FHWA-EPD-86-116A

Hydraulic Design of Improved Inlets for Culverts

using

Programable Calculators

MONROE

Compucorp - 325 Scientist

Calculator Design Series #1

October 1980

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

FEDERAL HIGHWAY ADMINISTRATION

Hydraulic Design Publications

The first hydraulic design publications were developed in the early 1960's to aid in the design of highway drainage structures. Since that time, the list of publications has expanded as research results and actual experience became available. Some material is preliminary or tentative, subject to change upon further research. Criticisms and suggestions on material contained in the publications are welcomed.

The publications listed below are available for purchase at the listed prices from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Payment should accompany orders to the Government Printing Office. Stock numbers should be used in ordering the publications.

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Hydraulic Design Series

HDS No. 1 HYDRAULICS OF BRIDGE WATERWAYS - Second Edition - Revised 1978 - $3.00 (Stock No. 050-001-00133-1)

Hydraulic Engineering Circulars

HEC No. 5 HYDRAULIC CHARTS FOR THE SELECTION OF HIGHWAY CULVERTS - December 1965 - 95 cents (Stock No. 050-002-00010-1)

HEC No. 12 DRAINAGE OF HIGHWAY PAVEMENTS - March 1969 - $1.55 (Stock No. 050-002-00043-8)

HEC No. 14 HYDRAULIC DESIGN OF ENERGY DISSIPATORS FOR CULVERTS AND CHANNELS - December 1975 - $4.70 (Stock No. 050-002-00102-7)

HEC No. 15 DESIGN OF STABLE CHANNELS WITH FLEXIBLE LININGS - October 1975 - $2.75 (Stock No. 050-002-00101-9)

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LIST OF SYMBOLS

Symbol	Units	Description
A	$ft.^2$	Area of flow in the culvert barrel
Alpha		Energy coefficient used obtain true velocity head
B	ft.	Width of the culvert barrel
BW	ft.	Width of channel bottom
b	ft.	Dimension of side bevel in plane of face
B_f	ft.	Width of face sections of tapered inlets
D	ft.	Height of box culvert or diameter of pipe culvert
d	ft.	Dimension of top bevel in plane of face
d_c	ft.	Critical depth of flow
d_n	ft.	Normal depth of flow in a uniform channel for steady flow
DHW El.	ft.	Design headwater elevation at the culvert entrance
Depth	ft.	A term to indicate the use of eitgher d_n, d_c, TW or D in the calculation of outlet velocity
E	ft.	Height of side-tapered pipe culvert face section, excluding bevel dimension
FALL	ft.	Approximate depression of control section below the stream crossing
H_c	ft.	Depth of pool, or head, above the crest
HW	ft.	Headwater elevation, subscript indicates control section
HW_f	ft.	Headwater elevation required for flow to pass face section in face control
HW_o	ft.	Headwater elevation required for flow to pass face in outlet control
HW_t	ft.	Headwater elevation required for flow to pass throat section in throat control

Symbol	Units	Description
k_e		Entrance energy loss coefficient
L_a	ft.	Approximate total length of culvert, including inlet
L_1, L_2, L_3, L_4	ft.	Dimensions relating to tapered inlets (see sketches in Step 9)
N		Number of barrels
n		Manning roughness coefficient
Q	cu.ft/sec.	Volume rate of flow
R	ft.	Hydraulic radius
S	ft/ft	Slope of culvert barrel
S_f	ft/ft	Slope of FALL for slope-tapered inlets, length : drop
S_o	ft/ft	Slope of natural channel
Taper	ft/ft	Sidewall flare angle, length : offset
TW	ft.	Tailwater depth at outlet of culvert referenced to outlet invert elevation
W	ft.	Width of weir crest for slope-tapered inlet with mitered face, or total weir length for a depressed entrance
X		a factor defined as $\left(\frac{AR^{2/3}}{B^{8/3}}\right)$ or $\left(\frac{AR^{2/3}}{D^{8/3}}\right)$ and used by Chow in determining normal depth
y	ft.	Difference in elevation between crest and face section of a slope-tapered inlet with mitered face
Z_1, Z_2	ft/ft	Horizontal distances per foot of depth for side slopes of channels, cotangent of side slopes

INTRODUCTION

The programable calculator as a culvert designing tool offers many desirable features. Compared with the hand method, the calculator is more accurate, less time consuming, and eliminates all the searching through charts and nomographs. In one quarter of the time it takes to design one culvert by hand, the designer could use the calculator to design the culvert, checking four or five different sizes to find the best one, while also evaluating several inlet configurations including both side- and slope-tapered inlets.

In an office where it is not feasible to use a computer for culvert design, the programable calculator becomes a desireable alternative. The accuracy remains the same, and the calculator method offers a segment by segment design approach. This method allows the culvert design parameters to be changed as the design is proceeding along.

The procedure herein covers both box and circular pipe culverts and follows the culvert design methods presented in "Hydraulic Design of Improved Inlets for Culverts," Hydraulic Engineering Circular No. 13 (HEC 13), dated August 1972. The programs begin with the computation of tailwater, proceed through the design of the culvert barrel, and conclude with the design of the culvert inlet most applicable to the site. The programs produce detailed inlet dimensions, performance curve data, and the outlet velocity.

Since the procedure is subdivided into a series of programs, the designer may enter the sequence at any point, provided the necessary input data is available, and obtain the desired design results.

These box and pipe culvert programs have been written for use on the MONROE (formerly Compucorp) - 325 Scientist. It is expected that with the equations, examples, and program listings, a designer will be able to write similar programs for any other calculator he may have available.

Terminology used in this publication assumes that the designer is familiar with HEC 13 and understands the principles and design philosophy expressed therein.

This document was written by Messrs. Patrick D. Wlaschin, Mark M. Chatfield, Albert H. Lowe, and Romeo G. Magalong and was edited by Mr Philip L. Thompson.

PROGRAM LIMITATIONS

In addition to improved inlets, which include bevel-edged, side-tapered and slope-tapered designs, this procedure includes programs for square-edged entrances for box culverts or thin-edged projecting, square-edged, or groove-edged entrances for circular pipe culverts.

When computing headwater, the upper and lower limits of HW/D for thin-edged projecting, square-edged, groove-edged and beveled inlets should be governed by the limitations of HEC No. 13. Because of the polynomial best-fit equations used, the headwater for improved inlets should be limited to not more than 4.5D or not less than 0.5D.

When designing either a side-tapered or slope-tapered inlet, the number of barrels, N, is limited to two.

Calculations of outlet velocity for box culverts is limited to a maximum D/B of 2.

In programs for circular pipe where d_n/D is greater than 0.89 the program assumes the pipe to be flowing full in calculating velocity.

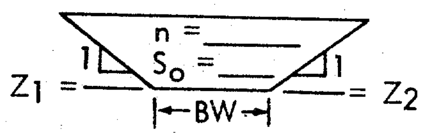
When calculating H in the outlet control performance programs 1-2, 1-3, 2-1, and 2-2, it is assumed that the culvert is flowing full.

PROCEDURAL OUTLINE
FOR BOX CULVERTS

STEP 1

Determine TW elevation from Q and channel geometry if TW is based on normal depth in the natural channel.

Use program #1-1



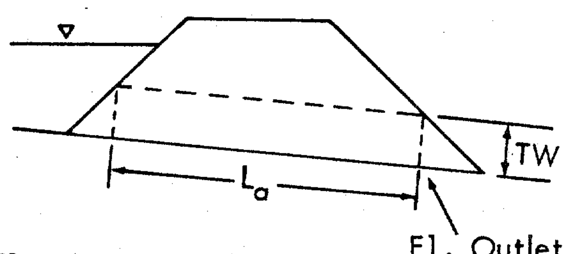
Enter: n - Manning roughness coefficient for the natural stream
S_o - Slope of natural channel
BW - Width of streambed bottom
Z_1 - Horizontal distance for side slope of channel
Z_2 - Horizontal distance for side slope of channel
Q - Volume rate of flow

Read: d_n, (TW) - To obtain values of TW for other values of Q, enter Q and press STOP START.

STEP 2

Using a known tailwater or the tailwater calculated in STEP 1, determine an acceptable box culvert size in outlet control.

Use program #1-2



Enter: Q - Volume rate of flow
N - Number of barrels
L_a - Approximate total length of culvert, including inlet
n - Manning roughness coefficient for the barrel
k_e - Entrance energy loss coefficient
TW - Tailwater depth at the outlet of the culvert
Elevation of the outlet invert
B - Width of the box culvert
D - Height of the box culvert

Read: TW or $\frac{d_c+D}{2}$, whichever is controlling

HW_o - Outlet control headwater elevation

If HW_o elevation is not approximately equal to DHW elevation, enter new B and D. Repeat until an acceptable HW_o is obtained.

STEP 3

With the selected box size and entrance configuration, enter the following data to obtain outlet control performance curve data.

Use program #1-3

Enter: L_a - Approximate length of culvert, including inlet
n - Manning roughness coefficient for the culvert barrel
k_e - Entrance energy loss coefficient
B - Width of box culvert
D - Height of box culvert
Elevation of the outlet invert
TW - Tailwater depth at outlet of culvert
Q/N - Volume rate of flow per barrel

Read: HW_o - Outlet control headwater elevation

To obtain values of HW_o for other values of Q/N, enter TW and Q/N. Repeat for each Q/N.

Since these values of HW_o are used for performance curve data, the different Q/N, values should reflect changes in Q, not N. TW will vary with Q if TW is based on normal depth in the natural channel.

STEP 4

Calculate outlet velocity for box culverts in outlet control.

Use program #1-4

Enter: TW - Tailwater depth at outlet of culvert
D - Height of box culvert
B - Width of box culvert
Q/N - Volume rate of flow per barrel

Read: Velocity - computed differently depending upon whether d_c, TW or D governs.

STEP 5

Select type of inlet by performing the following inlet control calculations and computing performance curve data.

Use program #1-5 if analyzing a square edged inlet with headwalls.
Use program #1-6 if anlayzing a 45° beveled inlet
Use program #1-7 if analyzing the throat section of a tapered inlet.

Enter: DHW Elevation
Elevation of the streambed at the face
B - Width of box culvert
D - Height of box culvert
Q/N - Volume rate of flow per barrel

Read: Elevation of face (or throat) invert - If this value exceeds that of the streambed at the face, the program will assume the elevation of the streambed at the face (zero FALL) in computing the performance curve.

FALL

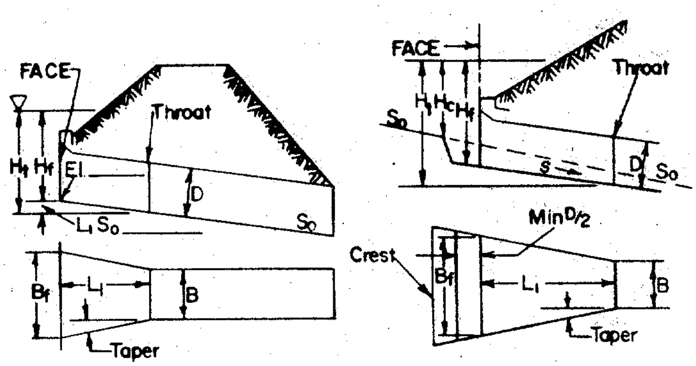
HW_f (or HW_t) - To obtain performance curve data, enter desired Q/N's.

At this point, evaluate the box size chosen. The question should be asked, "Is the minimum FALL excessive for the type of inlet being designed?" If the answer is yes, then return to STEP 2, select a larger box size and proceed through STEPS 3 and 4 again. If the answer is no, the culvert is either adequate or over designed. Use program # 1-13 to check the crest of depressed conventional or beveled designs.

STEP 6

If both the conventional and beveled inlet designs used are inadequate to handle the design Q at the DHW elevation or with a reasonable FALL, and a tapered inlet appears to be both desirable and economical, then design the tapered inlet throat. It is recommended that both side-tapered and slope-tapered designs be analyzed in order that the proper choice be made. To design a side-tapered inlet, proceed as follows. To design a slope-tapered inlet, go to STEP 8.

(SIDE-TAPERED INLET)



Use program #1-8 if the wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)

Use program #1-9 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)

Enter: HW_f - Headwater elevation with face control
Elevation of throat invert
Taper + S - Sidewall flare angle plus
slope of culvert barrel, $S = (S_o - FALL/L_a)$
NxB - Total clear width of culvert
Q - Volume rate of flow
D - Height of box culvert

Read: B_f - to round off B_f, enter the new, higher B_f value and press STOP START
L_1 - Length of improved inlet
Elevation of the face invert

Step 7

To complete the design of a side-tapered inlet, check crest control.

Use program #1-13

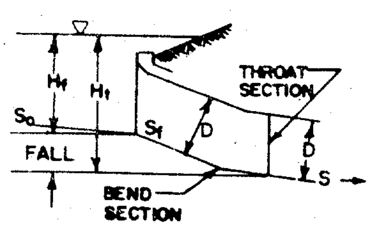
Enter: Q - Volume rate of flow
N - Number of barrels
HW_f - Headwater elevation required for flow to pass face section in face control
W - Weir length = 10 times the FALL

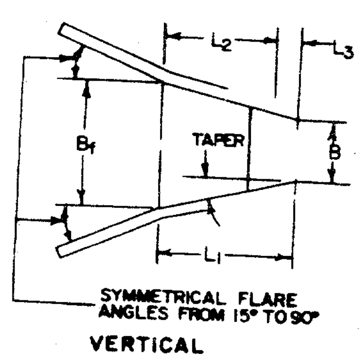
Read: H_c

Maximum crest elevation

STEP 8

Design a slope-tapered inlet for box culvert. If designing a vertical face slope-tapered inlet, proceed as follows. If designing a mitered face slope-tapered inlet, go to STEP 10.





Use program #1-10 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)

Use program #1-11 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)

Enter: Q - Volume rate of flow
D - Height of box culvert
HW_f - Headwater elevation required for flow to pass face section in face control
Elevation of face invert
y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face,
= 0 for vertical face

Read: Minimum B_f

Step 9

Calculate design dimensions for slope-tapered inlet with vertical face.

Use program #1-12

Enter: B - Width of box culvert
D - Height of box culvert
N - Number of barrels
B_f - Width of face section of improved inlet (May be rounded up from results of program 1-10 or 1-11)
y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face,
= 0 for vertical face

Taper - Sidewall flare angle

Elevation crest invert

Elevation throat invert

S_f - slope between the face and throat

Read: L_2

L_3

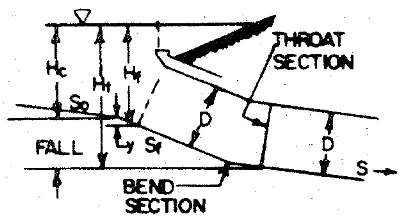
L_4

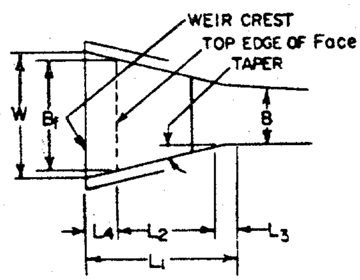
L_1

Taper

STEP 10

Mitered face slope-tapered inlet





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Use program #1-10 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)

Use program #1-11 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)

Enter: Q - Volume rate of flow

D - Height of box culvert

HW_f - Headwater elevation required for flow to pass face section in face control

Elevation of crest

y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face, = (.4D)

Read: Minimum B_f

Step 11

Calculate design dimensions for slope-tapered inlet with vertical face.

Use program #1-12

Enter: B - Width of box culvert

D - Height of box culvert

N - Number of barrels

B_f - Width of face section of improved inlet (May be rounded up from results of program 1-10 or 1-11)

y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face,
= (.4D)

Taper - Sidewall flare angle

Elevation crest invert

Elevation throat invert

S_f - Slope between the face and throat

Read: L_2

L_3

L_4

L_1

Taper

STEP 12

Check crest control for a slope-tapered inlet with a mitered face.

Use program #1-13

Enter: Q - Volume rate of flow

N - Number of barrels

HW_f - Headwater elevation required for flow to pass face section in face control

B - Width of box culvert

L_1 - Distance between the throat and face

Taper - Sidewall flare angle

Read: H_c

Maximum crest elevation

Step 13

Calculate outlet velocity for box culverts in inlet control.

Use program #1-14

Enter: D - Height of box culvert

B - Width of box culvert

n - Manning roughness coefficient for culvert barrel

Q/N - Volume rate of flow per barrel

S - Slope of culvert barrel

Read: d_n/B

Velocity

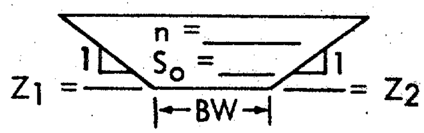
PROCEDURAL OUTLINE

FOR CIRCULAR PIPE CULVERTS

STEP 1

Determine TW elevation from Q and channel geometry if TW is based on normal depth in the natural channel.

Use program #1-1



Enter: n - Manning roughness coefficient for the natural stream

S_o - Slope of natural channel

BW - Width of streambed bottom

Z_1 - Horizontal distance for side slope of channel

Z_2 - Horizontal distance for side slope of channel

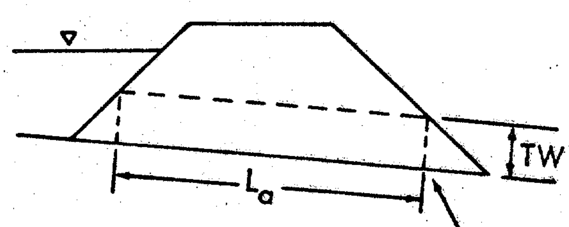
Q - Volume rate of flow

Read: d_n, (TW) - To obtain values of TW for other values of Q, enter Q and press STOP START.

STEP 2

Using a known tailwater or the tailwater calculated in STEP 1, determine an acceptable pipe culvert size in outlet control.

Use program #2-1



Enter: Q - Volume rate of flow

N - Number of barrels

L_a - Approximate total length of culvert, including inlet

n - Manning roughness coefficient for the barrel

k_e - Entrance energy loss coefficient

TW - Tailwater depth at the outlet of the culvert

Elevation of the outlet invert

d_c - Critical depth of flow

D - Diameter of the pipe culvert

Read: TW or $\frac{d_c+D}{2}$, whichever is controlling

HW_o - Outlet control headwater elevation

If HW_o elevation is not approximately equal to DHW elevation, enter new d_c and D. Repeat until an acceptable HW_o is obtained.

The value of d_c may be obtained from charts in Hydraulic Design Series 3, Design Charts for Open-Channel Flow, or any other source that shows critical depth as a function of culvert size and Q. If charts are unavailable, program #2-3 could be used to determine d_c.

STEP 3

With the selected pipe size and entrance configuration, enter the following data to obtain outlet control performance curve data.

Use program #2-2

Enter: L_a - Approximate length of culvert, including inlet
n - Manning roughness coefficient for the culvert barrel
k_e - Entrance energy loss coefficient
D - Diameter of pipe culvert
Elevation of the outlet invert
TW - Tailwater depth at outlet of culvert
d_c - Critrical depth of flow
Q/N - Volume rate of flow per barrel

Read: HW_o - Outlet control headwater elevation

To obtain values of HW_o for other values of Q/N, enter TW, d_c and Q/N. Repeat for each Q/N.

Since these values of HW_o are used for performance curve data, the different Q/N, values should reflect changes in Q, not N. TW will vary with Q if TW is based on normal depth in the natural channel.

STEP 4

Calculate outlet velocity for pipe culverts in outlet control.

Use program #2-3

Enter: D - Diameter of pipe culvert
Q/N - Volume rate of flow per barrel
Alpha - Energy coefficient
Use 1.04 for concrete pipe
Use 1.12 for corrugated pipe
TW - Tailwater depth at outlet of culvert

Read: Velocity - computed differently depending upon whether d_c, TW or D governs.

STEP 5

Select type of inlet by performing the following inlet control calculations and computing performance curve data.

Use program #2-4 if analyzing a thin-edged projecting inlet.
Use program #2-5 if analyzing an inlet with square edges.
Use program #2-6 if analyzing a beveled inlet.
Use program #2-7 if analyzing a groove end projecting inlet.
Use program #2-8 if anlayzing a groove end inlet and headwalls.
Use program #2-9 if analyzing a tapered inlet throat. (smooth inlet)
Use program #2-10 if analyzing a tapered inlet throat. (rough inlet)

Enter: DHW - Elevation
Elevation of streambed at the face.
D - Diameter pipe culvert
Q/N - Volume rate of flow per barrel

Read: Elevation of face (or throat) invert - If this value exceeds that of the streambed at the face, the program will assume the elevation of the streambed at the face (zero FALL) in computing the performance curve.

FALL

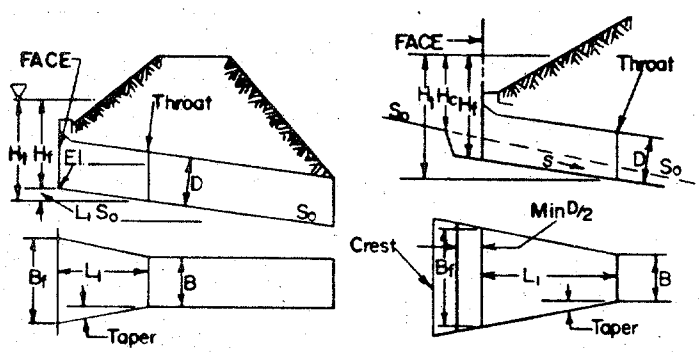
HW_f (or HW_t) - To obtain performance curve data, enter desired Q/N's.

At this point, evaluate the pipe size chosen. The question should be asked, "Is the minimum FALL excessive for the type of inlet being designed?" If the answer is yes, then return to STEP 2, select a larger pipe size and proceed through STEPS 3 and 4 again. If the answer is no, the culvert is either adequate or over designed. Use program # 1-13 to check the crest of depressed conventional or beveled designs.

STEP 6

If both the conventional and beveled inlet designs used are inadequate to handle the design Q at the DHW elevation or with a reasonable FALL, and a tapered inlet appears to be both desirable and economical, then design the tapered inlet throat. It is recommended that both side-tapered and slope-tapered designs be analyzed in order that the proper choice be made. To design a side-tapered inlet, proceed as follows. To design a slope-tapered inlet, go to STEP 8.

(SIDE-TAPERED INLET)



Use program #2-11 if the face has projecting thin edges.
Use program #2-12 if the face has square edges in a headwall.
Use program #2-13 if the face has bevels or a grooved end.

Enter: HW_f - Headwater elevation with face control

Elevation of throat invert

Taper + S - Sidewall flare angle plus slope of culvert barrel, $S = (S_o - FALL/L_a)$

NxD - Total clear width of culvert

Q - Volume rate of flow

E - $D \leq E \leq 1.1D$

Read: B_f - to round off B_f, enter the new, higher B_f value and press STOP START

L_1 - Length of improved inlet

Elevation of the face invert

Step 7

To complete the design of a side-tapered inlet, check crest control.

Use program #1-13

Enter: Q - Volume rate of flow

N - Number of barrels

HW_f - Headwater elevation required for flow to pass face section in face control

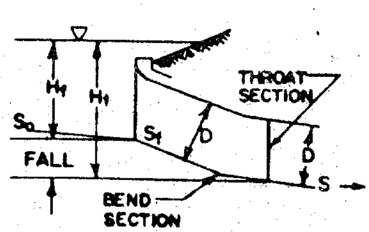
W - Weir length = 10 times the FALL

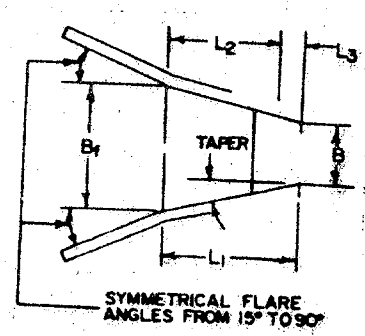
Read: H_c

Maximum crest elevation

STEP 8

Design a slope-tapered inlet for box culvert. If designing a vertical face slope-tapered inlet, proceed as follows. If designing a mitered face slope-tapered inlet, go to STEP 10.





VERTICAL

Use program #1-10 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)

Use program #1-11 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)

Enter: Q - Volume rate of flow

D - Diameter of pipe culvert

HW_f - Headwater elevation required for flow to pass face section in face control

Elevation of face invert

y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face, = 0 for vertical face

Read: Minimum B_f

Step 9

Calculate design dimensions for slope-tapered inlet with vertical face.

Use program #1-12

Enter: B - Width of pipe culvert

D - Diameter of pipe culvert

N - Number of barrels

B_f - Width of face section of improved inlet (May be rounded up from results of program 1-10 or 1-11)

y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face, = 0 for vertical face

Taper - Sidewall flare angle

Elevation, crest invert

Elevation throat invert

S_f - slope between the face and throat

Read: L_2

L_3

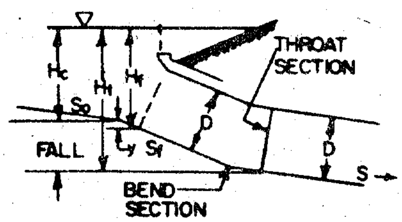
L_4

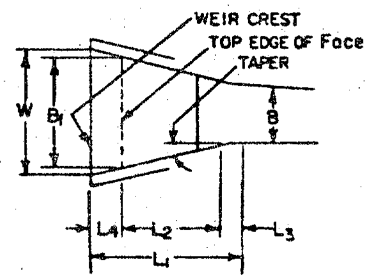
L_1

Taper

STEP 10

Mitered face slope-tapered inlet





MITERED

Use program #1-10 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)

Use program #1-11 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)

Enter: Q - Volume rate of flow

D - Diameter of pipe culvert

HW_f - Headwater elevation required for flow to pass face section in face control

Elevation of crest

y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face, = (.4D)

Read: Minimum B_f

Step 11

Calculate design dimensions for slope-tapered inlet with vertical face.

Use program #1-12

Enter: B - Width of pipe culvert

D - Diameter of pipe culvert

N - Number of barrels

B_f - Width of face section of improved inlet (May be rounded up from results of program 1-10 or 1-11)

y - Difference in elevation between crest and face section of a slope-tapered inlet with mitered face,
= (.4D)

Taper - Sidewall flare angle

Elevation crest invert

Elevation throat invert

S_f - Slope between the face and throat

Read: L_2

L_3

L_4

L_1

Taper

STEP 12

Check crest control for a slope-tapered inlet with a mitered face.

Use program #1-13

Enter: Q - Volume rate of flow

N - Number of barrels

HW_f - Headwater elevation required for flow to pass face section in face control

D - Diameter of pipe culvert

L_1 - Distance between the throat and face

Taper - Sidewall flare angle

Read: H_c

Maximum crest elevation

Step 13

Calculate outlet velocity for pipe culverts in inlet control.

Use program #2-14

Enter: D - Diameter of pipe culvert

B - Width of pipe culvert

n - Manning roughness coefficient for culvert barrel

Q/N - Volume rate of flow per barrel

S - Slope of culvert barrel

Read: Velocity

Example Problems

BOX CULVERT EXAMPLE NO. 1

Given: Design Discharge (Q) = 1,000 cfs, for a 50-year recurrence interval

Slope of stream bed (S_o) = 0.05 ft./ft.

Allowable Headwater Elevation = 200

Elevation Outlet Invert = 172.5

Culvert Length (L_a) = 350 ft.

Downstream channel approximates an 8' wide trapezoidal channel with 2:1 side slopes and a Manning's "n" of 0.03.

Requirements: This box culvert will be located in a rural area where the Allowable Headwater Elevation is not too critical; that is, the damages are low due to exceeding that elevation at infrequent times. Thus, the culvert should have the smallest possible barrel to pass design Q without exceeding AHW El. Use a reinforced concrete box with n = 0.012.

WORKSHEET FOR CULVERT DESIGN

PROJECT: Example #1 DESIGNER: PDW

STATION: ______ DATE: 6/1/79

INITIAL DATA

Design Q_{50} = 1000 cfs

Channel Slope, S_o = 0.05 ft./ft.

AHW Elevation = 200 ft.

El. Stream bed at Face 190 ft.

Approx. Culvert length, L_a = 350 ft.

Barrel Shape Box

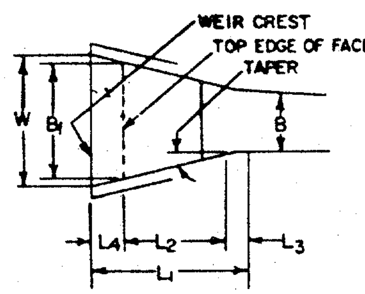
Barrel Material Reinf. Conc.

El. Outlet Invert = 172.5 ft.

Barrel Roughness, n. 0.012

(See page 2 for natural stream data)

SUMMARY INFORMATION
FOR
SELECTED DESIGN



Barrel Shape and Material Reinf. Conc. Box Culvert

Face Edge Description 45° Bevels

Type of Improved Inlet Slope - Tapered Inlet

Width of box, B = 7 ft.

Inlet length, L_1 = 15.22 ft.

Depth or Diameter, D = 6 ft.

Face to Bend, L_2 = 11.72 ft.

Width of face, B_f = 14 ft.

Bend to Throat, L_3 = 3.50 ft.

No. of Barrels, N = 1

Crest to Face, L_4 = — ft.

Inlet fall, FALL = 5.85 ft.

Side Taper = 4.34 :1

Barrel Slope, S = 0.033 ft./ft.

Crest Length, W = — ft.

Top bevel height, d = 3 in.

Side bevel width, b = 3.5 in.

Outlet velocity, V = 34.43 ft./sec.

COMMENTS ON DESIGN: ______

STEP 1
CALCULATE TAILWATER

Use file 1, block 1

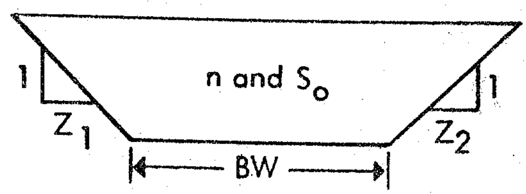
Enter: 1. n = 0.03 (channel)

2. S_o = 0.05

3. BW = 8

4. Z_1 = 2

5. Z_2 = 2



6. (Enter) Q	(Read) TW, Based on d_n	COMMENTS
1000	3.51	
800	3.14	
600	2.71	
1200	3.85	

STEP 2
DETERMINE AN ACCEPTABLE CULVERT SIZE

Use file 1, block 2 if designing a box culvert.
~~Use file 2, block 1 if designing a circular pipe culvert~~.

Enter: 1. Q = 1000

2. N = 1

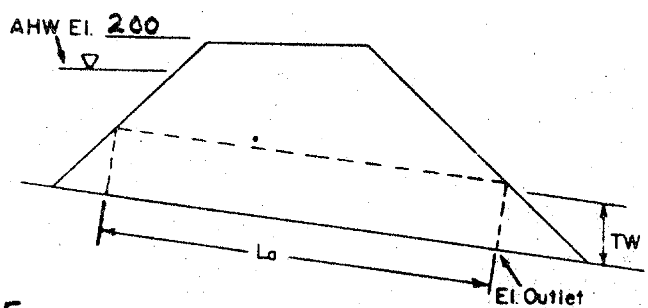
3. L_a = 350

4. n = 0.012 (Barrel)

5. k_e = 0.2

6. TW = 3.51

7. Elev. outlet invert = 172.5



8. (Enter) B – If box ~~(1) d_c – If pipe~~	9. (Enter) D	(Read) $\frac{d_c + D}{2}$ or TW	(Read) HW_o	COMMENTS
7	7	7.00	191.74	OK - but try smaller size
7	6	6.00	195.85	OK – USE
6	6	6.0	203.07	Exceeds AHW El.

