is converted into an equivalent rectangular cross section in which the width is twice the depth of flow.

Limitations

Discharges up to 400 cfs per barrel and velocities as high as 30 ft./s. can be used without subjecting the structure to cavitation damage.

Tailwater

A moderate depth of tailwater will improve performance. For best performance, set the basin so that maximum tailwater does not exceed $h_3 + (h_2/2)$.

Slope

If culvert slope is greater than 15 degrees, a horizontal section of at least four culvert widths should be provided upstream.

End Treatment

An end sill with a low-flow drainage slot, 45 degree wingwalls and a cutoff wall should be provided at the end of the basin.

Riprap

Riprap should be placed downstream of the basin for a length of at least four conduit widths.

Venting

At each installation, the designer should evaluate the need for venting to facilitate the hydraulic jump.

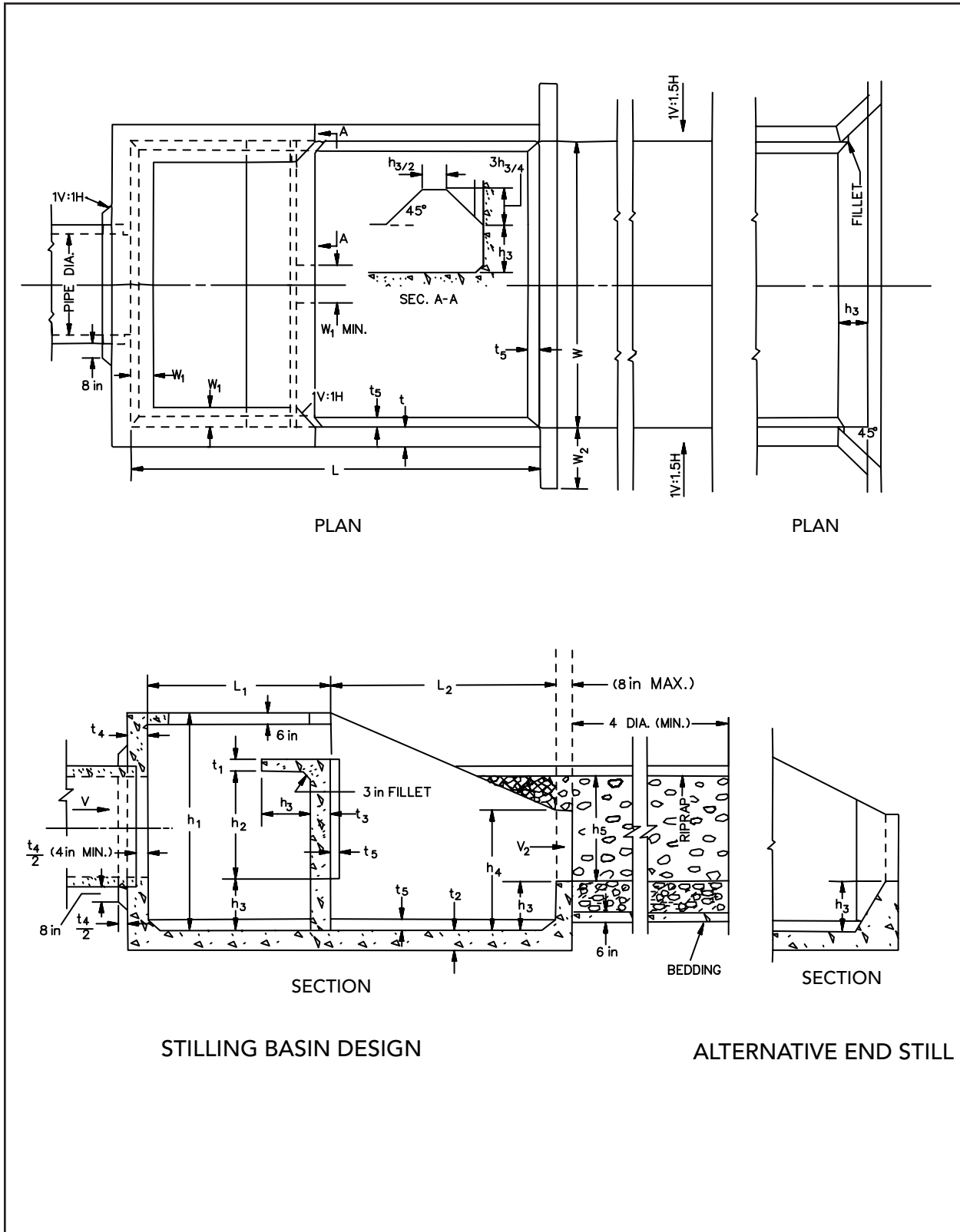


Figure 7-10 USBR Type VI (Impact) Dissipator

7.7.2 Design Procedure

- Step 1:** Calculate equivalent depth, d_E
- Rectangular section, $d_E = d_o = y_o$
 - Other sections, $d_E = (A/2)^{0.5}$
- Step 2:** Determine Input Flow
- Froude number, $Fr = V_o / (gd_E)^{0.5}$
 - Specific energy, $H_o = d_E + V_o^2 / 2g$
- Step 3:** Determine Basin Width, W
- Use [Figures 7-11](#) and [7-13](#)
 - Enter with Fr and read H_o/W
 - $W = H_o / (H_o/W)$
- Step 4:** Size Basin
- Use [Table 7-3](#) and W
 - Obtain the remaining dimensions
- Step 5:** Energy Loss
- Use [Figure 7-12](#)
 - Enter with Fr and read H_L/H_o
 - $H_L = (H_L/H_o)H_o$
- Step 6:** Exit Velocity (V_B)
- Exit energy (H_E) = $H_o - H_L$
 - $H_E = d_B + V_B^2 / 2g$
 $V_B = (Q/W) / d_B$

7.7.3 Design Example

Inputs

$D = 48$ in. pipe, $S_o = 0.15$ ft./ft., $n = 0.015$
