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Computer Program
Hydraulic Analysis of Culverts

PROGRAM HY-6

1979

U.S. Department
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**Federal Highway
Administration**

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
Washington, D.C.

HY-6 - ELECTRONIC COMPUTER PROGRAM FOR HYDRAULIC ANALYSIS OF CULVERTS

- BOX CULVERTS
- CIRCULAR CULVERTS

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PREFACE

This computer program is for the hydraulic analysis of concrete box and circular (concrete, CMP) culverts for any given hydrological data and site condition. This program supersedes the conventional culvert designs provided by the existing Computer Programs HY-1, "Hydraulic Analysis of Circular Culverts," and HY-3, "Hydraulic Analysis of Box Culverts." In addition to designs for conventional culverts, this program includes analysis and designs for improved inlets based on concepts presented in Hydraulic Engineering Circular No. 13, "Hydraulic Design of Improved Inlets for Culverts," dated August 1972. The improved inlet designs include bevel-edged, side-tapered and slope-tapered inlets. The original HY-1 and HY-3 computer programs are based on the concepts presented in Hydraulic Engineering Circular No. 5, "Hydraulic Charts for the Selection of Highway Culverts." Development of improved inlet designs for other geometric configurations (pipe arch, ovals, etc.) are not included in this publication because design criteria are not available.

Terminology used in this publication assumes that the reader is familiar with HEC No. 13 and understands the principles and design approach expressed therein.

STATEMENT OF THE PROBLEM

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The Federal Highway Administration's (FHWA) earlier computer programs for the Hydraulic Design of Culverts, HY-1, "Hydraulic Analysis of Circular Culverts," and HY-3, "Hydraulic Analysis of Box Culverts," utilized the principles presented in Hydraulic Engineering Circular (HEC) No. 5 (1)[1/].

With the advent of HEC No. 13, "Hydraulic Design of Improved Inlets for Culverts," (2) the development of this program was made possible. This program incorporates the principles in HEC No. 5 and HEC No. 13 with significant changes in program data output when compared to the HY-3 and HY-1 data output and a new approach to hydraulic analysis for the design of culverts.

Program output consists of a list of optional culvert sizes, including pertinent performance data for the hydraulic design engineer's use in selecting a culvert which will meet hydraulic requirements at the least cost. This output information is provided in recognition of several facts regarding culvert hydraulic design. (1) There is not a unique solution for any culvert site, i.e., several culvert sizes, shapes, inlet configurations and elevation, materials, etc. can satisfactorily meet the criteria and constraints established by the hydraulic design engineer for the site. (2) Highway agency practices differ regarding the use of materials and the configuration of culverts and practices differ dependent upon environmental conditions at the site and location within a State. (3) The hydraulic performance of any culvert operating with inlet control can be optimized. (4) The so-called "design flood" and the "allowable" headwater at any culvert site can be exceeded and there is a statistical probability that they will be exceeded. In choosing the preferred design alternative or if the contractor is required to bid on design alternatives, the hydraulic design engineer needs to consider the performance of alternative design options for a range of flow rates and the probability of potential damage to the highway and other properties.

The new culvert design approach can be summarized as follows:

1. Introduces the alternative of using external FALL[*] at a culvert inlet if the culvert will operate in inlet control and the headwater elevation computed for the culvert performance otherwise exceeds the allowable headwater elevation.

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[*] External Fall refers to the change in the total barrel slope whereas Internal FALL refers to the inlet FALL for a slope-tapered design.

1/ Underlined numbers in parentheses refer to references on page 98.

2. Utilizes elevations with regard to headwater, inlet and outlet inverts, roadway embankment toe elevations. The advantage in using elevations rather than water depths is a unique outlet and inlet control performance curve regardless of inlet invert elevation (figure 2).

3. Ties the roadway cross section (embankment slopes) with the stream profile and the culvert length and height.

4. Use of optimization for design of box and circular culverts (See figures 1 and 2) for three conditions:

   (a) Minimum fall -- Curve A

   (b) Maximum discharge -- Curve B

   (c) Minimum headwater -- Curve C

5. Provides the designer with performance information on all logical culvert sizes, shapes and vertical locations for use in evaluating the cost-effectiveness of available options.

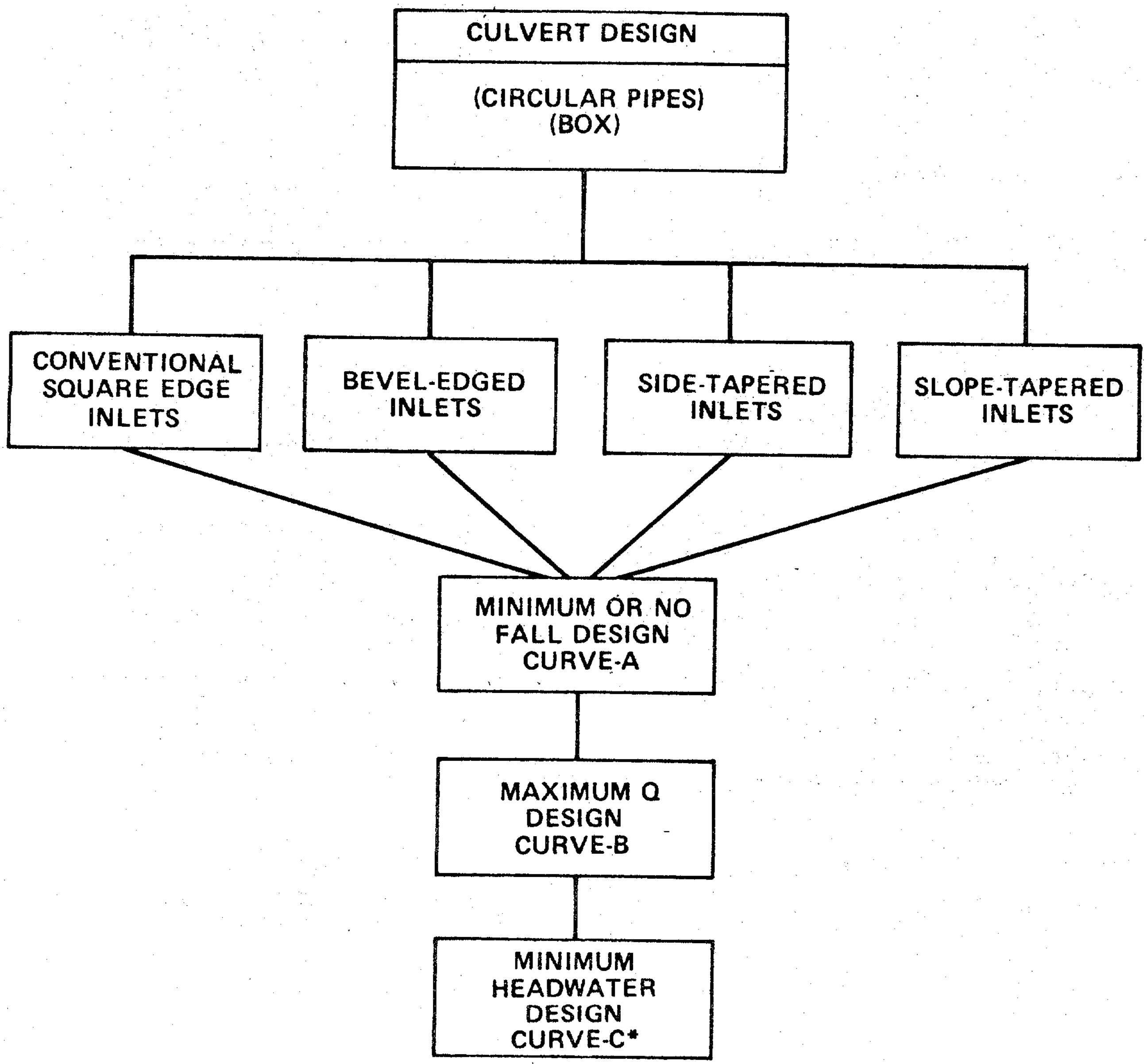
Figure 1 represents an overview of three design conditions provided by the computer program for each of the four inlet configurations. Figure 2 illustrates a typical performance curve relationship for the three design conditions. The dashed curve shows the extent of the computed inlet control headwater elevation above the allowable headwater for a given culvert size and design discharge. Normally for this situation, the culvert would not be accepted for use, but by depressing the culvert inlet, the culvert hydraulic performance is represented by Curve A (figure 2). Curve A represents the minimum design condition required to meet the selected design criteria.

Curve B illustrates the performance of a design which takes full advantage of the potential capacity of the selected culvert and the site to pass the maximum possible flow at the allowable headwater elevation (AHWEL). A safety factor in capacity is thereby incorporated in the design, usually at little cost. This can be accomplished by use of a depression (FALL), by geometry improvements at the inlet or by a combination of the two.

Curve C illustrates the passage of the design flow at the lowest possible headwater elevation. At design discharge, the minimum headwater is a function of outlet control (point 3) or water surface elevation in the stream at the culvert inlet, whichever is higher.

It should be realized that if the invert or throat elevation for a Curve B design is lower than the maximum allowable fall elevation, then the maximum discharge (Q) will not be at Point 2 (figure 2), but will occur where the inlet control curve crosses the allowable headwater elevation. Also, for this situation, Curve C will superimpose Curve B.

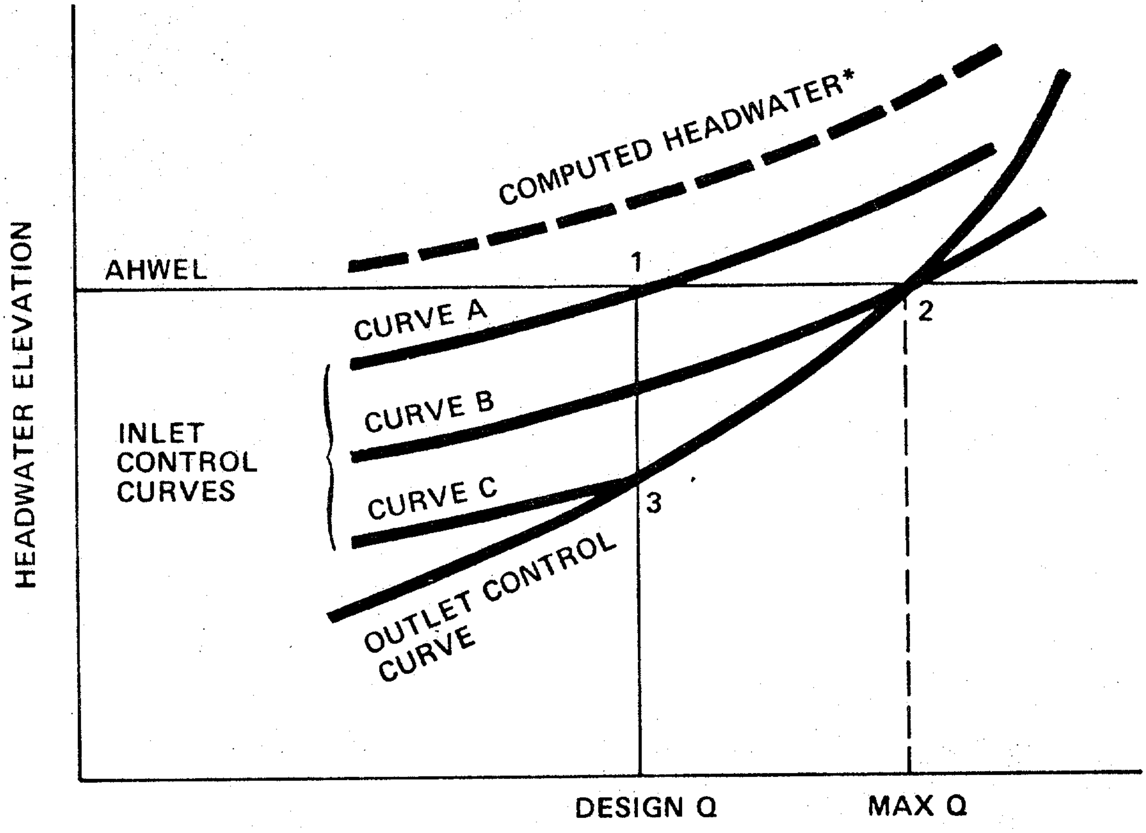
ORGANIZATION CHART FOR CULVERT DESIGN



*CURVE-C FOR SLOPE-TAPERED DESIGN NOT INCLUDED AT THIS TIME

Figure 1

TYPICAL PERFORMANCE CURVES FOR OPTIMIZED CULVERT DESIGN



PERFORMANCE CURVES

Figure 2

*This curve shows the computed headwater elevation greater than the "allowable" headwater, therefore necessitating either an external FALL at the inlet or geometry improvements to achieve the minimum design condition imposed by the hydraulic design engineer and illustrated by curve A. When the computed headwater is less than the "allowable" no external FALL is necessary to achieve the minimum design condition.

DESCRIPTION OF PROGRAM

DESCRIPTION OF PROGRAM

Figure 3 presents an overview of the culvert program which will eventually encompass the various culvert geometric designs within the total program. The program includes the main program (driver) plus the subroutines associated with the applicable culvert design. The program was developed in modular (subroutine) form for ease in utilization. Figure 4 shows a macroflow diagram of the computer process for this program.

It is beyond the scope of this report to give a full understanding of the concepts presented in Hydraulic Engineering Circulars No. 5 and No. 13. The user of this program should be well acquainted with the two circulars or have them available for reference.

The initial function of the program is to read and store the input data for a particular culvert problem. The program tests the data to determine if the data are valid. If the data are invalid, an invalid message is printed and the problem is bypassed by the program.

As part of the input data, the user identifies the type of conventional inlet he desires by choosing the corresponding culvert code shown in Table 1 for box culverts or Table 6 for circular pipes. In this regard, the program has a built-in feature which will automatically provide the user with an optional bevel-edged inlet design which has a geometry similar to the conventional inlet design. For example, noting Table 1 - BOX CULVERT SECTION, if a wingwall type inlet code 41111 is selected, the program also provides design data for the comparable wingwall type code 41146 which is bevel Option 2. If the user wishes to bypass the conventional designs, he can choose a bevel-edged design and the program will provide data for that design and improved inlets only. The user must enter the program with one of the codes from Table 1 for either box culverts or Table 6 for circular culverts. In addition to the conventional design and/or bevel-edged designs the program provides side- and slope-tapered improved inlet designs for culverts flowing with inlet control.

The first major function of the program is to analyze a series of box culvert sizes or pipe diameters to compute the following:

Outlet Control Section

1. The required outlet control headwater elevation.
2. The outlet invert elevation for a conventional, bevel-edged and tapered inlet type culvert.

Inlet Control Section

1. The required inlet control headwater elevation.
2. The amount of external FALL, if the computed inlet control headwater elevation exceeds the "allowable" headwater elevation.
3. The face invert elevation for the conventional and bevel-edged culverts. For the tapered inlet, the throat invert elevation is determined along with the face invert elevation.

The amount of data for all the culvert sizes analyzed is printed on one sheet. This print-out sheet, "INDEX SHEET," allows the hydraulic engineer to make comparisons of inlet and outlet control headwaters and the external FALLS required for any box or circular pipe size. A more detailed description of the INDEX SHEET is found in the output section of this report.

The second major function of the program is to reanalyze the culvert sizes listed on the INDEX SHEET and compute the necessary design data for each culvert size and inlet type. The design data for each individual size is printed on a separate page as indicated by the page reference numbers listed on the INDEX SHEET.

PROGRAM OVERVIEW

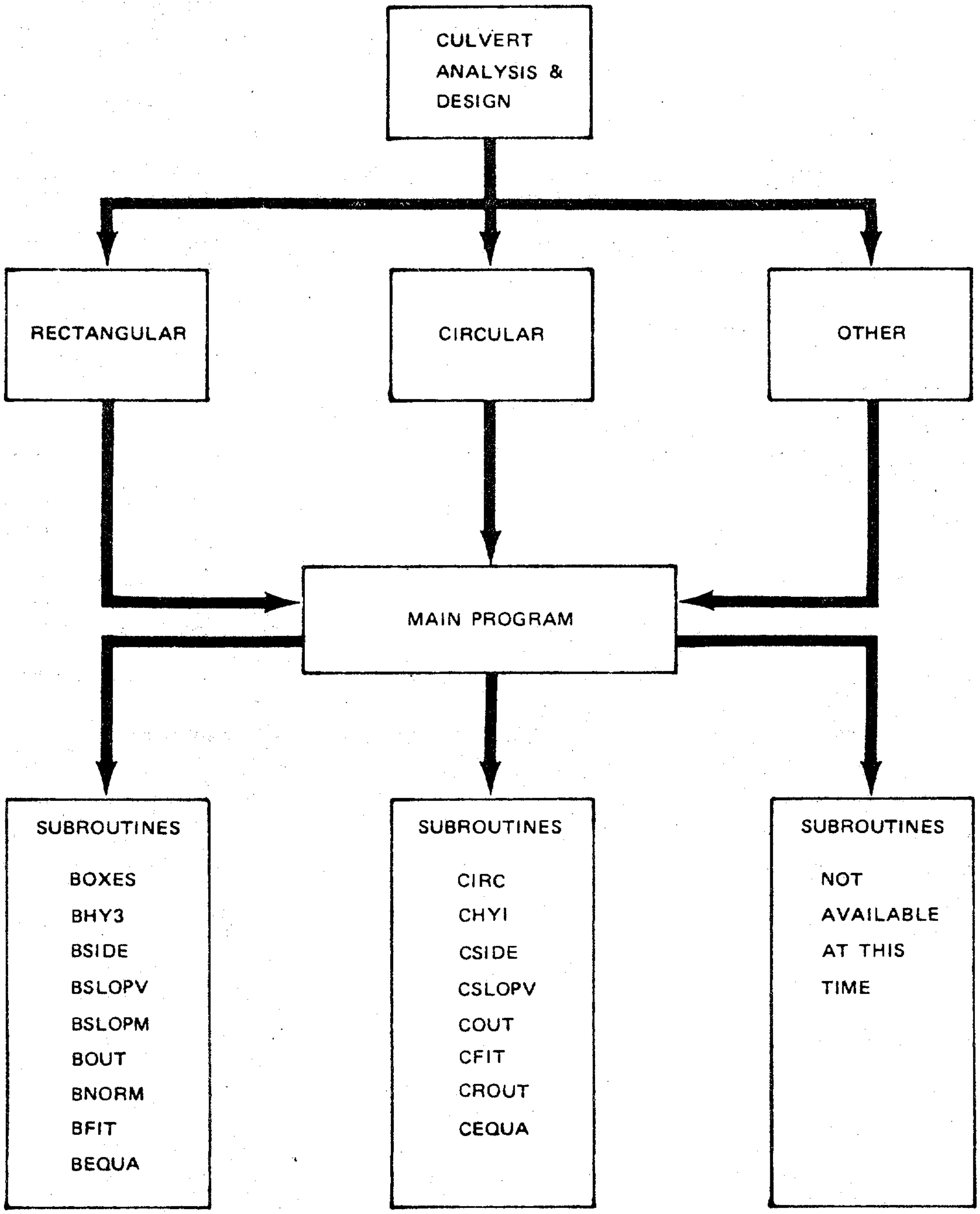


Figure 3

MACRO FLOW DIAGRAM

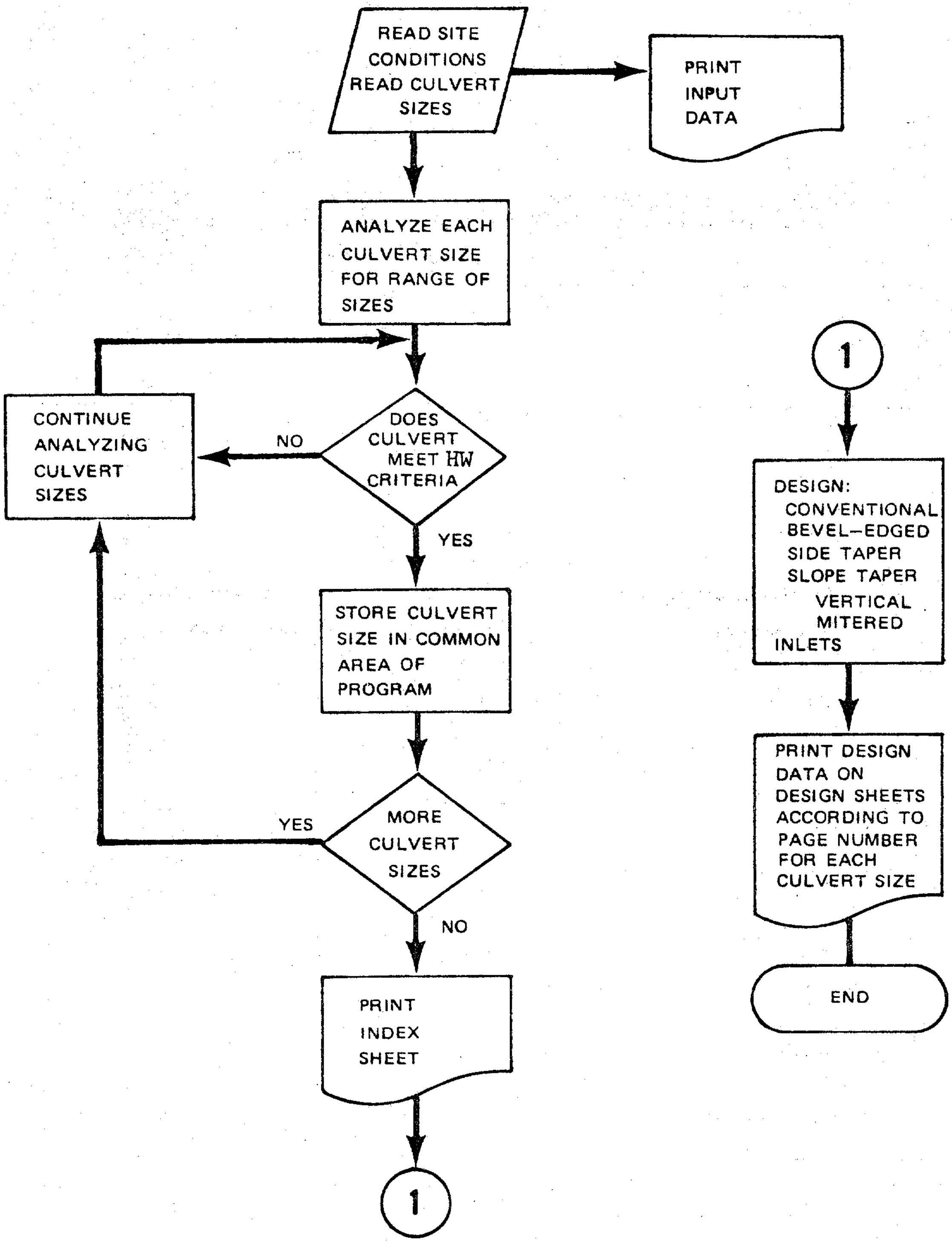


Figure 4

INPUT DATA SECTION

INPUT DATA SECTION

This section describes the input data card requirements including a detailed description of the input data items, format coding and sample card setup for program processing.

Card No. 1

Project identification

Card No. 2

		Field Size
1.	Culvert code	XXXXX
2.	Stream slope	XX.XXXX
3.	Approximate culvert length (identification only)	XXXXX.X
4.	Design discharge	XXXXX.X
5.	Design tailwater	XXXXX.X
6.	Allowable headwater	XXXXX.X
7.	Upstream elevation where roadway embankment meets stream profile	XXXXX.X
8.	Downstream elevation where roadway embankment meets stream profile	XXXXX.X
9.	Upstream roadway embankment slope	XXXXX.X
10.	Downstream roadway embankment slope	XXXXX.X
11.	Fall slope for slope-tapered inlet	XXXXX.X

Card No. 3 - For range of box culvert sizes

1.	Culvert width, initial value	XX
2.	Culvert width, final value	XX
3.	Culvert depth, initial value	XX
4.	Culvert depth, final value	XX

INPUT DATA SECTION

Card No. 3 - For range of circular culvert sizes

1.	Culvert diameter, initial value	XX.XX
2.	Culvert diameter, final value	XX.XX

Card No. 4

Blank card to terminate program execution.

The field size and number of decimals to the right of the units position are shown to the right of each item. A more detailed discussion of the input data follows.

Culvert Code*

The Culvert Code is a five-digit number which represents five separate integers that are used by the program to define different culvert and inlet types. Refer to Table 1 for the box culvert codes and Table 6 for circular pipe culverts. These five separate code integers are referred to as I1, I2, I3, I4 and I5. The symbol I1 indicates a type of culvert that the program is to analyze. Thus, for all box culverts, I1 is the integer 4; for CM pipe it is 1; and for concrete pipe, it is 2. Symbols I2 and I3 for box culverts, at the present time, are dummy values which are assigned the integer 1. Symbol I2 for circular pipe indicates whether paved or unpaved and I3 denotes the corrugation type. Symbol I4 defines the type of wingwall and enables the program to select an appropriate value for the entrance loss coefficient. I4 has four values that can be assigned to it, 1, 2, 3 and 4. I5 also refers to a particular entrance condition, namely, square or bevel-edged inlets and is used by the subroutine BEQUA or CEQUA to assign the appropriate mathematical equations for the chosen inlet condition.

An example culvert code that might be used is 41122. This five-digit number indicates to the program that coefficients must be used for a square-edged box culvert with a headwall either normal or skewed up to 45 degrees.

Stream Slope

Stream slope, SLOPE, is the elevation of the point of intersection of the upstream roadway embankment with the stream profile minus the elevation of the point of intersection of the downstream roadway embankment with the stream profile divided by the horizontal distance between these two points. It is measured in feet per foot. A zero slope can be used.

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* See Tables 1 and 6 on pages 38 and 71

INPUT DATA SECTION

Approximate Culvert Length

The approximate culvert length, DIST, represents the distance between the intersection points mentioned in the section Stream Slope and is measured horizontally. Since the program computes true culvert lengths for the three design conditions, this value is printed out with the input data to allow the designer to know the width of the roadway embankment at the stream measured in feet.

Design Discharge

Design discharge, Q1, is the quantity of water in cubic feet per second to be used in the selection of the barrel dimensions.

Design Tailwater

Design tailwater, DTW, is the depth of water measured in feet between the water surface elevation and the invert elevation at the outlet end of the culvert.

Allowable Headwater Elevation

Allowable headwater elevation, AHWEL, is the chosen water surface elevation at the culvert inlet for the design discharge at the culvert site.

Upstream Elevation for Roadway Embankment Intersecting Stream Profile

This elevation, ELIN, represents the elevation at the point where the upstream embankment slope intersects the stream profile.

Downstream Elevation for Roadway Embankment Intersecting Stream Profile

This elevation, ELOUT, represents the elevation at the point where the downstream embankment slope intersects the stream profile.

Upstream Embankment Slope

The embankment slope, SEL, is the embankment slope on the upstream side of the roadway cross section templet measured as 1:1, 2:1, 3.5:1, etc. For a vertical embankment slope SEL=0.0.

Downstream Embankment Slope

The embankment slope, SER, is the embankment slope on the downstream side of the roadway cross section templet measured as 1:1, 2:1, etc. For a vertical embankment slope SER=0.0.

INPUT DATA SECTION

Fall Slope

The fall slope for a slope-tapered inlet. User inputs value between 2:1 to 3:1, inclusive.

Culvert Sizes (Boxes or Circular Pipes)

Input the range of culvert widths and depths or diameters desired. For example: B(Base) ranges from 4' to 10' and D(Depth) ranges from 4' to 8', or a single box size can be submitted as B ranges from 7' to 7' and D ranges from 6' to 6' for a 7' x 6' box.

For Box Culverts - the range of sizes are:

KBAS1 is the initial box width size

KBAS2 is the final box width size

KDEP1 is the initial box depth size

KDEP2 is the final box depth size

For Pipe Culverts - the range of diameter sizes are:

DIA1 is the initial diameter size

DIA2 is the final diameter size

Figure 5 represents a typical roadway cross-section depicting several of the variables (symbolic names) used as input data items.

Figure 6 shows a sample input data sheet.

Figure 7 illustrates the source card arrangement including job control cards to process culvert hydraulic analysis.

The following tabulation describes the input data as to the card type, and card columns used, the associated format and the symbolic variable names.

INPUT FORMATS

CARD TYPE	COLUMNS	FORMAT	SYMBOLS	DEFINITION
1	1-78	26A3	IPROJ	Project identification
2	1-5	5I1	I1, I2, I3, I4, I5	Culvert code number (boxes or pipes)
	6-12	F7.4	SLOPE	Slope of the streambed
	13-19	F7.1	DIST	Distance between point of intersection of stream slope and upstream embankment slope and point of intersection of stream slope and downstream embankment of slope measured horizontally
	20-26	F7.1	Q1	Design discharge
	27-33	F7.1	DTW	Design tailwater
	34-40	F7.1	AHWEL	Allowable headwater elevation
	41-47	F7.1	ELIN	Elevation of intersection point of stream slope and upstream embankment slope
	48-54	F7.1	ELOUT	Elevation of intersection point of stream slope and downstream embankment slope
	55-61	F7.1	SEL	Slope of upstream.embankment For vertical slopes SEL=0.0

INPUT FORMATS (continued)

CARD TYPE	COLUMNS	FORMAT	SYMBOLS	DEFINITION
	62-68	F7.1	SER	Slope of downstream embankment
	69-75	F7.1	SFACE	Fall slope for slope-tapered inlets
3 (boxes)**	1-2	I2	KBAS1 *	First Base width (B) value for range of culvert sizes
	3-4	I2	KBAS2 *	Last B value for range of culvert sizes
	5-6	I2	KDEP1 *	First Depth (D) value for range of culvert size
	7-8	I2	KDEP2 *	Last D value for range of culvert sizes
3 (pipes)**	1-5	F5.2	DIA1	Initial pipe diameter (ft.)
	6-10	F5.2	DIA2	Final pipe diameter (ft.)

* To analyze a single box size, for example a 7' x 7' or single pipe size of 7' diameter then

For Boxes
KBAS1 = 7'
KBAS2 = 7'
KDEP1 = 7'
KDEP2 = 7'
or For Pipes
DIA1 = 7'
DIA2 = 7'

** Each type of geometric design represents a specific design as indicated by Card No. 3 for boxes or Card No. 3 for pipes. Use only one Card No. 3 per data set.

TYPICAL ROADWAY CROSS SECTION

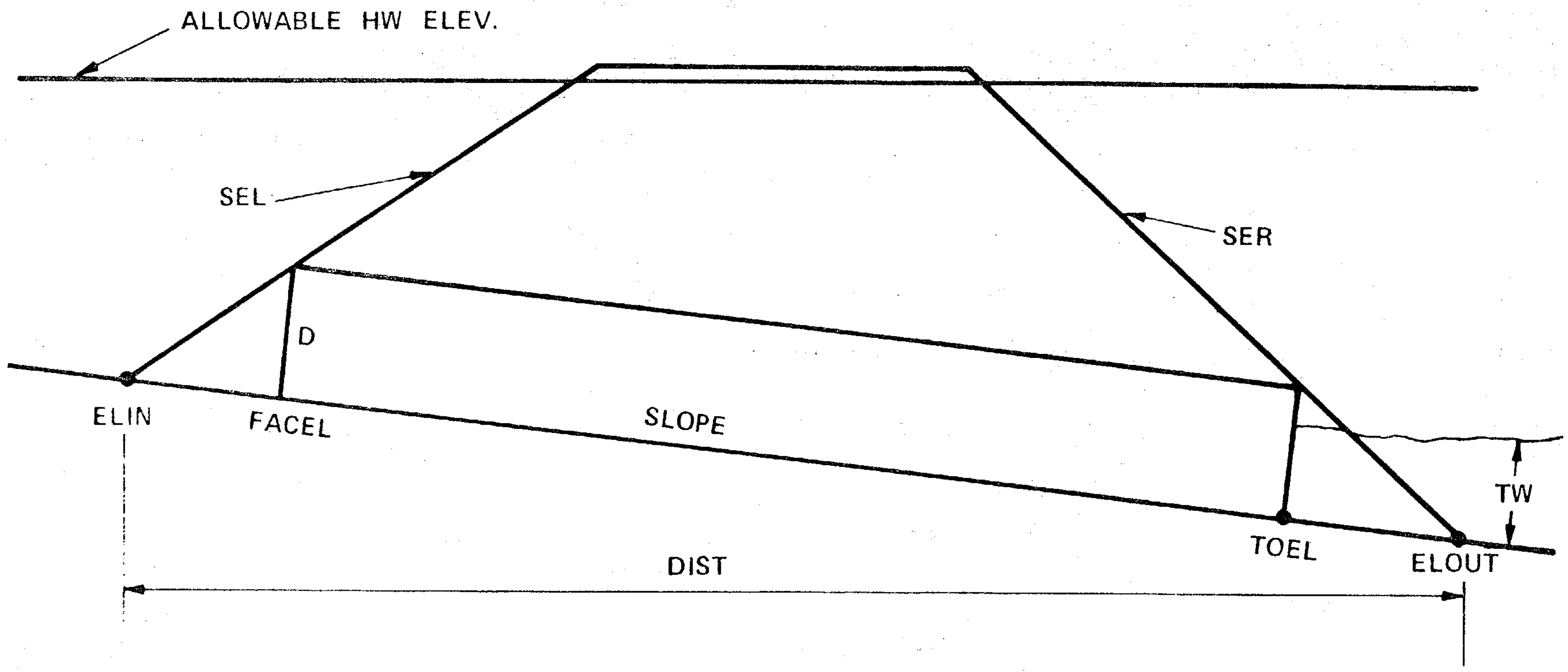
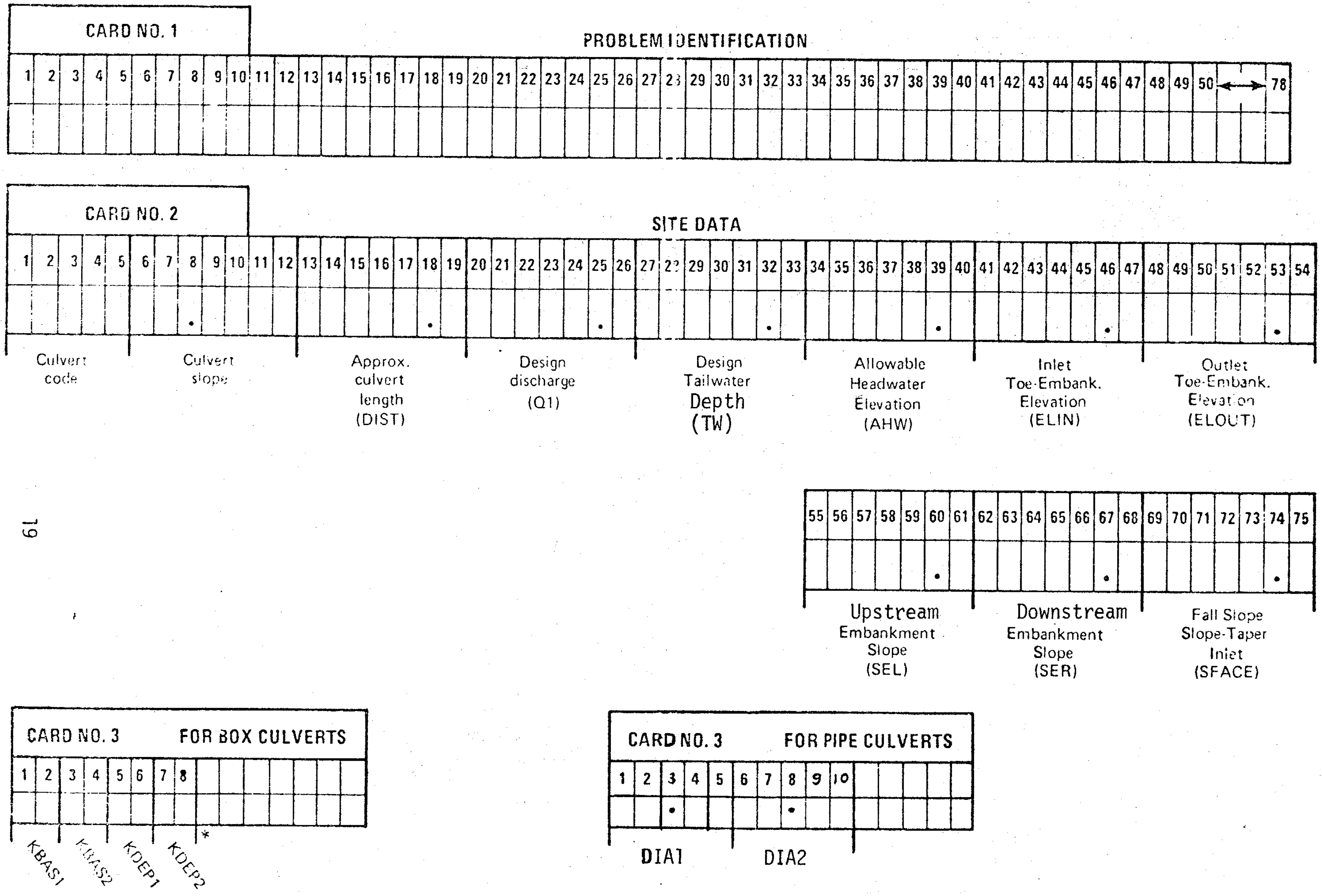


Figure 5

INPU)TA



*BOX CULVERT AND PIPE CULVERT SIZES—SEE INPUT SECTION

Figure 6

INPUT SECTION

DATA CARD SET-UP

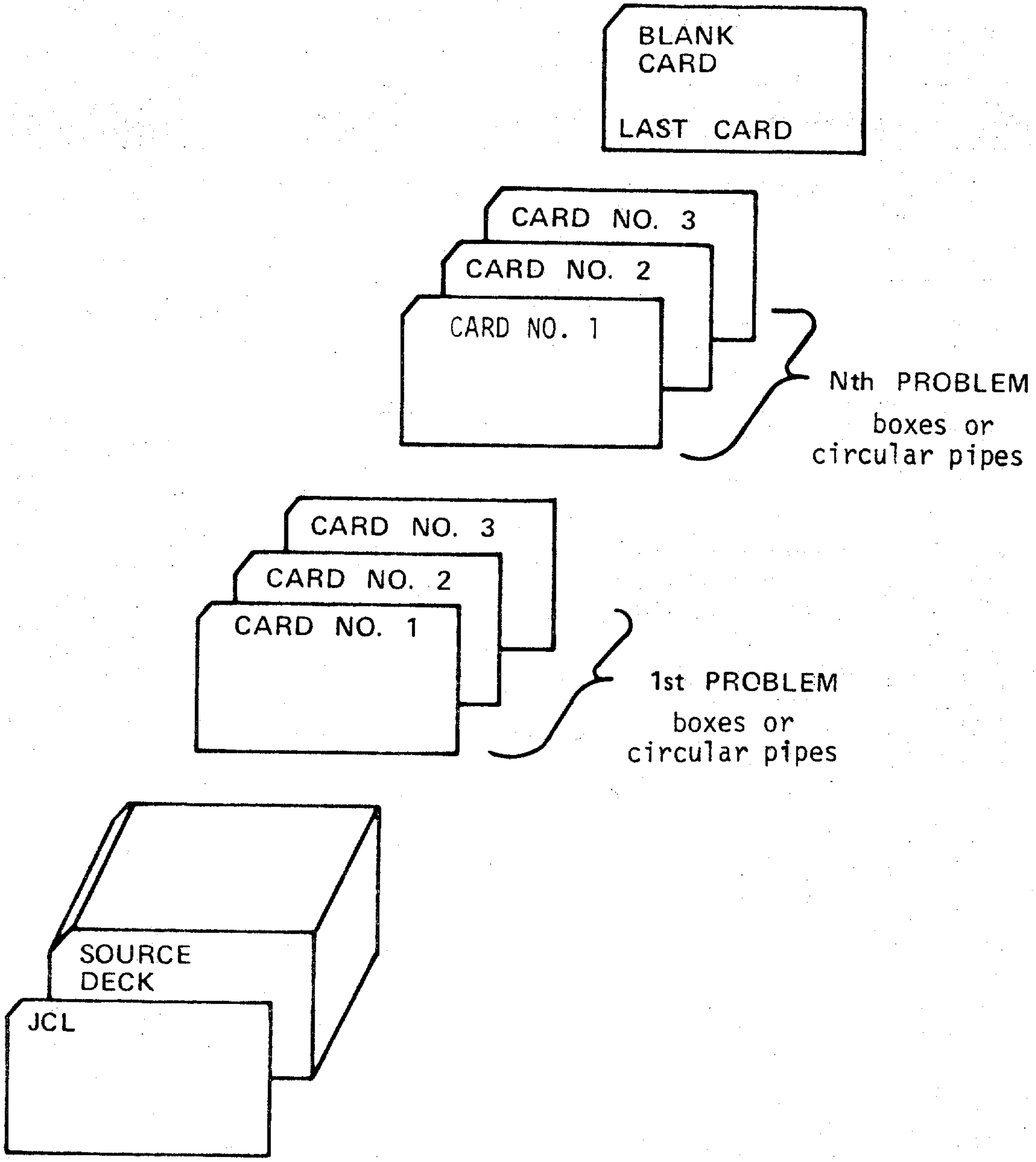


Figure 7

OUTPUT DATA SECTION

OUTPUT DATA SECTION

The output data for this program is divided into two groups, (1) INDEX SHEET and (2) CULVERT DESIGN DATA SHEETS.

I. INDEX SHEET

The problem identification, information describing the types of bevel-edged inlets used and the design input data are printed at the top of the INDEX SHEET.

As previously stated, the function of the INDEX SHEET is to show the relationship between the inlet control section (headwater elevation, necessary external FALL and invert elevation) for a conventional inlet, a bevel-edged inlet and a tapered inlet (throat); also the headwater elevation and invert elevation for the outlet control section of a culvert.

The following is a description of the input data items by columns. See example problem No. 1 for output reference.

Page Reference

This page number refers to the culvert design data sheet for each culvert size listed on the INDEX SHEET.

Number of Barrels

This column is self-explanatory.

Barrel Width

The barrel width, in feet.

Barrel Depth or Diameter

The barrel depth or diameter, in feet.

Outlet Control Headwater Computations

KE = 0.5 - this column represents the outlet control headwater elevation for a culvert with a conventional inlet where the entrance loss coefficient is 0.5. Other possible coefficients used in this program are described in Table 2 for box culverts and Table 7 for circular pipes.

KE = 0.2 - This columns represents the outlet control headwater elevation for a bevel-edged, side-tapered and slope-tapered culvert inlet, where the entrance loss coefficient is 0.2.

The third column represents the culvert outlet invert elevation.

Inlet Headwater Computations

Conventional Culvert - The three columns in the group represent the headwater elevation, the external FALL, and the invert elevation for a culvert with a conventional inlet.

Bevel-Edged Culvert - The three columns in this group represent the headwater elevation, the external FALL, and the invert elevation for the optional bevel-edged inlet culvert.

Throat-Improved Inlets - The three columns in this group represent the throat elevation, the throat FALL*, and the throat invert elevation for side-tapered and slope-tapered vertical face inlets.

Whenever a box or pipe size being analyzed by the computer does not satisfy the design criteria, a set of dashes "---" will be printed as output data on the INDEX SHEET and the culvert design data sheets; also, when the program user wishes to bypass the conventional culvert design and go directly to the bevel and improved inlet design, the computer will print dashes "---" in the column noted by the conventional culvert heading.

For pipe culverts, the INDEX SHEET will show the pipe sizes in groups according to the type of corrugated metal group investigated. For instance, the INDEX SHEET for example problem No. 2A shows three pipe sizes listed under the 2 2/3" by 1/2" corrugated metal and three pipe sizes listed under 3" by 1" corrugated metal. More information on the grouping of pipe sizes by corrugation type is presented under the section for Circular Pipes.

II.. CULVERT DESIGN DATA SHEET

A culvert design data sheet will be printed for each culvert size listed on the INDEX SHEET with the reference page number printed at the top of the page. This page numbering system will be helpful

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* This FALL is measured between the face invert elevation at the stream bed and the throat elevation for side-tapered and slope-tapered vertical face designs. FALL for slope-tapered mitered face inlet is measured from crest elevation to throat elevation (not shown on INDEX SHEET, but shown on design sheets).

in locating the design data for any of the culverts listed on the INDEX SHEET. Also printed at the top of the page for easy reference will be the number of barrels, barrel width, barrel depth, design discharge, allowable headwater elevation, stream slope and the FALL slope for a slope-tapered inlet.

The design output data are printed under the following five headings:

1. Conventional inlet design for culvert code: (XXXXX).
2. Beveled inlet design for culvert code: (XXXXX).
3. Side-tapered inlet design.
4. Slope-tapered inlet design - vertical face.
5. Slope-tapered inlet design - mitered face.

A brief discussion of each heading follows:

1. Conventional Inlet Design for Culvert Code: (XXXXX)

If the INDEX SHEET shows dashes for a particular culvert size, no design data is available and the program prints a message, bypasses the conventional design and proceeds to the bevel inlet design (see example problem 1).

If there is data on the INDEX SHEET, then the program computes and prints inlet design data for (1) Minimum Fall — Curve A, (2) Maximum Q — Curve B, and (3) Minimum Headwater — Curve C. This is followed by performance curve data for each of the three mentioned conditions and the outlet control performance curve data for the culvert.

2. Beveled Inlet Design for Culvert Code: (XXXXX)

The output design data for this type inlet consists of (1) Minimum FALL — Curve A, (2) Maximum Q — Curve B, and (3) Minimum Headwater — Curve C, plus the inlet and outlet control performance curve data. If bevel-edged design data is not available (represented by dashes on INDEX SHEET), the data output will consist of a message plus the outlet control performance curve data. This performance curve also applies as the outlet control performance curve for culverts designed with improved inlets (refer to HEC No. 13).

3. Side-tapered Inlet Design

The output consists of the Minimum FALL — Curve A, Maximum Q -- Curve B, Minimum Headwater -- Curve C, and the inlet control performance curve data. The outlet control performance curve data is shown under bevel-edged design.

4. Slope-tapered Inlet Design -- Vertical Face

The output data consists of the Minimum FALL — Curve A, Maximum Q -- Curve B plus the inlet control performance curve data for each design. The outlet control performance curve data is shown under beveled design. The computer algorithm for the Minimum Headwater -- Curve C design has not been developed.

5 Slope-tapered Inlet Design -- Mitered Face

Same as 4.

TECHNICAL PROCEDURES

- BOX CULVERT SECTION
- CIRCULAR CULVERT SECTION

BOX SECTION

This portion of the program presents the equations and the design criteria pertaining to box culvert analysis and design.

MATHEMATICAL EQUATIONS

Inlet Control

Headwater Depth (1)

$H_f = (D)\ [(Y) - (S)(SCORR)]$

Where: H_f = headwater in feet

D = height of culvert in feet

$Y = a+bX+cX^2+dX^3+eX^4+fX^5$

a, b, c, d, e, f = coefficients determined by polynomial curve fitting (see subroutine BEQUA for coefficients)

S = slope of culvert in feet per foot

SCORR = slope correction factor (Table 2, page 39)

$X = Q/BD^{3/2}$

Q = discharge in cubic feet per second

B = width in feet

The equations were determined by a computer program which fitted a polynomial curve by the method of least squares to data taken from the nomographs for inlet control in HEC No. 5 and throat control and face control from HEC No. 13.

The equations are located in subroutines called BEQUA, BSIDE, BSLOPV, BSLOPM.

BOX SECTION

Outlet Velocity

$V = Q/A$ (2)

$A = Q/[(1.486/n)(R^{2/3}S^{1/2})]$ (3)

Where: V = outlet velocity in feet per second

Q = discharge in cubic feet per second

A = Cross-sectional area of water in square feet at any depth of flow

R = hydraulic radius in feet

S = slope of culvert in feet per foot

n = Manning's roughness factor

Normal depth is computed by subroutine BNORM using a polynomial equation developed from OPEN CHANNEL HYDRAULICS (5).

Outlet Control

Head

$H = (Q/10)^2[(1.555(K_e+1.0)/A^2)+(45.095n^2L/(A^2R^{4/3}))]$ (4)

Where: H = head in feet for culvert flowing full

Q = discharge in cubic feet per second

K_e = coefficient for entrance loss

A = total cross-sectional area of box

n = Manning's roughness factor

L = length of culvert in feet (actual culvert length)

R = hydraulic radius in feet

Critical Depth

$D_c = 0.315(Q/B)^{2/3}$

Where: D_c = critical depth in feet

Q = discharge in cubic feet per second

B = width of box in feet

Headwater Elevation

$$HWEL = HO + H + \text{Culvert Outlet Invert Elevation} \quad (6)$$

Where: HWEL = headwater elevation in feet

H = head for full flow in feet

HO = design tailwater or $(D_c + D)/2$ whichever is greater

D = height of culvert in feet

D_c = critical depth in feet

The critical depth cannot exceed the height of the box.

