APPENDIX 9.E — TABLES AND FORMS

TABLE 9.E-1 — Manning's n Values for Culverts*

Type of Conduit	Wall Description	Manning's n
Concrete Pipe	Smooth	0.010-0.011
Concrete Boxes	Smooth	0.012-0.015
Spiral Rib Metal Pipe	Smooth walls	0.012-0.013
Corrugated Metal Pipe, Pipe-Arch and Box (Annular and Helical corrugations — See Figure B-3, Manning's n varies with barrel size (See HDS 5))	2 2/3 x 1/2 in Annular	0.022-0.027
	2 2/3 x 1/2 in Helical	0.011-0.023
	6 x 1 in Helical	0.022-0.025
	5 x 1 in	0.025-0.026
	3 x 1 in	0.027-0.028
	6 x 2 in Structural Plate	0.033-0.035
	9 x 2 1/2 in Structural Plate	0.033-0.037
Corrugated Polyethylene	Smooth	0.009-0.015
Corrugated Polyethylene	Corrugated	0.018-0.025
Polyvinyl Chloride (PVC)	Smooth	0.009-0.011

Source: HDS 5 *(8)*.

* The values indicated in this Table are Manning's n value ranges obtained from laboratory reports. For further information concerning Manning n values for selected conduits, consult manufacturer's literature.

TABLE 9.E-2 — Entrance Loss Coefficients (Outlet Control, Full or Partly Full)

$$H_e = k_e \left[\frac{y^2}{2g} \right]$$

Type of Structure and Design of Entrance	Coefficient, k_e
Pipe, Concrete	
Mitered to conform to fill slope	0.7
* End section conforming to fill slope	0.5
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Socket end of pipe (groove-end)	0.2
Projecting from fill, socket end (groove-end)	0.2
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Mitered to conform to fill slope, paved or unpaved slope	0.7
Headwall or headwall and wingwalls square-edge	0.5
* End section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Wingwalls at 10° to 25° or 30° to 75° to barrel	
Square-edged at crown	0.5
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2
Side- or slope-tapered inlet	0.2

* "End section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests, they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design, have a superior hydraulic performance. These latter sections can be designed using the information given for the beveled inlet.

PROJECT: _____

_____

STATION: _____

SHEET _____ OF _____

CULVERT DESIGN FORM

DESIGNER / DATE: _____ OF _____

REVIEWER / DATE: _____ OF _____

HYDROLOGICAL DATA

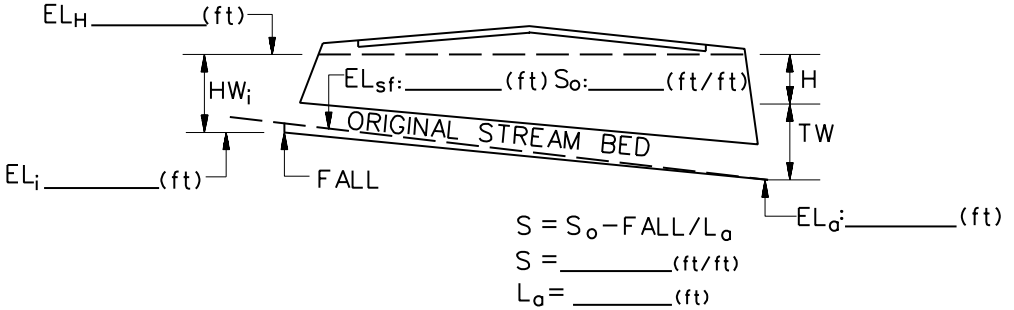
SEE ADDL SHTS.

