PB-168 718

Electronic Computer Program For

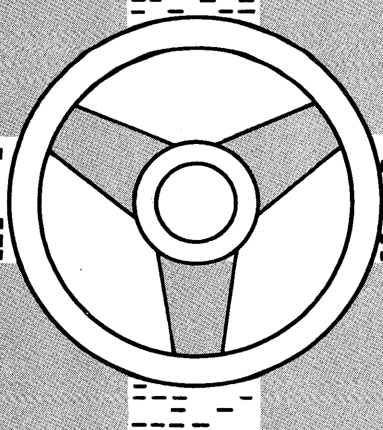
HYDRAULICS OF BRIDGE WATERWAYS

(BPR PROGRAM HY-4)

Developed by:

U. S. DEPARTMENT OF COMMERCE
Bureau of Public Roads

PB168718



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A COMPUTER PROGRAM FOR HYDRAULICS OF BRIDGE WATERWAYS

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ABSTRACT

This program is used for the hydraulic analysis of waterways at bridge sites and for determining information on backwater that can be produced or caused by a bridge. The program consists of two parts. Part 1 analyzes the open channel or natural stream section and produces typical stage-discharge information. Part 2 analyzes the constricted opening and determines water velocities and backwater heights for given discharges. The program was developed for the IBM 1410 computer in FORTRAN, a problem oriented programming language. The FORTRAN statements are furnished in place of the usual block diagram.

STATEMENT OF THE PROBLEM

Highway organizations find the electronic computer helpful in performing the numerous computations needed for the planning, designing and construction of modern highways. Programs are available for various phases of road and bridge design, but only a few programs deal with hydraulic design. This program then, is an attempt at closing the gap that exists for electronic computation in hydraulic design.

The rapidity with which the electronic computer performs calculations makes its use advantageous in making analyses of the hydraulic characteristics of bridge waterways. Similar analyses by manual calculations would be time consuming. As a consequence, in many cases, this latter approach would either not be attempted or be found uneconomical.

For crossings where land use imposes a limit on water surface elevations upstream from the crossing, the appropriate length of structure could be governed by the backwater that could be induced by the structure. This computer program calculates bridge backwater which may be defined as the increased depth of water upstream of a bridge above the water surface elevation at the same location exclusive of confinement for the same rate of discharge. With this tool, the selection of bridge spans and span lengths is limited only by the designer's imagination.

This program is based on the principles discussed in "Hydraulics of Bridge Waterways" 1/ and figures 5, 6, 7, 8, 9, and 10 were reproduced from this publication.

1/ "Hydraulics of Bridge Waterways", Hydraulic Design Series No. 1, by J. N. Bradley, U. S. Department of Commerce, Bureau of Public Roads, 1960.

DESCRIPTION OF THE PROGRAM

With respect to the program, the hydraulic designer's primary interest is what must be given as input and what will be returned as output. These items are explained under their respective titles in the sections to follow. However, to more fully understand what is needed, the designer should acquaint himself with the operation of the program and how it uses the input data.

Prior to using the program a horizontal datum plane is chosen. This datum plane must be below the lowest point of the channel. In addition a vertical reference plane is selected. These reference planes are necessary in order to define a channel cross section. All vertical measurements or distances for a cross section are measured from the horizontal datum plane. Horizontal measurements for a cross section are made from the vertical reference plane which should be outside and to the left of the cross section so that all horizontal or X-distances will be positive.

In assembling the physical data, the assumption must be made that Manning's n values cover the point where listed and the area between it and the next point along the section line. A Manning's n value for a subsection between the point at the top of an abutment face and the point at the base of an abutment must reflect a change of 0.0001 in the value associated with the area into which an abutment is placed. This has minor effect on resultant values but is required to act as a check point for the computer. If Manning's n should change between the point at the top of an abutment and the point at the base of an abutment thus resulting in two Manning's n values in this area, an average value should be used.

All cross sections for a study must be along a line that is perpendicular to the stream flow line. Whenever a skewed crossing is studied, the skewed bridge opening must be projected onto the perpendicular cross section in its reduced size.

Initially the program reads the set of data records or cards. The first input record gives the minimum, maximum, and increment values for the river stage elevations which are to be tested. In addition, it gives the design discharge, the slope of the channel in this area, and the total number of points along the given cross section line to be studied.

The first card also contains numerical values for variables referred to as METHD and IPRT2. The first variable designates which method of two is to be used in computing the discharge. Method 1 uses the formula:

$$Q = Q1 \left(\frac{CON(J)}{CONT}\right)$$

The design discharge, Q1, is multiplied by that portion of the total conveyance factor, CON(J)/CONT, that applies to the unit of area being considered. The slope of the channel required to give this total discharge is then computed and printed out for each stage elevation.

Method 2 computes the discharge by use of the formula:

$$Q = (CON(J))(SZERO)^{1/2}$$

This solves for the discharge using the conveyance of the subsection, CON(J), and the square root of the given slope of the channel, SZERO.

The second item, IPRT2, is a 1 or a Ø and controls whether or not the program goes into the second part of the program, backwater computations. The use of a Ø for IPRT2 in the first run results in only stages and related discharges being calculated. From these, a stage vs. discharge or rating curve can be drawn to determine the stage of most interest. The card can then be changed along with the stage information and a 1 put in this item so that all computations will be made including that of backwater height.

The last item, IEOF, on the first card is a number to indicate whether or not an end of file condition has been found. Blank or Ø means it is not the last set of data. A positive number in this position means it is the last set of data and an end of file condition.

The next card will contain cross section data. The program will read and store this data for as many points as it was directed to read on the first card of the data set. After all cross section information has been read and stored the next card, called a title card, is read. This card can contain some meaningful and descriptive information pertaining to a particular section line that could serve as a title or an identification mark for a problem. In addition to the identifying information in the title card, there should be a number 1 in the first card column. The number 1 in this case is a code number that enables the program to advance paper in the printer and cause the results for the problem under consideration to be written or printed on a new and separate page.

If a number 1 was assigned to IPRT2 in the first card of the data set, thus calling for backwater computations, additional data cards would have to be read into the computing system.

The first of these cards contains six items. The first is ABTYP, abutment type, which is 5.0 or 6.0. The second item is IWWSL, the wingwall or spillthrough curve used on figure 5 or 6. Third is the number of piers, NPR, which will appear in the cross section. Fourth is ITP7A which is a number 1 through 8 designating the curve which would be used in figure 7A. The next is ITP7B which will be a number 1 through 6 to designate the curve to be used on figure 7B. The last item is the angle of skew, SKEW.

The next card contains bridge opening data as follows: XL, XLG, XRG, XR, YBL, YGL, YGR, and YBR. These terms are explained in the Definition of Terms section.

If NPR equals zero, meaning there are no piers within the bridge waterway opening, no other cards are involved in the particular data set. If it is a positive number, the next card will contain the base elevations of each pier beginning at the left. The base elevation of a pier is the ground elevation at the pier.

The next card contains the widths of the piers. If the width varies, the value used must be the average width between the ground point and the stage elevation of the river.

The program is now ready for operation and begins by initializing all values to their minimum value. It continues by comparing the stage elevation to the ground elevation. As long as the stage is below the ground at each station, the computer simply goes on to the next station. When the stage is above the ground, the computer detects that the edge of the river has been passed and goes into an interpolation routine to locate the exact point where the stage elevation and the ground elevation are the same. The computer stores this beginning X-distance and proceeds along the cross section making calculations and storing data according to the computing system set up by Joseph N. Bradley. 1/

While proceeding along the cross section the program checks all data that is given. When the computer detects a point where the ground is again above the stage elevation, it continues checking to be sure that it has not just come upon an island. After checking the entire cross section, it completes the cross section calculations and prints the results before going into backwater computations.

Should the stage elevation happen to be above the ground data at the first or last stations, this would mean that insufficient ground data has been recorded for these areas and that more must be supplied.

1/ Ibid.

The designer is notified by a printed message to that effect. Additional remarks on this matter are mentioned in the Output section.

The hydraulic discharges to the right and left of the bridge opening as well as through the opening are computed in the second part of the program. In addition the hydraulic cross-sectional area under bridge and the area taken up by the piers within the bridge opening are determined. The approximate backwater is computed by means of equations that have been substituted for the figures that appear in Hydraulic Design Series No. 1. 1/

Although the hydraulic analysis for determination of bridge backwater as found in the Hydraulic Design Series No 1.is applicable to a wide variety of bridge waterway problems, the method applies strictly to subcritical flow through the bridge constriction. Therefore, between statements 400 and 415 of the fortran listing of the program a check is made to determine the validity of the method, and messages are printed when invalid conditions exist. These inform the engineer of the supercritical condition.

In the event that a given bridge backwater problem results in an invalid message, the engineer should analyze the average velocity and critical velocity in the main channel segment of the natural channel cross section. Since the main channel segment of the cross section will ordinarily have a Manning "n" value differing from values assigned to the segments on either side, the output results for natural channel conditions will indicate the average main channel velocity. If the average velocity in relation to the critical velocity is 1.0 or greater, as defined by the equation presented below, supercritical flow prevails in the main channel and this method cannot be used to analyze bridge backwater. If, however, application of the equation that follows results in a value less than 1.0, thought should be given to lengthening the bridge and resubmitting this information to the HY-4 program.

$$F = \frac{V_{ave.}}{[gD_m]^{1/2}}$$

$V_{ave.}$ = average main channel velocity for natural conditions, fps.

g = 32.2 ft/sec^2

D_m = $\frac{A}{T}$ = mean depth, ft.

A = area of flow bounded by limits of main channel, natural conditions, ft^2

T = top width of main channel segment,ft.

1/ Ibid.

After calculations for the last stage are completed, the value coded for end of file is checked. The program will start the next problem if another set of data is present. If, however, the last set of data has been used, the end of run message is printed and the computer stops.

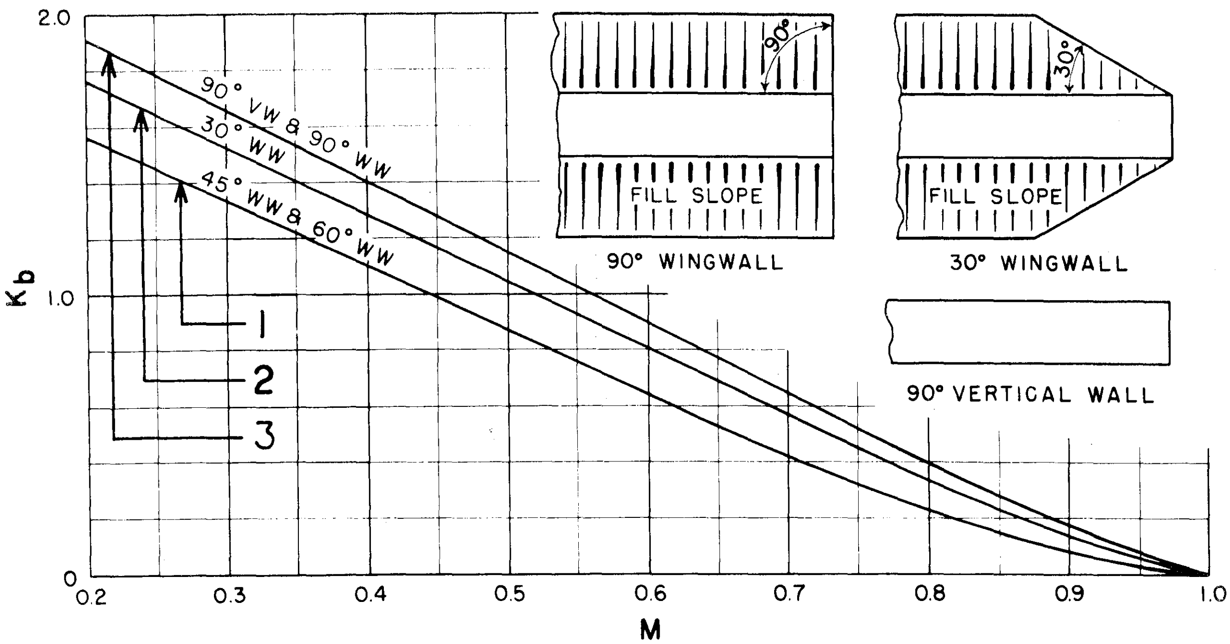


Figure 5.—Base curves for wingwall abutments.