Test for Full Flow Condition

$$H_f = D + (1 + K_e)\ V^2/2g \quad (7)$$

Where: H_f = headwater depth in feet

K_e = coefficient for entrance loss

D = height of culvert in feet

V = mean velocity for full cross section of barrel in feet per second

<u>Backwater</u> (Water surface profile for normal depth greater than or equal to critical depth)

When tailwater is equal to or less than critical depth or normal depth, equations (8) and (9) are used to compute water surface profiles. When tailwater is greater than normal and critical depth, equations (9) and (10) are used to compute water surface profiles.

$$X = [(d_2+V_2^2/2g) - (d_1+V_1^2/2g)]/(S - S_o) \qquad \text{(M2 Curve)} \qquad (8)$$

Where: X = distance in feet between cross sections 1 and 2

d_1, d_2 = depths of water in feet at cross sections 1 and 2

V_1, V_2 = velocities in feet per second at sections 1 and 2

S_o = slope of the culvert in feet per foot

$g = 32.2$ ft./sec.^{2}

$S = n^2V^2/(2.21R^{4/3})$, average slope of the water surface between cross sections 1 and 2 in feet per foot (9)

n = Manning's roughness factor

V = average velocity in feet per second of the two cross sections

R = average hydraulic radius in feet of the two cross sections

$$X = [(d_1+V_1^2/2g) - (d_2+V_2^2/2g)]/(S_o - S) \qquad \text{(M1 Curve)} \qquad (10)$$

so that: $HW = d_2 + V_2^2/2g + k_eV_1^2/2g$ (10A)

Outlet Velocity

$$V=Q/A \qquad (11)$$

Where: V = outlet velocity in feet per second

Q = discharge in cubic feet per second

A = cross-sectional area of water in square feet

Area is determined from the following conditions:

When: $DTW \geq D$, $A = (B)(D)$

$DSUBC \geq D$, $DSUBC = D$

$DSUBC > DTW$, $A = (B)(DSUBC)$

$DSUBC < DTW$, $A = (B)(DTW)$

Where: DTW = design tailwater in feet

D = height of culvert in feet

$DSUBC$ = critical depth in feet

BOX SECTION

DESIGN CRITERIA

This program is based on the hydraulic design criteria in HEC No. 5 and HEC No. 13 and was developed to provide flexibility in satisfying many different design requirements used by various highway agencies.

To assist users wanting to change design features (within the limits expressed in HEC No. 13), the following is a presentation of the design criteria used in this program. Before modifying the limitations, check HEC No. 13 to ascertain that such modifications are valid.

CONVENTIONAL CULVERT DESIGN CRITERIA - Square and Bevel-Edged

1. Inlet and outlet control headwater $\geq$ (AHWEL - D/4) and $\leq$ AHWEL
2. D (height) not greater than 1.2B (width)
3. B not greater than 2D
4. Crown elevation not greater than controlling headwater elevation.
5. If inlet headwater elevation > allowable headwater elevation, use a FALL at inlet invert.
6. FALL not to exceed Max FALL

   Where: Max FALL = 1.5D*
   or inlet invert elevation not less
   than outlet invert elevation
7. Culvert sizes range from B = KBAS1** to B = KBAS2 and

   D = KDEP1** to D = KDEP2 in increments of even feet.
8. Minimum crest length based on Chart 17 in HEC No. 13.

---

* Limitations related to HEC No. 13

** See input data

BOX SECTION

SIDE-TAPERED INLET - Design Criteria

1. Design limited to two barrel structure*
2. Taper = 4:1 to 6:1*
3. FALL $\leq$ Max FALL

   Where: Max FALL = 1.5D*
   or face invert elevation not less than
   outlet invert elevation
4. 45° face bevels: $b = BF/2$ inches
   if $BF > 3D$ use $b = 3D/2$
   $d = D/2$ inches
5. If FALL $< D/4$, there is no minimum crest length

SLOPE-TAPERED INLET - VERTICAL FACE - Design Criteria

1. Design limited to two barrel structure*
2. Taper = 4:1 to 6:1*
3. Fall slope (SF) = input data from 2:1 to 3:1 inclusive*
4. L3 $\geq$ 0.5B*
5. 1.5D $\geq$ FALL $\geq$ D/4*
6. Throat elevation > outlet invert elevation
7. FALL = Vertical distance between face invert elevation and throat invert elevation

---

* Limitations related to HEC No. 13

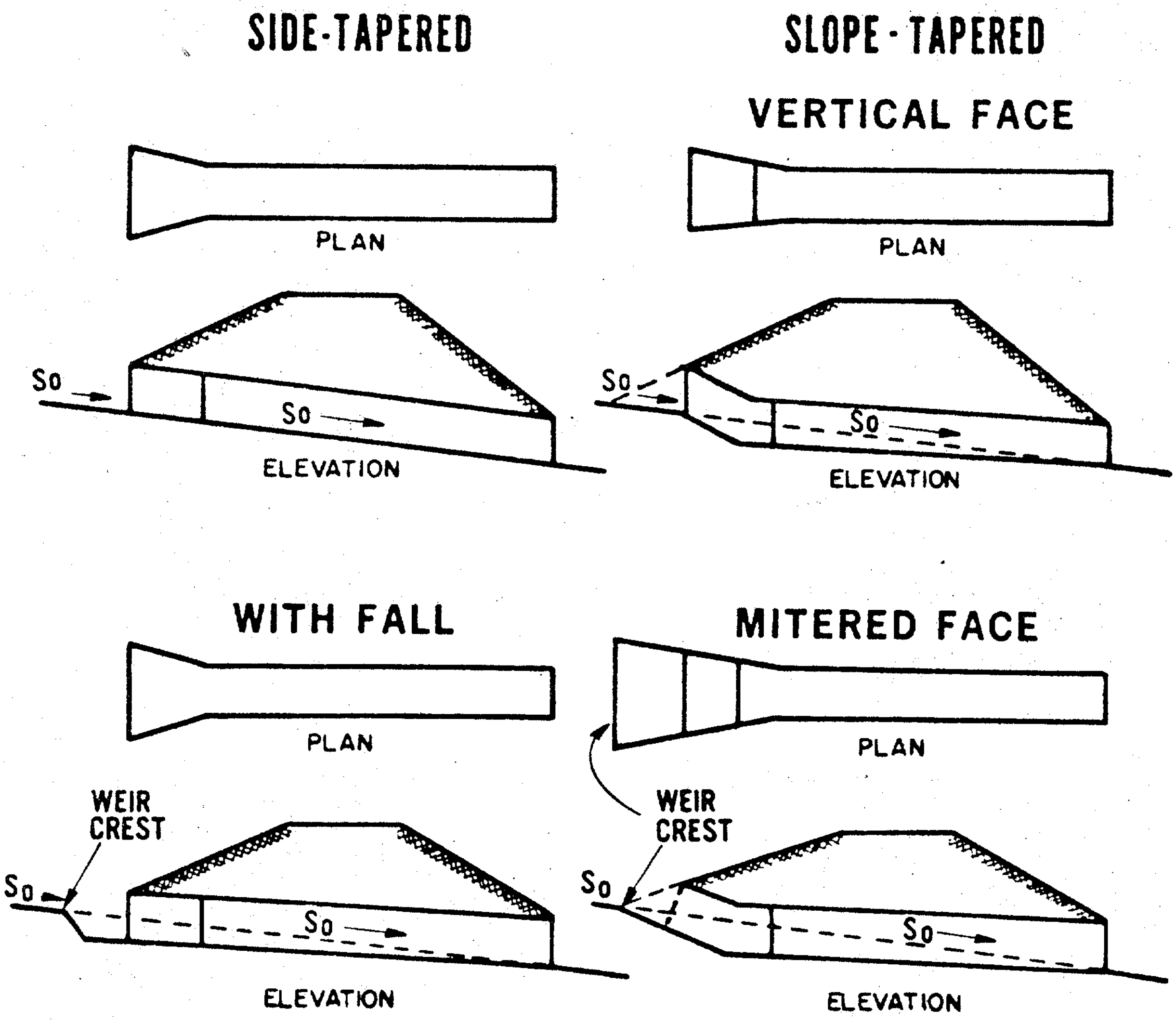
BOX SECTION

SLOPE-TAPERED INLET--MITERED-FACE - Design Criteria

1. Design limited to two barrel structure*
2. Taper = 4:1 to 6:1*
3. Fall slope (SF) = input data from 2:1 to 3:1 inclusive*
4. L3 $\geq$ 0.5B*
5. 1.5D $\geq$ FALL $\geq$ D/4*
6. Throat elevation > outlet invert elevation
7. FALL = Vertical distance between crest invert elevation and throat invert elevation

---

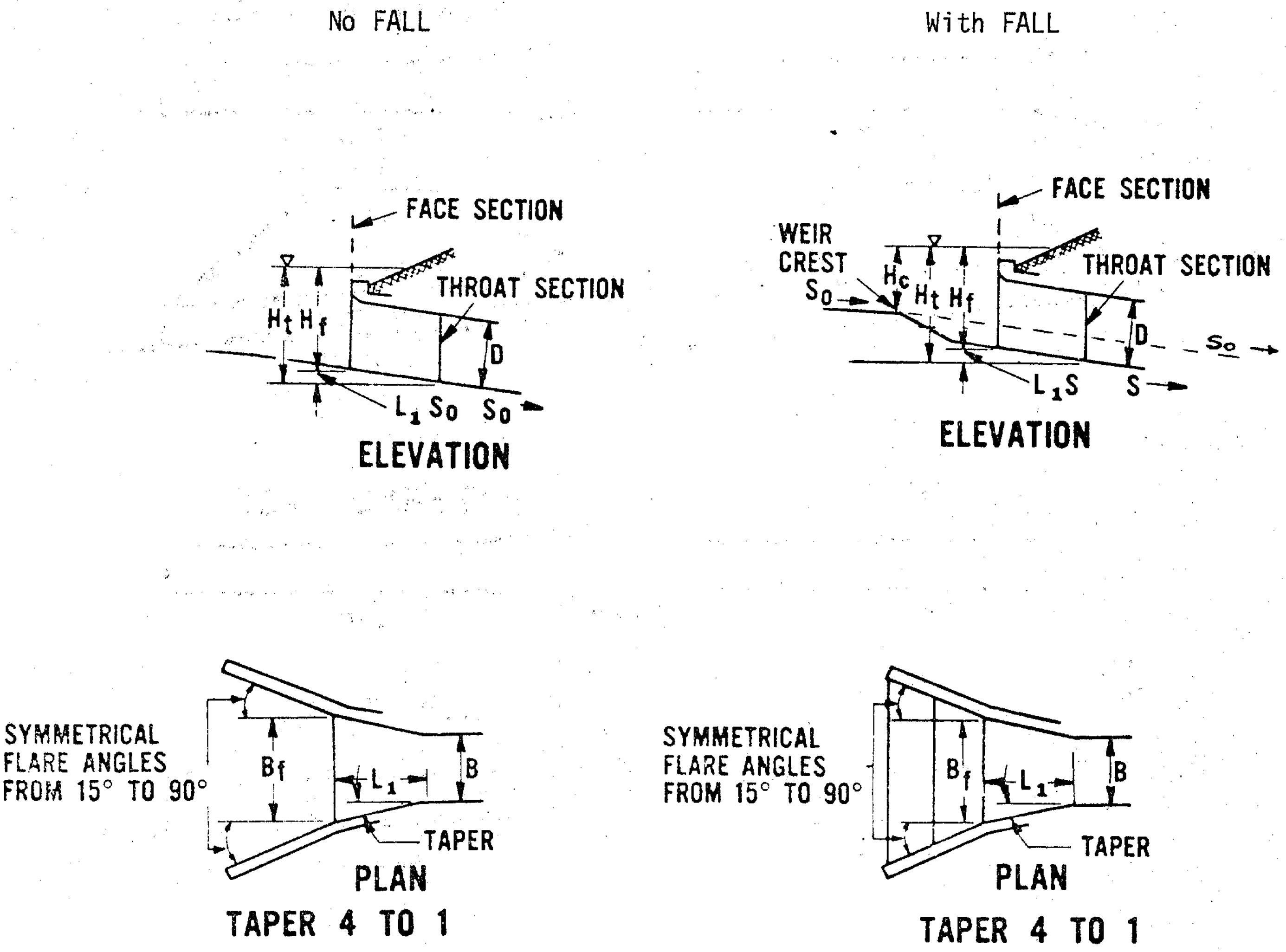
* Limitations related to HEC No. 13



TYPES OF IMPROVED INLETS FOR BOX CULVERTS

Figure 8

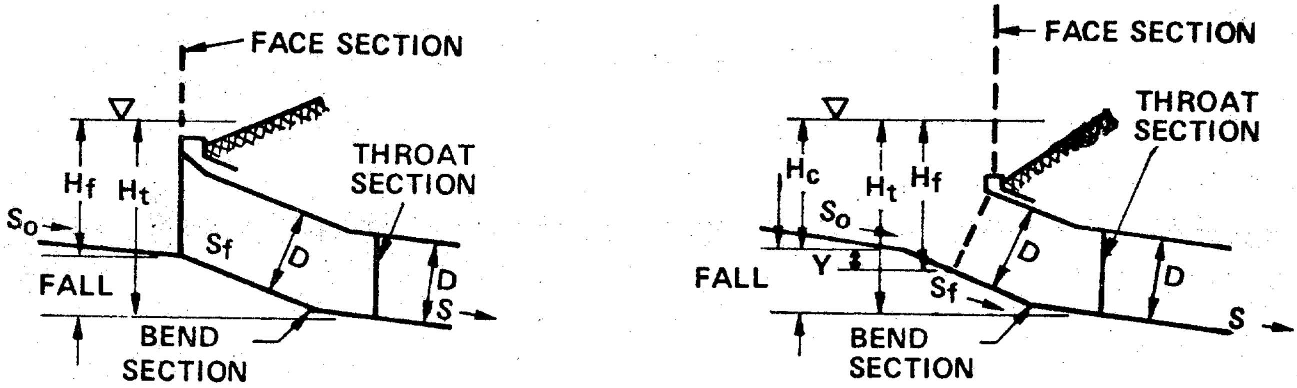
BOX SECTION



SIDE-TAPERED INLETS

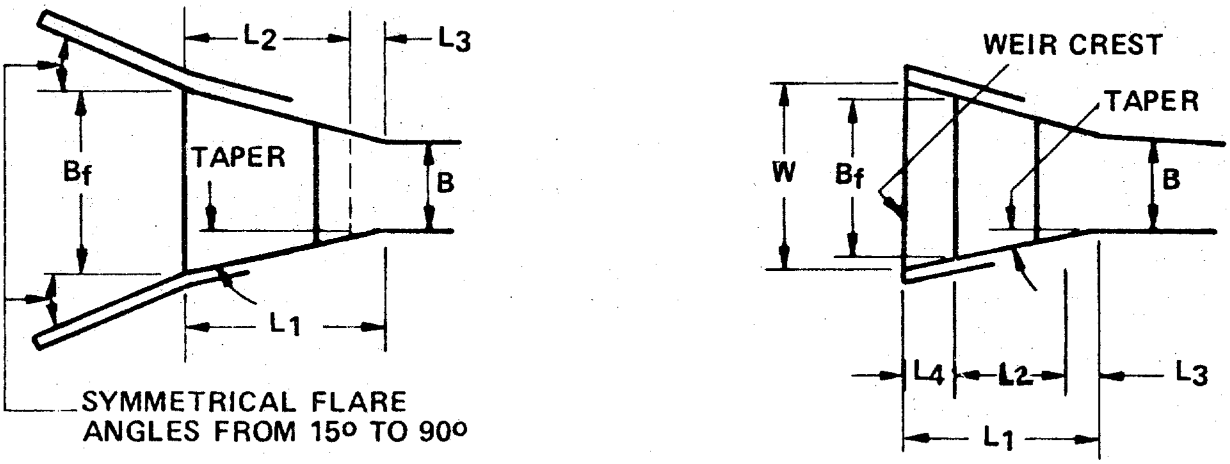
Figure 9

BOX SECTION



ELEVATION

ELEVATION



PLAN

PLAN

SLOPE-TAPERED VERTICAL FACE and SLOPE-TAPERED MITERED FACE

Figure 10

BOX SECTION

Table 1 - Box Culvert Codes

Square-Edge and Bevel-Edge Reinforced Concrete Box (RCB)

CODE					INLET TYPE
I1	I2	I3	I4	I5	
4	1	1	1	1	WINGWALLS - 30° - 75° WW Flare Square-top edge HEC 13, Chart 7
4	1	1	2	2	HEADWALLS - Normal (90°) or skewed to 45° - Square edge HEC 13, Chart 7
4	1	1	2	3	WINGWALLS - with 15° WW flare having square edges HEC 13, Chart 7
4	1	1	3	4	WINGWALLS - 0° flare square top edge HEC 13, Chart 7
4	1	1 Bevel Option 1	4	5	HEADWALL - Normal or skewed to 45° with 1:1 bevels (variable bevel on acute angle of skewed HEADWALL, HEC 13 Chart No. 8, 9)
4	1	1 Bevel Option 2	4	6	WINGWALLS - 18° - 33.7° WW flare with 1 1/2:1 top bevel - with 45° flare with 1:1 top bevel HEC 13 Chart No. 10
4	1	1	4	7	HEADWALL - Normal with 1 1/2:1 bevels on 3 sides HEC 13, Chart 8

BOX SECTION

Table 2 - Hydraulic Constants

Velocity Distribution	Alpha = 1.00
Slope Correction Factor	SCORR = 0.50
Manning's n	cn = 0.012

I4	Entrance Loss Coefficients	
1	30° to 75° WW flare	CKE(1) = 0.40
2	HEADWALL (90° WW) or skewed to 45°	CKE(2) = 0.50
2	15° WW flare	CKE(2) = 0.50
3	0° WW flare (parallel)	CKE(3) = 0.70
4	Bevel-edged inlets	CKE(4) = 0.20

EXAMPLE PROBLEM

- BOX CULVERT

EXAMPLE PROBLEM No. 1

This problem simulates the site conditions for a box culvert design (problem No. 1) found in HEC No. 13. The following INDEX SHEET illustrates the various culvert sizes (both single and double barrel) which can accommodate the design flow.

At a glance, the hydraulic design engineer can view the headwater relationship for inlet control and outlet control for a conventional, bevel-edged and slide-tapered inlet and determine which control governs. For the range of culvert sizes analyzed, all the single barrel and several double barrel culverts require a certain amount of FALL. The page numbers listed in the left-hand column of the INDEX SHEET refer to the data output page containing the design data for each culvert size. For this example, only the design data referred to by pages 1 and 2 (6 ft. by 7 ft. and 7 ft. by 6 ft. culverts) are included to limit the size of the publication.

A comparison of the design data for the 7 ft. width by 6 ft. depth culvert (page 2 of the output) with example problem No. 1 in HEC No. 13 shows the closeness of the respective values. The differences arise from the methods of calculation. The hand method is based on chart and nomograph readings whereas the computer solution utilizes mathematical equations.

Figure 11 shows the performance curves for the side-tapered design.

CARD NO. 1

PROBLEM IDENTIFICATION

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 ←→ 73	TEST PROBLEM FOR CODE 41122 SLOPE=0.05

CARD NO. 2

SITE DATA

1 2 3 4 5	6 7 8 9 10 11 12	13 14 15 16 17 18 19	20 21 22 23 24 25 26	27 28 29 30 31 32 33	34 35 36 37 38 39 40	41 42 43 44 45 46 47	48 49 50 51 52 53 54	55 56 57 58 59 60 61	62 63 64 55 66 67 68	69 70 71 72 73 74 75
41122	0.05	386.0	1000.0	3.5	200.0	191.0	171.7	3.0	3.0	2.0
Culvert code	Culvert slope	Approx. culvert length (DIST)	Design discharge (Q1)	Design Tailwater (TW)	Allowable Headwater Elevation (AHW)	Inlet Toe-Embank. Elevation (ELIN)	Outlet Toe-Embank. Elevation (ELOUT)	Left Embankment Slope (SEL)	Right Embankment Slope (SER)	Fall Slope Slope-Taper Inlet (SFACE)

CARD NO. 3 FOR BOX CULVERTS

1 2	3 4	5 6	7 8*	
6	7	6	7	
KBAS1	KBAS2	KDEP1	KDEP2	

CARD NO. 3 FOR PIPE CULVERTS

~~1 2~~	~~3 4~~*	5 6 7 8
KD1A1	KD1A2	

*BOX CULVERT AND PIPE CULVERT SIZES—SEE INPUT SECTION

INDEX SHEET

```
>>>>  BOX CULVERT DESIGN FOR PROJECT >>>   SAMPLE PROBLEM FOR CODE 41122  SLOPE=.05


>>>>  THE PROGRAM PROVIDES A RANGE OF CONVENTIONAL BOX CULVERT SIZES WITH AND WITHOUT BEVELS WHICH SATISFY SITE REQUIREMENTS

                         WHERE:  BEVELED EDGES INCLUDE THE FOLLOWING.

                              HEADWALLS-NORMAL -CHART NO. 8 IN HEC-13
                                    -SKEWED -CHART NO. 9 IN HEC-13

                              WINGWALLS -CHART NO. 10 IN HEC-13


>>>>  IF INLET CONTROL GOVERNS - IMPROVED INLET DESIGNS ARE PROVIDED FOR SIDE-TAPERED INLETS
                                                       AND SLOPE-TAPERED INLETS


***********************************************************************************************************************
**************************      DESIGN INPUT DATA      ****************************************************************
**************************      DESIGN INPUT DATA      ****************************************************************
***********************************************************************************************************************

   CONVENTIONAL CULVERT CODE:  41122  HEADWALL  - NORMAL OR SKEWED TO 45 DEGREES - SQ TOP EDGES       KE= 0.5

   BEVEL-EDGED CULVERT CODE:   41145  HEADWALL - NORMAL OR SKEWED TO 45 DEGREES WITH 1:1 BEVELS
                               (VARIABLE BEVEL ON ACUTE ANGLE OF SKEWED HEADWALL)                     KE= 0.2

               APPROX     TOE-TOE                                ALLOWABLE   STREAM BED   STREAM BED   LEFT ROADWAY   RIGHT ROADWAY
   CULVERT     STREAM     CULVERT    DESIGN      DESIGN          HEADWATER   ELEVATION    ELEVATION    EMBANKMENT     EMBANKMENT
    CODE       SLOPE      LENGTH    DISCHARGE   TAILWATER        ELEVATION   AT INLET     AT OUTLET      SLOPE          SLOPE
   41122       0.0500     396.0     1000.0        3.5             200.0       191.0        171.7         3.0:1          3.0:1

   CULVERT  SIZES                              SLOPE-TAPER
      B  FROM   6 FT TO   7 FT                 FALL SLOPE            COMPUTED STREAM
      D  FROM   6 FT TO   7 FT                   2.0:1                SLOPE = 0.0500

***********************************************************************************************************************
**************************      INDEX  SHEET  FOR  BOX  CULVERTS      *************************************************
**************************      INDEX  SHEET  FOR  BOX  CULVERTS      *************************************************
***********************************************************************************************************************

                              *  -- OUTLET CONTROL --    **                          -- INLET CONTROL --                           *
                              *                          **                                                                        *
                              * KE= 0.5  KE=0.2  OUTLET ** CONVENTIONAL CULVERT  *  BEVEL-EDGED CULVERT   * SIDE-TAPERED CULVERT   *
                              ----------------------------------------------------------------------------------------------------
* SEE  *NUMBER *BARREL*BARREL*  H       HW      INVERT ** HW              INVERT *  HW              INVERT * THROAT            INVERT *
* PAGE *  OF   * WIDTH* DEPTH* ELEV    ELEV     ELEV  ** ELEV    FALL     ELEV  *  ELEV    FALL     ELEV  *HW ELEV   FALL     ELEV  *
*      *BARRELS* (FT) * (FT) * (FT)    (FT)     (FT)  ** (FT)    (FT)     (FT)  *  (FT)    (FT)     (FT)  *  (FT)    (FT)     (FT)  *
*      *       *      *      *                        **                        *                         *                         *
*  1   *   1   *  6.0 *  7.0 *  --     197.1    172.9 **  --      --       --   *   --      --       --   * 200.0    6.9     183.2 *
*  2   *   1   *  7.0 *  6.0 *  --     190.1    172.7 **  --      --       --   *   --      --       --   * 200.0    6.1     184.1 *
```

INDEX SHEET (CONT'D)

```
*  3  *  1  *  7.0 *  7.0 *   --     192.1    172.9 **   --      --       -- * 200.0    8.6    181.2 * 200.0    4.3    185.8 *
*  4  *  2  *  6.0 *  6.0 *  185.8   184.9    172.7 ** 200.0    2.5    187.7 * 200.0    1.1    189.1 * 198.9    0.5    189.7 *
*  5  *  2  *  6.0 *  7.0 *  184.4   183.7    172.9 ** 200.0    1.1    189.0 * 200.0    0.2    189.9 * 198.8    0.5    189.6 *
*  6  *  2  *  7.0 *  6.0 *  183.4   182.8    172.7 ** 200.0    0.5    189.3 * 199.5    0.0    190.2 * 197.8    0.7    189.6 *
*  7  *  2  *  7.0 *  7.0 *  182.6   182.1    172.9 ** 199.5    0.0    190.1 * 198.9    0.0    190.1 * 197.6    0.6    189.5 *

          BY DEFINITION OF FALL, WHEN A SIDE-TAPERED INLET LIES ON THE STREAM SLOPE,
          THE FALL IS THE DIFFERENCE IN ELEVATION OF THE FACE INVERT AND THE THROAT INVERT

          WHEN SIDE-TAPERED CULVERT COLUMN (ABOVE) CONTAINS 0.0 0.0 0.0
              1. THROAT DESIGN EXCEEDS DESIGN LIMITS
           OR 2. IMPROVED INLETS FOR MORE THAN 2 BARRELS NOT AVAILABLE
```

DESIGN A-PAGE 1

BOX SECTION

```
PAGE=  1     NO. BARRELS= 1    WIDTH=  6.0 FT    HEIGHT=  7.0 FT    Q(50)= 1000.0 CFS    AHWEL=  200.0 FT    STREAM SLOPE = 0.0500
                                                 OUTLET INVERT ELEV. =  172.9 FT


CONVENTIONAL INLET DESIGN FOR CULVERT CODE; 41122
**************************************************

              DESIGN DATA NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE CONVENTIONAL INLET EXCEEDS 1.5D OR LSO.


BEVELED INLET DESIGN FOR CULVERT CODE:41145
**************************************************

              DESIGN DATA NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE BEVEL-EDGED INLET EXCEEDS 1.5D OR LSO
              THIS OUTPUT CONSISTS OF THE OUTLET CONTROL PERFORMANCE CURVE DATA FOR KE = 0.2
              WHICH IS APPLICABLE FOR THE IMPROVED INLETS.

                       Q           HWO                 MAX Q =    1078. CFS

                     800.0        190.9
                    1000.0        197.1
                    1200.0        204.7
                    1400.0        213.7
                    1600.0        224.1


SIDE TAPERED INLET DESIGN
************************           FACE EDGE BEVELS = 45 DEG    SIDE TAPER = 4:1

       MIN FALL DESIGN                         MAX  Q  DESIGN                               MIN HW DESIGN

                                               MAX Q =  1078. CFS


  CULVERT LENGTH     =  364.0 FT          CULVERT LENGTH     =  368.9 FT          CULVERT LENGTH     =  372.5 FT
  FALL               =    6.9 FT          FALL               =    8.5 FT          FALL               =    9.8 FT
  ELEV THROAT INVERT=  183.2 FT           ELEV THROAT INVERT=  181.5 FT           ELEV THROAT INVERT=  180.3 FT
  ELEV FACE INVERT   =  183.3 FT          ELEV FACE INVERT   =  181.7 FT          ELEV FACE INVERT   =  180.4 FT
  CULVERT SLOPE      = 0.0087             CULVERT SLOPE      = 0.0238             CULVERT SLOPE      = 0.0202
  VEL AT DESIGN Q    =  32.1 FPS          VEL AT MAX Q       =  30.3 FPS          VEL AT DESIGN Q    =  27.9 FPS
  FACE WIDTH         =   8.52 FT          FACE WIDTH         =   8.53 FT          FACE WIDTH         =   8.5 FT
  L1                 =   5.05 FT          L1                 =   5.07 FT          L1                 =   5.00 FT
  MIN CREST LENGTH   =   16.7 FT          MIN CREST LENGTH   =   19.8 FT          MIN CREST LENGTH   =   19.9 FT
  BEVELS =  45 DEGREE                     BEVELS =  45 DEGREE                     BEVELS =  45 DEGREE
      B =  4.3 IN  D =  3.5 IN                B =  4.3 IN  D =  3.5 IN                B =  4.2 IN  D =  3.5 IN
```

DESIGN DATA -PAGE 1 (CONT'D)

```
     Q          HWT         HWF

   800.0       196.4       196.0
  1000.0       200.0       199.8
  1200.0       204.4       204.6
  1400.0       209.8       210.3
  1500.0       215.8       216.4


SLOPE TAPERED INLET DESIGN - VERTICAL FACE
******************************************

    DISTANCE EMBANKMENT-TOE TO FACE =  20.42 FT

        MIN FALL DESIGN

    CULVERT LENGTH      =  341.8 FT
    FALL                =    6.8 FT
    ELEV THROAT INVERT=  183.2 FT
    ELEV FACE INVERT    =  190.0 FT
    CULVERT SLOPE       = 0.0318
    VEL AT DESIGN Q     =  33.5 FT
    FACE WIDTH          =  12.64 FT
    L1                  =  18.39 FT
    L2                  =   15.4 FT
    L3                  =    3.0 FT
    SF                  =   2.00
    TAPER               = 5.54:1

      Q          HWT         HWF

    800.0       196.4       196.0
   1000.0       200.0       199.8
   1200.0       204.4       201.8
   1400.0       209.8       204.3
   1600.0       215.8       207.2
```

```
     Q          HWT         HWF

   800.0       194.8       194.3
  1000.0       198.4       198.1
  1200.0       202.8       202.9
  1400.0       208.2       208.6
  1600.0       214.2       214.7


CULVERT OUTLET TO EMBANKMENT-TOE =  23.74 FT

 MAX  Q  DESIGN

 CULVERT LENGTH      =  341.8 FT
 FALL                =    8.4 FT
 ELEV THROAT INVERT=  181.5 FT
 ELEV FACE INVERT    =  190.0 FT
 CULVERT SLOPE       = 0.0271
 VEL AT MAX Q        =  31.9 FT
 FACE WIDTH          =  13.62 FT
 L1                  =  21.69 FT
 L2                  =   18.7 FT
 L3                  =    3.0 FT
 SF                  =   2.00
 TAPER               = 5.69:1

       Q          HWT         HWF

     800.0       194.8       197.6
    1000.0       198.4       199.1
    1200.0       202.8       200.9
    1400.0       208.2       203.0
    1600.0       214.2       205.5
```

```
     Q          HWT         HWF

   800.0       193.6       193.1
  1000.0       197.1       196.9
  1200.0       201.6       201.8
  1400.0       206.9       207.5
  1600.0       213.0       213.6
```

DESIGN DATA-PAGE 1 (CONT'D)

```
SLOPE TAPERED INLET DESIGN - MITERED  FACE
******************************************

      MIN FALL DESIGN

   CULVERT LENGTH      =  362.3 FT
   FALL                =    7.9 FT
   ELEV THROAT INVERT=  183.2 FT
   ELEV FACE INVERT    =  187.9 FT
   CULVERT SLOPE       = 0.0301
   VEL AT DESIGN Q     =   32.3 FPS
   FACE WIDTH          =  10.62 FT
   L1                  =  20.22 FT
   L2                  =    7.8 FT
   L3                  =    3.0 FT
   L4                  =    9.4 FT
   SF                  =   2.00
   TAPER               = 1.69:1

       Q          HWT         HWF

     800.0       196.4       197.2
    1000.0       200.0       199.6
    1200.0       204.4       202.5
    1400.0       209.8       206.2
    1600.0       215.8       210.4
```

```
      MAX  Q  DESIGN

   CULVERT LENGTH      =  362.3 FT
   FALL                =    9.5 FT
   ELEV THROAT INVERT=  181.5 FT
   ELEV FACE INVERT    =  187.9 FT
   CULVERT SLOPE       = 0.0255
   VEL AT MAX  Q       =   31.1 FPS
   FACE WIDTH          =  11.44 FT
   L1                  =  23.57 FT
   L2                  =   11.2 FT
   L3                  =    3.0 FT
   L4                  =    9.4 FT
   SF                  =   2.00
   TAPER               = 5.22:1

       Q          HWT         HWF

     800.0       194.8       196.6
    1000.0       198.4       198.7
    1200.0       202.8       201.2
    1400.0       208.2       204.3
    1600.0       214.2       207.9
```

DESIGN DATA-PAGE 2

```
PAGE=  2     NO. BARRELS= 1    WIDTH=  7.0 FT    HEIGHT=  6.0 FT    Q(50)= 1000.0 CFS    AHWEL=  200.0 FT    STREAM SLOPE = 0.0500
                                                 OUTLET INVERT ELEV. =  172.7 FT


CONVENTIONAL INLET DESIGN FOR CULVERT CODE  41122
*************************************************

              DESIGN DATA NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE CONVENTIONAL INLET EXCEEDS 1.5D OR LSO.


BEVELED INLET DESIGN FOR CULVERT CODE:41145
*************************************************

              DESIGN DATA NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE BEVEL-EDGED INLET EXCEEDS 1.5D OR LSO
              THIS OUTPUT CONSISTS OF THE OUTLET CONTROL PERFORMANCE CURVE DATA FOR KE = 0.2
              WHICH IS APPLICABLE FOR THE IMPROVED INLETS.

                     Q          HWO                MAX Q =   1106. CFS

                   800.0       189.3
                  1000.0       196.1
                  1200.0       203.7
                  1400.0       212.8
                  1600.0       223.2


SIDE TAPERED INLET DESIGN
*************************        FACE EDGE BEVELS = 45 DEG     SIDE TAPER = 4:1

        MIN FALL DESIGN                           MAX  Q  DESIGN                          MIN HW DESIGN

                                                  MAX Q =  1106. CFS

   CULVERT LENGTH     =  367.3 FT           CULVERT LENGTH     =  374.2 FT           CULVERT LENGTH     =  376.0 FT
   FALL               =    6.1 FT           FALL               =    8.3 FT           FALL               =    9.0 FT
   ELEV THROAT INVERT=  184.1 FT            ELEV THROAT INVERT=  181.9 FT            ELEV THROAT INVERT=  181.2 FT
   ELEV FACE INVERT   =  184.3 FT           ELEV FACE INVERT   =  182.0 FT           ELEV FACE INVERT   =  181.4 FT
   CULVERT SLOPE      = 0.0316              CULVERT SLOPE      = 0.0249              CULVERT SLOPE      = 0.0230
   VEL AT DESIGN Q    =  33.9 FPS           VEL AT MAX Q       =  31.6 FPS           VEL AT DESIGN Q    =  29.9 FPS
   FACE WIDTH         =   9.99 FT           FACE WIDTH         =  10.03 FT           FACE WIDTH         =   10.0 FT
   L1                 =   5.98 FT           L1                 =   6.06 FT           L1                 =   5.91 FT
   MIN CREST LENGTH   =   16.2 FT           MIN CREST LENGTH   =   20.5 FT           MIN CREST LENGTH   =   19.4 FT
   BEVELS =  45 DEGREE                      BEVELS =  45 DEGREE                      BEVELS =  45 DEGREE
      B =  5.0 IN  D =  3.0 IN                 B =  5.0 IN  D =  3.0 IN                 B =  5.0 IN  D =  3.0 IN
```

DESIGN DATA-PAGE 2 (CONT'D)

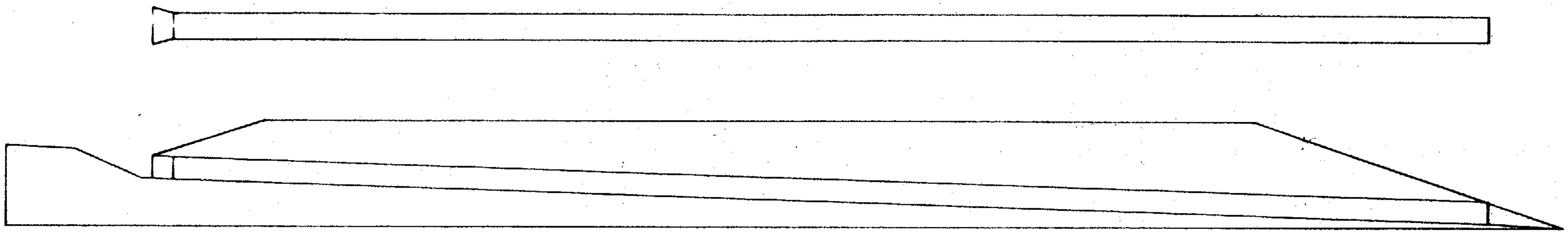
```
   Q        HWT      HWF               Q        HWT        HWF              Q        HWT       HWF

  800.0    196.4    196.1             800.0    194.1      193.7           800.0    193.5     193.1
 1000.0    200.0    199.9            1000.0    197.7      197.5          1000.0    197.1     197.0
 1200.0    204.5    204.7            1200.0    202.2      202.3          1200.0    201.6     201.8
 1400.0    209.8    210.2            1400.0    207.5      207.7          1400.0    206.9     207.3
 1600.0    215.6    215.7            1600.0    213.4      213.3          1600.0    212.7     212.9


SLOPE TAPERED INLET DESIGN - VERTICAL FACE
******************************************

    DISTANCE EMBANKMENT-TOE TO FACE =  17.50 FT          CULVERT OUTLET TO EMBANKMENT-TOE =  20.35 FT

         MIN FALL DESIGN                                   MAX  Q  DESIGN


    CULVERT LENGTH     =  348.1 FT                        CULVERT LENGTH     =  348.1 FT
    FALL               =    6.0 FT                        FALL               =    8.2 FT
    ELEV THROAT INVERT=  184.1 FT                         ELEV THROAT INVERT=  181.9 FT
    ELEV FACE INVERT   =  190.1 FT                        ELEV FACE INVERT   =  190.1 FT
    CULVERT SLOPE      = 0.0345                           CULVERT SLOPE      = 0.0280
    VEL AT DESIGN Q    =  35.0 FT                         VEL AT MAX Q       =  33.1 FT
    FACE WIDTH         =  13.98 FT                        FACE WIDTH         =  15.45 FT
    L1                 =  15.33 FT                        L1                 =  21.46 FT
    L2                 =   13.3 FT                        L2                 =   18.0 FT
    L3                 =    3.5 FT                        L3                 =    3.5 FT
    SF                 =   2.00                           SF                 =   2.00
    TAPER              = 4.82:1                           TAPER              = 5.08:1
```

DESIGN DATA-PAGE 2 (CONT'D)

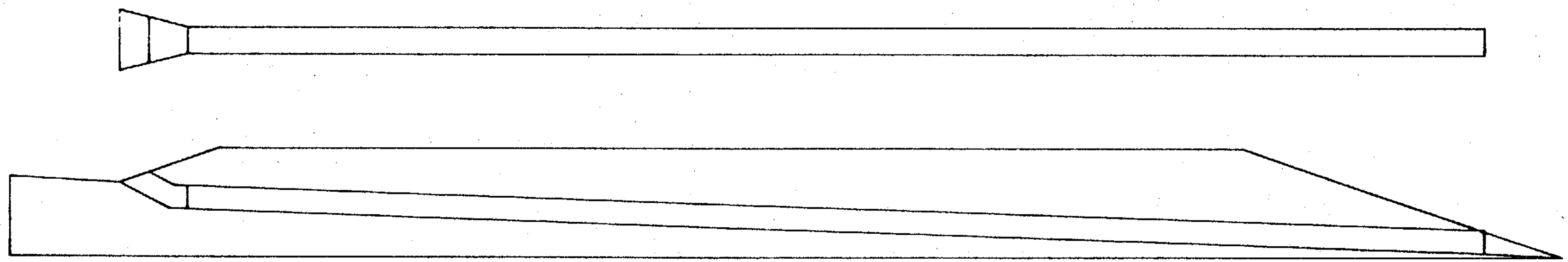
```
      Q          HWT         HWF                                  Q          HWT         HWF

    800.0       196.4       197.8                               800.0       194.1       197.2
   1000.0       200.0       199.7                              1000.0       197.7       198.6
   1200.0       204.5       202.0                              1200.0       202.2       200.6
   1400.0       209.8       204.8                              1400.0       207.5       202.9
   1600.0       215.6       208.1                              1600.0       213.4       205.6


SLOPE TAPERED INLET DESIGN - MITERED  FACE
*****************************************

      MIN FALL DESIGN                                        MAX  Q  DESIGN


      MIN FALL DESIGN                                        MAX Q DESIGN

   CULVERT LENGTH     =  365.6 FT                               - -
   FALL               =    6.9 FT                               - -
   ELEV THROAT INVERT=  184.1 FT                                - -
   ELEV FACE INVERT   =  186.3 FT                               - -
   CULVERT SLOPE      =   0.0329                                - -
   VEL AT DESIGN  Q    =  34.4 FPS                              - -
   FACE WIDTH         =  12.07 FT                               - -
   L1                 =  18.40 FT                               - -
   L2                 =    6.9 FT                               - -
   L3                 =    3.5 FT                               - -
   L4                 =    8.0 FT                               - -
   SF                 =     2.00                                - -
   TAPER              = 4.08:1                            --

      Q          HWT         HWF                                  Q          HWT         HWF

    800.0       196.4       197.2                                           --
   1000.0       200.0       199.7                                           --
   1200.0       204.5       202.8                                           --
   1400.0       209.8       206.7                                           --
   1600.0       215.6       211.1                                           --
```

PLAN AND PROFILE PLOTS

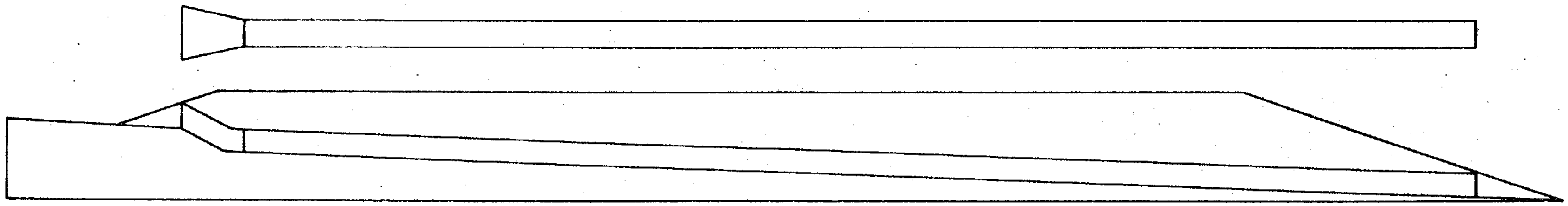
EXAMPLE NO. 1 HEC No. 13 for 7' x 6' Box Culvert



SIDE-TAPERED INLET



SLOPE-TAPERED INLET - MITERED FACE



SLOPE-TAPERED INLET - VERTICAL FACE

EXAMPLE PROBLEM No. 1, PERFORMANCE CURVES
FOR 1-7'x6' SIDE TAPERED BOX CULVERT

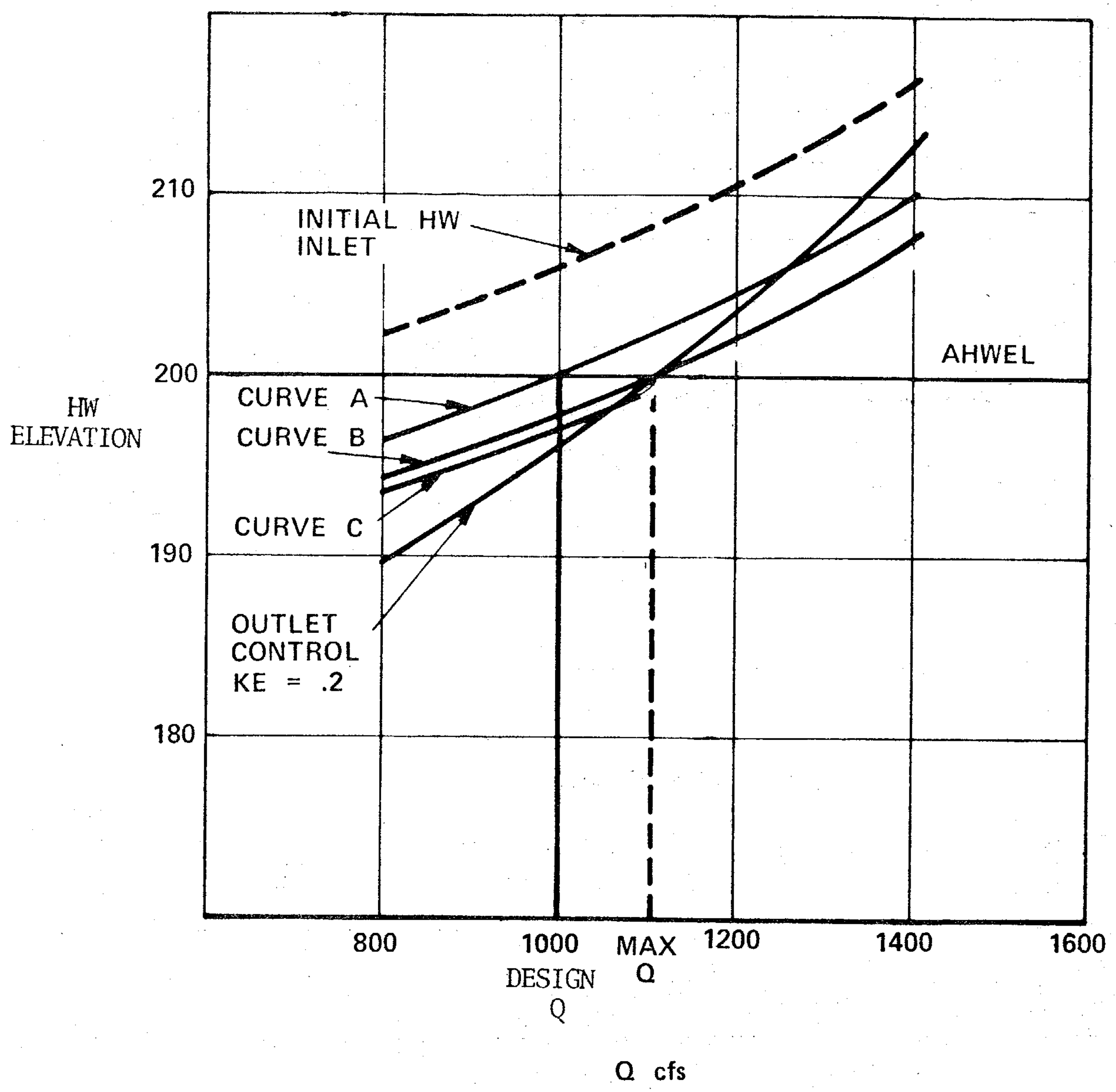


Figure 11

CIRCULAR PIPE SECTION

CIRCULAR PIPE SECTION

This section of the documentation presents design information for conventional and improved inlets for circular pipes, both corrugated metal and concrete. Included herein are the mathematical equations, design criteria and limitations, code numbers for selecting a pipe type, tables of pipe sizes with associated "n" values for each pipe size, a table of hydraulic constants and example problems.

It should be noted under the section on "Design Criteria and Limitations," that design for side-tapered (flared) metal inlets is based on the standard metal inlet design shown in Figure 12. HEC No. 13 side-tapered designs can be used by initiating the program instructions which are stored in the program as comment cards.

The pipe designs provided by the computer program are divided into three basic categories, i.e., partly paved corrugated metal, unpaved corrugated metal and concrete pipes.

For the metal pipes, Figure 13 shows the three types of metal corrugations that were programmed into the computer process to provide the hydraulic design engineer with sufficient data and still maintain some flexibility in his choice of design options. The choice of design options is controlled by the culvert code indicator, I3, and the options are shown in Table 3.