(1) d_c values taken from Design Charts For Open-Channel Flow, Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 3

OUTLET CONTROL PERFORMANCE CURVE DATA

Use file 1, block 3 if designing a box culvert
~~Use file 2, block 2 if designing a pipe culvert~~

ENTER: 1. L_a = 350
2. n = 0.012 (Barrel)
3. k_e = 0.2
4. B = 7 (for box only)
5. D = 6
6. Elev. outlet invert = 172.5

7. (2) (Enter) TW	8. (3) (Enter) ~~d_c pipe only~~	9. (Enter) Q/N	(Read) HW_o	COMMENTS
3.51	—	1000	195.85	
3.14	—	800	189.60	
2.71	—	600	184.74	
3.85	—	1200	203.48	

Note: Plot outlet control performance curve
(2) Obtain values from Step 1
(3) d_c obtained from Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 4

OUTLET VELOCITY WHEN CULVERT IS IN OUTLET CONTROL

If designing a Box Culvert

Use file 1, block 4

Enter: 1. TW = 3.51
2. D = 6.0
3. B = 7.0
4. Q/N = 1000

(Read): Velocity
23.80

~~If designing a pipe culvert~~

~~Use file 2, block 3~~

Enter: 1. D =
2. Q/N =
3. Alpha = (1.04 for RCP, 1.12 for CMP)
4. TW =

(Read): Velocity

STEP 5

INLET CONTROL CALCULATIONS AND PERFORMANCE CURVE DATA

(BOX CULVERTS)

~~Use file 1, block 5 if analyzing a square-edge inlet with headwalls.~~
Use file 1, block 6 if analyzing a 45° beveled inlet.
Use file 1, block 7 if analyzing a tapered inlet throat.

(PIPE CULVERTS)

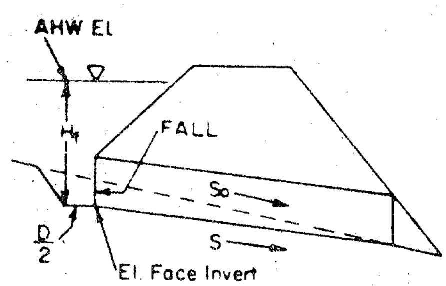
~~Use file 2, block 4 if analyzing a thin-edged projecting inlet.~~
~~Use file 2, block 5 if analyzing an inlet with square edges in a headwall.~~
~~Use file 2, block 7 if analyzing a groove end projecting inlet.~~
~~Use file 2, block 8 if analyzing a groove end inlet and headwalls.~~
~~Use file 2, block 6 if analyzing a beveled inlet.~~
~~Use file 2, block 9 if analyzing a tapered inlet throat. (Smooth inlet)~~
~~Use file 2, block 10 if analyzing a tapered inlet throat. (Rough inlet)~~

Enter: 1. AHW Elev. = 200

2. El. Stream bed at face = 190

3. B = 7 (~~D, if pipe~~)

4. D = 6



CONVENTIONAL or BEVELED

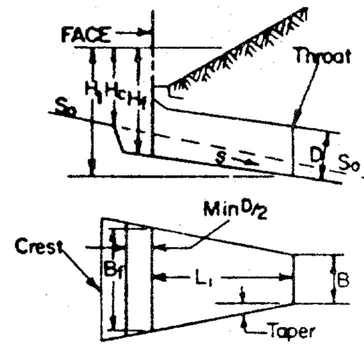
Q	5. (Enter) Q/N	(Read) El. Face invert / El. Throat invert	(Read) FALL	(Read) HW_f / HW_t	Note: Use Upper headings for Conventional or beveled face: Lower headings for tapered inlet throat. COMMENTS
Program No. 1-6		Inlet and Edge Description 45° BEVELS			
1000	1000	177.33	12.66	200.00	
					FALL IS TOO LARGE - TRY
					TAPERED THROAT INLET
Program No. 1-7		Inlet and Edge Description TAPERED INLET THROAT			
1000	1000	184.14	5.85	200.00	OK - DRAW PERFORMANCE
800	800			196.41	CURVES
600	600			193.58	
1200	1200			204.48	

Note: Plot inlet control section performance curve

STEP 6 & 7

SIDE-TAPERED INLET AND CREST CHECK

(BOX CULVERTS)

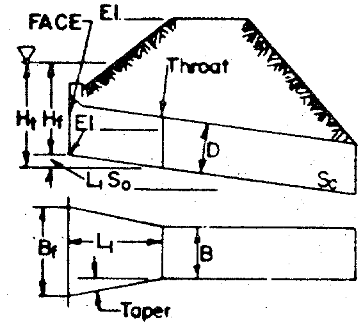


(side-tapered)

Use file 1, block 8 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)
~~Use file 1, block 9 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)~~

(PIPE CULVERTS)

~~Use file 2, block 11 if the face has projecting thin edges.~~
~~Use file 2, block 12 if the face has quare edges in a headwall.~~
~~Use file 2, block 13 if the face has bevels or a groove end.~~



(Slope-tapered)

(CREST CHECK)

Use file 1, block 13 for crest check on a conventional, beveled or side-tapered inlet.

Enter: 1. HW_f = 200

2. El. Throat Invert = 184.14

3. (Taper + S) = 4.033 (Taper is 4:1 to 6:1), (S ≈ S_o–FALL/L_a)

4. N×B = 7 (N×D for pipe)

5. Q = 1000

6. D = 6 (E for pipe, where D ≤ E ≤ 1.1 D)

(4) (Read) Min. B_f	B_f Used	(Read) L_1	(Read) El. face invert	COMMENTS
10.28	10.50	7.00	184.37	

(4) To use a B_f that is rounded off enter new B_f and press START STOP

Enter: (Crest Check)

1. Q = 1000 2. N = 1 3. HW_f = 200 4. W = 58.5

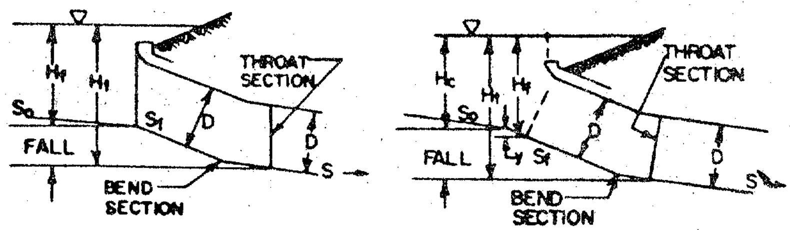
5. B = 0 6. L_1 = 0 7. Taper = 0

Crest Check: (Read) H_c = 3.31 , (Read) Max. Crest El. = 196.68

STEP 8 THROUGH 12

SLOPE-TAPERED INLET AND CREST CHECK

Use file 1, block 10 for B_f if face has favorable edge conditions as in STEP 5.
~~Use file 1, block 11 for B_f if face has unfavorable edge conditions as in STEP 5.~~



Enter: 1. Q = 1000

2. D = 6

3. HW_f = 200

4. El. Streambed at face = 190 (if vertical face)
~~El. Crest = ______ (if mitered face)~~

5. y = 0

(Read) Min. B_f, or higher rounded value	Type of Face
13.72 (USE 14.0)	Vertical, y = 0
	Mitered, y = .4D

Use file 1, block 12 for L dimensions of an inlet with a vertical face.

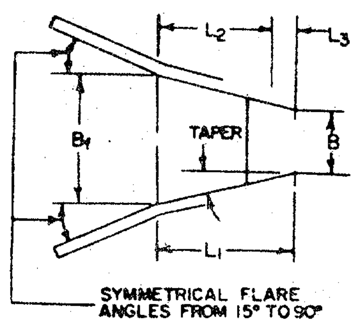
Enter: 1. B = 7 6. Taper = 4 :1

2. D = 6 7. El. Crest Inv. = 190

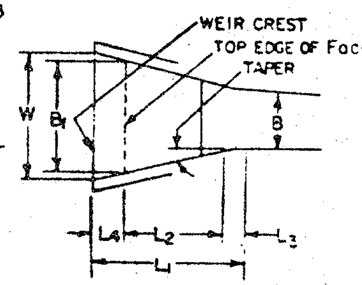
3. N = 1 8. El. Throat Inv. = 184.14

4. B_f = 14 9. S_f = 2 :1 (2:1 to 3:1)

5. y = 0



VERTICAL



MITERED

(Read) L_2	(Read) L_3	(Read) L_4	(Read) L_1	(Read) Taper	Type of Face
11.72	3.50	0	15.22	4.34	Vertical, y = 0
					Mitered, y = .4D

~~Use file 1, block 13 for crest check on a slope-tapered inlet with mitered face.~~

Enter: 1. Q = ______ 3. HW_f = ______ 6. L_1 = ______

2. N = ______ 4. W = 0 7. Taper = ______ : 1

5. B = ______

Crest Check: (Read) H_c = ______, (Read) Max, Crest El. = ______

STEP 13
OUTLET VELOCITY WHEN CULVERT IS IN INLET CONTROL

Use file 1, block 14 if designing a box culvert
~~Use file 2, block 14 if designing a pipe culvert~~

Enter: 1. D = 6

2. B = 7 (Use D if designing a pipe)

3. n = 0.012

4. Q/N = 1000

5. S = 0.033 = (S_o - FALL/L_a)

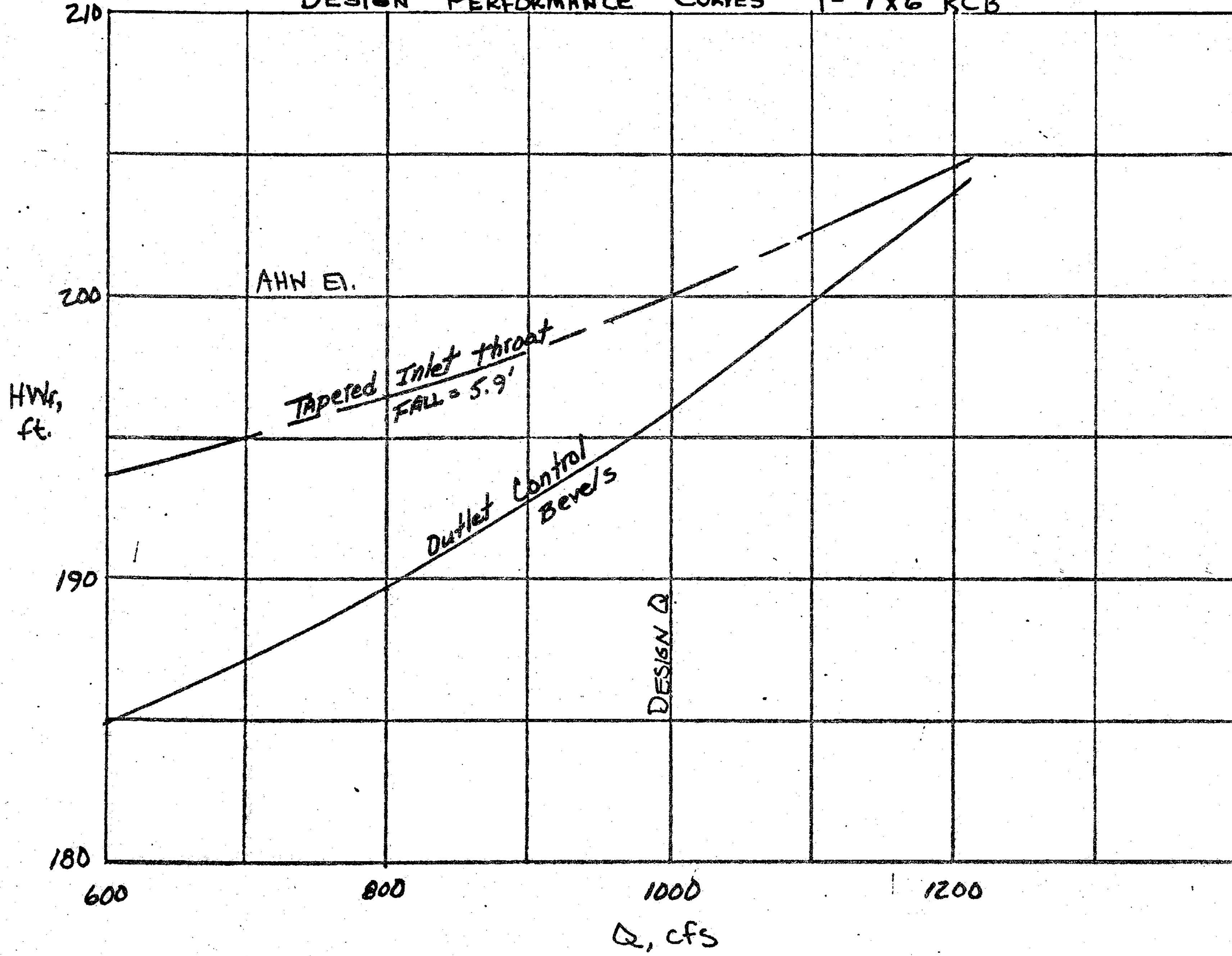
(READ) d_n/B	(READ) Velocity
0.59	34.43

For Box Culvert

(READ) Velocity

For pipe culvert

DESIGN PERFORMANCE CURVES 1-7'X6' RCB



PIPE CULVERT EXAMPLE NO. 2

Given: Same as example no. 1

Requirements: Use a concrete pipe with $n = 0.012$

WORKSHEET FOR CULVERT DESIGN

PROJECT: *EXAMPLE #2*

DESIGNER: *PDW*

STATION: ______

DATE: *6/1-79*

INITIAL DATA

Design Q *50* = *1000* cfs

Channel Slope, S_o = *0.05* ft./ft.

AHW Elevation = *200* ft.

El. Stream bed at Face *190* ft.

Approx. Culvert length, L_a = *350* ft.

Barrel Shape *CIRCULAR PIPE*

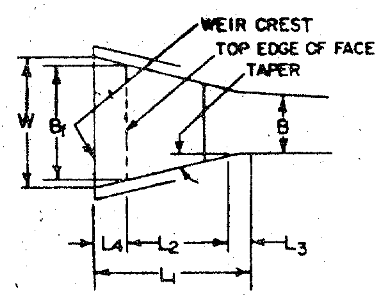
Barrel Material *REINF. CONC.*

El. Outlet Invert = *172.5* ft.

Barrel Roughness, n. *0.012*

(See page 2 for natural stream data)

SUMMARY INFORMATION FOR SELECTED DESIGN



Barrel Shape and Material *REINF. CONC. CIRC. PIPE*

Face Edge Description *45° BEVELS*

Type of Improved Inlet *SLOPE - TAPERED INLET*

Width of box, B = *—* ft.

Inlet length, L_1 = *24.78* ft.

Depth or Diameter, D = *7* ft.

Face to Bend, L_2 = *21.28* ft.

Width of face, B_f = *13.0* ft.

Bend to Throat, L_3 = *3.50* ft.

No. of Barrels, N = *1*

Crest to Face, L_4 = *—* ft.

Inlet fall, FALL = *10.63* ft.

Side Taper = *8.26* :1

Barrel Slope, S = *0.020* ft./ft.

Crest Length, W = *—* ft.

Top bevel height, d = *3.5* in.

Side bevel width, b = *6.5* in.

Outlet velocity, V = *29.14* ft./sec.

COMMENTS ON DESIGN: ______

STEP 1
CALCULATE TAILWATER

Use file 1, block 1

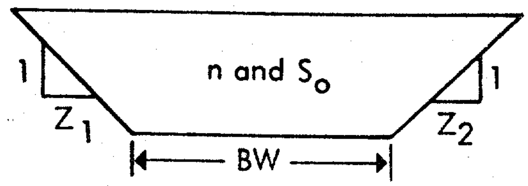
Enter: 1. n = 0.03 (channel)

2. S_o = 0.05

3. BW = 8

4. Z_1 = 2

5. Z_2 = 2



6. (Enter) Q	(Read) TW, Based on d_n	COMMENTS
1000	3.51	
800	3.14	
600	2.71	
1200	3.85	

STEP 2
DETERMINE AN ACCEPTABLE CULVERT SIZE

~~Use file 1, block 2 if designing a box culvert.~~
Use file 2, block 1 if designing a circular pipe culvert.

Enter: 1. Q = 1000

2. N = 1

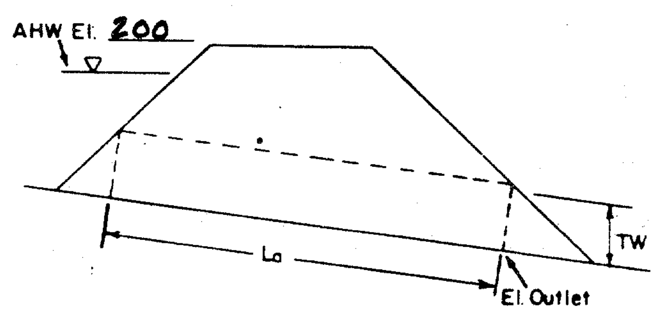
3. L_a = 350

4. n = 0.012 (Barrel)

5. k_e = 0.2

6. TW = 3.5

7. Elev. outlet invert = 172.5



8. (Enter) ~~B - If box~~ (1) d_c - If pipe	9. (Enter) D	(Read) $\frac{d_c+D}{2}$ or TW	(Read) HW_o	COMMENTS
> 7	7	7.0	199.34	OK - USE
7.73	8	7.86	191.30	
7 6.5	6.5	6.5	206.71	EXCEEDS AHW El.

(1) d_c values taken from Design Charts For Open-Channel Flow, Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 3

OUTLET CONTROL PERFORMANCE CURVE DATA

~~Use file 1, block 3 if designing a box culvert~~
Use file 2, block 2 if designing a pipe culvert

ENTER: 1. L_a = 350
2. n = 0.012 (Barrel)
3. k_e = 0.2
~~4. B = (for box only)~~
5. D = 7
6. Elev. outlet invert = 172.5

7. (2) (Enter) TW	8. (3) (Enter) d_c - pipe only	9. (Enter) Q/N	(Read) HW_o	COMMENTS
3.51	> 7	1000	199.34	
3.14	> 7	800	192.20	
2.71	6.3	600	186.29	
3.85	> 7	1200	208.08	

Note: Plot outlet control performance curve
(2) Obtain values from Step 1
(3) d_c obtained from Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 4

OUTLET VELOCITY WHEN CULVERT IS IN OUTLET CONTROL

~~If designing a Box Culvert~~

~~Use file 1, block 4~~

Enter: 1. TW =
2. D =
3. B =
4. Q/N =

(Read): Velocity

If designing a pipe culvert

Use file 2, block 3

Enter: 1. D = 7
2. Q/N = 1000
3. Alpha = 1.04 (1.04 for RCP, ~~1.12 for CMP~~)
4. TW = 3.51

(Read): Velocity
26.06

STEP 5

INLET CONTROL CALCULATIONS AND PERFORMANCE CURVE DATA

(BOX CULVERTS)

~~Use file 1, block 5 if analyzing a square-edge inlet with headwalls.~~

~~Use file 1, block 6 if analyzing a 45° beveled inlet.~~

~~Use file 1, block 7 if analyzing a tapered inlet throat.~~

(PIPE CULVERTS)

~~Use file 2, block 4 if analyzing a thin-edged projecting inlet.~~

~~Use file 2, block 5 if analyzing an inlet with square edges in a headwall.~~

~~Use file 2, block 7 if analyzing a groove end projecting inlet.~~

~~Use file 2, block 8 if analyzing a groove end inlet and headwalls.~~

Use file 2, block 6 if analyzing a beveled inlet.

Use file 2, block 9 if analyzing a tapered inlet throat. (Smooth inlet)

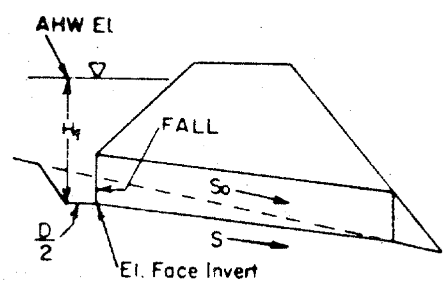
~~Use file 2, block 10 if analyzing a tapered inlet throat. (Rough inlet)~~

Enter: 1. AHW Elev. = 200

2. El. Stream bed at face = 190

3. ~~B =~~ 7 (D, if pipe)

4. D = 7



CONVENTIONAL or BEVELED

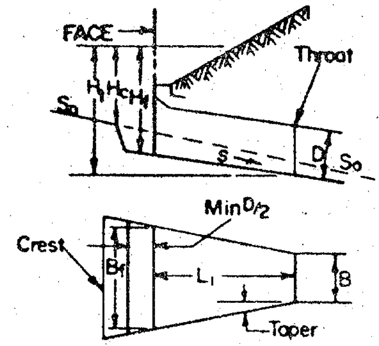
Q	5. (Enter) Q/N	(Read) El. Face invert / El. Throat invert	(Read) FALL	(Read) HW_f / HW_t	Note: Use Upper headings for Conventional or beveled face: Lower headings for tapered inlet throat. COMMENTS
Program No. 2-6		Inlet and Edge Description 45° BEVELS			
1000	1000	172.27	17.72	200.00	
					FALL TOO LARGE
Program No. 2-9		Inlet and Edge Description TAPERED INLET - SMOOTH THROAT			
1000	1000	179.36	10.63	200.00	FALL ≈ 1.5 D - OK
800	800			194.84	
600	600			190.79	DRAW PERFORMANCE CURVES
1200	1200			205.92	

Note: Plot inlet control section performance curve

SIDE-TAPERED INLET AND CREST CHECK

(BOX CULVERTS)

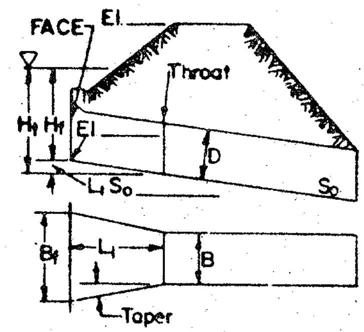
~~Use file 1, block 8 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)~~
~~Use file 1, block 9 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)~~



(side-tapered)

(PIPE CULVERTS)

~~Use file 2, block 11 if the face has projecting thin edges.~~
~~Use file 2, block 12 if the face has quare edges in a headwall.~~
Use file 2, block 13 if the face has bevels or a groove end.



(Slope-tapered)

(CREST CHECK)

Use file 1, block 13 for crest check on a conventional, beveled or side-tapered inlet.

Enter: 1. HW_f = 200

2. El. Throat Invert = 179.36

3. (Taper + S) = 4.020 (Taper is 4:1 to 6:1), ($S \approx S_o$–FALL/L_a)

4. ~~N×B =~~ 7 (N×D for pipe)

5. Q = 1000

6. D = 7 (E for pipe, where $D \leq E \leq 1.1 D$)

(4) (Read) Min. B_f	B_f Used	(Read) L_1	(Read) El. face invert	COMMENTS
9.42	10.00	6.0	179.48	

(4) To use a B_f that is rounded off enter new B_f and press START STOP

Enter: (Crest Check)

1. Q = 1000 2. N = 1 3. HW_f = 200 4. W = 106.30

5. B = 0 6. L_1 = 0 7. Taper = 0

Crest Check: (Read) H_c = 2.22 , (Read) Max. Crest El. = 197.77

STEP 8 THROUGH 12

SLOPE-TAPERED INLET AND CREST CHECK

Use file 1, block 10 for B_f if face has favorable edge conditions as in STEP 5.
~~Use file 1, block 11 for B_f if face has unfavorable edge conditions as in STEP 5.~~

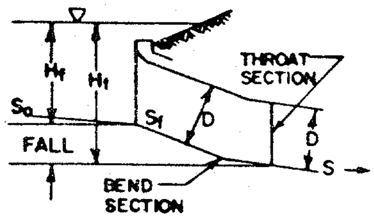
Enter: 1. Q = 1000

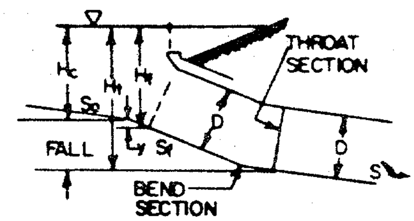
2. D = 7

3. HW_f = 200

4. El. Streambed at face = 190 (if vertical face)
~~El. Crest = ______ (if mitered face)~~

5. y = 0





(Read) Min. B_f, or higher rounded value	Type of Face
12.56 (USE 13.0)	Vertical, y = 0
	Mitered, y = .4D

Use file 1, block 12 for L dimensions of an inlet with a vertical face.

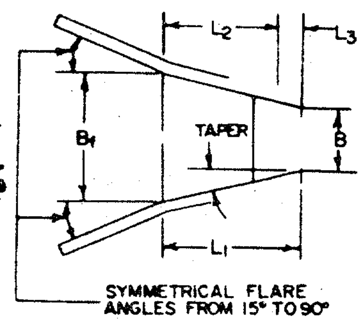
Enter: 1. B = 7 6. Taper = 4 :1

2. D = 7 7. El. Crest Inv. = 190

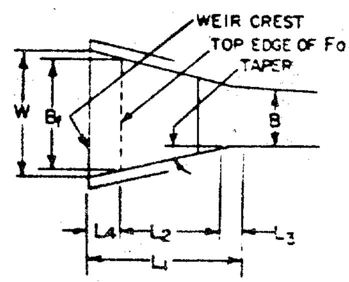
3. N = 1 8. El. Throat Inv. = 179.36

4. B_f = 13 9. S_f = 2 :1
(2:1 to 3:1)

5. y = 0



VERTICAL



MITERED

(Read) L_2	(Read) L_3	(Read) L_4	(Read) L_1	(Read) Taper	Type of Face
21.28	3.50	0	24.78	8.26	Vertical, y = 0
					Mitered, y = .4D

~~Use file 1, block 13 for crest check on a slope-tapered inlet with mitered face.~~

Enter: 1. Q = ______ 3. HW_f = ______ 6. L_1 = ______

2. N = ______ 4. W = 0 7. Taper = ______ : 1

5. B = ______

Crest Check: (Read) H_c = ______, (Read) Max, Crest El. = ______

STEP 13
OUTLET VELOCITY WHEN CULVERT IS IN INLET CONTROL

~~Use file 1, block 14 if designing a box culvert~~
Use file 2, block 14 if designing a pipe culvert

Enter: 1. D = 7

2. ~~B~~ = 7 (Use D if designing a pipe)

3. n = 0.012

4. Q/N = 1000

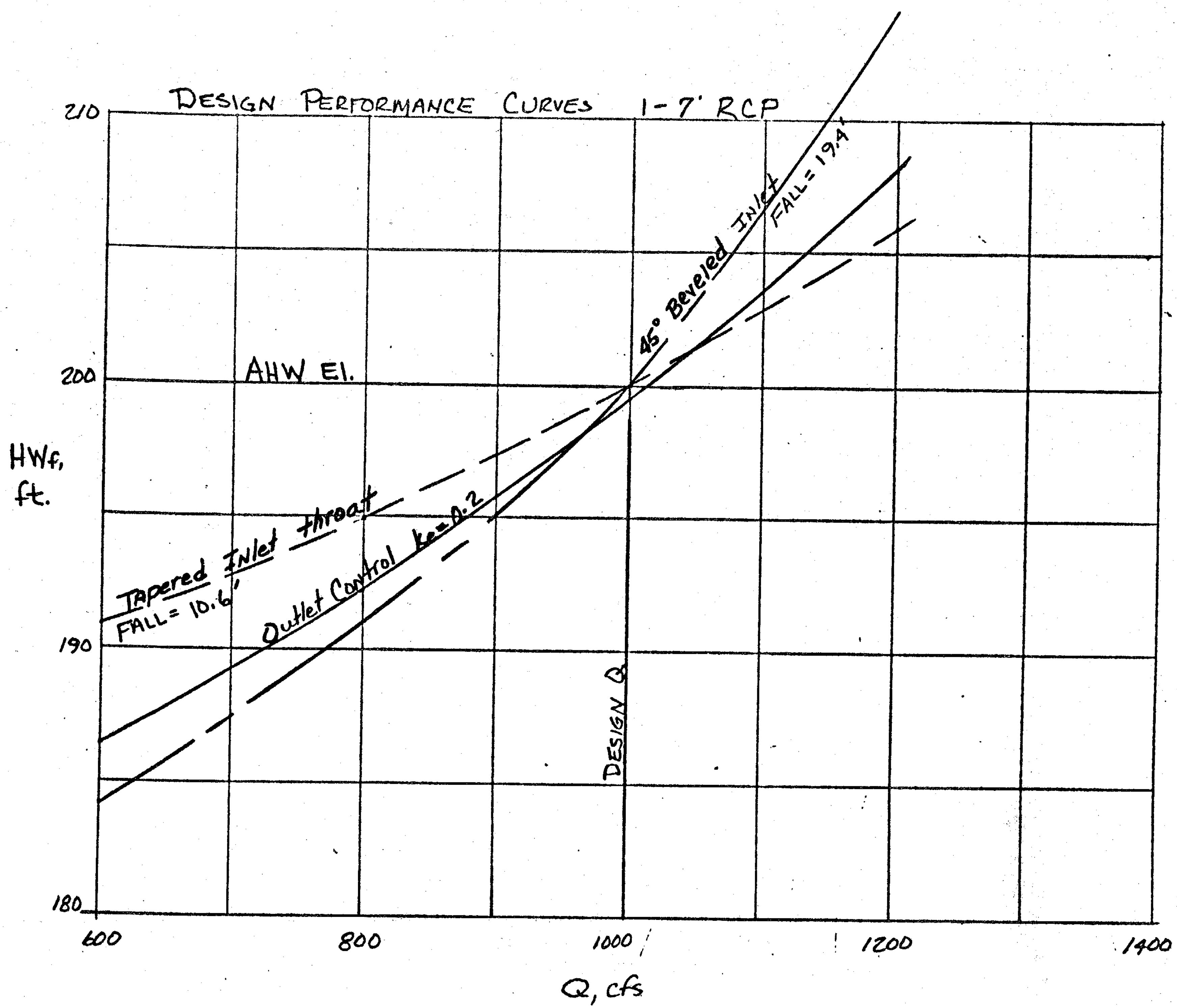
5. S = 0.02 = (S_o - FALL/L_a)

(READ) d_n/B	(READ) Velocity

For Box Culvert

(READ) Velocity
29.14

For pipe culvert



DESIGN PERFORMANCE CURVES 1-7' RCP
210
200
190
180
HWf, ft.
600
800
1000
1200
1400
Q, cfs
AHW El.
DESIGN Q
45° Beveled Inlet
FALL = 19.4'
Tapered Inlet throat
FALL = 10.6'
Outlet Control ke = 0.2

BOX CULVERT EXAMPLE NO. 3

Given: Same as example no. 1 except

Slope of stream bed (S_o) = 0.005 ft./ft.

Elevation Outlet Invert = 188.25

Requirements: Same as example no. 1

WORKSHEET FOR CULVERT DESIGN

PROJECT: Example #3

STATION: ____________

DESIGNER: PDW

DATE: 6/11/79

INITIAL DATA

Design Q 50 = 1000 cfs

Channel Slope, S_o = 0.005 ft./ft.

AHW Elevation = 200 ft.

El. Stream bed at Face 190 ft.

Approx. Culvert length, L_a = 350 ft.

Barrel Shape Box

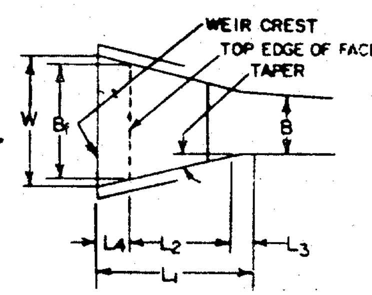
Barrel Material Reinf. Conc.

El. Outlet Invert = 188.25 ft.

Barrel Roughness, n. 0.012

(See page 2 for natural stream data)

SUMMARY INFORMATION FOR SELECTED DESIGN



Barrel Shape and Material Reinf. Conc. Box Culvert

Face Edge Description 45° Bevels

Type of Improved Inlet None

Width of box, B = 10 ft.

Inlet length, L_1 = — ft.

Depth or Diameter, D = 9 ft.

Face to Bend, L_2 = — ft.

Width of face, B_f = — ft.

Bend to Throat, L_3 = — ft.

No. of Barrels, N = 1

Crest to Face, L_4 = — ft.

Inlet fall, FALL = 0.92 ft.

Side Taper = — :1

Barrel Slope, S = 0.005 ft./ft.

Crest Length, W = — ft.

Top bevel height, d = 4.5 in.

Side bevel width, b = 5 in.

Outlet velocity, V = 16.97 ft./sec.