 $Q = 300$ cfs, $d_o = 2.3$ ft, $V_o = 40$ ft./s.

- Step 1:** Calculate equivalent depth, d_E
- Other sections, $d_E = (A/2)^{0.5}$
 $A = Q/V_o = 300/40 = 7.5$ ft.²
 $d_E = (7.5/2)^{0.5} = 1.94$ ft.
- Step 2:** Determine Input Flow
- Froude number, $Fr_o = V_o / (gd_E)^{0.5}$
 $Fr = 40 / [32.2(1.94)]^{0.5} = 5.05$
 - Specific energy, $H_o = d_E + V_o^2 / 2g$
 $H_o = 1.94 + (40)^2 / (2)(32.2) = 26.8$ ft.
- Step 3:** Determine basin width, W
- Use [Figures 7-11](#) and [7-13](#)
 - Enter with $Fr = 5.05$ and read $H_o/W = 1.68$
 - $W = H_o / (H_o/W) = 26.8 / 1.68 = 16$ ft.

Table 7-2 Dimensions Of USBR Type VI Basin (Dimensions, ft.) (See [Figure 7-10](#))

W	h ₁	h ₂	h ₃	h ₄	L	L ₁	L ₂
4	3-1	1-6	0-8	1-8	5-5	2-4	3-1
5	3-10	1-11	0-10	2-1	6-8	2-11	3-10
6	4-7	2-3	1-0	2-6	8-0	3-5	4-7
7	5-5	2-7	1-2	2-11	9-5	4-0	5-5
8	6-2	3-0	1-4	3-4	10-8	4-7	6-2
9	6-11	3-5	1-6	3-9	12-0	5-2	6-11
10	7-8	3-9	1-8	4-2	13-5	5-9	7-8
11	8-5	4-2	1-10	4-7	14-7	6-4	8-5
12	9-2	4-6	2-0	5-0	16-0	6-10	9-2
13	10-2	4-11	2-2	5-5	17-4	7-5	10-0
14	10-9	5-3	2-4	5-10	18-8	8-0	10-9
15	11-6	5-7	2-6	6-3	20-0	8-6	11-6
16	12-3	6-0	2-8	6-8	21-4	9-1	12-3
17	13-0	6-4	2-10	7-1	21-6	9-8	13-0
18	13-9	6-8	3-0	7-6	23-11	10-3	13-9
19	14-7	7-1	3-2	7-11	25-4	10-10	14-7
20	15-4	7-6	3-4	8-4	26-7	11-5	15-4
W	W ₁	W ₂	t ₁	t ₂	t ₃	t ₄	t ₅
4	0-4	1-1	0-6	0-6	0-6	0-6	0-3
5	0-5	1-5	0-6	0-6	0-6	0-6	0-3
6	0-6	1-8	0-6	0-6	0-6	0-6	0-3
7	0-6	1-11	0-6	0-6	0-6	0-6	0-3
8	0-7	2-2	0-6	0-7	0-7	0-6	0-3
9	0-8	2-6	0-7	0-7	0-8	0-7	0-3
10	0-9	2-9	0-8	0-8	0-9	0-8	0-3
11	0-10	3-0	0-8	0-9	0-9	0-8	0-4
12	0-11	3-0	0-8	0-10	0-10	0-9	0-4
13	1-0	3-0	0-8	0-11	0-10	0-10	0-4
14	1-1	3-0	0-8	1-0	0-11	0-11	0-5
15	1-2	3-0	0-8	1-0	1-0	1-0	0-5
16	1-3	3-0	0-9	1-0	1-0	1-0	0-6
17	1-4	3-0	0-9	1-1	1-0	1-0	0-6
18	1-4	3-0	0-9	1-1	1-1	1-1	0-7
19	1-5	3-0	0-10	1-2	1-1	1-1	0-7
20	1-6	3-0	0-10	1-2	1-2	1-2	0-8