CIRCULAR PIPE SECTION

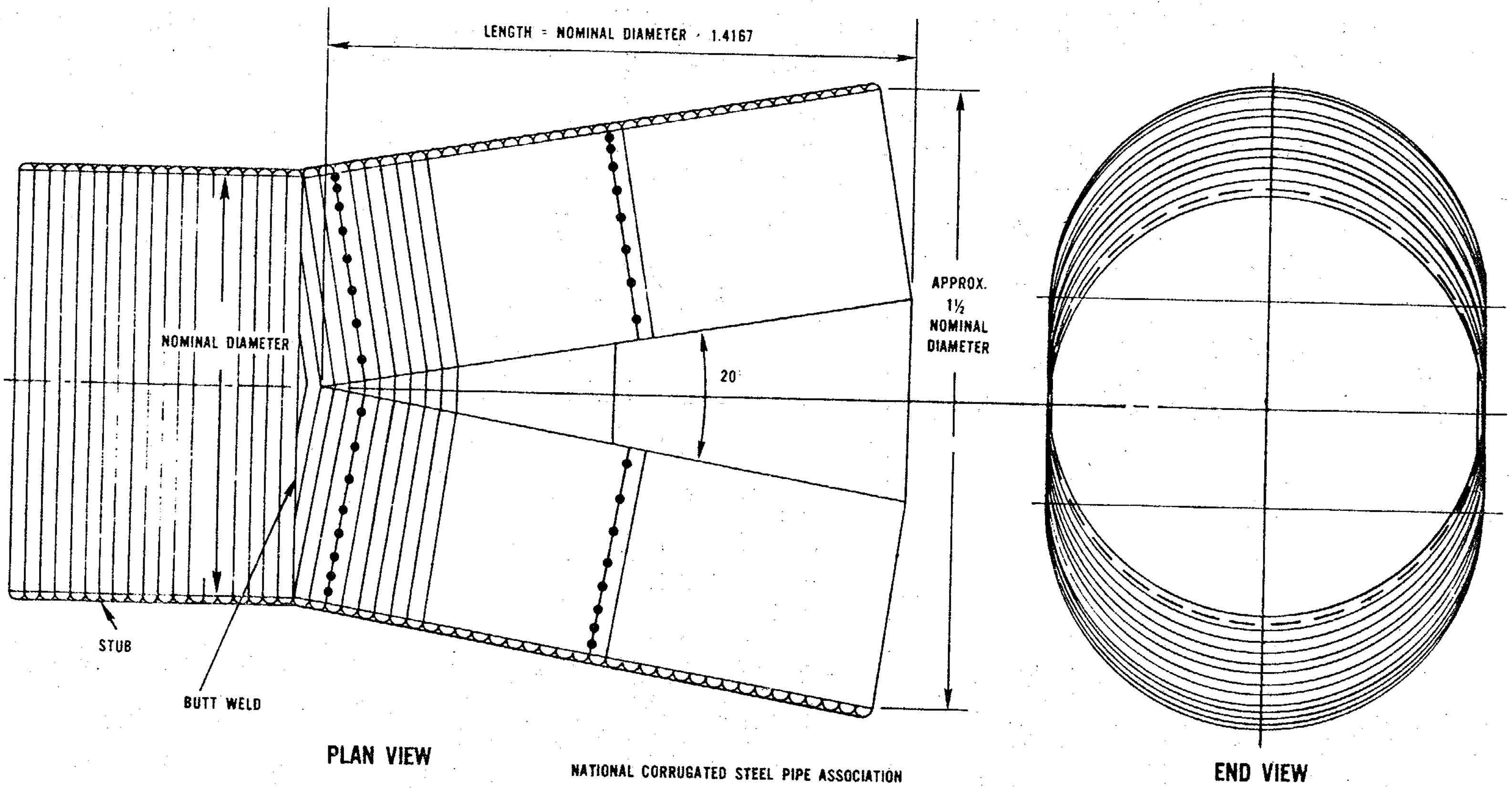
Table 3

Code Indicator: I3	Options for Corrugated Metal Designs	
	25% Paved Pipe	Unpaved Pipe
When I3 = 1	2-2/3"x1/2", 3"x1", 6"x2"	2-2/3"x1/2", 3"x1", 6"x2"
I3 = 2	3"x1", 6"x2"	3"x1", 6"x2"
I3 = 3	6"x2"	6"x2"

The design options presented in Table 3 are interpreted as follows: If I3 is equal to 1, then the culvert output design data for each of the three corrugated metal types is provided for either the paved or unpaved culverts. If I3 is equal to 2 or 3, then the design data for the corrugated metal types shown is provided for either the paved or unpaved culverts. In example problems 2A and 2B, I3 is equal to 1 and the Index Sheets show the design option as indicated by Table 3 for unpaved CMP. However, in problem 2A, for the range of pipe sizes investigated (4 ft. to 5 ft. diameter) no 6" by 2" corrugated metal pipes satisfied the design criteria.

---

* See Table 6 page 71 for the Circular Pipe Culvert Codes.



NATIONAL CORRUGATED STEEL PIPE ASSOCIATION
DATE = MARCH 1975

STANDARD FLARED INLET

Figure 12

CIRCULAR PIPE SECTION

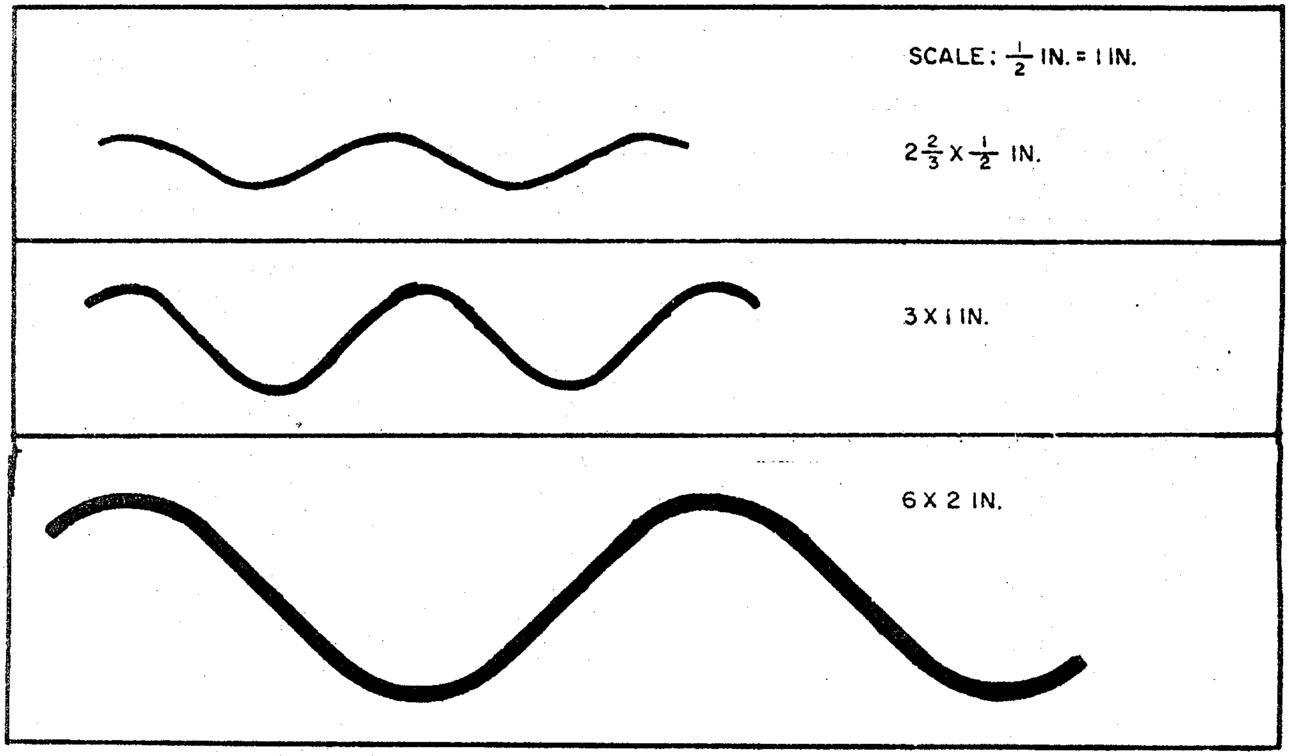


Figure 13. Types of Corrugations Investigated.

The 2 2/3" by 1/2" and 3" by 1" corrugated metal pipes are normally riveted and the 6" by 2" structural plate pipes are assembled at the construction site.

CIRCULAR PIPE SECTION

Table 4

Circular Corrugated Metal Pipe Sizes and "n" Values -- Unpaved* for Full Flow

2 2/3" x 1/2" corrugations		3" x 1" corrugations		6" x 2" corrugations	
Dia	n**	Dia	n**	Dia	n**
1.0	.0260	3.0	.0281	5.0	.0332
1.5	.0255	3.5	.0278	5.5	.0330
2.0	.0247	4.0	.0275	6.0	.0327
2.5	.0244	4.5	.0273	6.5	.0325
3.0	.0241	5.0	.0271	7.0	.0323
3.5	.0237	5.5	.0269	7.5	.0321
4.0	.0235	6.0	.0267	8.0	.0320
4.5	.0233	6.5	.0266	8.5	.0318
5.0	.0232	7.0	.0265	9.0	.0317
5.5	.0231	7.5	.0264	9.5	.0315
6.0	.0229	8.0	.0263	10.0	.0314
6.5	.0228	8.5	.0262	10.5	.0313
7.0	.0227	9.0	.0261	11.0	.0312
7.5	.0226	9.5	.0260	11.5	.0311
8.0	.0225	10.0	.0260	12.0	.0310
				12.5	.0309
				13.0	.0308
				13.5	.0307
				14.0	.0307
				14.5	.0306
				15.0	.0305
				15.5	.0305
				16.0	.0304
				16.5	.0304
				17.0	.0303
				17.5	.0303
				18.0	.0302
				18.5	.0302
				19.0	.0301
				19.5	.0301
				20.0	.0300
				20.5	.0300
				21.0	.0300

* For partly paved CMP, the program uses "n" values based on the equation n = .75 x n + (.25)(.012).

** Based on Research and Development Staff Report "Hydraulic Flow Resistance Factors for Corrugated Metal Conduits," dated September 1970.

Table 5

Concrete Pipe Sizes and "n" Values

Dia	"n"
2.00	.012
2.25	"
2.50	"
2.75	"
3.00	"
3.50	"
4.00	"
4.50	"
5.00	"
5.50	"
6.00	"
6.50	"
7.00	"
7.50	"
8.00	"
8.50	"
9.00	"
9.50	"
10.00	"
10.50	"
11.00	"
11.50	"
12.00	"
12.50	"
13.00	"
13.50	"
14.00	"
14.50	"
15.00	"

CIRCULAR PIPE SECTION

MATHEMATICAL EQUATIONS

The mathematical equations for circular pipes are as follows:

INLET CONTROL HEADWATER - Conventional and Bevel-Edged Inlets

$$H_f = (D)[Y-(S)(SCORR)] \tag{1}$$

Where: H_f = headwater depth in feet

$Y = A + BX + CX^2 + DX^3 + EX^4 + FX^5$

D = diameter of pipe in feet

A, B, C, D, E & F are coefficients listed on page 73

SCORR = slope correction factor (table 7, page 73)

S = the slope of the pipe in feet per foot

$X = Q/D^{5/2}$

Q = discharge in cfs

INLET CONTROL HEADWATER - Side-Tapered Inlets

1. Throat Control - (Chart 18, HEC No. 13)

a. Rough Inlets (CMP)

$$H_t/D = -.23339 + .48913X + 1.06864X^2 - 3.074435X^3 + 3.711165X^4 - 1.32836X^5 \tag{2}$$

Where: $X' = (Q/BAR)/DIA^{5/2}$
$X = \log (X')$
BAR = No. of barrels

b. Smooth Inlets - (concrete)

$$H_t/D = -0.23714 + .14679X + 2.18932X^2 - 4.354114X^3 + 4.210539X^4 - 1.347032X^5 \tag{3}$$

Where: $X' = (Q/BAR)/DIA^{5/2}$
$X = \log (X')$

2. Face Control - (Chart 19, HEC No. 13)
Face control headwater is computed based on face sizes established by Standard Flared Inlets, where face width is 1.5D and L1 = 1.4167D. Figure 12 represents a standard flared inlet proposed by the National Corrugated Steel Pipe Association. Equations for face control based on HEC No. 13 are found in Subroutine CSIDE.

INLET CONTROL HEADWATER - Slope-Tapered Inlets (Chart 16, HEC No. 13)

The inlet designs for slope-tapered inlets are based on Chart 16 (Solid line) in HEC No. 13, face control curves for box culverts. The equation to compute face width is:

$$B_f = Q/(Y \times DIA^{3/2})$$

Where:

$$Y = 2.26586 + 7.94244X - 4.03503X^2 + 1.61948X^3 -.34582X^4 +.0284677X^5 \qquad (4)$$

$X = H_f/DIA$

H_f = allowable Headwater elevation minus face elevation

Throat control equations for slope-tapered inlets same as for side-tapered inlets on page 60.

Outlet Velocity

$$Q = [1.486/n](AR^{2/3} S^{1/2})$$

Where:
Q = discharge in cfs
A = area of water in sq. ft. at any depth of flow defined by equation (13), page 64
WP = wetted perimeter in feet at an depth of flow by equation 14, page 64
R = hydraulic radius in feet = A/WP
S = slope of the pipe in feet per foot
n = Manning's roughness value

CIRCULAR PIPE SECTION

Outlet Control Equations

$$H = \left[1 + K_e + \frac{185.0\ n^2 L}{D^{4/3}} \right] \left[\frac{Q^2}{(39.725)(D)^4} \right] \qquad (6)$$

Where: H = the head for circular culverts flowing full, in feet

K_e = the entrance loss coefficient

L = length of pipe in feet

D = diameter of pipe in feet

Critical Depth

$$\frac{\alpha Q^2}{g} = \frac{A^3}{T} \qquad (7)$$

Where: Q = discharge in cfs

α = alpha, coefficient

g = 32.2 ft/sec^2

A = the area of water in sq. ft. at any depth defined by equation (13), page 64

T = the top surface width of water in feet at any depth of flow defined by equation (15), page 64

Outlet Control Headwater

HW = TEMP + H + elevation of outlet invert, in feet

Where: TEMP = Distance to the hydraulic gradeline from the culvert outlet invert

HW = the headwater elevation, in feet

d_c = critical depth, in feet

When: $d_c \geq D$ and $D > TW$, then TEMP = D

$d_c < D$ and $\frac{d_c + D}{2} > TW$, then $TEMP = \frac{d_c + D}{2}$

$TW > D$ or $TW > \frac{d_c + D}{2}$, then TEMP = TW

Where: TW = tailwater height, in feet

H = head for full flow, in feet

CIRCULAR PIPE SECTION

Water Surface Profiles for $d_n \geq d_c$

$$X = \frac{\left(d_1 + \frac{V_1^2}{2g} \right) - \left(d_2 + \frac{V_2^2}{2g} \right)}{S_o - S} \qquad \text{(M1 Curve)} \qquad (9)$$

$$X = \frac{\left(d_2 + \frac{V_2^2}{2g} \right) - \left(d_1 + \frac{V_1^2}{2g} \right)}{S - S_o} \qquad \text{(M2 Curve)} \qquad (10)$$

Where:

X = distance in feet between two sections of water

d_1, d_2 = depths in feet at sections 1 and 2 respectively

V_1, V_2 = velocities in feet per second at sections 1 and 2

S_o = slope of the pipe in feet per foot

$$S = \frac{n^2V^2}{2.21\ R^{4/3}}$$

S = the slope of the water surface in feet per foot

R = the average hydraulic radius in feet of the two sections

Based on water surface profiles in the culvert, the headwater is:

$$HW = d_2 + \frac{V_2^2}{2g} + \frac{k_eV_1^2}{2g} \qquad (11)$$

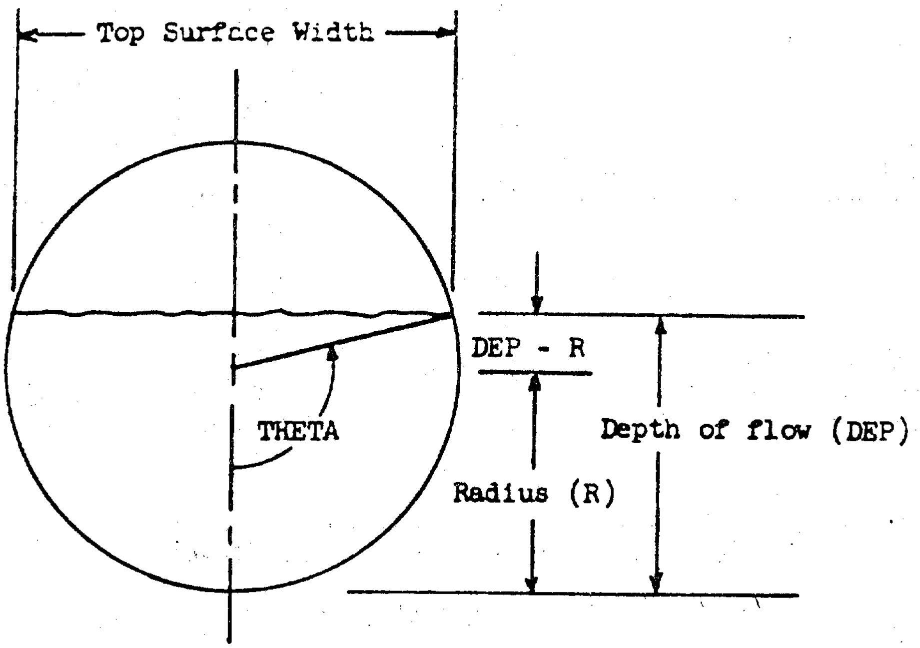
Where: d_2 = either the height of culvert or water depth at inlet depending on the water surface profile in the culvert

k_e = the entrance loss coefficient for the specific inlet type

Outlet Velocity

$$V = \frac{Q}{A}$$

CIRCULAR PIPE SECTION



$$A = (DEP-R)\sqrt{(2R)\ (DEP) - DEP^2} + R^2\left[\pi/2 + \mathrm{Sin}^{-1}\ \left(\frac{DEP-R}{R}\right)\right] \qquad (13)$$

For DEP $<$ R use ABS((DEP-R)/R) and use ($-\mathrm{Sin}^{-1}$)

Where A is the area in square feet

$$WP = 2R\ [\pi/2 + \mathrm{Sin}^{-1}\ (\frac{DEP-R}{R})] \qquad (14)$$

Where WP is the wetted perimeter in feet

$$T = 2\sqrt{R^2 - (DEP-R)^2} \qquad (15)$$

Where T is the top surface width in feet

Side-Tapered and Slope-Tapered Inlets

The equations for throat control and face control for the CMP and concrete pipes (representing charts 18 and 19, HEC No. 13) are located in subroutines CSIDE and CSLOPV. These equations are polynomials developed by a curve fitting technique.

CIRCULAR PIPE SECTION

DESIGN CRITERIA AND LIMITATIONS

The design criteria and limitations are basically the same as for box culverts as indicated in HEC No. 13 and are listed below along with additional circular pipe criteria for ease in accessability.

<u>CONVENTIONAL CMP AND CONCRETE PIPE - Culvert Design Criteria</u>

1. Inlet control headwater and outlet control headwater $\geq$ (AHWEL - D/4) $\leq$ AHWEL. Where AHWEL is the allowable headwater elevation.

2. Pipe sizes limited to diameter sizes listed in tables 4 and 5.

3. Pipe material includes 2 2/3" by 1/2", 3" by 1", 6" by 2" corrugated metal and concrete.

4. Mannings "n" values for partly paved CMP are based on the equation:

   $n = (0.75)\ n_1 + .25\ (.012)$, where n_1 represents the "n" value for the same pipe diameter as "n" but without paving and .012 represents "n" value for concrete.

5. Crown elevation not greater than controlling headwater elevation.

6. Use FALL at inlet invert when inlet headwater is greater than allowable headwater.

7. FALL not to exceed Maximum FALL.

   Where: Max FALL = 1.5D*
   or inlet invert elevation not less than outlet invert elevation.

8. Minimum crest length based on Chart 17 in HEC No. 13.

---

*Limitations related to HEC No. 13.

CIRCULAR PIPE SECTION

SIDE-TAPERED INLET - Design Criteria

1. E (height) equal to diameter*
2. Face width equal to standard flared inlets (See Figure 12)**
3. $L_1 = 1.4167D$
4. Taper = L_1/(Face width minus DIA)/2
5. FALL = Max FALL*

   Where: Max FALL = 1.5D* or inlet invert elevation not less than outlet invert elevation.
6. Multiple barrels designed as separate single barrels
7. Throat control represented by curves on Chart 18 of HEC No. 13*

---

* Limitations related to HEC No. 13

** National Corrugated Steel Pipe Association

CIRCULAR PIPE SECTION

VERTICAL FACE, SLOPE-TAPERED INLET DESIGN

Inlet design same as for box culvert inlet.

1. Multiple barrels designed as single barrels
2. Taper = 4:1 to 6:1*
3. Fall slope (SF) - Input data from 2:1 to 3:1 inclusive*
4. $L_3 = .5B^*$ Minimum
5. $1.5D \geq \text{FALL} \geq D/4^*$
6. Throat elevation > outlet toe elevation
7. FALL = vertical distance between face invert elevation and throat invert elevation
8. Design for face section limited to solid line curve on Chart 16 of HEC No. 13
9. Rectangular throat section of inlet must be square section with sides equal to diameter of pipe culvert
10. Minimum transition section = D/2

---

* Limitations related to HEC No. 13

CIRCULAR PIPE SECTION

To assist in the use of the pipe culvert code tables, the following definitions will be helpful:

Type of Pipe

1. Riveted corrugated metal pipe - commonly used riveted metal pipe with 2 2/3" x 1/2" corrugations.
2. Riveted corrugated metal pipe - commonly used riveted metal pipe with 3" x 1 corrugations.
3. Structural plate pipe - sections of structural steel plates with 6" x 2" corrugations. Plates are field assembled.
4. Concrete pipe - any concrete pipe in common use. No distinction is made for length of sections or method of casting.

Paved Invert

Paved invert relates to a material, asphalt or concrete plated in the bottom portion of the metal culvert barrel.

Types of Conventional Inlets

1. Projecting - The culvert barrel extends from the embankment. The transverse section at the inlet is perpendicular to the longitudinal axis of the culvert.
2. Mitered - The end of the culvert barrel is on a miter or bevel to conform with the fill slope. All degrees of miter are treated alike in this program since research data on this type of inlet are limited. Headwater is measured from the culvert invert midway of the mitered section.
3. Headwall - A headwall is a concrete or metal structure placed around the entrance of the culvert. Headwalls considered are those having a flush or square edge with the outside edge of the culvert barrel. No distinction is made for wingwalls or skews.

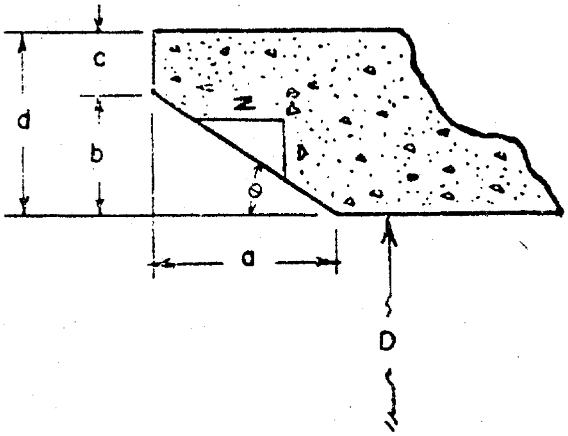
4. End section - This section is the common prefabricated end made of either concrete or metal and placed on the inlet or outlet end of a culvert. The closed portion of the section, if present, is not tapered.

5. Grooved edge - The bell or socket end of a standard concrete pipe is an example of this entrance.

6. Bevel A and Bevel B - These bevels, a type of improved entrance, can be formed of concrete or metal. The shape and dimension for types A and B are shown in the following sketch and table.

BEVELED RING

The bevel should extend a minimum of 300 degrees around the upper portion of the pipe's circumference.



Bevel can be made of Metal or Concrete

BEVEL	$\frac{b}{D}$	$\frac{a}{D}$	$\frac{c}{D}$	$\frac{d}{D}$	Z	θ
A	0.042	0.042	0.042	0.083	1	45°
B	0.063	0.125	0.042	0.125	1 1/2	33.7

CIRCULAR PIPE SECTION

Types of Improved Inlets

The improved inlet types are well defined in HEC No. 13. For side-tapered inlets, the face width determined by HEC No. 13 design procedures for any pipe diameter should be compared to the face width for comparable ready-made standardized side-tapered inlet. The computer program utilizes the face dimensions for a standard inlet as shown in Figure 12.

Slope-tapered inlets for circular pipes, are designed the same as for box culverts with the exception of a transition section with minimum length of D/2 between the rectangular and circular sections. The controlling throat section is at the circular section of the throat.

Table 6

METAL PIPE CULVERT CODE INDICATORS[**]

Inlet Type	RIVETED With 2 2/3" x 1/2" Corrugation					RIVETED With 3" x 1" Corrugation					STRUCTURAL PLATE With 6"x2" Corrugation				
	I1	I2	I3	I4	I5	I1	I2	I3	I4	I5	I1	I2	I3	I4	I5
Projecting (112)[***]	1	1	1	1	1*	1	1	2	1	1*	1	1	3	1	1*
Mitered (81)	1	1	1	2	2*	1	1	2	2	2*	1	1	3	2	2*
Headwall (7)	1	1	1	3	3*	1	1	2	3	3*	1	1	3	3	3*
End Section (51)	1	1	1	3	5	1	1	2	3	5	-	-	-	-	-
Bevel (A) (option)	1	1	1	4	6	1	1	2	4	6	1	1	3	4	6
Bevel (B)	1	1	1	4	7	1	1	2	4	7	1	1	3	4	7

	RIVETED % 25% Paved 2 2/3" x 1/2" Corrugation					RIVETED & 25% Paved 3" x 1" Corrugation					STRUCTURAL PLATE & 25% Paved 6" x 2" Corrugation				
	I1	I2	I3	I4	I5	I1	I2	I3	I4	I5	I1	I2	I3	I4	I5
Projecting (112)	1	2	1	1	1*	1	2	2	1	1*	1	2	3	1	1*
Mitered (81)	1	2	1	2	2*	1	2	2	2	2*	1	2	3	2	2*
Headwall (7)	1	2	1	3	3*	1	2	2	3	3*	1	1	3	3	3*
End Section (51)	1	2	1	3	5	1	2	2	3	5	-	-	-	-	-
Bevel (A) (option)	1	2	1	4	6	1	2	2	4	6	1	2	3	4	6
Bevel (B)	1	2	1	4	7	1	2	2	4	7	1	2	3	4	7

---

[*] In the computer, I5 value equals the above value plus 7, giving I5 values of 8, 9, 10

[**] Used in the computer program and references the subscript of the CONSTANTS and Inlet Control Equation Coefficients.

[***] See note on page 72

CIRCULAR PIPE SECTION

Table 6 (cont'd)

CONCRETE PIPE CODE INDICATORS

	I1	I2	I3	I4	I5
Socket-end Projecting (102)***	2	3	4	4	1
Socket-end Headwall (4)	2	3	4	4	2
Square-edge Projecting (101)	2	3	4	3	3
Square-edge Headwall (1)	2	3	4	3	4
End Section (51)	2	3	4	3	5
Bevel (A) (option)	2	3	4	4	6
Bevel (B)	2	3	4	4	7

*** Values in parentheses following the inlet types refer to the hydraulic experimental model number taken from "First Progress Report on Hydraulics of Short Pipes, Hydraulic Characteristics of Commonly Used Pipe Entrances," by John L. French, dated 1955, U.S. Department of Commerce, National Bureau of Standards, pages 48-74.

CIRCULAR PIPE SECTION

Table 7

HYDRAULIC CONSTANTS

I1 - Velocity Distribution Factors

1 CMP $ALPHA_1 = 1.12$**
2 Concrete $ALPHA_2 = 1.04$**

Slope Correction Factor

Scorr = 0.50
Scorr = 0.00 (mitered face)

I4 - Entrance Loss Coefficients

1	CM projecting	$CKE_1 = 0.90$
2	CM mitered	$CKE_2 = 0.70$
3	Sq. edge; Concrete or CMP and end section	$CKE_3 = 0.50$
4	Improved inlets	$CKE_4 = 0.20$
5	Socket-end, concrete headwall or projecting	$CKE_5 = 0.20$

Inlet Control Equation Coefficients

I5	A	B	C	D	E	F	I5
1	0.108786	0.662381	-0.233801	0.0579585	-0.00557890	0.000205052	1
2	0.114099	0.653562	-0.233615	0.0597723	-0.00616338	0.000242832	2
3	0.167287	0.558766	-0.159813	0.0420069	-0.00369252	0.000125169	3
4	0.087483	0.706578	-0.253295	0.0667001	-0.00661651	0.000250619	4
5	0.120659	0.630768	-0.218423	0.0591815	-0.00599169	0.000229287	5
6	0.063343	0.766512	-0.316097	0.0876701	-0.00983695	0.000416760	6
7	0.081730	0.698353	-0.253683	0.0651250	-0.00719750	0.000312451	7
8	0.187321	0.567710	-0.156544	0.0447052	-0.00343602	0.000089661	8
9	0.107137	0.757789	-0.361462	0.1233932	-0.01606422	0.000767390	9
10	0.167433	0.538595	-0.149374	0.0391543	-0.00343974	0.000115882	10

** Values based on Research and Development Staff Report, "Computation of Uniform and Nonuniform Flow in Prismatic Conduits," U.S. Department of Transportation, Federal Highway Administration, November 1972.

EXAMPLE PROBLEM NO. 2A - Corrugated Metal Pipe Design

This design problem, 2A, and the accompanying problem, 2B, simulate corrugated metal and reinforced concrete pipe culvert designs contained in HEC No. 13. The input data for each problem is presented on the attached input data forms. The insignificant difference in values is attributed to the methods of computations, i.e., the computer versus the hand calculation method. Where the hand method uses close approximations in geometric configuration and nomograph interpretation, the computer process is more precise, using geometric and equation oriented computer (algorithms) routines to perform the computations.

As noted previously, the side-tapered (flared) inlet designs produced by the computer program for the Corrugated Metal Pipe follow the standardized inlet dimensions.

INPU [illegible] TA

CIRCULAR PIPE SECTION

CARD NO. 1

PROBLEM IDENTIFICATION

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 ←→ 72
SAMPLE PROB. 2a CM PIPE UNPAVED AHWEL 100 FT

CARD NO. 2

SITE DATA

Culvert code	Culvert slope	Approx. culvert length (DIST)	Design discharge (Q1)	Design Tailwater (TW)	Allowable Headwater Elevation (AHW)	Inlet Toe-Embank. Elevation (ELIN)	Outlet Toe-Embank. Elevation (ELOUT)
1 2 3 4 5	6 7 8 9 10 11 12	13 14 15 16 17 18 19	20 21 22 23 24 25 26	27 28 29 30 31 32 33	34 35 36 37 38 39 40	41 42 43 44 45 46 47	48 49 50 51 52 53 54
11133	0.0500	366.0	150.0	2.0	100.0	93.3	75.0

Left Embankment Slope (SEL)	Right Embankment Slope (SER)	Fall Slope Slope-Taper Inlet (SFACE)
55 56 57 58 59 60 61	62 63 64 65 66 67 68	69 70 71 72 73 74 75
2.0	2.0	2.0

CARD NO. 3 FOR BOX CULVERTS

1 2 3 4 5 6 7 8

CARD NO. 3 FOR PIPE CULVERTS

DIA1	DIA2
1 2 3 4 5	6 7 8 9 10
4.0	5.0

[illegible] SECTION

Figure 6

CIRCULAR PIPE SECTION

The INDEX SHEET for problem 2A lists three pipe sizes (4.0, 4.5 and 5.0 ft. diameter) under the 2-2/3 inch by 1/2 inch corrugated metal and the same three pipe sizes for the 3 inch by 1 inch corrugated metal. For the 6 inch by 2 inch multiplate pipe, the INDEX SHEET shows a 5.0 foot diameter pipe. The advantage in providing the INDEX SHEET is self evident, in that the hydraulic design engineer has at his "finger tips" the pipe culvert sizes, number of barrels, the outlet control headwater and the inlet control headwater for the available inlet types. The availability of all this information reduces the amount of time and effort needed by the engineer to make a thorough investigation of the hydraulic problem at hand. Along with the INDEX SHEET, the design data sheets provide the necessary geometric dimensions for the culverts listed on the INDEX SHEET. More importantly, performance curve data is provided for additional culvert analysis.

INDEX SHEET - PROBLEM 2A

```
>>>> PIPE CULVERT DESIGN FOR PROJECT >>>     SAMPLE #2A CMP HEC-13 AHW=100.


>>>> THE PROGRAM PROVIDES A RANGE OF CONVENTIONAL PIPE CULVERT SIZES WITH AND WITHOUT BEVELS WHICH SATISFY SITE REQUIREMENTS

                          WHERE:  BEVELED EDGES FOR CMP AND CONCRETE PIPES
                                ARE BASED ON CHART 13 IN HEC-13


>>>>  IF INLET CONTROL GOVERNS - IMPROVED INLET DESIGNS ARE PROVIDED FOR SIDE-TAPERED INLETS
                                                            AND SLOPE-TAPERED INLETS


*****************************************************************************************************************
**********************     DESIGN INPUT DATA     ****************************************************************
**********************     DESIGN INPUT DATA     ****************************************************************
*****************************************************************************************************************

  CONVENTIONAL CULVERT ----------       CM PIPE - HEADWALL - UNPAVED                  KE= 0.5

  BEVEL-EDGED CULVERT ----------        CM PIPE - UNPAVED WITH BEVEL(A)               KE= 0.2

                APPROX    TOE-TOE                                ALLOWABLE  STREAM BED  STREAM BED  LEFT ROADWAY  RIGHT ROADWAY
  CULVERT       STREAM    CULVERT     DESIGN       DESIGN        HEADWATER  ELEVATION   ELEVATION   EMBANKMENT    EMBANKMENT
   CODE         SLOPE     LENGTH     DISCHARGE    TAILWATER      ELEVATION  AT INLET    AT OUTLET      SLOPE          SLOPE
  11133         0.0500    368.0       150.0          2.0          100.0       93.3        75.0         2.0:1          2.0:1

  CULVERT  SIZES                                  SLOPE-TAPER
     DIAMETER  FROM  4.00 FT TO  5.00 FT          FALL SLOPE          COMPUTED STREAM
                                                    2.0:1             SLOPE = 0.0500

*****************************************************************************************************************
**********************     INDEX  SHEET  FOR PIPE  CULVERTS     *************************************************
**********************     INDEX  SHEET  FOR PIPE  CULVERTS     *************************************************
*****************************************************************************************************************

                           *  -- OUTLET CONTROL --    **                           -- INLET CONTROL --              *
                           *                          **                                                            *
                           * KE= 0.5  KE=0.2  OUTLET ** CONVENTIONAL CULVERT  *  BEVEL-EDGED CULVERT   * SIDE-TAPERED CULVERT  *
                           ---------------------------*-------------------------------------------------+---------------------*
* SEE  *NUMBER *   BARREL  *  HW      HW     INVERT ** HW                INVERT *  HW                INVERT * THROAT           INVERT *
* PAGE *  OF   *  DIAMETER *  ELEV    ELEV    ELEV  ** ELEV     FALL     ELEV  *  ELEV     FALL     ELEV  *HW ELEV   FALL    ELEV  *
*      *BARRELS*    (FT)   *  (FT)    (FT)    (FT)  ** (FT)     (FT)     (FT)  *  (FT)     (FT)     (FT)  *  (FT)    (FT)    (FT)  *
*      *       *     *                              **                         *                          *                         *

      2-2/3 IN X 1/2 IN CORRUGATED-METAL PIPE - UNPAVED
*  1   *   1   *    4.00   *  95.0    94.4    75.4 ** 100.0     1.0      91.9 * 100.0      0.6      92.4 *  99.3     0.3     92.7 *
*  2   *   1   *    4.50   *  88.2    87.7    75.5 **  99.3     0.0      92.9 *  99.0      0.0      92.9 *  98.4     0.3     92.6 *
*  3   *   1   *    5.00   *  84.9    84.6    75.5 **  98.4     0.0      92.8 *  98.2      0.0      92.8 *  97.9     0.4     92.5 *
```

INDEX SHEET - PROBLEM 2A (Cont'd)

```
          3 IN X 1 IN CORRUGATED-METAL PIPE ---------UNPAVED
*  4  *   1   *    4.00    *    99.6   99.0       75.4 ** 100.0     1.0      91.9 * 100.0     0.6     92.4 *  93.3     0.3     92.7 *
*  5  *   1   *    4.50    *    90.6   90.2       75.5 **  99.3     0.0      92.9 *  99.0     0.0     92.9 *  98.4     0.3     92.6 *
*  6  *   1   *    5.00    *    85.2   85.9       75.5 **  93.4     0.0      92.3 *  98.2     0.0     92.3 *  97.9     0.4     92.5 *

          6 IN X 2 IN MULTIPLATE PIPE ---------------UNPAVED
*  7  *   1   *    5.00    *    83.7   93.4       75.5 **  93.4     0.0      92.5 *  98.2     0.0     92.3 *  97.9     0.4     92.5 *
```

```
BY DEFINITION OF FALL, WHEN A SIDE-TAPERED INLET LIES ON THE STREAM SLOPE,
THE FALL IS THE DIFFERENCE IN ELEVATION OF THE FACE INVERT AND THE THROAT INVERT

WHEN SIDE-TAPERED CULVERT COLUMN (ABOVE) CONTAINS 0.0  0.0  0.0
     1. THE THROAT DESIGN EXCEEDED THE DESIGN CRITERIA
  OR 2. IMPROVED INLETS FOR MORE THAN 2 BARRELS NOT AVAILABLE
```

DESIGN DATA - Page 1

CIRCULAR PIPE SECTION

```
PAGE=  1     NO. BARRELS= 1     DIAMETER = 4.00 FT     Q(50)=  150.0 CFS     AHWEL=  100.0 FT    STREAM SLOPE = 0.0500
                                                   OUTLET INVERT ELEV. =    75.4 FT


CONVENTIONAL INLET DESIGN FOR CULVERT CODE: 11133
**************************************************************

  OUTLET COMPUTATIONS                                     INLET COMPUTATIONS
  *******************          ***********************************************************************************

      KE =    0.5                   MIN FALL CURVE                 MAX Q CURVE                      MIN HW CURVE

                                                             MAX Q =  170.0 CFS


                             CULVERT LENGTH  =  352.0 FT    CULVERT LENGTH   =  355.1 FT     CULVERT LENGTH  =  361.9 FT
                             FALL AT FACE    =   1.01 FT    FALL AT FACE     =   2.57 FT     FALL AT FACE    =   5.97 FT
                             ELEV FACE INVERT=   91.9 FT    ELEV FACE INVERT=    90.4 FT     ELEV FACE INVERT=   87.0 FT
                             CULVERT SLOPE   =  0.0468      CULVERT SLOPE    =  0.0420       CULVERT SLOPE   =  0.0319
                             VEL AT DESIGN Q =  15.4 FPS    VEL AT MAX Q     =   14.6 FPS    VEL AT DESIGN Q =  12.6 FPS
                             MIN CREST LENGTH=    3.1 FT    MIN CREST LENGTH=     3.8 FT     MIN CREST LENGTH=    4.1 FT

     Q          HWO                Q        HWF                 Q        HWF                    Q         HWF

   120.0       89.2              120.0      98.1              120.0      96.5                 120.0       93.1
   150.0       95.0              150.0     100.0              150.0      98.5                 150.0       95.1
   180.0      102.1              180.0     102.4              180.0     100.9                 180.0       97.5
   210.0      110.3              210.0     105.3              210.0     103.7                 210.0      100.4
   240.0      119.8              240.0     108.6              240.0     107.0                 240.0      103.7
   270.0      130.5              270.0     112.3              270.0     110.8                 270.0      107.4
   300.0      142.5              300.0     116.5              300.0     115.0                 300.0      111.6


BEVELED INLET DESIGN   FOR CULVERT CODE: 11146
**************************************************************

  OUTLET COMPUTATIONS                                     INLET COMPUTATIONS
  *******************          ***********************************************************************************

      KE = 0.2                      MIN FALL CURVE                 MAX Q CURVE                     MIN HW CURVE

                                                             MAX Q =   174. CFS


                             CULVERT LENGTH  =  351.1 FT    CULVERT LENGTH   =  354.6 FT     CULVERT LENGTH  =  362.0 FT
                             FALL AT FACE    =   0.57 FT    FALL AT FACE     =   2.28 FT     FALL AT FACE    =   6.00 FT
                             ELEV FACE INVERT=   92.4 FT    ELEV FACE INVERT=    90.7 FT     ELEV FACE INVERT=   86.9 FT
                             CULVERT SLOPE   =  0.0482      CULVERT SLOPE    =  0.0429       CULVERT SLOPE   =  0.0318
                             VEL AT DESIGN Q =  15.6 FPS    VEL AT MAX Q     =   14.7 FPS    VEL AT DESIGN Q =  12.6 FPS
                             MIN CREST LENGTH=    3.0 FT    MIN CREST LENGTH=     3.8 FT     MIN CREST LENGTH=    4.2 FT
```

DESIGN DATA - Page 1 (Cont'd)

```
   Q       HWO                Q       HWF                 Q       HWF                 Q       HWF

 120.0     86.8             120.0     93.2              120.0     96.5              120.0     92.3
 150.0     94.4             150.0    100.0              150.0     98.3              150.0     94.6
 180.0    101.1             180.0    102.2              180.0    100.5              180.0     95.8
 210.0    109.0             210.0    104.6              210.0    102.9              210.0     99.2
 240.0    118.1             240.0    107.4              240.0    105.7              240.0    102.0
 270.0    128.4             270.0    110.9              270.0    109.2              270.0    105.5
 300.0    139.9             300.0    115.9              300.0    114.2              300.0    110.5


SIDE TAPERED INLET DESIGN
*************************          FACE EDGE BEVELS = 45 DEG     SIDE TAPER= 5.667:1

     MIN FALL DESIGN                                MAX  Q  DESIGN                                   MIN HW DESIGN

     E = D =  4.00 FT                               MAX Q =   174. CFS
     FACE WIDTH= 1.5D=  6.00 FT
     L1= 1.4167D=  5.67 FT


  CULVERT LENGTH     =  380.0 FT                CULVERT LENGTH     =  350.5 FT              CULVERT LENGTH     =  359.8 FT
  FALL               =   0.28 FT                FALL               =   0.53 FT              FALL               =   5.17 FT
  ELEV THROAT INVERT=   92.7 FT                 ELEV THROAT INVERT=   92.4 FT               ELEV THROAT INVERT=   87.8 FT
  ELEV FACE INVERT   =   92.9 FT                ELEV FACE INVERT   =   92.7 FT              ELEV FACE INVERT   =   88.0 FT
  CULVERT SLOPE      = 0.0500                   CULVERT SLOPE      = 0.0492                 CULVERT SLOPE      = 0.0348
  VEL AT DESIGN Q    =  15.8 FPS                VEL AT MAX  Q      =  16.1 FPS              VEL AT DESIGN Q    =  13.5 FT
  MIN CREST LENGTH   =    0.0 FT                MIN CREST LENGTH   =    3.4 FT              MIN CREST LENGTH   =    4.8 FT
  BEVELS =  45 DEGREE                           B5VELS =  45 DEGREE                         BEVELS =  45 DEGREE
     B =  3.0 IN  D =  2.0 IN                      B =  3.0 IN  D =  2.0 IN                    B =  3.0 IN  D =  2.0 IN

  Q          HWT         HWF                   Q          HWT         HWF                   Q          HWT         HWF

  120.0      98.2        97.6                  120.0      97.9        97.3                  120.0      93.3        92.6
  150.0      99.3        98.6                  150.0      99.0        98.3                  150.0      94.4        93.6
  180.0     100.6        99.7                  180.0     100.3        99.4                  180.0      95.7        94.7
  210.0     102.1       100.9                  210.0     101.8       100.7                  210.0      97.2        95.9
  240.0     103.9       102.3                  240.0     103.6       102.0                  240.0      99.0        97.3
  270.0     105.0       103.8                  270.0     105.6       103.6                  270.0     101.0        98.8
  300.0     108.2       105.5                  300.0     107.9       105.3                  300.0     103.3       100.5
```

DESIGN DATA - Page 1 (cont'd)

```
SLOPE TAPERED INLET DESIGN - VERTICAL FACE
******************************************

   DISTANCE EMBANKMENT-TOE TO FACE =   8.13 FT          CULVERT OUTLET TO EMBANKMENT-TOE =   8.73 FT

       MIN FALL DESIGN                                   MAX  Q  DESIGN

       TRANSITION SECTION= D/2
       INLET DESIGNED AS BOX TYPE INLET


              NO SLOPE TAPERED INLET - VERTICAL FACE - DESIGN APPLICABLE
```

CIRCULAR PIPE SECTION

DESIGN DATA - Page 2

```
PAGE=  2     NO. BARRELS= 1      DIAMETER = 4.50 FT      Q(50)=  150.0 CFS     AHWEL=  100.0 FT    STREAM SLOPE = 0.0500
                                                      OUTLET INVERT ELEV. =    75.5 FT


CONVENTIONAL INLET DESIGN FOR CULVERT CODE: 11133
**********************************************************

  OUTLET COMPUTATIONS                                  INLET COMPUTATIONS
  *******************         *****************************************************************************************

      KE =    0.5                  MIN FALL CURVE                   MAX Q CURVE                      MIN HW CURVE

                                                               MAX Q =  230.0 CFS

                          CULVERT LENGTH   =  348.0 FT      CULVERT LENGTH   =  355.7 FT      CULVERT LENGTH   =  351.5 FT
                          FALL AT FACE     =    0.0  FT     FALL AT FACE     =    3.86 FT     FALL AT FACE     =    6.75 FT
                          ELEV FACE INVERT=   92.9 FT       ELEV FACE INVERT=   89.0 FT       ELEV FACE INVERT=   86.1 FT
                          CULVERT SLOPE    =  0.0500        CULVERT SLOPE    =  0.0361        CULVERT SLOPE    =  0.0295
                          VEL AT DESIGN Q =   16.2 FPS      VEL AT MAX Q     =   15.0 FPS     VEL AT DESIGN Q =   13.2 FPS
                          MIN CREST LENGTH=    0.0 FT       MIN CREST LENGTH=    5.5 FT       MIN CREST LENGTH=    5.4 FT

       Q         HWO                  Q         HWF                  Q        HWF                  Q         HWF

     120.0      84.9               120.0       93.0               120.0      94.2               120.0       91.3
     150.0      88.2               150.0       99.3               150.0      95.4               150.0       92.6
     180.0      92.1               180.0      100.8               180.0      96.9               180.0       94.0
     210.0      96.6               210.0      102.5               210.0      98.7             * 210.0       95.8
     240.0     101.8               240.0      104.6               240.0     100.7               240.0       97.9
     270.0     107.7               270.0      106.9               270.0     103.1               270.0      100.2
     300.0     114.2               300.0      109.5               300.0     105.7               300.0      102.8


BEVELED INLET DESIGN   FOR CULVERT CODE: 11146
**************************************************

  OUTLET COMPUTATIONS                                  INLET COMPUTATIONS
  ******************          ******************************************************************************************

      KE = 0.2                   MIN FALL CURVE                   MAX Q CURVE                      MIN HW CURVE

                                                               MAX Q =   236. CFS

                          CULVERT LENGTH   =  348.0 FT      CULVERT LENGTH   =  355.1 FT      CULVERT LENGTH   =  351.5 FT
                          FALL AT FACE     =    0.0  FT     FALL AT FACE     =    3.56 FT     FALL AT FACE     =    6.75 FT
                          ELEV FACE INVERT=   92.9 FT       ELEV FACE INVERT=   89.3 FT       ELEV FACE INVERT=   86.1 FT
                          CULVERT SLOPE    =  0.0500        CULVERT SLOPE    =  0.0390        CULVERT SLOPE    =  0.0295
                          VEL AT DESIGN Q =   16.2 FPS      VEL AT MAX Q     =   15.1 FPS     VEL AT DESIGN Q =   13.2 FPS
                          MIN CREST LENGTH=    0.0 FT       MIN CREST LENGTH=    5.5 FT       MIN CREST LENGTH=    6.0 FT
```

DESIGN DATA - Page 2 (cont'd)

```
   Q        HWC              Q        HWF              Q        HWF              Q        HWF

 120.0      94.6           120.0      97.8           120.0      94.3           120.0      91.1
 150.0      87.7           150.0      99.0           150.0      95.4           150.0      92.2
 180.0      91.5           180.0     100.3           180.0      96.8           180.0      93.5
 210.0      95.8           210.0     102.0           210.0      98.4           210.0      95.3
 240.0     100.9           240.0     103.8           240.0     100.3           240.0      97.1
 270.0     108.3           270.0     105.6           270.0     102.3           270.0      99.1
 300.0     112.6           300.0     108.0           300.0     104.5           300.0     101.3


SIDE TAPERED INLET DESIGN
*************************          FACE EDGE BEVELS = 45 DEG     SIDE TAPER= 5.667:1

     MIN FALL DESIGN                            MAX  Q  DESIGN                              MIN HW DESIGN

     B = D =   4.50 FT                          MAX Q =   236. CFS
     FACE WIDTH= 1.5D=  6.75 FT
     L1= 1.4167D=  6.38 FT

   CULVERT LENGTH     =  346.0 FT            CULVERT LENGTH     =  350.4 FT            CULVERT LENGTH     =  360.9 FT
   FALL               =    0.32 FT           FALL               =    1.53 FT           FALL               =    5.75 FT
   ELEV THROAT INVERT=   92.6 FT            ELEV THROAT INVERT=   91.4 FT            ELEV THROAT INVERT=   86.1 FT
   ELEV FACE INVERT   =   92.9 FT            ELEV FACE INVERT   =   91.7 FT            ELEV FACE INVERT   =   86.3 FT
   CULVERT SLOPE      = 0.0500               CULVERT SLOPE      = 0.0461               CULVERT SLOPE      = 0.0300
   VEL AT DESIGN Q    =  16.2 FPS            VEL AT MAX  Q      =  17.6 FPS            VEL AT DESIGN Q    =  13.3 FT
   MIN CREST LENGTH   =     0.0 FT           MIN CREST LENGTH   =    4.9 FT            MIN CREST LENGTH   =    7.3 FT
   BEVELS =  45 DEGREE                       BEVELS =  45 DEGREE                       BEVELS =  45 DEGREE
      B =  3.4 IN  D =  2.3 IN                  B =  3.4 IN  D =  2.3 IN                  B =  3.4 IN  D =  2.3 IN

   Q          HWT        HWF                 Q          HWT        HWF                 Q          HWT        HWF

 120.0       97.6       97.1               120.0       96.4       95.9               120.0       91.2       90.5
 150.0       98.4       97.8               150.0       97.2       96.6               150.0       92.0       91.3
 180.0       99.3       98.6               180.0       98.1       97.4               180.0       92.9       92.1
 210.0      100.3       99.5               210.0       99.1       98.3               210.0       93.9       92.9
 240.0      101.4      100.4               240.0      100.2       99.2               240.0       95.0       93.9
 270.0      102.7      101.5               270.0      101.5      100.2               270.0       96.2       94.9
 300.0      104.0      102.5               300.0      102.8      101.3               300.0       97.6       96.0
```

CIRCULAR PIPE SECTION

DESIGN DATA - Page 2 (cont'd)

```
SLOPE TAPERED INLET DESIGN - VERTICAL FACE
*******************************************

  DISTANCE EMBANKMENT-TOE TO FACE =   9.15 FT        CULVERT OUTLET TO EMBANKMENT-TOE =   9.82 FT

      MIN FALL DESIGN                                  MAX  Q  DESIGN

      TRANSITION SECTION= D/2
      INLET DESIGNED AS BOX TYPE INLET


              - -                                    CULVERT LENGTH     =  347.03 FT
              - -                                    FALL                =     1.48 FT
              - -                                    ELEV THROAT INVERT=   91.36 FT
              - -                                    ELEV FACE INVERT   =   92.84 FT
              - -                                    CULVERT SLOPE      =  0.0439
              - -                                    VELOCITY           =   17.05 FPS
              - -                                    FACE WIDTH         =   6.707 FT
              - -                                    L1                 =   5.988 FT
              - -                                    L2                     3.74 FT
              - -                                    L3                 =    2.25 FT
              - -                                    SF                 =    2.00
              - -                                    TAPER              =   5.426:1
      Q       HWT       HWF
                                                          Q         HWT        HWF
              --
              --                                        120.0       96.4       96.2
              --                                        150.0       97.2       96.8
              --                                        180.0       98.1       97.3
              --                                        210.0       99.1       97.9
              --                                        240.0      100.2       98.4
              --                                        270.0      101.5       99.1
                                                        300.0      102.8       99.7
```

EXAMPLE PROBLEM NO. 2B - Reinforced Concrete Pipe

The input data for problem 2B is the same as problem 2A. The INDEX SHEET shows an output design for the 4.0, 4.5, and 5.0 foot diameter concrete pipes.