COMMENTS ON DESIGN: ____________

STEP 1
CALCULATE TAILWATER

Use file 1, block 1

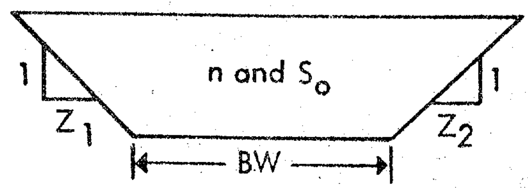
Enter: 1. n = 0.03 (channel)

2. S_o = 0.005

3. BW = 8

4. Z_1 = 2

5. Z_2 = 2



6. (Enter) Q	(Read) TW, Based on d_n	COMMENTS
1000	6.11	
800	5.51	
600	4.81	
1200	6.65	

STEP 2
DETERMINE AN ACCEPTABLE CULVERT SIZE

Use file 1, block 2 if designing a box culvert.

~~Use file 2, block 1 if designing a circular pipe culvert.~~

Enter: 1. Q = 1000

2. N = 1

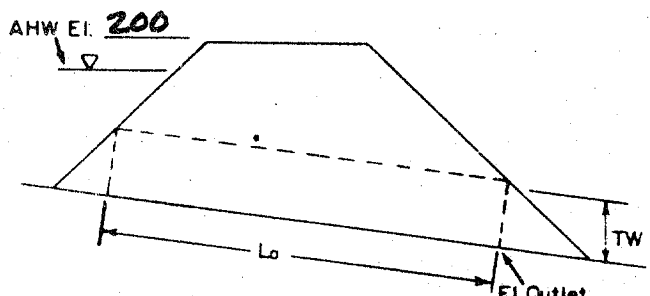
3. L_a = 350

4. n = 0.012 (Barrel)

5. k_e = 0.5 & 0.2

6. TW = 6.11

7. Elev. outlet invert = 188.25



8. (Enter) B – If box (1) d_c – If pipe	9. (Enter) D	(Read) $\frac{d_c+D}{2}$ or TW	(Read) HW_o	COMMENTS
8	8	7.93	204.07	EXCEEDS AHWEL. Ke=.5
9	9	8.14	200.40	EXCEEDS AHW EL ke=.2
10	9	7.89	199.33	OK- USE Ke=.2

(1) d_c values taken from Design Charts For Open-Channel Flow, Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 3

OUTLET CONTROL PERFORMANCE CURVE DATA

Use file 1, block 3 if designing a box culvert
~~Use file 2, block 2 if designing a pipe culvert~~

ENTER: 1. L_a = 350
2. n = 0.012 (Barrel)
3. k_e = 0.2
4. B = 10 (for box only)
5. D = 9
6. Elev. outlet invert = 188.25

7. (2) (Enter) TW	8. (3) (Enter) ~~d_c = pipe only~~	9. (Enter) Q/N	(Read) HW_o	COMMENTS
6.11	—	1000	199.33	
5.51	—	800	197.71	
4.81	—	600	196.31	
6.65	—	1200	201.17	

Note: Plot outlet control performance curve
(2) Obtain values from Step 1
(3) d_c obtained from Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 4

OUTLET VELOCITY WHEN CULVERT IS IN OUTLET CONTROL

If designing a Box Culvert

Use file 1, block 4

Enter: 1. TW = 6.11
2. D = 9
3. B = 10
4. Q/N = 1000

(Read): Velocity
14.73

~~If designing a pipe culvert~~

~~Use file 2, block 3~~

Enter: 1. D = _____
2. Q/N = _____
3. Alpha = _____ (1.04 for RCP, 1.12 for CMP)
4. TW = _____

(Read): Velocity

STEP 5

INLET CONTROL CALCULATIONS AND PERFORMANCE CURVE DATA

(BOX CULVERTS)

Use file 1, block 5 if analyzing a square-edge inlet with headwalls.
Use file 1, block 6 if analyzing a 45° beveled inlet.
~~Use file 1, block 7 if analyzing a tapered inlet throat~~.

(PIPE CULVERTS)

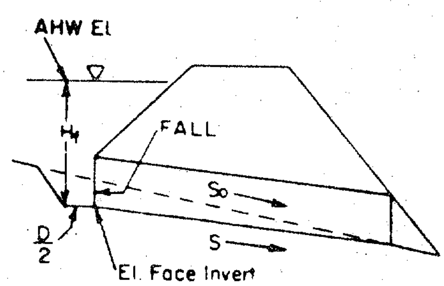
~~Use file 2, block 4 if analyzing a thin-edged projecting inlet.~~
~~Use file 2, block 5 if analyzing an inlet with square edges in a headwall.~~
~~Use file 2, block 7 if analyzing a groove end projecting inlet~~.
~~Use file 2, block 8 if analyzing a groove end inlet and headwalls~~.
~~Use file 2, block 6 if analyzing a beveled inlet~~.
~~Use file 2, block 9 if analyzing a tapered inlet throat. (Smooth inlet)~~
~~Use file 2, block 10 if analyzing a tapered inlet throat. (Rough inlet)~~

Enter: 1. AHW Elev. = 200

2. El. Stream bed at face = 190

3. B = 10 (~~D, if pipe~~)

4. D = 9



CONVENTIONAL or BEVELED

Q	5. (Enter) Q/N	(Read) El. Face invert / El. Throat invert	(Read) FALL	(Read) HW_f / HW_t	Note: Use Upper headings for Conventional or beveled face: Lower headings for tapered inlet throat. COMMENTS
Program No. 1-5 ,		Inlet and Edge Description SQ. EDGES W/HEADWALLS			
1000	1000	188.05	1.94	200.00	
800	800			198.03	TRY BEVELED INLET
600	600			196.20	
1200	1200			202.22	
Program No. 1-6 ,		Inlet and Edge Description 45° BEVELS			
1000	1000	189.07	0.92	200.00	FALL IS MINOR - NOT NECESSARY
800	800			198.27	TO INCREASE SIZE JUST TO
600	600			196.59	ELIMINATE FALL
1200	1200			201.87	DRAW PERFORMANCE CURVES

Note: Plot inlet control section performance curve

STEP 13

OUTLET VELOCITY WHEN CULVERT IS IN INLET CONTROL

Use file 1, block 14 if designing a box culvert
~~Use file 2, block 14 if designing a pipe culvert~~

Enter: 1. D = 9

2. B = 10 (~~Use D if designing a pipe~~)

3. n = 0.012

4. Q/N = 1000

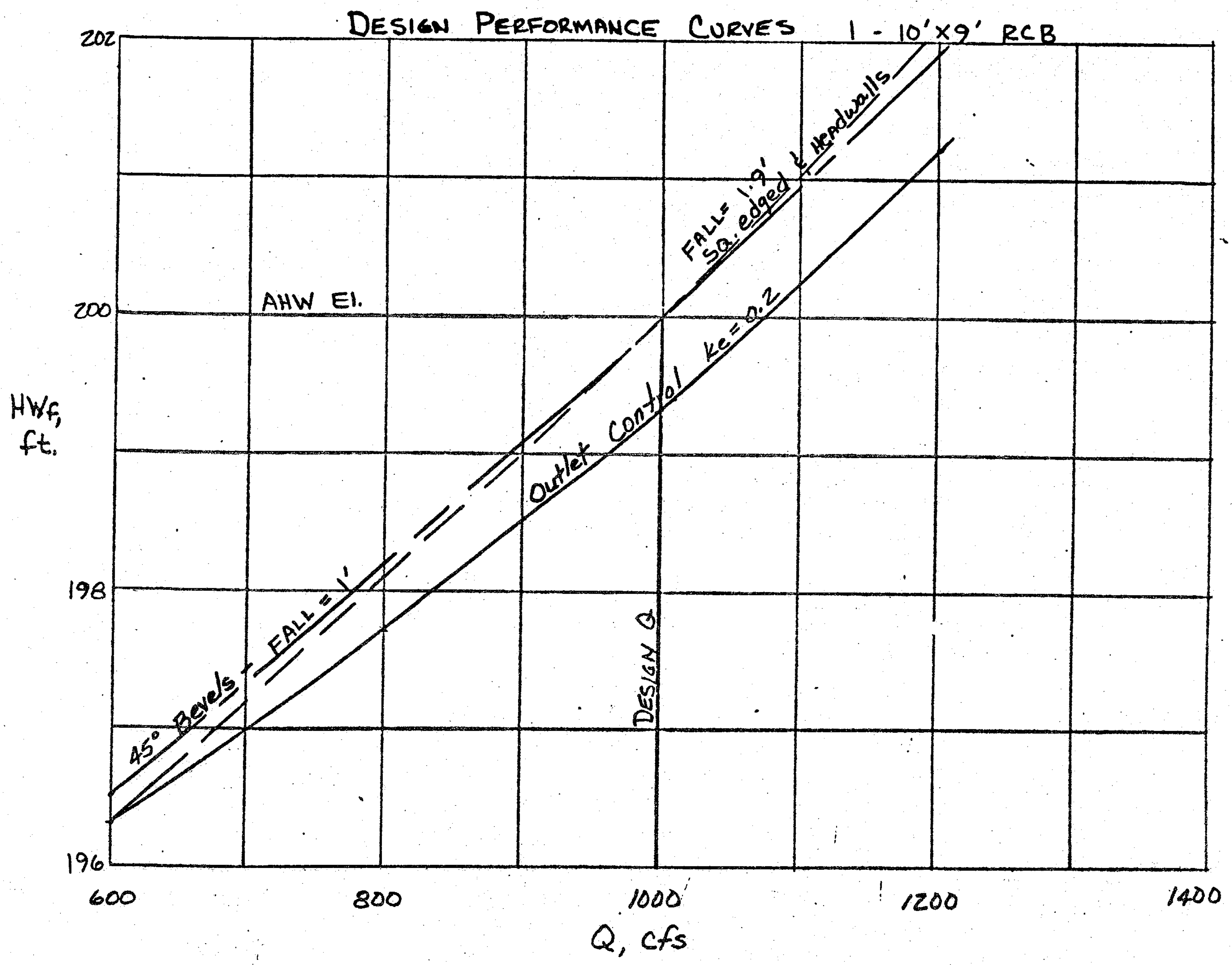
5. S = 0.005 = (S_o - FALL/L_a)

(READ) d_n/B	(READ) Velocity
.58	16.97

For Box Culvert

(READ) Velocity

For pipe culvert



DESIGN PERFORMANCE CURVES 1 - 10'x9' RCB
202
200
198
196
HWf, ft.
600
800
1000
1200
1400
Q, cfs
AHW El.
FALL= 1.9' SQ. edged & Headwalls
Outlet Control ke=0.2
45° Bevels - FALL = 1'
DESIGN Q

BOX CULVERT EXAMPLE NO. 4

Given: An existing box culvert built on a rock foundation requires modification to handle higher than anticipated flows.

Original Design: Box size = 7' x 6'

Design discharge, Q_{50} = 350 cfs

Allowable headwater elevation = 100

Elevation outlet invert = 75.0

Elevation inlet invert = 92.5

Culvert length = 350 ft.

Barrel Slope, S = 0.05 ft./ft.

Channel Slope, S_o = 0.05 ft./ft.

Manning n = 0.012

Entrance configuration = square edges with headwalls

Downstream channel approximates a 6' wide trapezoidal channel with 2:1 side slopes and a Manning's "n" of 0.03

Requirements: Modify box culvert to handle Q_{50} = 425 cfs.

WORKSHEET FOR CULVERT DESIGN

PROJECT: EXAMPLE #4 DESIGNER: PDW

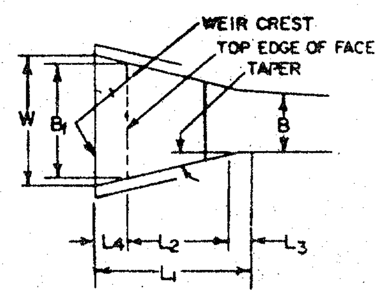
STATION: ______ DATE: 6/1/79

INITIAL DATA

Design Q_{50} = 350 cfs
Channel Slope, S_o = 0.05 ft./ft.
AHW Elevation = 100 ft.
El. Stream bed at Face 92.5 ft.
Approx. Culvert length, L_a = 350 ft.
Barrel Shape BOX
Barrel Material REINF. CONC.
El. Outlet Invert = 75 ft.
Barrel Roughness, n. 0.012

(See page 2 for natural stream data)

SUMMARY INFORMATION FOR SELECTED DESIGN



Barrel Shape and Material REINF. CONC. BOX CULVERT

Face Edge Description 45° BEVELS

Type of Improved Inlet SIDE-TAPERED INLET

Width of box, B = 7 ft.
Inlet length, L_1 = 8 ft.
Depth or Diameter, D = 6 ft.
Face to Bend, L_2 = — ft.
Width of face, B_f = 11 ft.
Bend to Throat, L_3 = — ft.
No. of Barrels, N = 1
Crest to Face, L_4 = — ft.
Inlet fall, FALL = 0 ft.
Side Taper = 4 :1
Barrel Slope, S = 0.05 ft./ft.
Crest Length, W = — ft.
Top bevel height, d = 3 in.
Side bevel width, b = 3.5 in.
Outlet velocity, V = 32.27 ft./sec.

COMMENTS ON DESIGN: BUILD SIDE-TAPERED INLET AS AN EXTENSION OF THE EXISTING BOX CULVERT.

STEP 1
CALCULATE TAILWATER

Use file 1, block 1

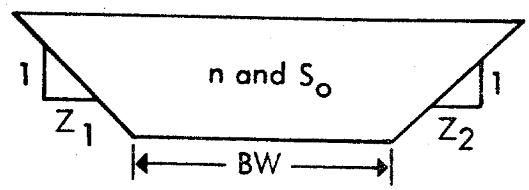
Enter: 1. n = 0.03 (channel)

2. S_o = 0.05

3. BW = 6

4. Z_1 = 2

5. Z_2 = 2



6. (Enter) Q	(Read) TW, Based on d_n	COMMENTS
350	2.28	
300	2.11	
400	2.44	
500	2.73	

STEP 2
DETERMINE AN ACCEPTABLE CULVERT SIZE

Use file 1, block 2 if designing a box culvert.
Use file 2, block 1 if designing a circular pipe culvert.

Enter: 1. Q = ______

2. N = ______

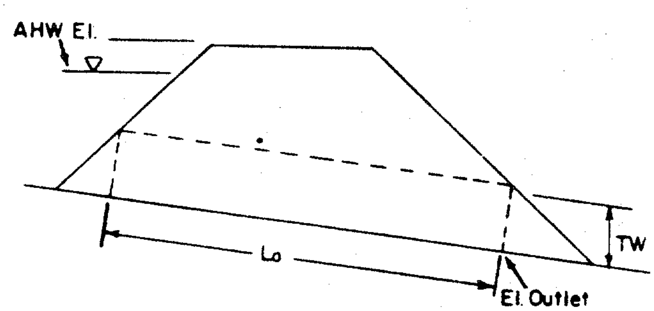
3. L_a = ______

4. n = ______ (Barrel)

5. k_e = ______

6. TW = ______

7. Elev. outlet invert = ______



8. (Enter) B - If box (1) d_c - If pipe	9. (Enter) D	(Read) $\frac{d_c+D}{2}$ or TW	(Read) HW_o	COMMENTS
Since we already	know	the culvert	size,	STEP #2 is
unnecessary.	However,	it is good	to plot	the outlet and
inlet control performance	curves	for the	existing	culvert.

(1) d_c values taken from Design Charts For Open-Channel Flow, Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 3

OUTLET CONTROL PERFORMANCE CURVE DATA

Use file 1, block 3 if designing a box culvert
~~Use file 2, block 2 if designing a pipe culvert~~

ENTER: 1. L_a = 350
2. n = 0.012 (Barrel)
3. k_e = 0.5
4. B = 7 (for box only)
5. D = 6
6. Elev. outlet invert = 75

7. (2) (Enter) TW	8. (3) (Enter) ~~d_c = pipe only~~	9. (Enter) Q/N	(Read) HW_o	COMMENTS
2.28	—	350	82.85	
2.15	—	300	81.92	
2.47	—	400	83.88	
2.76	—	500	86.25	

Note: Plot outlet control performance curve
(2) Obtain values from Step 1
(3) d_c obtained from Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 4

OUTLET VELOCITY WHEN CULVERT IS IN OUTLET CONTROL

If designing a Box Culvert

Use file 1, block 4

Enter: 1. TW = 2.28
2. D = 6
3. B = 7
4. Q/N = 350

(Read): Velocity
11.69

~~If designing a pipe culvert~~

~~Use file 2, block 3~~

Enter: 1. D = ______
2. Q/N = ______
3. Alpha = ______ (1.04 for RCP, 1.12 for CMP)
4. TW = ______

(Read): Velocity

STEP 5

INLET CONTROL CALCULATIONS AND PERFORMANCE CURVE DATA

(BOX CULVERTS)

Use file 1, block 5 if analyzing a square-edge inlet with headwalls.
Use file 1, block 6 if analyzing a 45° beveled inlet.
~~Use file 1, block 7 if analyzing a tapered inlet throat.~~

(PIPE CULVERTS)

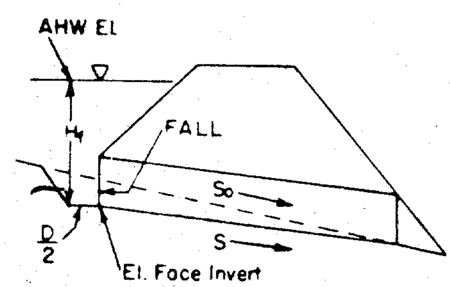
~~Use file 2, block 4 if analyzing a thin-edged projecting inlet.~~
~~Use file 2, block 5 if analyzing an inlet with square edges in a headwall.~~
~~Use file 2, block 7 if analyzing a groove end projecting inlet.~~
~~Use file 2, block 8 if analyzing a groove end inlet and headwalls.~~
~~Use file 2, block 6 if analyzing a beveled inlet.~~
~~Use file 2, block 9 if analyzing a tapered inlet throat. (Smooth inlet)~~
~~Use file 2, block 10 if analyzing a tapered inlet throat. (Rough inlet)~~

Enter: 1. AHW Elev. = 100

2. El. Stream bed at face = 92.5

3. B = 7 (D, if pipe)

4. D = 6



CONVENTIONAL or BEVELED

Q	5. (Enter) Q/N	(Read) El. Face invert / El. Throat invert	(Read) FALL	(Read) HW_f / HW_t	Note: Use Upper headings for Conventional or beveled face: Lower headings for tapered inlet throat. COMMENTS
Program No. 1-5 ,		Inlet and Edge Description SQ. EDGES W/ HEADWALLS			
350	350	92.50	0.00	99.91	
300	300			99.07	DRAW PERFORMANCE CURVES
400	400			100.81	
500	500			102.88	
Program No. 1-6 ,		Inlet and Edge Description 45° BEVELS			
360	350	92.50	0.00	99.30	USE
300	300			98.55	DRAW PERFORMANCE CURVE
400	400			100.08	
500	500			101.79	TRY SIDE-TAPERED INLET

Note: Plot inlet control section performance curve

STEP 5

INLET CONTROL CALCULATIONS AND PERFORMANCE CURVE DATA

(BOX CULVERTS)

~~Use file 1, block 5 if analyzing a square-edge inlet with headwalls.~~
~~Use file 1, block 6 if analyzing a 45° beveled inlet.~~
Use file 1, block 7 if analyzing a tapered inlet throat.

(PIPE CULVERTS)

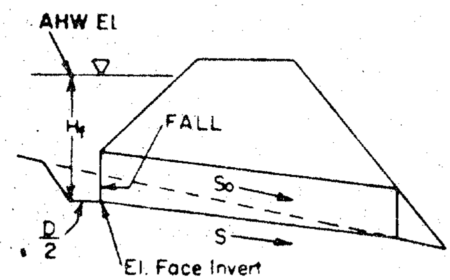
~~Use file 2, block 4 if analyzing a thin-edged projecting inlet.~~
~~Use file 2, block 5 if analyzing an inlet with square edges in a headwall.~~
~~Use file 2, block 7 if analyzing a groove end projecting inlet.~~
~~Use file 2, block 8 if analyzing a groove end inlet and headwalls.~~
~~Use file 2, block 6 if analyzing a beveled inlet.~~
~~Use file 2, block 9 if analyzing a tapered inlet throat. (Smooth inlet)~~
~~Use file 2, block 10 if analyzing a tapered inlet throat. (Rough inlet)~~

Enter: 1. AHW Elev. = 100

2. El. Stream bed at face = 92.5

3. B = 7 (D, if pipe)

4. D = 6



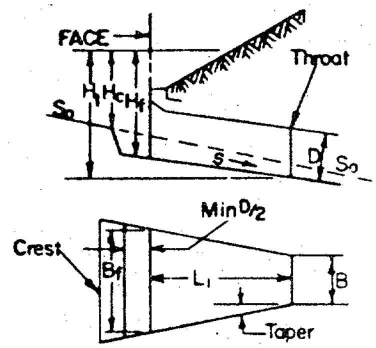
CONVENTIONAL or BEVELED

Q	5. (Enter) Q/N	(Read) El. Face invert / El. Throat invert	(Read) FALL	(Read) HW_f / HW_t	Note: Use Upper headings for Conventional or beveled face: Lower headings for tapered inlet throat. COMMENTS
Program No. 1-7 ,		Inlet and Edge Description TAPERED INLET			
350	350	92.50	0.00	98.89	
300	300			98.26	DRAW CURVE
400	400			99.50	
500	500			100.70	
Program No. ,		Inlet and Edge Description			

Note: Plot inlet control section performance curve

STEP 6 & 7

SIDE-TAPERED INLET AND CREST CHECK



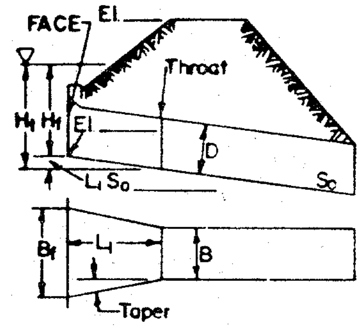
(side-tapered)

(BOX CULVERTS)

Use file 1, block 8 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)
~~Use file 1, block 9 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)~~

(PIPE CULVERTS)

~~Use file 2, block 11 if the face has projecting thin edges.~~
~~Use file 2, block 12 if the face has quare edges in a headwall~~.
~~Use file 2, block 13 if the face has bevels or a groove end.~~



(Slope-tapered)

(CREST CHECK)

~~Use file 1, block 13 for crest check on a conventional, beveled or side-tapered inlet~~.

Enter: 1. HW_f = 100

2. El. Throat Invert = 92.5

3. (Taper + S) = 4.05 (Taper is 4:1 to 6:1), (S ≈ S_o - FALL/ L_a)

4. N×B = 7 (N×D for pipe)

5. Q = 445 FROM PERFORMANCE CURVE

6. D = 6 (E for pipe, where D ≤ E ≤ 1.1 D)

(4) (Read) Min. B_f	B_f Used	(Read) L_1	(Read) El. face invert	COMMENTS
10.86	11.00	8.0	92.90	FACE DESIGNED FOR LARGER FLOWRATE.

(4) To use a B_f that is rounded off enter new B_f and press START STOP

RECOMPUTE OUTLET CONTROL PERFORMANCE CURVE FOR CULVERT

Enter: (Crest Check) WITH ADDITIONAL 8 FEET AND AN IMPROVED INLET. La = 358 , ke = .2

1. Q = ______ 2. N = ______ 3. HW_f = ______ 4. W = ______

5. B = 0 6. L_1 = 0 7. Taper = 0

Crest Check: (Read) H_c = ______, (Read) Max. Crest El. = ______

STEP 3

OUTLET CONTROL PERFORMANCE CURVE DATA

Use file 1, block 3 if designing a box culvert

~~Use file 2, block 2 if designing a pipe culvert~~

ENTER: 1. L_a = 358

2. n = 0.012 (Barrel)

3. k_e = 0.2

4. B = 7 (for box only)

5. D = 6

6. Elev. outlet invert = 75

READJUSTED FOR NEW L_a, ke

7. (2) (Enter) TW	8. (3) (Enter) ~~d_c - pipe only~~	9. (Enter) Q/N	(Read) HW_o	COMMENTS
2.28	—	350	81.80	
2.15	—	300	81.15	
2.47	—	400	82.51	DRAW PERFORMANCE
2.76	—	500	84.11	CURVE

Note: Plot outlet control performance curve

(2) Obtain values from Step 1

(3) d_c obtained from Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 4

OUTLET VELOCITY WHEN CULVERT IS IN OUTLET CONTROL

If designing a Box Culvert

Use file 1, block 4

Enter: 1. TW = 2.58 @ 445 cfs

2. D = 6

3. B = 7

4. Q/N = 445

(Read): Velocity
12.67

~~If designing a pipe culvert~~

~~Use file 2, block 3~~

Enter: 1. D = ________

2. Q/N = ________

3. Alpha = ________ (1.04 for RCP, 1.12 for CMP)

4. TW = ________

(Read): Velocity

STEP 13
OUTLET VELOCITY WHEN CULVERT IS IN INLET CONTROL

Use file 1, block 14 if designing a box culvert
~~Use file 2, block 14 if designing a pipe culvert~~

Enter:
1. D = 6
2. B = 7 (Use D if designing a pipe)
3. n = 0.012
4. Q/N = 445
5. S = 0.05 = (S_o - FALL/L_a)

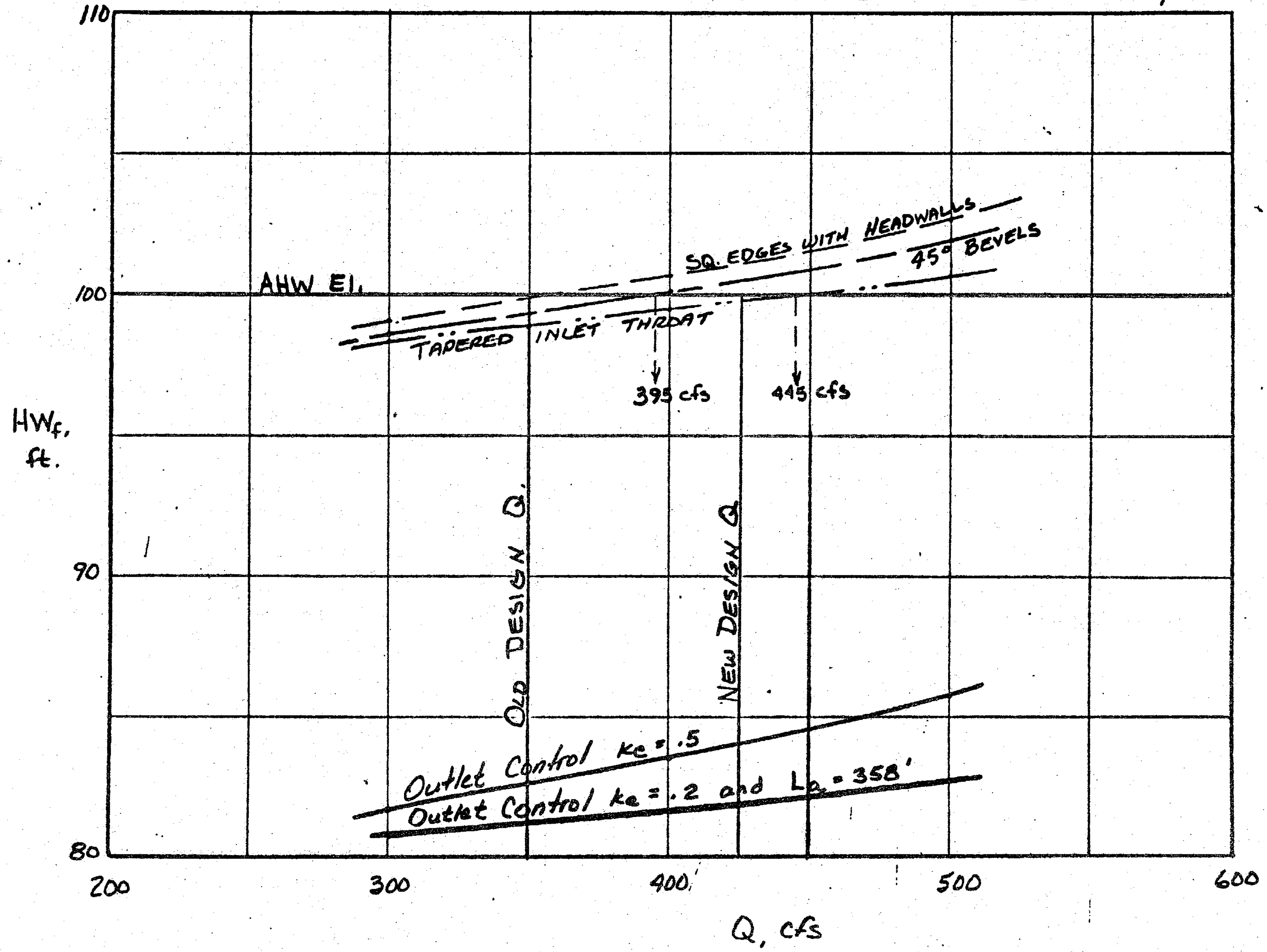
(READ) d_n/B	(READ) Velocity
.28	32.27

For Box Culvert

(READ) Velocity

For pipe culvert

DESIGN PERFORMANCE CURVES 1 - 7' x 6' REINF. CONC. BOX, ZERO FALL

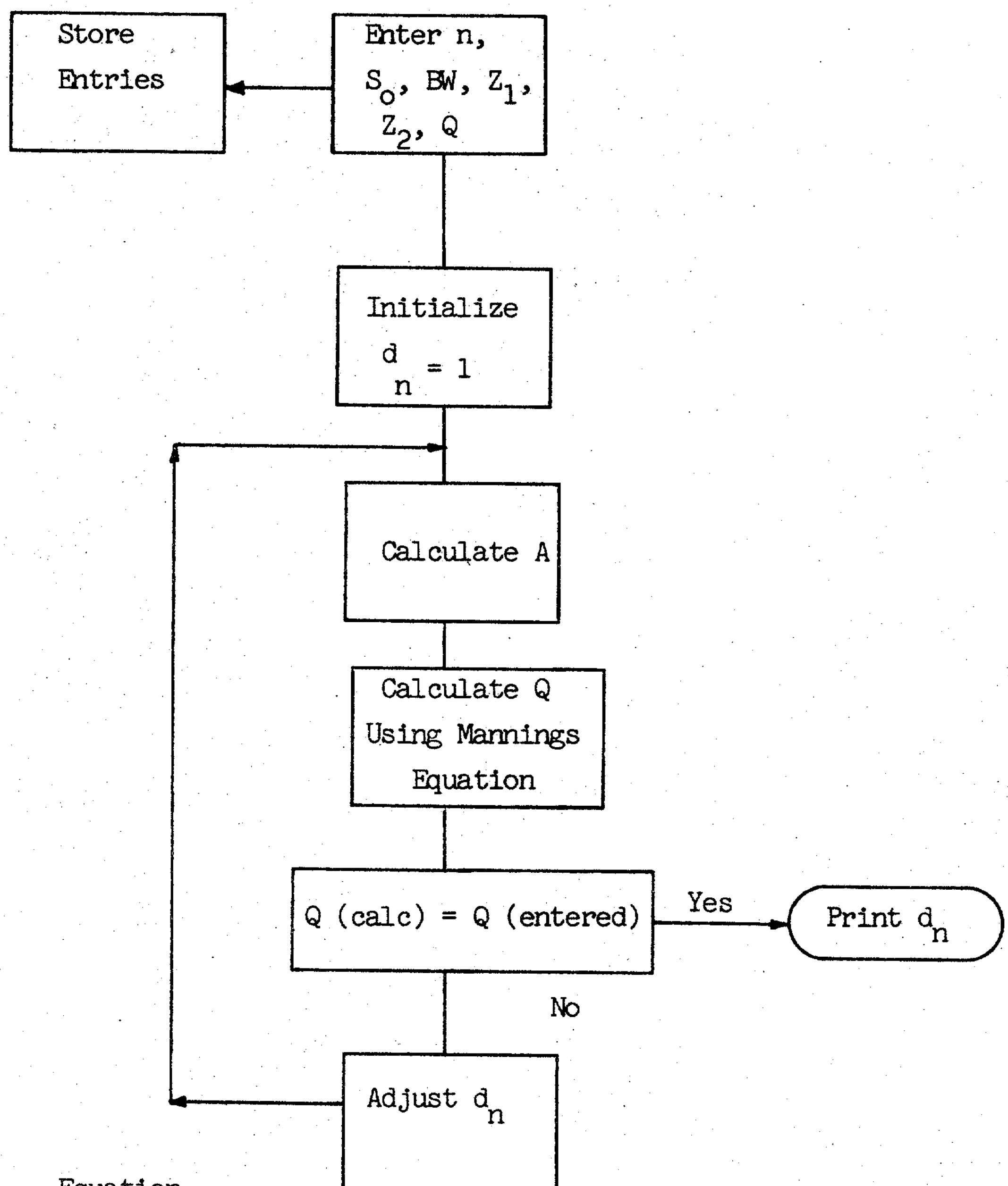


Conclusion - Example Problem No. 4

From the performance curves it can be seen that the addition of bevels does not satisfy the Q_{50} of 425 cfs at the AHW elevation. It is also seen that the addition of a side-tapered inlet increases the capacity of the culvert to 445 cfs at the AHW elevation of 100 feet. This increase is obtained with the side-tapered inlet built at the same slope as the existing barrel and channel. The side-tapered inlet is the least costly type of modification that will handle the increase flow.