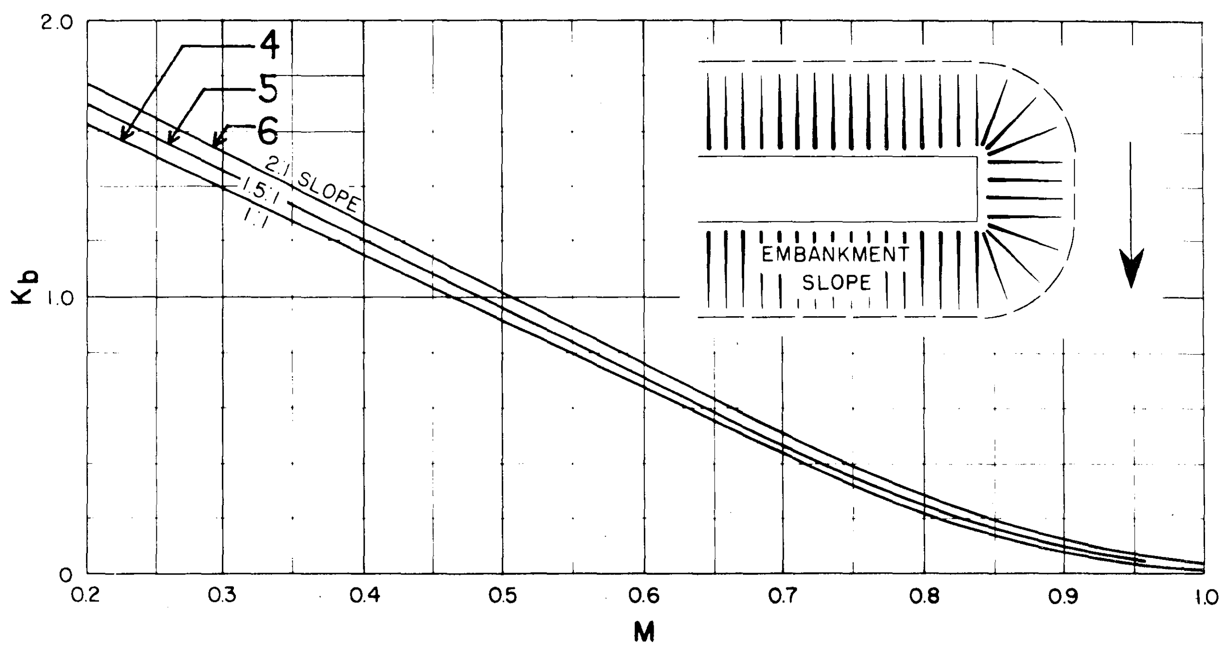


Figure 6.—Base curves for spillthrough abutments.

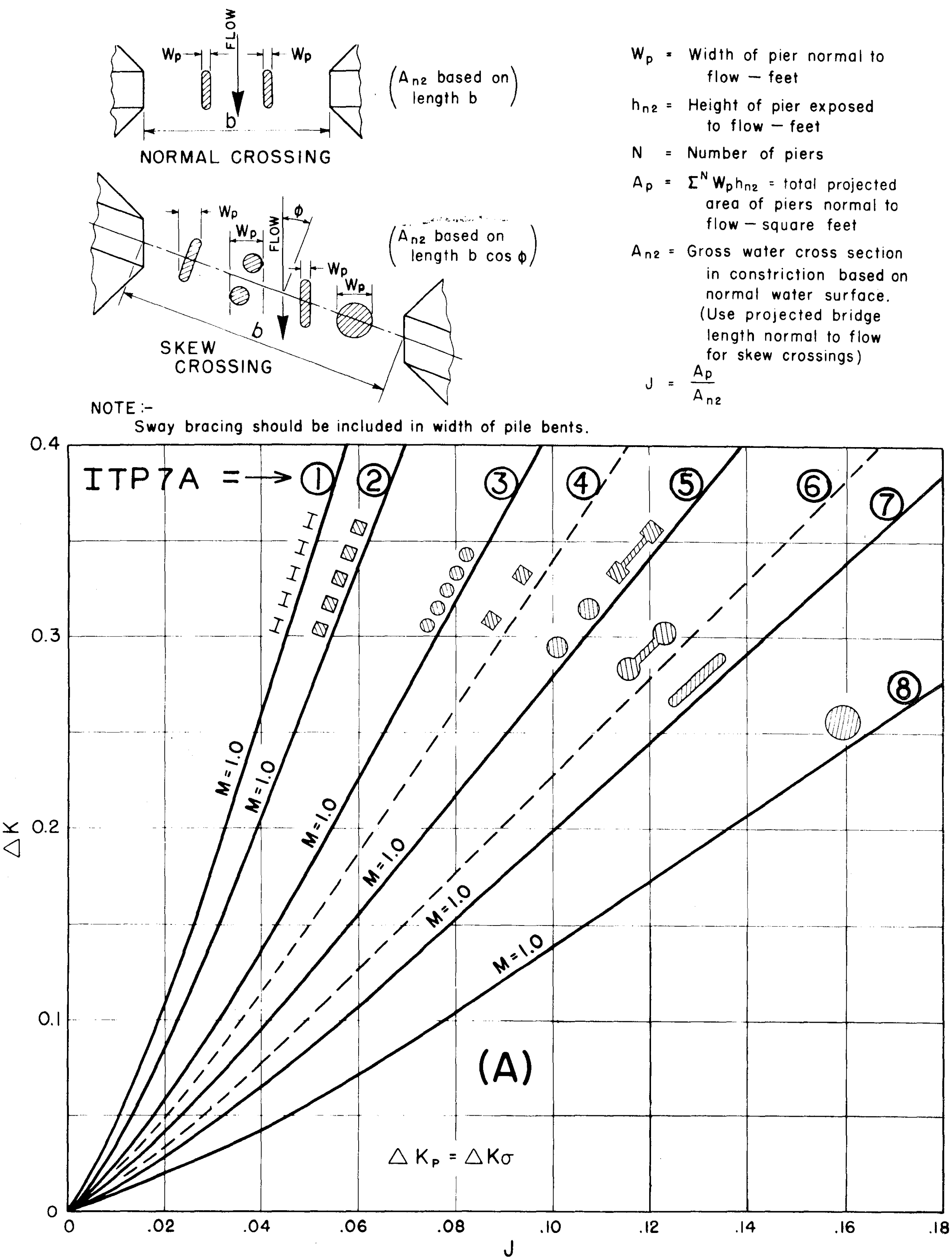


Figure 7.—Incremental backwater coefficient for piers.

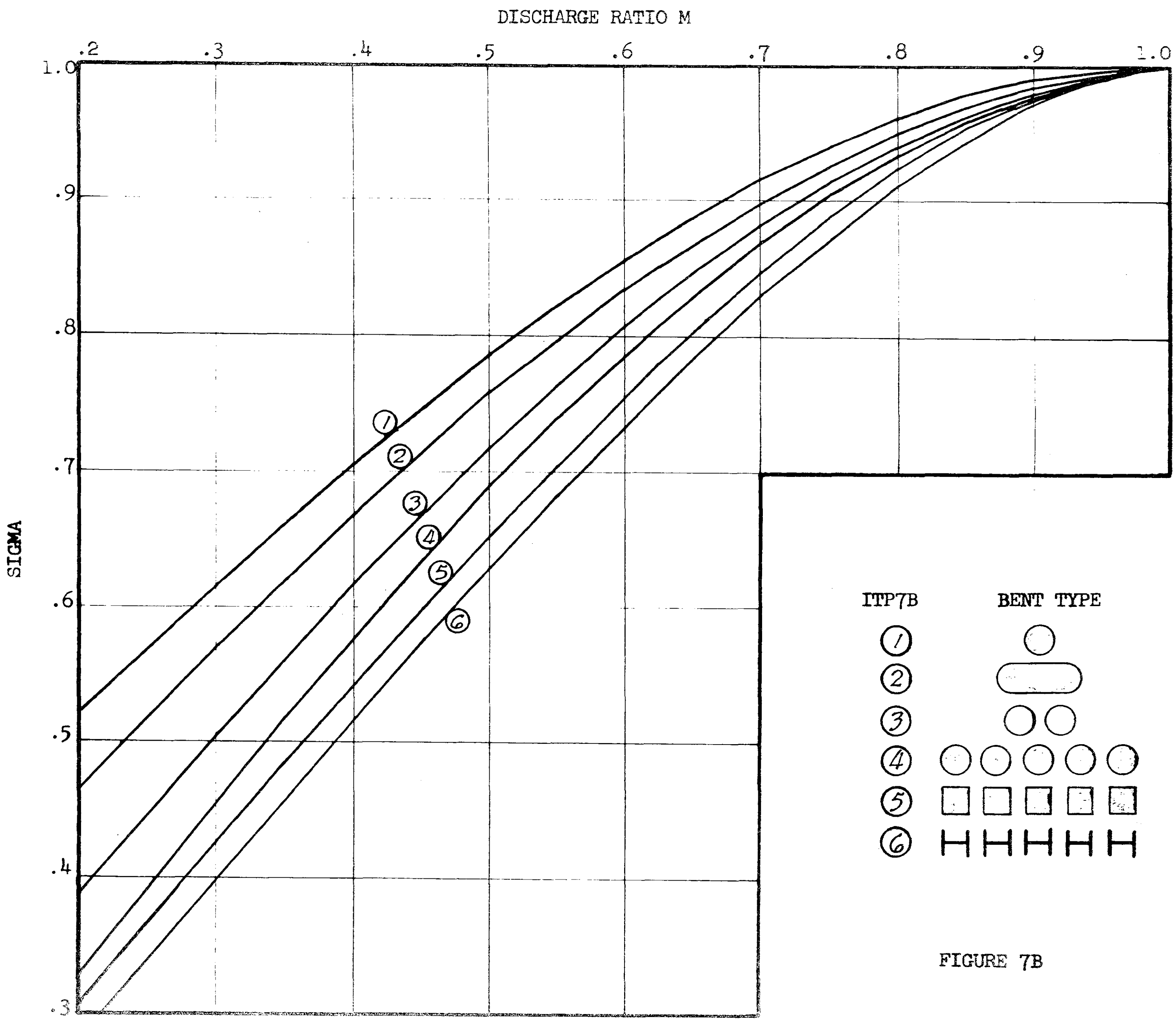
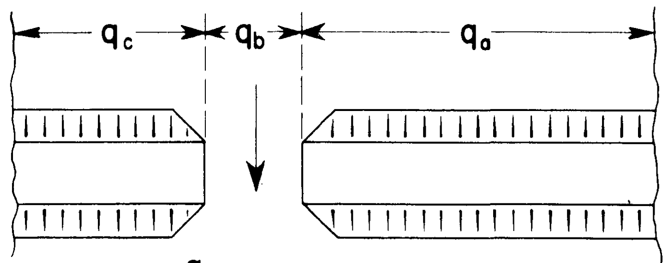

DISCHARGE RATIO M
.2
.3
.4
.5
.6
.7
.8
.9
1.0
SIGMA
1.0
.9
.8
.7
.6
.5
.4
.3
1
2
3
4
5
6
ITP7B
BENT TYPE
1
2
3
4
5
6

FIGURE 7B



$$e = \left(1 - \frac{q_c}{q_a}\right) \quad \text{where} \quad q_c < q_a \quad \text{or}$$

$$e = \left(1 - \frac{q_a}{q_c}\right) \quad \text{where} \quad q_a < q_c$$

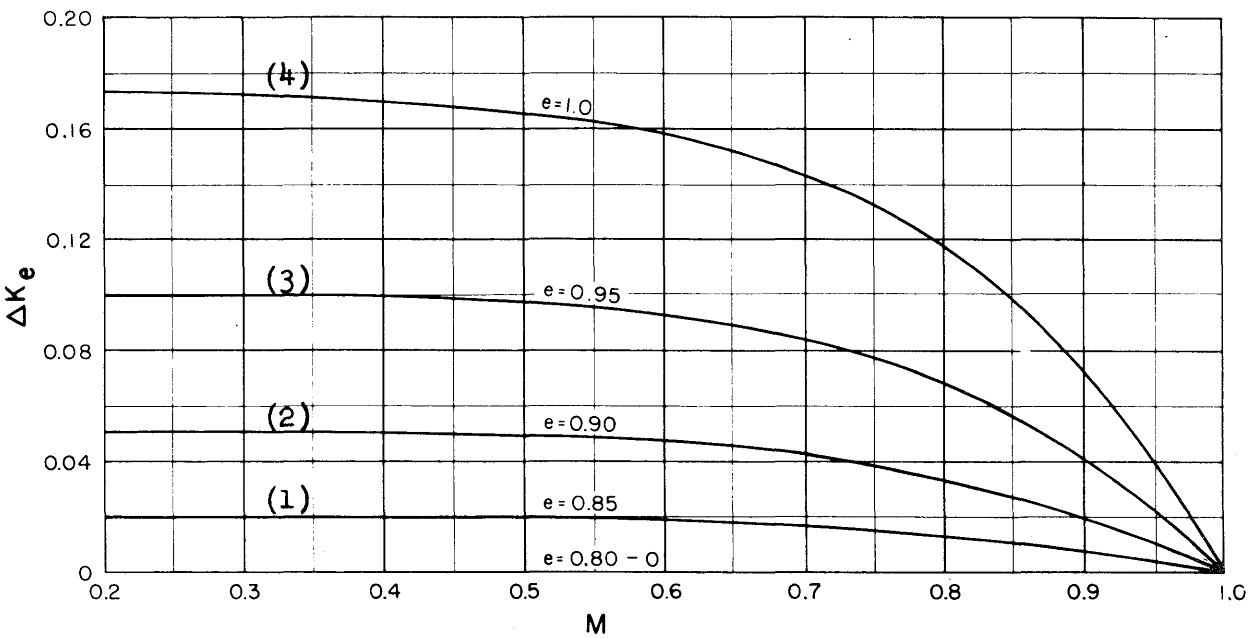


Figure 8.—Incremental backwater coefficient for eccentricity.