INPUT DATA

CARD NO. 1

PROBLEM IDENTIFICATION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	←→	78
	S	A	M	P	L	E		P	R	O	B		2	B		R	C.		P	I	P	E	-	U	N	P	A	V	E	D			A	H	W	E	L	=	1	0	0		F	T							

CARD NO. 2

SITE DATA

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
2	3	4	3	4		0	.	0	5					3	6	6	.				1	5	0	.						2	.	0			1	0	0	.	0				9	3	.	3				7	5	.	0
Culvert code					Culvert slope							Approx. culvert length (DIST)							Design discharge (Q1)							Design Tailwater Depth (TW)							Allowable Headwater Elevation (AHW)							Inlet Toe-Embank. Elevation (ELIN)							Outlet Toe-Embank. Elevation (ELOUT)						

55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
				2	.	0					2	.	0					2	.	0
Upstream Embankment Slope (SEL)							Downstream Embankment Slope (SER)							Fall Slope Slope-Taper Inlet (SFACE)						

~~CARD NO. 3 FOR BOX CULVERTS~~

1	2	3	4	5	6	7	8							
KBAS1		KBAS2		KDEP1		KDEP2		*						

CARD NO. 3 FOR PIPE CULVERTS

1	2	3	4	5	6	7	8	9	10					
	4	.	0			5	.	0						
DIA1					DIA2					*				

*BOX CULVERT AND PIPE CULVERT SIZES–SEE INPUT SECTION

Figure 6

INDEX SHEET

```
>>>> PIPE CULVERT DESIGN FOR PROJECT >>>    SAMPLE  R C PIPE  AHW=100.


>>>> THE PROGRAM PROVIDES A RANGE OF CONVENTIONAL PIPE CULVERT SIZES WITH AND WITHOUT BEVELS WHICH SATISFY SITE REQUIREMENTS

                             WHERE:  BEVELED EDGES FOR CMP AND CONCRETE PIPES
                                          ARE BASED ON CHART 13 IN HEC-13


>>>>  IF INLET CONTROL GOVERNS - IMPROVED INLET DESIGNS ARE PROVIDED FOR SIDE-TAPERED INLETS
                                                                    AND SLOPE-TAPERED INLETS


******************************************************************************************************
**********************      DESIGN INPUT DATA      ***************************************************
**********************      DESIGN INPUT DATA      ***************************************************
******************************************************************************************************

  CONVENTIONAL CULVERT ----------        CONCRETE PIPE - SQUARE-EDGE HEADWALL                KE= 0.5

  BEVEL-EDGED CULVERT -----------        CONCRETE PIPE WITH BEVEL(A)                         KE= 0.2

                 APPROX    TOE-TOE                               ALLOWABLE   STREAM BED   STREAM BED   LEFT ROADWAY    RIGHT ROADWAY
  CULVERT        STREAM    CULVERT    DESIGN        DESIGN       HEADWATER   ELEVATION    ELEVATION    EMBANKMENT      EMBANKMENT
   CODE          SLOPE     LENGTH    DISCHARGE    TAILWATER      ELEVATION   AT INLET     AT OUTLET       SLOPE            SLOPE
  23434          0.0500    366.0      150.0          2.0          100.0        93.3         75.0          2.0:1            2.0:1

  CULVERT  SIZES                                 SLOPE-TAPER
     DIAMETER  FROM  4.00 FT TO  5.00 FT          FALL SLOPE             COMPUTED STREAM
                                                   2.0:1                 SLOPE = 0.0500

******************************************************************************************************
**********************      INDEX  SHEET  FOR PIPE  CULVERTS      ************************************
**********************      INDEX  SHEET  FOR PIPE  CULVERTS      ************************************
******************************************************************************************************

                                 *  -- OUTLET CONTROL --     **                        -- INLET CONTROL --                                *
                                 *                           **                                                                           *
                                 *  KE= 0.5  KE=0.2  OUTLET  ** CONVENTIONAL CULVERT   *  BEVEL-EDGED CULVERT    * SIDE-TAPERED CULVERT   *
                                 *---------------------------**-----------------------*------------------------*-----------------------*
* SEE  *NUMBER *   BARREL        *   HW      HW     INVERT   ** HW              INVERT *  HW              INVERT * THROAT           INVERT *
* PAGE *  OF   *  DIAMETER       *  ELEV    ELEV     ELEV    ** ELEV    FALL     ELEV  *  ELEV    FALL     ELEV  *HW ELEV   FALL     ELEV  *
*      *BARRELS*    (FT)         *  (FT)    (FT)     (FT)    ** (FT)    (FT)     (FT)  *  (FT)    (FT)     (FT)  *  (FT)    (FT)     (FT)  *
*      *       *                 *                           **                        *                         *                          *

        CONCRETE PIPES
*  1   *   1   *    4.00         *  85.8    85.2     75.4 ** 100.0     1.1      91.8 * 100.0     0.6      92.4 *  99.0     0.3      92.7 *
*  2   *   1   *    4.50         *  83.3    82.9     75.5 **  99.3     0.0      92.9 *  99.0     0.0      92.9 *  98.2     0.3      92.6 *
*  3   *   1   *    5.00         *  82.2    81.9     75.5 **  98.4     0.0      92.8 *  98.2     0.0      92.8 *  97.6     0.4      92.5 *
```

INDEX SHEET (cont)

```
BY DEFINITION OF FALL, WHEN A SIDE-TAPERED INLET LIES ON THE STREAM SLOPE,
THE FALL IS THE DIFFERENCE IN ELEVATION OF THE FACE INVERT AND THE THROAT INVERT

WHEN SIDE-TAPERED CULVERT COLUMN (ABOVE) CONTAINS 0.0  0.0  0.0
     1. THE THROAT DESIGN EXCEEDED THE DESIGN CRITERIA
  OR 2. IMPROVED INLETS FOR MORE THAN 2 BARRELS NOT AVAILABLE
```

DESIGN DATA FOR PAGE 1

```
PAGE=  1     NO. BARRELS= 1     DIAMETER = 4.00 FT     Q(50)=  150.0 CFS     AHWEL=  100.0 FT    STREAM SLOPE = 0.0500
                                                 OUTLET INVERT ELEV. =    75.4 FT


CONVENTIONAL INLET DESIGN FOR CULVERT CODE: 23434
**************************************************************

  OUTLET COMPUTATIONS                                      INLET COMPUTATIONS
 *******************        **************************************************************************************************

      KE =    0.5                      MIN FALL CURVE                    MAX Q CURVE                       MIN HW CURVE

                                                                      MAX Q =   204.0 CFS

                               CULVERT LENGTH   =  352.3 FT     CULVERT LENGTH   =  352.0 FT     CULVERT LENGTH   =  352.0 FT
                               FALL AT FACE     =   1.14 FT     FALL AT FACE     =   6.00 FT     FALL AT FACE     =   6.00 FT
                               ELEV FACE INVERT=   91.8 FT     ELEV FACE INVERT=   86.9 FT     ELEV FACE INVERT=   86.9 FT
                               CULVERT SLOPE    =  0.0464       CULVERT SLOPE    =  0.0318       CULVERT SLOPE    =  0.0318
                               VEL AT DESIGN Q =   26.0 FPS    VEL AT MAX Q     =   24.1 FPS    VEL AT DESIGN Q =   22.5 FPS
                               MIN CREST LENGTH=    3.1 FT     MIN CREST LENGTH=    5.6 FT     MIN CREST LENGTH=    4.2 FT
      Q          HWO                  Q         HWF                 Q         HWF                  Q         HWF

    120.0        83.3               120.0       98.0              120.0       93.2               120.0       93.2
    150.0        85.8               150.0      100.0              150.0       95.2               150.0       95.2
    180.0        88.8               180.0      102.5              180.0       97.7               180.0       97.7
    210.0        92.2               210.0      105.5              210.0      100.7               210.0      100.7
    240.0        96.[illegible]               240.0      108.9              240.0      104.0               240.0      104.0
    270.0       100.7               270.0      112.8              270.0      107.9               270.0      107.9
    300.0       105.7               300.0      117.5              300.0      112.7               300.0      112.7


BEVELED INLET DESIGN   FOR CULVERT CODE: 23446
******************************************************

  OUTLET COMPUTATIONS                                      INLET COMPUTATIONS
 *****************          **************************************************************************************************

      KE = 0.2                      MIN FALL CURVE                    MAX Q CURVE                       MIN HW CURVE

                                                                   MAX Q =    218. CFS

                               CULVERT LENGTH   =  351.1 FT     CULVERT LENGTH   =  362.0 FT     CULVERT LENGTH   =  362.0 FT
                               FALL AT FACE     =   0.57 FT     FALL AT FACE     =   6.00 FT     FALL AT FACE     =   6.00 FT
                               ELEV FACE INVERT=   92.4 FT     ELEV FACE INVERT=   86.9 FT     ELEV FACE INVERT=   86.9 FT
                               CULVFRT SLOPE    =  0.0482       CULVERT SLOPE    =  0.0318       CULVERT SLOPE    =  0.0318
                               VEL AT DESIGN Q =   26.3 FPS    VEL AT MAX Q     =   24.5 FPS    VEL AT DESIGN Q =   22.5 FPS
                               MIN CREST LENGTH=    3.0 FT     MIN CREST LENGTH=    6.0 FT     MIN CREST LENGTH=    4.2 FT
```

DESIGN DATA FOR PAGE 1 (cont)

```
    Q        HWO              Q        HWF              Q        HWF              Q        HWF

  120.0     82.9            120.0     98.2            120.0     92.8            120.0     92.8
  150.0     85.2            150.0    100.0            150.0     94.5            150.0     94.6
  180.0     87.8            180.0    102.2            160.0     96.8            180.0     96.8
  210.0     90.9            210.0    104.6            210.0     99.2            210.0     99.2
  240.0     94.5            240.0    107.4            240.0    102.0            240.0    102.0
  270.0     98.5            270.0    110.9            270.0    105.5            270.0    105.5
  300.0    103.0            300.0    115.9            300.0    110.5            300.0    110.5


SIDE TAPERED INLET DESIGN
************************          FACE EDGE BEVELS = 45 DEG     SIDE TAPER= 5.667:1

      MIN FALL DESIGN                            MAX  Q  DESIGN                              MIN HW DESIGN

      E = D =   4.00 FT                          MAX Q =   276. CFS
      FACE WIDTH= 1.5D=   6.00 FT
      L1= 1.4167D=   5.67 FT

  CULVERT LENGTH     =  350.0 FT             CULVERT LENGTH     =  361.4 FT             CULVERT LENGTH     =  361.4 FT
  FALL               =    0.28 FT            FALL               =    6.00 FT            FALL               =    6.00 FT
  ELEV THROAT INVERT=    92.7 FT             ELEV THROAT INVERT=    86.9 FT             ELEV THROAT INVERT=    86.9 FT
  ELEV FACE INVERT   =   92.9 FT             ELEV FACE INVERT   =   87.1 FT             ELEV FACE INVERT   =   87.1 FT
  CULVERT SLOPE      = 0.0500                CULVERT SLOPE      = 0.0323                CULVERT SLOPE      = 0.0323
  VEL AT DESIGN Q    =   26.7 FPS            VEL AT MAX  Q      =   30.7 FPS            VEL AT DESIGN Q    =   22.6 FT
  MIN CREST LENGTH   =     0.0 FT            MIN CREST LENGTH   =     7.6 FT            MIN CREST LENGTH   =      5.6 FT
  BEVELS =   45 DEGREE                       B5VELS =   45 DEGREE                       BEVELS =   45 DEGREE
       B =   3.0 IN   D =   2.0 IN                B =   3.0 IN   D =   2.0 IN                B =   3.0 IN   D =   2.0 IN

  Q         HWT        HWF                     Q         HWT        HWF                  Q         HWT        HWF

  120.0      97.9       97.6                  120.0      92.2       91.8                120.0      92.2       91.8
  150.0      99.0       98.6                  150.0      93.3       92.8                150.0      93.3       92.8
  180.0     100.3       99.7                  180.0      94.6       93.9                180.0      94.6       93.9
  210.0     101.7      100.9                  210.0      96.0       95.1                210.0      96.0       95.1
  240.0     103.4      102.3                  240.0      97.7       96.5                240.0      97.7       96.5
  270.0     105.2      103.8                  270.0      99.5       98.0                270.0      99.5       98.0
  300.0     107.3      105.5                  300.0     101.6       99.7                300.0     101.6       99.7
```

DESIGN DATA FOR PAGE 1 (cont)

```
SLOPE TAPERED INLET DESIGN - VERTICAL FACE
*******************************************.

   DISTANCE EMBANKMENT-TOE TO FACE =   8.13 FT          CULVERT OUTLET TO EMBANKMENT-TOE =   8.73 FT

       MIN FALL DESIGN                                    MAX  Q  DESIGN

       TRANSITION SECTION= D/2
       INLET DESIGNED AS BOX TYPE INLET


                - -                                       CULVERT LENGTH     =  349.13 FT
                - -                                       FALL                =    5.96 FT
                - -                                       ELEV THROAT INVERT=   86.94 FT
                - -                                       ELEV FACE INVERT   =   92.89 FT
                - -                                       CULVERT SLOPE      =  0.0346
                - -                                       VELOCITY           =   26.20 FPS
                - -                                       FACE WIDTH         =   7.517 FT
                - -                                       L1                 =  15.117 FT
                - -                                       L2                    13.12 FT
                - -                                       L3                 =    2.00 FT
                - -                                       SF                 =    2.00
                - -                                       TAPER              =   8.358:1

       Q        HWT        HWF                                 Q         HWT        HWF

                --                                           120.0       92.2       96.0
                --                                           150.0       93.3       96.5
                --                                           180.0       94.6       97.0
                --                                           210.0       96.0       97.5
                --                                           240.0       97.7       98.1
                --                                           270.0       99.5       98.7
                --                                           300.0      101.6       99.4
```

DESIGN DATA FOR PAGE 2

```
PAGE=  2     NO. BARRELS= 1     DIAMETER = 4.50 FT     Q(50)=  150.0 CFS     AHWEL=  100.0 FT     STREAM SLOPE = 0.0500
                                                 OUTLET INVERT ELEV. =    75.5 FT


CONVENTIONAL INLET DESIGN FOR CULVERT CODE: 23434
*****************************************************

  OUTLET COMPUTATIONS                                  INLET COMPUTATIONS
 *****************     ***************************************************************************************************

       KE =    0.5                   MIN FALL CURVE                      MAX Q CURVE                        MIN HW CURVE

                                                                     MAX Q =  264.0 CFS

                        CULVERT LENGTH   =  348.0 FT     CULVERT LENGTH   =  361.5 FT     CULVERT LENGTH   =  361.5 FT
                        FALL AT FACE     =    0.0  FT    FALL AT FACE     =   6.75 FT     FALL AT FACE     =   6.75 FT
                        ELEV FACE INVERT=   92.9 FT      ELEV FACE INVERT=   86.1 FT      ELEV FACE INVERT=   86.1 FT
                        CULVERT SLOPE    =  0.0500       CULVERT SLOPE    =  0.0295       CULVERT SLOPE    =  0.0295
                        VEL AT DESIGN Q =   26.5 FPS     VEL AT MAX Q     =   25.0 FPS    VEL AT DESIGN Q =   21.9 FPS
                        MIN CREST LENGTH=    0.0 FT      MIN CREST LENGTH=    7.6 FT      MIN CREST LENGTH=    5.3 FT

      Q        HWO                 Q        HWF                 Q        HWF                 Q        HWF

    120.0     81.8               120.0      93.1              120.0      91.4              120.0      91.4
    150.0     83.3               150.0      99.3              150.0      92.6              150.0      92.6
    180.0     85.2               180.0     100.8              180.0      94.1              180.0      94.1
    210.0     87.2               210.0     102.7              210.0      96.0              210.0      96.0
    240.0     89.6               240.0     104.8              240.0      98.1              240.0      98.1
    270.0     92.2               270.0     107.3              270.0     100.5              270.0     100.5
    300.0     95.1               300.0     109.9              300.0     103.2              300.0     103.2


BEVELED INLET DESIGN   FOR CULVERT CODE: 23446
**********************************************

  OUTLET COMPUTATIONS                                 INLET COMPUTATIONS
 ******************    ***************************************************************************************************

       KE = 0.2                   MIN FALL CURVE                        MAX Q CURVE                        MIN HW CURVE

                                                                    MAX Q =    282. CFS

                        CULVERT LENGTH   =  348.0 FT     CULVERT LENGTH   =  361.5 FT     CULVERT LENGTH   =  361.5 FT
                        FALL AT FACE     =    0.0  FT    FALL AT FACE     =   6.75 FT     FALL AT FACE     =   6.75 FT
                        ELEV FACE INVERT=   92.9 FT      ELEV FACE INVERT=   86.1 FT      ELEV FACE INVERT=   86.1 FT
                        CULVERT SLOPE    =  0.0500       CULVERT SLOPE    =  0.0295       CULVERT SLOPE    =  0.0295
                        VEL AT DESIGN Q =   26.5 FPS     VEL AT MAX Q     =   25.4 FPS    VEL AT DESIGN Q =   21.9 FPS
                        MIN CREST LENGTH=    0.0 FT      MIN CREST LENGTH=    8.2 FT      MIN CREST LENGTH=    6.0 FT
```

DESIGN DATA FOR PAGE 2 (cont) .

```
   Q       HWO             Q       HWF             Q       HWF             Q       HWF

 120.0    81.5           120.0    97.8           120.0    91.1           120.0    91.1
 150.0    82.9           150.0    99.0           150.0    92.2           150.0    92.2
 180.0    84.6           180.0   100.3           180.0    93.6           180.0    93.6
 210.0    86.4           210.0   102.0           210.0    95.3           210.0    95.3
 240.0    88.5           240.0   103.8           240.0    97.1           240.0    97.1
 270.0    90.9           270.0   105.8           270.0    99.1           270.0    99.1
 300.0    93.5           300.0   108.0           300.0   101.3           300.0   101.3


SIDE TAPERED INLET DESIGN
************************          FACE EDGE BEVELS = 45 DEG     SIDE TAPER= 5.667:1

     MIN FALL DESIGN                         MAX  Q  DESIGN                         MIN HW DESIGN

     E = D =  4.50 FT                        MAX Q =   356. CFS
     FACE WIDTH= 1.50D=  6.75 FT
     L1= 1.4167D=  6.38 FT

 CULVERT LENGTH     =  348.0 FT           CULVERT LENGTH     =  360.9 FT          CULVERT LENGTH     =  360.9 FT
 FALL               =    0.32 FT          FALL               =    6.75 FT         FALL               =    6.75 FT
 ELEV THROAT INVERT=    92.6 FT           ELEV THROAT INVERT=    86.1 FT          ELEV THROAT INVERT=    86.1 FT
 ELEV FACE INVERT  =    92.9 FT           ELEV FACE INVERT  =    86.3 FT          ELEV FACE INVERT  =    86.3 FT
 CULVERT SLOPE     = 0.0500               CULVERT SLOPE     = 0.0300              CULVERT SLOPE     = 0.0300
 VEL AT DESIGN Q   =   26.5 FPS           VEL AT MAX  Q     =   32.9 FPS          VEL AT DESIGN Q   =  22.0 FT
 MIN CREST LENGTH  =     0.0 FT           MIN CREST LENGTH  =   10.3 FT           MIN CREST LENGTH  =     8.2 FT
 BEVELS =  45 DEGREE                      B5VELS =  45 DEGREE                     BEVELS =  45 DEGREE
     B =   3.4 IN  D =   2.3 IN               B =   3.4 IN  D =   2.3 IN              B =   3.4 IN  D =   2.3 IN

 Q         HWT        HWF                  Q        HWT        HWF                Q        HWT        HWF

 120.0     97.3       97.1                120.0     90.9       90.5              120.0     90.9       90.5
 150.0     98.2       97.8                150.0     91.7       91.3              150.0     91.7       91.3
 180.0     99.1       98.6                180.0     92.6       92.1              180.0     92.6       92.1
 210.0    100.0       99.5                210.0     93.6       92.9              210.0     93.6       92.9
 240.0    101.1      100.4                240.0     94.7       93.9              240.0     94.7       93.9
 270.0    102.3      101.5                270.0     95.8       94.9              270.0     95.8       94.9
 300.0    103.6      102.5                300.0     97.1       96.0              300.0     97.1       96.0
```

DESIGN DATA FOR PAGE 2 (cont)

```
SLOPE TAPERED INLET DESIGN - VERTICAL FACE
******************************************

    DISTANCE EMBANKMENT-TOE TO FACE =   9.15 FT         CULVERT OUTLET TO EMBANKMENT-TOE =   9.82 FT

         MIN FALL DESIGN                                   MAX  Q  DESIGN

         TRANSITION SECTION= D/2
         INLET DESIGNED AS BOX TYPE INLET



              - -                                         CULVERT LENGTH     =  347.03 FT
              - -                                         FALL                  =    5.70 FT
              - -                                         ELEV THROAT INVERT=   86.14 FT
              - -                                         ELEV FACE INVERT   =   92.34 FT
              - -                                         CULVERT SLOPE      =  0.0325
              - -                                         VELOCITY           =   27.36 FPS
              - -                                         FACE WIDTH         =  10.624 FT
              - -                                         L1                 =  16.709 FT
              - -                                         L2                    14.46 FT
              - -                                         L3                 =    2.25 FT
              - -                                         SF                 =    2.00
              - -                                         TAPER              =   5.457:1

      Q      HWT        HWF                                  Q          HWT        HWF

             --                                            120.0        90.9       95.4
             --                                            150.0        91.7       95.7
             --                                            180.0        92.6       96.1
             --                                            210.0        93.6       96.5
             --                                            240.0        94.7       96.8
             --                                            270.0        95.8       97.1
             --                                            300.0        97.1       97.5
```

PROGRAM IMPLEMENTATION

JOB CONTROL LANGUAGE

The following job control language for this program is for a typical batch mode processing on an IBM 360/65 computer. More efficient processing can be realized by storing the program in a load mode status on a direct access system.

```
// JOB
// EXEC                    FORTGCLG,PARM.FORT=BCD
// FORT.SYSLIN             SPACE=(80,(2000,100),RLSE)
// FORT.SYSIN              DD *

                           *
                           *

                        SOURCE DECK

                           *
                           *

// LKED.SYSLMOD            DD SPACE=(1024,(80,10,1),RLSE)
// LKED.SYSUT1             DD SPACE=(1024,(200,10),RLSE)
// LKED.SYSUDUMP           DD SYSOUT=A
// GO.FT09F001             DD SYSOUT=A,DCB=(RECFM=UA,BLKSIZE=133)
// GO.SYSIN                DD *


                           DATA CARD 1   Header card
 Problem No. 1             DATA CARD 2   Hydraulic site data
                           DATA CARD 3   Range of culvert sizes
                           DATA CARD 4   Blank card

/*
```

COMPUTER REQUIREMENTS

The computer process described herein is written in FORTRAN IV and was developed on an IBM 360/65 computer with OS operating system. The program is essentially written in EBCDIC but several of the routines contain BCD features which should not pose any problems. This version of the program utilizes about 110K-bytes of storage and the source card deck contains about 3600 cards (1800 for box culvert program and 1800 for circular pipe culvert program).

APPENDIX

REFERENCES

1. "Hydraulic Charts for the Selection of Highway Culverts," HEC No. 5, U.S. Department of Transportation, Federal Highway Administration, December 1965.

2. "Hydraulic Design of Improved Inlets for Culverts," HEC No. 13, U.S. Department of Transportation, Federal Highway Administration, August 1972.

3. Electronic Computer Program, "Hydraulic Analysis of Circular Culverts," U.S. Department of Transportation, Federal Highway Administration, July 1970.

4. Electronic Computer Program, "Hydraulic Analysis of Box Culverts," U.S. Department of Transportation, Federal Highway Administration, April 1969.

5. "Open Channel Hydraulics," McGraw-Hill Book Company, Inc., New York, 1959.

DEFINITION OF TERMS

The following named variables are used in both the box culvert and circular culvert design subroutines. Subroutine names beginning with a "B" refer to box culverts and subroutines beginning with "C" refer to circular pipes.

Main Program

Input data items described in INPUT SECTION

CIRC - Subroutine to design improved inlets for CMP and concrete pipes.

BOXES - Subroutine to design improved inlets for box culverts.

ARCH - Proposed subroutine for pipe-arch design.

Subroutine BOXES

This subroutine initiates the culvert analysis for the range of box culvert sizes requested by the user, computes headwater for inlet and outlet control sections and the throat elevation for improved inlets. Subroutine BOXES also computes the data for Curves A, B, and C which is used by the other subroutines.

ITAB and Tab arrays contain stored information for:

IBAR - Number of barrels

AK - Barrel width (b)

AKK - Barrel depth (d)

HWO(1) - Outlet control headwater elevation for conventional culverts

HWO(2) - Outlet control headwater elevation for bevel-edge culverts

TOEL - Elevation at toe of culvert

HWEL(1) and HWEL(2) - Inlet headwater elevation for square-edge and bevel-edge inlets

SUMP(1) and SUMP(2) - Inlet FALL if required or else FALL = 0

FACE(1) and FACE(2) - Inlet invert elevations for square- and bevel-edge inlets

HWT - Elevation headwater at throat control section

FALL (external) - Difference in elevation of throat and stream face elevation

TROEL - Elevation of invert at throat

NOCA, NOCB, NOCC - Variables indicating no designs applicable for the three design conditions mentioned in this report

HWOUT - Headwater for outlet control

FACEL - Elevation of face invert

ELINCA, ELINCB, ELINCC - Inlet invert elevation for curves A, B and C

CRESA, CRESB, CRESC - Minimum crest length necessary at inlets for three curve designs

DISL, DISR - Distances from toe of embankments to face and outlet of culvert

VELIN - Velocity at outlet for inlet control

VELOUT - Velocity at outlet for outlet control

SER, SEL - Embankment slopes, downstream and upstream respectively

SLOPA, SLOPB, SLOPC - Culvert slopes for the three curve conditions

Subroutine BHY3

Subroutine to design conventional and bevel-edge inlets and performance curves for design curves A, B and C.

BAR - Number of barrels

B, D - Culvert width and height

DISL, DISR - Variables denoting distances from embankment toe to inlet face and outlet face to toe of culverts

DISTA - Culvert length

HDCA, HDCB, HDCC - Headwater elevations for performance curves for design curves A, B, and C

HWO1, HWO2 - Outlet control headwater elevations for culverts with conventional and bevel-edges, respectively

SA, SB, SC - Culvert slopes for design curves A, B, and C

Subroutine BSIDE

Subroutine to design side-tapered inlets for design curves A, B and C.

BAR - Number of barrels

B, BB - Width of barrel, ft.

BIT, BITB , BITC - Variables denoting extensions to culvert lengths when the face section is moved toward the toe due to a fall in the culvert design

BF, BFB, BFC	- Variables denoting face widths
ELFACA	- Elevation of face invert for curve "A"
ELTRCA	- Elevation of throat for curve "A"
ELFACB	- Elevation of face invert for curve "B"
ELTRCB	- Elevation of throat for curve "B"
ELFACC	- Elevation of face invert for curve "C"
ELTRCC	- Elevation of throat for curve "C"
FALLM	- Maximum FALL allowed for inlet
FACEL	- Elevation of face invert
HWFA, HWFB, HWFC	- Face headwater elevations for performance curves A, B and C
HWTA, HWTB, HWTC	- Throat headwater elevations for peformance curves A, B and C
L1	- Length of improved inlet
NOCAS, NOCBS, NOCCS	- Variables. No curve A, B and C designs applicable
SCORR	- Slope correction factor
SLO, SA, SB, SC	- Variables for barrel slopes for curves A, B and C
STROEL	- Streambed elevation at the culvert throat
TBFALL	- Inlet FALL for curve "B"
TOEL	- Elevation of culvert outlet invert
WB	- Minimum crest length for curve "B" design

Subroutine BSLOPV

This subroutine is called to design slope-tapered vertical face box culverts and performance curve data for the two design conditions referred to as curves A and B. The design for curve C is not included at this time.

BAR - Number of barrels

BF - Face width, ft.

DIST - Culvert length from face to outflow, ft.

FACEL - Face elevation, ft.

FALL - Vertical distance between crest point elevation and throat elevation, ft.

HWTA - Headwater at throat for curve A, ft.

HWTB - Headwater at throat for curve B, ft.

HWFA - Headwater at face for curve A, ft.

HWFB - Headwater at face for curve B, ft.

L1, L2, L3, L4 - Variables denoting length of improved culvert entrance design

NOC - Variable to indicate no design applicable for either curve A and/or B

QUE - Maximum discharge for curve B design

SF - Fall slope

S - Variable for actual culvert barrel slopes

TROE - Variable used to denote throat elevation for curve A and B

Y - Vertical distance between crest point and face normal to slope

VELIN - Inlet control velocity

VELOUT - Outlet control velocity

Subroutine BSLOPM

Subroutine to design slope-tapered mitered face box culverts and performance curve data for curves "A" and "B" design. Variables are essentially the same for the vertical face design.

Subroutine BOUT

Subroutine to compute outlet control headwaters

AVEV - Average velocity for backwater calculations

AVER - Average hydraulic radius for backwater calculations

CKE - Entrance loss coefficient variable

DSUBN - Normal depth, in feet

DSUBC - Critical depth, in feet

DTW - Design tailwater, in feet

HEAD - Hydraulic head required for outlet control, in feet

HO - Variable equal to tailwater or to critical depth plus D divided by 2

WHW - Outlet control headwater, in feet

S1 - Friction slope

SPH - Specific head for backwater calculations, in feet

SUMX - Distance between two cross-sections in backwater computations, in feet

TOEL - Elevation at outlet of culvert

V - Velocity, fps

Subroutine BNORM

Subroutine to compute normal depth.

AR23 - Refers to area times hydraulic radius raised to two-thirds power

AREA - Area based on normal depth

B & D - Culvert base width and height

DEP - Normal depth

WP - Wetted perimeter

Subroutine BFIT

Subroutine to find maximum discharge

A - Variable used to increment discharge

AREA - Cross-sectional area of culvert

AHWEL - Allowable headwater elevation

B - Width of box culvert, in feet

CKE - Variable for energy loss coefficients

CLTH - Culvert length measured on stream slope

CN - Manning's "n" value

D - Culvert height, in feet

DC - Critical depth

HD - Hydraulic head for given flow in outlet control, in feet

HO - Variable equal to tailwater or $\frac{D + d_c}{2}$ whichever is larger

Q_{max} - Maximum discharge measured at the intersection of outlet control curve and allowable headwater

Subroutine BEQUA

Subroutine to compute inlet control headwater.

HWOVD - Variable referring to headwater over "D"

I1, I5 - Variable part of input code number

DEP - Normal depth

PROGRAM LISTING

Routines containing identification numbers beginning with "B" followed by an integer value refer to box culverts and routines containing identification numbers beginning with "C" plus the integer value refer to circular pipe culverts. Subsequent to the release of the preliminary draft of HY-6, program changes have been incorporated in this version of HY-6.