EQUATIONS AND FLOW CHARTS USED IN PROGRAMS

Program 1-1



Equation

$$Q = \frac{1.486}{n} AR^{2/3} S_o^{1/2} \text{ (Basic Equation)}$$

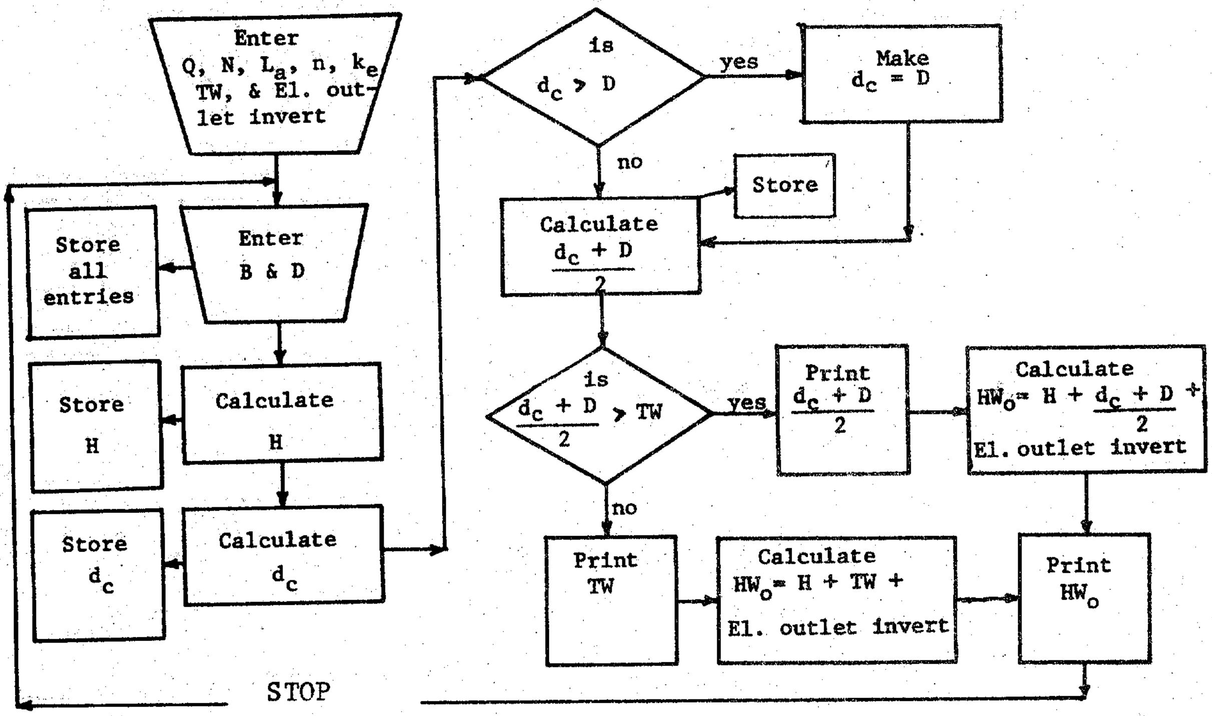
$$R = A/WP$$

$$A = BW\, d_n + 1/2\, Z_1 d_n^{\,2} + 1/2\, Z_2 d_n^{\,2}$$

$$WP = BW + d_n \sqrt{Z_1^{\,2} + 1} + d_n \sqrt{Z_2^{\,2} + 1}$$

d_n is calculated to $\pm$ .0001

Program 1-2



$$HW_o = H + h_o + \text{Elev. Outlet invert} \quad \text{(Basic Equation)} \qquad (2)$$

where

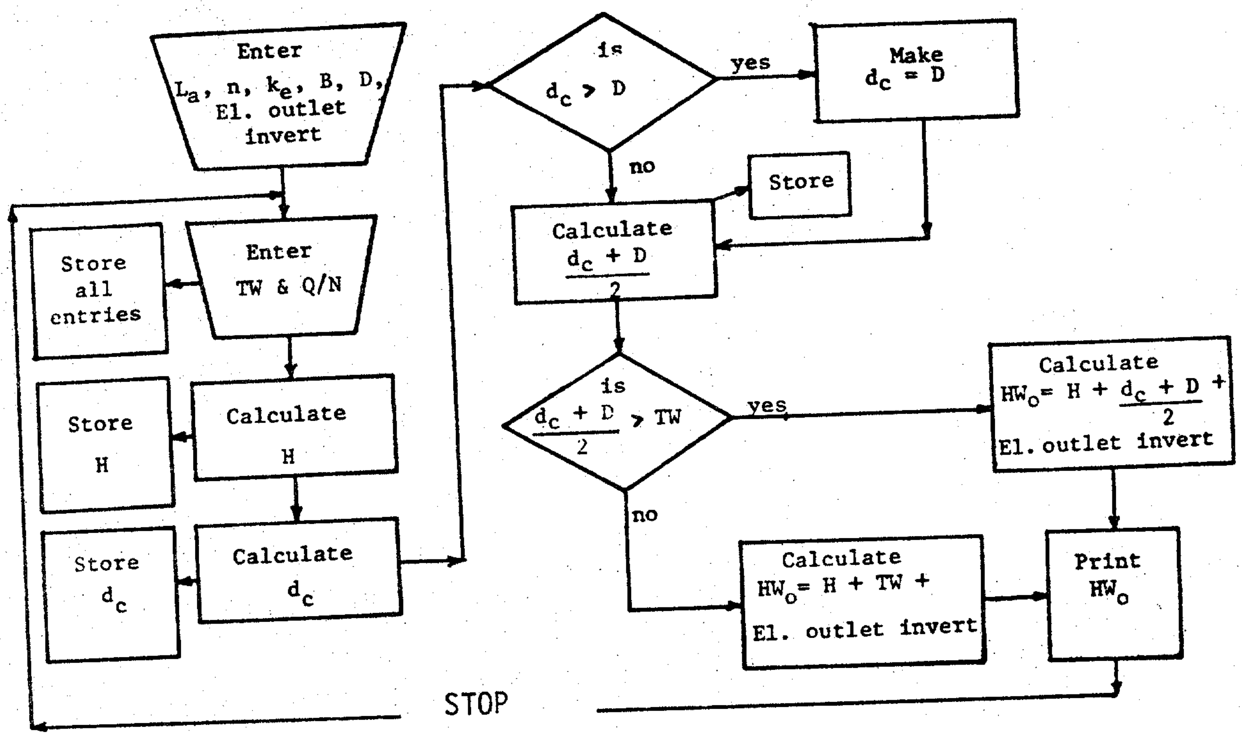
$$H = \left[1 + k_e + \frac{29n^2 L_a}{\left[\frac{BD}{2(B+D)}\right]^{1.33}}\right] \frac{(Q/NBD)^2}{64.4} \qquad (2)$$

$$h_o = \frac{d_c + D}{2} \text{ or TW, whichever is greater} \qquad (2)$$

$$\text{and } d_c = 0.315 \left(\frac{Q}{NB}\right)^{2/3} \qquad (2)$$

Note: d_c cannot exceed D

Program 1-3



$HW_o = H + h_o$ + Elev. Outlet invert (Basic Equation) (2)

where

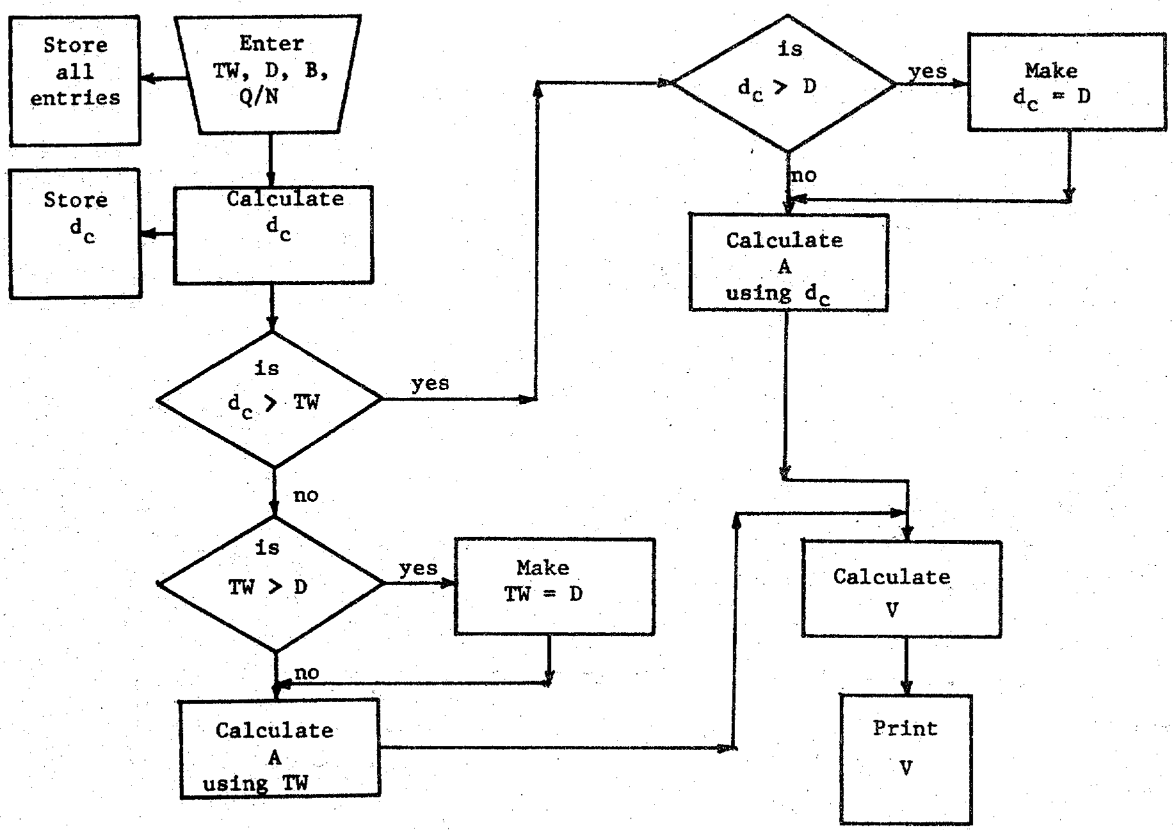
$$H = \left[1 + k_e + \frac{29n^2 L_a}{\left[\frac{BD}{2(B+D)}\right]^{1.33}}\right] \frac{(Q/NBD)^2}{64.4} \quad (2)$$

$h_o = \frac{d_c + D}{2}$ or TW, whichever is greater (2)

and $d_c = 0.315 \left(\frac{Q}{NB}\right)^{2/3}$ (2)

Note: d_c cannot exceed D

Program 1-4



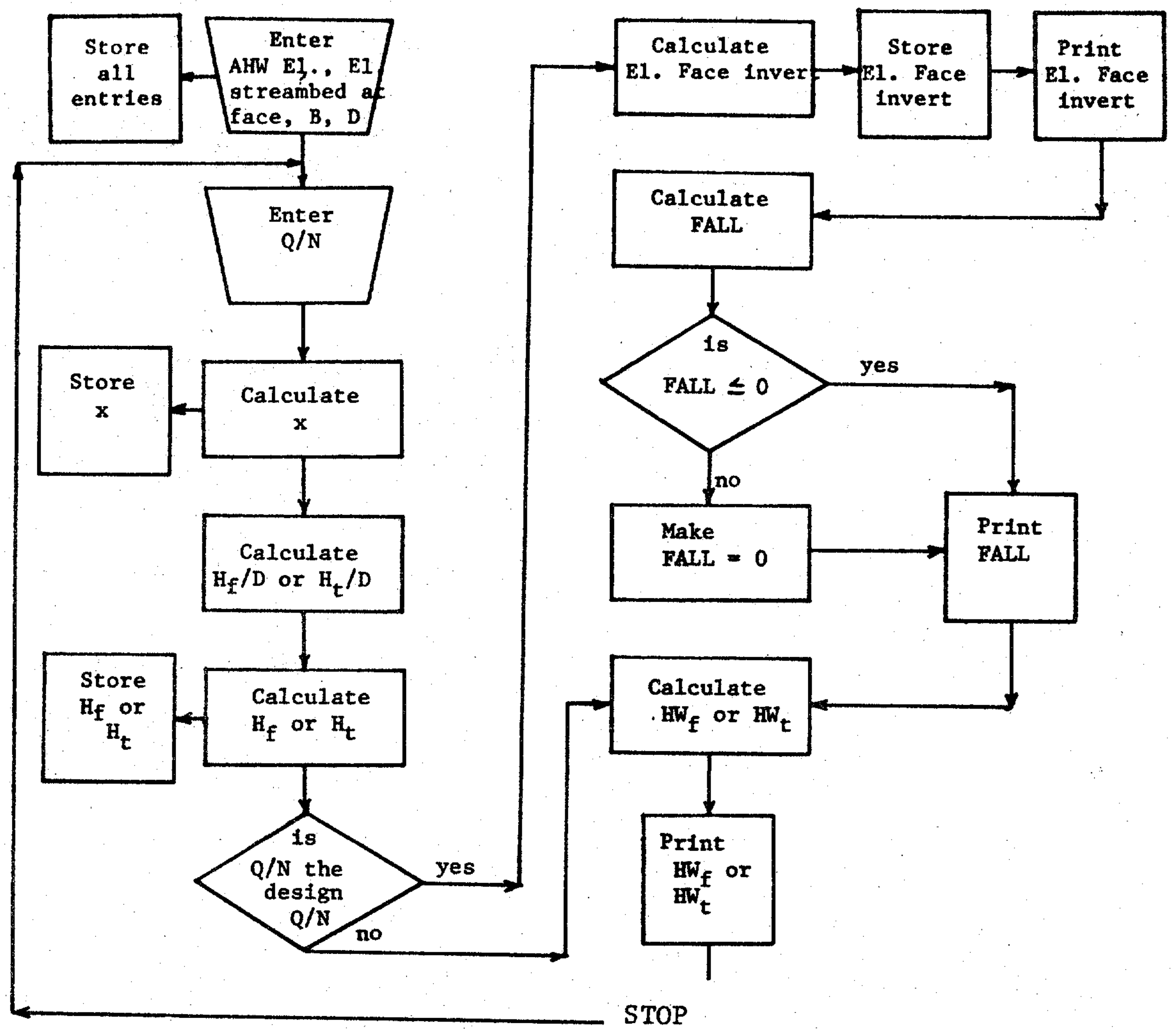
$V = \frac{Q}{A \times N}$ and A = B x depth of water, (d_c, TW, or D)

$d_c = 0.315 \left(\frac{Q}{NB}\right)^{2/3}$

TW is based on program #1

To find area use d_c or TW, whichever is greater, but not to exceed D

Program 1-5, 1-6, & 1-7



(Square edge in headwall)

$$\frac{H_f}{D} = .122117 + .505435x - .10856x^2 + .0207809x^3 - .00136757x^4 + .00003456x^5 \quad (3)$$

(45° Bevels)

$$\frac{H_f}{D} = .1566086 + .3989353x - .0640392x^2 + .01120135x^3 - .0006449x^4 + .000014566x^5 \quad (4)$$

(Tapered inlet throat)

$$\frac{H_t}{D} = .1295033 + .3789445x - .0437778x^2 + .00426329x^3 - .000106358x^4 \quad (4)$$

Where $x = \frac{Q}{NBD^{3/2}}$ and

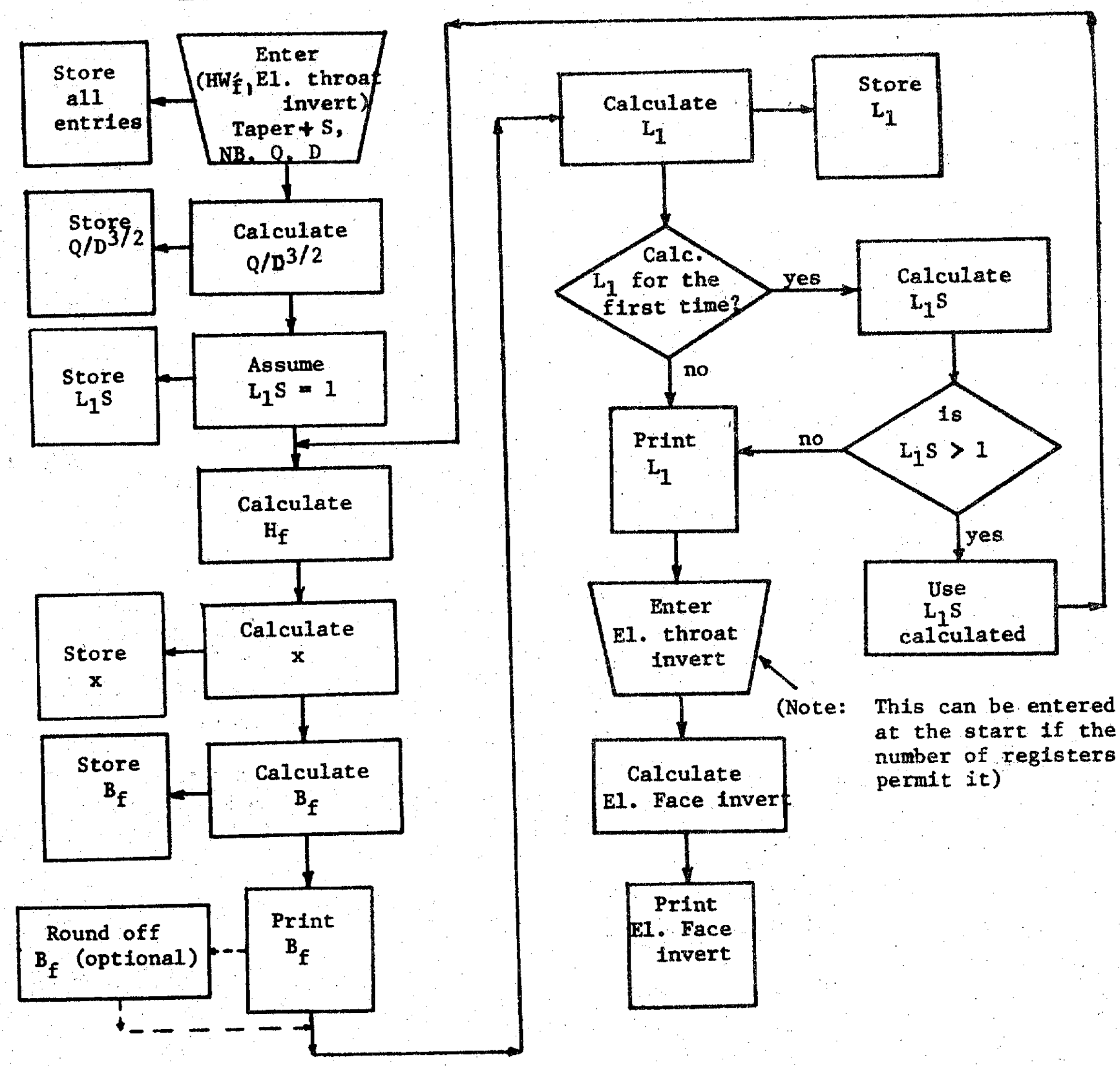
AHW Elev. - H_f = Elev. face invert

(AHW ELEV. - H_f) - Elev. Streambed at face = FALL

Elev. face invert + H_f = HW_f

(Same procedure for $\frac{H_t}{D}$)

Program 1-8, 1-9



(Solid Curve - Favorable edges)

$$B_f = \frac{Q}{D^{3/2}} \div [-1.13607 + 3.69853x + .12128x^2 - .205339x^3 + .0256923x^4]$$

(Dashed Curve - Unfavorable edges)

$$B_f = \frac{Q}{D^{3/2}} \div [-1.219 + 4.3x - .6153x^2 + .0273x^3 + .0027x^4]$$

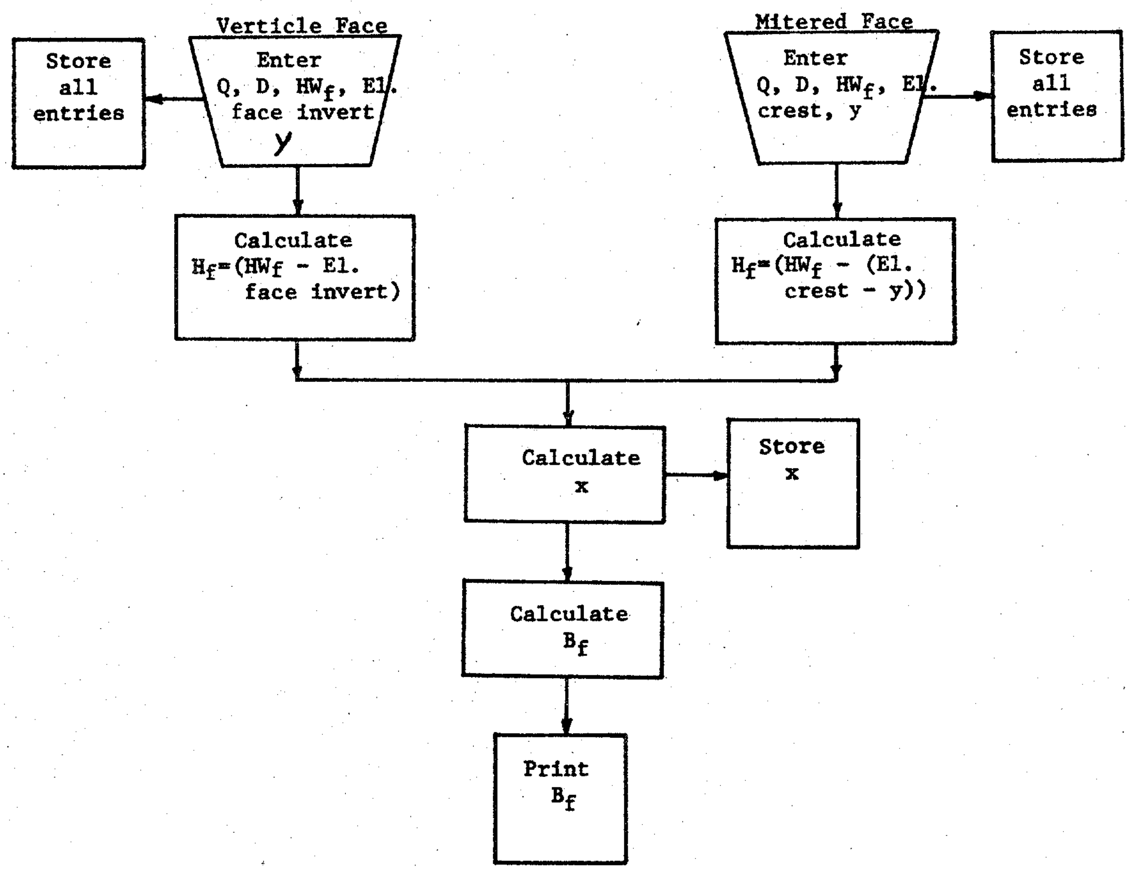
where $x = \frac{H_f}{D}$; $H_f = (HW_f - \text{Elev. Throat Invert} - L_1S)$, (4)

$L_1 = \frac{[B_f - NxB]}{2}$ TAPER, $S \approx S_0 - FALL/L_a$,

El. face invert = El. throat invert + L_1S

Note that it is necessary to know B_f before L_1 can be computed. Since it is also necessary to know L_1 in order to compute B_f assume $L_1S = 1$, and compute B_f, L_1 and L_1S. If the computed L_1S is greater than the assumed value, recalculate B_f using the calculated value.

Program 1-10, 1-11



(Solid Curve - Favorable edges)

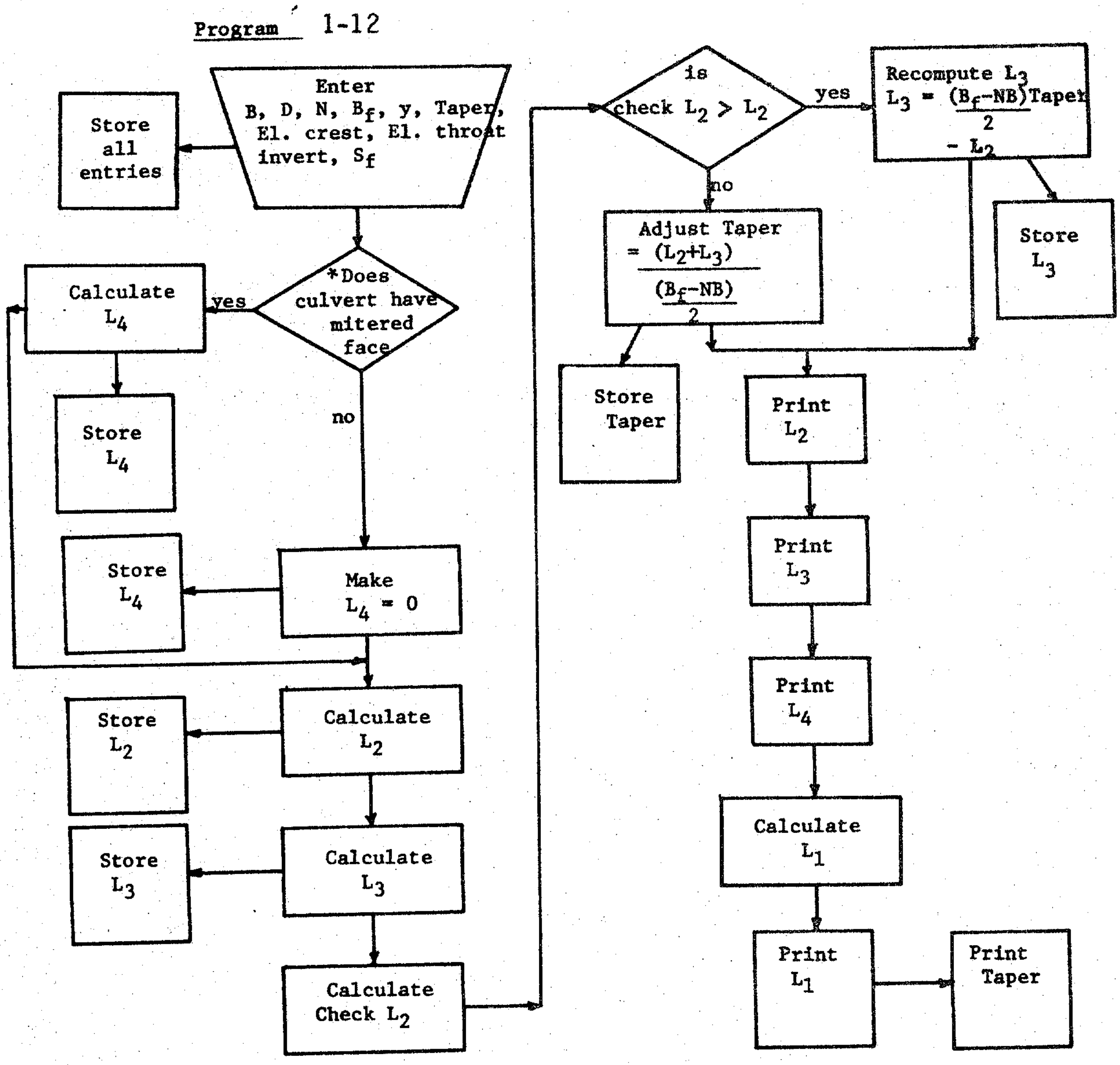
$$B_f = \frac{Q}{D^{3/2}} [-2.265863+7.942441x-4.0352094x^2+1.619481x^3-.3458214x^4+.028146767$$

(Dashed Curve - Unfavorable edges)

$$B_f = \frac{Q}{D^{3/2}} \div [-1.353 + 5.150x - 1.131x^2 + .1578x^3 - .0144x^4 + .0011x^5](4)$$

where $x = H_f/D$; $H_f = (HW_f - \text{El. face invert})$ for verticle face

$H_f = (HW_f - (\text{El. crest} - y))$ for mitered face



Min $L_3 = 0.5NB$ (5)

$L_4 \approx S_f y + D/S_f$ (5)

$L_2 \approx$ (El. Crest Invert - El. Throat Invert) $S_f - L_4$ (5)

$L_1 = L_2 + L_3 + L_4$ (5)

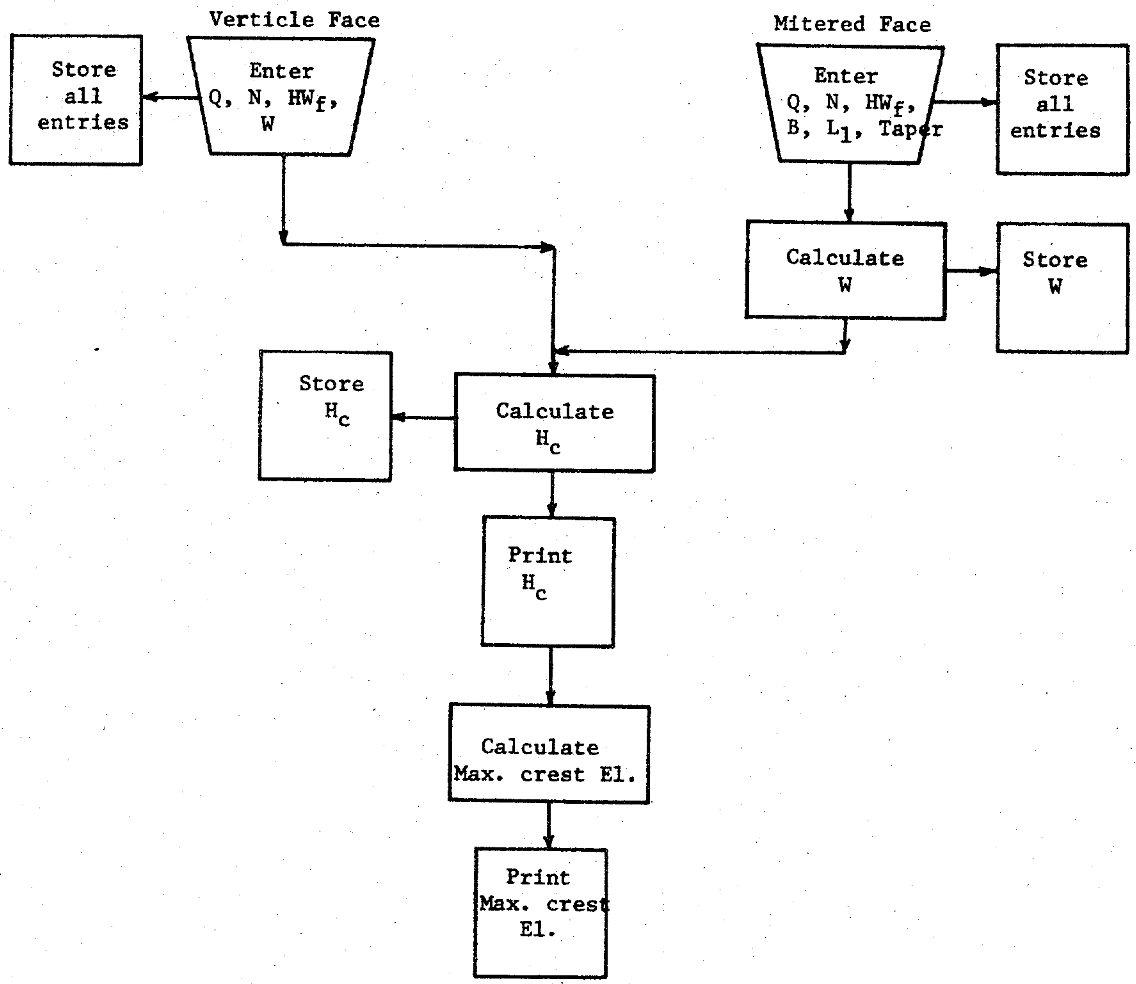
Check $L_2 = \left[\frac{B_f - NxB}{2}\right]$ TAPER $- L_3$