Step 4: Size Basin

- a. Use Table 7-3 and W
- b. Obtain the remaining dimensions

Step 5: Energy Loss

- a. Use [Figure 7-12](#)
- b. Enter with $Fr = 5.05$ and read $H_L/H_0 = 0.67$
- c. $H_L = (H_L/H_0)H_0 = 0.67(26.8) = 18$ ft.

Step 6: Exit Velocity (V_B)

- a. Exit energy $H_E = H_0 - H_L = 26.8 - 18 = 8.8$ ft.
- b. $H_E = d_B + V_B^2/2g = 8.8$ ft.
 $V_B = (Q/W)/d_B = (300/16)/d_B = 18.75/d_B$

d_B	V_B	$d_B + V_B^2/2g = 2.69$
2.3 = d_0	8.1	3.3
1.0	18.8	6.5
0.8	23.4	9.3, use
0.9	20.8	7.6

[Figure 7-14](#) shows a summary of the design example calculations based on the form provided in [Figure 7-11](#).

USER TYPE VI DISSIPATOR COMPUTATION FORM

PROJECT: _____ PLAN SHEET NO. _____ DATE _____
 _____ DESIGNER _____ REVIEWER _____

SECTION

PLAN

CHOOSE BASIN WIDTH (W)	TRIALS		
	1	2	3
$d_e = y_e$			
V_o			
$H_o = d_e + V_o^2 / 2g$			
Fr			
H_o / W			
$W = H_o / (H_o / W)$			

CHECK OUTLET VELOCITY (V_B)	
H_L / H_o	
$H_L = (H_L / H_o) H_o$	
$H_e = H_o - H_L$	
d_B	
$V_E = (Q/W) / d_B$	
$(H_e)_T = d_B + V_B^2 / 2g$	
IF $(H_e)_T \neq H_e$ CHOOSE ANOTHER D_B	

BASIN DIMENSIONS (FT.-IN.)							
W	h_1	h_2	h_3	h_4	L	L_1	L_2
W	W_1	W_2	t_1	t_2	t_3	t_4	t_5