Changes to the computer program are shown on the program listing with two asterisks following the statement sequence number.

```
C
C      THIS VERSION OF THE PROGRAM WILL ANALYZE BOX CULVERTS
C      AND CIRCULAR PIPES (CMP and Concrete)
C
C       BY MARIO MARQUES  -- FHWA -- 1979
C
C
        COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),     **
       1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),  **
       2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100), **
       3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100), **
       4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),    **
       5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,   **
       6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100), **
       7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100), **
       8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100), **
       9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,    **
       ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2      **
        INTEGER SYSIN, SYSOT
        DATA IBLANK/3H   /
        SYSIN=1
        SYSOT=3
C
C-----READ DESIGN DATA
   10 READ(SYSIN,901)IPROJ
      IF(IPROJ(1).EQ.IBLANK) GO TO 11
   12 READ(SYSIN,903) I1,I2,I3,I4,I5,SLOPE,DIST,Q1,DTW,AHWEL,ELIN ,
     1ELOUT,  SEL,SER,SFACE
   50 IF(I1.EQ.1) GO TO 58
   52 IF(I1.EQ.2) GO TO 58
   54 IF(I1.EQ.3) GO TO 58
   56 IF(I1.EQ.4) GO TO 58
      WRITE (SYSOT,2130)
 2130 FORMAT( 22H  CULVERT CODE INVALID)
      GO TO 10
   58 SLOPE = SLOPE + 0.000001
C
C-----ROUTINES TO DESIGN PIPES,ARCHES,OR BOXES
   15 GO TO (110,110,130,140),I1
C.....CALL TO CIRCULAR CULVERTS(NOT INCLUDED BUT AVAILABLE)
  110 CALL CIRC(DIST,SLOPE)
      GO TO 10                                                         **
C.....CALL TO ARCH PIPES( NOT AVAILABLE AT THIS TIME
  130 CALL ARCH
      GO TO 10
C.....CALL BOX CULVERT
  140 CALL BOXES(DIST,SLOPE)
      GO TO 10                                                         **
   11 WRITE(SYSOT,910)
      STOP
  910 FORMAT(11H END OF JOB)
  901 FORMAT(26A3)
  903 FORMAT(5I1,F7.4,9F7.1)
  904 FORMAT(2F4.1)
      END
```

```
      SUBROUTINE BOXES(DIST,SLOPE)
C
C     SUBROUTINE TO DEVELOP INDEX SHEET (INCLUDES OUTLET AND INLET
C          CONTROL HEADWATER ,EXTERNAL FALL AND INVERT ELEVATIONS)
C
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100).TAB4(100).
     1TAB5(100),TAB6(100).TAB7(100),TAB8(100).TAB9(100).TAB10(100).
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100).TAB15(100).TAB16(100).
     3TQMAX(2.100),ELINCB(2,100),ELINCC(2,100).HWCB(2.100).HWCC(2.100).
     4L,LL.K.SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL.SER.ELINCA(2.100).
     5        IPROJ(26),I1.I2.I3,I4.I5.ELL,ELR,Q1.AHW,DTW.CLTH.I55.
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100).TCFALL(2.100).
     7DISTA(2,100).SLOPA(2,100),CRESA(2,100).VELA(2,100),DISTB(2,100).
     8SLOPB(2.100),CRESB(2,100).VELB(2,100),DISTC(2,100).SLOPC(2,100).
     9CRESC(2.100).VELC(2.100),ELTRCB.ELTRCC,QUE.DISL,DISR.SFACE.
     ADIA1,DIA2,ELLE,ELRR.NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2
      DIMENSION HWO(2),SUMP(2), FACEHW(2),HWEL(2)
      DIMENSION CKE(4),FACE(2),KT(7)
      INTEGER SYSIN, SYSOT
      DATA KT/1111,1122,1123,1134,1145,1146,1147/
      DATA ALPHA,SCORR,CN/1.0,.5,.012/
      DATA CKE/.4,.5,.7,.2/
C
C     PRINT CONVENTIONAL CULVERT DESIGN DATA
C
      READ(SYSIN,2 )KBAS1.KBAS2.KDEP1.KDEP2
   2  FORMAT(4I2)
      WRITE(SYSOT,902) IPROJ
 902 FORMAT(1H1,' >>>>  BOX CULVERT DESIGN FOR PROJECT >>>    '.26A3.///
    1/ ' >>>>  THE PROGRAM PROVIDES A RANGE OF CONVENTIONAL BOX CULVERT
    2 SIZES WITH AND WITHOUT BEVELS WHICH SATISFY SITE REQUIREMENTS'//
    330X,'WHERE:  BEVELED EDGES INCLUDE THE FOLLOWING.'//37X.'HEADWALLS
    4-NORMAL -CHART NO. 8 IN HEC-13'/37X,'          -SKEWED  CHART NO. 9
    5 INHEC-13'//37X,'WINGWALLS -CHART NO. 10 IN HEC-13'////
    6  ' >>>>  IF INLET CONTROL GOVERNS - IMPROVED INLET DESIGNS ARE PR
    7OVIDED FOR SIDE-TAPERED INLETS '              /66X.'AND SLOPE-TAPER
    8ED INLETS '///)
 903 WRITE(SYSOT,904)
 904 FORMAT(1X,'*******************************************************
    1******************************************************************
    2********'/'*************************    DESIGN INPUT DATA      ***
    3******************************************************************
    4*********'/'*************************    DESIGN INPUT DATA      **
    5******************************************************************
    6********'/'*******************************************************
    7******************************************************************
    8************'//)
   5 GO TO (10,20,30.40.50,60,70),I5
  10 WRITE(SYSOT,12)I1,I2,I3,I4,I5
  12 FORMAT(4X,'CONVENTIONAL CULVERT CODE:',2X.5I1,'  WINGWALL  - WITH
    130-75 DEGREE WW FLARE, SQUARE TOP EDGES        KE= 0.4'/)
      GO TO 49
  20 WRITE(SYSOT,22)I1,I2,I3,I4,I5
  22 FORMAT(4X,'CONVENTIONAL CULVERT CODE:',2X.5I1,'  HEADWALL  - NORMA
    1L OR SKEWED TO 45 DEGREES - SQ TOP EDGES        KE= 0.5'/)
```

```
      GO TO 49
   30 WRITE(SYSOT,32) I1,I2,I3,I4,I5
   32 FORMAT(4X,'CONVENTIONAL CULVERT CODE:',2X,5I1,'  WINGWALL  - 15 DE
     1GREE FLARE - SQ TOP EDGES                        KE= 0.5'/)
      GO TO 49
   40 WRITE(SYSOT,42)I1,I2,I3,I4,I5
   42 FORMAT(4X,'CONVENTIONAL CULVERT CODE:',2X,5I1,'  WINGWALL  - NORMA
     1L OR SKEWED  -  ZERO DEGREE WW FLARE             KE= 0.7'/)
   49 IF(I5.NE.2) GO TO  60
   50 WRITE(SYSOT,52)
   52 FORMAT(4X,'BEVEL-EDGED CULVERT CODE:   41145  HEADWALL - NORMAL OR
     1 SKEWED TO 45 DEGREES WITH 1:1 BEVELS'/40X,'(VARIABLE BEVEL ON ACU
     2TE ANGLE OF SKEWED HEADWALL)              KE= 0.2'//)
      GO TO 80
   60 WRITE(SYSOT,62)
   62 FORMAT(4X,'BEVEL-EDGED CULVERT CODE:   41146  WINGWALL - 18 TO 33.
     17 DEGREE WW FLARE WITH 1.5:1 TOP BEVEL OR'/40X,' 45 DEGREE FLARE W
     2ITH 1:1 TOP BEVEL                         KE= 0.2'//)
      GO TO 80
   70 WRITE(SYSOT,72)
   72 FORMAT(4X,'BEVEL-EDGED CULVERT CODE:   41147  HEADWALL - NORMAL
     1WITH 1.5:1 BEVELS ON 3 SIDES                     KE= 0.2'//)
   80 ISEL=SEL
      ISER=SER
      SLOPP=SLOPE
      SLOPE=(ELIN-ELOUT)/DIST +.000001
      WRITE(SYSOT,1900)I1,I2,I3,I4,I5,SLOPP,DIST,Q1,DTW,AHWEL,ELIN,              **
     1ELOUT,  SEL, SER,KBAS1,KBAS2,KDEP1,KDEP2,SFACE,SLOPE
 1900 FORMAT(18X,'APPROX     TOE-TOE',27X,
     A          'ALLOWABLE   STREAM BED   STREAM BED   LEFT ROADWAY   R
     1IGHT ROADWAY'/4X,'CULVERT',7X,'STREAM    CULVERT     DESIGN',6X,'DE
     2SIGN',5X,'HEADWATER   ELEVATION    ELEVATION',5X,'EMBANKMENT',
     35X,'EMBANKMENT'/6X,'CODE',8X,'SLOPE',4X,' LENGTH   DISCHARGE   TAI
     4LWATER    ELEVATION   AT INLET     AT OUTLET',7X,'SLOPE',11X,'SLOP
     5E'/4X,5I1,8X,F7.4,2X,F8.1,2X,F8.1,4X,F8.1,4X,F8.1,4X,F8.1,5X,
     6F8.1,9X,F4.1,':1',10X,F4.1,':1'//4X,'CULVERT  SIZES',25X,'SLOPE-TA
     7PER'/7X,'B  FROM',I4,' FT TO',I4,' FT',12X,'FALL SLOPE',12X,'COMPU
     8TED STREAM'/7X,'D  FROM',I4,' FT TO',I4,' FT',14X,F4.1,':1',15X,
     9'SLOPE =',F7.4//)
      WRITE(SYSOT,2100)
 2100 FORMAT(130H*******************************************************
     1******************************************************************
     2********/'************************', '       INDEX  SHEET  FOR  BOX
     3  CULVERTS      **************','**********************************
     4***************'/'************************',  '      INDEX  SHEET
     5FOR  BOX  CULVERTS      *******************************************
     6******************,'    /'****************************************
     7******************************************************************
     8*************************'/)
  459 WRITE(SYSOT 2105) CKE(I4)
 2105 FORMAT(30X,'*  -- OUTLET CONTROL --    **',27X,'-- INLET CONTROL --
     1',27X,'*'/
     130X,'*',25X,'**',73X,'*'/30X,'* KE=',F4.1,'  KE=0.2  OUTLET ** CON
     2VENTIONAL CULVERT  *  BEVEL-EDGED CULVERT   * SIDE-TAPERED CULVERT
     3   *'/30X,'---------------------------------------------------------
```

```
     4----------------------------------------------------------'/' * SEE   *NUMBER
     5*BARREL*BARREL*  HW        HW      INVERT **  HW '.11X.'INVERT *  HW
     6'.13X.'INVERT * THROAT',10X,'INVERT *'/' * PAGE *  OF    * WIDTH* D
     7EPTH*  ELEV     ELEV  .  ELEV ** ELEV      FALL     ELEV  *  ELEV
     8FALL     ELEV  *HW ELEV   FALL     ELEV  *'/
     9                ' *'.6X,'*BARRELS* (FT) * (FT) *  (FT)     (FT)
     A(FT)  ** (FT)     (FT)     (FT)  *  (FT)     (FT)     (FT)
     B (FT)     (FT)  *'/' *',6X,'*',7X,'*',6X,'*'.6X,'*',25X,'**',23X.
     C'*'.24X.'*',24X,'*')
      DO 457 J=1,100
      ITAB(J)=0                                                              **
      TAB1(J)=0.0
      TAB2(J)=0.0
      TAB3(J)=0.0
      TAB4(J)=0.0
      TAB5(J)=0.0
      TAB6(J)=0.0
      TAB7(J)=0.0
      TAB8(J)=0.0
      TAB9(J)=0.0
      TAB10(J)=0.0
      TAB11(J)=0.0
      TAB12(J)=0.0
      TAB13(J)=0.0
      TAB14(J)=0.0
      TAB15(J)=0.0
      TAB16(J)=0.0
      TQMAX(1.J)=0.0
      TQMAX(2.J)=0.0
  457 CONTINUE
      L=1
  458 BAR=1.
      II4=I4
      II5=I5
      IMP=0
      ICOUNT=0
   53 KODE= I2*1000+I3*100+I4*10+I5
      DO 63 I=1,7
      IF(KODE.EQ.KT(I)) GO TO 460
   63 CONTINUE
C
C       PRINT CULVERT CODE INVALID
   73 PRINT 2130
 2130 FORMAT(22H  CULVERT CODE INVALID)
      RETURN
C
C.....START ANALYSIS OF BOX CULVERTS
  460 DO 480 K=KBAS1,KBAS2
      B=BAR*K
      DO 480 KK=KDEP1,KDEP2
      D=KK
      NOCA(1.L)=0
      NOCA(2.L)=0
      NOCB(1.L)=0
      NOCB(2.L)=0
```

```
      NOCC(1,L)=0
      NOCC(2,L)=0
      HWIN=0.0
      HWO(1)=0.0
      HWO(2)=0.0
      SUMP(1)=0.0
      SUMP(2)=0.0
      FACEHW(1)=0.0
      FACEHW(2)=0.0
      HWOUT=0.0
      VELIN=0.0
      VELOUT=0.0
      IBET=0
      SMALL=(SLOPE*SEL**2*D)/(1+SLOPE*SEL)
      SMALR=(SLOPE*SER**2*D)/(1.+SLOPE*SER)
      DISL=SEL*D-SMALL
      DISR=SER*D+SMALR
      ELL=DISL*SLOPE
      ELR=DISR*SLOPE
      FACEL=ELIN-ELL
      FAHC=FACEL
      CROWN = FACEL+D
      TOEL=ELOUT+ELR
      HH=FACEL-TOEL
      DIST1=DIST-DISL-DISR
      CLTH=((DIST1*DIST1)+(HH*HH))**.5
      IF(D.GT.(1.2*(B/BAR))) GO TO 480
      IF((B/BAR).GT.(2.0*D)) GO TO 480
      I4=II4
      I5=II5
      IBEV=1
      IF(I5.GT.4) IBEV=2
      IF(IBEV.EQ.2) NOCA(1,L)=1
      IF(IBEV.EQ.2) IBET=1
      Q=Q1/BAR
      BB=B/BAR
  461 QMAX=0.0
C.....COMPUTE OUTLET CONTROL HEADWATER
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO(IBEV)=HWOUT+TOEL
      IF(IBEV.EQ.1) GO TO 465
  462 IF(HWO(2).GT.AHWEL.AND.NOCA(1,L).EQ.1) NOCA(1,L)=0
      IF(HWO(2).GT.AHWEL) GO TO 480
      IF(HWO(2).LT.TOEL) GO TO 480
C.....COMPUTE MAX Q
  465 CALL BFIT(Q,BB,D,QMAX,TOEL,SLOPE)
      Q=Q1/BAR
      TQMAX(IBEV,L)=QMAX*BAR
      X=Q1/(B*D**1.5)
C.....COMPUTE INLET CONTROL HEADWATER
      CALL BEQUA(X,HWIN,B,D,SLOPE)
  124 FACEHW(IBEV)=FACEL+HWIN
      IF(IBEV.EQ.2) GO TO 132
      IF(FACEHW(1).LT.(AHWEL-D/3.).AND.HWO(1).LT.(AHWEL-D/3.)) GO TO 480  **
      GO TO 134
```

```
 132 IF(FACEHW(2).LT.(AHWEL-D/3.).AND.HWO(2).LT.(AHWEL-D/3.)) GO TO 480   **
 134 FALLM=1.5*D
     FALLT=DIST1*SLOPE
     IF(FALLM.GT.FALLT) FALLM=FALLT
     IF(FACEHW(IBEV).GT.AHWEL) GO TO 140
     GO TO 150
C    COMPUTE THE SUMP
 140 SUMP(IBEV)=FACEHW(IBEV)-AHWEL
     IF(SUMP(IBEV).GE.FALLM) NOCA(IBEV,L)=1
     DISTA(IBEV,L)=DIST1
     IF(NOCA(IBEV,L).EQ.1) GO TO 153
     DIS=SUMP(IBEV)*SEL
     DISTA(IBEV,L)=DIS+DIST1
     FACEL=FACEL+SLOPE*DIS
     DIF=FACEL-SUMP(IBEV)-DIS*SLOPE
     IF(DIF.LT.TOEL) DIF=TOEL+.01
     SLOPA(IBEV,L)=(DIF-TOEL)/DISTA(IBEV,L)
     CROWN=DIF+D
     FACE(IBEV)=DIF
     FACEHW(1)=FACE(IBEV)+HWIN
     IF(FACEHW(1).GE.CROWN.OR.HWO(IBEV).GE.CROWN)GO TO 142   **
     GO TO 480
 142 HWEL(IBEV)=AHWEL
     GO TO 155
C    NO SUMP
 150 SUMP(IBEV)=0.0
     SLOPA(IBEV,L)=SLOPE
     DISTA(IBEV,L)=DIST1
     FACE(IBEV)=FACEL
     CROWN=FACEL+D
     HWEL(IBEV)=FACEL+HWIN
     IF(FACEHW(IBEV).GE.CROWN.OR.HWO(IBEV).GE.CROWN)GO TO 155   **
     GO TO 480
 155 IF(SUMP(IBEV).EQ.0.0) CRESA(IBEV,L)=0.0
C    COMPUTE VELOCITY
     SLO=SLOPA(IBEV,L)
     DA=DISTA(IBEV,L)
     CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DA    ,TOEL,QMAX,SLO)
     CALL BNORM(Q,CN,SLO,BB,D,DEP,AREA,WP)
C.....VELOCITY BASED ON EITHER INLET OR OUTLET CONTROL
     VELA(IBEV,L)=Q /AREA
     IF(VELOUT.GT.VELA(IBEV,L)) VELA(IBEV,L)=VELOUT
     IF(DN.GE.DC) GO TO 164
     IF(DTW.LT.DC) GO TO 164
     WHY2=0.247*VELA(IBEV,L)*DN**.5-(.5*DN)
     IF(WHY2.GT.DTW) GO TO 164
     IF(DTW.GE.D) VELA(IBEV,L)=Q/(BB*D)
     IF(DTW.LT.D) VELA(IBEV,L)=Q/(BB*DTW)
 164 IF(SUMP(IBEV).EQ.0.0) GO TO 151
     HCA=FAHC+(SUMP(IBEV)*SEL*SLOPE)+(SUMP(IBEV)*3.+D/2.)*SLOPE
     HC=HWEL(IBEV)-HCA
     IF(HC.LT.1.) HC=1.0
     CRES=(.5*Q1**.6667)/HC
     CRESA(IBEV,L)=CRES**1.5
C.....COMPUTE CURVE B
```

```
  151 ELINCA(IBEV,L)=FACE(IBEV)
  154 X=TQMAX(IBEV,L)/(B*D**1.5)
      CALL BEQUA(X,HWI,B,D,SLOPE)
      TEMP=ELINCA(IBEV,L)+HWI
      IF(TEMP.LE.AHWEL) GO TO 144
      BFALL=TEMP-AHWEL
      TBFALL(IBEV,L)=BFALL      +SUMP(IBEV)
      IF(TBFALL(IBEV,L ).GT.FALLM) GO TO 160
      ELINCB(IBEV,L)=ELINCA(IBEV,L)-BFALL
      IF(ELINCB(IBEV,L).LE.TOEL) ELINCB(IBEV,L)=TOEL+.01
      HWCB(IBEV,L)=ELINCB(IBEV,L)+HWI
      GO TO 139
  160 ELINCB(IBEV,L)=ELINCA(IBEV,L)-(FALLM-SUMP(IBEV))
      IF(ELINCB(IBEV,L).LE.TOEL) ELINCB(IBEV,L)=TOEL+.01
      BFALL=ELINCA(IBEV,L)-ELINCB(IBEV,L)
      TBFALL(IBEV,L)=BFALL+SUMP(IBEV)
C.....COMPUTE MAX Q BASED ON INLET CONTROL CURVE
      AIN=50.
      QUE=Q1
  162 QUE=QUE+AIN
      X=QUE/(B*D**1.5)
      CALL BEQUA(X,HIGH,B,D,SLOPE)
      HI=HIGH+ELINCB(IBEV,L)
      IF(HI.GT.AHWEL) GO TO 170
      GO TO 162
  170 QUE=QUE-AIN
      IF(AIN.LT.10.) GO TO 172
      AIN=2.0
      GO TO 162
  172 TQMAX(IBEV,L)=QUE
      X=QUE/(B*D**1.5)
      CALL BEQUA(X,HWI,B,D,SLOPE)
      HWCB(IBEV,L)=ELINCB(IBEV,L)+HWI
  139 DISB=BFALL*SEL
      DISTB(IBEV,L)=DISTA(IBEV,L)+DISB
      SLOPB(IBEV,L)=(ELINCB(IBEV,L)-TOEL)/DISTB(IBEV,L)
C.....COMPUTE VELOCITY BASED ON MAX Q
      SLO=SLOPB(IBEV,L)
      QQ=TQMAX(IBEV,L)/BAR
      DB=DISTB(IBEV,L)
      CALL BOUT(QQ,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DB    ,TOEL,QMAX,SLO)
      CALL BNORM(QQ,CN,SLO,BB,D,DEP,AREA,WP)
      VELB(IBEV,L)=QQ/AREA
      IF(VELOUT.GT.VELB(IBEV,L)) VELB(IBEV,L)=VELOUT
      IF(DN.GE.DC) GO TO 168
      IF(DTW.LT.DC) GO TO 168
      WHY2=0.247*VELB(IBEV,L)*DN**.5-(.5*DN)
      IF(WHY2.GT.DTW) GO TO 168
      IF(DTW.GE.D) VELB(IBEV,L)=Q/(BB*D)
      IF(DTW.LT.D) VELB(IBEV,L)=Q/(BB*DTW)
  168 HCB=FAHC+(TBFALL(IBEV,L)*SEL*SLOPE)+(TBFALL(IBEV,L)*3.+D/2.)*SLOPE
      HC=AHWEL-HCB
      IF(HC.LT.1.) HC=1.0
      CRES=(.5*TQMAX(IBEV,L)**.6667)/HC
      CRESB(IBEV,L)=CRES**1.5
```

```
      GO TO 145
  144 TBFALL(IBEV,L)=0.0
      NOCB(IBEV,L)=1
C.....COMPUTE CURVE C
  145 TEMP=ELINCA(IBEV,L)+HWIN
      IF(HWO(IBEV).GE.TEMP) GO TO 143
      CFALL=TEMP-HWO(IBEV)
      TCFALL(IBEV,L)=CFALL       +SUMP(IBEV)
      ELINCC(IBEV,L)=ELINCA(IBEV,L)-CFALL
      IF(TCFALL(IBEV,L).GT.FALLM) ELINCC(IBEV,L)=ELINCA(IBEV,L)-(FALLM-
     1SUMP(IBEV))
      IF(ELINCC(IBEV,L).LE.TOEL) ELINCC(IBEV,L)=TOEL+.01
      CFALL=ELINCA(IBEV,L)-ELINCC(IBEV,L)
      TCFALL(IBEV,L)=CFALL+SUMP(IBEV)
      HWCC(IBEV,L)=ELINCC(IBEV,L)+HWIN
      DISC=CFALL*SEL
      DISTC(IBEV,L)=DISC+DISTA(IBEV,L)
      SLOPC(IBEV,L)=(ELINCC(IBEV,L)-TOEL)/DISTC(IBEV,L)
      SLO =SLOPC(IBEV,L)
      DCC=DISTC(IBEV,L)
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DCC   ,TOEL,QMAX,SLO)
      CALL BNORM(Q,CN,SLO,BB,D,DEP,AREA,WP)
      VELC(IBEV,L)=Q /AREA
      IF(VELOUT.GT.VELC(IBEV,L)) VELC(IBEV,L)=VELOUT
      IF(DN.GE.DC) GO TO 169
      IF(DTW.LT.DC) GO TO 169
      WHY2=0.247*VELC(IBEV,L)*DN**.5-(.5*DN)
      IF(WHY2.GT.DTW) GO TO 169
      IF(DTW.GE.D) VELC(IBEV,L)=Q/(BB*D)
      IF(DTW.LT.D) VELC(IBEV,L)=Q/(BB*DTW)
  169 HCC=FAHC+(TCFALL(IBEV,L)*SEL*SLOPE)+(TCFALL(IBEV,L)*3.+D/2.)*SLOPE
      HC=TEMP-HCC
      IF(HC.LT.1.) HC=1.0
      CRES=(.5*Q1**.6667)/HC
      CRESC(IBEV,L)=CRES**1.5
      GO TO 153
  143 TCFALL(IBEV,L)=0.0
      NOCC(IBEV,L)=1
  153 CONTINUE
      IF(IBEV.EQ.2) GO TO 464
      FACEL=ELIN-ELL
      IBEV=IBEV+1
      IF(I5.EQ.2) GO TO 463
      I5=6
      I4=4
      GO TO 461
  463 I5=5
      I4=4
      GO TO 461
  464 I4=II4
      I5=II5
      IF(NOCA(1,L).EQ.1) NOCB(1,L)=1
      IF(NOCA(1,L).EQ.1) NOCC(1,L)=1
      IF(NOCA(2,L).EQ.1) NOCB(2,L)=1
      IF(NOCA(2,L).EQ.1) NOCC(2,L)=1
```

```
      INDEX=0
      IF(BAR.GT.2.) GO TO 120
      IBAR=BAR
      CALL BSIDE(B,D,FALL,HWT,TROEL,IBAR,DIST1,INDEX,SLOPE)
      IF(FALL.GT.900.) GO TO 120
      IF(FALL.GE.FALLM) GO TO 480
      GO TO 122
  120 FALL=0.0
      TROEL=0.0
      HWT=0.0
      IF(NOCA(1,L).EQ.1.AND.NOCA(2,L).EQ.1) GO TO 480
  122 IBAR=BAR
      AK=K
      AKK=KK
      ITAB(L)=IBAR
      TAB1(L)=AK
      TAB2(L)= AKK
      TAB3(L)=HWO(1)
      TAB4(L)=HWO(2)
      TAB5(L)=TOEL
      TAB6(L)=HWEL(1)
      TAB7(L)=SUMP(1)
      TAB8(L)=FACE(1)
      TAB9(L)=HWEL(2)
      TAB10(L)=SUMP(2)
      TAB11(L)=FACE(2)
      TAB12(L)=HWT
      TAB13(L)=FALL
      TAB14(L)=TROEL
      TAB15(L)=DIST2
      TAB16(L)=QMAX*IBAR
      IF(NOCA(1,L).EQ.1.AND.NOCA(2,L).EQ.1.AND.TAB4(L).GT.TAB12(L))
     1GO TO 480
      IF(NOCA(1,L).EQ.0.AND.NOCA(2,L).EQ.0) GO TO 126
      IF(NOCA(2,L).EQ.0) GO TO 130
      GO TO 125
  130 TAB3(L)=0.0
      TAB6(L)=0.0
      TAB7(L)=0.0
      TAB8(L)=0.0
C.....PRINT DATA FOR INDEX SHEET
      WRITE(SYSOT,127)L,IBAR,AK,AKK,HWO(2),TOEL,HWEL(2),SUMP(2),
     1 FACE(2),HWT,FALL,TROEL
  127 FORMAT(' *',I3,3X,'*',I4,3X,'*',F5.1,' *',F5.1,' *    --',F9.1,
     1F10.1,' **    --',5X,'--',7X,'--   *',2(F6.1,4X,F4.1,3X,F6.1,' *'))
      GO TO 128
  126 WRITE(SYSOT,123)L,IBAR,AK,AKK,HWO(1),HWO(2),TOEL,HWEL(1),
     1SUMP(1),FACE(1),HWEL(2),SUMP(2),FACE(2),HWT,FALL,TROEL
  123 FORMAT(' *',I3,3X,'*',I4,3X,'*',F5.1,' *',F5.1,' *',2F7.1,F10.1,
     1' **',F6.1,5X,F4.1,3X,F6.1,' *',2(F6.1,4X,F4.1,3X,F6.1,' *'))
      GO TO 128
  125 WRITE(SYSOT,129)L,IBAR,AK,AKK,HWO(2),TOEL,HWT,FALL,TROEL
  129 FORMAT(' *',I3,3X,'*',I4,3X,'*',F5.1,' *',F5.1,' *    --',F9.1,
     1 F10.1,' **    --',5X,'--',7X,'--   *',3X,'--',6X,'--',7X,'--   *',
     2F6.1,4X,F4.1,3X,F6.1,' *')
```

```
  128 L=L+1
  479 ICOUNT=IBAR
  480 CONTINUE
  481 BAR=BAR+1.
      IF(BAR.GT.5) L=L-1
      IF(BAR.GT.5.) GO TO 482
      GO TO 460
  482 IF(ICOUNT.EQ.0)WRITE(SYSOT,483)                                          **
  483 FORMAT(///5X,'RANGE OF CULVERT SIZES EXCEED DESIGN CRITERIA')            **
      IF(ICOUNT.EQ.0)RETURN                                                    **
      WRITE(SYSOT,484)
  484 FORMAT(///25X,'BY DEFINITION OF FALL, WHEN A SIDE-TAPERED INLET LI
     1ES ON THE STREAM SLOPE,'/25X,'THE FALL IS THE DIFFERENCE IN ELEVAT
     2ION OF THE FACE INVERT AND THE THROAT INVERT'//25X,'WHEN SIDE-TAPE
     3RED CULVERT COLUMN (ABOVE) CONTAINS 0.0 0.0 0.0'/30X,'1. THROAT DE
     4SIGN EXCEEDS DESIGN LIMITS'/27X,'OR 2. IMPROVED INLETS FOR MORE TH
     5AN 2 BARRELS NOT AVAILABLE')
C.....CALL TO BHY3 FOR CONVENTIONAL AND BEVEL DESIGN
      CALL BHY3(DIST,SLOPE)
      RETURN
      END
```

```
      SUBROUTINE BHY3(DIST,SLOPE)                                       B 2585
C                                                                       B 2590
C.....DESIGN CULVERTS LISTED ON INDEX SHEET                             B 2595
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),         B 2600   **
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),     B 2605   **
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),B 2610   **
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100), B 2615   **
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),        B 2620   **
     5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,     B 2625   **
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),  B 2630   **
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),  B 2635   **
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),  B 2640   **
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,       B 2645   **
     ADIA1,DIA2,ELLE,ELRR,NCCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2          B 2650   **
      DIMENSION HWO(2),SUMP(2), FACEHW(2),HWEL(2)                       B 2655
      DIMENSION CKE(4),FACE(2)                                          B 2660
      REAL L1,L2,L3,L4                                                  B 2665
      INTEGER SYSIN, SYSOT                                              B 2670
      DATA CKE/.4,.5,.7,.2/                                             B 2675
      II4=I4                                                            B 2680
      II5=I5                                                            B 2685
   90 LL=1                                                              B 2690
  100 IBAR=ITAB(LL)                                                     B 2695
      B=TAB1(LL)*IBAR                                                   B 2700
      D=TAB2(LL)                                                        B 2705
      SMALL=(SLOPE*SEL**2*D)/(1.+SLOPE*SEL)                             B 2710   **
      SMALR=(SLOPE*SER**2*D)/(1.+SLOPE*SER)                             B 2715   **
      DISL=SEL*D-SMALL                                                  B 2720   **
      DISR=SER*D+SMALR                                                  B 2725   **
      ELL=DISL*SLOPE                                                    B 2730
      ELR=DISR*SLOPE                                                    B 2735
      DIST1=DIST-DISL-DISR                                              B 2740
C     PAGE HEADINGS                                                     B 2745
   94 WRITE(SYSOT,80) LL,ITAB(LL),TAB1(LL),TAB2(LL),Q1,AHWEL,SLOPE      B 2750
     1,TAB5(LL)                                                         B 2755
   80 FORMAT(1H1,' PAGE=',I3, 5X,'NO. BARRELS=',I2,4X,'WIDTH=',F5.1,' FTB 2760
     1',4X,'HEIGHT=',F5.1,' FT',4X,'Q(50)=',F7.1,' CFS    AHWEL=',      B 2765
     2F7.1,' FT',4X,'STREAM SLOPE =',F7.4/50X,'OUTLET INVERT ELEV. =',  B 2770
     3F7.1,' FT'///)                                                    B 2775
      IF(I5.GT.4)WRITE(SYSOT,8)                                         B 2780
    8 FORMAT(1X,'CONVENTIONAL INLET DESIGN'/1X,'************************B 2785
     1*'//,20X,'CONVENTIONAL CULVERT DESIGN NOT REQUESTED'//)            B 2790
      IF(I5.GT.4) GO TO 212                                             B 2795
      IF(NOCA(1,LL).EQ.0) GO TO 89                                      B 2800
      WRITE(SYSOT,91)I1,I2,I3,I4,I5                                     B 2805
   91 FORMAT(1X,'CONVENTIONAL INLET DESIGN FOR CULVERT CODE  ',5I1/     B 2810
     11X,'***********************************************'///20X,       B 2815
     2'DESIGN DATA NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE CONVB 2820
     3ENTIONAL INLET EXCEEDS 1.5D OR LSO.')                             B 2825
      GO TO 206                                                         B 2830
C                                                                       B 2835
C.....CONVENTIONAL INLET DESIGN + PERFORMANCE CURVE DATA                B 2840
   89 WRITE(SYSOT,81)I1,I2,I3,I4,I5,CKE(I4),TQMAX(1,LL)                 B 2845
   81 FORMAT(1X,'CONVENTIONAL INLET DESIGN FOR CULVERT CODE: ',5I1/     B 2850
     11X,'*************************************************'//4X,'OUTB 2855
```

```
     2LET COMPUTATIONS',34X,'INLET COMPUTATIONS'/3X,'*******************
     3*',8X,'*************************************************************
     4******************************'//10X,'KE =',F7.1,18X,'MIN FALL C
     5URVE',17X,'MAX Q CURVE',21X,'MIN HW CURVE'//67X,'MAX Q =',F7.1,
     6' CFS'//)
      DA=DISTA(1,LL)
      SA=SLOPA(1,LL)
      SB=SLOPB(1,LL)
      SC=SLOPC(1,LL)
      IF(NOCB(1,LL).EQ.1.AND.NOCC(1,LL).EQ.1) GO TO 14
      IF(NOCB(1,LL).EQ.1) GO TO 32
      IF(NOCC(1,LL).EQ.1) GO TO 18
   10 WRITE(SYSOT,12)DISTA(1,LL),DISTB(1,LL),DISTC(1,LL),TAB7(LL),
     1TBFALL(1,LL),TCFALL(1,LL),ELINCA(1,LL),ELINCB(1,LL),ELINCC(1,LL),
     2SLOPA(1,LL),SLOPB(1,LL),SLOPC(1,LL),VELA(1,LL),VELB(1,LL),VELC(1,
     3LL),CRESA(1,LL),CRESB(1,LL),CRESC(1,LL)
   12 FORMAT(30X,'CULVERT LENGTH  =',F7.1,' FT',6X,'CULVERT LENGTH  =',
     1F7.1,' FT',6X,'CULVERT LENGTH  =',F7.1,' FT'/30X,'FALL AT FACE
     2=',F7.1,' FT',6X,'FALL AT FACE    =',F7.1,' FT',6X,'FALL AT FACE
     3  =',F7.1,' FT'/30X,'ELEV FACE INVERT=',F7.1,' FT',6X,'ELEV FACE I
     4NVERT=',F7.1,' FT',6X,'ELEV FACE INVERT=',F7.1,' FT'/30X,'CULVERT
     5SLOPE   =',F9.4,7X,'CULVERT SLOPE   =',F9.4,7X,'CULVERT SLOPE   ='
     6,F9.4/30X,'VEL AT DESIGN Q =',F7.1,' FPS',5X,'VEL AT MAX Q    =',
     7F7.1,' FPS',5X,'VEL AT DESIGN Q =',F7.1,' FPS'/30X,'MIN CREST LENG
     8TH=',F7.1,' FT',6X,'MIN CREST LENGTH=',F7.1,' FT',6X,'MIN CREST LE
     9NGTH=',F7.1,' FT'//8X,'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HW
     AF',20X,'Q',8X,'HWF'/)
      QD=Q1-(Q1*.2)
   63 Q=QD/IBAR
      BB=B/IBAR
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO1=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN,B,D,SA)
      HDCA=ELINCA(1,LL)+HWN
      CALL BEQUA(X,HWN,B,D,SB)
      HDCB=ELINCB(1,LL)+HWN
      CALL BEQUA(X,HWN,B,D,SC)
      HDCC=ELINCC(1,LL)+HWN
      WRITE(SYSOT,85)QD,HWO1,QD,HDCA,QD,HDCB,QD,HDCC
   85 FORMAT(3X,F9.0,F9.1,3(13X,F9.0,1X,F9.1))
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 206
      QD=QD+(Q1*.2)
      GO TO 63
   14 WRITE(SYSOT, 16)DISTA(1,LL), TAB7(LL),ELINCA(1,LL),SLOPA(1,LL),
     1VELA(1,LL),CRESA(1,LL)
   16 FORMAT(30X,'CULVERT LENGTH  =',F7.1,' FT',19X,'--',26X,'--'/30X,
     1'FALL AT FACE    =',F7.1,' FT',19X,'--', 26X,'--'/30X,'ELEV FACE I
     2NVERT=',F7.1,' FT',19X,'--',26X,'--'/30X,'CULVERT SLOPE   =',F9.4,
     320X,'--',26X,'--'/30X,'VEL AT DESIGN Q =',F7.1,' FPS',18X,'--',
     426X,'--'/30X,'MIN CREST LENGTH=',F7.1,' FT',19X,'--',26X,'--'//8X,
     5'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HWF',18X,'Q',8X,'HWF'/)
      QD=Q1-(Q1*.2)
   60 Q=QD/IBAR
      BB=B/IBAR
```

```
      CALL BOUT(Q.BB.D,HWOUT,VELOUT.DEP,DN.DC.Z.DIST1.TOEL.QMAX.SLOPE)
      HWO1=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN ,B.D,,SA)
      HDCA=ELINCA(1,LL)+HWN
      WRITE(SYSOT,186)QD,HWO1,QD,HDCA
  186 FORMAT(3X,F9.0,F9.1,14X,F9.0,F9.1,20X,'--',8X,'--',18X,'--',8X,'--
     1')
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 206
      QD=QD+(Q1*.2)
      GO TO 60
   18 WRITE(SYSOT,20)DISTA(1,LL),DISTB(1,LL),TAB7(LL),TBFALL(1,LL),
     1ELINCA(1,LL),ELINCB(1,LL),SLOPA(1,LL),SLOPB(1,LL),VELA(1,LL),
     2VELB(1,LL ),CRESA(1,LL),CRESB(1,LL)
   20 FORMAT(30X,'CULVERT LENGTH  =',F7.1,' FT',6X,'CULVERT LENGTH  =',
     1F7.1,' FT',14X,'--'/30X,'FALL AT FACE     =',F7.1,' FT',6X,'FALL AT
     2 FACE     =',F7.1,' FT',14X,'--'/30X,'ELEV FACE INVERT=',F7.1,' FT'
     4,6X,'ELEV FACE INVERT=',F7.1,' FT',14X,'--'/30X,'CULVERT SLOPE   =
     5',F9.4,7X,'CULVERT SLOPE   =',F9.4,15X,'--'/30X,'VEL AT DESIGN Q =
     6',F7.1,' FPS',5X,'VEL AT MAX Q    =',F7.1,' FPS',13X,'--'/30X,'MIN
     7 CREST LENGTH=',F7.1,' FT',6X,'MIN CREST LENGTH=',F7.1,' FT',14X,
     8'--'//8X,'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HWF',18X,'Q',
     98X,'HWF'/)
      QD=Q1-(Q1*.2)
   64 Q=QD/IBAR
      BB=B/IBAR
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO1=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN ,B,D,SA)
      HDCA=ELINCA(1,LL)+HWN
      CALL BEQUA(X,HWN ,B,D,SB)
      HDCB=ELINCB(1,LL)+HWN
      WRITE(SYSOT,183)QD,HWO1,QD,HDCA,QD,HDCB
  183 FORMAT(3X,F9.0,F9.1,14X,F9.0,F9.1,14X,F9.0,F9.1,15X,'--',8X,'--')   **
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 206
      QD=QD+(Q1*.2)
      GO TO 64
   32 WRITE(SYSOT,24)DISTA(1,LL),DISTC(1,LL), TAB7(LL),TCFALL(1,LL),
     1ELINCA(1,LL),ELINCC(1,LL),SLOPA(1,LL),SLOPC(1,LL),VELA(1,LL),
     2VELC(1,LL),CRESA(1,LL),CRESB(1,LL)
   24 FORMAT(30X,'CULVERT LENGTH  =',F7.1,' FT',19X,'--',15X,'CULVERT LE
     1NGTH  =',F7.1,' FT'/30X,'FALL AT FACE     =',
     2F7.1,' FT',19X,'--',15X,'FALL AT FACE     =',
     3              F7.1,' FT'/30X,'ELEV FACE INVERT=',F7.1,' FT',19X,'--'
     4,15X,'ELEV FACE INVERT=',F7.1,' FT'/30X,'CULVERT SLOPE   =',F9.4,
     520X,'--',15X,'CULVERT SLOPE   =',F9.4/30X,'VEL AT DESIGN Q=',F7.1,
     6' FPS',19X,'--',15X,'VEL AT DESIGN Q =',F7.1,' FPS'/30X,'MIN CREST
     7 LENGTH=',F7.1,' FT',19X,'--',15X,'MIN CREST LENGTH=',F7.1,' FT'//
     88X,'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HWF',18X,'Q',8X,
     9'HWF'/)
      QD=Q1-(Q1*.2)
   86 Q=QD/IBAR
      BB=B/IBAR
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
```

```
      HWO1=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN ,B,D,SA)
      HDCA=ELINCA(1,LL)+HWN
      CALL BEQUA(X,HWN ,B,D,SC)
      HDCC=ELINCC(1,LL)+HWN
      WRITE(SYSOT,180)QD,HWO1,QD,HDCA,QD,HDCC
  180 FORMAT(3X,F9.0,F9.1,14X,F9.0,F9.1,19X,'--',8X,'--',13X,F9.0,F9.1)
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 206
      QD=QD+(Q1*.2)
      GO TO 86
  206 IF(I5.EQ.2) GO TO 210
      I5=6
      I4=4
      GO TO 212
  210 I5=5
      I4=4
C
C.....BEVELED INLETS
C
  212 DA=DISTA(2,LL)
      SA=SLOPA(2,LL)
      SB=SLOPB(2,LL)
      SC=SLOPC(2,LL)
      IF(NOCA(2,LL).EQ.0) GO TO 208
      WRITE(SYSOT,211) I1,I2,I3,I4,I5,TQMAX(2,LL)
  211 FORMAT(///1X,'BEVELED INLET DESIGN FOR CULVERT CODE:',5I1/1X,'****
     1**********************************************'///20X,'DESIGN DATA
     2 NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE BEVEL-EDGED INLE
     3T EXCEEDS 1.5D OR LSO'/20X,'THIS OUTPUT CONSISTS OF THE OUTLET CON
     4TROL PERFORMANCE CURVE DATA FOR KE = 0.2'/20X,'WHICH IS APPLICABLE
     5 FOR THE IMPROVED INLETS.'//30X,'Q',10X,'HWO',15X,'MAX Q = ',
     6F7.0,' CFS'/)
  240 QD=Q1-(Q1*.2)
  214 Q=QD/IBAR
      BB=B/IBAR
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO1=HWOUT+TAB5(LL)
  241 WRITE(SYSOT,243)QD,HWO1
  243 FORMAT(26X,F7.1,6X,F6.1)
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 330
      QD=QD+(Q1*.2)
      GO TO 214
  208 WRITE(SYSOT,213) I1,I2,I3,I4,I5,CKE(I4),TQMAX(2,LL)
  213 FORMAT(////1X,'BEVELED INLET DESIGN   FOR CULVERT CODE: ',5I1/
     A1X,'**********************************************'//
     1 4X,'OUTLET COMPUTATIONS',34X,'INLET COMPUTATIONS'/ 3X,'**********
     2*********',8X,'***************************************************
     2***************************************'//10X,'KE =',
     3F4.1,18X,'MIN FALL CURVE',17X,'MAX Q CURVE',21X,'MIN HW CURVE'/
     4 /67X,'MAX Q =',F7.0,' CFS'//)
      IF(NOCB(2,LL).EQ.1.AND.NOCC(2,LL).EQ.1) GO TO 25
      IF(NOCB(2,LL).EQ.1) GO TO 22
      IF(NOCC(2,LL).EQ.1) GO TO 28
   21 WRITE(SYSOT,12)DISTA(2,LL),DISTB(2,LL),DISTC(2,LL),TAB10(LL),
```

```
     1TBFALL(2,LL),TCFALL(2,LL),ELINCA(2,LL),ELINCB(2,LL),ELINCC(2,LL),
     2SLOPA(2,LL),SLOPB(2,LL),SLOPC(2,LL),VELA(2,LL),VELB(2,LL),VELC(2,
     3LL),CRESA(2,LL),CRESB(2,LL),CRESC(2,LL)
      QD=Q1-(Q1*.2)
   88 Q=QD/IBAR
      BB=B/IBAR
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO2=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN,B,D,SA)
      HDCA=ELINCA(2,LL)+HWN
      CALL BEQUA(X,HWN,B,D,SB)
      HDCB=ELINCB(2,LL)+HWN
      CALL BEQUA(X,HWN,B,D,SC)
      HDCC=ELINCC(2,LL)+HWN
      WRITE(SYSOT,85)QD,HWO2,QD,HDCA,QD,HDCB,QD,HDCC
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 330
      QD=QD+(Q1*.2)
      GO TO 88
   25 WRITE(SYSOT, 16)DISTA(2,LL),TAB10(LL),ELINCA(2,LL),SLOPA(2,LL),
     1VELA(2,LL),CRESA(2,LL)
      QD=Q1-(Q1*.2)
   62 Q=QD/IBAR
      BB=B/IBAR
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO2=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN ,B,D,SA)
      HDCA=ELINCA(2,LL)+HWN
      WRITE(SYSOT,186)QD,HWO2,QD,HDCA
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 330
      QD=QD+(Q1*.2)
      GO TO 62
   28 WRITE(SYS0T,20)DISTA(2,LL),DISTB(2,LL),TAB10(LL),TBFALL(2,LL),
     1ELINCA(2,LL),ELINCB(2,LL),SLOPA(2,LL),SL^PB(2,LL),VELA(2,LL),
     2VELB(2,LL ),CRESA(2,LL),CRESB(2,LL)
      QD=Q1-(Q1*.2)
   66 Q=QD/IBAR
      BB=B/IBAR
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO2=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN ,B,D,SA)
      HDCA=ELINCA(2,LL)+HWN
      HDCB=ELINCB(2,LL)+HWN
      WRITE(SYSOT,183)QD,HWO2,QD,HDCA,QD,HDCB
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 330
      QD=QD+(Q1*.2)
      GO TO 66
   22 WRITE(SYSOT 34)DISTA(2,LL),DISTC(2,LL),TAB10(LL),TCFALL(2,LL),
     1ELINCA(2,LL),ELINCC(2,LL),SLOPA(2,LL),SL^PC(2,LL),VELA(2,LL),
     2VELC(2,LL),CRESA(2,LL),CRESC(2,LL)
      QD=Q1-(Q1*.2)
   87 Q=QD/IBAR
      BB=B/IBAR
```

```
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST1,TOEL,QMAX,SLOPE)
      HWO2=HWOUT+TAB5(LL)
      X=QD/(B*D**1.5)
      CALL BEQUA(X,HWN ,B,D,SA)
      HDCA=ELINCA(2,LL)+HWN
      CALL BEQUA(X,HWN ,B,D,SC)
      HDCC=ELINCC(2,LL)+HWN
      WRITE(SYSOT,180)QD,HWO2,QD,HDCA,QD,HDCC
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 330
      QD=QD+(Q1*.2)
      GO TO 87
C
C     SIDE TAPERED INLETS
  330 IF(ITAB(LL).GT.2) WRITE(SYSOT,250)
  250 FORMAT(//'   IMPROVED-INLET DESIGN'/5X,'*********************'////
     135X,'NO IMPROVED-INLET DESIGNS AVAILABLE FOR CULVERTS HAVING MORE
     1THAN  " 2 " BARRELS  ')
      IF(ITAB(LL).GT.2) GO TO 362
      INDEX=2
C.....DESIGN SIDE-TAPERED INLETS
      CALL BSIDE(B,D,FALL,HWT,TROEL,IBAR,DIST1,INDEX,SLOPE)
C
C.....DESIGN SLOPE-TAPERED INLETS(VERTICAL AND MITERED
      CALL BSLOPV(B,D,SLOPE)
      CALL BSLOPM(B,D,SLOPE)
  362 LL=LL+1
      IF(LL.GT.L) RETURN
      I4=II4
      I5=II5
      GO TO 100
      END
```

```
      SUBROUTINE BSIDE(B,D,FALL,HWT,TROEL,IBAR,DIST1,INDEX,SLOPE)
C       DESIGN SIDE TAPERED INLETS
C
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),          **
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),      **
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100), **
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),  **
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),         **
     5       IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,        **
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),   **
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),   **
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),   **
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,        **
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2           **
      REAL L1,L1B,L1C
      INTEGER SYSIN, SYSOT
      DATA ALPHA,SCORR,CN/1.0,.5,.012/
      TAPER=4.
      IF(IBAR.GT.2) GO TO 480
  460 HWOUT=0.0
      HW=0.
      NOCAS=0
      NOCBS=0
      NOCCS=0
      FACEL=ELIN-ELL
      TOEL=ELOUT+ELR
C.....THROAT EQUATION - CHART 14 - HEC-13
      X=Q1/(B*D**1.5)
      Y16  =.1295033+.3789445*X-.0437778*X*X+.00426329*X*X*X
     1-.000106358*X*X*X*X
      IF(Y16.LT.1.0) FALL=999.
      IF(Y16.LT.1.0.AND.INDEX.GT.1) WRITE(SYSOT,18)                      **
   18 FORMAT(////1X,'SIDE-TAPER DESIGN'/1X,'*****************'///20X,    **
     1'THIS SIDE-TAPERED INLET EXCEEDS DESIGN CRITERIA')                 **
      IF(Y16.LT.1)RETURN                                                 **
      HT=Y16*D                                                           **
   52 X=(HT-1.)/D
C.....FACE EQUATION - CHART 15 - HEC 13
   20 Y15  =-1.13607+3.698525*X+.1212797*X*X-.20533949*X*X*X
     1+.0256923*X*X*X*X
      TROEL=AHWEL-HT
      BF=Q1/(Y15*D**1.5)+.1
   42 L1=((BF-B)/2.)*TAPER
      DLEFT=DISL+L1
      DROP= DLEFT*SLOPE
      SUBT=DIST1-L1
      STROEL=ELIN-DROP
      DIF=STROEL-TROEL
      IF(DIF.LE.0.0) GO TO 10
C     COMPUTE FALL
      FALL=DIF+L1*SLOPE
      HWT=AHWEL
    3 IF(INDEX.EQ.1) RETURN
      IF(INDEX.EQ.2) GO TO 5
      IF(INDEX.EQ.3) GO TO 5
```

```
      INDEX=INDEX+1                                                     B 4390
      X=(HT-L1*SLOPE)/D                                                 B 4395
      GO TO 20                                                          B 4400
    5 BIT=SEL*DIF                                                       B 4405
      SUBT=SUBT+BIT                                                     B 4410
      TOTA=SUBT+L1                                                      B 4415
      SA=(TROEL-TOEL)/SUBT                                              B 4420
      STFACE=STROEL+SLOPE*L1+BIT*SLOPE                                  B 4425
      ELFACA=TROEL+SA*L1                                                B 4430
      ELTRCA=TROEL                                                      B 4435
      IF(FALL.LT.D/4.) WA=0.0                                           B 4440
      IF(FALL.LT.D/4.)GO TO 100                                         B 4445
      HCA=FACEL+(FALL*SEL*SLOPE)+(FALL*3.+D/2.)*SLOPE                   B 4450
      HC=AHWEL-HCA                                                      B 4455
      IF(HC.LT.1.) HC=1.0                                               B 4460
      W23A=(.5*Q1**.6667)/HC                                            B 4465
      WA=W23A**1.5                                                      B 4470
      GO TO 100                                                         B 4475
C       NO FALL                                                         B 4480
   10 WA=0.0                                                            B 4485
      FALL=FACEL-STROEL                                                 B 4490
      TROEL=STROEL                                                      B 4495
      HWT=TROEL+HT                                                      B 4500
      IF(INDEX.EQ.1)RETURN                                              B 4505
      IF(INDEX.EQ.0) GO TO 3                                            B 4510
      ELFACA=TROEL+SLOPE*L1                                             B 4515
      TOTA=SUBT+L1                                                      B 4520
      ELTRCA=TROEL                                                      B 4525
      SA=SLOPE                                                          B 4530
      STFACE=ELFACA                                                     B 4535
  100 SLO=SA                                                            B 4540
      BAR=IBAR                                                          B 4545
      Q=Q1/BAR                                                          B 4550
      BB=B/BAR                                                          B 4555
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,SUBT ,TOEL,QMAX,SLO)    B 4560
      CALL BNORM(Q ,CN,SLO ,BB,D,DEP,AREA,WP)                           B 4565
      VELAA=Q /AREA                                                     B 4570
      IF(VELOUT.GT.VELAA) VELAA=VELOUT                                  B 4575
      IF(DN.GE.DC) GO TO 12                                             B 4580
      IF(DTW.LT.DC) GO TO 12                                            B 4585
      WHY2=0.247*VELAA*DN**.5-(.5*DN)                                   B 4590
      IF(WHY2.GT.DTW) GO TO 12                                          B 4595
      IF(DTW.GE.D) VELAA=Q/(BB*D)                                       B 4600
      IF(DTW.LT.D) VELAA=Q/(BB*DTW)                                     B 4605
   12 BEA=BF*.5                                                         B 4610
      DEA=D*.5                                                          B 4615
  101 INDEX=INDEX+1                                                     B 4620
      IF(INDEX.EQ.4) GO TO 102                                          B 4625
      X=(HT-L1*SA)/D                                                    B 4630
      GO TO 20                                                          B 4635
C     COMPUTE CURVE B - SIDE TAPER                                      B 4640
  102 INDEX=2                                                           B 4645
      HWTEMP=HWT                                                        B 4650
      FALLM=1.5*D                                                       B 4655
      FALLT=SUBT*SLOPE                                                  B 4660
```

```
      IF(FALLM.GT.FALLT) FALLM=FALLT
      QUE= TAB16(LL)
      X=QUE/(B*D**1.5)
      Y16  =.1295033+.3789445*X-.0437778*X*X+.00426329*X*X*X
     1-.000106358*X*X*X*X
      HWATER=Y16*D
      TEMP=ELTRCA+HWATER
      IF(TEMP.LE.AHWEL)GO TO 466
      BFALL=TEMP-AHWEL
      TBFAL =BFALL+FALL
      ELTRCB=ELTRCA-BFALL
      IF(ELTRCB.LT.TOEL) ELTRCB=TOEL+.01
      IF(TBFAL.GT.FALLM) ELTRCB=ELTRCA-(FALLM-FALL)