Note: If check $L_2 > L_2$, adjust $L_3 = \left[\frac{B_f - NxB}{2}\right]$ TAPER $- L_2$

If $L_2 >$ check L_2, adjust TAPER $= (L_2 + L_3)/\left[\frac{B_f - NxB}{2}\right]$

* Can use a conditional jump: Y = 0 for verticle face
Y is positive for mitered face

Program 1-13



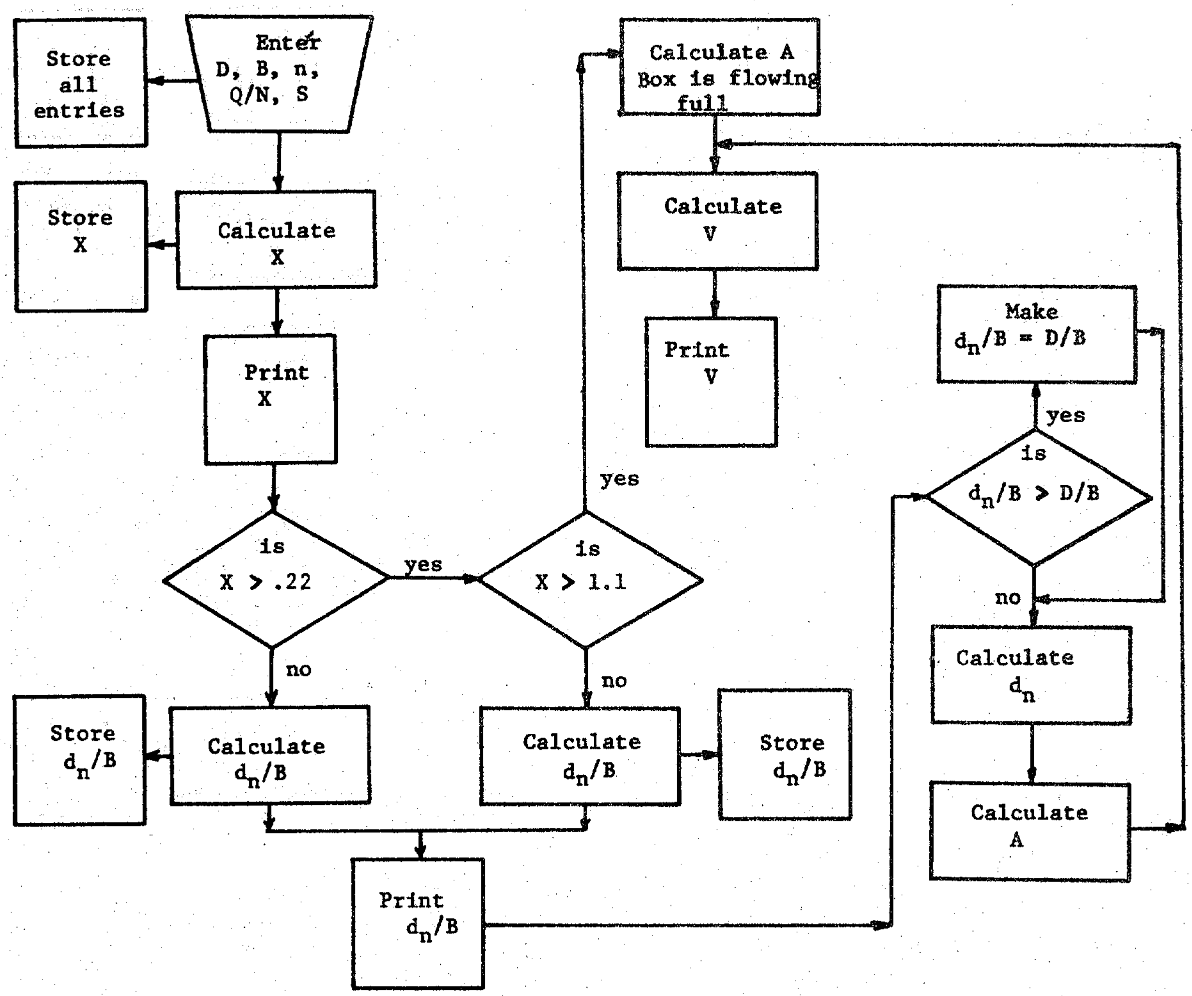
$$H_c = 0.50 \left(\frac{Q}{W}\right)^{2/3} \quad (5)$$

Max. Crest Elev. = $HW_f - H_c$ (5)

$W = NB + 2\ [L_1/\text{Taper}]$ for mitered face slope-tapered inlet (5)

$W \approx 10$ times FALL for side-tapered inlet

Program 1-14



$$X = \frac{Qn}{\frac{1.486\, S^{1/2} N}{B^{2.667}}} \qquad (8)$$

if $X > 1.1$, velocity = $\frac{Q}{B \times D \times N}$

if $.22 < X \leq 1.1$, velocity = $\frac{Q}{B \times d_n \times N}$

and $\frac{d_n}{B} = .084468 + 2.34061X - 1.53643X^2 + 1.636594X^3 - .677621X^4$

if $X \leq .22$, Velocity = $\frac{Q}{B \times d_n \times N}$

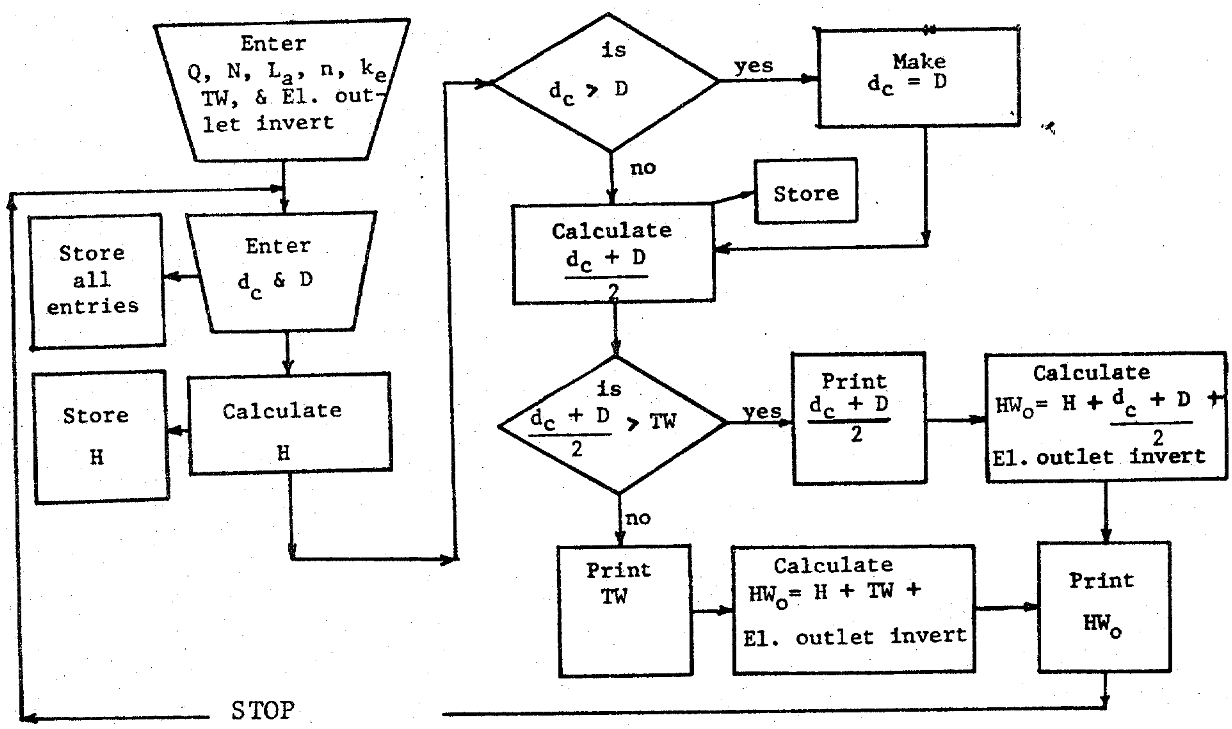
and $\frac{d_n}{B} = .036402 + 3.6483784X - 15.152238X^2 + 64.991913X^3 - 110.31635X^4$

$d_n = \frac{d_n}{B} \times B$

$\frac{d_n}{B}$ is limited to 2 $\qquad A = B \times d_n \qquad V = Q/A$

Note: d_n cannot exceed D

Program 2-1



$HW_o = H + h_o +$ El. Outlet Invert (Basic Equation)

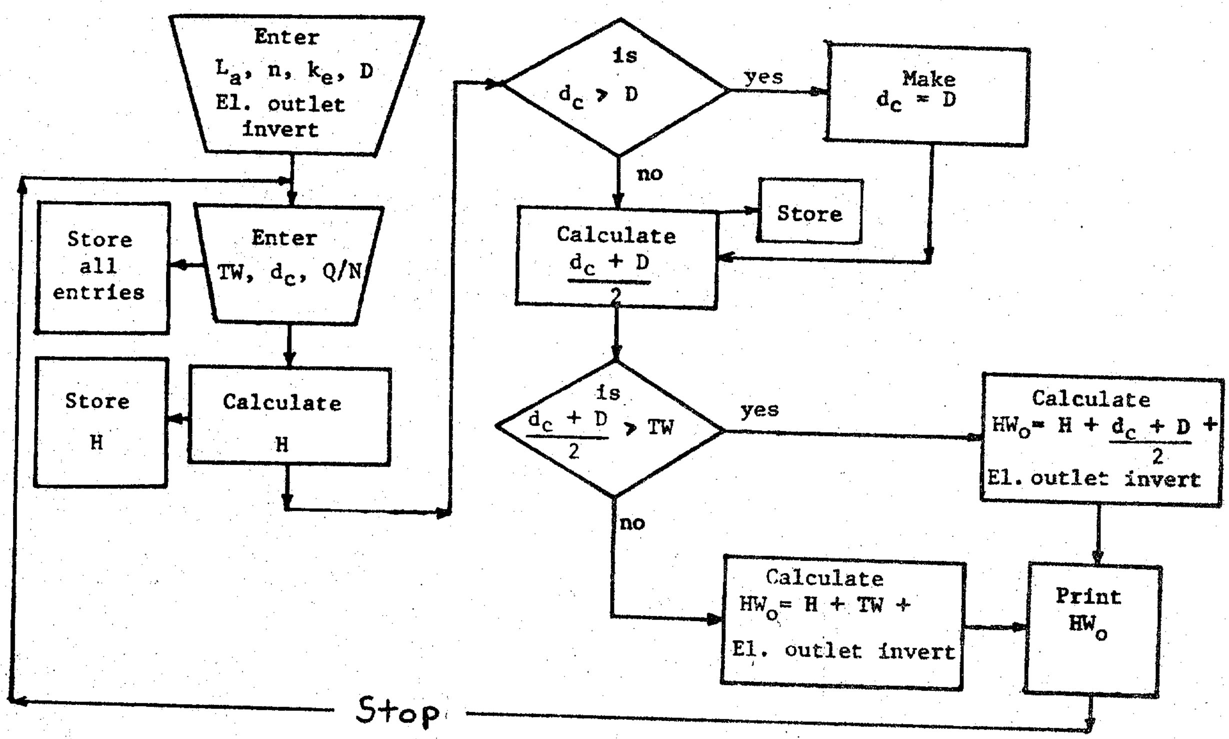
$$\text{Where} \quad H = \left[1 + k_e + \frac{29n^2L_a}{(D/4)^{1.33}}\right] \frac{\left(\frac{Q/N\pi D^2}{4}\right)^2}{64.4} \qquad (2)$$

$$h_o = \frac{d_c + D}{2} \text{ or TW, whichever is greater}$$

d_c must be read from charts and entered into calculator. However, if your calculator is large enough to calculate d_c then calculate it rather than enter it. Program 2-3 calculates d_c.

Note: d_c cannot exceed D

Program 2-2



$$HW_o = H + h_o + \text{El. Outlet Invert} \qquad \text{(Basic Equation)}$$

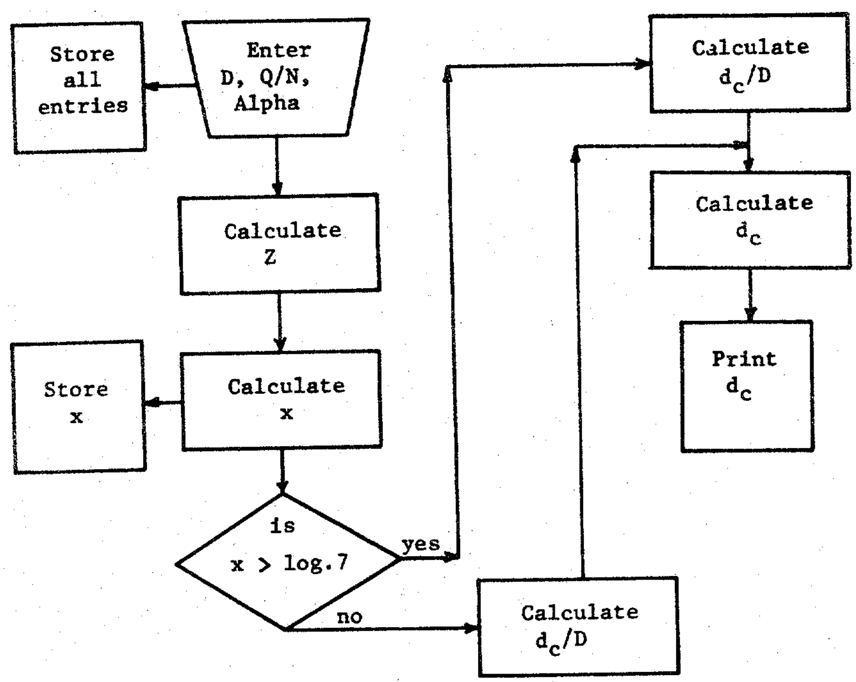
Where
$$H = \left[1 + k_e + \frac{29n^2 L_a}{(D/4)^{1.33}}\right] \frac{\left(\frac{Q/N}{\frac{\pi D^2}{4}}\right)^2}{64.4} \qquad (2)$$

$$h_o = \frac{d_c + D}{2} \text{ or TW, whichever is greater}$$

d_c must be read from charts and entered into calculator. However, if your calculator is large enough to calculate d_c then calculate it rather than enter it. Program 2-3 calculates d_c.

Note: d_c cannot exceed D

Program 2-3



$$Z = \frac{Q}{\frac{N\left(\frac{32.2}{\alpha}\right)^{.5}}{D^{2.5}}}$$

$$x = \log Z$$

if $x > \log .7$

$$\frac{d_c}{D} = 10^{(-.0244603 + .2017057X - .64009815X^2 - .695619X^3)}$$

if $x \leq \log .7$

$$\frac{d_c}{D} = 10^{(-.0051657 + .407362X - .1830236X^2 - .0915565X^3)}$$

$$d_c = \frac{d_c}{D} \times D$$

Program 2-4, 2-5, 2-6, 2-9, & 2-10

Use same flow chart as programs #4a, #4b and #5, except enter D for B in addition to entering D at its regular place.

(Thin Edged Projecting)

$$\frac{H_f}{D} = .187321 + .56771x - .156544^2 + .0447052x^3 - .00343602x^4 + .000089661x^5 \quad (6)$$

(Headwall - Sq. Edges)

$$\frac{H_f}{D} = .087483 + .706578x - .253295x^2 + .0667001x^3 - .00661651x^4 + .000250619x^5 \quad (6)$$

(Beveled edge)

$$\frac{H_f}{D} = .063343 + .766512x - .316097x^2 + .0876701x^3 - .00983695x^4 + .00041676x^5 \quad (6)$$

(Tapered inlet throat - Smooth inlet)

$$\frac{H_t}{D} = .2115 + .3927x - .0414x^2\ .0042x^3 + .0003x^4 - .00003x^5 \quad (7)$$

(Tapered inlet throat - Rough inlet)

$$\frac{H_t}{D} = .2252 + .3471x - .0252x^2\ .0011x^3 + .0005x^4 - .00003x^5 \quad (7)$$

Where $x = \frac{Q}{ND^{5/2}}$ and

AHW Elev. - H_f = Elev. face invert

(AHW Elev. - H_f) - Elev. Streambed at face = FALL

Elev. face invert + H_f = HW_f

(Same procedure for $\frac{H_t}{D}$)

Program 2-7 & 2-8

Use same flow chart as programs 1-5, 1-6 and 1-7 except enter D for B in addition to entering D at its regular place.

(Groove - edged projecting)

$$\frac{H_f}{D} = .108786 + .662381x - .233801x^2\ .0579585x^3 + .0055789x^4 - .000205052x^5 \quad (6)$$

(Groove - edged with headwalls)

$$\frac{H_f}{D} = .114099 + .653562x - .233615x^2 + .0597723x^3 + .006166338x^4 + .000242832x^5 \quad (6)$$

Where $x = \frac{Q}{ND^{5/2}}$ and

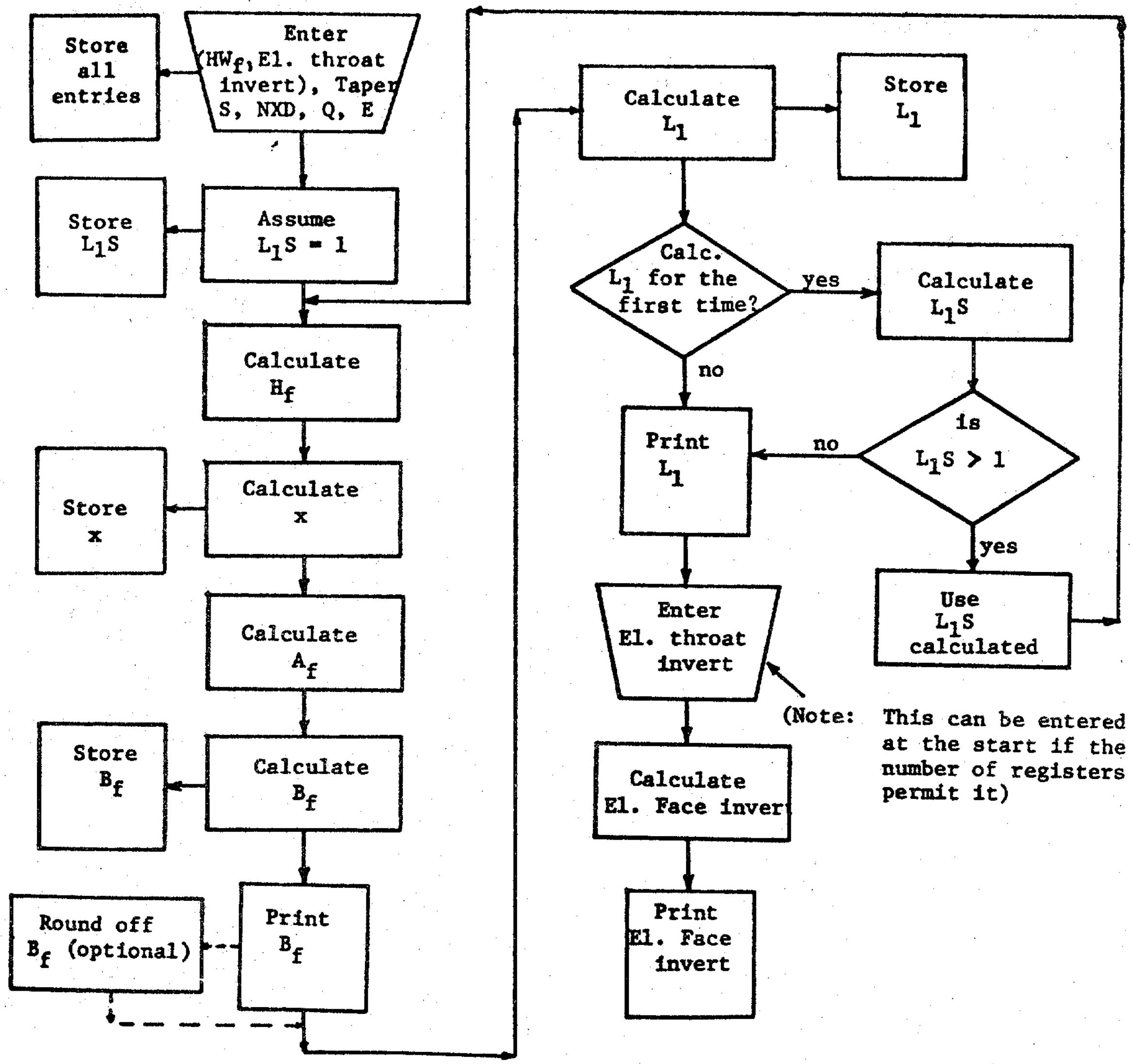
AHW Elev. - H_f = Elev. face invert

(AHW Elev. - H_f) - Elev. Streambed at face = FALL

Elev. face invert + H_f = HW_f

(Same procedure for $\frac{H_t}{D}$)

Program 2-11, 2-12, 2-13



(Thin Edged Projecting)

$$A_f = \frac{Q}{E^{1/2}} \div [.0144 + 1.1505x + 1.8167x^2 - .9642x^3 + .1974x^4 - .0148x^5](7)$$

(Headwall with Sq. Edges)

$$A_f = \frac{Q}{E^{1/2}} \div [-.0048 + .9426x + 2.9784x^2 - 1.792x^3 + .4228x^4 - .0357x^5](7)$$

(Beveled edge)

$$A_f = \frac{Q}{E^{1/2}} \div [0.0 + .73932x + 3.2994x^2 - 1.764x^3 + .3744x^4 - .0287x^5](7)$$

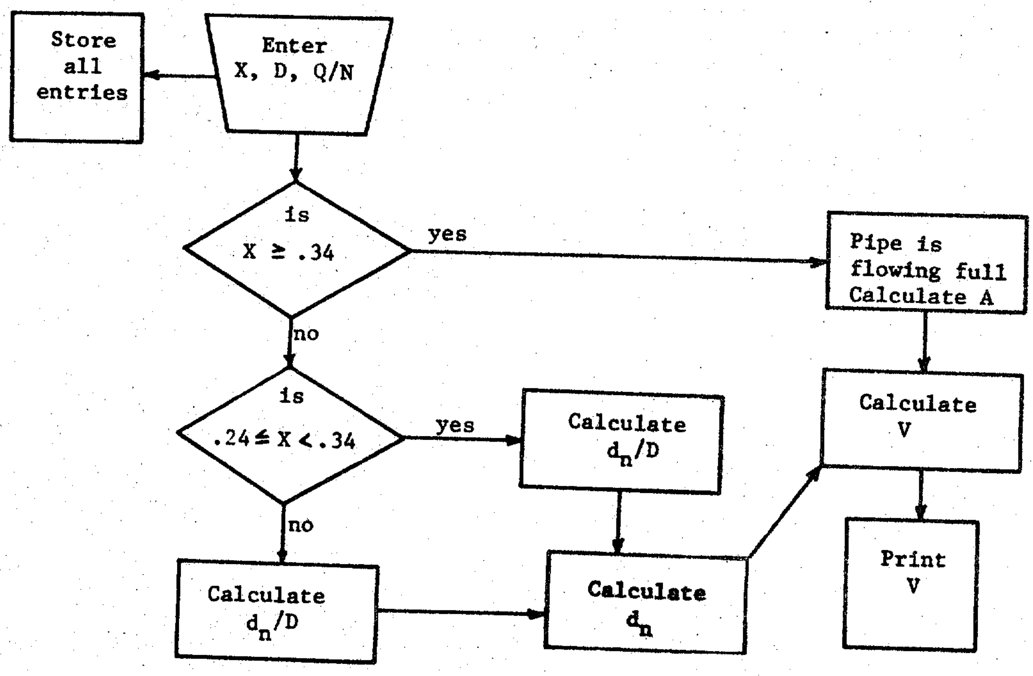
where $x = \frac{H_f}{E}$, H_f = (HW$_f$ - Elev. Throat Inv. - L_1S)

El. face invert = El. throat invert + L_1S

$B_f = \frac{4A_f}{\pi E}$ $L_1 = \frac{(B_f - \text{NXD})\text{Taper}}{2}$ $S \approx S_o - \text{FALL}/L_a$

E is the height of the face of a side-tapered inlet. It is usually equal to D, however, it can vary between D and 1.1D.

Program 2-14



$$X = \frac{Qn}{\frac{1.486\ S^{1/2}N}{B^{2.667}}} \qquad \text{(computed by program \#11a)} \qquad (8)$$

$Z = \log X$

if $.24 \leq .34$, $\frac{d_n}{D} = 10^{(.685734 + 2.097532z + 1.125836z^2)}$

if $X < .24$, $\frac{d_n}{D} = 10^{(.3063639 + .907884z + .192615z^2)}$

For $d_n > R$: $(R = D/2)$

$A = \pi R^2 - (\pi R^2 \text{Cos}^{-1} (r/R)/180) + r(R^2 - r^2)^{.5}$

Otherwise:

$A = (\pi R^2 \text{Cos}^{-1} (r/R)/180) + r(R^2 - r^2)^{.5}$

$r = \text{ABS}(R - d_n)$

REFERENCES

1. "Design Charts for Open Channel Flow" (HDS No. 3), Hydraulics Branch, Bridge Division, FHWA, Washington, D.C.; August 1961.

2. "Hydraulic Charts for the Selection of Highway Culverts" (HEC No. 5), Hydraulics Branch, Bridge Division, FHWA, Washington, D.C.; December 1965.

3. "Electronic Computer Program for Hydraulic Analysis of Box Culverts" (Program HY-3), Office of Development, FHWA, Washington, D.C.; December 1970.

4. Equations Derived by Mario Marques, Hydraulics Branch, Bridge Division, FHWA, Washington, D.C.; November 1972.

5. "Hydraulic Design of Improved Inlets for Culverts" (HEC No. 13), Hydraulics Branch, Bridge Division, FHWA, Washington, D.C.; November 1971.

6. "Electronic Computer Program for Hydraulic Analysis of Circular Culverts" (Program HY-1), Office of Research & Development, FHWA, Washington, D.C.; July 1970.

7. "New York State Improved Inlet Analysis," State of New York, Department of Transportation, Region #1, Albany, New York; January 1973.

8. "Open-Channel Hydraulics," V. T. Chow, McGraw-Hill Book Company, Inc., New York, New York; 1959.

WORKSHEET FOR CULVERT DESIGN

PROJECT: ______________ DESIGNER: ______________

STATION: ______________ DATE: ______________

INITIAL DATA

Design Q ______ = ______________ cfs

Channel Slope, S_o = ______________ ft./ft.

AHW Elevation = ______________ ft.

El. Stream bed at Face ______________ ft.

Approx. Culvert length,

L_a = ______________ ft.

Barrel Shape ______________

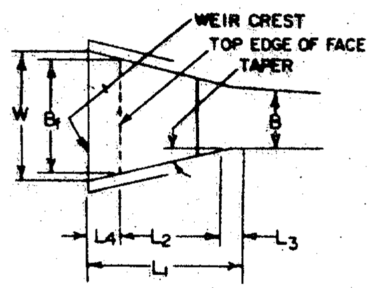
Barrel Material ______________

El. Outlet Invert = ______________ ft.

Barrel Roughness, n. ______________

(See page 2 for natural stream data)

SUMMARY INFORMATION FOR SELECTED DESIGN



Barrel Shape and Material ______________

Face Edge Description ______________

Type of Improved Inlet ______________

Width of box, B = ______________ ft.

Inlet length, L_1 = ______________ ft.

Depth or Diameter, D = ______________ ft.

Face to Bend, L_2 = ______________ ft.

Width of face, B_f = ______________ ft.

Bend to Throat, L_3 = ______________ ft.

No. of Barrels, N = ______________

Crest to Face, L_4 = ______________ ft.

Inlet fall, FALL = ______________ ft.

Side Taper = ______________ :1

Barrel Slope, S = ______________ ft./ft.

Crest Length, W = ______________ ft.

Top bevel height, d = ______________ in.

Side bevel width, b = ______________ in.

Outlet velocity, V = ______________ ft./sec.

COMMENTS ON DESIGN: ______________

STEP 1
CALCULATE TAILWATER

Use file 1, block 1

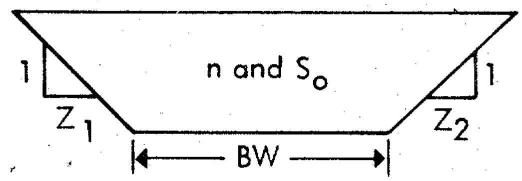
Enter: 1. n = ______________ (channel)

2. S_o = ______________

3. BW = ______________

4. Z_1 = ______________

5. Z_2 = ______________



6. (Enter) Q	(Read) TW, Based on d_n	COMMENTS

STEP 2
DETERMINE AN ACCEPTABLE CULVERT SIZE

Use file 1, block 2 if designing a box culvert.
Use file 2, block 1 if designing a circular pipe culvert.

Enter: 1. Q = ______________

2. N = ______________

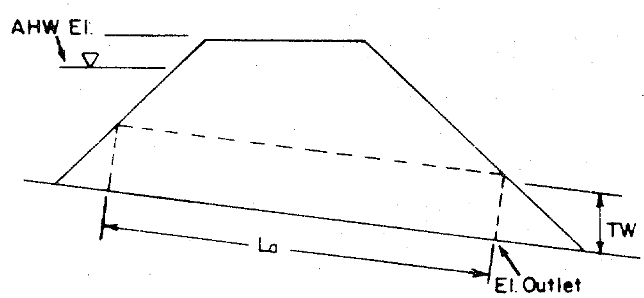
3. L_a = ______________

4. n = ______________ (Barrel)

5. k_e = ______________

6. TW = ______________

7. Elev. outlet invert = ______________



8. (Enter) B - If box (1) d_c - If pipe	9. (Enter) D	(Read) $\frac{d_c+D}{2}$ or TW	(Read) HW_o	COMMENTS

(1) d_c values taken from Design Charts For Open-Channel Flow, Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 3

OUTLET CONTROL PERFORMANCE CURVE DATA

Use file 1, block 3 if designing a box culvert
Use file 2, block 2 if designing a pipe culvert

ENTER: 1. L_a= ____________
2. n = ____________ (Barrel)
3. k_e= ____________
4. B = ____________ (for box only)
5. D = ____________
6. Elev. outlet invert = ____________

7. (2) (Enter) TW	8. (3) (Enter) d_c- pipe only	9. (Enter) Q/N	(Read) HW_o	COMMENTS

Note: Plot outlet control performance curve
(2) Obtain values from Step 1
(3) d_c obtained from Hydraulic Design Series No. 3, HEC #5, or HEC #13

STEP 4

OUTLET VELOCITY WHEN CULVERT IS IN OUTLET CONTROL

If designing a Box Culvert

Use file 1, block 4

Enter: 1. TW = ____________

2. D = ____________

3. B = ____________

4. Q/N = ____________

(Read): Velocity

If designing a pipe culvert

Use file 2, block 3

Enter: 1. D = ____________

2. Q/N = ____________

3. Alpha = ____________ (1.04 for RCP, 1.12 for CMP)

4. TW = ____________

(Read): Velocity

STEP 5

INLET CONTROL CALCULATIONS AND PERFORMANCE CURVE DATA

(BOX CULVERTS)
Use file 1, block 5 if analyzing a square-edge inlet with headwalls.
Use file 1, block 6 if analyzing a 45° beveled inlet.
Use file 1, block 7 if analyzing a tapered inlet throat.