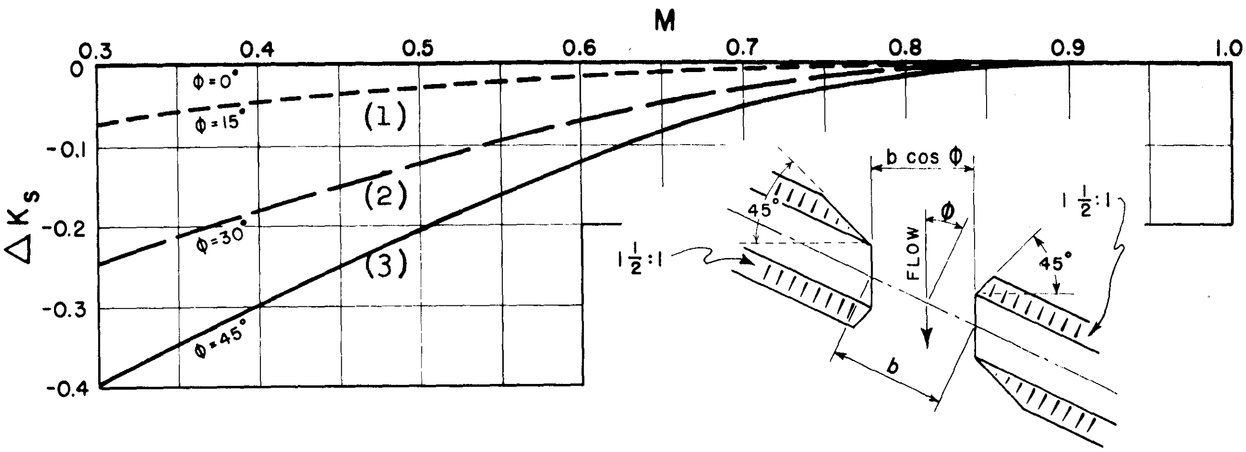


Figure 9.—Incremental backwater coefficient for skew, wingwall abutments.

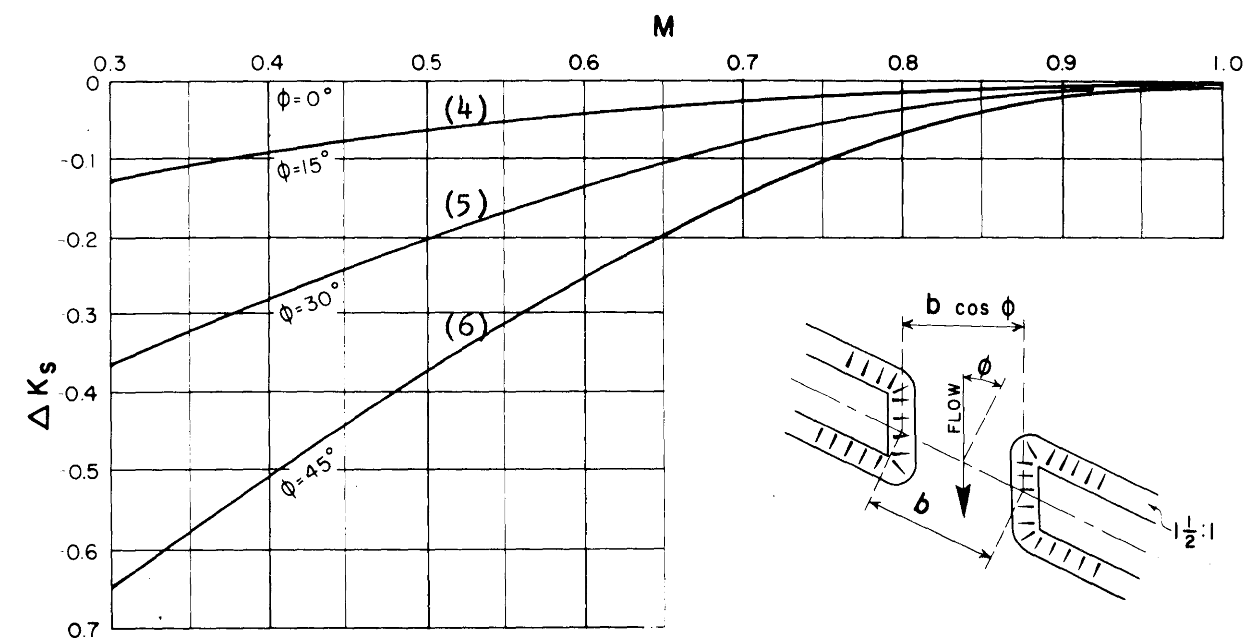


Figure 10.—Incremental backwater coefficient for skew, spillthrough abutments.

INPUT DATA

The input data items for the program are:

A. Part 1

1.	Minimum stage elevation	XXXX.XX
2.	Maximum storage elevation	XXXX.XX
3.	Stage elevation increment	XX.XX
4.	Design discharge	XXXXXX.XX
5.	Design slope	0.00XXXX
6.	Number of observation points on section line	XXX
7.	Method code	X
8.	Part 2 code	X
9.	Cross section	
	a. Distance	XXX.XX
	b. Ground elevation	XXXX.XX
	c. Roughness coefficient	0.XXXX

B. Part 2

1.	Abutment type code	X.Ø
2.	Wingwall angle code	X
3.	Number of piles, piers or abutments	XX
4.	Figure 7A curve code	X
5.	Figure 7B curve code	X
6.	Skew angle	XX.XXX
7.	Bridge opening data	
	a. Distance to left abutment top	XXX.XX
	b. Distance to left abutment base	XXX.XX
	c. Distance to right abutment base	XXX.XX
	d. Distance to right abutment top	XXX.XX
	e. Elevation, left abutment top	XXXX.XX
	f. Elevation, left abutment base	XXXX.XX
	g. Elevation, right abutment base	XXXX.XX
	h. Elevation, right abutment top	XXXX.XX
8.	Elevation, pier base	XXXX.XX
9.	Average pier width	XX.XX

The minimum stage elevation, YSMIN, is an assumed water surface elevation at a section line that is being considered. The maximum stage elevation, YSMAX, is another assumed water surface elevation. Stage elevation increment, YSINC, is the amount by which the minimum stage elevation will be increased until it reaches the maximum stage elevation. These input items, in addition to the cross section details, are needed for the calculations of stages and discharges in stream channels. From these calculations the designer can determine accurately the stage of the stream or river for the design discharge, Q1, at the bridge site.

Design slope, SZERO, is the average slope of the stream or river in the vicinity of the bridge site.

The number of observation points, NMAX, tells how many points are considered along the section line and is expressed as an integer number. It is used by the program to determine when it has reached the end of the section in the stage discharge computations.

METHD and IPRT2 are code values for use by the program. The functions of these input items have been mentioned previously.

The cross section of the stream or river is defined by points. These points are referenced by horizontal distances, X, and vertical distances, YG. There is one additional item for each point on the section line, CN for Manning's n, which is a value of roughness for the point and the section between it and the next point.

Abutment type code, ABTYP, is a code item that defines the type of abutment to be used at the bridge site. There are only two values to be assigned to this item; 5.0 and 6.0. A 5.0 means a wingwall type while a 6.0 signifies a spillthrough type abutment. The five and six code values were selected because they represent the figures which would be used if manual computations were done by following the procedure outlined by J. N. Bradley. 1/

The wingwall angle and spillthrough slope, IWWSL, enables the program to select the proper equation, 1 through 6, for calculating the coefficient K_b that is used in the bridge backwater computations.

The number of piles, piers, or abutments visible in the cross section being considered is specified by the input variable NPR.

1/ Ibid.

The figure 7A curve code, ITP7A, is a number 1 through 8. The number selected by the designer defines or selects the curve or equation on figure 7A that is used to evaluate the incremental backwater coefficient Δ_k.

The figure 7B curve code, ITP7B, is a number 1 through 6. It is used to select the appropriate equation from the equations or curves shown on figure 7B that are used to determine the backwater coefficient, SIGMA.

Skew angle, SKEW, is an angular measure in degrees and indicates the angle included between a line that is normal to the bridge longitudinal line and the stream flow line.

The bridge opening data is similar to cross section data and consists of points that are used to characterize the channel section between the bridge abutments, such as distances and elevations for top and bottom points at each abutment. In addition to abutments, the bridge opening may include piers or piling. In these cases a ground elevation, BELPR, at each pier must be included in the input items together with an average width of pier, WPR, for each pier.

OUTPUT DATA

The output of this program is either a set or several sets of answers, a message or a combination of these two, depending on the input data.

The output answers of the first part of the program will first list the important input items that must be considered when studying the results. These will include the design discharge, stage elevation used in computing the results, and the slope of the channel surface, all of which have been defined as part of the input data. It will also list the computed results which will include the following: the beginning and ending points for sections of constant roughness, Manning's n value, area, wetted perimeter, hydraulic radius, conveyance, discharge, and velocity for each subsection. The total cross-sectional area, total conveyance, and total discharge are listed as well as the necessary channel slope required to achieve the design discharge given in the input data.

The second part of the program will then print its output. This also will include a listing of the data used to compute the bridge backwater height. These will include the number of piers and the curves to be used for each of the calculations.

The computed data which will be output from this second part of the program will be the following:

1. QA, the discharge to the left of the bridge opening.
2. QB, the portion of the discharge thru the bridge opening.
3. QC, the discharge to the right of the bridge opening.
4. AN2, the flow area through the bridge.
5. VN2, the average velocity through the bridge.
6. M, bridge opening ratio.
7. RTIOJ, the ratio of the pier area to AN_2.
8. K, the total backwater coefficient.
9. BWAP1, the approximate value for the backwater.
10. BWAP2, the second approximation of backwater.
11. BWAP3, the third and final approximation of backwater.

Possible messages which may be printed as part of the results are as follows:

"Insufficient ground data on the left at Ground Data, X = _____ YG = _____, Stage Elevation = _____". The computer and the program will fill in the blanks with appropriate figures or numbers.

MATHEMATICAL EQUATIONS

In the following paragraphs five equations will be stated and explained. These equations replace the curves used in the referenced manual and illustrated in this publication. The equations for the curves were found by using the "Least Squares Curve Fitting Computer Program" developed by the Bureau of Public Roads. 2/ The curve fit program uses the Doolittle Method of Least Squares Curve Fitting.

The curves of figures 5 and 6 are replaced by the equation for the backwater coefficient:

$$AKB = AKBA_{(IWWSL)} + [AKBB_{(IWWSL)}]\,[DRM] + [AKBC_{(IWWSL)}]\,[DRM]^2 + [AKBD_{(IWWSL)}]\,[DRM]^3 \quad (1)$$

Where

AKB = Backwater coefficient K_b.

AKBA, AKBB, AKBC, and AKBD = Coefficients determined by polynomial curve fitting.

IWWSL = Control to determine which coefficients are being used.

Curve No. (IWWSL)	Figure		COEFFICIENTS: AKBA	AKBB	AKBC	AKBD
	Fig. 5	1	1.84077	-0.867548	-3.21297	2.23256
	Fig. 5	2	2.041142	-0.839403	-3.250639	2.042721
	Fig. 5	3	2.293090	-1.661530	-1.838878	1.197734
	Fig. 6	4	1.922891	-0.841071	-3.722713	2.656176
	Fig. 6	5	2.016526	-0.994235	-3.551535	2.548148
	Fig. 6	6	2.087884	-1.077633	-3.366953	2.387174

2/ "Least Squares Polynomial Curve Fitting", by R. C. Tennent, U. S. Department of Commerce, Bureau of Public Roads, Library Program M-1, Washington 25, D. C., 1962.

"Insufficient ground data on the right at Ground Data, X = _____ YG = _____, Stage Elevation = _____". Here too the computer will supply the missing data to properly complete the blanks.

"The number of changes of Manning's n is too many." This means that the number of subsections where n is constant is in excess of the storage allocation of the program.

"Error in Coding Method" means that the method must be a 1 or a 2. If anything else, then this message will be printed.