      BFALL=ELTRCA-ELTRCB
      TBFAL=BFALL+FALL
      BITB=SEL*BFALL
      SB=(ELTRCB-TOEL)/(SUBT+BITB)
      AIN= 50.
      QUE=Q1
  470 QUE=QUE+AIN
      X=QUE/(B*D**1.5)
      Y16  =.1295033+.3789445*X-.0437778*X*X+.00426329*X*X*X
     1-.000106358*X*X*X*X
      HIGH=Y16*D
      HI=HIGH+ELTRCB
      IF(HI.GT.AHWEL) GO TO 474
      H=HIGH
      GO TO 470
  474 QUE=QUE-AIN
      IF(AIN.LT.10.) GO TO 475
      AIN=2.0
      GO TO 470
  475 IF(QUE.GT.TAB16(LL)) QUE=TAB16(LL)
      X=(AHWEL-ELTRCB-L1*SB)/D
      Y15  =-1.13607+3.698525*X+.1212797*X*X-.20533949*X*X*X
     1+.0256923*X*X*X*X
      BFB=QUE/(Y15*D**1.5)+.1
      L1B=((BFB-B)/2.)*TAPER
      TOTB=SUBT+L1B+BITB
      ELFACB=ELTRCB+L1B*SB
      QQ=QUE/BAR
      TB=SUBT+BITB
      CALL BOUT(QQ,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,TB    ,TOEL,QMAX,SLO)
      CALL BNORM(QQ,CN,SB,BB,D,DEP,AREA,WP)
      VELBB=QQ /AREA
      IF(VELOUT.GT.VELBB) VELBB=VELOUT
      IF(DN.GE.DC) GO TO 14
      IF(DTW.LT.DC) GO TO 14
      WHY2=0.247*VELBB*DN**.5-(.5*DN)
      IF(WHY2.GT.DTW) GO TO 14
      IF(DTW.GE.D) VELBB=Q/(BB*D)
      IF(DTW.LT.D) VELBB=Q/(BB*DTW)
   14 HCB=FACEL+(TBFAL*SEL*SLOPE)+(TBFAL*3.+D/2.)*SLOPE
      HC=AHWEL-HCB
      IF(HC.LT.1.) HC=1.0
```

```
      W23B=(.5*QUE**.6667)/HC
      WB=W23B**1.5
      BEB=BFB*.5
      DEB=D*.5
      GO TO 490
  466 TBFAL =0.0
      NOCBS=1
C     COMPUTE CURVE C - SIDE TAPER
  490 TEMP=ELTRCA+HT
      IF(TAB4(LL).GE.TEMP) GO TO 482
      CFAL=TEMP-TAB4(LL)
      TCFAL=CFAL+FALL
      ELTRCC=ELTRCA-CFAL
      IF(TCFAL.GT.FALLM) ELTRCC=ELTRCA-(FALLM-FALL)
      IF(ELTRCC.LT.TOEL) ELTRCC=TOEL+.01
      CFAL=ELTRCA-ELTRCC
      TCFAL=CFAL+FALL
      BITC=SEL*CFAL
      SC=(ELTRCC-TOEL)/(SUBT+BITC)
      X=(TEMP -CFAL-ELTRCC-L1*SC)/D
      Y15  =-1.13607+3.698525*X+.1212797*X*X-.20533949*X*X*X
     1+.0256923*X*X*X*X
      BFC=Q1/(Y15*D**1.5)+.1
      L1C=((BFC-B)/2.)*TAPER
      TOTC=SUBT+L1C+BITC
      ELFACC=ELTRCC+L1C*SC
      HCC=FACEL+(TCFAL*SEL*SLOPE)+(TCFAL*3.+D/2.)*SLOPE
      HC=TEMP-HCC
      IF(HC.LT.1.) HC=1.0
      W23C=(.5*Q1**.6667)/HC
      WC=W23C**1.5
      SLO=SC
      TC=SUBT+BITC
      CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,TC    ,TOEL,QMAX,SLO)
      CALL SNORM(Q ,CN,SC,BS,D,DEP,AREA,WP)
      VELCC=Q /AREA
      IF(VELOUT.GT.VELCC) VELCC=VELOUT
      IF(DN.GE.DC) GO TO 16
      IF(DTW.LT.DC) GO TO 16
      WHY2=0.247*VELCC*DN**.5-(.5*DN)
      IF(WHY2.GT.DTW) GO TO 16
      IF(DTW.GE.D) VELCC=Q/(BB*D)
      IF(DTW.LT.D) VELCC=Q/(BB*DTW)
   16 BEC=BFC*.5
      DEC=D*.5
      GO TO 483
  482 TCFAL=0.0
      NOCCS=1
C.....DESIGN PRINTOUT + PERFORMANCE CURVE DATA
  483 WRITE(SYSOT,104)QUE
  104 FORMAT(////1X,'SIDE TAPERED INLET DESIGN'/'***********************
     1***', 10X,'FACE EDGE BEVELS = 45 DEG',5X,'SIDE TAPER = 4:1'//
     2       10X,'MIN FALL DESIGN',30X,'MAX  Q  DESIGN'.30X,'MIN HW DESIG
     3N'//55X, 'MAX Q =',F7.0,' CFS'//)
      IF(NOCBS.EQ.0.AND.NOCCS.EQ.0) GO TO 30
```

```
      IF(NCCBS.EQ.0) GO TO 32
      IF(NCCCS.EQ.0) GO TO 34
      WRITE(SYSOT,28)TOTA,TAB13(LL),TAB14(LL),ELFACA,SA,VELAA,BF,L1,WA,
     1BEA,DEA
   28 FORMAT(5X,'CULVERT LENGTH     =',F7.1,' FT',26X,'--',44X,'--'/5X,
     1'FALL',14X,'=',F7.1,' FT',26X,'--',44X,'--'/5X,'ELEV THROAT INVERT
     2=',F7.1,' FT',26X,'--',44X,'--'/5X,'ELEV FACE INVERT  =',F7.1,' FT
     3',26X,'--',44X,'--'/5X,'CULVERT SLOPE',5X,'=',F7.4,29X,'--',44X,'-
     4-'/5X,'VEL AT DESIGN Q    =',F6.1,' FPS',26X,'--',44X,'--'/5X,'FACE
     5 WIDTH',8X,'=',F7.2,' FT',26X,'--',44X,'--'/5X,'L1',16X,'=',F7.2,
     6' FT',26X,'--',44X,'--'/5X,'MIN CREST LENGTH  =',F7.1,' FT',26X,'-
     7-',44X,'--'/5X,'BEVELS =  45 DEGREE',36X,'--',44X,'--'/9X,'B =',
     8F5.1,' IN  D =',F5.1,' IN',27X,'--',44X,'--'//5X,'Q',8X,'HWT',8X,
     9'HWF',32X,'--',44X,'--'/)
      QD=Q1-Q1*.2
   29 X=QD/(B*D**1.5)
      Y16   =.1295033+.3789445*X-.0437778*X*X+.00426329*X*X*X
     1- .000106358*X*X*X*X
      HWTA=ELTRCA+Y16*D
      X=QD/(BF*D**1.5)
      Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
     1-.0006418302*X*X*X*X
      HWFA=ELFACA+Y13*D
      WRITE(SYSOT,27)QD,HWTA,HWFA
   27 FORMAT(3X,F7.1,2X,F7.1,3X,F7.1,31X,'--',44X,'--')
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
      QD=QD+Q1*.2
      GO TO 29
   30 WRITE(SYSOT,332)TOTA,TOTB,TOTC,TAB13(LL),TBFAL,TCFAL,TAB14(LL),
     1ELTRCB,ELTRCC,
     2ELFACA,ELFACB,ELFACC,SA,SB,SC,VELAA,VELBB,VELCC,BF,BFB,BFC
  332 FORMAT( 5X,'CULVERT LENGTH     =',F7.1,' FT',20X,'CULVERT LENGTH
     1 =',F7.1,' FT',15X,'CULVERT LENGTH     =',F7.1,' FT'/
     2          5X,'FALL',14X,'=',F7.1,' FT',20X,'FALL',14X,'=',F7.1,' FT',
     3  15X,'FALL',14X,'=',F7.1,' FT'/5X,'ELEV THROAT INVERT=',F7.1,
     4 ' FT',20X,'ELEV THROAT INVERT=',F7.1,' FT',15X,'ELEV THROAT INVER
     5T=',F7.1,' FT'/5X,'ELEV FACE INVERT  =',F7.1,' FT',20X,'ELEV FACE
     6INVERT  =',F7.1,' FT',15X,'ELEV FACE INVERT  =',F7.1,' FT'/  5X,
     7 'CULVERT SLOPE      =',F7.4,23X, 'CULVERT SLOPE      =',F7.4,18X,
     8 'CULVERT SLOPE      =',F7.4/ 5X,'VEL AT DESIGN Q    =',F6.1,' FPS',
     920X,'VEL AT MAX Q       =',F6.1,' FPS',15X,'VEL AT DESIGN Q    =',
     AF6.1,  ' FPS'/ 5X,'FACE WIDTH',8X,'=',F7.2,' FT',20X,'FACE WIDTH',
     B8X,'=',F7.2,' FT',15X,'FACE WIDTH',8X,'=',F7.1,' FT' )
      WRITE(SYSOT,504)L1,L1B,L1C,WA,WB,WC,BEA,DEA,BEB,DEB,BEC,DEC
  504 FORMAT(                                           5X,'L1',16X,'=',
     1F7.2,' FT',20X,'L1',16X,'=',F7.2,' FT',15X,'L1',16X,'=',F7.2,' FT'
     2/5X,'MIN CREST LENGTH  =',F7.1,' FT',20X,'MIN CREST LENGTH  =',
     3F7.1,' FT',15X,'MIN CREST LENGTH  =',F7.1,' FT'/5X,'BEVELS =  45 D
     4EGREE',30X,'BEVELS =  45 DEGREE',25X,'BEVELS =  45 DEGREE'/9X,'B =
     5',F5.1,' IN  D =',F5.1,' IN',24X,'B =',F5.1,' IN  D =',F5.1,' IN',
     622X,'B =',F5.1,' IN  D =',F5.1,' IN'//5X,'Q',8X,'HWT',8X,'HWF',
     729X,'Q',8X,'HWT',8X,'HWF',20X,'Q',8X,'HWT',8X,'HWF'/)
      QD=Q1-(Q1 *.2)
   31 X=QD/(B*D**1.5)
      Y16   =.1295033+.3789445*X-.0437778*X*X+.00426329*X*X*X
```

```
     1-.000106358*X*X*X*X
      HWTA=ELTRCA+(Y16*D)
      HWTB=ELTRCB+(Y16*D)
      HWTC=ELTRCC+(Y16*D)
      X=QD/(BF*D**1.5)
      Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
     1-.0006418302*X*X*X*X
      HWFA=ELFACA+(Y13*D)
      X=QD/(BFB*D**1.5)
      Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
     1-.0006418302*X*X*X*X
      HWFB=ELFACB+(Y13*D)
      X=QD/(BFC*D**1.5)
      Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
     1-.0006418302*X*X*X*X
      HWFC=ELFACC+Y13*D
      WRITE(SYSOT,36)QD,HWTA,HWFA,QD,HWTB,HWFB,QD,HWTC,HWFC
   36 FORMAT(3X,F7.1,2X,F7.1,3X,F7.1,22X,F9.1,1X,F9.1,3X,F9.1,13X,
     12F9.1,2X,F9.1)
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
      QD=QD+Q1*.2
      GO TO 31
   32 WRITE(SYSOT,110)TOTA,TOTB,TA313(LL),TBFAL,TAB14(LL),ELTRCB,ELFACA,
     1ELFACB,SA,SB,VELAA,VELBB,BF,BFB
  110 FORMAT(5X,'CULVERT LENGTH     =',F7.1,' FT',20X,'CULVERT LENGTH
     1=',F7.1,' FT',21X,'--'/5X,'FALL',14X,'=',F7.1,' FT',20X,'FALL',14X
     2,'=',F7.1,' FT',21X,'--'/5X,'ELEV THROAT INVERT=',F7.1,' FT',20X,
     3'ELEV THROAT INVERT=',F7.1,' FT',21X,'--'/  5X,'ELEV FACE INVERT
     4=',F7.1,' FT',20X,'ELEV FACE INVERT  =',F7.1,' FT',21X,'--'/  5X,
     5'CULVERT SLOPE',5X,'=',F7.4,23X,'CULVERT SLOPE',5X,'=',F7.4,24X,'-   **
     6-'/  5X,'VEL AT DESIGN Q    =',F6.1,' FPS',20X,'VEL AT MAX  Q      =
     7',F6.1,  ' FPS',21X,'--'/  5X,'FACE WIDTH',8X,'=',F7.2,' FT',20X,'
     8FACE WIDTH',8X,'=',F7.2,' FT' ,21X,'--')
      WRITE(SYSOT,112)L1,L1B,WA ,WB,BEA,DEA,BEB,DEB
  112 FORMAT(5X,'L1',16X,'=',F7.2,' FT',20X,'L1',16X,'=',F7.2,' FT',21X,
     1'--'/  5X,'MIN CREST LENGTH  =',F7.1,' FT',20X,'MIN CREST LENGTH
     2=',F7.1,' FT',21X,'--'/5X,'BEVELS =  45 DEGREE',31X,'BEVELS =  45
     3DEGREE',30X,'--'/9X,'B =',F5.1,' IN  D =',F5.1,' IN',25X,'B =',    **
     4F5.1,' IN  D =',F5.1,' IN',22X,'--'//5X,'Q',8X,'HWT',8X,'HWF',     **
     529X,'Q',8X,'HWT',8X,'HWF',24X,'--'/)                               **
      QD=Q1-Q1*.2
   33 X=QD/(B*D**1.5)
      Y16  =.1295033+.3789445*X-.0437778*X*X+.00426329*X*X*X
     1-.000106358*X*X*X*X
      HWTA=ELTRCA+Y16*D
      HWTB=ELTRCB+Y16*D
      X=QD/(BF*D**1.5)
      Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
     1-.0006418302*X*X*X*X
      HWFA=ELFACA+Y13*D
      X=QD/(BFB*D**1.5)
      Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
     1-.0006418302*X*X*X*X
      HWFB=ELFACB+Y13*D
      WRITE(SYSOT,38)QD,HWTA,HWFA,QD,HWTB,HWFB
```

```
 38 FORMAT(3X,F7.1,2X,F7.1,3X,F7.1,22X,F9.1,1X,F9.1,3X,F9.1.
   122X,'--')
    IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480                                   **
    QD=QD+Q1*.2
    GO TO 33
 34 WRITE(SYSOT,106)TOTA,TOTC,TAB13(LL),TCFAL,TAB14(LL),ELTRCC,ELFACA
   1,ELFACC,SA,SC,VELAA,VELCC,BF,BFC,L1,L1C,WA,WC,BEA,DEA,BEC,DEC
106 FORMAT(5X,'CULVERT LENGTH     =',F7.1,' FT',26X,'--',36X,'CULVERT L
   1ENGTH     =',F7.1,' FT'/5X,'FALL',14X,'=',F7.1,' FT',26X,'--',36X,
   2'FALL',14X,'=',F7.1,' FT'/5X,'ELEV THROAT INVERT=',F7.1,' FT',26X,
   3'--',36X,'ELEV THROAT INVERT=',F7.1,' FT'/5X,'ELEV FACE INVERT  ='
   5,F7.1,' FT',26X,'--',36X,'ELEV FACE INVERT  =',F7.1,' FT'/ 5X,'CUL
   6VERT SLOPE',5X,'=',F7.4,29X,'--',36X,'CULVERT SLOPE',5X,'=',F7.4/
   75X,'VEL AT DESIGN Q  =',F7.1,' FPS',26X,'--',36X,'VEL AT DESIGN Q
   8 =',F7.1,' FPS'/5X,'FACE WIDTH',8X,'=',F7.2,' FT',26X,'--',35X,'FA
   9CE WIDTH',8X,'=',F7.2,' FT'/5X,'L1',16X,'=',F7.2,' FT',26X,'--',
   A36X,'L1',16X,'=',F7.2,' FT'/5X,'MIN CREST LENGTH  =',F7.1,' FT',
   B26X,'--',36X,'MIN CREST LENGTH  =',F7.1,' FT'/5X,'BEVELS = 45 DEGR
   CEE',37X,'--',36X,'BEVELS = 45 DEGREE'/9X,'B =',F5.1,' IN  D =',
   DF5.1,' IN',27X,'--',41X,'B =',F5.1,' IN  D =',F5.1,' IN'//5X,'Q',
   E8X,'HWT',8X,'HWF',32X,'--',38X,'Q',8X,'HWT',8X,'HWF'/)
    QD=Q1-(Q1*.2)
 35 X=QD/(B*D**1.5)
    Y16   =.1295033+.3789445*X-.0437778*X*X+.00426329*X*X*X
   1-.000106358*X*X*X*X
    HWTA=ELTRCA+Y16*D
    HWTC=ELTRCC+Y16*D
    X=QD/(3F*D**1.5)
    Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
   1-.0006418302*X*X*X*X
    HWFA=ELFACA+Y13*D
    X=QD/(BFC*D**1.5)
    Y13=.11111164+.53786558*X-.10516936*X*X+.016074687*X*X*X
   1-.0006418302*X*X*X*X
    HWFC=ELFACC+Y13*D
    WRITE(SYSOT,37)QD,HWTA,HWFA,QD,HWTC,HWFC
 37 FORMAT(3X,F7.1,2X,F7.1,3X,F7.1,31X,'--',33X,2F9.1,2X,F9.1)
    IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
    QD=QD+Q1*.2
    GO TO 35
480 RETURN
    END
```

```
      SUBROUTINE BSLOPV(B,D,SLOPE)                                      B 5975
C     DESIGN SLOPE-TAPERED INLETS                                       B 5980
C                                                                       B 5985
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),         B 5990   **
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),     B 5995   **
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),B 6000   **
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100), B 6005   **
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),        B 6010   **
     5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,     B 6015   **
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),  B 6020   **
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),  B 6025   **
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),  B 6030   **
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,       B 6035   **
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2          B 6040   **
      DIMENSION FALL(2),S(2),L1(2),L2(2),L3(2),VEL(2),BF(2),            B 6045
     1TAPER(2),NOC(2),DA(2)                                             B 6050
      INTEGER SYSIN, SYSOT                                              B 6055
      REAL L1,L2,L3,L4,L150                                             B 6060
      DATA ALPHA,SCORR,CN/1.0,.5,.012/                                  B 6065
  460 ISLOPE=0                                                          B 6070
      HW=0.0                                                            B 6075
      QS=Q1                                                             B 6080
      BAR=ITAB(LL)                                                      B 6085
      NOC(1)=0                                                          B 6090
      NOC(2)=0                                                          B 6095
      I=1                                                               B 6100
      TAPER(1)=4.0                                                      B 6105
      TAPER(2)=4.0                                                      B 6110
      Y1=(D**2/(SFACE**2+1.))**.5                                       B 6115
      Y2=Y1/SFACE                                                       B 6120
      DY=SFACE*Y1+Y2                                                    B 6125
      SMAL3=(SLOPE*SEL**2*DY)/(1.+SLOPE*SEL)                            B 6130
      DIL3=SEL*DY-SMAL3                                                 B 6135
      EL3=DIL3*SLOPE                                                    B 6140
      FACEL=ELIN-EL3                                                    B 6145
      TOEL=ELOUT+ELR                                                    B 6150
      DIST=(FACEL-TOEL)/SLOPE                                           B 6155
C                                                                       B 6160
C     CURVE A                                                           B 6165
      TROE=TAB14(LL)                                                    B 6170
      TROE=TROEL                                                        B 6175
   14 FALL(I)=FACEL-TROE                                                B 6180
      IF(TAB14(LL).EQ.0.0)NOC(2)=1                                      B 6185   **
      IF(TROE.LE.TOEL) NOC(I)=1                                         B 6190
      IF(FALL(I).LT.(D/4.).OR.FALL(I).GT.(1.5*D))NOC(I)=1               B 6195
      IF(NOC(I).EQ.1) GO TO 481                                         B 6200
   24 HW=HWTEMP-FACEL                                                   B 6205
      X=HW/D                                                            B 6210
C.....FACE EQUATION - CHART 16 - HEC 13                                 B 6215
      Y21=-2.265813+7.942441*X-4.0350294*X*X+1.619481*X*X*X-.3458214*X  B 6220
     1*X*X*X+.02846767*X*X*X*X*X                                        B 6225
      BF(I)=QS/(Y21*D**1.5)+.1                                          B 6230
      L1(I)=((BF(I)-B)/2.)*TAPER(I)                                     B 6235
   26 S(I)=(TROE-TOEL)           /(DIST-L1(I))                          B 6240
      DIF=FACEL+DY-(TROE+(D**2+(D*S(I))**2)**.5)                        B 6245
```

```
      L3(I)=.5*B                                                          B 6250
   28 L2(I)=L1(I)-L3(I)                                                   B 6255
      SF=L2(I)/(DIF-S(I)*L1(I)+L2(I)*S(I))                                B 6260
      IF(SF.EQ.SFACE) GO TO 450                                           B 6265
      IF(SF.LT.SFACE) GO TO 30                                            B 6270
      SF=SFACE                                                            B 6275
      L2(I)=SFACE*(DIF-S(I)*L1(I))/(1.-S(I)*SFACE)                        B 6280
      L3(I)=L1(I)-L2(I)                                                   B 6285
      IF(L3(I).LT.(.5*B)) L3(I)=.5*B                                      B 6290
      L2(I)= L1(I)-L3(I)                                                  B 6295
      GO TO 450                                                           B 6300
   30 SF=SFACE                                                            B 6305
      L2(I)=SFACE*(DIF-S(I)*L1(I))/(1.-S(I)*SFACE)                        B 6310
      L1(I)=L2(I)+L3(I)                                                   B 6315
      TAPER(I)=2.*L1(I)/(BF(I)-B)                                         B 6320
  450 S(I)=(TROE-TOEL)          /(DIST-L1(I))                             B 6325
      SLO=S(I)                                                            B 6330
      DA(I)=DIST-L1(I)                                                    B 6335
      DD=DA(I)                                                            B 6340
      Q=QS/BAR                                                            B 6345
      BB=B/BAR                                                            B 6350
      CALL BCUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST,TOEL,QMAX.SLO)       B 6355
      CALL BNORM(Q ,CN,SLO ,BB,D,DEP,AREA,WP)                             B 6360
      VELIN=Q /AREA                                                       B 6365
      VEL(I)=VELIN                                                        B 6370
      IF(VELOUT.GT.VELIN) VEL(I)=VELOUT                                   B 6375
      IF(DN.GE.DC) GO TO 122                                              B 6380
      IF(DTW.LT.DC) GO TO 122                                             B 6385
      IF(WHY2.GT.DTW) GO TO 122                                           B 6390
      WHY2=0.247* ELIN*DN**.5-(.5*DN)                                     B 6395
      IF(DTW.GE.D) VEL(I)=Q/(BB*D)                                        B 6400
      IF(DTW.LT.D) VEL(I)=Q/(BB*DTW)                                      B 6405
  122 IBAR=BAR                                                            B 6410
  481 QS=QUE                                                              B 6415
      TROE=ELTRCB                                                         B 6420
      I=I+1                                                               B 6425
      IF(I.EQ.3) GO TO 483                                                B 6430
      GO TO 14                                                            B 6435
  483 WRITE(SYSOT,478)  DIL3,DISR                                         B 6440  **
  478 FORMAT(////1X,'SLOPE TAPERED INLET DESIGN - VERTICAL FACE'/'******  B 6445
     1*************************************'//5X,'DISTANCE EMBANKMENT-TO  B 6450
     2E TO FACE =',F7.2,' FT',10X,'CULVERT OUTLET TO EMBANKMENT-TOE =',   B 6455
     3 F7.2,' FT'//10X,'MIN FALL DESIGN',35X,'MAX  Q  DESIGN')            B 6460
       IF(NOC(1).EQ.1.AND.NOC(2).EQ.1) GO TO 484                          B 6465
       IF(NOC(1).EQ.1.AND.NOC(2).EQ.0) GO TO 486                          B 6470
       IF(NOC(1).EQ.0.AND.NOC(2).EQ.1) GO TO 488                          B 6475
  340 WRITE(SYSOT,342)DIST,DIST  ,FALL(1),FALL(2),TROEL.ELTRCB.FACEL.     B 6480
     9'HWF',34X,'Q',8X,'HWT',8X,'HWF'/)                                   B 6485
       QD=Q1-Q1*.2                                                        B 6490
     1FACEL,S(1),S(2),VEL(1),VEL(2),BF(1),BF(2),L1(1),L1(2),L2(1),L2(2),  B 6495
     2L3(1),L3(2),SFACE,SFACE,TAPER(1),TAPER(2)                           B 6500
  342 FORMAT(//5X,'CULVERT LENGTH    =',F7.1,' FT',25X,'CULVERT LENGTH    B 6505
     1  =',F7.1,' FT'/5X,'FALL',14X,'=',F7.1,' FT',25X,'FALL',14X,'=',    B 6510
     2F7.1,' FT'/5X,'ELEV THROAT INVERT=',F7.1,' FT',25X,'ELEV THROAT IN  B 6515
     3VERT=',F7.1,' FT'/5X,'ELEV FACE INVERT  =',F7.1,' FT',25X,'ELEV FA  B 6520
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```
     4CE INVERT  =',F7.1,' FT'/ 5X,'CULVERT SLOPE      =',F7.4,28X,'CULVE
     5RT SLOPE      =',F7.4/5X,'VEL AT DESIGN Q    =',F6.1,' FT',26X,'VEL
     6AT MAX Q       =',F6.1,' FT'/5X,'FACE WIDTH',8X,'=',F7.2,' FT',
     725X,'FACE WIDTH',8X,'=',F7.2,' FT'/5X,'L1',15X,'=',
     8F7.2,' FT',25X,'L1',16X,'=',F7.2,' FT'
     9/5X,'L2',16X,'=',F7.1,' FT',25X,'L2',16X,'=',F7.1,' FT'
     A                      /5X,'L3',16X,'=',F7.1,' FT',  25X,'L3',16X,'=',
     BF7.1,' FT'/5X,
     C 'SF',16X,'=',F7.2,28X,'SF',16X,'=',F7.2/
     D 5X,'TAPER' '3X,'=',F5.2,':1',28X,'TAPER',13X,'=',F5.2,':1'//8X,
     E'Q' ,8X,'HWT',8X,'HWF',34X,'Q',8X,'HWT',8X,'HWF'/)
      QD=Q1-Q1*.2
   31 X=QD/(B*D**1.5)
      Y16=.12950325+.37894446*X-.04377779*X*X+.00426329*X*X*X
     1-.00010635862*X*X*X*X
      HWTA=TROEL+Y16*D
      HWTB=ELTRCB+Y16*D
      X=QD/(BF(1)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFA=FACEL+Y18*D
      X=QD/(BF(2)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFB=FACEL+Y18*D
      WRITE(SYSOT,32)QD,HWTA,HWFA,QD,HWTB,HWFB
   32 FORMAT(1X,3F10.1,30X,3F10.1)
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
      QD=QD+Q1*.2
      GO TO 31
  484 WRITE(SYSOT,485)
  485 FORMAT(///20X,'NO SLOPE TAPERED INLET - VERTICAL FACE - DESIGN APP
     1LICABLE')
      GO TO 480
  486 WRITE(SYSOT,487)DIST,  FALL(2),ELTRCB,FACEL,S(2),VEL(2),BF(2),
     2L1(2),L2(2),L3(2),SFACE,TAPER(2)
  487 FORMAT(//16X,'- -',40X,'CULVERT LENGTH     =',F7.1,' FT' /16X,'- -'
     1,40X,
     2'FALL',15X,'=',F7.1,' FT'/16X,'- -',40X,'ELEV THROAT INVERT=',F7.1
     3,' FT'/16X,'- -',40X,'ELEV FACE INVERT  =',F7.1,' FT'/16X,'- -',40
     4X,'CULVERT SLOPE      =',F9.4/16X,'- -',40X,'VEL AT MAX Q       =',
     5F6.1,' FPS'/16X,'- -',40X,'FACE WIDTH',8X,'=',F7.2,' FT'/16X,'- -'
     6,40X,'L1',16X,'=',F7.2,' FT'/16X,'- -',40X,'L2',16X,F7.1,' FT'/
     716X,'- -',40X,'L3',16X,'=',F7.1,' FT'/16X,'- -',40X,'SF',16X,'=',
     8F9.2/16X,'- -',40X,'TAPER',13X,'=',F5.2,':1'//8X,'Q',8X,'HWT',8X,
   33 X=QD/(B*D**1.5)
      Y16=.12950325+.37894446*X-.04377779*X*X+.00426329*X*X*X
     1-.00010635862*X*X*X*X
      HWTB=ELTRCB+Y16*D
      X=QD/(BF(2)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFB=FACEL+Y18*D
      WRITE(SYSOT,34)QD,HWTB,HWFB
   34 FORMAT(16X,'--',40X,3F10.1)
```

```
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
      QD=QD+Q1*.2
      GO TO 33
  488 WRITE(SYSOT,489)DIST, FALL(1),TROEL,FACEL,S(1),VEL(1),BF(1),L1(1).
     1L2(1),L3(1),SFACE,TAPER(1)
  489 FORMAT(//5X,'CULVERT LENGTH     =',F7.1,' FT',30X,'--'/5X,'FALL',14
     1X,'=',F7.1,' FT',30X,'- -'/5X,'ELEV THROAT INVERT=',F7.1,' FT',30X
     3,'- -'/5X,'ELEV FACE INVERT  =',F7.1,' FT',30X,'- -'/5X,'CULVERT S
     4LOPE       =',F9.4,33X,'- -'/5X,'VEL AT DESIGN Q   =',F6.1,' FPS',
     530X,'- -'/5X,'FACE WIDTH',8X,'=',F7.2,' FT',30X,'- -'/5X,'L1',16X,
     6'=', F7.2,' FT',30X,'- -'/5X,'L2',16X,'=',F7.1,' FT',30X,'- -'/5X,
     7'L3',16X,'=',F7.1,' FT',30X,'- -'/5X,'SF',16X,'=',F9.2,33X,'- -'/
     85X,'TAPER',13X,'=',F5.2,':1'//8X,'Q',8X,'HWT',8X,'HWF',34X,'Q',8X,
     9'HWT',8X,'HWF'/)
      QD=Q1-Q1*.2
   35 X=QD/(B*D**1.5)
      Y16=.12950325+.37894446*X-.04377779*X*X+.00426329*X*X*X
     1-.00010635862*X*X*X*X
      HWTA=TROEL+Y16*D
      X=QD/(BF(1)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFA=FACEL+Y18*D
      WRITE(SYSOT,36)QD,HWTA,HWFA
   36 FORMAT(1X,3F10.1,40X,'--')
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
      QD=QD+Q1*.2
      GO TO 35
  480 RETURN
      END
```

```
      SUBROUTINE BSLOPM(B,D,SLOPE)
C     DESIGN SLOPE-TAPERED INLETS - MITERED FACE
C
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),
     5       IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2
      DIMENSION FALL(2),S(2),L1(2),L2(2),L3(2),VEL(2),BF(2),L4(2),
     1TAPER(2),NOC(2),CL(2)
      INTEGER SYSIN, SYSOT
      REAL L1,L2,L3,L4,L1S0,L2L3
      DATA ALPHA,SCORR,CN/1.0,.5,.012/
      HW=0.0
      SF=SFACE
      QS=Q1
      BAR=ITAB(LL)
      NOC(1)=0
      NOC(2)=0
      I=1
      TAPER(1)=4.0
      TAPER(2)=4.0
      TOEL=ELOUT+ELR
      FACE=ELIN-E[illegible]
      DIST=(ELIN -TOEL)/SLOPE
      TROEL=TAB14(LL)
      TROE=TROEL
      Y=(D*(SF*SEL-1))/((SF+SEL)*(1+SF**2)**.5)
      FACEL=ELIN-Y
   14 FALL(I)=ELIN -TROE
      IF(TAB14(LL).EQ.0.0)NOC(2)=1
      IF(FACEL.LT.TROE) NOC(I)=1
      IF(TROE.LE.TOEL) NOC(I)=1
      IF(FALL(I).LT.(D/4.+Y).OR.FALL(I).GT.(1.5*D))NOC(I)=1
      IF(NOC(I).EQ.1) GO TO 481
   24 HW=HWTEMP-FACEL
      X=HW/D
      Y21=-2.265863+7.942441*X-4.0350294*X*X+1.619481*X*X*X-.3458214*X
     1*X*X*X+.02846767*X*X*X*X*X
      L4(I)=D*SEL*(1+SF**2)**.5 /(SEL+SF)
      BF(I)=QS/(Y21*D**1.5)+.1
      XL4=(D**2/(1.+SF**2))**.5
      SFX=SF*XL4
      L2L3=((BF(I)-B)/2.)*TAPER(I)
      L1(I)=L2L3+L4(I)
   26 S(I)=(TROE-TOEL)/(DIST-L1(I))
      DIFF=TROE+(D**2+(D*S(I))**2)**.5
      DIF=FACEL+SFX-DIFF
      L3(I)=.5*B
```

```
 28 L2(I)=L1(I)-L3(I)-L4(I)                                               B 7225
    SF=L2(I)/(DIF-S(I)*(L1(I)-L4(I)-L2(I)))                               B 7230
    IF(SF.EQ.SFACE) GO TO 450                                             B 7235
    IF(SF.LT.SFACE) GO TO 30                                              B 7240
    SF=SFACE                                                              B 7245
    L2(I)=(SF*(DIF-S(I)*L1(I)+S(I)*L4(I)))/(1.-SF*S(I))                   B 7250
    L3(I)=L1(I)-L2(I)-L4(I)                                               B 7255
    GO TO 450                                                             B 7260
 30 SF=SFACE                                                              B 7265
    L2(I)=(SF*(DIF-S(I)*L1(I)+S(I)*L4(I)))/(1.-SF*S(I))                   B 7270
    L1(I)=L2(I)+L3(I)+L4(I)                                               B 7275
    TAPER(I)=2.*(L2(I)+L3(I))/(BF(I)-B)                                   B 7280
450 S(I)=(TROE-TOEL)           /(DIST-L1(I))                              B 7285
    SLO=S(I)                                                              B 7290
    CL(I)=DIST-L1(I)                                                      B 7295
    Q=QS/BAR                                                              B 7300
    BB=B/BAR                                                              B 7305
    DA=CL(I)                                                              B 7310
    CALL BOUT(Q,BB,D,HWOUT,VELOUT,DEP,DN,DC,Z,DIST,TOEL,QMAX,SLO)         B 7315
    CALL BNORM(Q ,CN,SLO ,BB,D,DEP,AREA,WP)                               B 7320
    VELIN=Q/AREA                                                          B 7325
    VEL(I)=VELIN                                                          B 7330
    IF(VELOUT.GT.VELIN) VEL(I)=VELOUT                                     B 7335
    IF(DN.GE.DC) GO TO 122                                                B 7340
    IF(DTW.LT.DC) GO TO 122                                               B 7345
    WHY2=0.247*VELIN*DN**.5-(.5*DN)                                       B 7350
    IF(WHY2.GT.DTW) GO TO 122                                             B 7355
    IF(DTW.GE.D) VEL(I)=Q/(BB*D)                                          B 7360
    IF(DTW.LT.D) VEL(I)=Q/(BB*DTW)                                        B 7365
122 IBAR=BAR                                                              B 7370
481 QS=QUE                                                                B 7375
    TROE=ELTRCB                                                           B 7380
    I=I+1                                                                 B 7385
    IF(I.EQ.3) GO TO 483                                                  B 7390
    GO TO 14                                                              B 7395
483 WRITE(SYSOT,478)                                                      B 7400
478 FORMAT(////1X,'SLOPE TAPERED INLET DESIGN - MITERED  FACE'/'******    B 7405
   1*************************************'//10X,'MIN FALL DESIGN',35X,    B 7410
   2'MAX  Q  DESIGN')                                                     B 7415
    IF(NOC(1).EQ.1.AND.NOC(2).EQ.1) GO TO 484                             B 7420
    IF(NOC(1).EQ.1.AND.NOC(2).EQ.0) GO TO 486                             B 7425
    IF(NOC(1).EQ.0.AND.NOC(2).EQ.1) GO TO 488                             B 7430
340 WRITE(SYSOT,342)DIST,DIST,    FALL(1),FALL(2),TROEL,ELTRCB,FACEL,     B 7435
   1FACEL,S(1),S(2),VEL(1),VEL(2),BF(1),BF(2),L1(1),L1(2),L2(1),L2(2),    B 7440
   2L3(1),L3(2)                                                           B 7445
342 FORMAT(//5X,'CULVERT LENGTH     =',F7.1,' FT',25X,'CULVERT LENGTH     B 7450
   1  =',F7.1,' FT'/5X,'FALL',14X,'=',F7.1,' FT',25X,'FALL',14X,'=',F7    B 7455
   2.1,' FT'/5X, 'ELEV THROAT INVERT=',F7.1,' FT',25X,'ELEV THROAT INV    B 7460
   3ERT=',F7.1,' FT'/  5X,'ELEV FACE INVERT  =',F7.1,' FT',25X,'ELEV F    B 7465
   4ACE INVERT  =',F7.1,' FT'/5X,'CULVERT SLOPE     =',F7.4,28X,'CULVE    B 7470
   5RT SLOPE     =',F7.4/5X,'VEL AT DESIGN Q   =',F6.1,' FPS',25X,'VEL    B 7475
   6 AT MAX  Q      =',F6.1,' FPS'/5X,'FACE WIDTH',8X,'=',F7.2,' FT',25   B 7480
   7X,'FACE WIDTH',8X,'=',F7.2,' FT'/5X,'L1',16X,'=',F7.2,' FT',25X,'L    B 7485
   81',16X,'=',F7.2,' FT'/5X,'L2',16X,'=',F7.1,' FT',25X,'L2',16X,'=',    B 7490
   9F7.1,' FT'/5X,'L3',16X,'=',F7.1,' FT',25X,'L3',16X,'=',F7.1,' FT')    B 7495
```

```
      WRITE(SYSOT,346)L4(1),L4(2),SFACE,SFACE,TAPER(1),TAPER(2)
  346 FORMAT(5X,'L4',16X,'=',F7.1,' FT',25X,'L4',16X,'=',F7.1,' FT'/5X,
     1'SF',16X,'=',F7.2,28X,'SF',16X,'=',F7.2/5X,'TAPER',13X,'=',F5.2,
     2':1',28X,'TAPER',13X,'=',F5.2,':1'//8X,'Q',8X,'HWT',8X,'HWF',34X,
     3'Q',8X,'HWT',8X,'HWF'/)
      QD=Q1-Q1*.2
   31 X=QD/(B*D**1.5)
      Y16=.12950325+.37894446*X-.04377779 *X*X+.00426329*X*X*X
     1-.0001063586*X*X*X*X
      HWTA=TROEL+Y16*D
      HWTB=ELTRCB+Y16*D
      X=QD/(BF(1)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745 *X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFA=FACEL+Y18*D
      X=QD/(BF(2)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFB=FACEL+Y18*D
      WRITE(SYSOT,32)QD,HWTA,HWFA,QD,HWTB,HWFB
   32 FORMAT(1X,3F10.1,24X,3F10.1)
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
      QD=QD+Q1*.2
      GO TO 31
  484 WRITE(SYSOT,485)
  485 FORMAT(//20X,'NO SLOPE TAPERED MITERED INLET DESIGN APPLICABLE')
      GO TO 480
  486 WRITE(SYSOT,487)DIST, FALL(2),ELTRCB,FACEL,S(2),VEL(2),BF(2),L1(2)
     2,L2(2),L3(2),L4(2),SFACE,TAPER(2)
  487 FORMAT(//10X,'MIN FALL DESIGN',35X,'MAX Q DESIGN'//16X,'- -',40X,
     1'CULVERT LENGTH      =',F7.1,' FT'/16X,'- -',40X,
     2'FALL',15X,'=',F7.1,' FT'/16X,'- -',40X,'ELEV THROAT INVERT=',F7.1
     3,' FT'/16X,'- -',40X,'ELEV FACE INVERT  =',F7.1,' FT'/16X,'- -',40
     4X,'CULVERT SLOPE      =',F9.4/16X,'- -',40X,'VEL AT MAX  Q      =',
     5F6.1,' FPS'/16X,'- -',40X,'FACE WIDTH',8X,'=',F7.2,' FT'/16X,'- -'
     6,40X,'L1',16X,'=',F7.2,' FT'/16X,'- -',40X,'L2',16X,'=',F7.1,
     7' FT'/16X,'- -',40X,'L3',16X,'=',F7.1,' FT'/16X,'- -',40X,'L4',
     816X,'=',F7.1,' FT'/                          16X,'- -',40X,'SF',16X,'=',
     9F9.2/16X,'- -',40X,'TAPER',13X,'=',F5.2,':1'//8X,'Q',8X,'HWT',8X,
     A'HWF',34X,'Q',8X,'HWT',8X,'HWF'/)
      QD=Q1-Q1*.2
   33 X=QD/(B*D**1.5)
      Y16=.12950325+.37894446*X-.04377779*X*X+.00426329*X*X*X
     1-.0001063586*X*X*X*X
      HWTB=ELTRCB+Y16*D
      X=QD/(BF(2)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFB=FACEL+Y18*D
      WRITE(SYSOT,34)QD,HWTB,HWFB
   34 FORMAT(16X,'--',40X,3F10.1)
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480
      QD=QD+Q1*.2
      GO TO 33
  488 WRITE(SYSOT,489)DIST, FALL(1),TROEL,FACEL,S(1),VEL(1),BF(1),L1(1),
```

```
     1L2(1),L3(1),L4(1),SFACE,TAPER(1)
 489 FORMAT( //10X,'MIN FALL DESIGN',35X,'MAX Q DESIGN'//5X,'CULVERT LE  B 7775
     1NGTH     =',F7.1,' FT',30X,'- -'/                 5X,'FALL',14X,'=',F7.1  B 7780
     2 ,' FT' ,30X,'- -'/5X,'ELEV THROAT INVERT=',F7.1,' FT',30X,'- -'/  B 7785
     35X,'ELEV FACE INVERT  =',F7.1,' FT',30X,'- -'/5X,'CULVERT SLOPE    B 7790 **
     4  =',F9.4,31X,'- -'/5X,'VEL AT DESIGN  Q   =',F6.1,' FPS',29X,    B 7795
     5'- -'/5X,'FACE WIDTH',8X,'=',F7.2,' FT',30X,'- -'/5X,'L1',16X,'=',  B 7800 **
     6F7.2,' FT',30X,'- -'/5X,'L2',16X,'=',F7.1,' FT',30X,'- -'/5X,'L3',  B 7805
     716X,'=',F7.1,' FT',30X,'- -'/5X,'L4',16X,'=',F7.1,' FT',30X,'- -'/  B 7810
     85X,'SF',16X,'=',F9.2,31X,'- -'/5X,'TAPER',13X ,'=',F5.2,':1',25X,  B 7815
     9'--'//8X,'Q',8X,'HWT',8X,'HWF',34X,'Q',8X,'HWT',8X,'HWF'/)         B 7820 **
      QD=Q1-Q1*.2                                                       B 7825 **
  35  X=QD/(B*D**1.5)                                                   B 7830
      Y16=.12950325+.37894446*X-.04377779*X*X+.00426329*X*X*X           B 7835
     1-.00010635862*X*X*X*X                                             B 7840
      HWTA=TROEL+Y16*D                                                  B 7845
      X=QD/(BF(1)*D**1.5)                                               B 7850
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X           B 7855
     1-.000496383*X*X*X*X                                               B 7860
      HWFA=FACEL+Y18*D                                                  B 7865
      WRITE(SYSOT,36)QD,HWTA,HWFA                                       B 7870
  36  FORMAT(1X,3F10.1,40X,'--')                                        B 7875
      IF(QD.GT.(Q1+2*(Q1*.2)+5.)) GO TO 480                             B 7880
      QD=QD+Q1*.2                                                       B 7885
      GO TO 35                                                          B 7890
 480  RETURN                                                            B 7895
      END                                                               B 7900
                                                                        B 7905
```

```
      SUBROUTINE BOUT(QADJ,B,D,WHW,VEL,DEP,DSUBN,DSUBC,Z,DIST,TOEL,        B 7910
     1QMAX,SLOPE)                                                          B 7915
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),            B 7920 **
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),        B 7925 **
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),   B 7930 **
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),    B 7935 **
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),           B 7940 **
     5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,        B 7945 **
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),     B 7950 **
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),     B 7955 **
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),     B 7960 **
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,          B 7965 **
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2             B 7970 **
      DIMENSION CKE(4),V(2),R(2),SPH(2)                                    B 7975
      DATA CKE/.4,.5,.7,.2/,ALPHA,SCORR,CN/1.0,.5,.012/                    B 7980
C                                                                          B 7985
C           OUTLET CONTROL COMPUTATIONS                                    B 7990
  410 CALL BNORM%QADJ,CN,SLOPE,B,D,DEP,AREA,WP<                            B 7995
  585 DSUBN # DEP                                                          B 8000
      AREA # B*D                                                           B 8005
      HR # AREA/%2.*%D&B<<                                                 B 8010
      HEAD # %QADJ/10.<*%QADJ/10.<*%%1.555*%1.&CKE%I4<<</%AREA*            B 8015
     1AREA<&%45.095*CN*CN*DIST/%AREA*AREA*HR**1.333333<<<                  B 8020
      DSUBC # .315*%QADJ/B<**.666667                                       B 8025
      IF %DSUBC-D< 630,630,620                                             B 8030
  620 DSUBC # D                                                            B 8035
  630 TEMP # %DSUBC&D</2.                                                  B 8040
      IF %DTW-TEMP< 640,640,650                                            B 8045
  640 HO # TEMP                                                            B 8050
      GO TO 655                                                            B 8055
  650 HO # DTW                                                             B 8060
  655 WHW # HO&HEAD                                                        B 8065
  656 IF(WHW.LE.0) GO TO 710                                               B 8070
  690 TEMP # D&%1.&CKE%I4<<*%%QADJ*QADJ</%64.4*AREA*AREA<<                 B 8075
      IF %WHW-TEMP< 710,700,700                                            B 8080
  700 GO TO 900                                                            B 8085
  710 K22 # 0                                                              B 8090
C                                                                          B 8095
C           TEST FOR INLET CONTROL GOVERNS                                 B 8100
C                                                                          B 8105
      IF %DSUBN-DSUBC< 900,720,720                                         B 8110
  720 IF %DTW-DSUBC< 730,730,725                                           B 8115
  725 IF %DTW-DSUBN< 740,740,735                                           B 8120
  730 DEP # DSUBC                                                          B 8125
      GO TO 750                                                            B 8130
  735 K22 # 1                                                              B 8135
  740 DEP # DTW                                                            B 8140
  750 I # 1                                                                B 8145
      SUMX # 0.                                                            B 8150
      IF%DEP-D<700,751,752                                                 B 8155
  751 IF%K22<752,700,752                                                   B 8160
  752 DEP # DTW - SLOPE * DIST                                             B 8165
      IF%DEP-DSUBN<753,753,754                                             B 8170
  753 DEP # DSUBN                                                          B 8175
  754 K22 # -1                                                             B 8180
```

```
      I # 1
C
C           BACKWATER COMPUTATIONS
C
  760 AREA # DEP*B
      V%I< # QADJ/AREA
      SPH%I< # DEP&ALPHA*V%I<*V%I</64.4
      R%I< # AREA/%2.*DEP&B<
  770 IF %I-2< 780,790,790
  780 I # 2
      IF%K22< 800,781,782
  781 DEP # DEP&.2
      IF%DEP-D<760,700,700
  782 DEP # DEP-.2
      GO TO 760
  790 AVEV # %V%1<&V%2<</2.
      AVER # %R%1<&R%2<</2.
      S1 # CN*CN*AVEV*AVEV/%2.21*AVER**1.33333<
      IF %K22< 795,795,796
  795 IF%S1-SLOPE<753,753,810
  796 IF%SLOPE-S1<753,753,811
  800 SPH%2< # SPH%1<
      WHW # SPH%2<&CKE%I4<*V%1<*V%1</64.4
      GO TO 700
  810 DX1 # %SPH%2<-SPH%1<</%S1-SLOPE<
      GO TO 812
  811 DX1 # %SPH%1<-SPH%2<</%SLOPE - S1<
  812 SUMX # SUMX&DX1
      IF%SUMX-CLTH< 820,813,813
  813 IF%K22<815,814,815
  814 DEP # DEP-%SUMX-CLTH</DX1*.2
      GO TO 754
  815 DEP # DEP&%SUMX-CLTH</DX1*.2
      GO TO 754
  820 V%1< # V%2<
      SPH%1< # SPH%2<
      R%1< # R%2<
      GO TO 780
  900 IF(D.LT.DSUBC) GO TO 1020
 1010 IF %DTW-D< 1030,1020,1020
 1020 AREA # B*D
      GO TO 1060
 1030 IF %DSUBC-DTW< 1050,1050,1040
 1040 AREA # B*DSUBC
      GO TO 1060
 1050 AREA # B*DTW
 1060 VEL  # QADJ/AREA
      RETURN
      END
```

```
      SUBROUTINE BFIT(Q,B,D,QMAX,TOEL.SLOPE)
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),
     5          IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2
      DIMENSION CKE(4)
      DATA CKE/.4,.5,.7,.2/,CN/.012/
      DIST=CLTH
      A=50.
   10 Q=Q+A
      AREA=B*D
      HR=AREA/(2.*(B+D))
      HD=(Q/10.)*(Q/10.)*((1.555*(1.+CKE(I4)))/(AREA*AREA)+(45.095*CN*
     1CN*DIST/(AREA*AREA*HR**1.333333)))
      DC=.315*(Q/B)**.666667
      IF(DC.LE.D) GO TO 30
   20 DC=D
   30 T = (DC+D)/2.
      IF(DTW.GT.T) GO TO 50
   40 HO= T
      GO TO 55
   50 HO=DTW
   55 WHW=HO+HD
      HWO=WHW+TOEL
      IF(HWO.GT.AHWEL)GO TO 60
      GO TO 10
   60 Q=Q-A
      IF(A.LT.5.) GO TO 70
      A=2.0
      GO TO 10
   70 QMAX=Q
      RETURN
      END
```

```
      SUBROUTINE BNORM%QADJ,CN,SLOPE,B,D,DEP,AREA,WP<                   B 8630
C                                                                       B 8635
C     COMPUTE NORMAL DEPTH                                              B 8640
C                                                                       B 8645
      DEP#D                                                             B 8650
      AR23#QADJ*CN/%1.486*SLOPE**.5<                                    B 8655
      XX#AR23/B**2.6667                                                 B 8660
      IF%XX.GT.2.0< GO TO 440                                           B 8665
      IF%XX.GT.0.22< GO TO 420                                          B 8670
      YOB#.030402&3.6483784*XX-15.152238*XX*XX&64.991913*XX*XX*XX       B 8675
     1-110.31635*XX*XX*XX*XX                                            B 8680
      GO TO 430                                                         B 8685
  420 YOB#.084468&2.34061*XX-1.53643*XX*XX&1.636594*XX*XX*XX            B 8690