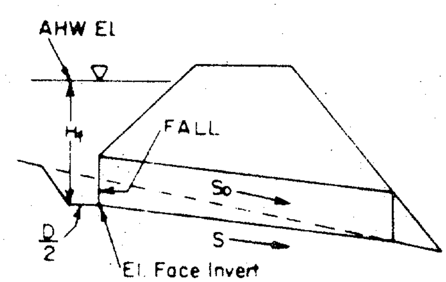
(PIPE CULVERTS)
Use file 2, block 4 if analyzing a thin-edged projecting inlet.
Use file 2, block 5 if analyzing an inlet with square edges in a headwall.
Use file 2, block 7 if analyzing a groove end projecting inlet.
Use file 2, block 8 if analyzing a groove end inlet and headwalls.
Use file 2, block 6 if analyzing a beveled inlet.
Use file 2, block 9 if analyzing a tapered inlet throat. (Smooth inlet)
Use file 2, block 10 if analyzing a tapered inlet throat. (Rough inlet)

Enter: 1. AHW Elev. = ______________

2. El. Stream bed at face = ______________

3. B = ______________ (D, if pipe)

4. D = ______________



CONVENTIONAL or BEVELED

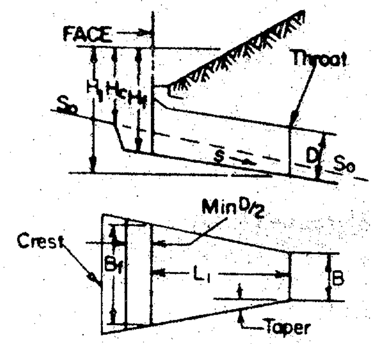
Q	5. (Enter) Q/N	(Read) El. Face invert / El. Throat invert	(Read) FALL	(Read) HW_f / HW_t	Note: Use Upper headings for Conventional or beveled face: Lower headings for tapered inlet throat. COMMENTS
Program No. ______________ ,		Inlet and Edge Description ______________			
Program No. ______________ ,		Inlet and Edge Description ______________			

Note: Plot inlet control section performance curve

STEP 6 & 7

SIDE-TAPERED INLET AND CREST CHECK

(BOX CULVERTS)

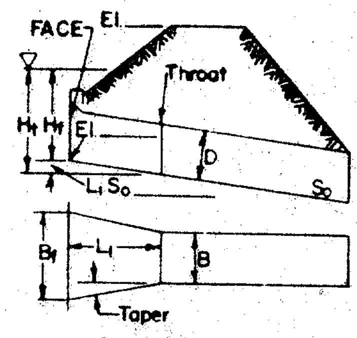


(side-tapered)

Use file 1, block 8 if wingwalls have a 26° to 45° flare angle with top edge beveled or 45° to 90° flare angle with bevels on top and sides. (Favorable face edge conditions)
Use file 1, block 9 if wingwalls have a 15° to 26° flare angle with top edge beveled or 26° to 90° flare angle with no bevels. (Unfavorable face edge conditions)

(PIPE CULVERTS)

Use file 2, block 11 if the face has projecting thin edges.
Use file 2, block 12 if the face has quare edges in a headwall.
Use file 2, block 13 if the face has bevels or a groove end.



(Slope-tapered)

(CREST CHECK)

Use file 1, block 13 for crest check on a conventional, beveled or side-tapered inlet.

Enter: 1. HW_f = ______________

2. El. Throat Invert = __________

3. (Taper + S) = __________ (Taper is 4:1 to 6:1), ($S \approx S_o$-FALL/L_a)

4. N×B = ____________ (N×D for pipe)

5. Q = ______________

6. D = ______________ (E for pipe, where $D \leq E \leq 1.1\ D$)

(4) (Read) Min. B_f	B_f Used	(Read) L_1	(Read) El. face invert	COMMENTS

(4) To use a B_f that is rounded off enter new B_f and press START STOP

Enter: (Crest Check)

1. Q = ________ 2. N = ________ 3. HW_f = ________ 4. W = ________

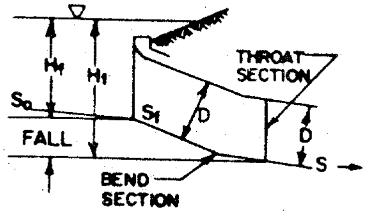
5. B = ___0___ 6. L_1 = ___0___ 7. Taper = ___0___

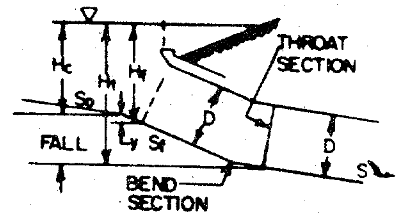
Crest Check: (Read) H_c = ____________, (Read) Max. Crest El. = ____________

STEP 8 THROUGH 12

SLOPE-TAPERED INLET AND CREST CHECK

Use file 1, block 10 for B_f if face has favorable edge conditions as in STEP 5.
Use file 1, block 11 for B_f if face has unfavorable edge conditions as in STEP 5.





Enter: 1. Q = ______

2. D = ______

3. HW_f = ______

4. El. Streambed at face = ______ (if vertical face)
El. Crest = ______ (if mitered face)

5. y = ______

(Read) Min. B_f, or higher rounded value	Type of Face
	Vertical, y = 0
	Mitered, y = .4D

Use file 1, block 12 for L dimensions of an inlet with a vertical face.

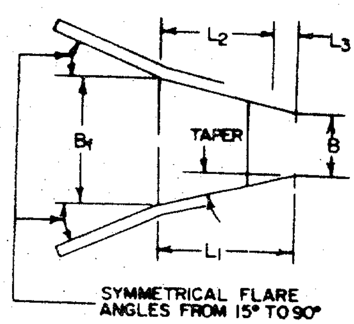
Enter 1. B = ______ 6. Taper = ______ :1

2. D = ______ 7. El. Crest Inv. = ______

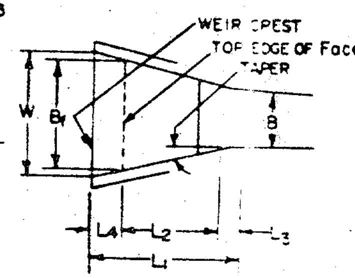
3. N = ______ 8. El. Throat Inv. = ______

4. B_f = ______ 9. S_f = ______ :1 (2:1 to 3:1)

5. y = ______



VERTICAL



MITERED

(Read) L_2	(Read) L_3	(Read) L_4	(Read) L_1	(Read) Taper	Type of Face
					Vertical, y = 0
					Mitered, y = .4D

Use file 1, block 13 for crest check on a slope-tapered inlet with mitered face.

Enter: 1. Q = ______ 3. HW_f = ______ 6. L_1 = ______
2. N = ______ 4. W = 0 7. Taper = ______ : 1
5. B = ______

Crest Check: (Read) H_c = ______, (Read) Max, Crest El. = ______

STEP 13

OUTLET VELOCITY WHEN CULVERT IS IN INLET CONTROL

Use file 1, block 14 if designing a box culvert
Use file 2, block 14 if designing a pipe culvert

Enter: 1. D = ____________

2. B = ____________ (Use D if designing a pipe)

3. n = ____________

4. Q/N = ____________

5. S = ____________ $= (S_o - FALL/L_a)$

(READ) d_n/B	(READ) Velocity

For Box Culvert

(READ) Velocity

For pipe culvert

1 1 Calculates channel tailwater.

•001	001		1
•002	032	I D	
•003	033	S S	
•004	034	PT	
•005	300	ST	
•006	001		1
•007	002		2
•008	032	I D	
•009	033	S S	
•010	034	PT	
•011	300	ST	
•012	002		2
•013	003		3
•014	032	I D	
•015	033	S S	
•016	034	PT	
•017	300	ST	
•018	003		3
•019	004		4
•020	032	I D	
•021	033	S S	
•022	034	PT	
•023	300	ST	
•024	004		4
•025	005		5
•026	032	I D	
•027	033	S S	
•028	034	PT	
•029	300	ST	
•030	005		5
•031	203	L	3
•032	006		6
•033	032	I D	
•034	033	S S	
•035	034	PT	
•036	300	ST	
•037	006		6
•038	001		1
•039	300	ST	
•040	000		0
•041	300	ST	
•042	010		8
•043	201	L	1
•044	310	RC	
•045	004		4
•046	021		+
•047	310	RC	
•048	005		5
•049	023		×
•050	310	RC	
•051	000		0
•052	024		÷
•053	002		2
•054	021		+
•055	310	RC	
•056	003		3
•057	023		×
•058	310	RC	
•059	000		0
•060	020		=
•061	300	ST	
•062	011		9
•063	310	RC	
•064	004		4
•065	162	SQ	
•066	021		+
•067	001		1
•068	020		=
•069	062	√	
•070	021		+
•071	026	(	
•072	310	RC	
•073	005		5
•074	162	SQ	
•075	021		+
•076	001		1
•077	020		=
•078	062	√	
•079	027		)
•080	023		×
•081	310	RC	
•082	000		0
•083	021		+
•084	310	RC	
•085	003		3
•086	020		=
•087	063	1/x	
•088	023		×
•089	310	RC	
•090	011		9
•091	020		=
•092	025		d
•093	026	(	
•094	002		2
•095	024		÷
•096	003		3
•097	027		)
•098	023		×
•099	310	RC	
•100	011		9
•101	023		×
•102	310	RC	
•103	002		2
•104	062	√	
•105	023		×
•106	001		1
•107	012		d
•108	004		4
•109	010		8
•110	006		6
•111	024		÷
•112	310	RC	
•113	001		1
•114	022		−
•115	310	RC	
•116	006		6
•117	020		=
•118	110	R	
•119	354	JC	
•120	002		2
•121	320	XC	
•122	007		7
•123	312	RC−	
•124	007		7
•125	354	JC	
•126	002		2
•127	063	1/x	
•128	023		×
•129	310	RC	
•130	007		7
•131	023		×
•132	310	RC	
•133	010		8
•134	020		=
•135	300	ST	

```
•136  010          8
•137  302   ST-
•138  000          0
•139  350   J
•140  001          1
•141  202     L 2
•142  310   RC
•143  000          0
•144  035   P A
•145  035   P A
•146  222  DP     2
•147  034   PT
•148  112  D T
•149  224  DP     4
•150  350   J
•151  003          3
```

1 2 **Determines an acceptable box size by calculating HW_o.**

•001	001		1
•002	032	I D	
•003	033	S S	
•004	034	PT	
•005	300	ST	
•006	001		1
•007	002		2
•008	032	I D	
•009	033	S S	
•010	034	PT	
•011	300	ST	
•012	002		2
•013	003		3
•014	032	I D	
•015	033	S S	
•016	034	PT	
•017	300	ST	
•018	003		3
•019	004		4
•020	032	I D	
•021	033	S S	
•022	034	PT	
•023	300	ST	
•024	004		4
•025	005		5
•026	032	I D	
•027	033	S S	
•028	034	PT	
•029	300	ST	
•030	005		5
•031	006		6
•032	032	I D	
•033	033	S S	
•034	034	PT	
•035	300	ST	
•036	006		6
•037	007		7
•038	032	I D	
•039	033	S S	
•040	034	PT	
•041	300	ST	
•042	007		7
•043	201	L	1
•044	222	DP	2
•045	010		8
•046	032	I D	
•047	033	S S	
•048	034	PT	
•049	300	ST	
•050	010		8
•051	011		9
•052	032	I D	
•053	033	S S	
•054	034	PT	
•055	300	ST	
•056	011		9
•057	310	RC	
•058	004		4
•059	162	SQ	
•060	023		×
•061	310	RC	
•062	003		3
•063	023		×
•064	002		2
•065	011		9
•066	024		÷
•067	026		(
•068	310	RC	
•069	010		8
•070	023		×
•071	310	RC	
•072	011		9
•073	024		÷
•074	002		2
•075	024		+
•076	026		(
•077	310	RC	
•078	010		8
•079	021		+
•080	310	RC	
•081	011		9
•082	027		)
•083	025		d
•084	026		(
•085	004		4
•086	024		÷
•087	003		3
•088	027		)
•089	027		)
•090	021		+
•091	001		1
•092	021		+
•093	310	RC	
•094	005		5
•095	023		×
•096	026		(
•097	310	RC	
•098	001		1
•099	024		÷
•100	310	RC	
•101	002		2
•102	024		÷
•103	310	RC	
•104	010		8
•105	024		÷
•106	310	RC	
•107	011		9
•108	027		)
•109	162	SQ	
•110	024		÷
•111	006		6
•112	004		4
•113	012		d
•114	004		4
•115	020		=
•116	300	ST	
•117	000		0
•118	310	RC	
•119	001		1
•120	024		÷
•121	310	RC	
•122	002		2
•123	024		÷
•124	310	RC	
•125	010		8
•126	025		d
•127	026		(
•128	002		2
•129	024		÷
•130	003		3
•131	027		)
•132	023		×
•133	012		d
•134	003		3
•135	001		1

```
•136  005        5
•137  022        -
•138  300   ST
•139  012        d
•140  310   RC
•141  011        9
•142  020        =
•143  356   JC
•144  002        2
•145  310   RC
•146  011        9
•147  300   ST
•148  012        d
•149  202   L  2
•150  310   RC
•151  011        9
•152  021        +
•153  310   RC
•154  012        d
•155  024        ÷
•156  002        2
•157  022        -
•158  300   ST
•159  013        S
•160  310   RC
•161  006        6
•162  020        =
•163  035   P  A
•164  035   P  A
•165  356   JC
•166  003        3
•167  310   RC
•168  013        S
•169  034   PT
•170  350   J
•171  004        4
•172  203   L  3
•173  310   RC
•174  005        5
•175  034   PT
•176  310   RC
•177  006        6
•178  204   L  4
•179  112   D  T
•180  021        +
•181  310   RC
•182  000        0
•183  021        +
•184  310   RC
•185  007        7
•186  020        =
•187  035   P  A
•188  035   P  A
•189  034   PT
•190  112   D  T
•191  350   J
•192  001        1
```

1 3 Calculates outlet control performance curve data for box culverts.

•001	001		1
•002	032	I D	
•003	033	S S	
•004	034	PT	
•005	300	ST	
•006	001		1
•007	002		2
•008	032	I D	
•009	033	S S	
•010	034	PT	
•011	300	ST	
•012	002		2
•013	003		3
•014	032	I D	
•015	033	S S	
•016	034	PT	
•017	300	ST	
•018	003		3
•019	004		4
•020	032	I D	
•021	033	S S	
•022	034	PT	
•023	300	ST	
•024	004		4
•025	005		5
•026	032	I D	
•027	033	S S	
•028	034	PT	
•029	300	ST	
•030	005		5
•031	006		6
•032	032	I D	
•033	033	S S	
•034	034	PT	
•035	300	ST	
•036	006		6
•037	201	L	1
•038	222	DP	2
•039	007		7
•040	032	I D	
•041	033	S S	
•042	034	PT	
•043	300	ST	
•044	007		7
•045	011		9
•046	032	I D	
•047	033	S S	
•048	034	PT	
•049	300	ST	
•050	010		8
•051	310	RC	
•052	002		2
•053	162	SQ	
•054	023		×
•055	310	RC	
•056	001		1
•057	023		×
•058	002		2
•059	011		9
•060	024		÷
•061	026		(
•062	310	RC	
•063	004		4
•064	023		×
•065	310	RC	
•066	005		5
•067	024		÷
•068	002		2
•069	024		÷
•070	026		(
•071	310	RC	
•072	004		4
•073	021		+
•074	310	RC	
•075	~~011~~ 005		~~9~~ 5
•076	027		)
•077	025		d
•078	026		(
•079	004		4
•080	024		÷
•081	003		3
•082	027		)
•083	027		)
•084	021		+
•085	001		1
•086	021		+
•087	310	RC	
•088	003		3
•089	023		×
•090	026		(
•091	310	RC	
•092	010		8
•093	024		÷
•094	310	RC	
•095	004		4
•096	024		÷
•097	310	RC	
•098	005		5
•099	027		)
•100	162	SQ	
•101	024		÷
•102	006		6
•103	004		4
•104	012		d
•105	004		4
•106	020		=
•107	300	ST	
•108	000		0
•109	310	RC	
•110	010		8
•111	024		÷
•112	310	RC	
•113	004		4
•114	025		d
•115	026		(
•116	002		2
•117	024		÷
•118	003		3
•119	027		)
•120	023		×
•121	012		d
•122	003		3
•123	001		1
•124	005		5
•125	022		−
•126	300	ST	
•127	012		d
•128	310	RC	
•129	005		5
•130	020		=
•131	356	JC	
•132	002		2
•133	310	RC	
•134	005		5
•135	300	ST	

```
•136  012      ' d
•137  202     L 2
•138  310   RC
•139  005        5
•140  021      +
•141  310   RC
•142  012      d
•143  024      ÷
•144  002        2
•145  022      -
•146  300   ST
•147  013       S
•148  310   RC
•149  007        7
•150  020      =
•151  035  P A
•152  035  P A
•153  356  JC
•154  003        3
•155  310   RC
•156  013       S
•157  350  J
•158  004        4
•159  203     L 3
•160  310   RC
•161  007        7
•162  204     L 4
•163  021      +
•164  310   RC
•165  000        0
•166  021      +
•167  310   RC
•168  006        6
•169  020      =
•170  034  PT
•171  112 D T
•172  350  J
•173  001        1
```

1 4 **Calculates outlet velocity for box culverts in outlet control.**

•001	001	1
•002	032	I D
•003	033	S S
•004	034	PT
•005	300	ST
•006	001	1
•007	002	2
•008	032	I D
•009	033	S S
•010	034	PT
•011	300	ST
•012	002	2
•013	003	3
•014	032	I D
•015	033	S S
•016	034	PT
•017	300	ST
•018	003	3
•019	004	4
•020	032	I D
•021	033	S S
•022	034	PT
•023	300	ST
•024	004	4
•025	222	DP 2
•026	310	RC
•027	004	4
•028	024	÷
•029	310	RC
•030	003	3
•031	025	a
•032	026	(
•033	002	2
•034	024	÷
•035	003	3
•036	027	)
•037	023	×
•038	012	o
•039	003	3
•040	001	1
•041	005	5
•042	022	−
•043	300	ST
•044	005	5
•045	310	RC
•046	001	1
•047	020	=
•048	351	JC
•049	001	1
•050	310	RC
•051	001	1
•052	022	−
•053	310	RC
•054	002	2
•055	020	=
•056	356	JC
•057	002	2
•058	310	RC
•059	002	2
•060	300	ST
•061	001	1
•062	202	L 2
•063	310	RC
•064	001	1
•065	063	½
•066	350	J
•067	003	3
•068	201	L 1
•069	310	RC
•070	005	5
•071	022	−
•072	310	RC
•073	002	2
•074	020	=
•075	356	JC
•076	004	4
•077	310	RC
•078	002	2
•079	300	ST
•080	005	5
•081	204	L 4
•082	310	RC
•083	005	5
•084	063	½
•085	203	L 3
•086	023	×
•087	310	RC
•088	004	4
•089	024	÷
•090	310	RC
•091	003	3
•092	020	=
•093	035	P A
•094	035	P A
•095	034	PT
•096	112	D T
•097	350	J
•098	033	S S

1 5 Calculates the performance of a square-edged inlet with headwalls on a box culvert.

Step	Code	Key	Symbol
001	001		1
002	032	I D	
003	033	S S	
004	034	PT	
005	300	ST	
006	001		1
007	002		2
008	032	I D	-
009	033	S - S	
010	034	PT	
011	300	ST	
012	002		2
013	003		3
014	032	I D	
015	033	S S	
016	034	PT	
017	300	ST	
018	003		3
019	004		4
020	032	I D	
021	033	S S	
022	034	PT	
023	300	ST	
024	004		4
025	001		1
026	300	ST	
027	000		0
028	201	⊢	1
029	222	DP	2
030	005		5
031	032	I D	
032	033	S S	
033	034	PT	
034	300	ST	
035	005		5
036	024		÷
037	310	RC	
038	003		3
039	024		÷
040	026		(
041	310	RC	
042	004		4
043	025		×
044	001		1
045	012		d
046	005		5
047	027		)
048	020		=
049	300	ST	
050	006		6
051	023		×
052	012		d
053	000		0
054	000		0
055	000		0
056	000		0
057	003		3
058	004		4
059	005		5
060	006		6
061	022		-
062	012		d
063	000		0
064	000		0
065	001		1
066	003		3
067	006		6
068	007		7
069	005		5
070	007		7
071	023		×
072	310	RC	
073	006		6
074	021		+
075	012		d
076	000		0
077	002		2
078	000		0
079	007		7
080	010		8
081	000		0
082	011		9
083	023		×
084	310	RC	
085	006		6
086	022		-
087	012		d
088	001		1
089	000		0
090	010		8
091	005		5
092	006		6
093	023		×
094	310	RC	
095	006		6
096	021		+
097	012		d
098	005		5
099	000		0
100	005		5
101	004		4
102	003		3
103	005		5
104	023		×
105	310	RC	
106	006		6
107	021		+
108	012		d
109	001		1
110	002		2
111	002		2
112	001		1
113	001		1
114	007		7
115	023		×
116	310	RC	
117	004		4
118	020		=
119	300	ST	
120	007		7
121	001		1
122	302	ST-	
123	000		0
124	310	RC	
125	000		0
126	352	JC	
127	003		3
128	310	RC	
129	001		1
130	022		-
131	310	RC	
132	007		7
133	020		=
134	300	ST	
135	010		9
136	022		-
137	310	RC	
138	002		2
139	020		=
140	300	ST	
141	012		d
142	352	JC	
143	004		4
144	310	RC	

```
•145  002          2
•146  300    ST
•147  010          8
•148  000          0
•149  300    ST
•150  012          d
•151  204      L   4
•152  310    RC
•153  010          8
•154  035   P  A
•155  035   P  A
•156  034   PT
•157  112  L  T
•158  310    RC
•159  012          o
•160  035   P  A
•161  035   P  A
•162  102       F  2
•163  034   PT
•164  112  D  T
•165  203      L   3
•166  310    RC
•167  010          8
•168  021       +
•169  310    RC
•170  007          7
•171  020       =
•172  035   P  A
•173  035   P  A
•174  034   PT
•175  112  D  T
•176  350   J
•177  001          1
```

1 6 Calculates the performance of a 45° beveled inlet on a box culvert.

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	I D
•010	033	S S
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	I D
•016	033	S S
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	I D
•022	033	S S
•023	034	PT
•024	300	ST
•025	004	4
•026	001	1
•027	300	ST
•028	000	0
•029	201	L 1
•030	222	DP 2
•031	005	5
•032	032	I D
•033	033	S S
•034	034	PT
•035	300	ST
•036	005	5
•037	024	÷
•038	310	RC
•039	003	3
•040	024	÷
•041	026	(
•042	310	RC
•043	004	4
•044	025	d
•045	001	1
•046	012	d
•047	005	5
•048	027	)
•049	020	=
•050	300	ST
•051	006	6
•052	023	×
•053	012	d
•054	000	0
•055	000	0
•056	000	0
•057	000	0
•058	001	1
•059	004	4
•060	005	5
•061	006	6
•062	006	6
•063	022	−
•064	012	d
•065	000	0
•066	000	0
•067	000	0
•068	006	6
•069	004	4
•070	004	4
•071	011	9
•072	023	×
•073	310	RC
•074	006	6
•075	021	+
•076	012	d
•077	000	0
•078	001	1
•079	001	1
•080	002	2
•081	000	0
•082	001	1
•083	003	3
•084	005	5
•085	023	×
•086	310	RC
•087	006	6
•088	022	−
•089	012	d
•090	000	0
•091	006	6
•092	004	4
•093	000	0
•094	003	3
•095	011	9
•096	002	2
•097	023	×
•098	310	RC
•099	006	6
•100	021	+
•101	012	d
•102	003	3
•103	011	9
•104	010	8
•105	011	9
•106	003	3
•107	005	5
•108	003	3
•109	023	×
•110	310	RC
•111	006	6
•112	021	+
•113	012	d
•114	001	1
•115	005	5
•116	006	6
•117	006	6
•118	000	0
•119	010	8
•120	006	6
•121	023	×
•122	310	RC
•123	004	4
•124	020	=
•125	300	ST
•126	007	7
•127	001	1
•128	302	ST−
•129	000	0
•130	310	RC
•131	000	0
•132	352	JC
•133	003	3
•134	310	RC
•135	001	1
•136	022	−
•137	310	RC
•138	007	7
•139	020	=
•140	300	ST
•141	010	8
•142	022	−
•143	310	RC
•144	002	2
•145	020	=

```
•146   300    ST
•147   012        d
•148   355   JC
•149   004          4
•150   310    RC
•151   002          2
•152   300    ST
•153   013          a
•154   000          0
•155   300    ST
•156   012        d
•157   204     L  4
•158   310    RC
•159   310          3
•160   035   P  A
•161   035   P  A
•162   034   PT
•163   112  D  T
•164   310    RC
•165   012        d
•166   035   P  A
•167   035   P  A
•168   102       F2
•169   034   PT
•170   112  D  T
•171   203     L  3
•172   310    RC
•173   010          9
•174   021       +
•175   310    RC
•176   007          7
•177   020       =
•178   035   P  A
•179   035   P  A
•180   034   PT
•181   112  D  T
•182   350   J
•183   001          1
```

1 7 **Calculates the performance of the throat section of a tapered inlet in a box culvert.**

•001	037	CL		•049	020		=	•097	005		5
•002	001		1	•050	300	ST		•096	023		×
•003	032	I D		•051	006		6	•099	310	RC	
•004	033	S S		•052	023		×	•100	006		6
•005	034	PT		•053	012		d	•101	021		+
•006	300	ST		•054	000		0	•102	012		d
•007	001		1	•055	000		0	•103	001		1
•008	002		2	•056	000		0	•104	002		2
•009	032	I D		•057	001		1	•105	011		9
•010	033	S S		•058	000		0	•106	005		5
•011	034	PT		•059	006		6	•107	000		0
•012	300	ST		•060	003		3	•108	003		3
•013	002		2	•061	005		5	•109	003		3
•014	003		3	•062	010		8	•110	023		×
•015	032	I D		•063	013		S	•111	310	RC	
•016	033	S S		•064	021		+	•112	004		4
•017	034	PT		•065	012		d	•113	020		=
•018	300	ST		•066	000		0	•114	300	ST	
•019	003		3	•067	000		0	•115	007		7
•020	004		4	•068	004		4	•116	001		1
•021	032	I D		•069	002		2	•117	302	ST−	
•022	033	S S		•070	006		6	•118	000		0
•023	034	PT		•071	003		3	•119	310	RC	
•024	300	ST		•072	002		2	•120	000		0
•025	004		4	•073	011		9	•121	352	JC	
•026	001		1	•074	023		×	•122	003		3
•027	300	ST		•075	310	RC		•123	310	RC	
•028	000		0	•076	006		6	•124	001		1
•029	201	L	1	•077	022		−	•125	022		−
•030	222	DP	2	•078	012		d	•126	310	RC	
•031	005		5	•079	000		0	•127	007		7
•032	032	I D		•080	004		4	•128	020		=
•033	033	S S		•081	003		3	•129	300	ST	
•034	034	PT		•082	007		7	•130	010		8
•035	300	ST		•083	007		7	•131	022		−
•036	005		5	•084	007		7	•132	310	RC	
•037	024		÷	•085	010		8	•133	002		2
•038	310	RC		•086	023		×	•134	020		=
•039	003		3	•087	310	RC		•135	300	ST	
•040	024		÷	•088	006		6	•136	012		d
•041	026		(	•089	021		+	•137	352	JC	
•042	310	RC		•090	012		d	•138	004		4
•043	004		4	•091	003		3	•139	310	RC	
•044	025		α	•092	007		7	•140	002		2
•045	001		1	•093	010		8	•141	300	ST	
•046	012		d	•094	011		9	•142	010		8
•047	005		5	•095	004		4	•143	000		0
•048	027		)	•096	004		4	•144	300	ST	

```
•145   012        d
•146   204      L 4
•147   310    RC
•148   010          8
•149   035   P  A
•150   035   P  A
•151   034   PT
•152   112  D  T
•153   310    RC
•154   012        d
•155   035   P  A
•156   035   P  A
•157   102          F2
•158   034   PT
•159   112  D  T
•160   203      L 3
•161   310    RC
•162   010          8
•163   021        +
•164   310    RC
•165   007          7
•166   020        =
•167   035   P  A
•168   035   P  A
•169   034   PT
•170   112  D  T
•171   350   J
•172   001          1
```

1 8 Calculates B_f and L_1 for a side-tapered inlet on a box culvert with favorable face edge conditions. (See Step 7 for definition of favorable conditions).

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	022	−
•007	002	2
•008	032	I D
•009	033	S S
•010	034	PT
•011	300	ST
•012	003	3
•013	020	=
•014	300	ST
•015	001	1
•016	003	3
•017	032	I D
•018	033	S S
•019	034	PT
•020	300	ST
•021	002	2
•022	004	4
•023	032	I D
•024	033	S S
•025	034	PT
•026	300	ST
•027	004	4
•028	005	5
•029	032	I D
•030	033	S S
•031	034	PT
•032	300	ST
•033	005	5
•034	006	6
•035	032	I D
•036	033	S S
•037	034	PT
•038	222	DP 2
•039	300	ST
•040	005	5
•041	025	∂
•042	001	1
•043	012	d
•044	005	5
•045	024	÷
•046	310	RC
•047	005	5
•048	020	=
•049	300	ST
•050	007	7
•051	001	1
•052	300	ST
•053	013	S
•054	300	ST
•055	012	d
•056	201	L 1
•057	310	RC
•058	001	1
•059	022	−
•060	310	RC
•061	013	S
•062	024	÷
•063	310	RC
•064	006	6
•065	020	=
•066	300	ST
•067	010	8
•068	023	×
•069	012	d
•070	000	0
•071	002	2
•072	005	5
•073	006	6
•074	011	9
•075	002	2
•076	003	3
•077	022	−
•078	012	d
•079	002	2
•080	000	0
•081	005	5
•082	003	3
•083	003	3
•084	011	9
•085	023	×
•086	310	RC
•087	010	8
•088	021	+
•089	012	d
•090	001	1
•091	002	2
•092	001	1
•093	002	2
•094	010	8
•095	023	×
•096	310	RC
•097	010	8
•098	021	+
•099	003	3
•100	012	d
•101	006	6
•102	011	9
•103	010	8
•104	005	5
•105	003	3
•106	023	×
•107	310	RC
•108	010	8
•109	022	−
•110	001	1
•111	012	d
•112	001	1
•113	003	3
•114	006	6
•115	000	0
•116	007	7
•117	023	×
•118	310	RC
•119	007	7
•120	020	=
•121	063	√
•122	035	F A
•123	035	F A
•124	034	PT
•125	112	D T
•126	033	S S
•127	022	−
•128	310	RC
•129	004	4
•130	024	÷
•131	002	2
•132	023	×
•133	310	RC
•134	002	2
•135	106	I
•136	020	=

```
•137  300  ST
•138  000        0
•139  001        1
•140  302  ST-
•141  012       d
•142  310  RC
•143  012       d
•144  352  JC
•145  002        2
•146  310  RC
•147  000        0
•148  023      x
•149  310  RC
•150  002        2
•151  105      Fs
•152  020      =
•153  300  ST
•154  013       S
•155  022      -
•156  001        1
•157  020      =
•158  356  JC
•159  002        2
•160  310  RC
•161  000        0
•162  023      x
•163  310  RC
•164  002        2
•165  105      Fs
•166  020      =
•167  300  ST
•168  013       S
•169  350  J
•170  001        1
•171  202      L 2
•172  035  P A
•173  035  P A
•174  310  RC
•175  000        0
•176  034  PT
•177  112  D T
•178  023      x
•179  310  RC
•180  002        2
•181  105      Fs
•182  021      +
•183  310  RC
•184  003        3
•185  020      =
•186  035  P A
•187  035  P A
•188  034  PT
•189  112  D T
•190  350  J
•191  033    S  S
```

1 9 Calculates B_f and L_1 for a side-tapered inlet on a box culvert with unfavorable face edge conditions. (See Step 7 for definition of unfavorable conditions).