"XLeft (or XRight) is not a Manning's n change point in the cross section." Change the CN value for the section between the abutments by 0.0001 if they are not different than the adjacent sections.

"Error in coding abutment type". This message will be printed if the abutment type is anything other than a 5.0 or a 6.0. These numbers represent the figures which would be used in the reference manual.

"End of Run", will be typed on the console to signify that the last set of input data has been processed and the use of the computer by the program is completed.

"Econ Exceeded 1.0", is printed at the top of the sheet when some error causes E to exceed 1.0, which is not permissible within the computer and the program. The general cause for type of error is improperly coded bridge data causing QA or QC to be negative quantities.

"Velocity Exceeds Critical - Backwater Calculations Invalid - Check Next Stage." This message is printed if the average velocity through the bridge opening is greater than critical velocity (supercritical velocity) and will be printed for each stage up to the one at which the calculated discharge is equal to or greater than the design discharge.

"Critical Velocity = ________, Average Velocity Through the Opening = ________, This Design Method is Invalid". This message is printed for all stages where the discharge is equal to or greater than the design discharge and supercritical velocity prevails.

The curves for figure 7A replaced by the equation for the non-adjusted value of the incremental backwater coefficient for the piers. It is:

$$DLTAK = DTAA_{(ITP7A)} + [DTAB_{(ITP7A)}]\ [RTIOJ] \qquad (2)$$

Where

DLTAK = Nonadjusted backwater coefficient for the piers.

DTAA & DTAB = Coefficients for equation.

ITP7A = Control to determine which coefficients are to be used.

RTIOJ = Ratio of area obstructed by piers to gross area of bridge waterway below the normal water surface.

		COEFFICIENTS	
		DTAA	DTAB
Curve No. (ITP7A)	1	-.05968	8.06452
	2	-.05395	6.57895
	3	-.04907	4.62963
	4	-.03939	3.78788
	5	-.02593	3.08642
	6	-.02564	2.56410
	7	-.02844	2.29358
	8	-.02978	1.68539

The value of SIGMA, the multiplication factor for influence of M on the backwater coefficient for piers, is determined by the equation which replaces the curve of figure 7B. It is:

$$SIGMA = SCA_{(ITP7B)} + [SCB_{(ITP7B)}]\,[DRM] + [SCC_{(ITP7B)}]\,[DRM]^2 + [SCD_{(ITP7B)}]\,[DRM]^3 \quad (3)$$

Where SIGMA = Multiplication factor.

SCA, SCB, SCC, and SCD = Coefficients for equation.

ITP7B = Control which coefficients are used.

DRM = Bridge opening ratio.

Curve No. (ITP7B)	COEFFICIENTS SCA	SCB	SCC	SCD
1	.327245	.989413	.044095	-.361134
2	.238817	1.174765	-.136850	-.277804
3	.146077	1.232713	.035751	-.416684
4	.056796	1.383878	-.023734	-.416702
5	.174052	.607318	1.190511	-.972239
6	.099387	.837630	.841710	-.777799

The incremental backwater coefficient, normally taken from the eccentricity curves of figure 8, is replaced by the equation:

$$DKE = ECA_{(IEC)} + [ECB_{(IEC)}]\,[DRM] + [ECC_{(IEC)}]\,[DRM]^2 + [ECD_{(IEC)}]\,[DRM]^3 \qquad (4)$$

Where DKE = Eccentricity backwater coefficient.

ECA, ECB, ECC, and ECD = Equation coefficients.

IEC = Control coefficients to be used in the equation.

DRM = Bridge opening ratio.

Curve No. (IEC)	COEFFICIENTS ECA	ECB	ECC	ECD
1	.019508	-.002953	.032035	-.048822
2	.058524	-.077194	.218074	-.199495
3	.118143	-.155989	.422079	-.383839
4	.205484	-.266695	.683660	-.619530

The incremental backwater coefficient for skew curves of figures 9 and 10 are replaced by the equation:

$$DKS = SKA_{(ISKW)} + [SKB_{(ISKW)}]\ [DRM] + [SKC_{(ISKW)}]\ [DRM]^2 \qquad (5)$$

Where DKS = Backwater coefficient for skew.

SKA, SKB, and SKC = Equation coefficients.

ISKW = Controls which coefficients are used.

DRM = Bridge opening ratio.

Curve No. (ISKW)			COEFFICIENTS		
			SKA	SKB	SKC
	Fig.9	1	-.155585	.341092	-.186555
	Fig.9	2	-.524091	1.099576	-.574564
	Fig.9	3	-.868571	1.808105	-.936619
	Fig.10	4	-.248466	.485294	-.239237
	Fig.10	5	-.730913	1.387357	-.655494
	Fig.10	6	-1.263679	2.311828	-1.039593

The coefficients for the above five equations must be entered into the computing system and stored in separate arrays so that individual coefficients can be selected and used as needed in the computations. The selection of a particular coefficient from an array of coefficients will be made on the basis of a value or number in some integer variable such as IWWSL, ITP7A, ITP7B, IEC, or ISKW.

The coefficients for these equations must be read and stored by the program itself. These activities should be done before the first data item is entered into the system. The reader should read and study the first five READ statements along with FORMAT statement no. 1000, in the attached FORTRAN listing so that he can get an understanding of one way that these coefficients can be entered and stored.

PROGRAMMING PROCEDURES

The following steps suggest a method that may be used to put this program into production on a FORTRAN programming system.

1. Review the FORTRAN program listing that follows and note changes to the program that appear to be necessary. In many cases changes will have to be made so that the program can be compiled and run on the user's equipment. Normally, the changes that are needed will be limited to the input and output statements. This means that changes may be required for those operations that bring information into the computing system, or transfer results out of the system. As an example, it may be necessary for one user to change all PRINT statements included in the attached listing to PUNCH statements. This change is needed because the computing system to be used produces results in punched card form in place of printing them directly by means of a printing device. The FORMAT statements included in the listing that control the arrangement of input and output information must be checked carefully. When computer controlled line printers are to be used, special attention should be given to the printer carriage control codes.

2. Keypunch or type the source FORTRAN program. The source program is then compiled on the user's system by means of the compiler to obtain the object computer program. The compilation of a source FORTRAN program is a routine operation for most computing centers equipped to handle FORTRAN compilation. Any special instructions needed to perform this step can readily be found with the operating instructions that are furnished with the FORTRAN compiler programs.

3. Operate the program. For a punched card system, constants for use in the equations that substitute for the curves in figures 5, 6, 7, 8, 9, and 10 should be keypunched. The values should be taken from the tables included in the section entitled Mathematical Equations. It should be noted however that the cards containing values for coefficients can be used over and over again with the object program. In addition to the constants, data pertaining to a specific problem should be keypunched according to the specifications or card arrangements that are given in the separate FORMAT statements. The cards should be assembled and presented to the computer system in the order shown in figure 11.

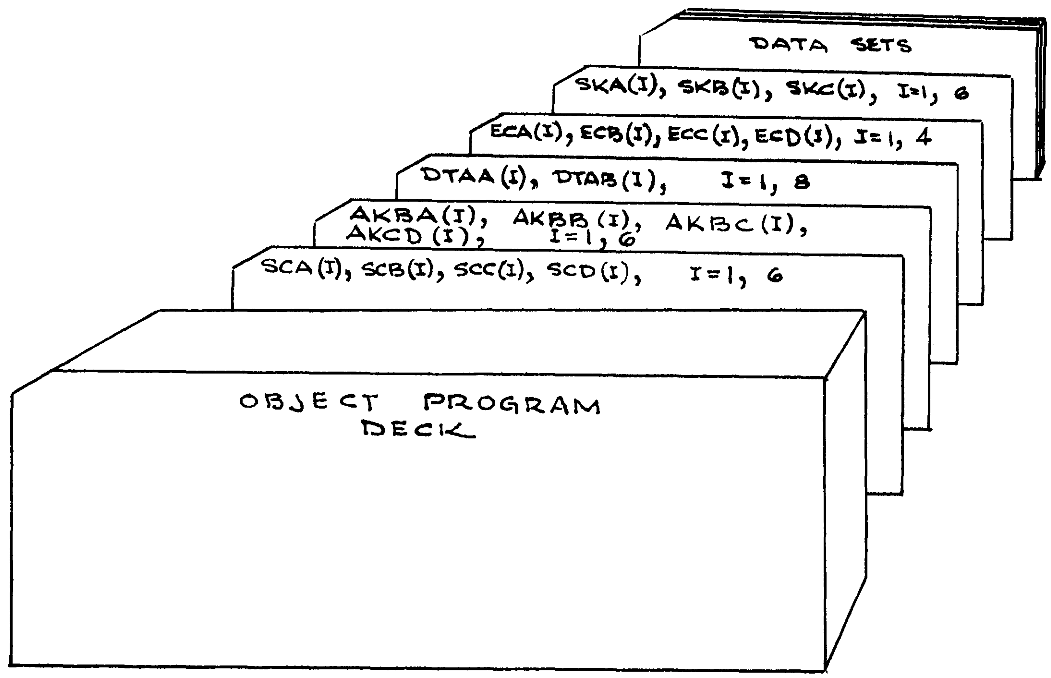


Figure 11.

In the figure, the first cards that follow the object program deck are the cards containing values for the coefficients that appear in the previously mentioned special equations. The order of assembly for these cards is important. The order must agree with the separate reading operations as given in the source program. In the above figure, coefficients for equation (3) appear first, followed by coefficients for equations (1), (2), (4), and (5), in that order. This arrangement agrees with the first five read operations that appear in the attached FORTRAN listing. It should be noted that other arrangements are possible. Care must be taken to preserve the order to be used and specified in the source program.

Each data set consists of the items that were discussed previously. Any number of data sets can be assembled and submitted for processing at one time. For a clearer understanding of the data set items and their order the reader should carefully study the separate READ instructions and the data lists that are included in the FORTRAN listing together with the example problems.

DEFINITION OF TERMS

A	--	is the accumulated cross-sectional area between ground elevation and water surface elevation across an area where Manning's n, CN, remains constant.
AB1 & AB2	--	is the area formed between the abutment wall, the water surface, and a vertical plane through the ground line intersection with the base of the abutment face. (See Figure D)
ABTYP	--	represents the type of abutment being used. Since in the reference material figure 5 is for wingwall abutments, a 5.0 for ABTYP is used to identify wingwall abutments. A 6.0 for ABTYP is used to represent spill-through abutments because figure 6 refers to that type of abutment. No other codes are possible.
AKB	--	is the base curve backwater coefficient.
AKBA, AKBB, AKBC, and AKBD	--	are coefficients A, B, C, and D in the mathematical equation for the curves in figures 5 and 6 that are used to determine K_b.
ALPHA	--	is the kinetic energy coefficient.
AN2	--	is the cross-sectional area of flow between the abutments below the normal water surface.
APRS	--	is the total area of all piers below the water surface.
ATOT	--	is the accumulated cross-sectional area between the ground line and the water surface for any particular stage, YS.
BELPR	--	is the base elevation of each pier. This is the elevation of the ground at the point where the center line of the pier meets the ground.
BWAP1	--	is an approximate backwater value computed by multiplying the total backwater coefficient times the velocity head, VN2.
BWAP2	--	is a second approximation of the backwater and is equal to BWAP1 + an added factor calculated by using BWAP1.

BWAP3 -- is the third and final approximation and is equal to BWAP1 + an added factor calculated using BWAP2.

CN -- is the value of Manning's n, the roughness coefficient, for the point where it is recorded and for the area between it and the next point.

CNC -- is the value of Manning's n that is constant for one area, A.

COEFK -- is the total backwater coefficient.

CON -- is the conveyance factor for a subsection of the cross section, corresponding to one area, A. It is a measure of the ability of the channel to transport the flow.

CONB1 & CONB2 -- are the conveyance factors of areas AB1 and AB2.

CONT -- is a summation of the conveyance factor, CON, for each subsection.

DKE -- is the value of the coefficient of eccentricity.

DKE1 & DKE2 -- are values of DKE on the curves each side of where the actual value lies. The actual value is interpolated between them.

DKS -- is the value of the skew coefficient.

DKS1 & DKS2 -- are values of DKS on the curves each side of where the desired value lies. DKS is then interpolated between the two points.

DLTAK -- is the incremental backwater coefficient that relates to piers.

DRM -- is the bridge opening ratio.

DTAA & DTAB -- are coefficients A and B for the straight line equation for straight portion of the curves in figure 7A used for computation of DLTAK or the incremental backwater coefficient for piers.

E -- is the eccentricity and is equal 1 minus (QA/QC) or (QC/QA) with the small discharge as the numerator.

ECA, ECB, ECC, and ECD -- are coefficients A, B, C, and D used to compute the coefficient for eccentricity.

ECON -- is the constant value for eccentricity for the curves for which the equations and constants for them are input.