     1-.677621*XX*XX*XX*XX                                              B 8695
  430 DEP # YOB*B                                                       B 8700
      IF%DEP.GT.D<DEP#D                                                 B 8705
  440 AREA # B*DEP                                                      B 8710
      WP # 2.*DEP&B                                                     B 8715
      RETURN                                                            B 8720
      END                                                               B 8725
```

```
      SUBROUTINE BEQUA(X, HW,B,D,SLOPE)
C
C      SUBROUTINE CONTAINING CULVERT EQUATIONS
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),            **
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),       **
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),  **
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),   **
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),          **
     5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,      **
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),    **
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),    **
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),    **
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,         **
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2            **
      INTEGER SYSIN, SYSOT
      DATA SCORR/.5/
      SYSIN=1
      SYSOT=3
      GO TO (100,100,200,310),I1
C     CIRCULAR PIPES -- METAL AND CONCRETE
  100 WRITE(SYSOT,10)
   10 FORMAT(27H CIRCULAR NOT AVAILABLE YET)
C     PIPE-ARCH EQUATIONS
  200 WRITE(SYSOT,20)
   20 FORMAT(29H  PIPE-ARCH NOT AVAILABLE YET)
C
C     BOX CULVERT EQUATIONS
C     WINGWALLS - SQUARE EDGES - HEC NO. 5
  310 GO TO (312,314,314,316,330,331,332),I5
  312 HWOVD=.0724927+.507087*X-.117474*X*X+.0221702*X*X*X-.00148958*X*X
     1*X*X+.0000380*X*X*X*X*X -SCORR*SLOPE
      GO TO 318
  314 HWOVD=.122117+.505435*X-.10856*X*X+.0207809*X*X*X-.00136757*X*X*X
     1*X+.00003456*X*X*X*X*X -SCORR*SLOPE
      GO TO 318
  316 HWOVD=.144133+.461363*X-.0921507*X*X+.0200028*X*X*X-.00136449*X*X
     1*X*X+.0000358*X*X*X*X*X -SCORR*SLOPE
  318 HW=HWOVD*D
      RETURN
C.....BEVEL EDGES - WINGWALLS, SKEWS  HEC NO. 13  CHARTS 8,9,10
  330 HWOVD=.1566086+.3980353*X-.0640392*X*X+.01120135*X*X*X-.0006449*X
     1*X*X*X+.000014566*X*X*X*X*X
      GO TO 342
  331 HWOVD=.0895633+.4412465*X-.0743498*X*X+.01273183*X*X*X
     1-.0007588*X*X*X*X+.00001774*X*X*X *X*X -.02
      GO TO 342
  332 HWOVD=.0967588+.4551575*X-.0812895*X*X+.01215577*X*X*X-.00067794*X
     1*X*X*X+.0000148*X*X*X*X*X
  342 HW=HWOVD*D
      RETURN
      END
```

```
      SUBROUTINE CIRC(DIST,SLOPE)                                       B 8985
      WRITE(3,10)                                                       B 8990
   10 FORMAT(20X,'CIRCULAR PIPE PROGRAM     AVAILABLE              )    B 8995
      RETURN                                                            B 9000
      END                                                               B 9005
      SUBROUTINE ARCH                                                   B 9010
      WRITE(3,10)                                                       B 9015
   10 FORMAT(20X,'PIPE ARCH PROGRAM NOT AVAILABLE AT THIS TIME')        B 9020
      RETURN                                                            B 9025
      END                                                               B 9030
```

```
C
C     ROUTINES  TO DESIGN AND ANALYZE PIPE CULVERTS
C
C     BY MARIO MARQUES  -- FHWA
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),
     5       IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2
      INTEGER SYSIN, SYSOT
      DATA IBLANK/3H   /
      SYSIN=1
      SYSOT=3
C
C-----READ DESIGN DATA
   10 READ(SYSIN,901)IPROJ
      IF(IPROJ(1).EQ.IBLANK) GO TO 11
   12 READ(SYSIN,903) I1,I2,I3,I4,I5,SLOPE,DIST,Q1,DTW,AHWEL,ELIN,
     1 ELOUT,SEL,SER,SFACE
   50 IF(I1.EQ.1) GO TO 58
   52 IF(I1.EQ.2) GO TO 58
   54 IF(I1.EQ.3) GO TO 58
   56 IF(I1.EQ.4) GO TO 58
      WRITE (SYSOT,2130)
 2130 FORMAT( 22H  CULVERT CODE INVALID)
      GO TO 10
   58 SLOPE = SLOPE + 0.000001
C
C
C-----ROUTINES TO DESIGN PIPES,ARCHES,OR BOXES
C  15 GO TO (110,110,130,140),I1
  110 CALL CIRC(DIST,SLOPE)
      GO TO 10
C 130 CALL ARCH
C     GO TO 10
C 140 CALL BOXES(DIST,SLOPE)
C     GO TO 10
   11 WRITE(SYSOT,910)
      STOP
  910 FORMAT(11H END OF JOB)
  901 FORMAT(26A3)
  903 FORMAT(5I1,F7.4,9F7.1)
  904 FORMAT(2F4.1)
      END
```

```
      SUBROUTINE CIRC(DIST,SLOPE)
C
C     SUBROUTINE FOR HYDRAULIC DESIGN OF PIPE CULVERTS
C
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100).
     2TAB11(100),TAB12(100).TAB13(100),TAB14(100).TAB15(100).TAB16(100).
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100).
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),
     5          IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100).
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100).
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100).
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUF,DISL,DISR,SFACE,
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2
      DIMENSION HWO(2),SUMP(2), FACEHW(2),HWEL(2)
      DIMENSION CKE(5),FACE(2),CMP(90),CN(90)
      INTEGER SYSIN, SYSOT
      DATA CN/.0247,.0244,.0241,.0237,.0235,.0233,.0232,.0231,.0229,
     1.0228,.0227,.0226,.0225,.0281,.0278,.0275,.0273,.0271,.0269,.0267.
     2.0266,.0265,.0263,.0263,.0262,.0261,.026,.026,.0332,.033,.0327,
     3.0325,.0323,.0321,.032,.0318,.0317,.0315,.0314,.0313,.0312,.0311.
     4.031,.0309,.0308,.0307,.0307,.0306,.0305,.0305,.0304,.0304,.0303.
     5.0303,.0302,.0302,.0301,.0301,.03,.03,.03,29*.012/
      DATA                     CKE/.9,.7,.5,.2,.2/
      DATA CMP/2.,2.5,3.,3.5,4.,4.5,5.,5.5,6.,6.5,7.,7.5,8.,3.,3.5,4.,4.
     15.5,.5.5,6.,6.5,7.,7.5,8.,8.5,9.,9.5,10.,5.,5.5,6.,6.5,7.,7.5,8.,
     28.5,9.,9.5,10.,10.5,11.,11.5,12.,12.5,13.,13.5,14.,14.5,15.,15.5.
     316.,16.5,17.,17.5,18.,18.5,19.,19.5,20.,20.5,21.,2.,2.25,2.5.
     42.75,3.,3.5,4.,4.5,5.,5.5,6.,6.5,7.,7.5,8.,8.5,9.,9.5,10.,10.5.
     511.,11.5,12.,12.5,13.,13.5,14.,14.5,15./
C
C     PRINT CONVENTIONAL CULVERT DESIGN DATA
C
      READ(SYSIN,20)  DIA1, DIA2
   20 FORMAT(2F5.2)
      WRITE(SYSOT,902) IPROJ
  902 FORMAT(1H1,' >>>> PIPE CULVERT DESIGN FOR PROJECT >>>   ',26A3,///
     1/ ' >>>> THE PROGRAM PROVIDES A RANGE OF CONVENTIONAL PIPE CULVERT
     2 SIZES WITH AND WITHOUT BEVELS WHICH SATISFY SITE REQUIREMENTS'//
     330X,'WHERE:  BEVELED EDGES FOR CMP AND CONCRETE PIPES'/37X,'ARE BA
     4SED ON CHART 13 IN HEC-13'////
     A ' >>>>  IF INLET CONTROL GOVERNS - IMPROVED INLET DESIGNS ARE PR
     BOVIDED FOR SIDE-TAPERED INLETS '                /66X,'AND SLOPE-TAPER
     CED INLETS '////)
  903 WRITE(SYSOT,904)
  904 FORMAT(1X,'*************************************************************
     1*************************************    DESIGN INPUT DATA      ***
     2**********'/'*************************************************************
     3*************************************    DESIGN INPUT DATA      **
     4**********'/'*************************************************************
     5*************************************************************************
     6************'/'***********************************************************
     7*************************************************************************
     8************'/ )
```

```
   GO TO (12,14),I1
12 GO TO (42,44),I2
42 GO TO (48,50,52,52,56,58,58),I5
48 WRITE(SYSOT,41)
41 FORMAT(4X,'CONVENTIONAL CULVERT ----------       CM PIPE - PROJECT
  1ING - UNPAVED                       KE= 0.9'/)
   GO TO 58
50 WRITE(SYSOT,43)
43 FORMAT(4X,'CONVENTIONAL CULVERT ----------       CM PIPE - MITERED
  1 - UNPAVED                          KE= 0.7'/)
   GO TO 58
52 WRITE(SYSOT,45)
45 FORMAT(4X,'CONVENTIONAL CULVERT ----------       CM PIPE - HEADWAL
  1L - UNPAVED                         KE= 0.5'/)
   GO TO 58
56 WRITE(SYSOT,47)
47 FORMAT(4X,'CONVENTIONAL CULVERT ----------       CM PIPE - END-SEC
  1TION - UNPAVED                      KE= 0.5'/)
58 IF(I5.EQ.7) GO TO 60
   WRITE(SYSOT,49)
49 FORMAT(4X,'BEVEL-EDGED CULVERT ----------       CM PIPE - UNPAVED
  1WITH BEVEL(A)                       KE= 0.2'//)
   GO TO 80
60 WRITE(SYSOT,61)
61 FORMAT(4X,'BEVEL-EDGED CULVERT ----------       CM PIPE - UNPAVED
  1WITH BEVEL(B)                       KE= 0.2'//)
   GO TO 80
44 GO TO (64,66,68,68,70,72,72),I5
64 WRITE(SYSOT,65)
65 FORMAT(4X,'CONVENTIONAL CULVERT -------     CM PIPE - PROJECTING -
  1 PAVED                              KE= 0.9'/)
   GO TO 72
66 WRITE(SYSOT,67)
67 FORMAT(4X,'CONVENTIONAL CULVERT ----------       CM PIPE - MITERED
  1 - PAVED                            KE= 0.7'/)
   GO TO 72
68 WRITE(SYSOT,69)
69 FORMAT(4X,'CONVENTIONAL CULVERT ----------       CM PIPE - HEADWAL
  1L - PAVED                           KE= C.5'/)
   GO TO 72
70 WRITE(SYSOT,71)
71 FORMAT(4X,'CONVENTIONAL CULVERT ----------       CM PIPE - END-SEC
  1TION - PAVED                        KE= 0.5'/)
72 IF(I5.EQ.7) GO TO 74
   WRITE(SYSOT,73)
73 FORMAT(4X,'BEVEL-EDGED CULVERT  ----------      CM PIPE - PAVED WI
  1TH BEVEL(A)                         KE= 0.2'//)
   GO TO 80
74 WRITE(SYSOT,75)
75 FORMAT(4X,'BEVEL-EDGED CULVERT ----------       CM PIPE - PAVED WI
  1TH BEVEL(B)                         KE= 0.2'//)
   GO TO 80
14 IF(I5.GT.5) GO TO 19
   GO TO (21,23,25,27,29),I5
21 WRITE(SYSOT,22)
```

```
   22 FORMAT(4X,'CONVENTIONAL CULVERT ----------        CONCRETE PIPE - S
     1OCKET-END - PROJECTING               KE= 0.2'/)
      GO TO 19
   23 WRITE(SYSOT,24)
   24 FORMAT(4X,'CONVENTIONAL CULVERT ----------        CONCRETE PIPE - S
     1OCKET-END HEADWALL                   KE= 0.2'/)
      GO TO 19
   25 WRITE(SYSOT,26)
   26 FORMAT(4X,'CONVENTIONAL CULVERT ----------        CONCRETE PIPE - S
     1QUARE-EDGE PROJECTING                KE= 0.5'/)
      GO TO 19
   27 WRITE(SYSOT,28)
   28 FORMAT(4X,'CONVENTIONAL CULVERT ----------        CONCRETE PIPE - S
     1QUARE-EDGE HEADWALL                  KE= 0.5'/)
      GO TO 19
   29 WRITE(SYSOT,16)
   16 FORMAT(4X,'CONVENTIONAL CULVERT ----------        CONCRETE PIPE - E
     1ND SECTION                           KE= 0.5'/)
   19 IF(I5.EQ.7) GO TO 15
   18 WRITE(SYSOT,13)
   13 FORMAT(4X,'BEVEL-EDGED CULVERT -----------      CONCRETE PIPE WITH
     1 BEVEL(A)                            KE= 0.2'//)
      GO TO 80
   15 WRITE(SYSOT,17)
   17 FORMAT(4X,'BEVEL-EDGED CULVERT ----------       CONCRETE PIPE WITH
     1 BEVEL(B)                            KE= 0.2'//)
   80 ISEL=SEL
      ISER=SER
      SLOPP=SLOPE
      SLOPE = (EL I-ELOUT)/DIST + .000001                                    **
      WRITE(SYSOT,1900)I1,I2,I3,I4,I5,SLOPP,DIST,Q1,DTW,AHWEL,ELIN,
     1ELOUT,  SEL, SER, DIA1, DIA2,                SFACE,SLOPE
 1900 FORMAT(18X,'APPROX     TOE-TOE',27X,
     A              'ALLOWABLE   STREAM BED   STREAM BED      US ROADWAY
     1 DS   ROADWAY',4X,'CULVERT',7X,'STREAM     CULVERT     DESIGN',6X,'DE  **
     2SIGN',5X,'HEADWATER    ELEVATION     ELEVATION',5X,'EMBANKMENT',       **
     35X,'EMBANKMENT',6X,'CODE',8X,'SLOPE',4X,' LENGTH    DISCHARGE    TAI
     4LWATER     ELEVATION    AT INLET      AT OUTLET',7X,'SLOPE',11X,'SLOP
     5E' 4X,5I1.8X,F7.4.2X,F8.1,2X,F8.1,4X,F8.1,4X,F8.1.4X,F8.1,5X,
     6F8.1,9X,F4.1,':1',10X,F4.1,':1'//4X,'CULVERT  SIZES',33X,'SLOPE-TA
     7PER' 7X,'DIAMETER  FROM',F6.2, ' FT TO',F6.2,  ' FT',9X,'FALL SLOP
     8E',12X,'COMPUTED STREAM'/52X,F4.1,':1',15X,'SLOPE =',F7.4//)
      WRITE(SYSOT,2100)
 2100 FORMAT(130H*****************************************  **************
     1**********************************************************************
     2*********/'**************************',  '      INDEX  SHEET  FOR PIPE
     3  CULVERTS         ***************','**********************************
     4*****************'/'*************************',  '      INDEX  SHEET
     5FOR PIPE  CULVERTS        **********************************************
     6***********************'    /'******************************************
     7**  ***  *****************************************************************
     8****************************'/)
  459 WRITE(SYSOT,2105) KE(I4)
 2105 FORMAT(30X,'*  -- OUTLET CONTROL --    **',27X,'-- INLET CONTROL --
     1',27X,'*'/
```

```
     130X,'*'.25X,'**'.73X,'*'/30X,'* KE=',F4.1,'  KE=0.2  OUTLET ** CON
     2VENTIONAL CULVERT  *  BEVEL-EDGED CULVERT   * SIDE-TAPERED CULVERT
     3   +'/30X,'*--------------------------**--------------------------*---
     4-----------------------*-------------------------------*'/' * SEE  *NUMBER
     5*   BARREL     *  HW        HW      INVERT **  HW '.11X.'INVERT *  HW
     6'.13X.'INVERT * THROAT',10X,'INVERT *'/' * PAGE *  OF    *  DIAMETE
     7R    *  ELEV     ELEV      ELEV  ** ELEV     FALL     ELEV  *  ELEV
     8FALL     ELEV  *HW ELEV    FALL     ELEV  *'/
     9                    ' *',6X,'*BARRELS*      (FT)     *  (FT)     (FT)
     A(FT)  ** (FT      (FT)     (FT)  *  (FT)     (FT)     (FT)  *  (FT)
     B (FT)      (FT)  *'/' *',6X,'*',7X,'*',6X,'*',6X,'*',25X,'**',23X,
     C'*',24X,'*',24X,'*')
      I55=I5
   30 IF(I1.EQ.1.AND.I5.LE.3) I5=I5+7
      DO 457 J=1,100                                                      **
      ITAB(J)=0
      TAB1(J)=0.0
      TAB2(J)=0.0
      TAB3(J)=0.0
      TAB4(J)=0.0
      TAB5(J)=0.0
      TAB6(J)=0.0
      TAB7(J)=0.0
      TAB8(J)=0.0
      TAB9(J)=0.0
      TAB10(J)=0.0
      TAB11(J)=0.0
      TAB12(J)=0.0
      TAB13(J)=0.0
      TAB14(J)=0.0
      TAB15(J)=0.0
      TAB16(J)=0.0
      TQMAX(1,J)=0.0
      TQMAX(2,J)=0.0
  457 CONTINUE
      L=1
      II4=I4
      II5=I5
      II3=I3
      IF(I3.EQ.4)II3=3
      KD1=1
      KD2=13
      JL2=0
C  TO ANALYZE SEPERATE CORRUGATED METAL PIPES REPLACE THE NEXT CARD WITH  **
C       '' DO 480 K1 = II3,II3 ''                                         **
      DO 480 K1=II3,3
      JL=0
      IF(I1.EQ.2) GO TO 10
      IF(K1.EQ.2) KD1=14
      IF(K1.EQ.2) KD2=28
      IF(K1.EQ.3) KD1=29
      IF(K1.EQ.3) KD2=61
   10 IF(I1.EQ.2) KD1=62
      IF(I1.EQ.2)KD2=90
      DO 480 IBAR=1,5
```

```
      ICOUNT=0
  460 HWIN=0.0
      HWO(1)=0.0
      HWO(2)=0.0
      SUMP(1)=0.0
      SUMP(2)=0.0
      FACEHW(1)=0.0
      FACEHW(2)=0.0
      HWOUT=0.0
      VELIN=0.0
      VELOUT=0.0
C
C       START DESIGN OF PIPE CULVERTS
      DO 480 K=KD1,KD2
      NOCA(1,L)=0
      NOCA(2,L)=0
      NOCB(1,L)=0
      NOCB(2,L)=0
      NOCC(1,L)=0
      NOCC(2,L)=0
      D=CMP(K)
      DIA=D
      BAR=IBAR
      I4=II4
      I5=II5
      IBEV=1
      IF(I5.EQ.6.OR.I5.EQ.7)IBEV=2
      IF(IBEV.EQ.2) NOCA(1,L)=1
      Q=Q1/BAR
      IF(K.EQ.29.AND.I5.EQ.5) GO TO 462
      IF(D.GE.DIA1.AND.D.LE.DIA2) GO TO 461
      GO TO 480
  461 SMALL=(SLOPE*SEL**2*D)/(1+SLOPE*SEL)
      SMALR=(SLOPE*SER**2*D)/(1.+SLOPE*SER)
      DISL=SEL*D-SMALL
      DISR=SER*D+SMALR
      IF(I5.EQ.1.OR.I5.EQ.3.OR.I5.EQ.8) DISL=0.0
      IF(I5.EQ.1.OR.I5.EQ.3.OR.I5.EQ.8) DISR=0.0
      ELL=DISL*SLOPE                                                          **
      ELR=DISR*SLOPE
      FACEL=ELIN-ELL
      FAHC=FACEL
      CROWN = FACEL+D
      TOEL=ELOUT+ELR
      HH=FACEL-TOEL
      DIST1=DIST-DISL-DISR
      CLTH=((DIST1*DIST1)-(HH*HH))**.5
   39 QMAX=0.0
      AN=CN(K)
      IF(I2.EQ.2) AN=.75*CN(K)+.25*.012
      CALL   COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,AN)
      HWO(IBEV)=HWOUT+TOEL
      IF(IBEV.EQ.1) GO TO 465
      IF(HWO(2).GT.AHWEL.AND.NOCA(1,L).EQ.1) NOCA(1,L)=0
      IF(HWO(2).GT.AHWEL.AND.NOCB(1,L).EQ.1) NOCB(1,L)=0
```

```
      IF(HWO(2).GT.AHWEL.AND.NOCC(1,L).EQ.1) NOCC(1,L)=C
      IF(HWO(2).GT.AHWEL) GO TO 480
      IF(HWO(2).LT.TOEL) GO TO 480
  465 CALL CRIT(Q,AN,D,QMAX,TOEL,SLOPE,I4,I1,CLTH,DTW,AHWEL)
      Q=Q1/BAR
      TQMAX(IBEV,L)=QMAX*BAR
      X=Q /D**2.5
      CALL CEQUA(X,HWIN,  D,SLOPE,I5)
  124 FACEHW(IBEV)=FACEL+HWIN
      IF(FACEHW(IBEV).LT.(AHWEL-D   ).AND.HWO(IBEV).LT.(AHWEL-D   ))      **
     1 GO TO 480
  134 FALLM=1.5*D
      FALLT=CLTH*SLOPE
      IF(FALLM.GT.FALLT) FALLM=FALLT
      IF(FACEHW(IBEV).GT.AHWEL) GO TO 140
      GO TO 150
C     COMPUTE THE SUMP
  140 SUMP(IBEV)=FACEHW(IBEV)-AHWEL
      IF(SUMP(IBEV).GE.FALLM) NOCA(IBEV,L)=1
      DISTA(IBEV,L)=DIST1
      IF(NOCA(IBEV,L).EQ.1) GO TO 153
      DIS=SUMP(IBEV)*SEL
      DISTA(IBEV,L)=DIS+DIST1
      FACEL=FACEL+SLOPE*DIS
      DIF=FACEL-SUMP(IBEV)-DIS*SLOPE
      IF(DIF.LT.TOEL) DIF=TOEL+.01
      SLOPA(IBEV,L)=(DIF-TOEL)/DISTA(IBEV,L)
      CROWN=DIF+D
      FACE(IBEV)=DIF
      FACEHW(1)=FACE(IBEV)+HWIN
      IF(FACEHW(IBEV).GE.CROWN.OR.HWO(IBEV).GE.CROWN) GO TO 142         **
      GO TO 480
  142 HWEL(IBEV)=AHWEL
      GO TO 155
C     NO SUMP
  150 SUMP(IBEV)=0.0
      SLOPA(IBEV,L)=SLOPE
      DISTA(IBEV,L)=DIST1
      FACE(IBEV)=FACEL
      CROWN=FACEL+D
      HWEL(IBEV)=FACEL+HWIN
      IF(FACEHW(IBEV).GE.CROWN.OR.HWO(IBEV).GE.CROWN) GO TO 155         **
      GO TO 480
  155 IF(SUMP(IBEV).EQ.0.0) CRESA(IBEV,L)=0.0
C     COMPUTE VELOCITY
      SLO=SLOPA(IBEV,L)
      DA=DISTA(IBEV,L)
      CALL   COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DA,SLO,AN)
      CALL CROUT(DN,AREA,T,WP,DIA,R)
      VELA(IBEV,L)=Q /AREA
      IF(VELOUT.GT.VELA(IBEV,L)) VELA(IBEV,L)=VELOUT
      IF(SUMP(IBEV).EQ.0.0) GO TO 151
C..... COMPUTE MINIMUM CREST LENGTH
      HCA=FAHC+(SUMP(IBEV)*SEL*SLOPE)+(SUMP(IBEV)*3.+D/2.)*SLOPE
      HC=HWEL(IBEV)-HCA
```

```
      IF(HC.LT.1.) HC=1.0
      CRES=(.5*Q1**.6667)/HC
      CRESA(IBEV,L)=CRES**1.5
C     COMPUTE CURVE B
  151 ELINCA(IBEV,L)=FACE(IBEV)
  154 X=(TQMAX(IBEV,L)/BAR)/(D**2.5)
      CALL CEQUA(X,HWI,DIA,SLOPE,I5)
      TEMP=ELINCA(IBEV,L)+HWI
      IF(TEMP.LE.AHWEL) GO TO 144
      BFALL=TEMP-AHWEL
      TBFALL(IBEV,L)=BFALL       +SUMP(IBEV)
      IF(TBFALL(IBEV,L ).GT.FALLM) GO TO 160
      ELINCB(IBEV,L)=ELINCA(IBEV,L)-BFALL
      IF(ELINCB(IBEV,L).LT.TOEL) ELINCB(IBEV,L)=TOEL+.01
      HWCB(IBEV,L)=ELINCB(IBEV,L)+HWI
      GO TO 139
  160 ELINCB(IBEV,L)=ELINCA(IBEV,L)-(FALLM-SUMP(IBEV))
      IF(ELINCB(IBEV.L).LT.(TOEL+.01))ELINCB(IBEV.L)=TOEL+.01
      BFALL=ELINCA(IBEV,L)-ELINCB(IBEV,L)
      TBFALL(IBEV,L)=BFALL+SUMP(IBEV)
C     COMPUTE MAX Q BASED ON INLET CURVE
      AIN=50.
      QUE=Q1/BAR
  162 QUE=QUE+AIN
      X=QUE/D**2.5
      CALL CEQUA(X,HIGH,DIA,SLOPE,I5)
      HI=HIGH+ELINCB(IBEV,L)
      IF(HI.GT.AHWEL) GO TO 170
      GO TO 162
  170 QUE=QUE-AIN
      IF(AIN.LT.10.) GO TO 172
      AIN=2.0
      GO TO 162
  172 TQMAX(IBEV,L)=QUE*BAR
      X=QUE/D**2.5
      CALL CEQUA(X,HWI,DIA,SLOPE,I5)
      HWCB(IBEV,L)=ELINCB(IBEV,L)+HWI
  139 DISB=BFALL*SEL
      DISTB(IBEV,L)=DISTA(IBEV,L)+DISB
      SLOPB(IBEV,L)=(ELINCB(IBEV,L)-TOEL)/DISTB(IBEV,L)
C     COMPUTE VELOCITY
      SLO=SLOPB(IBEV,L)
      QQ=TQMAX(IBEV,L)/BAR
      DB=DISTB(IBEV,L)
      CALL    COUT(QQ,D,HWOUT,VELOUT,DEP,DN,DC,DB,SLO,AN)
      CALL CROUT(DN,AREA,T,WP,DIA,R)
      VELB(IBEV,L)=QQ/AREA
      IF(VELOUT.GT.VELB(IBEV,L)) VELB(IBEV,L)=VELOUT
      HCB=FAHC+(TBFALL(IBEV,L)*SEL*SLOPE)+(TBFALL(IBEV.L)*3.+D/2.)*SLOPE
      HC=AHWEL-HCB
      IF(HC.LT.1.) HC=1.0
      CRES=(.5*TQMAX(IBEV,L)**.6667)/HC
      CRESB(IBEV,L)=CRES**1.5
      GO TO 145
  144 TBFALL(IBEV,L)=0.0
```

```
      NOCB(IBEV,L)=1
C     COMPUTE CURVE C
  145 TEMP=ELINCA(IBEV,L)+HWIN
      IF(HWO(IBEV).GE.TEMP) GO TO 143
      CFALL=TEMP-HWO(IBEV)
      TCFALL(IBEV,L)=CFALL       +SUMP(IBEV)
      ELINCC(IBEV,L)=ELINCA(IBEV,L)-CFALL
      IF(TCFALL(IBEV,L).GT.FALLM) ELINCC(IBEV,L)=ELINCA(IBEV,L)-(FALLM-
     1SUMP(IBEV))
      IF(ELINCC(IBEV,L).LT.(TOEL+.01))ELINCC(IBEV,L)=TOEL+.01
      CFALL=ELINCA(IBEV,L)-ELINCC(IBEV,L)
      TCFALL(IBEV,L)=CFALL+SUMP(IBEV)
      HWCC(IBEV,L)=ELINCC(IBEV,L)+HWIN
      DISC=CFALL*SEL
      DISTC(IBEV,L)=DISC+DISTA(IBEV,L)
      SLOPC(IBEV,L)=(ELINCC(IBEV,L)-TOEL)/DISTC(IBEV,L)
      SLO =SLOPC(IBEV,L)
      DCC=DISTC(IBEV,L)
      CALL   COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DCC,SLO,AN)
      CALL CROUT(DN,AREA,T,WP,DIA,R)
      VELC(IBEV,L)=Q /AREA
      IF(VELOUT.GT.VELC(IBEV,L)) VELC(IBEV,L)=VELOUT
      HCC=FAHC+(TCFALL(IBEV,L)*SEL*SLOPE)+(TCFALL(IBEV,L)*3.+D/2.)*SLOPE
      HC=TEMP-HCC
      IF(HC.LT.1.) HC=1.0
      CRES=(.5*Q1**.6667)/HC
      CRESC(IBEV,L)=CRES**1.5
      GO TO 153
  143 TCFALL(IBEV,L)=0.0
      NOCC(IBEV,L)=1
  153 CONTINUE
      IF(IBEV.EQ.2) GO TO 464
      IBEV=IBEV+1
      FACEL=ELIN-ELL
      I4=4
      I5=6
      GO TO 461
  464 IF(NOCA(1,L).EQ.1) NOCB(1,L)=1
      IF(NOCA(1,L).EQ.1) NOCC(1,L)=1
      IF(NOCA(2,L).EQ.1) NOCB(2,L)=1
      IF(NOCA(2,L).EQ.1) NOCC(2,L)=1
      INDEX=0
C     IF(BAR.GT.2.) GO TO 120
      IBAR=BAR
      CALL CSIDE(  D,FALL,HWT,TROEL,IBAR,DIST1,INDEX,SLOPE,AN)
      IF(FALL.GT.900.) GO TO 120                                        **
      IF(FALL.GE.FALLM) GO TO 480
      GO TO 121
  120 FALL=0.0
      TROEL=0.0
      HWT=0.0
      IF(NOCA(1,L).EQ.1.AND.NOCA(2,L).EQ.1) GO TO 480
  121 IF(I2.EQ.2) GO TO 32
      IF(I2.EQ.1) GO TO 31
      IF(JL2.EQ.0.AND.K.LT.90) GO TO 186
```

```
      IF(JL2.EQ.1.AND.K.LE.90) GO TO 122
   31 IF(L.EQ.1.AND.K.LE.13) GO TO 180
      IF(K.LE.13) GO TO 122
      IF(JL.EQ.0.AND.K.LE.28) GO TO 182
      IF(JL.EQ.1.AND.K.LE.28) GO TO 122
      IF(JL.EQ.0.AND.K.LE.61) GO TO 184
      IF(JL.EQ.1.AND.K.LE.61) GO TO 122
   32 IF(L.EQ.1.AND.K.LE.13) GO TO 34
      IF(K.LE.13) GO TO 122
      IF(JL.EQ.0.AND.K.LE.28) GO TO 36
      IF(JL.EQ.1.AND.K.LE.28) GO TO 122
      IF(JL.EQ.0.AND.K.LE.61) GO TO 38
      IF(JL.EQ.0.AND.K.LE.61) GO TO 122
   34 WRITE(SYSOT,35)
   35 FORMAT(/10X,'2-2/3 IN X 1/2 IN CORRUGATED-METAL PIPE - PAVED ')
      JL=1
      GO TO 122
   36 WRITE(SYSOT,37)
   37 FORMAT(/10X,'3 IN X 1 IN CORRUGATED-METAL PIPE ---------PAVED')
      JL=1
      GO TO 122
   38 WRITE(SYSOT,40)
   40 FORMAT(/10X,'6 IN X 2 IN MULTIPLATE PIPE ---------------PAVED')
      JL=1
      GO TO 122
  180 WRITE(SYSOT,181)
  181 FORMAT(/10X,'2-2/3 IN X 1/2 IN CORRUGATED-METAL PIPE - UNPAVED')
      JL=1
      GO TO 122
  182 WRITE(SYSOT '83)
  183 FORMAT(/10X,'3 IN X 1 IN CORRUGATED-METAL PIPE ---------UNPAVED')
      JL=1
      GO TO 122
  184 WRITE(SYSOT,185)
  185 FORMAT(/10X,'6 IN X 2 IN MULTIPLATE PIPE ---------------UNPAVED')
      JL=1
      GO TO 122
  186 WRITE(SYSOT,187)
  187 FORMAT(/10X,'CONCRETE PIPES')
      JL2=1
  122 IBAR=BAR
      ITAB(L)=IBAR
      TAB1(L)=D
      TAB2(L)=AN
      TAB3(L)=HWO(1)
      TAB4(L)=HWO(2)
      TAB5(L)=TOEL
      TAB6(L)=HWEL(1)
      TAB7(L)=SUMP(1)
      TAB8(L)=FACE(1)
      TAB9(L)=HWEL(2)
      TAB10(L)=SUMP(2)
      TAB11(L)=FACE(2)
      TAB12(L)=HWT
      TAB13(L)=FALL
```

```
      TAB14(L)=TROEL
      TAB15(L)=DIST2
      TAB16(L)=QMAX*IBAR
      IF(NOCA(1,L).EQ.0.AND.NOCA(2,L).EQ.0) GO TO 126
      IF(NOCA(2,L).EQ.0) GO TO 130
      GO TO 125
  130 TAB3(L)=0.0
      TAB6(L)=0.0
      TAB7(L)=0.0
      TAB8(L)=0.0
      WRITE(SYSOT,127)L,IBAR,D,      HWO(2),TOEL,HWEL(2),SUMP(2),
     1 FACE(2),HWT,FALL,TROEL
  127 FORMAT(' *',I3,3X,'*',I4,3X,'*',F9.2,3X,         ' *    --',F9.1,
     1F10.1,' **    --',5X,'--',7X,'--  *',2(F6.1,4X,F4.1,3X,F6.1,' *'))
      GO TO 128
  126 WRITE(SYSOT,123)L,IBAR,D,      HWO(1),HWO(2),TOEL,HWEL(1),
     1SUMP(1),FACE(1),HWEL(2),SUMP(2),FACE(2),HWT,FALL,TROEL
  123 FORMAT(' *',I3,3X,'*',I4,3X,'*',F9.2,3X,         ' *',2F7.1,F10.1,
     1' **',F5.1,3X,F4.1,3X,F6.1,' *',2(F6.1,4X,F4.1,3X,F6.1,' *'))
      GO TO 128
  125 WRITE(SYSOT,129)L,IBAR,D,      HWO(2),TOEL,HWT,FALL,TROEL
  129 FORMAT(' *',I3,3X,'*',I4,3X,'*',F9.2,3X,         ' *    --',F9.1,
     1 F10.1,' **   .--',5X,'--',7X,'--   *',3X,'--',6X,'--',7X,'--   *',
     2F6.1,4X,F4.1,3X,F6.1,' *')
  128 L=L+1
  479 ICOUNT=IBAR
  480 CONTINUE
  482 L=L-1
      IF(L.EQ.0) WRITE(SYSOT,483)
  483 FORMAT(///5X,'THE RANGE OF CULVERT SIZES ANALYZED EXCEED THE DESIG
     1N CRITERIA'//)
      IF(L.EQ.0) RETURN
      WRITE(SYSOT,484)
  484 FORMAT(///25X,'BY DEFINITION OF FALL, WHEN A SIDE-TAPERED INLET LI
     1ES ON THE STREAM SLOPE,'/25X,'THE FALL IS THE DIFFERENCE IN ELEVAT
     2ION OF THE FACE INVERT AND THE THROAT INVERT'//25X,'WHEN SIDE-TAPE
     3RED CULVERT COLUMN (ABOVE) CONTAINS 0.0  0.0  0.0 '/30X,'1. THE TH
     4ROAT DESIGN EXCEEDED THE DESIGN CRITERIA'/27X,'OR 2. IMPROVED INLE
     5TS FOR MORE THAN 2 BARRELS NOT AVAILABLE')
C.....CALL TO CHY1 FOR CONVENTIONAL AND BEVEL PIPE DESIGN
      CALL CHY1(DIST,SLOPE)
      RETURN
      END
```

```
      SUBROUTINE CHY1(DIST,SLOPE)                                       C 2945
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),         C 2950
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),     C 2955
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),C 2960
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100), C 2965
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),        C 2970
     5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,     C 2975
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),  C 2980
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),  C 2985
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),  C 2990
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,       C 2995
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2          C 3000
      DIMENSION HWO(2),SUMP(2), FACEHW(2),HWEL(2)                       C 3005
      DIMENSION CKE(5),FACE(2)                                          C 3010
      REAL L1,L2,L3,L4                                                  C 3015
      INTEGER SYSIN, SYSOT                                              C 3020
      DATA CKE/.9,.7,.5,.2,.2/                                          C 3025
      II1=I1                                                            C 3030
      II2=I2                                                            C 3035
      II3=I3                                                            C 3040
      II4=I4                                                            C 3045
      II5=I5                                                            C 3050
   90 LL=1                                                              C 3055
  100 IBAR=ITAB(LL)                                                     C 3060
      BAR=IBAR                                                          C 3065
      CN=TAB2(LL)                                                       C 3070
      D=TAB1(LL)                                                        C 3075 **
      SMALL=(SLOPE*SEL**2*D)/(1.+SLOPE*SEL)                             C 3080 **
      SMALR=(SLOPE*SER**2*D)/(1.+SLOPE*SER)                             C 3085 **
      DISL=SEL*D-SMALL                                                  C 3090 **
      DISR=SER*D+SMALR                                                  C 3095
      ELL=DISL*SLOPE                                                    C 3100
      ELR=DISR*SLOPE                                                    C 3105
      DIST1=DIST-DISL-DISR                                              C 3110
C     PAGE HEADINGS                                                     C 3115
   94 WRITE(SYSOT,80) LL,ITAB(LL),          TAB1(LL),Q1,AHWEL,SLOPE     C 3120
     1,TAB5(LL)                                                         C 3125
   80 FORMAT(1H1,' PAGE=',I3, 5X,'NO. BARRELS=',I2,5X,                  C 3130
     1'DIAMETER =',F5.2,' FT',5X,'Q(50)=',F7.1,' CFS     AHWEL=',F7.1,  C 3135 **
     2' FT',4X,'STREAM SLOPE =',F7.4/50X,'OUTLET INVERT ELEV. =',F7.1,  C 3140
     3' FT'///)                                                         C 3145
      IF(I5.EQ.6.OR.I5.EQ.7) GO TO 212                                  C 3150
      IF(NOCA(1,LL).EQ.0) GO TO 89                                      C 3155
      WRITE(SYSOT,91)I1,I2,I3,I4,I55                                    C 3160
   91 FORMAT(1X,'CONVENTIONAL INLET DESIGN FOR CULVERT CODE  ',5I1/     C 3165
     11X,'**********************************************'///20X,       C 3170
     2'DESIGN DATA NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE CONVC 3175
     3ENTIONAL INLET EXCEEDS 1.5D OR LSO.')                             C 3180
      GO TO 206                                                         C 3185
C                                                                       C 3190
C.....CONVENTIONAL PIPE CULVERTS + PERFORMANCE CURVE DATA               C 3195
C                                                                       C 3200
   89 WRITE(SYSOT,81)I1,I2,I3,I4,I55,CKE(I4),TQMAX(1,LL)                C 3205
   81 FORMAT(1X,'CONVENTIONAL INLET DESIGN FOR CULVERT CODE: ',5I1/     C 3210
     11X,'**********************************************'//4X,'OUT     C 3215
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     2LET COMPUTATIONS',34X,'INLET COMPUTATIONS'/3X,'*******************
     3*',8X,'**********************************************************
     4*******************************'//10X,'KE =',F7.1,18X,'MIN FALL C
     5URVE',17X,'MAX Q CURVE',21X,'MIN HW CURVE'//67X,'MAX Q =',F7.1,
     6' CFS'//)
      DA=DISTA(1,LL)
      SA=SLOPA(1,LL)
      SB=SLOPB(1,LL)
      SC=SLOPC(1,LL)
      IF(NOCB(1,LL).EQ.1.AND.NOCC(1,LL).EQ.1) GO TO 14
      IF(NOCB(1,LL).EQ.1) GO TO 32
      IF(NOCC(1,LL).EQ.1) GO TO 18
   10 WRITE(SYSOT,12)DISTA(1,LL),DISTB(1,LL),DISTC(1,LL),TAB7(LL),
     1TBFALL(1,LL),TCFALL(1,LL),ELINCA(1,LL),ELINCB(1,LL),ELINCC(1,LL),
     2SLOPA(1,LL),SLOPB(1,LL),SLOPC(1,LL),VELA(1,LL),VELB(1,LL),VELC(1,
     3LL),CRESA(1,LL),CRESB(1,LL),CRESC(1,LL)
   12 FORMAT(30X,'CULVERT LENGTH  =',F7.1,' FT',6X,'CULVERT LENGTH  =',
     1F7.1,' FT',6X,'CULVERT LENGTH  =',F7.1,' FT'/30X,'FALL AT FACE
     2=',F7.2,' FT',6X,'FALL AT FACE     =',F7.2,' FT',6X,'FALL AT FACE
     3  =',F7.2,' FT'/30X,'ELEV FACE INVERT=',F7.1,' FT',6X,'ELEV FACE I
     4NVERT=',F7.1,' FT',6X,'ELEV FACE INVERT=',F7.1,' FT'/30X,'CULVERT
     5SLOPE    =',F9.4,7X,'CULVERT SLOPE    =',F9.4,7X,'CULVERT SLOPE    =',
     6,F9.4/30X,'VEL AT DESIGN Q =',F7.1,' FPS',5X,'VEL AT MAX Q     =',
     7F7.1,' FPS',5X,'VEL AT DESIGN Q =',F7.1,' FPS'/30X,'MIN CREST LENG
     8TH=',F7.1,' FT',6X,'MIN CREST LENGTH=',F7.1,' FT',6X,'MIN CREST LE
     9NGTH=',F7.1,' FT'//8X,'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HW
     AF',20X,'Q',8X,'HWF'/)
      QD=Q1/BAR-(Q1/BAR*.2)
   63 Q=QD
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO1=HWOUT+TAB5(LL)
      X=Q /D**2.5
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(1,LL)+HWN
      CALL CEQUA(X,HWN,D,SB,I5)
      HDCB=ELINCB(1,LL)+HWN
      CALL CEQUA(X,HWN,D,SC,I5)
      HDCC=ELINCC(1,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,85)QU,HWO1,QU,HDCA,QU,HDCB,QU,HDCC
   85 FORMAT(3X,2F9.1,3(13X,F9.1,1X,F9.1))
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 206
      QD=QD+(Q1/BAR)*.2
      GO TO 63
   14 WRITE(SYSOT, 16)DISTA(1,LL), TAB7(LL),ELINCA(1,LL),SLOPA(1,LL),
     1VELA(1,LL),CRESA(1,LL)
   16 FORMAT(30X,'CULVERT LENGTH  =',F7.1,' FT',19X,'--',26X,'--'/30X,
     1'FALL AT FACE    =',F7.2,' FT',19X,'--', 26X,'--'/30X,'ELEV FACE I
     2NVERT=',F7.1,' FT',19X,'--',26X,'--'/30X,'CULVERT SLOPE    =',F9.4,
     320X,'--',26X,'--'/30X,'VEL AT DESIGN Q =',F7.1,' FPS',18X,'--',
     426X,'--'/30X,'MIN CREST LENGTH=',F7.1,' FT',19X,'--',26X,'--'//8X,
     5'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HWF',18X,'Q',8X,'HWF'/)
      QD=Q1/BAR-(Q1/BAR*.2)
   60 Q=QD
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
```

```
      HWO1=HWOUT+TAB5(LL)
      X=Q/D**2.5
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(1,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,186)QU,HWO1,QU,HDCA
  166 FORMAT(3X,2F9.1,14X,2F9.1,20X,'--',8X,'--',18X,'--',8X,'--')
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 206
      QD=QD+(Q1/BAR)*.2
      GO TO 60
   18 WRITE(SYSOT,20)DISTA(1,LL),DISTB(1,LL),TAB7(LL),TBFALL(1,LL),
     1ELINCA(1,LL),ELINCB(1,LL),SLOPA(1,LL),SL^PB(1,LL),VELA(1,LL),
     2VELB(1,LL ),CRESA(1,LL),CRESB(1,LL)
   20 FORMAT(30X,'CULVERT LENGTH   =',F7.1,' FT',6X,'CULVERT LENGTH   =',
     1F7.1,' FT',14X,'--'/30X,'FALL AT FACE     =',F7.2,' FT',6X,'FALL AT
     2 FACE     =',F7.2,' FT',14X,'--'/30X,'ELEV FACE INVERT=',F7.1,' FT'
     4,6X,'ELEV FACE INVERT=',F7.1,' FT',14X,'--'/30X,'CULVERT SLOPE    =
     5',F9.4,7X,'CULVERT SLOPE    =',F9.4,15X,'--'/30X,'VEL AT DESIGN Q =
     6',F7.1,' FPS',5X,'VEL AT MAX Q     =',F7.1,' FPS',13X,'--'/30X,'MIN
     7 CREST LENGTH=',F7.1,' FT',6X,'MIN CREST LENGTH=',F7.1,' FT',14X,
     8'--'//8X,'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HWF',18X,'Q',
     98X,'HWF /)
      QD=Q1/BAR-(Q1/BAR*.2)
   64 Q=QD
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO1=HWOUT+TAB5(LL)
      X= Q/D**2.5
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(1,LL)+HWN
      CALL CEQUA(X,HWN,D,SB,I5)
      HDCB=ELINCB(1,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,183)QU,HWO1,QU,HDCA,QU,HDCB
  183 FORMAT(3X,2F9.1,14X,2F9.1,14X,2F9.1,17X,'--',8X,'--')
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 206
      QD=QD+(Q1/BAR)*.2
      GO TO 64
   32 WRITE(SYSOT,24)DISTA(1,LL),DISTC(1,LL), TAB7(LL),TCFALL(1,LL),
     1ELINCA(1,LL),ELINCC(1,LL),SLOPA(1,LL),SL^PC(1,LL),VELA(1,LL),
     2VELC(1,LL),CRESA(1,LL),CRESC(1,LL)
   24 FORMAT(30X,'CULVERT LENGTH   =',F7.1,' FT',19X,'--',15X,'CULVERT LE
     1NGTH   =',F7.1,' FT'/30X,'FALL AT FACE     =',
     2F7.2,' FT',19X,'--',15X,'FALL AT FACE     =',
     3               F7.2,' FT'/30X,'ELEV FACE INVERT=',F7.1,' FT',19X,'--'
     4,15X,'ELEV FACE INVERT=',F7.1,' FT'/30X,'CULVERT SLOPE    =',F9.4,
     520X,'--',15X,'CULVERT SLOPE    =',F9.4/30X,'VEL AT DESIGN Q=',F7.1,
     6' FPS',19X,'--',15X,'VEL AT DESIGN Q =',F7.1,' FPS'/30X,'MIN CREST
     7 LENGTH=',F7.1,' FT',19X,'--',15X,'MIN CREST LENGTH=',F7.1,' FT'//
     88X,'Q',8X,'HWO',20X,'Q',8X,'HWF',20X,'Q',8X,'HWF',18X,'Q',8X,
     9'HWF'/)
      QD=Q1/BAR-(Q1/BAR*.2)
   66 Q=QD
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO1=HWOUT+TAB5(LL)
      X= Q/D**2.5
```

```
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(1,LL)+HWN
      CALL CEQUA(X,HWN,D,SC,I5)
      HDCC=ELINCC(1,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,180)QU,HWO1,QU,HDCA,QU,HDCC
  180 FORMAT(3X,2F9.1,14X,2F9.1,19X,'--',8X,'--',13X,2F9.1)
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 206
      QD=QD+(Q1/BAR)*.2
      GO TO 86
  206 I4=4
      I5=6
C
C.....BEVELED INLETS
C
  212 DA=DISTA(2,LL)
      SA=SLOPA(2,LL)
      SB=SLOPB(2,LL)
      SC=SLOPC(2,LL)
      IF(NOCA(2,LL).EQ.0) GO TO 208
      WRITE(SYSOT,211) I1,I2,I3,I4,I5,TQMAX(2,LL)
  211 FORMAT(///1X,'BEVELED INLET DESIGN FOR CULVERT CODE: ',5I1/1X,'***
     1*********************************************'///20X,'DESIGN DATA
     2 NOT APPLICABLE BECAUSE THE REQUIRED FALL FOR THE BEVEL-EDGED INLE
     3T EXCEEDS 1.5D OR LS0'/20X,'THIS OUTPUT CONSISTS OF THE OUTLET CON
     4TROL PERFORMANCE CURVE DATA FOR KE = 0.2'/20X,'WHICH IS APPLICABLE
     5 FOR THE IMPROVED INLETS.'//30X,'Q',10X,'HWO',15X,'MAX Q = ',
     6F7.0,' CFS'/)
  240 QD=Q1/BAR-(Q1/BAR*.2)
  214 Q=QD
      CALL   COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO1=HWOUT+TAB5(LL)
      QU=QD*BAR
  241 WRITE(SYSOT,243)QU,HWO1
  243 FORMAT(26X,F7.1,6X,F6.1)
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 330
      QD=QD+(Q1/BAR)*.2
      GO TO 214
  208 WRITE(SYSOT,213) I1,I2,I3,I4,I5,CKE(I4),TQMAX(2,LL)
  213 FORMAT(///1X,'BEVELED INLET DESIGN   FOR CULVERT CODE: ',5I1/
     A1X,'***********************************************'//
     1 4X,'OUTLET COMPUTATIONS',34X,'INLET COMPUTATIONS'/ 3X,'**********
     2*********',8X,'**********************************************
     2***********************************'//10X,'KE =',
     3F4.1,16X,'MIN FALL CURVE',17X,'MAX Q CURVE',21X,'MIN HW CURVE'/
     4 /67X,'MAX Q =',F7.0,' CFS'//)
       IF(NOCB(2,LL).EQ.1.AND.NOCC(2,LL).EQ.1) GO TO 25
       IF(NOCB(2,LL).EQ.1) GO TO 22
       IF(NOCC(2,LL).EQ.1) GO TO 28
   21 WRITE(SYSOT .2)DISTA(2,LL),DISTB(2,LL),DISTC(2,LL),TAB10(LL),
     1TBFALL(2,LL),TCFALL(2,LL),ELINCA(2,LL),ELINCB(2,LL),ELINCC(2,LL).
     2SLOPA(2,LL),SLOPB(2,LL),SLOPC(2,LL),VELA(2,LL),VELB(2,LL),VELC(2,
     3LL),CRESA(2,LL),CRESB(2,LL),CRESC(2,LL)
       QD=Q1/BAR-(Q1/BAR*.2)
   38 Q=QD
```

```
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO2=HWOUT+TAB5(LL)
      X= Q/D**2.5
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(2,LL)+HWN
      CALL CEQUA(X,HWN,D,SB,I5)
      HDCB=ELINCB(2,LL)+HWN
      CALL CEQUA(X,HWN,D,SC,I5)
      HDCC=ELINCC(2,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,85)QU,HWO2,QU,HDCA,QU,HDCB,QU,HDCC
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 330
      QD=QD+(Q1/BAR)*.2
      GO TO 88
   25 WRITE(SYSOT, 16)DISTA(2,LL),TAB10(LL),ELINCA(2,LL),SLOPA(2,LL),
     1VELA(2,LL),CRESA(2,LL)
      QD=Q1/BAR-(Q1/BAR*.2)
   62 Q=QD
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO2=HWOUT+TAB5(LL)
      X= Q/D**2.5
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(2,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,186)QU,HWO2,QU,HDCA
      IF(QD.GT.(Q1/BAR+6*((Q1/BAR)*.2)+5.)) GO TO 330
      QD=QD+(Q1/BAR)*.2
      GO TO 62
   28 WRITE(SYSOT,20)DISTA(2,LL),DISTB(2,LL),TAB10(LL),TBFALL(2,LL),
     1ELINCA(2,LL ,ELINCB(2,LL),SLOPA(2,LL),SLOPB(2,LL),VELA(2,LL),
     2VELB(2,LL ),CRESA(2,LL),CRESB(2,LL)
      QD=Q1/BAR-(Q1/BAR*.2)
   66 Q=QD
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO2=HWOUT+TAB5(LL)
      X= Q/D**2.5
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(2,LL)+HWN
      HDCB=ELINCB(2,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,183)QU,HWO2,QU,HDCA,QU,HDCB
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 330
      QD=QD+(Q1/BAR)*.2
      GO TO 66
   22 WRITE(SYSOT.24)DISTA(2,LL),DISTC(2,LL).TAB10(LL),TCFALL(2,LL),
     1ELINCA(2,LL),ELINCC(2,LL),SLOPA(2,LL),SLOPC(2,LL),VELA(2,LL).
     2VELC(2,LL),CRESA(2,LL),CRESC(2,LL)
      QD=Q1/BAR-(Q1/BAR*.2)
   87 Q=QD
      CALL    COUT(Q,D,HWOUT,VELOUT,DEP,DN,DC,DIST1,SLOPE,CN)
      HWO2=HWOUT+TAB5(LL)
      X= Q/D**2.5
      CALL CEQUA(X,HWN,D,SA,I5)
      HDCA=ELINCA(2,LL)+HWN
      CALL CEQUA(X,HWN,D,SC,I5)
```

```
      HDCC=ELINCC(2,LL)+HWN
      QU=QD*BAR
      WRITE(SYSOT,180)QU,HWO2,QU,HDCA,QU,HDCC
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 330
      QD=QD+(Q1/BAR)*.2
      GO TO 67
C
C     SIDE TAPERED INLETS
C 330 IF(ITAB(LL).GT.2) WRITE(SYSOT,250)
C 250 FORMAT(//'    IMPROVED-INLET DESIGN'/5X,'*********************'////
C    135X,'NO IMPROVED-INLET DESIGNS AVAILABLE FOR CULVERTS HAVING MORE
C    1THAN  " 2 " BARRELS  ')
C     IF(ITAB(LL).GT.2) GO TO 362
  330 INDEX=2
      CALL CSIDE(  D,FALL,HWT,TROEL,IBAR,DIST ,INDEX,SLOPE,CN)
C
C     SLOPE TAPERED INLETS
      CALL CSLOPV(  D,SLOPE)
C     CALL CSLOPM(B,D,SLOPE)
  362 LL=LL+1
      IF(LL.GT.L) RETURN
      I4=II4
      I5=II5
      GO TO 100
      END
```

```
      SUBROUTINE CSIDE(  D,FALL,HWT,TROEL,IBAR,DIST ,INDEX,SLOPE,AN)
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),
     5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,
     6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2
C       DESIGN SIDE TAPERED INLETS
C
      REAL L1,L1B,L1C
      INTEGER SYSIN, SYSOT, TYPE
C     IF(IBAR.GT.2) GO TO 480
C     TAPER=4.
  460 HWOUT=0.0
      BAR=IBAR
      E=D
      HW=0.
      NOCAS=0
      NOCBS=0
      NOCCS=0
      SMALL=(SLOPE*SEL**2*D)/(1.+SLOPE*SEL)
      SMALR=(SLOPE*SER**2*D)/(1.+SLOPE*SER)
      DIL=SEL*D-SMALL
      DIR=SER*D+SMALR
      ELLE=DIL*SLOPE
      ELRR=DIR*SLOPE
      DIST1=DIST-DIL-DIR
      FACEL=ELIN -ELLE
      TOEL=ELOUT +ELRR
C.....THROAT CONTROL - CHART 18 - HEC NO. 13
      X=(Q1/BAR)/D**2.5
      IF(X.LT.2.5) FALL=999.                                            **
      IF(X.LT.2.5.AND.INDEX.GT.1)WRITE(SYSOT,2)                         **
    2 FORMAT(///1X,'SIDE-TAPERED INLET DESIGN'/1X,'*********************
     1**'///20X,'THIS SIDE-TAPERED INLET EXCEEDED DESIGN CRITERIA'/)
      IF(X.LT.2.5) RETURN
      X=ALOG10(X)
      GO TO (4,6),I1
    4 HTOVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X
     1+3.711165*X*X*X*X-1.32836*X*X*X*X*X
      GO TO 8
    6 HTOVD=-.237139+.140792*X+2.180321*X*X-4.354114*X*X*X
     1+4.210539*X*X*X*X-1.347032*X*X*X*X*X
    8 HT=10.**HTOVD*D
   52 X=(HT-1.)*D
   20 X=ALOG10(X)
      YC19=.4140027+1.327566*X-.722612*X*X+.155368*X*X*X
     1-.4421735*X*X*X*X+.5065368*X*X*X*X*X
      YC19=10.**YC19
      TROEL=AHWEL-HT
```

```
C  STANDARD SIDE-TAPERED INLET DESIGN EQUATIONS FOR BF AND L1       C 4720 **