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	022	-
•007	002	2
•008	032	I D
•009	033	S S
•010	034	PT
•011	300	ST
•012	003	3
•013	020	=
•014	300	ST
•015	001	1
•016	003	3
•017	032	I D
•018	033	S S
•019	034	PT
•020	300	ST
•021	002	2
•022	004	4
•023	032	I D
•024	033	S S
•025	034	PT
•026	300	ST
•027	004	4
•028	005	5
•029	032	I D
•030	033	S S
•031	034	PT
•032	300	ST
•033	005	5
•034	006	6
•035	032	I D
•036	033	S S
•037	034	PT
•038	222	DP 2
•039	300	ST
•040	006	6
•041	025	c
•042	001	1
•043	012	d
•044	005	5
•045	024	÷
•046	310	RC
•047	005	5
•048	020	=
•049	300	ST
•050	007	7
•051	001	1
•052	300	ST
•053	013	S
•054	300	ST
•055	012	d
•056	201	L 1
•057	310	RC
•058	001	1
•059	022	-
•060	310	RC
•061	013	S
•062	024	÷
•063	310	RC
•064	006	6
•065	020	=
•066	300	ST
•067	010	8
•068	023	×
•069	012	d
•070	000	0
•071	000	0
•072	002	2
•073	007	7
•074	021	+
•075	012	d
•076	000	0
•077	002	2
•078	007	7
•079	003	3
•080	023	×
•081	310	RC
•082	010	9
•083	022	-
•084	012	d
•085	006	6
•086	001	1
•087	005	5
•088	003	3
•089	023	×
•090	310	RC
•091	010	8
•092	021	+
•093	004	4
•094	012	d
•095	003	3
•096	023	×
•097	310	RC
•098	010	9
•099	022	-
•100	001	1
•101	012	d
•102	002	2
•103	001	1
•104	011	9
•105	023	×
•106	310	RC
•107	007	7
•108	020	=
•109	063	K
•110	035	P A
•111	035	P A
•112	034	PT
•113	112	D T
•114	033	S S
•115	022	-
•116	310	RC
•117	004	4
•118	024	÷
•119	002	2
•120	023	×
•121	310	RC
•122	002	2
•123	106	I
•124	020	=
•125	300	ST
•126	000	0
•127	001	1
•128	302	ST-
•129	012	d
•130	310	RC
•131	012	d
•132	352	JC
•133	002	2
•134	310	RC
•135	000	0
•136	023	×
•137	310	RC
•138	002	2

```
•139   105        F5
•140   020        =
•141   300     ST
•142   013          S
•143   022        -
•144   001            1
•145   020        =
•146   356    JC
•147   002            2
•148   310     RC
•149   000            0
•150   023        x
•151   310     RC
•152   002            2
•153   105        F5
•154   020        =
•155   300     ST
•156   013          S
•157   350    J
•158   001            1
•159   202       L  2
•160   035    P  A
•161   035    P  A
•162   310     RC
•163   000            0
•164   034    PT
•165   112   D  T
•166   023        x
•167   310     RC
•168   002            2
•169   105        F5
•170   021        +
•171   310     RC
•172   003            3
•173   020        =
•174   035    P  A
•175   035    P  A
•176   034    PT
•177   112   D  T
•178   350    J
•179   033     S   S
```

1 10 Calculates B_f for slope-tapered inlets on culverts with favorable face edge conditions and either a vertical or mitered face.

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	I D
•010	033	S S
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	I D
•016	033	S S
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	I D
•022	033	S S
•023	034	PT
•024	300	ST
•025	004	4
•026	005	5
•027	032	I D
•028	033	S S
•029	034	PT
•030	300	ST
•031	007	7
•032	222	DP 2
•033	310	RC
•034	003	3
•035	022	−
•036	310	RC
•037	004	4
•038	021	+
•039	310	RC
•040	007	7
•041	024	÷
•042	310	RC
•043	002	2
•044	020	=
•045	300	ST
•046	005	5
•047	023	×
•048	012	d
•049	000	0
•050	002	2
•051	010	8
•052	004	4
•053	006	6
•054	007	7
•055	006	6
•056	007	7
•057	022	−
•058	012	d
•059	003	3
•060	004	4
•061	005	5
•062	010	8
•063	002	2
•064	001	1
•065	004	4
•066	023	×
•067	310	RC
•068	005	5
•069	021	+
•070	001	1
•071	012	d
•072	006	6
•073	001	1
•074	011	9
•075	004	4
•076	010	8
•077	001	1
•078	023	×
•079	310	RC
•080	005	5
•081	022	−
•082	004	4
•083	012	d
•084	000	0
•085	003	3
•086	005	5
•087	002	2
•088	000	0
•089	011	9
•090	004	4
•091	023	×
•092	310	RC
•093	005	5
•094	021	+
•095	007	7
•096	012	d
•097	011	9
•098	004	4
•099	002	2
•100	004	4
•101	004	4
•102	001	1
•103	023	×
•104	310	RC
•105	005	5
•106	022	−
•107	002	2
•108	012	d
•109	002	2
•110	006	6
•111	005	5
•112	010	8
•113	006	6
•114	003	3
115	023	×
116	026	(
117	310	RC
118	002	2
119	025	đ
120	001	1
121	012	d
122	005	5
123	027	)
124	020	=
•125	063	%
•126	023	×
•127	310	RC
•128	001	1
•129	020	=
•130	035	P A
•131	035	P A
•132	034	PT
•133	112	D T
•134	350	J
•135	033	S S

1 11 Calculates B_f for slope-tapered inlets on culverts with unfavorable face edge conditions and either a vertical or mitered face.

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	I D
•010	033	S S
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	I D
•016	033	S S
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	I D
•022	033	S S
•023	034	PT
•024	300	ST
•025	004	4
•026	005	5
•027	032	I D
•028	033	S S
•029	034	PT
•030	300	ST
•031	007	7
•032	222	DP 2
•033	310	RC
•034	003	3
•035	022	−
•036	310	RC
•037	004	4
•038	021	+
•039	310	RC
•040	007	7
•041	024	÷
•042	310	RC
•043	002	2
•044	020	=
•045	300	ST
•046	005	5
•047	023	×
•048	012	d
•049	000	0
•050	000	0
•051	001	1
•052	001	1
•053	022	−
•054	012	d
•055	000	0
•056	001	1
•057	004	4
•058	004	4
•059	023	×
•060	310	RC
•061	005	5
•062	021	+
•063	012	d
•064	001	1
•065	005	5
•066	007	7
•067	010	9
•068	023	×
•069	310	RC
•070	005	5
•071	022	−
•072	001	1
•073	012	d
•074	001	1
•075	003	3
•076	001	1
•077	023	×
•078	310	RC
•079	005	5
•080	021	+
•081	005	5
•082	012	d
•083	001	1
•084	005	5
•085	023	×
•086	310	RC
•087	005	5
•088	022	−
•089	001	1
•090	012	d
•091	003	3
•092	005	5
•093	003	3
•094	023	×
•095	026	(
•096	310	RC
•097	002	2
•098	025	[illegible]
•099	001	1
•100	012	d
•101	005	5
•102	027	)
•103	020	=
•104	063	1/x
•105	023	×
•106	310	RC
•107	001	1
•108	020	=
•109	035	P A
•110	035	P A
•111	034	PT
•112	112	D T
•113	350	J
•114	033	S S

1 12 Calculates L_1, L_2, L_3, L_4 and Taper for a slope-tapered inlet on culverts with either a vertical or mitered face.

Step	Code	Key		Step	Code	Key		Step	Code	Key	
•001	222	DP	2	•046	010		8	•091	310	RC	
•002	037	CL		•047	032	I D		•092	011		9
•003	137	CA		•048	033	S S		•093	022		−
•004	001		1	•049	034	PT		•094	310	RC	
•005	032	I D		•050	300	ST		•095	000		0
•006	033	S S		•051	010		8	•096	020		=
•007	034	PT		•052	011		9	•097	300	ST	
•008	300	ST		•053	032	I D		•098	012		d
•009	001		1	•054	033	S S		•099	310	RC	
•010	002		2	•055	034	PT		•100	001		1
•011	032	I D		•056	300	ST		•101	023		×
•012	033	S S		•057	011		9	•102	310	RC	
•013	034	PT		•058	310	RC		•103	003		3
•014	300	ST		•059	005		5	•104	024		÷
•015	002		2	•060	354	JC		•105	002		2
•016	003		3	•061	001		1	•106	020		=
•017	032	I D		•062	310	RC		•107	300	ST	
•018	033	S S		•063	011		9	•108	013		S
•019	034	PT		•064	023		×	•109	360	B	
•020	300	ST		•065	310	RC		•110	005		5
•021	003		3	•066	005		5	•111	023		×
•022	004		4	•067	021		+	•112	310	RC	
•023	032	I D		•068	026		(	•113	006		6
•024	033	S S		•069	310	RC		•114	022		−
•025	034	PT		•070	002		2	•115	310	RC	
•026	300	ST		•071	024		÷	•116	013		S
•027	004		4	•072	310	RC		•117	022		−
•028	005		5	•073	011		9	•118	310	RC	
•029	032	I D		•074	027		)	•119	012		d
•030	033	S S		•075	020		=	•120	020		=
•031	034	PT		•076	300	ST		•121	351	JC	
•032	300	ST		•077	000		0	•122	003		3
•033	005		5	•078	350	J		•123	310	RC	
•034	006		6	•079	002		2	•124	012		d
•035	032	I D		•080	201	L 1		•125	021		+
•036	033	S S		•081	000		0	•126	310	RC	
•037	034	PT		•082	300	ST		•127	013		S
•038	300	ST		•083	000		0	•128	024		÷
•039	006		6	•084	202	L 2		•129	026		(
•040	007		7	•085	310	RC		•130	360	B	
•041	032	I D		•086	007		7	•131	005		5
•042	033	S S		•087	022		−	•132	027		)
•043	034	PT		•088	310	RC		•133	020		=
•044	300	ST		•089	010		8	•134	300	ST	
•045	007		7	•090	023		×	•135	006		6

•136	350	J
•137	004	4
•138	203	L 3
•139	360	B
•140	005	5
•141	023	×
•142	310	RC
•143	006	6
•144	022	−
•145	310	RC
•146	012	d
•147	020	=
•148	300	ST
•149	013	S
•150	204	L 4
•151	035	P A
•152	035	P A
•153	310	RC
•154	012	d
•155	034	PT
•156	021	+
•157	112	D T
•158	035	P A
•159	035	P A
•160	310	RC
•161	013	S
•162	034	PT
•163	021	+
•164	112	D T
•165	035	P A
•166	035	P A
•167	310	RC
•168	000	0
•169	034	PT
•170	020	=
•171	112	D T
•172	035	P A
•173	035	P A
•174	034	PT
•175	112	D T
•176	035	P A
•177	035	P A
•178	310	RC
•179	006	6
•180	034	PT
•181	112	D T
•182	350	J
•183	033	S S
•184	205	L 5
•185	310	RC
•186	004	4
•187	022	−
•188	025	(
•189	310	RC
•190	001	1
•191	023	×
•192	310	RC
•193	003	3
•194	027	)
•195	024	÷
•196	002	2
•197	030	RT

1 13 **Checks crest control for either a side- or slope-tapered inlet.**

•001	222	DP 2
•002	037	CL
•003	001	1
•004	032	I D
•005	033	S S
•006	034	PT
•007	300	ST
•008	001	1
•009	002	2
•010	032	I D
•011	033	S S
•012	034	PT
•013	300	ST
•014	002	2
•015	003	3
•016	032	I D
•017	033	S S
•018	034	PT
•019	300	ST
•020	003	3
•021	004	4
•022	032	I D
•023	033	S S
•024	034	PT
•025	300	ST
•026	004	4
•027	005	5
•028	032	I D
•029	033	S S
•030	034	PT
•031	300	ST
•032	005	5
•033	006	6
•034	032	I D
•035	033	S S
•036	034	PT
•037	300	ST
•038	006	6
•039	007	7
•040	032	I D
•041	033	S S
•042	034	PT
•043	300	ST
•044	007	7
•045	310	RC
•046	005	5
•047	354	JC
•048	001	1
•049	310	RC
•050	002	2
•051	023	×
•052	310	RC
•053	005	5
•054	021	+
•055	026	(
•056	002	2
•057	023	×
•058	310	RC
•059	006	6
•060	024	÷
•061	310	RC
•062	007	7
•063	027	)
•064	020	=
•065	300	ST
•066	004	4
•067	201	L 1
•068	310	RC
•069	001	1
•070	024	÷
•071	310	RC
•072	004	4
•073	025	a
•074	026	(
•075	002	2
•076	024	÷
•077	003	3
•078	027	)
•079	024	÷
•080	002	2
•081	020	=
•082	035	P A
•083	035	P A
•084	034	PT
•085	112	D T
•086	022	−
•087	310	RC
•088	003	3
•089	020	=
•090	013	S
•091	035	P A
•092	035	P A
•093	034	PT
•094	112	D T
•095	350	J
•096	033	S S

1 14 **Calculates outlet velocity for box culverts in inlet control.**

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	I D
•010	033	S S
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	I D
•016	033	S S
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	I D
•022	033	S S
•023	034	PT
•024	300	ST
•025	004	4
•026	005	5
•027	032	I D
•028	033	S S
•029	034	PT
•030	300	ST
•031	005	5
•032	222	DP 2
•033	062	√
•034	063	½
•035	024	÷
•036	001	1
•037	012	d
•038	004	4
•039	010	8
•040	006	6
•041	023	×
•042	310	RC
•043	004	4
•044	023	×
•045	310	RC
•046	003	3
•047	024	÷
•048	026	(
•049	310	RC
•050	002	2
•051	025	d
•052	026	(
•053	010	8
•054	024	÷
•055	003	3
•056	027	)
•057	027	)
•058	020	=
•059	300	ST
•060	006	6
•061	022	−
•062	012	d
•063	002	2
•064	002	2
•065	020	=
•066	351	JC
•067	001	1
•068	001	1
•069	001	1
•070	000	0
•071	012	d
•072	003	3
•073	001	1
•074	006	6
•075	003	3
•076	005	5
•077	013	S
•078	023	×
•079	310	RC
•080	006	6
•081	021	+
•082	006	6
•083	004	4
•084	012	d
•085	011	9
•086	011	9
•087	001	1
•088	011	9
•089	001	1
•090	003	3
•091	023	×
•092	310	RC
•093	006	6
•094	022	−
•095	001	1
•096	005	5
•097	012	d
•098	001	1
•099	005	5
•100	002	2
•101	002	2
•102	003	3
•103	010	8
•104	023	×
•105	310	RC
•106	006	6
•107	021	+
•108	003	3
•109	012	d
•110	006	6
•111	004	4
•112	010	8
•113	003	3
•114	007	7
•115	010	8
•116	004	4
•117	023	×
•118	310	RC
•119	006	6
•120	021	+
•121	012	d
•122	000	0
•123	003	3
•124	006	6
•125	004	4
•126	000	0
•127	002	2
•128	360	B
•129	005	5
•130	350	J
•131	033	S S
•132	201	L 1
•133	310	RC
•134	006	6
•135	022	−
•136	001	1
•137	012	d
•138	001	1

•139	020	=
•140	351	JC
•141	002	2
•142	012	d
•143	006	6
•144	007	7
•145	007	7
•146	006	6
•147	002	2
•148	001	1
•149	013	S
•150	023	×
•151	310	RC
•152	006	6
•153	021	+
•154	001	1
•155	012	d
•156	006	6
•157	003	3
•158	006	6
•159	005	5
•160	011	9
•161	004	4
•162	023	×
•163	310	RC
•164	006	6
•165	022	−
•166	001	1
•167	012	d
•168	005	5
•169	003	3
•170	006	6
•171	004	4
•172	003	3
•173	023	×
•174	310	RC
•175	006	6
•176	021	+
•177	002	2
•178	012	d
•179	003	3
•180	004	4
•181	000	0
•182	006	6
•183	001	1
•184	023	×
•185	310	RC
•186	006	6
•187	021	+
•188	012	d
•189	000	0
•190	010	8
•191	004	4
•192	004	4
•193	006	6
•194	010	8
•195	360	D
•196	005	5
•197	350	J
•198	033	S S
•199	202	L 2
•200	310	RC
•201	001	1
•202	024	÷
•203	310	RC
•204	002	2
•205	020	=
•206	035	P A
•207	035	P A
•208	034	PT
•209	035	P A
•210	310	RC
•211	004	4
•212	024	÷
•213	310	RC
•214	002	2
•215	024	÷
•216	310	RC
•217	001	1
•218	020	=
•219	034	PT
•220	112	D T
•221	350	J
•222	033	S S
•223	205	L 5
•224	020	=
•225	300	ST
•226	007	7
•227	022	−
•228	026	(
•229	310	RC
•230	001	1
•231	024	÷
•232	310	RC
•233	002	2
•234	027	)
•235	020	=
•236	356	JC
•237	004	4
•238	310	RC
•239	001	1
•240	024	÷
•241	310	RC
•242	002	2
•243	020	=
•244	300	ST
•245	007	7
•246	204	L 4
•247	310	RC
•248	007	7
•249	035	P A
•250	035	P A
•251	034	PT
•252	035	P A
•253	023	×
•254	310	RC
•255	002	2
•256	162	SQ
•257	024	÷
•258	310	RC
•259	004	4
•260	020	=
•261	063	1/x
•262	034	PT
•263	112	D T
•264	030	RT

2 1 Determines an acceptable pipe size by computing HW_o.

Step	Code	Key	
•001	037	CL	
•002	001		1
•003	032	I D	
•004	033	S S	
•005	034	PT	
•006	300	ST	
•007	001		1
•008	002		2
•009	032	I D	
•010	033	S S	
•011	034	PT	
•012	300	ST	
•013	002		2
•014	003		3
•015	032	I D	
•016	033	S S	
•017	034	PT	
•018	300	ST	
•019	003		3
•020	004		4
•021	032	I D	
•022	033	S S	
•023	034	PT	
•024	300	ST	
•025	004		4
•026	005		5
•027	032	I D	
•028	033	S S	
•029	034	PT	
•030	300	ST	
•031	005		5
•032	006		6
•033	032	I D	
•034	033	S S	
•035	034	PT	
•036	300	ST	
•037	006		6
•038	007		7
•039	032	I D	
•040	033	S S	
•041	034	PT	
•042	300	ST	
•043	007		7
•044	201	L	1
•045	222	DP	2
•046	010		8
•047	032	I D	
•048	033	S S	
•049	034	PT	
•050	300	ST	
•051	012		d
•052	011		9
•053	032	I D	
•054	033	S S	
•055	034	PT	
•056	300	ST	
•057	011		9
•058	310	RC	
•059	004		4
•060	162	SQ	
•061	023	×	
•062	310	RC	
•063	003		3
•064	023	×	
•065	002		2
•066	011		9
•067	024	÷	
•068	026	(	
•069	026	(	
•070	310	RC	
•071	011		9
•072	024	÷	
•073	004		4
•074	027	)	
•075	025	d	
•076	026	(	
•077	004		4
•078	024	÷	
•079	003		3
•080	027	)	
•081	027	)	
•082	021	+	
•083	001		1
•084	021	+	
•085	310	RC	
•086	005		5
•087	023	×	
•088	026	(	
•089	310	RC	
•090	001		1
•091	023	×	
•092	004		4
•093	024	÷	
•094	310	RC	
•095	002		2
•096	024	÷	
•097	310	RC	
•098	011		9
•099	162	SQ	
•100	024	÷	
•101	107	π	
•102	027	)	
•103	162	SQ	
•104	024	÷	
•105	006		6
•106	004		4
•107	012		d
•108	004		4
•109	020	=	
•110	300	ST	
•111	000		0
•112	310	RC	
•113	012		d
•114	022	−	
•115	310	RC	
•116	011		9
•117	020	=	
•118	356	JC	
•119	002		2
•120	310	RC	
•121	011		9
•122	300	ST	
•123	012		d
•124	202	L	2
•125	310	RC	
•126	011		9
•127	021	+	
•128	310	RC	
•129	012		d
•130	024	÷	
•131	002		2
•132	020	=	
•133	300	ST	
•134	013		S
•135	022	−	
•136	310	RC	
•137	006		6
•138	020	=	

```
•139   035   P  A
•140   035   P  A
•141   356   JC
•142   003            3
•143   310    RC
•144   013         S
•145   034   PT
•146   350   J
•147   004            4
•148   203     L  3
•149   310    RC
•150   005            5
•151   034   PT
•152   310    RC
•153   006            6
•154   204     L  4
•155   112  D  T
•156   021        +
•157   310    RC
•158   000            0
•159   021        +
•160   310    RC
•161   007            7
•162   020        =
•163   035   P  A
•164   035   P  A
•165   034   PT
•166   112  D  T
•167   350   J
•168   001            1
```

2 **2** **Calculates outlet control performance curve data for pipe culverts.**

```
•001  037  CL
•002  001        1
•003  032  I D
•004  033  S  S
•005  034  PT
•006  300  ST
•007  001        1
•008  002        2
•009  032  I D
•010  033  S  S
•011  034  PT
•012  300  ST
•013  002        2
•014  003        3
•015  032  I D
•016  033  S  S
•017  034  PT
•018  300  ST
•019  003        3
•020  005        5
•021  032  I D
•022  033  S  S
•023  034  PT
•024  300  ST
•025  005        5
•026  006        6
•027  032  I D
•028  033  S  S
•029  034  PT
•030  300  ST
•031  006        6
•032  201  L     1
•033  222  UP    2
•034  007        7
•035  032  I D
•036  033  S  S
•037  034  PT
•038  300  ST
•039  007        7
•040  010        8
•041  032  I D
•042  033  S  S
•043  034  PT
•044  300  ST
•045  004        4
•046  011        9
•047  032  I D
•048  033  S  S
•049  034  PT
•050  300  ST
•051  010        9
•052  310  RC
•053  002        2
•054  162  SQ
•055  023     ×
•056  310  RC
•057  001        1
•058  023     ×
•059  002        2
•060  011        9
•061  024     ÷
•062  025     (
•063  026     (
•064  310  RC
•065  005        5
•066  024     ÷
•067  004        4
•068  027     )
•069  025     (
•070  026     (
•071  004        4
•072  024     ÷
•073  003        3
•074  027     )
•075  027     )
•076  021     +
•077  001        1
•078  021     +
•079  310  RC
•080  003        3
•081  023     ×
•082  026     (
•083  310  RC
•084  010        8
•085  023     ×
•086  004        4
•087  024     ÷
•088  310  RC
•089  005        5
•090  162  SQ
•091  024     ÷
•092  107  π
•093  027     )
•094  162  SQ
•095  024     ÷
•096  006        6
•097  004        4
•098  012     .
•099  004        4
•100  020     =
•101  300  ST
•102  000        0
•103  310  RC
•104  004        4
•105  022     −
•106  310  RC
•107  005        5
•108  020     =
•109  356  JC
•110  002        2
•111  310  RC
•112  005        5
•113  300  ST
•114  004        4
•115  202  L     2
•116  310  RC
•117  005        5
•118  021     +
•119  310  RC
•120  004        4
•121  024     ÷
•122  002        2
•123  020     =
•124  300  ST
•125  013        S
•126  022     −
•127  310  RC
•128  007        7
•129  020     =
•130  356  JC
•131  003        3
•132  310  RC
•133  013        S
•134  350  J
•135  004        4
•136  203  L     3
•137  310  RC
•138  007        7
```

```
•139  204      L' 4
•140  021        +
•141  310    RC
•142  000           0
•143  021        +
•144  310    RC
•145  006           6
•146  020        =
•147  035   P  A
•148  035   P  A
•149  034   PT
•150  112  D  T
•151  350   J
•152  001           1
```

2 3 **Calculates outlet velocity for pipe culverts in outlet control.**

•001	037	CL
•002	222	DP 2
•003	001	1
•004	032	I D
•005	033	S S
•006	034	PT
•007	300	ST
•008	001	1
•009	002	2
•010	032	I D
•011	033	S S
•012	034	PT
•013	300	ST
•014	002	2
•015	003	3
•016	032	I D
•017	033	S S
•018	034	PT
•019	300	ST
•020	003	3
•021	004	4
•022	032	I D
•023	033	S S
•024	034	PT
•025	300	ST
•026	004	4
•027	310	RC
•028	002	2
•029	024	÷
•030	026	(
•031	003	3
•032	002	2
•033	012	d
•034	002	2
•035	024	÷
•036	310	RC
•037	003	3
•038	027	)
•039	002	√
•040	024	÷
•041	026	(
•042	310	RC
•043	001	1
•044	025	d
•045	002	2
•046	012	d
•047	005	5
•048	027	)
•049	020	=
•050	061	LC
•051	300	ST
•052	005	5
•053	022	−
•054	012	d
•055	007	7
•056	061	LC
•057	020	=
•058	351	JC
•059	001	1
•060	012	d
•061	000	0
•062	011	3
•063	001	1
•064	005	5
•065	005	5
•066	006	6
•067	005	5
•068	013	S
•069	023	×
•070	310	RC
•071	005	5
•072	022	−
•073	012	d
•074	001	1
•075	010	9
•076	003	3
•077	000	0
•078	002	2
•079	003	3
•080	006	6
•081	023	×
•082	310	RC
•083	005	5
•084	021	+
•085	012	d
•086	004	4
•087	000	0
•088	007	7
•089	003	3
•090	006	5
•091	002	2
•092	023	×
•093	310	RC
•094	005	5
•095	022	−
•096	012	d
•097	000	0
•098	000	0
•099	005	5
•100	001	1
•101	006	6
•102	005	5
•103	007	7
•104	350	J
•105	002	2
•106	201	L 1
•107	012	d
•108	006	6
•109	011	9
•110	005	5
•111	006	5
•112	001	1
•113	011	9
•114	023	×
•115	310	RC
•116	005	5
•117	022	−
•118	012	d
•119	006	6
•120	004	4
•121	000	0
•122	000	0
•123	011	9
•124	010	9
•125	001	1
•126	005	5
•127	023	×
•128	310	RC
•129	005	5
•130	021	+
•131	012	d
•132	002	2
•133	000	0
•134	001	1
•135	007	7
•136	000	0
•137	005	5
•138	007	7

•139	023	×
•140	310	RC
•141	005	5
•142	022	−
•143	012	a
•144	000	0
•145	002	2
•146	004	4
•147	004	4
•148	005	5
•149	000	0
•150	003	3
•151	202	L 2
•152	020	=
•153	161	L−1
•154	023	×
•155	310	RC
•156	001	1
•157	020	=
•158	300	ST
•159	006	6
•160	022	−
•161	310	RC
•162	004	4
•163	020	=
•164	351	JC
•165	003	3
•166	310	RC
•167	004	4
•168	350	J
•169	004	4
•170	203	L 3
•171	310	RC
•172	006	6
•173	204	L 4
•174	300	ST
•175	007	7
•176	022	−
•177	310	RC
•178	001	1
•179	020	=
•180	352	JC
•181	005	5
•182	310	RC
•183	001	1
•184	300	ST
•185	007	7
•186	205	L 5
•187	310	RC
•188	007	7
•189	022	−
•190	026	(
•191	310	RC
•192	001	1
•193	024	÷
•194	002	2
•195	027	)
•196	300	ST
•197	012	a
•198	020	=
•199	013	b
•200	300	ST
•201	013	b
•202	162	F 2
•203	300	ST
•204	000	0
•205	310	RC
•206	013	b
•207	351	JC
•208	010	8
•209	167	π
•210	023	×
•211	310	RC
•212	012	a
•213	162	SQ
•214	022	−
•215	300	ST
•216	011	9
•217	021	+
•218	300	ST
•219	012	a
•220	020	=
•221	350	J
•222	013	b
•223	214	L [illegible]
•224	300	ST
•225	011	9
•226	022	−
•227	300	ST
•228	012	a
•229	020	=
•230	213	L b
•231	005	/
•232	025	>
•233	310	RC
•234	002	2
•235	020	=
•236	035	P A
•237	035	P A
•238	034	PT
•239	112	G T
•240	350	J
•241	300	S 0
•242	211	L 9
•243	026	(
•244	310	RC
•245	000	0
•246	024	÷
•247	310	RC
•248	012	a
•249	020	=
•250	171	C a
•251	024	÷
•252	001	1
•253	010	8
•254	000	0
•255	023	×
•256	167	π
•257	023	×
•258	310	RC
•259	012	a
•260	162	SQ
•261	027	)
•262	033	RT
•263	212	L a
•264	026	(
•265	310	RC
•266	012	a
•267	162	SQ
•268	022	−
•269	310	RC
•270	010	8
•271	162	SQ
•272	020	=
•273	002	/
•274	023	×
•275	310	RC
•276	000	0
•277	027	)
•278	033	RT

2 4 **Calculates performance of a thin-edged projecting inlet on a pipe culvert.**

•001	037	CL	•049	020	=	•097	310	RC
•002	001	1	•050	300	ST	•098	006	6
•003	032	I D	•051	006	6	•099	021	+
•004	033	S S	•052	023	×	•100	012	o
•005	034	PT	•053	012	d	•101	005	5
•006	300	ST	•054	000	0	•102	006	6
•007	001	1	•055	000	0	•103	007	7
•008	002	2	•056	000	0	•104	007	7
•009	032	I D	•057	000	0	•105	001	1
•010	033	S S	•058	010	9	•106	023	×
•011	034	PT	•059	011	3	•107	310	RC
•012	300	ST	•060	006	6	•108	006	6
•013	002	2	•061	006	6	•109	021	+
•014	003	3	•062	001	1	•110	012	d
•015	032	I D	•063	022	−	•111	001	1
•016	033	S S	•064	012	d	•112	010	9
•017	034	PT	•065	000	0	•113	007	7
•018	300	ST	•066	000	0	•114	003	3
•019	003	3	•067	003	3	•115	002	2
•020	004	4	•068	004	4	•116	001	1
•021	032	I D	•069	003	3	•117	023	×
•022	033	S S	•070	006	6	•118	310	RC
•023	034	PT	•071	000	0	•119	004	4
•024	300	ST	•072	002	2	•120	020	=
•025	004	4	•073	023	×	•121	300	ST
•026	001	1	•074	310	RC	•122	007	7
•027	300	ST	•075	006	5	•123	001	1
•028	000	0	•076	021	+	•124	302	ST−
•029	201	L 1	•077	012	d	•125	000	0
•030	222	DP 2	•078	000	0	•126	310	RC
•031	005	5	•079	004	4	•127	000	0
•032	032	I D	•080	004	4	•128	352	JC
•033	033	S S	•081	007	7	•129	003	3
•034	034	PT	•082	000	0	•130	310	RC
•035	300	ST	•083	005	5	•131	001	1
•036	005	5	•084	002	2	•132	022	−
•037	024	÷	•085	023	×	•133	310	RC
•038	310	RC	•086	310	RC	•134	007	7
•039	003	3	•087	006	6	•135	020	=
•040	024	÷	•088	022	−	•136	300	ST
•041	026	(	•089	012	d	•137	010	3
•042	310	RC	•090	001	1	•138	022	−
•043	004	4	•091	005	5	•139	310	RC
•044	025	d	•092	006	6	•140	002	2
•045	001	1	•093	005	5	•141	020	=
•046	012	o	•094	004	4	•142	300	ST
•047	005	5	•095	004	4	•143	012	d
•048	027	)	•096	023	×	•144	352	JC

•145	004		4
•146	310	RC	
•147	002		2
•148	300	ST	
•149	010		8
•150	000		0
•151	300	ST	
•152	012		d
•153	204	L	4
•154	310	RC	
•155	010		8
•156	035	P A	
•157	035	P A	
•158	034	PT	
•159	112	D T	
•160	310	RC	
•161	012		d
•162	035	P A	
•163	035	P A	
•164	102	F	2
•165	034	PT	
•166	112	D T	
•167	203	L	3
•168	310	RC	
•169	010		8
•170	021	+	
•171	310	RC	
•172	007		7
•173	020	=	
•174	035	P A	
•175	035	P A	
•176	034	PT	
•177	112	D T	
•178	350	J	
•179	001		1

2 5 Calculates performance of an inlet with square edges on a pipe culvert.