Figure 7-11 USBR Basin Type VI — Checklist

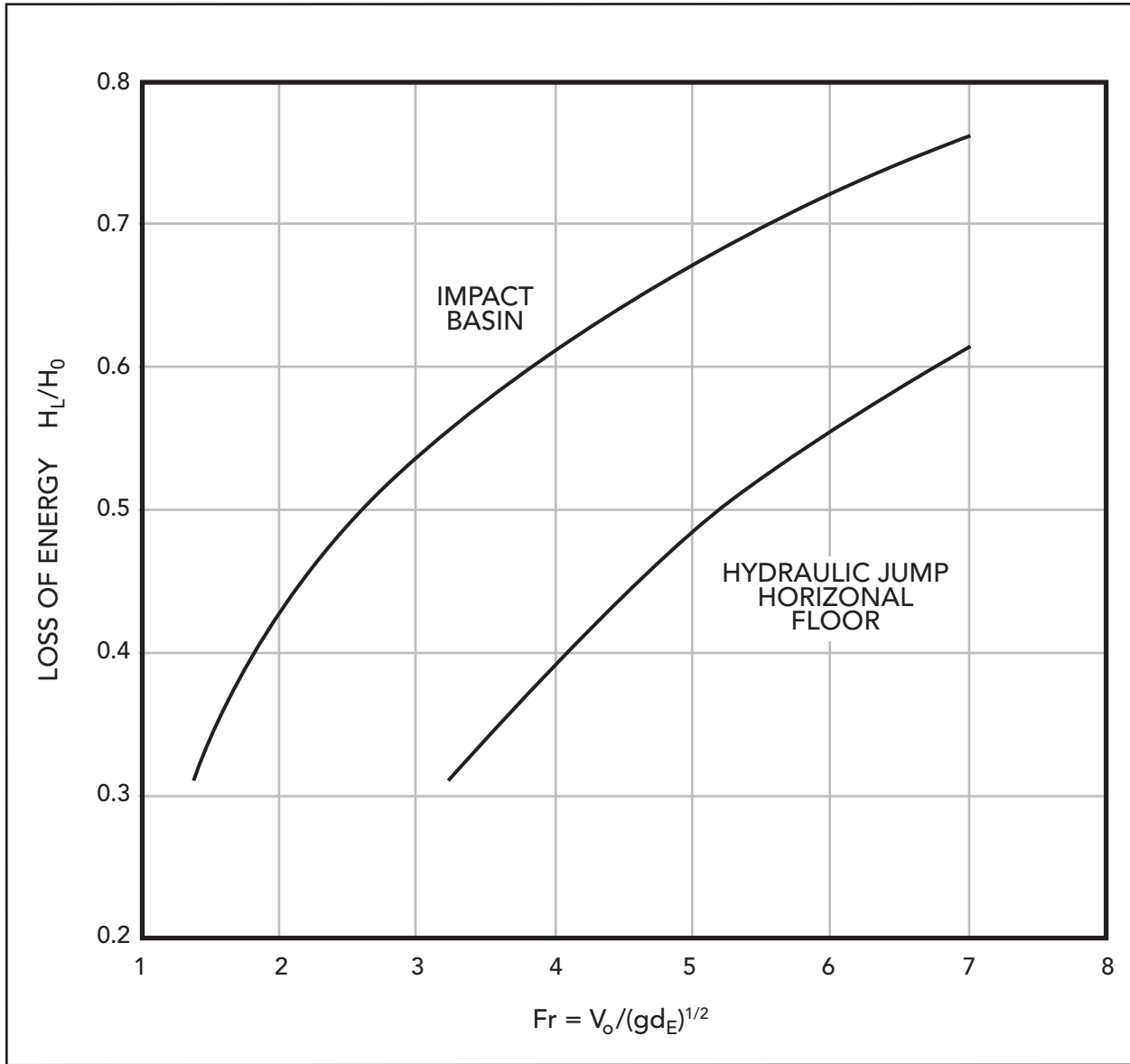


Figure 7-12 Energy Loss For USBR Type VI Dissipator

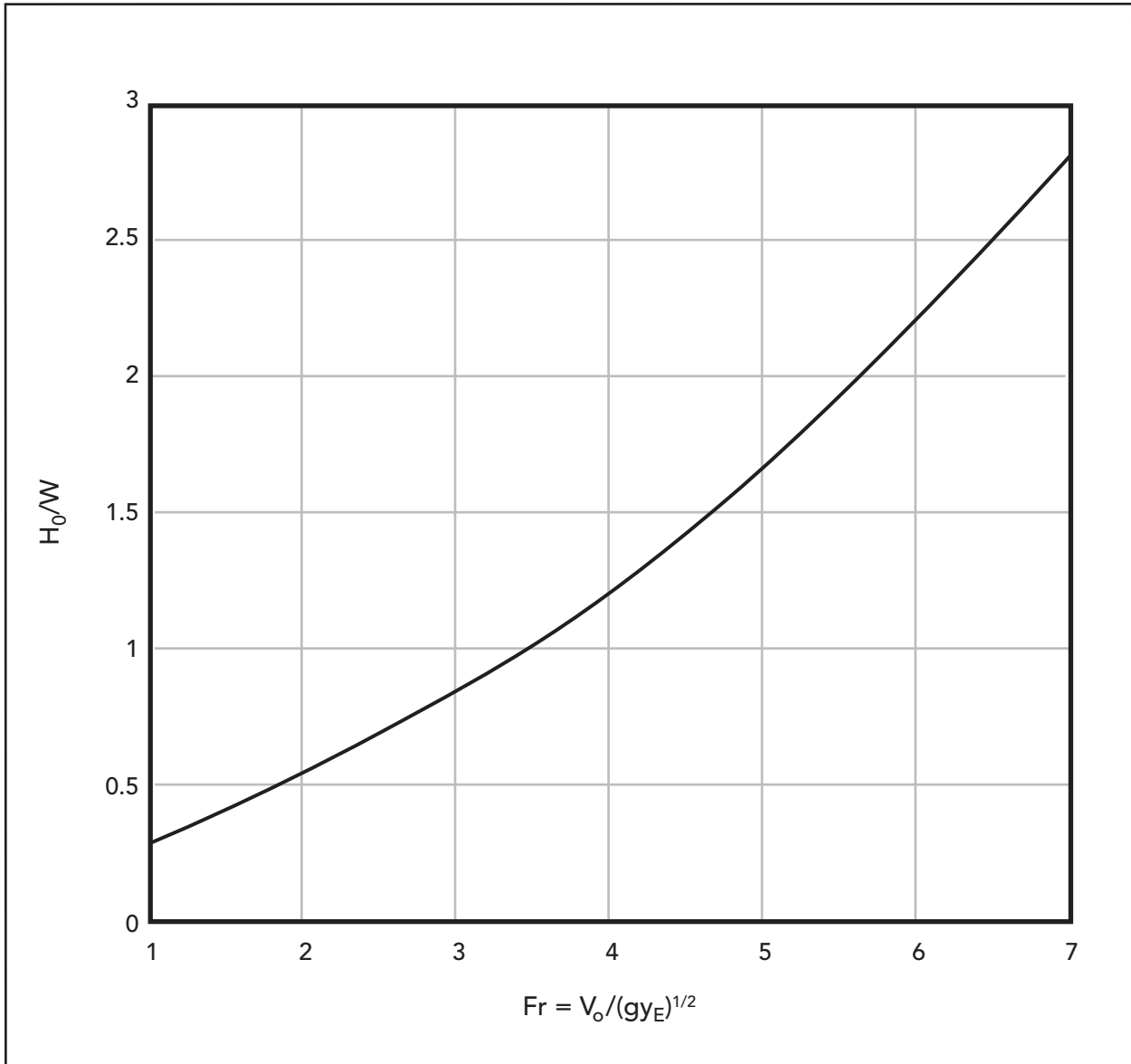


Figure 7-13 Design Curve For USBR Type VI Dissipator

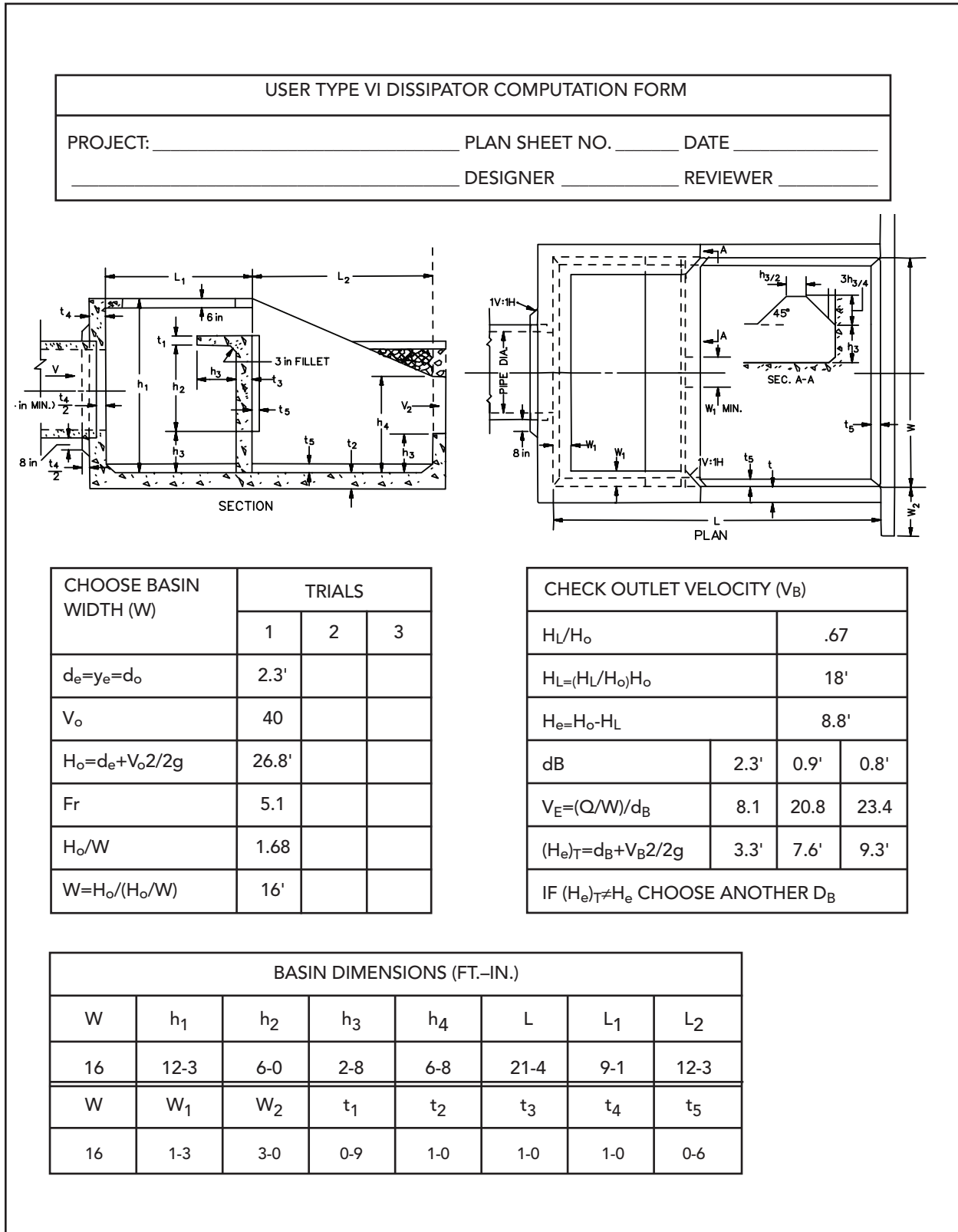


Figure 7-14 USBR Basin Type VI — Design Example

7.7.4 Computer Output

The USBR Type IV impact basin dissipator geometry can be computed using the “Energy Dissipator” module which is available in microcomputer program HY-8, Culvert Analysis. For an example