HEAD -- is a velocity head.

HTPR -- is the height of the pier between the base elevation of the pier and the water surface elevation.

I -- is an integer counter used for reading in and storing data.

IEC -- is an integer counter designating which curve is used for eccentricity.

IEOF -- stands for End Of File. The last item on the first data card for each cross section contains a coded number for program control. If it is blank, it means other cross sections follow. If it contains any positive number, it must be the last cross section to be handled. The program will type an "End Of Run" message and stop after completing the section.

IPAGE -- is a counter which increases by one for each page of results printed. Its value is printed in the upper right-hand corner of each printed page.

IPRT2 -- is to designate whether or not the bridge opening computations of part two of the program should be done or bypassed. By using any value greater than zero, part two is executed. If it is zero or less it is not.

ISKW -- is a counter used to designate which of the given curves is used to compute the skew coefficient.

ITP7A -- is the number of the curve on figure 7A representing the bent type being used to calculate the incremental backwater coefficient for the piers.

ITP7B -- is used to find the value of SIGMA in figure 7B. The value given for ITP7B together with the type of bent being used determines the curve to be used for finding SIGMA.

IWWSL -- is given the number of the curve on figure 5 or 6 used for determining the value of the backwater coefficient K_b. Thus it will have a value of 1 to 6.

J	--	is a counter of sections where there are different Manning's n values. It is incremented each time a change in CN occurs.
JMAX	--	is the maximum value for J for the cross section being calculated.
K	--	is another counter that is used only to zero the arrays for storage of the accumulated area and the accumulated wetted perimeter.
METHD	--	is a code for selecting one of two methods for calculating discharge. A 1 indicates method A is desired in which a portion of the given discharge is assigned to each section. A 2 is used to select method B whereby discharge is computed using slope and conveyance.
N	--	is a counter used to work from one point to the next in working along the cross section. It controls the location in the X, YG, and CN arrays that is being used.
NMAX	--	is the largest value of N being used for each data file. It is the total number of data locations or points across the section.
NPR	--	is the number of piers which will be placed in the bridge opening.
Q	--	is the discharge for each area, A, where Manning's n, CN, remains constant.
Q1	--	is the design discharge for the channel as observed at gauging stations or computed from runoff records.
QA	--	is the discharge which would pass to the left of the left abutment if the bridge were not there.
QB	--	is the discharge through the area AN2.
QC	--	is the discharge which would pass to the right of the right abutment if the bridge were present.
QT	--	is the accumulated discharge for the entire width of the channel cross section for a specified stage, YS.
QV2	--	is the quantity equal to discharge times velocity squared.
R	--	is the hydraulic radius of each subsection and equals the area divided by the wetted perimeter.

RB1 & RB2 -- are the hydraulic radii of area AB1 and AB2.

RTIOJ -- is the ratio of the total area of piers, APRS, divided by the area of the bridge opening, AN2.

SCA, SCB, SCC, and SCD -- are coefficients A, B, C, and D used in the third degree parabolic curve equation for SIGMA in figure 7B.

SIGMA -- is a factor used to modify DLTAK.

SKA, SKB, and SKC -- are coefficients, A, B, and C used in the second degree parabolic curve equation to compute the coefficient for skew effect on backwater.

SKEW -- is a given skew angle.

SKW1 -- is a constant value of skew angle for one of the given equations for the skew curves.

SLOP1 -- is the computed slope of the channel arrived at from the design discharge for the given flood stage as expressed in feet per foot.

SLOPE -- is the same as SLOP1 but is expressed in feet per mile.

SZERO -- is the actual longitudinal slope of the channel.

V -- is the computed value of the velocity for each subsection of the channel cross section.

VN2 -- is the average velocity through the constriction, Q1, divided by AN2.

WP -- is the wetted perimeter of any particular channel subsection.

WPB1 & WPB2 -- are the wetted face lengths of the abutments.

WPR -- is the average width of each pier.

X -- is the distance to the point along the X-axis of the cross section from some fixed reference point. It may be zero or a positive value but not negative. This requires that the X reference point be at the left edge or outside the left side of the cross section.

X1	--	is the positive X-distance from the last X Station to a point where the ground line and the water line intersect (the point where YG is equal to YS). (See Figure A)
XB	--	is the X-distance from the reference point to the point where a section begins due to ground and water elevations being equal. (See Figure A)
XDB	--	is the X-distance from the reference point to the beginning of a section where Manning's n is constant. It will equal XB for the first section. (See Figure A)
XDE	--	is the X-distance from the reference point to the end of a section where Manning's n was constant. This may be a point where n changes or it may be the point where the water ground elevations are equal. (See Figure B)
XDIF	--	is the difference in the X-distances to two adjacent stations. (See Figure C)
XE	--	is the distance from the reference point to the point where a section ends due to ground and water elevations being equal. (See Figure B)
XL	--	is the distance to the top of the left abutment wall from the reference point.
XLG	--	is the distance to the point on the ground at the left wall from the reference point.
XR	--	is the distance to the top of the right wall from the reference point.
XRG	--	is the distance to the point on the ground at the right abutment wall and measured from the reference point.
XX1 & XX2	--	are the horizontal components of the triangle formed by the face of the spillthrough abutment, the water surface and the vertical line from the intersection of the ground line and the abutment. (See Figure D)
Y	--	is the vertical leg of the triangular portion of each unit cross section. (See Figure C)

Y2 -- is the vertical leg of the triangular area formed when the water elevation and the ground elevation are equal within a section. (See Figure B)

YBL -- is the elevation of the top, or bridge contact, of the left abutment wall at XL.

YBR -- is the elevation of the top of the abutment wall, or the bridge contact elevation at XR.

YDIF1 & YDIF2 -- are the vertical distances, Y, between the ground and the water surface at points X(N-1) and X(N) respectively. (See Figure C)

YG -- is a ground elevation or a Y distance of the ground above a fixed datum plane, such as sea level. Its value must always be positive.

YGL -- is the ground elevation at the intersect point XLG.

YGR -- is the ground elevation at the right abutment intersect point at XRG.

YS -- is the stage elevation or water surface elevation.

YSINC -- is the input value by which the stage elevation will be modified to get from the minimum value to the maximum value.

YSMAX -- is the maximum value to be tested of the river stage elevation values.

YSMIN -- is the minimum value to be tested of the stage elevation.

YY1 & YY2 -- are the vertical legs of the triangle formed by the face of a spillthrough abutment, the water surface, and the vertical line from the ground line intersection with the abutment. (See Figure D)