- ☐ METHOD: _____
- ☐ DRAINAGE AREA: _____ ☐ STREAM SLOPE: _____
- ☐ CHANNEL SHAPE: _____
- ☐ ROUTING: _____ ☐ OTHER: _____

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (ft^3/s)	TW (ft)

ROADWAY ELEVATION: _____ (ft)



$S = S_o - FALL/L_o$

$S =$ _____ (ft/ft)

$L_o =$ _____ (ft)

CULVERT DESCRIPTION: MATERIAL-SHAPE-SIZE-ENTRANCE	TOTAL FLOW Q (ft^3/s)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS											CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
			INLET CONTROL				OUTLET CONTROL									
			HW/D (2)	HWi	FALL (3)	ELhi (4)	TW (5)	d_c	$\frac{d_c + D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)			

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) HW/D = HW/D OR HW/D FROM DESIGN CHARTS

(3) FALL = $HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $ELhi = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL

(6) h_o = TW or $(d_c + D)/2$ (WHICHEVER IS GREATER)

(7) $H = [1+k_e+(19.63\ n^2L)/R^{1.33}]\ V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUSCRIPT DEFINITIONS:

a. Approximate
f. Culvert Face
hd. Design Headwater
hi. Headwater in Inlet Control
ho. Headwater in Outlet Control
i. Inlet Control Section
o. Outlet
sf. Streamed at Culvert Face
tw. Tailwater

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED:

SIZE: _____

SHAPE: _____

MATERIAL: _____ n _____

ENTRANCE: _____

PROJECT: _____

STATION: _____

SHEET _____ **OF** _____

TAPERED INLET DESIGN FORM

DESIGNER/DATE: _____ / _____

REVIEWER/DATE: _____ / _____

DESIGN DATA:

Q _____ = _____ (ft^3/s); EL_N _____(ft)

EL. THROAT INVERT _____ (ft)

EL. STREAM BED AT FACE _____ (ft)

FALL _____ (ft) TAPER _____ : 1 (4H:1V TO 6H:1V)

STREAM SLOPE, S_o = _____ (ft/ft)

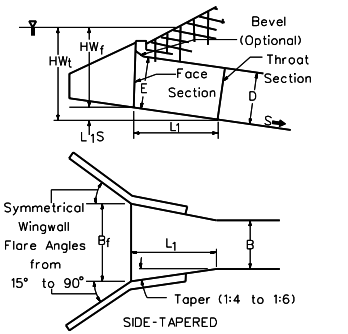
SLOPE OF BARREL, S = _____(ft/ft)

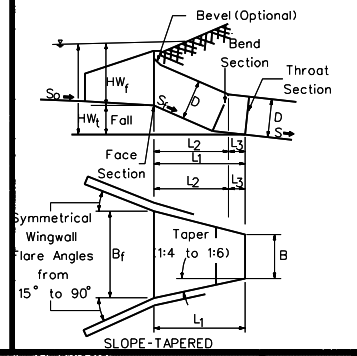
S_f _____ : 1 (2H:1V TO 3H:1V)

BARREL SHAPE AND MATERIAL : _____

N = _____, B = _____, D = _____

INLET EDGE DESCRIPTION _____





COMMENTS

Q (ft^3/s)	EL_N	EL. THROAT INVERT	EL. FACE INVERT (1)	HW_f (2)	HW_f / E (3)	Q / B_f (4)	MIN. B_f (5)	SELECTED B_f	SLOPE-TAPERED ONLY: MIN. L_3 (6)	L_2 (7)	CHECK L_2 (8)	ADJ. L_3 (9)	ADJ. TAPER (10)	L_1 (11)	SIDE-TAPERED W/ FALL: EL. CREST INV.	HW_o (12)	MIN. W (13)

(1) SIDE-TAPERED : EL. FACE INVERT = EL. THROAT INVERT (FIRST ESTIMATE)
SLOPE-TAPERED : EL. FACE INVERT = EL. STREAM BED AT FACE