•001	037	CL
•002	001	1
•003	032	ID
•004	033	SS
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	ID
•010	033	SS
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	ID
•016	033	SS
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	ID
•022	033	SS
•023	034	PT
•024	300	ST
•025	004	4
•026	001	1
•027	300	ST
•028	000	0
•029	201	L 1
•030	222	DP 2
•031	005	5
•032	032	ID
•033	033	SS
•034	034	PT
•035	300	ST
•036	005	5
•037	024	÷
•038	310	RC
•039	003	3
•040	024	÷
•041	026	(
•042	310	RC
•043	004	4
•044	025	a
•045	001	1
•046	012	d
•047	005	5
•048	027	)
•049	020	=
•050	300	ST
•051	006	6
•052	023	×
•053	012	d
•054	000	0
•055	000	0
•056	000	0
•057	002	2
•058	005	5
•059	000	0
•060	006	6
•061	001	1
•062	011	9
•063	022	−
•064	012	d
•065	000	0
•066	000	0
•067	006	6
•068	006	6
•069	001	1
•070	006	6
•071	005	5
•072	001	1
•073	023	×
•074	310	RC
•075	006	6
•076	021	+
•077	012	d
•078	000	0
•079	006	6
•080	006	6
•081	007	7
•082	000	0
•083	000	0
•084	001	1
•085	023	×
•086	310	RC
•087	006	6
•088	022	−
•089	012	d
•090	002	2
•091	005	5
•092	003	3
•093	002	2
•094	011	9
•095	005	5
•096	023	×
•097	310	RC
•098	006	6
•099	021	+
•100	012	d
•101	007	7
•102	000	0
•103	006	6
•104	005	5
•105	007	7
•106	010	8
•107	023	×
•108	310	RC
•109	006	6
•110	021	+
•111	012	d
•112	000	0
•113	010	8
•114	007	7
•115	004	4
•116	010	8
•117	003	3
•118	023	×
•119	310	RC
•120	004	4
•121	020	=
•122	300	ST
•123	007	7
•124	001	1
•125	302	ST−
•126	000	0
•127	310	RC
•128	000	0
•129	352	JC
•130	003	3
•131	310	RC
•132	001	1
•133	022	−
•134	310	RC
•135	007	7
•136	020	=
•137	300	ST
•138	010	8
•139	022	−
•140	310	RC
•141	002	2
•142	020	=
•143	300	ST
•144	012	d

```
•145  352  JC
•146  004          4
•147  310   RC
•148  002          2
•149  300   ST
•150  010          8
•151  000          0
•152  300   ST
•153  012        o
•154  204     L  4
•155  310   RC
•156  010          8
•157  035  P  A
•158  035  P  A
•159  034  PT
•160  112 D  T
•161  310   RC
•162  012        o
•163  035  P  A
•164  035  P  A
•165  102       F2
•166  034  PT
•167  112 D  T
•168  203     L  3
•169  310   RC
•170  010          8
•171  021       +
•172  310   RC
•173  007          7
•174  020       =
•175  035  P  A
•176  035  P  A
•177  034  PT
•178  112 D  T
•179  350  J
•180  001          1
```

2 6 Calculates performance of an inlet with 45° bevels on a pipe culvert.

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	I D
•010	033	S S
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	I D
•016	033	S S
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	I D
•022	033	S S
•023	034	PT
•024	300	ST
•025	004	4
•026	001	1
•027	300	ST
•028	000	0
•029	201	L 1
•030	222	DP 2
•031	005	5
•032	032	I D
•033	033	S S
•034	034	PT
•035	300	ST
•036	005	5
•037	024	÷
•038	310	RC
•039	003	3
•040	024	÷
•041	026	(
•042	310	RC
•043	004	4
•044	025	d
•045	001	1
•046	012	d
•047	005	5
•048	027	)
•049	020	=
•050	300	ST
•051	006	6
•052	023	×
•053	012	d
•054	000	0
•055	000	0
•056	000	0
•057	004	4
•058	001	1
•059	006	6
•060	007	7
•061	006	6
•062	022	−
•063	012	d
•064	000	0
•065	000	0
•066	011	9
•067	010	8
•068	003	3
•069	006	6
•070	011	9
•071	005	5
•072	023	×
•073	310	RC
•074	006	6
•075	021	+
•076	012	d
•077	000	0
•078	010	8
•079	007	7
•080	006	6
•081	007	7
•082	000	0
•083	001	1
•084	023	×
•085	310	RC
•086	006	6
•087	022	−
•088	012	d
•089	003	3
•090	001	1
•091	006	6
•092	000	0
•093	011	9
•094	007	7
•095	023	×
•096	310	RC
•097	006	6
•098	021	+
•099	012	d
•100	007	7
•101	006	6
•102	006	6
•103	005	5
•104	001	1
•105	002	2
•106	023	×
•107	310	RC
•108	006	6
•109	021	+
•110	012	d
•111	000	0
•112	006	6
•113	003	3
•114	003	3
•115	004	4
•116	003	3
•117	023	×
•118	310	RC
•119	004	4
•120	020	=
•121	300	ST
•122	007	7
•123	001	1
•124	302	ST−
•125	000	0
•126	310	RC
•127	000	0
•128	352	JC
•129	003	3
•130	310	RC
•131	001	1
•132	022	−
•133	310	RC
•134	007	7
•135	020	=
•136	300	ST
•137	010	8
•138	022	−
•139	310	RC
•140	002	2
•141	020	=
•142	300	ST
•143	012	d

```
•144  352  JC
•145  004           4
•146  310   RC
•147  002           2
•148  300   ST
•149  010           3
•150  000           0
•151  300   ST
•152  012          a
•153  204     L 4
•154  310   RC
•155  010           8
•156  035  P A
•157  035  P A
•158  034  PT
•159  112 D T
•160  310  RC
•161  012          d
•162  035  P A
•163  035  F A
•164  102        F2
•165  034  PT
•166  112 D T
•167  203      L 3
•168  310   RC
•169  010           8
•170  021       +
•171  310   RC
•172  007           7
•173  020       =
•174  035  P A
•175  035  P A
•176  034  PT
•177  112 D T
•178  350  J
•179  001           1
```

2 7 Calculates the performance of a groove end projecting inlet on a pipe culvert.

001	037	CL	050	300	ST	099	012	d
002	001	1	051	006	6	100	006	6
003	032	I D	052	023	×	101	006	6
004	033	S S	053	012	d	102	002	2
005	034	PT	054	000	0	103	003	3
006	300	ST	055	000	0	104	010	8
007	001	1	056	000	0	105	001	1
008	002	2	057	002	2	106	023	×
009	032	I D	058	000	0	107	310	RC
010	033	S S	059	005	5	108	006	6
011	034	PT	060	000	0	109	021	+
012	300	ST	061	005	5	110	012	d
013	002	2	062	002	2	111	001	1
014	003	3	063	022	−	112	000	0
015	032	I D	064	012	d	113	010	8
016	033	S S	065	000	0	114	007	7
017	034	PT	066	000	0	115	010	8
018	300	ST	067	005	5	116	006	6
019	003	3	068	005	5	117	023	×
020	004	4	069	007	7	118	310	RC
021	032	I D	070	010	8	119	004	4
022	033	S S	071	011	9	120	020	=
023	034	PT	072	023	×	121	300	ST
024	300	ST	073	310	RC	122	007	7
025	004	4	074	006	6	123	001	1
026	001	1	075	021	+	124	302	ST−
027	300	ST	076	012	d	125	000	0
028	000	0	077	000	0	126	310	RC
029	201	L 1	078	005	5	127	000	0
030	222	DP 2	079	007	7	128	352	JC
031	005	5	080	011	9	129	003	3
032	032	I D	081	005	5	130	310	RC
033	033	S S	082	010	8	131	001	1
034	034	PT	083	005	5	132	022	−
035	300	ST	084	023	×	133	310	RC
036	005	5	085	310	RC	134	007	7
037	024	÷	086	006	6	135	020	=
038	310	RC	087	022	−	136	300	ST
039	003	3	088	012	d	137	010	8
040	024	÷	089	002	2	138	022	−
041	026	(	090	003	3	139	310	RC
042	310	RC	091	003	3	140	002	2
043	004	4	092	010	8	141	020	=
044	025	d'	093	000	0	142	300	ST
045	001	1	094	001	1	143	012	d
046	012	d	095	023	×	144	352	JC
047	005	5	096	310	RC	145	004	4
048	027	)	097	006	6	146	310	RC
049	020	=	098	021	+	147	002	2

```
•148   300    ST
•149   010            9
•150   000            0
•151   300    ST
•152   012            d
•153   204      L  4
•154   310    RC
•155   010            9
•156   035   P  A
•157   035   P  A
•158   034   PT
•159   112  D  T
•160   310    RC
•161   012            d
•162   035   P  A
•163   035   P  A
•164   102        F2
•165   034   PT
•166   112  D  T
•167   203      L  3
•168   310    RC
•169   010            9
•170   021         +
•171   310    RC
•172   007            7
•173   020         =
•174   035   P  A
•175   035   P  A
•176   034   PT
•177   112  D  T
•178   350   J
•179   001            1
```

2 8 **Calculates the performance of a groove end inlet with headwalls on a pipe culvert.**

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	I D
•010	033	S S
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	I D
•016	033	S S
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	I D
•022	033	S S
•023	034	PT
•024	300	ST
•025	004	4
•026	001	1
•027	300	ST
•028	000	0
•029	201	L 1
•030	222	DP 2
•031	005	5
•032	032	I D
•033	033	S S
•034	034	PT
•035	300	ST
•036	005	5
•037	024	÷
•038	310	RC
•039	003	3
•040	024	÷
•041	026	(
•042	310	RC
•043	004	4
•044	025	d
•045	001	1
•046	012	d
•047	005	5
•048	027	)
•049	020	=
•050	300	ST
•051	006	6
•052	023	×
•053	012	d
•054	000	0
•055	000	0
•056	000	0
•057	002	2
•058	004	4
•059	002	2
•060	010	8
•061	003	3
•062	002	2
•063	022	−
•064	012	d
•065	000	0
•066	000	0
•067	006	6
•068	001	1
•069	006	6
•070	003	3
•071	003	3
•072	010	8
•073	023	×
•074	310	RC
•075	006	6
•076	021	+
•077	012	d
•078	000	0
•079	005	5
•080	011	9
•081	007	7
•082	007	7
•083	002	2
•084	003	3
•085	023	×
•086	310	RC
•087	006	6
•088	022	−
•089	012	d
•090	002	2
•091	003	3
•092	003	3
•093	006	6
•094	001	1
•095	005	5
•096	023	×
•097	310	RC
•098	006	6
•099	021	+
•100	012	d
•101	006	6
•102	005	5
•103	003	3
•104	005	5
•105	006	6
•106	002	2
•107	023	×
•108	310	RC
•109	006	6
•110	021	+
•111	012	d
•112	001	1
•113	001	1
•114	004	4
•115	000	0
•116	011	9
•117	011	9
•118	023	×
•119	310	RC
•120	004	4
•121	020	=
•122	300	ST
•123	007	7
•124	001	1
•125	302	ST−
•126	000	0
•127	310	RC
•128	000	0
•129	352	JC
•130	003	3
•131	310	RC
•132	001	1
•133	022	−
•134	310	RC
•135	007	7
•136	020	=
•137	300	ST
•138	010	8
•139	022	−
•140	310	RC
•141	002	2
•142	020	=
•143	300	ST
•144	012	d
•145	352	JC

```
•146   004          4
•147   310    RC
•148   002          2
•149   300    ST
•150   010          8
•151   000          0
•152   300    ST
•153   012         d
•154   204     L  4
•155   310    RC
•156   010          8
•157   035   P  A
•158   035   P  A
•159   034   PT
•160   112  D  T
•161   310    RC
•162   012         d
•163   035   P  A
•164   035   P  A
•165   102        F2
•166   034   PT
•167   112  D  T
•168   203     L  3
•169   310    RC
•170   010          8
•171   021        +
•172   310    RC
•173   007          7
•174   020        =
•175   035   P  A
•176   035   P  A
•177   034   PT
•178   112  D  T
•179   350   J
•180   001          1
```

2 9 **Calculates performance of a tapered inlet throat in a smooth pipe culvert.**

•001	037	CL	•049	020	=	•097	012	d
•002	001	1	•050	300	ST	•098	002	2
•003	032	I D	•051	006	6	•099	001	1
•004	033	S S	•052	023	×	•100	001	1
•005	034	PT	•053	012	d	•101	005	5
•006	300	ST	•054	000	0	•102	023	×
•007	001	1	•055	000	0	•103	310	RC
•008	002	2	•056	000	0	•104	004	4
•009	032	I D	•057	000	0	•105	020	=
•010	033	S S	•058	003	3	•106	300	ST
•011	034	PT	•059	013	E	•107	007	7
•012	300	ST	•060	021	+	•108	001	1
•013	002	2	•061	012	d	•109	302	ST–
•014	003	3	•062	000	0	•110	000	0
•015	032	I D	•063	000	0	•111	310	RC
•016	033	S S	•064	000	0	•112	000	0
•017	034	PT	•065	003	3	•113	352	JC
•018	300	ST	•066	023	×	•114	003	3
•019	003	3	•067	310	RC	•115	310	RC
•020	004	4	•068	006	6	•116	001	1
•021	032	I D	•069	021	+	•117	022	–
•022	033	S S	•070	012	d	•118	310	RC
•023	034	PT	•071	000	0	•119	007	7
•024	300	ST	•072	000	0	•120	020	=
•025	004	4	•073	004	4	•121	300	ST
•026	001	1	•074	002	2	•122	010	8
•027	300	ST	•075	023	×	•123	022	–
•028	000	0	•076	310	RC	•124	310	RC
•029	201	L 1	•077	006	5	•125	002	2
•030	222	DP 2	•078	022	–	•126	020	=
•031	005	5	•079	012	d	•127	300	ST
•032	032	I D	•080	000	0	•128	012	d
•033	033	S S	•081	004	4	•129	352	JC
•034	034	PT	•082	001	1	•130	004	4
•035	300	ST	•083	004	4	•131	310	RC
•036	005	5	•084	023	×	•132	002	2
•037	024	÷	•085	310	RC	•133	300	ST
•038	310	RC	•086	006	6	•134	010	8
•039	003	3	•087	021	+	•135	000	0
•040	024	÷	•088	012	d	•136	300	ST
•041	026	(	•089	003	3	•137	012	d
•042	310	RC	•090	011	3	•138	204	L 4
•043	004	4	•091	002	2	•139	310	RC
•044	025	a	•092	007	7	•140	010	8
•045	001	1	•093	023	×	•141	035	F A
•046	012	d	•094	310	RC	•142	035	F A
•047	005	5	•095	006	6	•143	034	PT
•048	027	)	•096	021	+	•144	112	U T

```
•145   310    RC
•146   012         c
•147   035   P  A
•148   035   P  A
•149   102        F2
•150   034   PT
•151   112  D T
•152   203      L 3
•153   310    RC
•154   010          9
•155   021        +
•156   310    RC
•157   007          7
•158   020        =
•159   035   P  A
•160   035   P  A
•161   034   PT
•162   112  U T
•163   350   J
•164   001          1
```

2 10 **Calculates the performance of a tapered inlet throat in a rough pipe culvert.**

•001	037	CL	•049	020	=	•097	012	d
•002	001	1	•050	300	ST	•098	002	2
•003	032	I D	•051	006	6	•099	002	2
•004	033	S S	•052	023	×	•100	005	5
•005	034	PT	•053	012	d	•101	002	2
•006	300	ST	•054	000	0	•102	023	×
•007	001	1	•055	000	0	•103	310	RC
•008	002	2	•056	000	0	•104	004	4
•009	032	I D	•057	000	0	•105	020	=
•010	033	S S	•058	003	3	•106	300	ST
•011	034	PT	•059	013	S	•107	007	7
•012	300	ST	•060	021	+	•108	001	1
•013	002	2	•061	012	d	•109	302	ST−
•014	003	3	•062	000	0	•110	000	0
•015	032	I D	•063	000	0	•111	310	RC
•016	033	S S	•064	000	0	•112	000	0
•017	034	PT	•065	005	5	•113	352	JC
•018	300	ST	•066	023	×	•114	003	3
•019	003	3	•067	310	RC	•115	310	RC
•020	004	4	•068	006	6	•116	001	1
•021	032	I D	•069	021	+	•117	022	−
•022	033	S S	•070	012	d	•118	310	RC
•023	034	PT	•071	000	0	•119	007	7
•024	300	ST	•072	000	0	•120	020	=
•025	004	4	•073	001	1	•121	300	ST
•026	001	1	•074	001	1	•122	010	8
•027	300	ST	•075	023	×	•123	022	−
•028	000	0	•076	310	RC	•124	310	RC
•029	201	L 1	•077	006	6	•125	002	2
•030	222	DF 2	•078	022	−	•126	020	=
•031	005	5	•079	012	d	•127	300	ST
•032	032	I D	•080	000	0	•128	012	d
•033	033	S S	•081	002	2	•129	352	JC
•034	034	PT	•082	005	5	•130	004	4
•035	300	ST	•083	002	2	•131	310	RC
•036	005	5	•084	023	×	•132	002	2
•037	024	÷	•085	310	RC	•133	300	ST
•038	310	RC	•086	006	6	•134	010	8
•039	003	3	•087	021	+	•135	000	0
•040	024	÷	•088	012	d	•136	300	ST
•041	026	(	•089	003	3	•137	012	d
•042	310	RC	•090	004	4	•138	204	L 4
•043	004	4	•091	007	7	•139	310	RC
•044	025	d	•092	001	1	•140	010	8
•045	001	1	•093	023	×	•141	035	P A
•046	012	d	•094	310	RC	•142	035	P A
•047	005	5	•095	006	6	•143	034	PT
•048	027	)	•096	021	+	•144	112	D·T

```
•145   310     RC
•146   012          d
•147   035   P  A
•148   035   P  A
•149   102        F2
•150   034   PT
•151   112  D T
•152   203      L  3
•153   310     RC
•154   010           8
•155   021         +
•156   310     RC
•157   007           7
•158   020         =
•159   035   P  A
•160   035   P  A
•161   034   PT
•162   112  D T
•163   350   ?
•164   001           1
```

2 11 Calculates B_f and L_1 for a side-tapered inlet on a pipe culvert if the face has projecting thin edges.

•001	037	CL	•046	300	ST	•091	001	1
•002	001	1	•047	007	7	•092	012	d
•003	032	I D	•048	001	1	•093	010	8
•004	033	S S	•049	300	ST	•094	001	1
•005	034	PT	•050	013	S	•095	006	6
•006	022	−	•051	300	ST	•096	007	7
•007	002	2	•052	012	d	•097	023	×
•008	032	I D	•053	201	L 1	•098	310	RC
•009	033	S S	•054	310	RC	•099	010	8
•010	034	PT	•055	001	1	•100	021	+
•011	300	ST	•056	022	−	•101	001	1
•012	003	3	•057	310	RC	•102	012	d
•013	020	=	•058	013	S	•103	001	1
•014	300	ST	•059	024	÷	•104	005	5
•015	001	1	•060	310	RC	•105	000	0
•016	003	3	•061	006	6	•106	005	5
•017	032	I D	•062	020	=	•107	023	×
•018	033	S S	•063	300	ST	•108	310	RC
•019	034	PT	•064	010	8	•109	010	8
•020	300	ST	•065	023	×	•110	021	+
•021	002	2	•066	012	d	•111	012	d
•022	004	4	•067	000	0	•112	000	0
•023	032	I D	•068	001	1	•113	001	1
•024	033	S S	•069	004	4	•114	004	4
•025	034	PT	•070	010	8	•115	004	4
•026	300	ST	•071	013	S	•116	023	×
•027	004	4	•072	021	+	•117	310	RC
•028	005	5	•073	012	d	•118	007	7
•029	032	I D	•074	001	1	•119	020	=
•030	033	S S	•075	011	9	•120	063	1/x
•031	034	PT	•076	007	7	•121	023	×
•032	300	ST	•077	004	4	•122	004	4
•033	005	5	•078	023	×	•123	024	÷
•034	006	6	•079	310	RC	•124	107	π
•035	032	I D	•080	010	9	•125	024	÷
•036	033	S S	•081	022	−	•126	310	RC
•037	034	PT	•082	012	d	•127	006	6
•038	300	ST	•083	011	9	•128	020	=
•039	006	6	•084	006	6	•129	035	P A
•040	222	DP 2	•085	004	4	•130	035	P A
•041	062	√	•086	002	2	•131	034	PT
•042	024	÷	•087	023	×	•132	112	D T
•043	310	RC	•088	310	RC	•133	033	S S
•044	005	5	•089	010	8	•134	022	−
•045	020	=	•090	021	+	•135	310	RC

```
•136   004          4
•137   024        ÷
•138   002          2
•139   023        ×
•140   310    RC
•141   002          2
•142   106    I
•143   020        =
•144   300    ST
•145   000          0
•146   001          1
•147   302    ST-
•148   012          d
•149   310    RC
•150   012          d
•151   352   JC
•152   002          2
•153   310    RC
•154   000          0
•155   023        ×
•156   310    RC
•157   002          2
•158   105        Fs
•159   020        =
•160   300    ST
•161   013          S
•162   022        -
•163   001          1
•164   020        =
•165   356   JC
•166   002          2
•167   310    RC
•168   000          0
•169   023        ×
•170   310    RC
•171   002          2
•172   105        Fs
•173   020        =
•174   300    ST
•175   013          S
•176   350   J
•177   001          1
•178   202      L  2
•179   035   F  A
•180   035   F  A
•181   310    RC
•182   000          0
•183   034   FT
•184   112  L  T
•185   023        ×
•186   310    RC
•187   002          2
•188   105        Fs
•189   021        +
•190   310    RC
•191   003          3
•192   020        =
•193   035   F  A
•194   035   F  A
•195   034   FT
•196   112  L  T
•197   350   J
•198   053    S    S
```

2 12 Calculates B_f and L_1 for a side-tapered inlet on a pipe culvert if the face has square edges in a headwall.

•001	037	CL	•047	007	7	•093	011	9
•002	001	1	•048	001	1	•094	007	7
•003	032	I D	•049	300	ST	•095	010	8
•004	033	S S	•050	013	S	•096	004	4
•005	034	PT	•051	300	ST	•097	023	×
•006	022	−	•052	012	d	•098	310	RC
•007	002	2	•053	201	L 1	•099	010	8
•008	032	I D	•054	310	RC	•100	021	+
•009	033	S S	•055	001	1	•101	012	d
•010	034	PT	•056	022	−	•102	011	9
•011	300	ST	•057	310	RC	•103	004	4
•012	003	3	•058	013	S	•104	002	2
•013	020	=	•059	024	÷	•105	006	6
•014	300	ST	•060	310	RC	•106	023	×
•015	001	1	•061	006	6	•107	310	RC
•016	003	3	•062	020	=	•108	010	8
•017	032	I D	•063	300	ST	•109	022	−
•018	033	S S	•064	010	8	•110	012	d
•019	034	PT	•065	023	×	•111	000	0
•020	300	ST	•066	012	d	•112	000	0
•021	002	2	•067	000	0	•113	004	4
•022	004	4	•068	003	3	•114	010	8
•023	032	I D	•069	005	5	•115	023	×
•024	033	S S	•070	007	7	•116	310	RC
•025	034	PT	•071	013	S	•117	007	7
•026	300	ST	•072	021	+	•118	020	=
•027	004	4	•073	012	d	•119	063	x̄
•028	005	5	•074	004	4	•120	023	×
•029	032	I D	•075	002	2	•121	004	4
•030	033	S S	•076	002	2	•122	024	÷
•031	034	PT	•077	010	8	•123	107	π
•032	300	ST	•078	023	×	•124	024	÷
•033	005	5	•079	310	RC	•125	310	RC
•034	006	6	•080	010	8	•126	006	6
•035	032	I D	•081	022	−	•127	020	=
•036	033	S S	•082	001	1	•128	035	P A
•037	034	PT	•083	012	d	•129	035	P A
•038	300	ST	•084	007	7	•130	034	PT
•039	006	6	•085	011	9	•131	112	D T
•040	222	DP 2	•086	002	2	•132	033	S S
•041	052	r	•087	023	×	•133	022	−
•042	024	÷	•088	310	RC	•134	310	RC
•043	310	RC	•089	010	8	•135	004	4
•044	005	5	•090	021	+	•136	024	÷
•045	020	=	•091	002	2	•137	002	2
•046	300	ST	•092	012	d	•138	023	×

•139	310	RC
•140	002	2
•141	106	I
•142	020	=
•143	300	ST
•144	000	0
•145	001	1
•146	302	ST–
•147	012	d
•148	310	RC
•149	012	d
•150	352	JC
•151	002	2
•152	310	RC
•153	000	0
•154	023	×
•155	310	RC
•156	002	2
•157	105	Fs
•158	020	=
•159	300	ST
•160	013	S
•161	022	–
•162	001	1
•163	020	=
•164	356	JC
•165	002	2
•166	310	RC
•167	000	0
•168	023	×
•169	310	RC
•170	002	2
•171	105	Fs
•172	020	=
•173	300	ST
•174	013	S
•175	350	J
•176	001	1
•177	202	L 2
•178	035	P A
•179	035	P A
•180	310	RC
•181	000	0
•182	034	PT
•183	112	D T
•184	023	×
•185	310	RC
•186	002	2
•187	105	Fs
•188	021	+
•189	310	RC
•190	003	3
•191	020	=
•192	033	P A
•193	035	P A
•194	034	PT
•195	112	D T
•196	350	J
•197	033	S S

2 13 **Calculates B_f and L_I for a side-tapered inlet on a pipe culvert if the face has 45° bevels or a grooved end.**

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	022	−
•007	002	2
•008	032	I D
•009	033	S S
•010	034	PT
•011	300	ST
•012	003	3
•013	020	=
•014	300	ST
•015	001	1
•016	003	3
•017	032	I D
•018	033	S S
•019	034	PT
•020	300	ST
•021	002	2
•022	004	4
•023	032	I D
•024	033	S S
•025	034	PT
•026	300	ST
•027	004	4
•028	005	5
•029	032	I D
•030	033	S S
•031	034	PT
•032	300	ST
•033	005	5
•034	006	5
•035	032	I D
•036	033	S S
•037	034	PT
•038	300	ST
•039	006	6
•040	222	DP 2
•041	062	r
•042	024	÷
•043	310	RC
•044	005	5
•045	020	=
•046	300	ST
•047	007	7
•048	001	1
•049	300	ST
•050	013	S
•051	300	ST
•052	012	d
•053	201	L 1
•054	310	RC
•055	001	1
•056	022	−
•057	310	RC
•058	013	S
•059	024	÷
•060	310	RC
•061	005	5
•062	020	=
•063	300	ST
•064	010	8
•065	023	×
•066	012	d
•067	000	0
•068	002	2
•069	010	8
•070	007	7
•071	013	S
•072	021	+
•073	012	d
•074	003	3
•075	007	7
•076	004	4
•077	004	4
•078	023	×
•079	310	RC
•080	010	8
•081	022	−
•082	001	1
•083	012	d
•084	007	7
•085	006	6
•086	004	4
•087	023	×
•088	310	RC
•089	010	8
•090	021	+
•091	003	3
•092	012	d
•093	002	2
•094	011	9
•095	011	9
•096	004	4
•097	023	×
•098	310	RC
•099	010	8
•100	021	+
•101	012	d
•102	007	7
•103	003	3
•104	011	9
•105	003	3
•106	002	2
•107	023	×
•108	310	RC
•109	010	8
•110	023	×
•111	310	RC
•112	007	7
•113	020	=
•114	063	%
•115	023	×
•116	004	4
•117	024	÷
•118	107	π
•119	024	÷
•120	310	RC
•121	006	6
•122	020	=
•123	035	P A
•124	035	P A
•125	034	PT
•126	112	D T
•127	033	S S
•128	022	−
•129	310	RC
•130	004	4
•131	024	÷
•132	002	2
•133	023	×
•134	310	RC
•135	002	2
•136	106	I
•137	020	=
•138	300	ST

```
•139  000       0     •191  350   J
•140  001       1     •192  033    S  S
•141  302   ST-
•142  012      d
•143  310   RC
•144  012      o
•145  352  JC
•146  002       2
•147  310   RC
•148  000       0
•149  023     x
•150  310   RC
•151  002       2
•152  105     Fs
•153  020     =
•154  300   ST
•155  013      S
•156  022     -
•157  001       1
•158  020     =
•159  355  JC
•160  002       2
•161  310   RC
•162  000       0
•163  023     x
•164  310   RC
•165  002       2
•166  105     Fs
•167  020     =
•168  300   ST
•169  013      S
•170  350  J
•171  001       1
•172  202     L  2
•173  035  P  A
•174  035  P  A
•175  310   RC
•176  000       0
•177  034  PT
•178  112  D  T
•179  023     x
•180  310   RC
•181  002       2
•182  105     Fs
•183  021     +
•184  310   RC
•185  003       3
•186  020     =
•187  035  P  A
•188  035  P  A
•189  034  PT
•190  112  D  T
```

2 14 Calculates outlet velocity for circular pipes in inlet control.

•001	037	CL
•002	001	1
•003	032	I D
•004	033	S S
•005	034	PT
•006	300	ST
•007	001	1
•008	002	2
•009	032	I D
•010	033	S S
•011	034	PT
•012	300	ST
•013	002	2
•014	003	3
•015	032	I D
•016	033	S S
•017	034	PT
•018	300	ST
•019	003	3
•020	004	4
•021	032	I D
•022	033	S S
•023	034	PT
•024	300	ST
•025	004	4
•026	005	5
•027	032	I D
•028	033	S S
•029	034	PT
•030	300	ST
•031	005	5
•032	222	UP 2
•033	062	√
•034	063	½
•035	024	÷
•036	001	1
•037	012	d
•038	004	4
•039	010	8
•040	006	6
•041	023	×
•042	310	RC
•043	004	4
•044	023	×
•045	310	RC
•046	003	3
•047	024	÷
•048	026	(
•049	310	RC
•050	002	2
•051	025	d
•052	026	(
•053	010	8
•054	024	÷
•055	003	3
•056	027	)
•057	027	)
•058	020	=
•059	300	ST
•060	006	6
•061	061	LG
•062	300	ST
•063	007	7
•064	161	L→1
•065	022	−
•066	012	d
•067	002	2
•068	004	4
•069	020	=
•070	355	JC
•071	001	1
•072	012	d
•073	001	1
•074	011	9
•075	002	2
•076	006	6
•077	001	1
•078	005	5
•079	023	×
•080	310	RC
•081	007	7
•082	021	+
•083	012	d
•084	011	9
•085	000	0
•086	007	7
•087	010	8
•088	010	8
•089	004	4
•090	023	×
•091	310	RC
•092	007	7
•093	021	+
•094	012	d
•095	003	3
•096	000	0
•097	006	6
•098	003	3
•099	006	6
•100	003	3
•101	011	9
•102	350	J
•103	003	3
•104	201	L 1
•105	310	RC
•106	006	6
•107	022	−
•108	012	d
•109	003	3
•110	004	4
•111	020	=
•112	355	JC
•113	002	2
•114	001	1
•115	012	d
•116	001	1
•117	002	2
•118	005	5
•119	010	8
•120	003	3
•121	006	6
•122	023	×
•123	310	RC
•124	007	7
•125	021	+
•126	002	2
•127	012	d
•128	000	0
•129	011	9
•130	007	7
•131	005	5
•132	003	3
•133	002	2
•134	023	×
•135	310	RC
•136	007	7
•137	021	+
•138	012	d

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