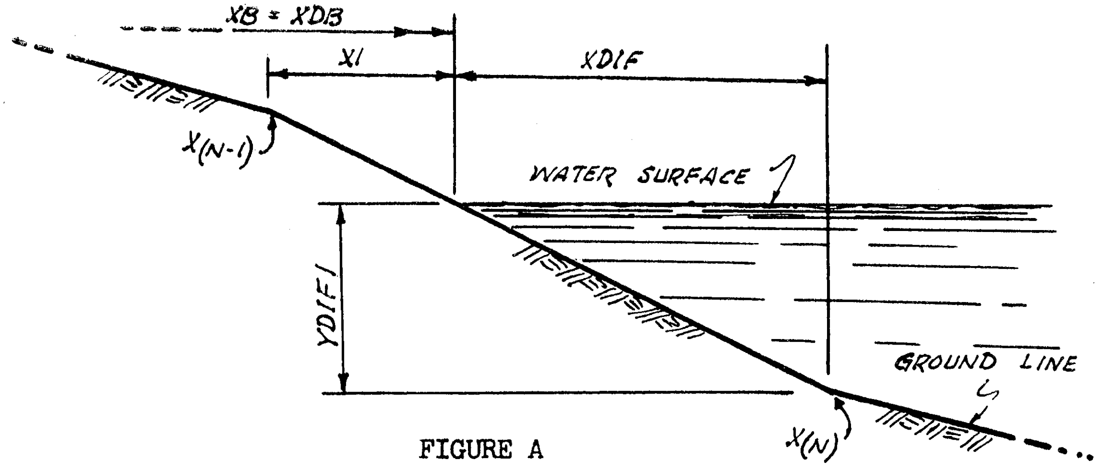


FIGURE A

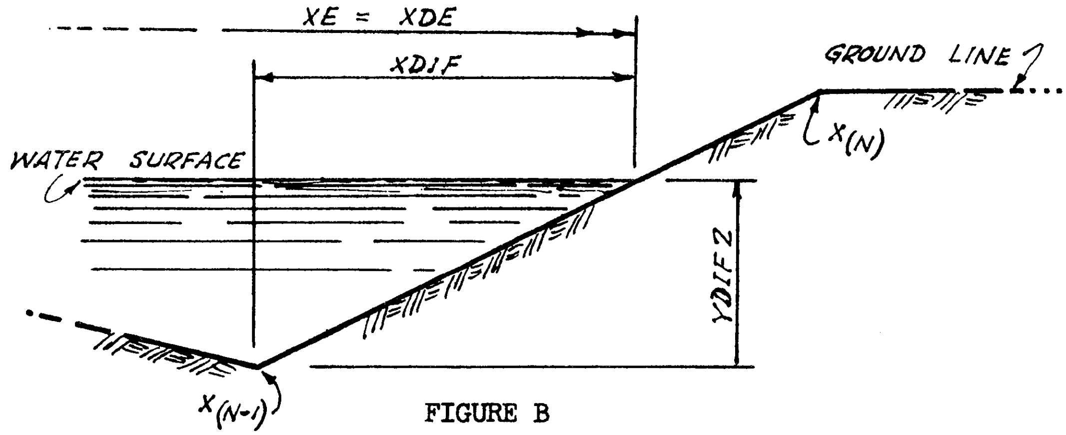


FIGURE B

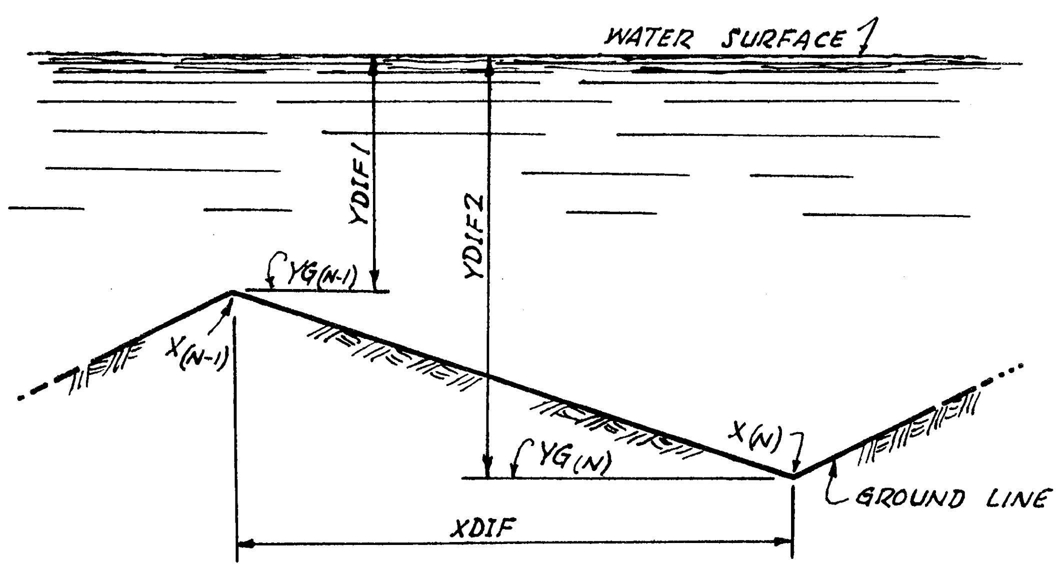


FIGURE C

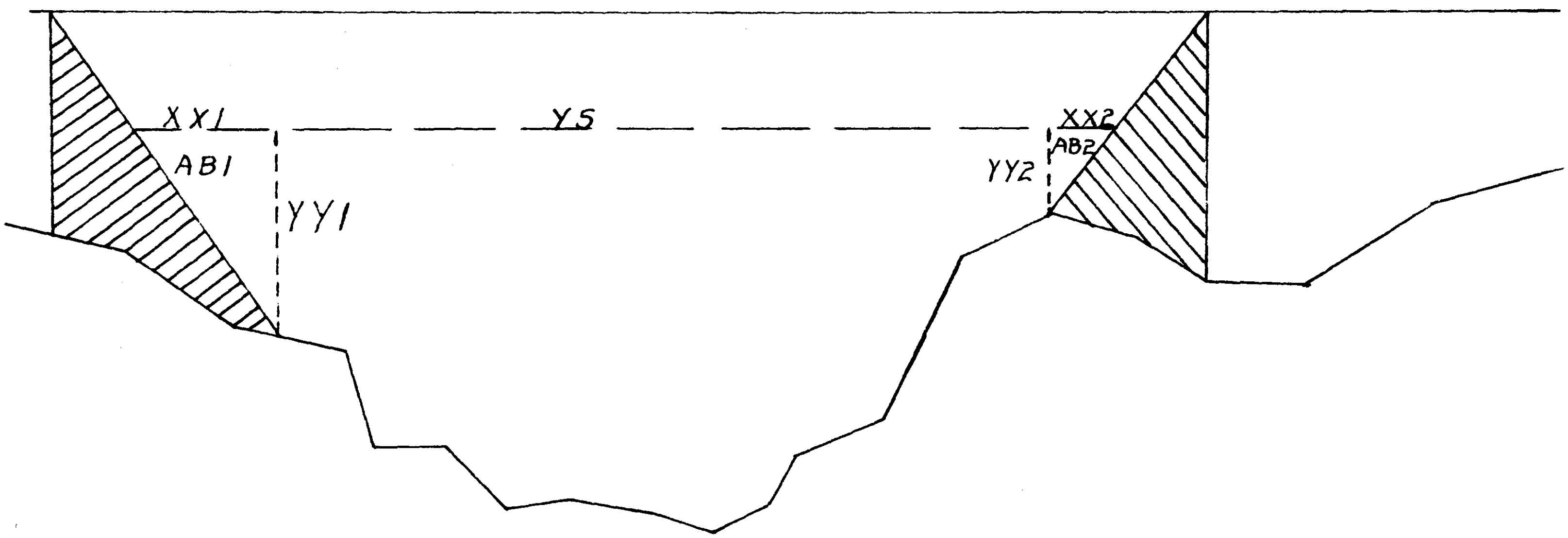


FIGURE D

```
C      COMPUTER PROGRAM FOR COMPUTATION OF BACKWATER CAUSED BY BRIDGES
C      BY K.H.WELTY , BUREAU OF PUBLIC ROADS
C      METHOD (A OR 1) GIVEN THE KNOWN DISCHARGE   OR
C      METHOD (B OR 2) COMPUTING DISCHARGE FROM SLOPE AND CONVEYANCE .
C
C      FIXED POINT WORD LENGTH IS 3 DIGITS
C      FLOATING POINT WORD LENGTH EQUALS
C      MANTISSA OF 8 + CHARACTERISTIC OF 2
C
C      ALL ELEVATION MEASUREMENTS MUST BE POSITIVE IN VALUE WHICH
C      REQUIRES THAT THE DATUM PLANE BE BELOW THE LOWEST CROSS
C      SECTION POINT.
C
C      SZERO SHOULD BE INPUT IN FEET PER FOOT. THE VALUE OF MANNINGS N
C      (CN) IS FOR THE AREA BETWEEN THE STATION  WHERE IT IS ENTERED AS
C      DATA AND THE NEXT STATION.
C
       DIMENSION X( 75),YG( 75),CN( 75),SCA(6),SCB(6),SCC(6),SCD(6)
       DIMENSION Q(20),V(20),BELPR(10),WPR(10),SKA(6),SKB(6),SKC(6)
       DIMENSION  AKBA(6),AKBB(6),AKBC(6),AKBD(6),DTAA(8),DTAB(8)
       DIMENSION  XDB(20), XDE(20), CNC(20), A(20), WP(20), R(20),CON(20)
       DIMENSION ECA(4) , ECB(4) , ECC(4) , ECD(4)
C
C      STORAGE ALLOCATIONS HAVE BEEN MADE. NOW READ IN CONSTANTS FOR USE
C      IN THE EQUATIONS FOR THE CURVES IN FIGURES 5 THRU 10 .
C
       READ1000,(SCA(N) , SCB(N) , SCC(N) , SCD(N) , N=1 , 6 )
       READ1000 ,(AKBA(I),AKBB(I),AKBC(I),AKBD(I),I = 1 , 6 )
       READ1000 ,(DTAA(I) , DTAB(I) , I = 1 , 8 )
       READ1000 , (ECA(I) , ECB(I) , ECC(I) , ECD(I) , I = 1 , 4 )
       READ 1000,(SKA(I),SKB(I),SKC(I),I=1,6)
C
C      READ THE INPUT DATA FOR A CROSS SECTION .
C
   100 READ 1035
       READ 1005,YSMIN,YSMAX,YSINC,Q1,SZERO,NMAX,METHD,IPRT2,IEOF
       READ 1010 , (X(N) , YG(N) , CN(N) , N = 1 , NMAX )
       IF (IPRT2)                103,103,102
C
C      CHECK TO SEE IF PART TWO OF THE PROGRAM IS TO BE WORKED WITH. IF
C      NOT,BRANCH AROUND READING OF DATA CARDS CONTAINING BRIDGE DATA.
C
   102 READ1020,ABTYP,IWWSL,NPR , ITP7A , ITP7B , SKEW
       READ 1025 ,XL, XLG, XRG, XR, YBL, YGL, YGR, YBR
       IF (NPR)                  103,103,2021
  2021 READ1100 ,(BELPR(I) , I = 1,NPR )
       READ1100 ,(WPR(I)   ,   I = 1,NPR )
C
C      INPUT DATA IS IN , NOW MINIMIZE ALL VALUES
C
```

```
  103 YS             = YSMIN
      IPAGE          = 1
  105 N              = 1
      J              = 1
      WDTHT          = 0.0
      QT             = 0.0
      QA             = 0.0
      QB             = 0.0
      QC             = 0.0
      XX1            = 0.0
      XX2            = 0.0
      CONT           = 0.0
      QV2            = 0.0
      AN2            = 0.0
      DO 110    K    = 1 , 20
      A(K)           = 0.0
  110 WP(K)          = 0.0
      GO TO 125
C
C     INCREASE N BY 1 AND CHECK TO SEE IF ITS THE LAST STATION .
C
  115 N              = N + 1
  120 IF (N - NMAX)              125,215,215
  125 YDIF1          = YS - YG(N)
      IF (YDIF1)                 115,145,130
  130 IF (N - 1)                 135,135,140
C
C     IF THE WATER SURFACE IS ABOVE THE GROUND ELEVATION AT THE FIRST
C     STATION, A MESSAGE IS PRINTED STATING SUCH AND THEN THE PROGRAM
C     CHECKS THE END OF FILE .
C
  135 PRINT 1035
      PRINT1015 ,X(N) , YG(N) , YS
      GO TO 815
C
C     INTERPOLATION ROUTINE TO DETERMINE LEFT INTERSECTION POINT OF THE
C     GROUND WITH THE WATER SURFACE.
C
  140 X1             = (YG(N-1)-YS) * (X(N)-X(N-1)) / (YG(N-1)-YG(N))
      XB             = X(N-1) + X1
      XDB(J)         = XB
      XDIF           = X(N) - XB
      YDIF2          = YDIF1
      YDIF1          = 0.0
      XE       = X(N)
      GO TO 170
  145 N              = N + 1
      YDIF2          = YS - YG(N)
      IF (YDIF2)                 120,120,150
  150 XDIF           = X(N) - X(N-1)
```

```
      XDB(J)       = X(N-1)
      YDIF1        = 0.0
      GO TO 170
  155 XDB(J)       = X(N)
  160 N            = N + 1
      YDIF1        = YS - YG(N-1)
      YDIF2        = YS - YG(N)
      IF (YDIF2)               175,165,165
  165 XDIF         = X(N) - X(N-1)
      XE           = X(N)
  170 Y            = YDIF1 - YDIF2
      WDTHT  = WDTHT + XDIF
      A(J)         = A(J) + (YDIF1 + YDIF2) * XDIF / 2.0
      WP(J)        = WP(J) + ( Y * Y + XDIF * XDIF ) * * 0.5
      IF (YDIF2)               190,190,180
C
C     INTERPOLATION ROUTINE TO DETERMINE RIGHT INTERSECTION POINT OF THE
C     GROUND WITH THE WATER SURFACE.
C
  175 XDIF         = (YS-YG(N-1)) * (X(N)-X(N-1)) / (YG(N) - YG(N-1))
      XE           = X(N-1) + XDIF
      XDE(J)       = XE
      YDIF1        = YS - YG(N-1)
      YDIF2        = 0.0
      GO TO 170
  180 IF (CN(N) - CN(N-1))     185,160,185
  185 XE      = X(N)
  190 XDE(J)       = XE
  195 CNC(J)       = CN(N-1)
      R(J)         = A(J) / WP(J)
      CON(J)       =  1.486 / CNC(J)  * A(J) *  R(J)** 0.6667
      CONT         = CONT + CON(J)
      J            = J + 1
      IF (N - NMAX)            200,215,215
  200 IF ( J - 20 )            210,210,205
  205 PRINT 1035
C
C     CORE STORAGE ALLOCATED FOR VARIABLES SUBSCRIPTED WITH J HAS BEEN
C     EXCEEDED AND A MESSAGE IS PRINTED.
C
      PRINT1065
      GO TO 815
  210 IF (YDIF2)               120,120,155
  215 IF (YDIF2)               220,220,216
  216 PRINT 1035
      PRINT1055 , X(N-1) , YG(N-1) , YS
      GO TO 815
  220 IF (CONT)                260,260,222
C
C     CHECK ONLY TO PREVENT PRINTING A ROW OF ZEROS
```

```
C
  222 PRINT 1035
      PRINT 1040 , IPAGE
      PRINT1045 , Q1 , YS, SZERO
      JMAX          = J - 1
      J             = 1
  225 IF (METHD - 1)          230,235,240
  230 PRINT 1035
      PRINT 1075
      GO TO 815
  235 Q(J)          = Q1 * CON(J) / CONT
      GO TO 245
  240 Q(J)          = CON(J) * SZERO ** 0.5
  245 QT            = QT + Q(J)
      IF (A(J))               250,260,250
  250 V(J)          = Q(J) / A(J)
      PRINT1050 ,XDB(J),XDE(J),CNC(J),A(J),WP(J),R(J),CON(J),Q(J),V(J)
      IF (J - JMAX)           255,260,260
  255 J             = J + 1
      GO TO 225
  260 ATOT          = 0.0
      DO 265   J = 1 , JMAX
      QV2           = QV2 + Q(J) * V(J) * V(J)
  265 ATOT          = ATOT + A(J)
      PRINT 1130 , ATOT , CONT , QT
      IF (METHD - 1)          270,275,280
  270 PRINT 1075
      GO TO 815
  275 SLOP1         = (QT / CONT) ** 2.0
      SLOPE         = SLOP1  * 5280.0
      PRINT1070 , SLOPE , SLOP1
  280 IF  (IPRT2)             805,805,285
C
C     IF IPRT2 IS EQUAL TO ZERO THE COMPUTATIONS WILL BRANCH AROUND THE
C     HEADWATER PORTION OF THE PROGRAM BUT BRIDGE DATA CARDS MUST BE
C     INCLUDED IN THE DECK.
C
  285 ALPHA   =(QV2 * ATOT * ATOT) / QT ** 3.0
      J             = 0
  290 J       = J + 1
      IF(XLG - XDE(J))        296,295,295
  295 QA      = QA + Q(J)
C
C     ACCUMULATE DISCHARGE LEFT OF LEFT ABUTMENT.
C
      GO TO 290
  296 IF(XLG - XDB(J))        300,300,297
  297 PRINT 1035
      PRINT 1080
      GO TO 815
```

```
  300 IF(ABTYP - 5.0)           310,345,305
  305 IF(ABTYP - 6.0)           310,315,310
  310 PRINT 1035
      PRINT 1095
      GO TO 815
  315 IF (YS - YGL)             345,341,320
  320 YY1      = YS - YGL
      XX1      =YY1*(XLG - XL) / (YBL - YGL)
      AB1      = XX1 * YY1 * 0.5
      AN2      = AB1
      QB1      = Q(J-1) * AB1 / A(J-1)
      QB       =QB1
      QA       = QA - QB1
      GO TO 341
  340 J        = J + 1
  341 IF (XRG - XDE(J))         346,345,345
  345 AN2      = AN2 + A(J)
C
C     ACCUMULATE AREA AND DISCHARGE THRU BRIDGE OPENING.
C
      QB       = QB + Q(J)
      IF(J-JMAX)      340,415,415
  346 IF (XRG - XDB(J))         365,370,355
  355 PRINT 1035
      PRINT 1085
      GO TO 815
  365 IF (YS - YGR)             400,400,370
  370 IF (ABTYP - 6.0)          400,375,310
  375 YY2      = YS - YGR
      XX2      = YY2 *(XR-XRG)/(YBR-YGR)
      AB2      = XX2 * YY2 * 0.5
      AN2      = AN2 + AB2
      QB2      = Q(J) * AB2 / A(J)
      QB       = QB + QB2
      QC       = QC - QB2
      GO TO 400
  395 J        = J + 1
  400 QC       = QC + Q(J)
C
C     ACCUMULATE DISCHARGE RIGHT OF THE RIGHT ABUTMENT.
C
      IF (J-JMAX)        395,405,405
  405 T = XX1 + XRG - XLG + XX2
C
C     COMPUTE CRITICAL VELOCITY AND FROUDE NUMBER TO DETERMINE VALIDITY
C     OF THIS METHOD OF BACKWATER COMPUTATION. MESSAGE GIVEN IF INVALID
C
      VC = (32.2 * AN2 / T)** 0.5
      VN2= QT / AN2
      FRDNO= VN2 / VC
```

```
    IF (FRDNO - 0.9) 415,410,410
410 IF( QT -Q1)  411 ,412,412
411 PRINT 1155
    GO TO 805
412 PRINT 1150 , VC , VN2
    GO TO 805
415 J          = 0
    DRM        = QB / QT
    AKB = AKBA(IWWSL)+(AKBB(IWWSL)+(AKBC(IWWSL)+AKBD(IWWSL)*DRM)*DRM)*
   1DRM
    IF (AKB)                    420,425,425
420 AKB        = 0.0
425 APRS      = 0.0
    DO 430     I = 1 , NPR
    HTPR    = YS - BELPR(I)
    IF (HTPR)                   428,430,430
428 HTPR    = 0.0
430 APRS    = APRS + WPR(I) * HTPR
    RTIOJ   = APRS / AN2
    DLTAK =  DTAA(ITP7A) + DTAB(ITP7A) * RTIOJ
    IF (DLTAK)                  435,440,440
435 DLTAK      = 0.0
440 SIGMA=SCA(ITP7B)+(SCB(ITP7B)+(SCC(ITP7B)+SCD(ITP7B)*DRM)*DRM)*DRM
    IF (QA - QC)                445,470,450
445 E       =1.0- QA / QC
    GO TO 455
450 E       =1.0- QC / QA
455 ECON    = 0.80
    IEC     = 0
    IF (E- 0.80 )  470,470,460
470 DKE     = 0.0
    GO TO 500
460 ECON    = ECON + 0.05
    IEC     = IEC + 1
    IF (ECON - 1.0)             465,465,495
465 IF(E - ECON)  490 ,480 ,460
480 DKE  = ECA(IEC)+(ECB(IEC)+(ECC(IEC)+ECD(IEC)*DRM)*DRM)*DRM
    GO TO 500
490 IF(IEC-1)                   460,491,492
491 DKE1    = 0.0
    GO TO 493
492 DKE1= ECA(IEC-1)+(ECB(IEC-1)+(ECC(IEC-1)+ECD(IEC-1)*DRM)*DRM)*DRM
493 DKE2= ECA(IEC)+(ECB(IEC)+(ECC(IEC)+ECD(IEC)*DRM)*DRM)*DRM
    DKE = DKE1 + (DKE2-DKE1)*((E-ECON+.05) / 0.05 )
    GO TO 500
495 PRINT 1035
    PRINT 1135
    GO TO 815
500 SKW1    =0.0
    IF (ABTYP - 6.0)        510,520,310
```

```
  510 ISKW    = 0
      GO TO 530
  520 ISKW    = 3
  530 IF (SKEW )                 545,545,535
  535 ISKW    = ISKW + 1
      SKW1    = SKW1 + 15.0
      GO TO 550
  545 DKS     = 0.0
      GO TO 800
  550 IF (SKEW - 15.0)           560,575,555
  555 IF (SKEW - SKW1)           565,575,535
  560 DKS1     = 0.0
      GO TO 570
  565 DKS1    = SKA(ISKW-1)+(SKB(ISKW-1)+SKC(ISKW-1)*DRM)*DRM
  570 DKS2    = SKA(ISKW)+(SKB(ISKW)+SKC(ISKW)*DRM)*DRM
      DKS     = DKS1 + (DKS2 - DKS1)*( SKEW - SKW1 + 15.0)/ 15.0
      GO TO 800
  575 DKS     = SKA(ISKW)+(SKB(ISKW)+SKC(ISKW)*DRM)*DRM
  800 COEFK   = AKB+DLTAK * SIGMA + DKE + DKS
      HEAD        =(VN2 * VN2)/  64.34
      BWAP1   = COEFK * HEAD
      AA1     = BWAP1 * WDTHT
      BWAP2   = BWAP1 + (AN2 * AN2 / (ATOT * ATOT) - AN2 * AN2 /((ATOT +
     1AA1) * (ATOT + AA1))) * ALPHA * HEAD
      AA2     = BWAP2 * WDTHT
      BWAP3   = BWAP1 + (AN2 * AN2 / (ATOT * ATOT) - AN2 * AN2 /((ATOT +
     1AA2) * (ATOT + AA2))) * ALPHA * HEAD
      IABTP   =ABTYP
      ISKEW   =SKEW
      PRINT 1105 , IABTP , IWWSL , ISKEW , ITP7A , ITP7B , NPR
      PRINT 1120,QA,QB,QC,AN2,VN2,DRM,RTIOJ,COEFK,BWAP1,BWAP2,BWAP3
  805 IF (YS - YSMAX)            810,815,815
  810 IPAGE        = IPAGE + 1
      YS           = YS + YSINC
      GO TO 105
  815 IF(IEOF)                   100,100,820
  820 TYPE  1060
      STOP 111
C
 1000 FORMAT(4F12.6)
 1005 FORMAT(4F12.2,F12.6 ,4I3 )
 1010 FORMAT(3(F8.2,F7.2,F6.4))
 1015 FORMAT(42H  INSUFFICIENT GROUND DATA ON THE LEFT AT /23H    GROUND
     1 DATA , X =   ,F8.2,7H YG =   ,F8.2,19H STAGE ELEVATION = ,F8.2)
 1020 FORMAT(F9.2,4I9,F9.2)
 1025 FORMAT (8F9.2)
 1035 FORMAT(70H1
     1                )
 1040 FORMAT(105X,6HPAGE   ,I3)
 1045 FORMAT(14HK    INPUT DATA//6X,20H DESIGN DISCHARGE = ,F10.2,19H  ST
```

```
     1AGE ELEVATION =,F9.2,19H  SLOPE OF RIVER = ,F12.6,15H  FEET PER FO
     2OT//18H    RESULTANT DATA //7X,32H X BEGINNING    X ENDING   MANNI
     3,83HNGS N     AREA      WETTED PER     HYD.RADIUS    CONVEYANCE
     4DISCHARGE     VELOCITY)
 1050 FORMAT(F16.2,F14.2,F12.4,F13.2,F12.2,F14.4,2F14.2,F12.2)
 1055 FORMAT(42H  INSUFFICIENT GROUND DATA ON THE RIGHT AT/23H    GROUND
     1 DATA , X =   ,F8.2,7H YG =   ,F8.2,18H STAGE ELEVATION =,F8.2)
 1060 FORMAT(// 10HEND OF RUN)
 1065 FORMAT(48H THE NUMBER OF CHANGES OF MANNINGS N IS TOO MANY)
 1070 FORMAT(21HK    SLOPE OF RIVER =,F10.2,18H  FEET PER MILE = ,F10.6,
     117H    FEET PER FOOT)
 1075 FORMAT(23H ERROR IN CODING METHOD)
 1080 FORMAT( 62HK XLEFT IS NOT A MANNINGS N CHANGE POINT IN THE CROSS S
     1ECTION. )
 1085 FORMAT( 63HK XRIGHT IS NOT A MANNINGS N CHANGE POINT IN THE CROSS
     1SECTION.)
 1095 FORMAT(33H   ERROR IN CODING ABUTMENT TYPE.)
 1100 FORMAT(10F7.2)
 1105 FORMAT(27HL  BRIDGE INFORMATION INPUT// 20H    ABUTMENT TYPE = ,
     1I6  ,26H    ABUTMENT CURVE NO. = ,I2,16H    SKEW ANGLE = ,I6   /
     230H    CURVE USED ON FIGURE 7A = ,I2,31H     CURVE USED ON FIGURE
     37B = ,I2,20H     NO. OF BENTS = ,I2 )
 1120 FORMAT  (25HL  CALCULATED INFORMATION/6H    QA,44X,1H=,F9.2/42H
     1 PORTION OF DISCHARGE THRU OPENING - QB,8X,1H=,F9.2/6H    QC,44X,1
     2H=,F9.2/7H    AN2,43X,1H=,F9.2/7H    VN2,43X,1H=,F9.2/23H    DISCH
     3ARGE RATIO - M,27X,1H=,F6.3/26H    RATIO OF AREAS - RTIOJ,24X,1H=,
     4F6.3/25H    TOTAL COEFFICIENT - K,25X,1H=,F6.3/32H    BACKWATER AP
     5PROXIMATION NO.1,18X,1H=,F6.3/32H    BACKWATER APPROXIMATION NO.2,
     618X,1H=,F6.3/32H    BACKWATER APPROXIMATION NO.3,18X,1H=,F6.3)
 1125 FORMAT (F9.1 )
 1130 FORMAT (16HK   TOTAL AREA =,F10.2 , 22H    CONVEYANCE TOTAL =,
     1          F14.2 , 21H    TOTAL DISCHARGE =,F10.2 )
 1135 FORMAT (21H    ECON EXCEEDED 1.0)
 1150 FORMAT(23HL   CRITICAL VELOCITY =,F6.2/42H    AVERAGE VELOCITY THR
     1OUGH THE OPENING =,F6.2/34H    THIS DESIGN METHOD IS INVALID )
 1155 FORMAT (82HL   VELOCITY EXCEEDS CRITICAL - BACKWATER CALCULATIONS
     1INVALID - CHECK NEXT STAGE )
C
      END
```