(2) $HW_f = EL_N$ - EL. FACE INVERT

(3) 1.1 D ≥ E ≥ D

(4) FROM DESIGN CHARTS

(5) MIN. $B_f = Q/(Q/B_f)$

(6) MIN. L_3 = 0.5 NB

(7) L_2 = (EL. FACE INVERT - EL. THROAT INVERT) S_f

(8) CHECK $L_2 = ((B_f - NB)/2) * TAPER - L_3$

(9) IF (8) > (7), ADJ. $L_3 = ((B_f - NB)/2) * TAPER - L_2$

(10) IF (7) > (8), ADJ. TAPER = $(L_2 + L_3)/((B_f - NB)/2)$

(11) SIDE-TAPERED : $L = ((B_f - NB)/2) * TAPER$
SLOPE-TAPERED : $L_1 = L_2 + L_3$

(12) $HW_o = EL_N$ - EL. CREST INVERT

(13) MIN. $W = 0.634\ Q/HW_o^{1.8}$

SELECTED DESIGN

B_f _____

L_1 _____

L_2 _____

L_3 _____

BEVELS ANGLE ____°

b = ___ in , d = ___ in

TAPER _____ : 1V

S_f = _____ : 1V

PROJECT: _____

STATION: _____

SHEET _____ OF _____

MITERED INLET DESIGN FORM

DESIGNER/DATE: _____ / _____

REVIEWER/DATE: _____ / _____

DESIGN DATA: N _____; B _____; D _____

Q _____ = _____ (ft^3/s); EL_{hi} _____ (ft)

EL. THROAT INVERT _____ (ft)

EL. STREAM BED AT CREST _____ (ft)

FALL _____ (ft); TAPER _____ : 1 (4H:1V TO 6H:1V)

STREAM SLOPE, S_o = _____ (ft/ft)

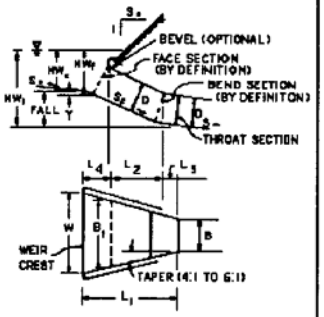
SLOPE OF BARREL, S = _____ ( )

SLOPE OF THE EMBANKMENT S_e = _____ : 1

S_f _____ : 1 (2H:1V TO 3H:1V)

BARREL SHAPE AND MATERIAL : _____

INLET EDGE DESCRIPTION : _____



SLOPE-TAPERED INLET/MITERED FACE

COMMENTS

Q (ft^3/s)	EL_{hi}	EL. THROAT INVERT	y (1)	EL. FACE INVERT (2)	HW_f (3)	$\frac{HW_f}{E}$ (4)	$\frac{Q}{B_f}$ (5)	MIN. B_f (6)	SELECTED B_f	MIN. L_3 (7)	L_4 (8)	L_2 (9)	CHECK L_2 (10)	ADJ. L_3 (11)	ADJ. TAPER (12)	L_1 (13)	EL. CREST INV.	HW_c (14)	MIN. W (15)	W (16)

(1) $y = [((S_o - S_f) - 1)/((S_o + S_f)(S_f + 1))] - D$

(2) EL. FACE INVERT = EL. STREAM BED AT CREST - y

(3) $HW_f = EL_{hi}$ - EL. FACE INVERT

(4) $1.1\,D \geq E \geq D$

(5) FROM DESIGN CHARTS

(6) MIN. $B_f = Q/(Q/B_f)$

(7) MIN. $L_3 = 0.5$ NB

(8) $L_4 = S_f y + D/S_f$

(9) L_2 = (EL.. CREST INVERT - EL. THROAT INVERT) S_f - L_4

*** IF L_2 IS NEGATIVE, DO NOT USE THIS INLET.

(10) CHECK $L_2 = ((B_f - NB)/2) * TAPER - L_3$

(11) IF (10) > (9), ADJ. $L_3 = ((B_f - NB)/2) * TAPER - L_2$

(12) IF (9) > (10), ADJ. TAPER = $(L_2 + L_3)/((B_f - NB)/2)$

(13) $L_1 = L_2 + L_3 + L_4$

(14) $HW_c = EL_{hi}$ - EL. CREST INVERT

(15) MIN. $W = 0.634\ Q/HW_c$

(16) $W = NB + 2\,(L_1/TAPER)$

IF W < MIN. W, ADJUST TAPER

SELECTED DESIGN

B_f _____

L_1 _____

L_2 _____

L_3 _____

L_4 _____

BEVELS ANGLE ____ °

b = __ in d = __ in

TAPER _____ :1V

S = _____ :1V