similar to that of 7.6.3, the output of the culvert and channel input data, and computed geometry using the “Energy Dissipator” module shown below.

FHWA CULVERT ANALYSIS, HY 8, VERSION 4.5

CURRENT DATE	CURRENT TIME	FILE NAME	FILE DATE
--------------	--------------	-----------	-----------

CULVERT AND CHANNEL DATA

CULVERT NO. 1	DOWNSTREAM CHANNEL
CULVERT TYPE: 4 ft. CIRCULAR	CHANNEL TYPE : IRREGULAR
CULVERT LENGTH = 300 ft.	BOTTOM WIDTH = 7 ft.
NO. OF BARRELS = 1.0	TAILWATER DEPTH = 2.5 ft.
FLOW PER BARREL = 300 cfs	TOTAL DESIGN FLOW = 300 cfs
INVERT ELEVATION = 172.5 ft.	BOTTOM ELEVATION = 172.5 ft.
OUTLET VELOCITY = 4.0 ft./s.	NORMAL VELOCITY = 15.9 ft./s.

USBR TYPE 6 DISSIPATOR — FINAL DESIGN

BASIN OUTLET VELOCITY = 2.1 ft./s.

W = 16 ft.	W1 = 1.3 ft.	W2 = 3.0 ft.
L = 21.3 ft.	L1 = 9.1 ft.	L2 = 12.3 ft.
H1 = 12.3 ft.	H2 = 6.0 ft.	H3 = 2.7 ft.
H4 = 6.7 ft.	T1 = 0.8 ft.	T2 = 1.0 ft.
T3 = 1.0 ft.	T4 = 1.0 ft.	T5 = 0.5 ft.

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Appendix 7-A

References

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