YSMIN	YSMAX	YSINC	QI	SZERO	NMAX	METHD	IPAT2	IEOF	
910.0	930.0	2.0	70000.0	0.00045	21	2	1	1	1

X	YG	CN	X	YG	CN	X	YG	CN	
0.0	938.0	0.03	25.0	935.0	0.07	55.0	925.0	0.07	2

1	SPECIAL PROBLEM FOR BRIDGE BACKWATER PROGRAM DEVELOPMENT DEC. 1963	9

TITLE CARD

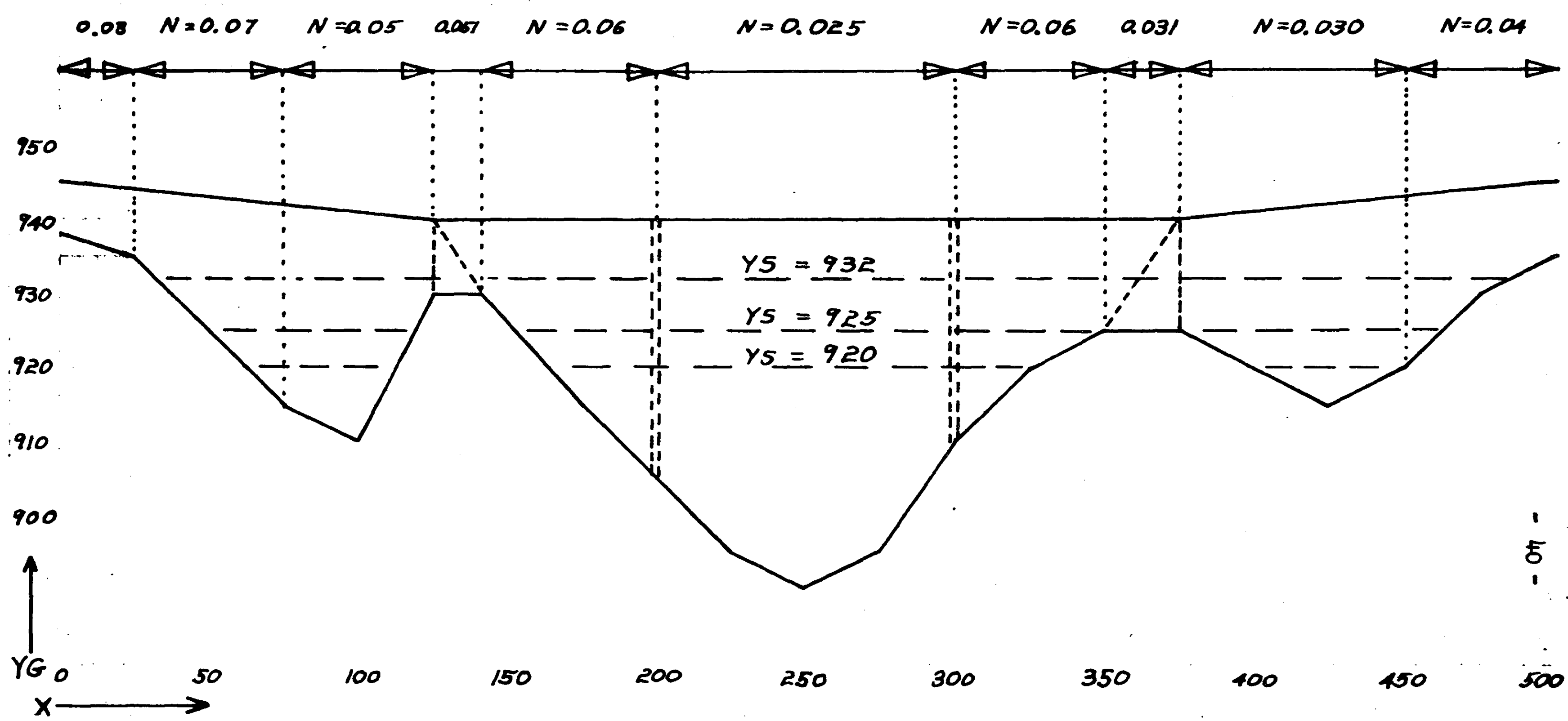
ABTYP	IWWSL	NPR	ITP7A	ITP7B	SKEW	
6.0	5	2	8	1	0.0	10