      BF=1.5*D                                                      C 4725
   42 L1=1.4167*D                                                   C 4730
C  HEC-13 SIDE-TAPERED INLET DESIGN EQUATIONS FOR BF AND L1         C 4735 **
C     BF=(Q1/BAR)/(YC19*(3.1416/4.)*E**1.5)                         C 4740
C  42 L1=((BF-D)/2.)*TAPER                                          C 4745
      TAPER=L1/((BF-D)/2.)                                          C 4750
      DLEFT=DIL +L1                                                 C 4755
      DROP= DLEFT*SLOPE                                             C 4760
      SUBT=DIST1-L1                                                 C 4765
      STROEL=ELIN -DROP                                             C 4770
      FAHC=STROEL+SLOPE*L1                                          C 4775
      DIF=STROEL-TROEL                                              C 4780
      IF(DIF.LE.0.0) GO TO 10                                       C 4785
C     COMPUTE FALL                                                  C 4790
      FALL=DIF+L1*SLOPE                                             C 4795
      HWT=AHWEL                                                     C 4800
    3 IF(INDEX.EQ.1) RETURN                                         C 4805
      IF(INDEX.EQ.2) GO TO 5                                        C 4810
      IF(INDEX.EQ.3) GO TO 5                                        C 4815
      INDEX=INDEX+1                                                 C 4820
      X=(HT-L1*SLOPE)/D                                             C 4825
      GO TO 20                                                      C 4830
    5 BIT=SEL*DIF                                                   C 4835
      SUBT=SUBT+BIT                                                 C 4840
      TOTA=SUBT+L1                                                  C 4845
      SA=(TROEL-TCEL)/SUBT                                          C 4850
      STFACE=STROEL+SLOPE*L1+BIT*SLOPE                              C 4855
      ELFACA=TROEL+SA*L1                                            C 4860
      ELTRCA=TROEL                                                  C 4865
      IF(FALL.LT.D/4.) WA=0.0                                       C 4870
      IF(FALL.LT.D/4.)GO TO 100                                     C 4875
C.....MINIMUM CREST LENGTH - CHART 17 - HEC 13                      C 4880
      HCA=FAHC+(FALL*SEL*SLOPE)+(FALL*3.+D/2.)*SLOPE                C 4885
      HC=AHWEL-HCA                                                  C 4890
      IF(HC.LT.1.) HC=1.0                                           C 4895
      W23A=(.5*Q1**.6667)/HC                                        C 4900
      WA=W23A**1.5                                                  C 4905
      GO TO 100                                                     C 4910
C      NO FALL                                                      C 4915
   10 WA=0.0                                                        C 4920
      FALL=FACEL-STROEL                                             C 4925
      TROEL=STROEL                                                  C 4930
      HWT=TROEL+HT                                                  C 4935
      IF(INDEX.EQ.1)RETURN                                          C 4940
      IF(INDEX.EQ.0) GO TO 3                                        C 4945
      ELFACA=TROEL+SLOPE*L1                                         C 4950
      TOTA=SUBT+L1                                                  C 4955
      ELTRCA=TROEL                                                  C 4960
      SA=SLOPE                                                      C 4965
      STFACE=ELFACA                                                 C 4970
  100 SLO=SA                                                        C 4975
      BAR=IBAR                                                      C 4980
      Q=Q1/BAR                                                      C 4985
      CALL   COUT(Q,   D,HWOUT,VELOUT,DEP,DN,DC,  SUBT,SLO,AN)      C 4990
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```
      CALL CROUT(DN,AREA,T,WP,D   ,R)                                   C 4995
      VELAA=Q /AREA                                                     C 5000
      IF(VELOUT.GT.VELAA) VELAA=VELOUT                                  C 5005
      BEA=BF*.5                                                         C 5010
      DEA=D*.5                                                          C 5015
  101 INDEX=INDEX+1                                                     C 5020
      IF(INDEX.EQ.4) GO TO 102                                          C 5025
      X=(HT-L1*SA)/D                                                    C 5030
      GO TO 20                                                          C 5035
C     COMPUTE CURVE B - SIDE TAPER                                      C 5040
  102 INDEX=2                                                           C 5045
      HWTEMP=HWT                                                        C 5050
      FALLM=1.5*D                                                       C 5055
      FALLT=SUBT*SLOPE                                                  C 5060
      IF(FALLM.GT.FALLT) FALLM=FALLT                                    C 5065
      QUE= TAB16(LL)/BAR                                                C 5070
      GO TO (12,14),I1                                                  C 5075
   12 HTOVD=.0341* (QUE/D**2.5 )**2+.89                                 C 5080
      GO TO 15                                                          C 5085
   14 HTOVD=.0318*(QUE/D**2.5)**2+.89                                   C 5090
   15 HWATER=HTOVD*D                                                    C 5095
      TEMP=ELTRCA+HWATER                                                C 5100
      IF(TEMP.LE.AHWEL)GO TO 466                                        C 5105
      BFALL=TEMP-AHWEL                                                  C 5110
      TBFAL =BFALL+FALL                                                 C 5115
      ELTRCB=ELTRCA-BFALL                                               C 5120
      IF(TBFAL.GT.FALLM) ELTRCB=ELTRCA-(FALLM-FALL)                     C 5125
      IF(ELTRCB.LT.TOEL) ELTRCB=TOEL+.01                                C 5130
      BFALL=ELTRCA-ELTRCB                                               C 5135
      TBFAL=BFALL+FALL                                                  C 5140
      BITB=SEL+BFALL                                                    C 5145
      SB=(ELTRCB-TOEL)/(SUBT+BITB)                                      C 5150
      AIN= 50.                                                          C 5155
      QUE=Q1/BAR                                                        C 5160
  470 QUE=QUE+AIN                                                       C 5165
      GO TO (17,18),I1                                                  C 5170
   17 HTOVD=.0341*(QUE/D**2.5)**2+.89                                   C 5175
      GO TO 19                                                          C 5180
   18 HTOVD=.0318*(QUE/D**2.5)**2+.89                                   C 5185
   19  HIGH=HTOVD*D                                                     C 5190
      HI=HIGH+ELTRCB                                                    C 5195
      IF(HI.GT.AHWEL) GO TO 474                                         C 5200
      H=HIGH                                                            C 5205
      GO TO 470                                                         C 5210
  474 QUE=QUE-AIN                                                       C 5215
      IF(AIN.LT.10.) GO TO 475                                          C 5220
      AIN=2.0                                                           C 5225
      GO TO 470                                                         C 5230
  475 IF(QUE.GT.TAB16(LL)/BAR) QUE=TAB16(LL)/BAR                        C 5235
      X=(AHWEL-ELTRCB-L1*SB)/D                                          C 5240
      X=ALOG10(X)                                                       C 5245
      YC19=.4140027+1.327566*X-.722612*X*X+.155368*X*X*X                C 5250
     1-.4421735*X*X*X*X+.5065368*X*X*X*X*X                              C 5255
      YC19=10.**YC19                                                    C 5260
C     BFB=QUE/(YC19*.7854*E**1.5)                                       C 5265
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C     L1B=((BFB-D)/2.)*TAPER                                            C 5270
      BFB=1.5*D                                                         C 5275
      L1B=1.4167*D                                                      C 5280
      TOTB=SUBT+L1B+BITB                                                C 5285
      ELFACB=ELTRCB+L1B*SB                                              C 5290
      QQ=QUE/BAR                                                        C 5295
      TB=SUBT+BITB                                                      C 5300
      CALL   COUT(QQ,  D,HWOUT,VELOUT,DEP,DN,DC,  SUBT,SLO,AN)          C 5305
      CALL CROUT(DN,AREA,T,WP,D  ,R)                                    C 5310
      VELBB= QQ/AREA                                                    C 5315
      IF(VELOUT.GT.VELBB) VELBB=VELOUT                                  C 5320
C.....MINIMUM CREST LENGTH - CHART 17 - HEC 13                          C 5325
      HCB=FAHC+(TBFAL*SEL*SLOPE)+(TBFAL*3.+D/2.)*SLOPE                  C 5330
      HC=AHWEL-HCB                                                      C 5335
      IF(HC.LT.1.) HC=1.0                                               C 5340
      W23B=(.5* QQ**.6667)/HC                                           C 5345
      WB=W23B**1.5                                                      C 5350
      BFB=BFB*.5                                                        C 5355
      DEB=D*.5                                                          C 5360
      GO TO 490                                                         C 5365
  466 TBFAL =0.0                                                        C 5370
      NOCBS=1                                                           C 5375
C    COMPUTE CURVE C - SIDE TAPER                                       C 5380
  490 TEMP=ELTRCA+HT                                                    C 5385
      IF(TAB4(LL).GE.TEMP) GO TO 482                                    C 5390
      CFAL=TEMP-TAB4(LL)                                                C 5395
      TCFAL=CFAL+FALL                                                   C 5400
      ELTRCC=ELTRCA-CFAL                                                C 5405
      IF(TCFAL.GT.FALLM) ELTRCC=ELTRCA-(FALLM-FALL)                     C 5410
      IF(ELTRCC.LT.TOEL) ELTRCC=TOEL+.01                                C 5415
      CFAL=ELTRCA-ELTRCC                                                C 5420
      TCFAL=CFAL+FALL                                                   C 5425
      BITC=SEL*CFAL                                                     C 5430
      SC=(ELTRCC-TOEL)/(SUBT+BITC)                                      C 5435
      X=(TEMP -CFAL-ELTRCC-L1*SC)/D                                     C 5440
      X=ALOG10(X)                                                       C 5445
      YC19=.4140027+1.327566*X-.722612*X*X+.155368*X*X*X                C 5450
     1-.4421735*X*X*X*X+.5065368*X*X*X*X*X                              C 5455
      YC19=10**YC19                                                     C 5460
      BFC=1.5*D                                                         C 5465
      L1C=1.4167*D                                                      C 5470
C     BFC=(Q1/BAR)/(YC19*.7854*E**1.5)                                  C 5475
C     L1C=((BFC-D)/2.)*TAPER                                            C 5480
      TOTC=SUBT+L1C+BITC                                                C 5485
      ELFACC=ELTRCC+L1C*SC                                              C 5490
C.....MINIMUM CREST LENGTH - CHART 17 - HEC 13                          C 5495
      HCC=FAHC+(TCFAL*SEL*SLOPE)+(TCFAL*3.+D/2.)*SLOPE                  C 5500
      HC=TEMP-HCC                                                       C 5505
      IF(HC.LT.1.) HC=1.0                                               C 5510
      W23C=(.5* Q**.6667)/HC                                            C 5515
      WC=W23C**1.5                                                      C 5520
      SLO=SC                                                            C 5525
      TC=SUBT+BITC                                                      C 5530
      CALL   COUT(Q,   D,HWOUT,VELOUT,DEP,DN,DC,  SUBT,SLO,AN)          C 5535
      CALL CROUT(DN,AREA,T,WP,D  ,R)                                    C 5540
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```
      VELCC=(Q1/BAR)/AREA
      IF(VELOUT.GT.VELCC) VELCC=VELOUT
      BEC=BFC*.5
      DEC=D*.5
      GO TO 483
  482 TCFAL=0.0
      NOCCS=1
  483 QUE=QUE*BAR
      WRITE(SYSOT,104) TAPER,E,QUE,BF,L1
  104 FORMAT(////1X,'SIDE TAPERED INLET DESIGN'/'***********************
     1***', 10X,'FACE EDGE BEVELS = 45 DEG',5X,'SIDE TAPER=',F6.3,':1'//
     2        10X,'MIN FALL DESIGN',30X,'MAX  Q  DESIGN',30X,'MIN HW DESIG
     3N'/,10X,'E = D =',F6.2,' FT',29X,'MAX Q =',F7.0,' CFS'/ 10X,'FACE
     4WIDTH= 1.5D=',F6.2,' FT'/10X,'L1= 1.4167D=',F6.2,' FT'//)
      IF(NOCBS.EQ.0.AND.NOCCS.EQ.0) GO TO 30
      IF(NOCBS.EQ.0) GO TO 32
      IF(NOCCS.EQ.0) GO TO 34
      WRITE(SYSOT,28)TOTA,TAB13(LL),TAB14(LL),ELFACA,SA,VELAA,      WA.
     1BEA,DEA
   28 FORMAT(5X,'CULVERT LENGTH     =',F7.1,' FT',26X,'--',44X,'--'/5X,
     1'FALL',14X,'=',F7.1,' FT',26X,'--',44X,'--'/5X,'ELEV THROAT INVERT
     2=',F7.1,' FT',26X,'--',44X,'--'/5X,'ELEV FACE INVERT  =',F7.1,' FT.
     3',26X,'--',44X,'--'/5X,'CULVERT SLOPE',5X,'=',F7.4,29X,'--',44X,'-
     4-'/5X,'VEL AT DESIGN Q    =',F6.1,' FPS',26X,'--',44X,'--'/
     6                               5X,'MIN CREST LENGTH  =',F7.1,' FT',26X,'-
     7-',44X,'--'/5X,'BEVELS =  45 DEGREE',36X,'--',44X,'--'/9X,'B =',
     8F5.1,' IN  D =',F5.1,' IN',27X,'--',44X,'--'//5X,'Q',8X,'HWT',8X,
     9'HWF',32X,'--',44X,'--'/)
C-----PERFORMANCE CURVE DATA
      QD=Q1-Q1*.2
      QD=QD/BAR
   29 X=QD/D**2.5
      X=ALOG10(X)
      GO TO (40,41),I1
   40 HTOVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X
     1+3.711165*X*X*X*X-1.32836*X*X*X*X*X
      GO TO 43
   41 HTOVD=-.237139+.146792*X+2.189321*X*X-4.354114*X*X*X
     1+4.210539*X*X*X*X-1.347032*X*X*X*X*X
   43 HT=10.**HTOVD*D
      HWTA=ELTRCA+HT
      X=QD/(BF*.7854*E**1.5)
      X=ALOG10(X)
      Y=-.2676+.61765*X-.11698*X*X+.41498*X*X*X
      HFOVE=10.**Y
      HWFA=ELFACA+HFOVE*E
      QU=QD*BAR
      WRITE(SYSOT,27)QU,HWTA,HWFA
   27 FORMAT(3X,F7.1,2X,F7.1,3X,F7.1.31X,'--',44X,'--')
      IF(QD.GT.(Q1/BAR+4*(Q1/BAR*.2)+5.)) GO TO 480
      QD=QD+(Q1*.2)/BAR
      GO TO 29
   30 WRITE(SYSOT,332)TOTA,TOTB,TOTC,TAB13(LL),TBFAL,TCFAL,TAB14(LL),
     1ELTRCB,ELTRCC,
     2ELFACA,ELFACB,ELFACC,SA,SB,SC,VELAA,VELBB,VELCC
```

```
332 FORMAT( 5X,'CULVERT LENGTH    =',F7.1,' FT',20X,'CULVERT LENGTH
   1 =',F7.1,' FT',15X,'CULVERT LENGTH    =',F7.1,' FT'/
   2      5X,'FALL',14X,'=',F7.2,' FT',20X,'FALL',14X,'=',F7.2,' FT',
   3  15X,'FALL',14X,'=',F7.2,' FT'/5X,'ELEV THROAT INVERT=',F7.1,
   4 ' FT',20X,'ELEV THROAT INVERT=',F7.1,' FT',15X,'ELEV THROAT INVER
   5T=',F7.1,' FT'/5X,'ELEV FACE INVERT  =',F7.1,' FT',20X,'ELEV FACE
   6INVERT  =',F7.1,' FT',15X,'ELEV FACE INVERT  =',F7.1,' FT'/  5X,
   7 'CULVERT SLOPE      =',F7.4,23X, 'CULVERT SLOPE      =',F7.4,18X,
   8 'CULVERT SLOPE      =',F7.4/ 5X,'VEL AT DESIGN Q   =',F6.1,' FPS',
   920X,'VEL AT MAX  Q      =',F6.1,' FPS',15X,'VEL AT DESIGN Q   =',
   AF6.1,' FT')
    WRITE(SYSOT,504)            WA,WB,WC,BEA,DEA,BEB,DEB,BEC,DEC
504 FORMAT(
   2 5X,'MIN CREST LENGTH  =',F7.1,' FT',20X,'MIN CREST LENGTH  =',
   3F7.1,' FT',15X,'MIN CREST LENGTH  =',F7.1,' FT'/5X,'BEVELS =  45 D
   4EGREE',30X,'B5VELS =  45 DEGREE',25X,'BEVELS =  45 DEGREE'/9X,'B =
   5',F5.1,' IN  D =',F5.1,' IN',24X,'B =',F5.1,' IN  D =',F5.1,' IN',
   622X,'B =',F5.1,' IN  D =',F5.1,' IN'//5X,'Q',8X,'HWT',8X,'HWF',
   729X,'O',8X,'HWT',8X,'HWF',20X,'Q',8X,'HWT',8X,'HWF'/)
    QD=Q1-(Q1 *.2)
    QD=QD/BAR
 31 X=QD/D**2.5
    X=ALOG10(X)
    GO TO (46,44),I1
 46 HTOVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X
   1+3.711165*X*X*X*X-1.32836*X*X*X*X*X
    GO TO 45
 44 HTOVD=-.237139+.146792*X+2.189321*X*X-4.354114*X*X*X
   1+4.210539*X*X*X*X-1.347032*X*X*X*X*X
 45 HT=10.**HTOVD*D
    HWTA=ELTRCA+HT
    HWTB=ELTRCB+HT
    HWTC=ELTRCC+HT
    X=QD/(BF*.7854*E**1.5)
    X=ALOG10(X)
    Y=-.2676+.61766*X-.11698*X*X+.41498*X*X*X
    HFOVE=10.**Y
    HWFA=ELFACA+HFOVE*E
    X=QD/(BFB*.7854*E**1.5)
    X=ALOG10(X)
    Y=-.2676+.61766*X-.11698*X*X+.41498*X*X*X
    HFOVE=10.**Y
    HWFB=ELFACB+HFOVE*E
    X=QD/(BFC*.7854*E**1.5)
    X=ALOG10(X)
    Y=-.2676+.61766*X-.11698*X*X+.41498*X*X*X
    HFOVE=10.**Y
    HWFC=ELFACC+HFOVE*E
    QU=QD*BAR
    WRITE(SYSOT,36)QU,HWTA,HWFA,QU,HWTB,HWFB,QU,HWTC,HWFC
 36 FORMAT(3X,F7.1,2X,F7.1,3X,F7.1,22X,F9.1,1X,F9.1,3X,F9.1,13X,
   12F9.1,2X,F9.1)
    IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 480
    QD=QD+(Q1/BAR)*.2
    GO TO 31
```

```
 32 WRITE(SYSOT,110)TOTA,TOTB,TAB13(LL),TBFAL,TAB14(LL),ELTRCB,ELFACA,
   1ELFACB,SA,SB,VELAA,VELBB
110 FORMAT(5X,'CULVERT LENGTH     =',F7.1,' FT',20X,'CULVERT LENGTH
   1=',F7.1,' FT',21X,'--'/5X,'FALL',14X,'=',F7.1,' FT',20X,'FALL',14X
   2,'=',F7.1,' FT',21X,'--'/5X,'ELEV THROAT INVERT=',F7.1,' FT',20X,
   3'ELEV THROAT INVERT=',F7.1,' FT',21X,'--'/  5X,'ELEV FACE INVERT
   4=',F7.1,' FT',20X,'ELEV FACE INVERT  =',F7.1,' FT',21X,'--'/  5X,
   5'CULVERT SLOPE',5X,'=',F7.4,23X,'CULVERT SLOPE',5X,'=',F7.4,24X,'-
   6-'/  5X,'VEL AT DESIGN Q    =',F6.1,' FPS',20X,'VEL AT MAX  Q      =
   7',F6.1,   ' FPS',21X,'--')
    WRITE(SYSOT,112)        WA ,WB,BEA,DEA,BEB,DEB
112 FORMAT(5X,'MIN CREST LENGTH  =',F7.1,' FT',20X,'MIN CREST LENGTH
   2=',F7.1,' FT',21X,'--'/5X,'BEVELS =  45 DEGREE',31X,'BEVELS =  45
   3DEGREE',27X,'--'/9X,'B =',F5.1,' IN  D =',F5.1,' IN',25X,'B =',
   4F5.1,' IN  D =',F5.1,' IN',27X,'--'//5X,'Q',8X,'HWT',8X,'HWF',
   529X,'Q',8X,'HWT',8X,'HWF',26X,'--'/)
    QD=Q1-(Q1*.2)
    QD=QD/BAR
 33 X=QD/D**2.5
    X=ALOG10(X)
    GO TO (56,57),I1
 56 HTOVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X
   1+3.711165*X*X*X*X-1.32836*X*X*X*X*X
    GO TO 58
 57 HTOVD=-.237139+.146792*X+2.189321*X*X-4.354114*X*X*X
   1+4.210539*X*X*X*X-1.347032*X*X*X*X*X
 58 HT=10.**HTOVD*D
    HWTA=ELTRCA+HT
    HWTB=ELTRCB+HT
    X=QD/(BF*.7854*E**1.5)
    X=ALOG10(X)
    Y=-.2676+.61766*X-.11698*X*X+.41498*X*X*X
    HFOVE=10.**Y
    HWFA=ELFACA+HFOVE*E
    X=QD/(BFB*.7854 *E**1.5)
    X=ALOG10(X)
    Y=-.2676+.61766*X-.11698*X*X+.41498*X*X*X
    HFOVE=10.**Y
    HWFB=ELFACB+HFOVE*E
    QU=QD*BAR
    WRITE(SYSOT,38)QU,HWTA,HWFA,QU,HWTB,HWFB
 38 FORMAT(3X,F7.1,2X,F7.1,3X,F7.1,22X,F9.1,1X,F9.1,3X,F9.1,
   130X,'--')
    IF(QD.GT.(Q1/BAR+6*((Q1/BAR)*.2)+5.)) GO TO 480
    QD=QD+(Q1/BAR)*.2
    GO TO 33
 34 WRITE(SYSOT,106)TOTA,TOTC,TAB13(LL),TCFAL,TAB14(LL),ELTRCC,ELFACA
   1,ELFACC,SA,SC,VELAA,VELCC,                   WA,WC,BEA,DEA,BEC,DEC
106 FORMAT(5X,'CULVERT LENGTH     =',F7.1,' FT',26X,'--',36X,'CULVERT L
   1ENGTH     =',F7.1,' FT'/5X,'FALL',14X,'=',F7.1,' FT',26X,'--',36X,
   2'FALL',14X,'=',F7.1,' FT'/5X,'ELEV THROAT INVERT=',F7.1,' FT',26X,
   3'--',36X,'ELEV THROAT INVERT=',F7.1,' FT'/5X,'ELEV FACE INVERT  ='
   5,F7.1,' FT',26X,'--',36X,'ELEV FACE INVERT  =',F7.1,' FT'/ 5X,'CUL
   6VERT SLOPE',5X,'=',F7.4,29X,'--',36X,'CULVERT SLOPE',5X,'=',F7.4/
   75X,'VEL AT DESIGN Q  =',F7.1,' FPS',26X,'--',36X,'VEL AT DESIGN Q
```

```
  8 =',F7.1,' FPS'/              5X,'MIN CREST LENGTH  =',F7.1,' FT',      C 6370
  B36X,'--',36X,'MIN CREST LENGTH  =',F7.1,' FT'/5X,'BEVELS = 45 DEGR  C 6375
  CEE',37X,'--',36X,'BEVELS = 45 DEGREE'/9X,'B =',F5.1,' IN  D =',       C 6380
  DF5.1,' IN',27X,'--',41X,'B =',F5.1,' IN  D =',F5.1,' IN'//5X,'Q',     C 6385
  E8X,'HWT',8X,'HWF',32X,'--',38X,'Q',8X,'HWT',8X,'HWF'/)               C 6390
   QD=Q1-(Q1*.2)                                                         C 6395
   QD=QD/BAR                                                             C 6400
35 X=QD/D**2.5                                                           C 6405
   X=ALOG10(X)                                                           C 6410
   GO TO (53,54),I1                                                      C 6415
53 HTOVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X                  C 6420
  1+3.711165*X*X*X*X-1.32836*X*X*X*X*X                                   C 6425
   GO TO 55                                                              C 6430
54 HTOVD=-.237139+.146792*X+2.189321*X*X-4.354114*X*X*X                  C 6435
  1+4.210539*X*X*X*X-1.347032*X*X*X*X*X                                  C 6440
55 HT=10.**HTOVD*D                                                       C 6445
   HWTA=ELTRCA+HT                                                        C 6450
   HWTC=ELTRCC+HT                                                        C 6455
   X=QD/(BF*.7854*E**1.5)                                                C 6460
   X=ALOG10(X)                                                           C 6465
   Y=-.2676+.61766*X-.11698*X*X+.41498*X*X*X                             C 6470
   HFOVE=10.**Y                                                          C 6475
   HWFA=ELFACA+HFOVE*E                                                   C 6480
   X=QD/(BFC*.7854*E**1.5)                                               C 6485
   X=ALOG10(X)                                                           C 6490
   Y=-.2676+.61766*X-.11698*X*X+.41498*X*X*X                             C 6495
   HFOVE=10.**Y                                                          C 6500
   HWFC=ELFACC+HFOVE*E                                                   C 6505
   QU=QD*BAR                                                             C 6510
   WRITE(SYSOT,37)QU,HWTA,HWFA,QU,HWTC,HWFC                              C 6515
37 FORMAT(3X,F7.1.2X,F7.1,3X,F7.1,31X,'--',33X,2F9.1.2X,F9.1)            C 6520
   IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 480                       C 6525
   QD=QD+(Q1/BAR)*.2                                                     C 6530
   GO TO 35                                                              C 6535
480 RETURN                                                               C 6540
   END                                                                   C 6545
```

```
      SUBROUTINE CSLOPV(  D,SLOPE)                                      C 6550
C     DESIGN SLOPE-TAPERED INLETS           - VERTICAL FACE             C 6555
C                                                                       C 6560
      COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),         C 6565
     1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),     C 6570
     2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),C 6575
     3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100), C 6580
     4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),        C 6585
     5       IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,      C 6590
     6NOCA(2,100) NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),  C 6595
     7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),  C 6600
     8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),  C 6605
     9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,       C 6610
     ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2          C 6615
      DIMENSION FALL(2),S(2),L1(2),L2(2),L3(2),VEL(2),BF(2),            C 6620
     1TAPER(2),NOC(2),DA(2)                                             C 6625
      INTEGER SYSIN, SYSOT                                              C 6630
      REAL L1,L2,L3,L4,L1SO                                             C 6635
  460 ISLOPE=0                                                          C 6640
      HW=0.0                                                            C 6645
      BAR=ITAB(LL)                                                      C 6650
      QS=Q1/BAR                                                         C 6655
      CN=TAB2(LL)                                                       C 6660
      NOC(1)=0                                                          C 6665
      NOC(2)=0                                                          C 6670
      B=D                                                               C 6675
      I=1                                                               C 6680
      TAPER(1)=4.0                                                      C 6685
      TAPER(2)=4.0                                                      C 6690
      Y1=(D **2/(SFACE**2+1.))**.5                                      C 6695
      Y2=Y1/SFACE                                                       C 6700
      DY=SFACE*Y1+Y2                                                    C 6705
      SMAL3=(SLOPE*SEL**2*DY)/(1.+SLOPE*SEL)                            C 6710
      DIL3=SEL*DY-SMAL3                                                 C 6715
      EL3=DIL3*SLOPE                                                    C 6720
      FACEL=ELIN-EL3                                                    C 6725
      TOEL=ELOUT+ELR                                                    C 6730
      DIST=(FACEL-TOEL)/SLOPE                                           C 6735
C                                                                       C 6740
C     [illegible]                AND B                                  C 6745
      TROEL=TAB14(LL)                                                   C 6750
      TROE=TROEL                                                        C 6755
   14 FALL(I)=FACEL-TROE                                                C 6760 **
      IF(TAB14(LL).EQ.0.0) NOC(2)=1                                     C 6765
      IF(TROE.LE.TOEL) NOC(I)=1                                         C 6770
      IF(FALL(I).LT.(D/4.).OR.FALL(I).GT.(1.5*D))NOC(I)=1               C 6775
      IF(NOC(I).EQ.1) GO TO 481                                         C 6780
   24 HW=HWTEMP-FACEL                                                   C 6785
      X=HW/D                                                            C 6790
      Y21=-2.265863+7.942441*X-4.0350294*X*X+1.619481*X*X*X-.3458214*X  C 6795
     1*X*X*X+.02846767*X*X*X*X*X                                        C 6800
C.....COMPUTE FACE WIDTH FROM CHART 16 - HEC-13                          C 6805
      BF(I)=QS/(Y21*D**1.5)+.1                                          C 6810
      L1(I)=((BF(I)-B)/2.)*TAPER(I)                                     C 6815
   26 S(I)=(DIST*SLOPE-FALL(I))/(DIST-L1(I)-D/2.)                       C 6820
```

```
      DIF=FACEL+DY-(TROE+(D**2+(D*S(I))**2)**.5)
      L3(I)=.5*B
   28 L2(I)=L1(I)-L3(I)
      SF=L2(I)/(DIF-S(I)*L1(I)-S(I)*(D/2.)+L2(I)*S(I))
      IF(SF.EQ.SFACE) GO TO 450
      IF(SF.LT.SFACE) GO TO 30
      SF=SFACE
      L2(I)=(SF*(DIF-S(I)*L1(I)-S(I)*(D/2.)))/(1.-S(I)*SF)
      L3(I)=L1(I)-L2(I)
      GO TO 450
   30 SF=SFACE
      L2(I)=(SF*(DIF-S(I)*L1(I)-S(I)*(D/2.)))/(1.-S(I)*SF)
      L1(I)=L2(I)+L3(I)
      TAPER(I)=2.*L1(I)/(BF(I)-B)
  450 S(I)=(DIST*SLOPE-FALL(I))/(DIST-L1(I)-D/2.)
      SLO=S(I)
      DA(I)=DIST
      DD=DA(I)-L1(I)
      CALL   COUT(QS,  D,HWOUT,VELOUT,DEP,DN,DC,DD,SLO,CN)
      CALL CROUT(DN,AREA,T,WP,D   ,R)
      VELIN=QS/AREA
      IF(VELIN.GT.VELOUT) GO TO 152
      VEL(I)=VELOUT
      GO TO 122
  152 VEL(I)=VELIN
  122 IBAR=BAR
  481 QS=QUE /BAR
      IF(NOCBS.EQ.1) NOC(2)=1
      IF(NOCBS.EQ.1) GO TO 483
      TROE=ELTRCB
      I=I+1
      IF(I.EQ.3) GO TO 483
      GO TO 14
  483 WRITE(SYSOT,478) DIL3,DISR
  478 FORMAT(////1X,'SLOPE TAPERED INLET DESIGN - VERTICAL FACE'/'******
     1*************************************'//5X,'DISTANCE EMBANKMENT-TO
     2E TO FACE =',F7.2,' FT',10X,'CULVERT OUTLET TO EMBANKMENT-TOE =',
     3F7.2,' FT'//                                  10X,'MIN FALL DESIGN',35X,
     4'MAX  Q  DESIGN'//10X,'TRANSITION SECTION= D/2'/10X,'INLET DESIGNE
     5D AS BOX TYPE INLET'//)
      IF(NOC(1).EQ.1.AND.NOC(2).EQ.1) GO TO 484
      IF(NOC(1).EQ.1.AND.NOC(2).EQ.0) GO TO 486
      IF(NOC(1).EQ.0.AND.NOC(2).EQ.1) GO TO 488
  340 WRITE(SYSOT,342)DA(1),DA(2),FALL(1),FALL(2),TROEL,ELTRCB,FACEL,
     1FACEL,S(1),S(2),VEL(1),VEL(2),BF(1),BF(2),L1(1),L1(2),L2(1),L2(2),
     2L3(1),L3(2),SFACE,SFACE,TAPER(1),TAPER(2)
  342 FORMAT(//5X,'CULVERT LENGTH     =',F8.2,' FT',24X,'CULVERT LENGTH
     1  =',F8.2,' FT'/5X,'FALL',14X,'=',F8.2,' FT',24X,'FALL',14X,'=',F8
     2.2,' FT'/5X, 'ELEV THROAT INVERT=',F8.2,' FT',24X,'ELEV THROAT INV
     3ERT=',F8.2,  FT'/5X,'ELEV FACE INVERT  =',F8.2,' FT',24X,'ELEV FAC
     4E INVERT  =',F8.2,' FT'/5X,'CULVERT SLOPE      =',F8.4,27X,'CULVERT
     5 SLOPE      =',F8.2/5X,'VELOCITY',10X,'=',F8.2,' FPS',
     6 23X,'VELOCITY',10X,'=',F8.2,' FPS'
     7        / 5X,'FACE WIDTH',8X,'=',F8.3,' FT',24X,'FACE WIDTH',8X,
     8'=',F8.3,' FT'                                    /5X,'L1',16X,'=',
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```
   9F8.3,' FT',24X,'L1',16X,'=',F8.3,' FT'
   A/5X,'L2',16X,'=',F8.2,' FT',24X,'L2',16X,'=',F8.2,' FT'
   B                    /5X,'L3',16X,'=',F8.2,' FT',  24X,'L3',16X,'=',
   CF8.2,' FT'/5X, 'SF',16X,'=',F8.2,27X,'SF',16X,'=',F8.2/
   D 5X,'TAPER',13X,'=',F8.3,':1',25X,'TAPER',13X,'=',F8.3,':1'//8X,
   E'Q' ,8X,'HWT',8X,'HWF',34X,'Q',8X,'HWT',8X,'HWF'/)
    QD=Q1-Q1*.2
    QD=QD/BAR
 31 X=QD/D**2.5
    X=ALOG10(X)
    GO TO (4,6),I1
  4 HTCVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X
   1+3.711165*X*X*X*X-1.32836*X*X*X*X*X
    GO TO 8
  6 HTCVD=-.237139+.146792*X+2.189321*X*X-4.354114*X*X*X
   1+4.210539*X*X*X*X-1.347032*X*X*X*X*X
  8 Y16=10.**HTCVD
    HWTA=TROEL+Y16*D
    HWTB=ELTRCB+Y16*D
    X=QD/(BF(1)*D**1.5)
    Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
   1-.000496383*X*X*X*X
    HWFA=FACEL+Y18*D
    X=QD/(BF(2)*D**1.5)
    Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
   1-.000496383*X*X*X*X
    HWFB=FACEL+Y18*D
    QU=QD*BAR
    WRITE(SYSOT,32)QU,HWTA,HWFA,QU,HWTB,HWFB
 32 FORMAT(1X,3F10.1,24X,3F10.1)
    IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 480
    QD=QD+(Q1/BAR)*.2
    GO TO 31
484 WRITE(SYSOT,485)
485 FORMAT(///20X,'NO SLOPE TAPERED INLET - VERTICAL FACE - DESIGN APP
   1LICABLE')
    GO TO 480
486 WRITE(SYSOT,487)DA(2), FALL(2),ELTRCB,FACEL,S(2),VEL(2),BF(2),
   2L1(2),L2(2),L3(2),SFACE,TAPER(2)
487 FORMAT(//16X,'- -',40X,'CULVERT LENGTH     =',F8.2,' FT' /16X,'- -'
   1,40X,
   2'FALL',15X,'=',F8.2,' FT'/16X,'- -',40X,'ELEV THROAT INVERT=',F8.2
   3,' FT'/16X,'- -',40X,'ELEV FACE INVERT  =',F8.2,' FT'/16X,'- -',40
   4X,'CULVERT SLOPE      =',F8.4/16X,'- -',40X,'VELOCITY',10X,'=',
   5F8.2,' FPS'/16X,'- -',40X,'FACE WIDTH',8X,'=',F8.3,' FT'/16X,'- -'
   6,40X,'L1',16X,'=',F8.3,' FT'/16X,'- -',40X,'L2',16X,F8.2,' FT'/
   716X,'- -',40X,'L3',16X,'=',F8.2,' FT'/16X,'- -',40X,'SF',16X,'=',
   8F8.2/16X,'- -',40X,'TAPER',13X,'=',F8.3,':1'//8X,'Q',8X,'HWT',8X,
   9'HWF',34X,'Q',8X,'HWT',8X,'HWF'/)
    QD=Q1-Q1*.2
    QD=QD/BAR
 33 X=QD/D**2.5
    X=ALOG10(X)
    GO TO (1,2),I1
  1 HTCVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X
```

```
     1+3.711165*X*X*X*X-1.32836*X*X*X*X*X
      GO TO 3
    2 HTOVD=-.237139+.146792*X+2.189321*X*X-4.354114*X*X*X
     1+4.210539*X*X*X*X-1.347032*X*X*X*X*X
    3 Y16=10.**HTOVD
      HWTB=ELTRCB+Y16*D
      X=QD/(BF(2)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      HWFB=FACEL+` 8*D
      QU=QD*BAR
      WRITE(SYSOT,34)QU,HWTB,HWFB
   34 FORMAT(16X,'--',40X,3F10.1)
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 480
      QD=QD+(Q1/BAR)*.2
      GO TO 33
  488 WRITE(SYSOT,489)DA(1),FALL(1),TROEL,FACEL,S(1),VEL(1),BF(1),L1(1),
     1L2(1),L3(1),SFACE,TAPER(1)
  489 FORMAT(//5X,'CULVERT LENGTH     =',F8.2,' FT',30X,'- -'/5X,'FALL',1
     14X,'=',F3.2,' FT',30X,'- -'/5X,'ELEV THROAT INVERT=',F8.2,' FT',30
     3X,'- -'/5X,'ELEV FACE INVERT  =',F8.2,' FT',30X,'- -'/5X,'CULVERT
     4SLOPE      =',F8.4,34X,'- -'/5X,'VELOCITY',10X,'=',F8.2,' FPS',28X,
     5'- -'/5X,'FACE WIDTH',8X,'=',F8.3,' FT',30X,'- -'/5X,'L1',16X,'=',
     6F8.3,' FT',30X,'- -'/5X,'L2',16X,'=',F8.2,' FT',30X,'- -'/5X,'L3',
     716X,'=',F8.2,' FT',30X,'- -'/5X,'SF',16X,'=',F8.2,34X,'- -'/
     85X,'TAPER',13X,'=',F8.3,':1'//8X,'Q',8X,'HWT',8X,'HWF',34X,'Q',8X,
     9'HWT',8X,'HWF'/)
      QD=Q1-Q1*.2
      QD=QD/BAR
   35 X=QD/D**2.5
      X=ALOG10(X)
      GO TO (5,7),I1
    5 HTOVD=-.233392+.489125*X+1.068638*X*X-3.074435*X*X*X
     1+3.711165*X*X*X*X-1.32836*X*X*X*X*X
      GO TO 9
    7 HTOVD=-.237139+.146792*X+2.189321*X*X-4.354114*X*X*X
     1+4.210539*X*X*X*X-1.347032*X*X*X*X*X
    9 Y16=10.**HTOVD
      H.. A=TROEL+Y16*D
      X=QD/(BF(1)*D**1.5)
      Y18=.1379509+.42974097*X-.07646745*X*X+.012651097*X*X*X
     1-.000496383*X*X*X*X
      QU=QD*BAR
      HWFA=FACEL+Y18*D
      WRITE(SYSOT,36)QU,HWTA,HWFA
   36 FORMAT(1X,3F10.1,40X,'--')
      IF(QD.GT.(Q1/BAR+4*((Q1/BAR)*.2)+5.)) GO TO 480
      QD=QD+(Q1/BAR)*.2
      GO TO 35
  480 RETURN
      END
```

```
       SUBROUTINE COUT(QADJ,DIA,WHW,VEL1,DEP,DSUBN.DSUBC.DIST.SLOPE.CN)
       COMMON ITAB(100),TAB1(100),TAB2(100),TAB3(100),TAB4(100),
      1TAB5(100),TAB6(100),TAB7(100),TAB8(100),TAB9(100),TAB10(100),
      2TAB11(100),TAB12(100),TAB13(100),TAB14(100),TAB15(100),TAB16(100),
      3TQMAX(2,100),ELINCB(2,100),ELINCC(2,100),HWCB(2,100),HWCC(2,100),
      4L,LL,K,SYSIN,SYSOT,ELIN,ELOUT,AHWEL,SEL,SER,ELINCA(2,100),
      5        IPROJ(26),I1,I2,I3,I4,I5,ELL,ELR,Q1,AHW,DTW,CLTH,I55,
      6NOCA(2,100),NOCB(2,100),NOCC(2,100),TBFALL(2,100),TCFALL(2,100),
      7DISTA(2,100),SLOPA(2,100),CRESA(2,100),VELA(2,100),DISTB(2,100),
      8SLOPB(2,100),CRESB(2,100),VELB(2,100),DISTC(2,100),SLOPC(2,100),
      9CRESC(2,100),VELC(2,100),ELTRCB,ELTRCC,QUE,DISL,DISR,SFACE,
      ADIA1,DIA2,ELLE,ELRR,NOCBS,HWTEMP,KBAS1,KBAS2,KDEP1,KDEP2
       DIMENSION  V(2),SPH(2),HYDR(2),CKE(5)
       DATA                    CKE/.9,.7,.5,.2,.2/
C
  101 HEAD = (1. + CKE(I4) + ( 185.0*CN    *CN    *DIST/DIA**1.33333  ))
     1* (QADJ*QADJ/39.725/DIA**4 )
      ALPHA=1.12
      IF(I1.EQ.2) ALPHA=1.04
C
C                    CRITICAL DEPTH CALCULATIONS
      Z=QADJ/(32.2/ALPHA)**.5
      X=ALOG10(Z/DIA**2.5)
      IF(X.GT.ALOG10(.7)) GO TO 80
      YOD=-.0051657+.407362*X-.1830236*X*X-.0915565*X*X*X
      GO TO 85
   80 YOD=-.0244603+.2017057*X-.64009815*X*X+.695619*X*X*X
   85 YOD=10.**YOD
  120 DSUBC=YOD*DIA
C                   NORMAL DEPTH CALCULATIONS
C
      Z=CN     *QADJ/(1.486*SLOPE**.5)
      X=ALOG10(Z/DIA**2.6667)
      IF(X.LE.ALOG10(.24)) GO TO 60
      IF(X.LE.ALOG10(.315)) GO TO 62
      YOD=1.0581646+2.82063*X+1.089492*X*X
      GO TO 64
   60 YOD=.3063639+.907884*X+.192615*X*X
      GO TO 64
   62 YOD=.685734+2.097532*X+1.125936*X*X
   64 IF(X.GT.ALOG10(.335)) YOD=0.0
      YOD=10.**YOD
  130 DSUBN=YOD*DIA
      WTW=DTW
      TEMP=(DSUBC+DIA)*0.5
  160 IF ( TEMP - WTW )161,161,170
  161 TEMP = WTW
  170 WHW = TEMP + HEAD
  180 IF(WHW - (DIA+(1.+CKE(I4))*(QADJ*QADJ/39.725/DIA**4)) )200,450,450   **
  200 IF(DSUBN-DSUBC)450,205,205                                            **
  205 NSW4 = 0
      IF ( WTW - DSUBC )225,225,210
  210 IF (WTW - DSUBN )220,220,215
  215 NSW4 = 1
  220 DEP = WTW
```

```
      GO TO 320
  225 DEP = DSUBC
      GO TO 320
C
  320 SUMX = 0.0
      I = 1
      NSW10 = 0
      IF ( DEP - DIA )700,325,330
  325 IF ( NSW4 )700,390,700
  330 DEP = WTW - SLOPE * DIST
      IF ( DEP - DSUBN )335,335,376
  335 SUMX = (WTW-DIA/(1.0+SLOPE*SLOPE)**0.5)*(1.0+1.0/SLOPE/SLOPE)**0.5
      DEP = DIA
  700 CALL CROUT(DEP,AREA,T,WP,DIA,R)
C
C     COMPUTE THE VELOCITY,SPECIFIC HEAD + HYDRAULIC RADIUS
C     FOR TWO CROSS-SECTIONS
C
  340 V(I) = QADJ / AREA
      SPH(I) = DEP   + ALPHA      * V(I)*V(I) / 64.4
      HYDR(I)= AREA / WP
      IF ( I - 2 )350,360,360
  350 I = I + 1
  351 IF ( NSW4 )380,355,356
  355 DEP = DEP + 0.2
      IF ( DEP - DIA )700,390,390
  356 DEP = DEP - 0.2
      GO TO 700
C
C     COMPUTE AVERAGE VELOCITY AND AVERAGE HYDRAULIC RADIUS
C     FOR THE CORSS-SECTIONS
C
  360 AVEV = (V(1) + V(2)) * 0.5
      AVEHR = (HYDR(1) + HYDR(2)) * 0.5
      S1 = CN      * CN      * AVEV * AVEV / 2.21 / AVEHR**1.33333
      IF ( NSW4 )362,361,362
  361 IF ( S1 - SLOPE )375,375,366
  362 IF ( SLOPE - S1 )375,375,367
C
C     COMPUTE DISTANCE X1
C
  366 DX1 = ( SPH(2) - SPH(1) ) / ( S1 - SLOPE )
      GO TO 368
  367 DX1 = ( SPH(1) - SPH(2) ) / ( SLOPE - S1 )
C
C     COMPUTE ACCUMULATED DISTANCE FROM THE OUTLET
C
  368 SUMX = SUMX + DX1
      IF ( SUMX - CLTH )370,371,371
  370 V(1) = V(2)
      SPH(1)= SPH(2)
      HYDR(1)= HYDR(2)
      GO TO 351
  371 IF ( NSW4 )373,372,373
  372 DEP = DEP - (SUMX-CLTH)/DX1*0.2
```

```
      GO TO 376
  373 DEP = DEP + (SUMX-CLTH)/DX1*0.2
      GO TO 375
  375 DEP = DSUBN
  376 NSW4 = -1
      I = 1
      CALL CROUT(DEP,AREA,T,WP,DIA,R)
  380 WHW = SPH(1) + CKE(I4) * V(1) * V(1) / 64.4
  390 GO TO  450
C
C     VELOCITY CALCULATIONS FOR INLET AND OUTLET CONTROL
C
C
C     OUTLET CONTROL CALCULATIONS
C
  450 IF ( WTW - DIA )451,470,470
  451 IF(DSUBC - DIA)452,470,470
  452 IF(DSUBC - WTW)453,454,454
  453 DEP = WTW
      GO TO 460
  454 DEP=DSUBC
  460 R = 0.5*DIA
      CALL CROUT(DEP,AREA,T,WP,DIA,R)
      GO TO 480
C
C     AREA CALCULATION FOR PIPE FLOWING FULL
C
  470 AREA = 0.785398 * DIA * DIA
  480 VEL1 = QADJ / AREA
      RETURN
      END
```

```
      SUBROUTINE CFIT(Q,CN,D,QMAX,TOEL,SLOPE,I4,I1,CLTH,DTW,AHWEL)
      DIMENSION CKE(5)
      DATA CKE/.9,.7,.5,.2,.2/
      DIST=CLTH
      ALPHA=1.12
      IF(I1.EQ.2) ALPHA=1.04
      QF=Q
      AREA=.785398*D*D
      WP=3.14159*D
      A=50.
   10 QF=QF+A
      HR=AREA/WP
      HD=(QF/10.)*(QF/10.)*((1.555*(1.+CKE(I4)))/(AREA*AREA)+(45.095*CN*
     1CN*DIST/(AREA*AREA*HR**1.333333)))
      Z=   QF/(32.2/ALPHA)**.5
      X=ALOG10(Z/D**2.5)
      IF(X.GT.ALOG10(.7)) GO TO 80
      YOD=-.0051657+.407362*X-.1830236*X*X-.0915565*X*X*X
      GO TO 85
   80 YOD=-.0244603+.2017057*X-.64009815*X*X+.695619*X*X*X
   85 YOD=10.**YOD
      DC=YOD*D
      IF(DC.LE.D) GO TO 30
   20 DC=D
   30 T = (DC+D)/2.
      IF(DTW.GT.T) GO TO 50
   40 HO= T
      GO TO 55
   50 HO=DTW
   55 WHW=HO+HD
      HWO=WHW+TOEL
      IF(HWO.GT.AHWEL)GO TO 60
      GO TO 10
   60 QF=QF-A
      IF(A.LT.5.) GO TO 70
      A=2.
      GO TO 10
   70 QMAX=QF
      RETURN
      END
```

```
      SUBROUTINE CEQUA(X,HW,DIA,SLOPE,I5)
      DIMENSION            A(10),B(10),C(10),D(10),E(10),F(10)
      DATA A/.108786,.114099,.167287,.087483,.120659,.063343,.081730,
     1        .187321..107137,.167433/
      DATA B/.662381..653562,.558766,.706578,.630768,.766512,.698353,
     1        .567710,.757769,.538595/
      DATA C/-.233801,-.233615,-.159813,-.253295,-.218423,-.316097,
     1-.253683,           -.156544,-.361462,-.149374/
      DATA D/.0579565,.0597723,.0420069 ,.0667001,.0591815,.0876701,
     1.0651250,           .0447052,.1233932,.0391543/
      DATA E/-.0055789,-.00616338,-.00369252,-.0066165,-.0059917,
     1-.00983695,-.0071975,           -.00343602,-.0160642,-.00343974/
      DATA F/.000205052,.000242832,.000125169,.000250619,.000229287,
     1.00041676,.00031245,          .00008966,.00076739,.000115882/
C
C-----CONVENTIONAL PIPES
      SCORR= .5
      IF(I5.EQ. 9) SCORR=0.0
      HWOVD = A(I5) + ( B(I5) + ( C(I5) + ( D(I5) + ( E(I5) + F(I5)*X )    **
     1 * X ) * X ) * X ) * X - SCORR      * SLOPE
       HW = HWOVD * DIA
      RETURN
      END
```

```
      SUBROUTINE CROUT(DEP,AREA,T,WP,DIA,R)
C     CALCULATIONS FOR PIPE CHARACTERISTICS FOR ANY DEPTH OF FLOW
C     ANSWERS ARE 1. AREA OF PIPE 2. WETTED PERIMETER 3. TOP WIDTH
C
      R=0.5*DIA
  700 DAB = DEP - R
      Y = DAB / R
      Y1 = ABS( Y )
C
C     ARCSIN APPROXIMATION
C
      PHIY = 1.570796 + (-0.214512 + ( 0.0878763 + (-0.0449589 + (
     10.0193499 - 0.00433777 * Y1) * Y1) * Y1) * Y1) * Y1
      ANGLE = 1.570796 - ( 1.0 - Y1) ** 0.5 * PHIY
      IF( Y )705,710,710
  705 ANGLE = - ANGLE
  710 DAC = ANGLE + 1.570796
      AREA = ( DAB * ( DIA*DEP - DEP*DEP )**0.5 ) + (R*R*DAC)
  712 T = 2.0 * ( R*R - DAB*DAB ) ** 0.5
  713 WP = DIA * DAC
      RETURN
      END
```