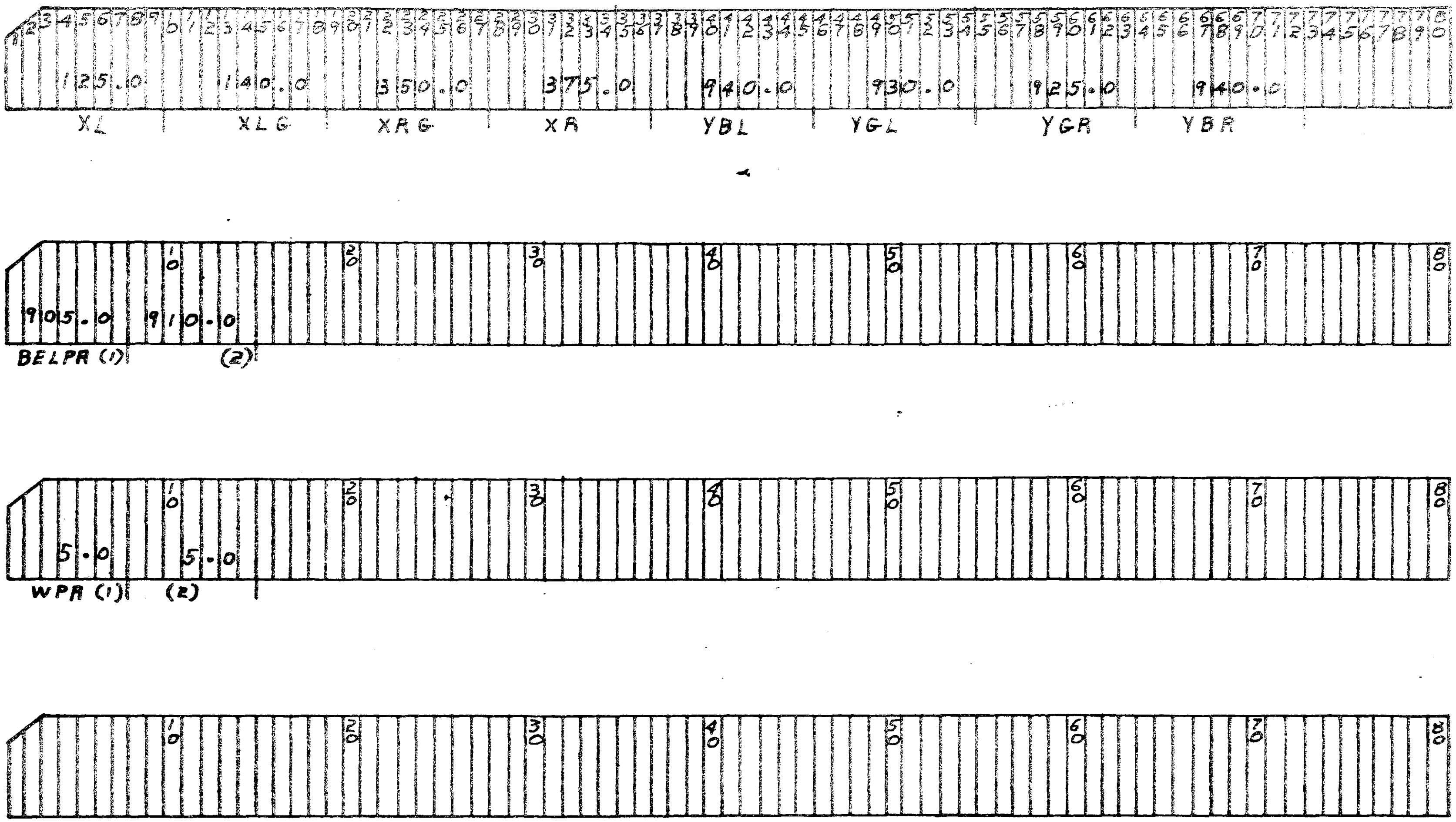
SAMPLE INPUT DATA CARDS FOR SAMPLE PROBLEM

Q1 = 70,000 CFS

XL = 125
XLG = 140
XRG = 350
XR = 375

YBL = 940
YGL = 930
YGR = 925
YBR = 940





SAMPLE INPUT DATA CARDS FOR SAMPLE PROBLEM

1 SPECIAL PROBLEM FOR BRIDGE BACKWATER PROGRAM DEVELOPMENT DEC.1963

INPUT DATA

DESIGN DISCHARGE # 70000.00
STAGE ELEVATION # 920.00
SLOPE OF RIVER # .000450 FEET PER FOOT

RESULTANT DATA

X BEGINNING	X ENDING	MANNINGS N	AREA	WETTED PER
62.50	75.00	.0700	31.25	13.46
75.00	112.50	.0500	250.00	41.50
163.33	200.00	.0600	279.16	39.61
200.00	300.00	.0250	2312.50	107.07
300.00	325.00	.0600	125.00	26.92
400.00	450.00	.0300	125.00	50.99

HYD.RADIUS	CONVEYANCE	DISCHARGE	VELOCITY
2.3211	1163.02	24.67	.78
6.0236	24599.28	521.82	2.08
7.0463	25413.68	539.10	1.93
21.5978	1066134.90	22616.13	9.77
4.6423	8615.76	182.76	1.46
2.4514	11257.34	238.80	1.91

TOTAL AREA # 3122.91
TOTAL CONVEYANCE # 1137183.80
TOTAL DISCHARGE # 24123.31

BRIDGE INFORMATION INPUT

ABUTMENT TYPE # 6
ABUTMENT CURVE NO. # 5
SKEW ANGLE # 0
CURVE USED ON FIGURE 7A # 8
CURVE USED ON FIGURE 7B # 1
NO. OF BENTS # 2

CALCULATED INFORMATION

QA # 546.50
PORTION OF DISCHARGE THRU OPENING - QB # 23338.00
QC # 238.80
AN2 # 2716.66
VN2 # 8.87
DISCHARGE RATIO - M # .967
RATIO OF AREAS - RTIOJ # .046
TOTAL COEFFICIENT - K # .085
BACKWATER APPROXIMATION NO.1 # .104
BACKWATER APPROXIMATION NO.2 # .129
BACKWATER APPROXIMATION NO.3 # .134

1 SPECIAL PROBLEM FOR BRIDGE BACKWATER PROGRAM DEVELOPMENT DEC.1963

INPUT DATA

DESIGN DISCHARGE # 70000.00
STAGE ELEVATION # 925.00
SLOPE OF RIVER # .000450 FEET PER FOOT

RESULTANT DATA

X BEGINNING	X ENDING	MANNINGS N	AREA	WETTED PER
50.00	75.00	.0700	125.00	26.92
75.00	118.75	.0500	453.12	49.50
151.66	200.00	.0600	491.66	52.31
200.00	300.00	.0250	2812.50	107.07
300.00	350.00	.0600	312.50	52.42
375.00	450.00	.0300	437.50	76.48
450.00	462.50	.0400	31.25	13.46

HYD.RADIUS	CONVEYANCE	DISCHARGE	VELOCITY
4.6423	7384.93	156.65	1.25
9.1527	58929.70	1250.08	2.75
9.3987	54235.67	1150.51	2.34
26.2676	1477405.20	31340.49	11.14
5.9613	25447.21	539.81	1.72
5.7200	69316.11	1470.41	3.36
2.3211	2035.29	43.17	1.38

TOTAL AREA # 4663.54
TOTAL CONVEYANCE # 1694754.00
TOTAL DISCHARGE # 35951.16

BRIDGE INFORMATION INPUT

ABUTMENT TYPE # 6
ABUTMENT CURVE NO. # 5
SKEW ANGLE # 0
CURVE USED ON FIGURE 7A # 8
CURVE USED ON FIGURE 7B # 1
NO. OF BENTS # 2

CALCULATED INFORMATION

QA # 1406.74
PORTION OF DISCHARGE THRU OPENING - QB # 33030.82
QC # 1513.59
AN2 # 3616.66
VN2 # 9.94
DISCHARGE RATIO - M # .918
RATIO OF AREAS - RTIOJ # .048
TOTAL COEFFICIENT - K # .132
BACKWATER APPROXIMATION NO.1 # .203
BACKWATER APPROXIMATION NO.2 # .255
BACKWATER APPROXIMATION NO.3 # .267

1 SPECIAL PROBLEM FOR BRIDGE BACKWATER PROGRAM DEVELOPMENT DEC.1963

INPUT DATA

DESIGN DISCHARGE # 70000.00
STAGE ELEVATION # 930.00
SLOPE OF RIVER # .000450 FEET PER FOOT

RESULTANT DATA

X BEGINNING	X ENDING	MANNINGS N	AREA	WETTED PER
37.50	75.00	.0700	281.25	40.38
75.00	125.00	.0500	687.50	57.51
140.00	200.00	.0600	762.50	65.00
200.00	300.00	.0250	3312.50	107.07
300.00	350.00	.0600	562.50	52.42
350.00	375.00	.0310	125.00	24.99
375.00	450.00	.0300	812.50	76.48
450.00	475.00	.0400	125.00	26.92

HYD.RADIUS	CONVEYANCE	DISCHARGE	VELOCITY
6.9635	21773.56	461.88	1.64
11.9542	106833.29	2266.27	3.29
11.7299	97500.40	2068.29	2.71
30.9374	1940621.80	41166.80	12.42
10.7304	67780.21	1437.83	2.55
5.0000	17521.46	371.68	2.97
10.6229	194499.58	4125.95	5.07
4.6423	12923.64	274.15	2.19

TOTAL AREA # 6668.75
TOTAL CONVEYANCE # 2459453.70
TOTAL DISCHARGE # 52172.89

BRIDGE INFORMATION INPUT

ABUTMENT TYPE # 6
ABUTMENT CURVE NO. # 5
SKEW ANGLE # 0
CURVE USED ON FIGURE 7A # 8
CURVE USED ON FIGURE 7B # 1
NO. OF BENTS # 2

CALCULATED INFORMATION

QA	#	2728.16
PORTION OF DISCHARGE THRU OPENING - QB	#	44734.88
QC	#	4709.84
AN2	#	4658.33
VN2	#	11.19
DISCHARGE RATIO - M	#	.857
RATIO OF AREAS - RTIOJ	#	.048
TOTAL COEFFICIENT - K	#	.209
BACKWATER APPROXIMATION NO.1	#	.409
BACKWATER APPROXIMATION NO.2	#	.506
BACKWATER APPROXIMATION NO.3	#	.527

1 SPECIAL PROBLEM FOR BRIDGE BACKWATER PROGRAM DEVELOPMENT DEC.1963

INPUT DATA

DESIGN DISCHARGE # 70000.00
STAGE ELEVATION # 935.00
SLOPE OF RIVER # .000450 FEET PER FOOT

RESULTANT DATA

X BEGINNING	X ENDING	MANNINGS N	AREA	WETTED PER
25.00	75.00	.0700	500.00	53.85
75.00	125.00	.0500	937.50	57.51
125.00	140.00	.0510	75.00	14.99
140.00	200.00	.0600	1062.50	65.00
200.00	300.00	.0250	3812.50	107.07
300.00	350.00	.0600	812.50	52.42
350.00	375.00	.0310	250.00	24.99
375.00	450.00	.0300	1187.50	76.48
450.00	500.00	.0400	312.50	52.42

HYD.RADIUS	CONVEYANCE	DISCHARGE	VELOCITY
9.2847	46892.52	994.74	1.98
16.3013	179146.67	3800.27	4.05
5.0000	6390.18	135.55	1.80
16.3449	169496.08	3595.55	3.38
35.6072	2453011.90	52036.24	13.64
15.4995	125105.48	2653.88	3.26
10.0000	55628.46	1180.05	4.72
15.5258	366106.89	7766.30	6.54
5.9613	38170.82	809.72	2.59

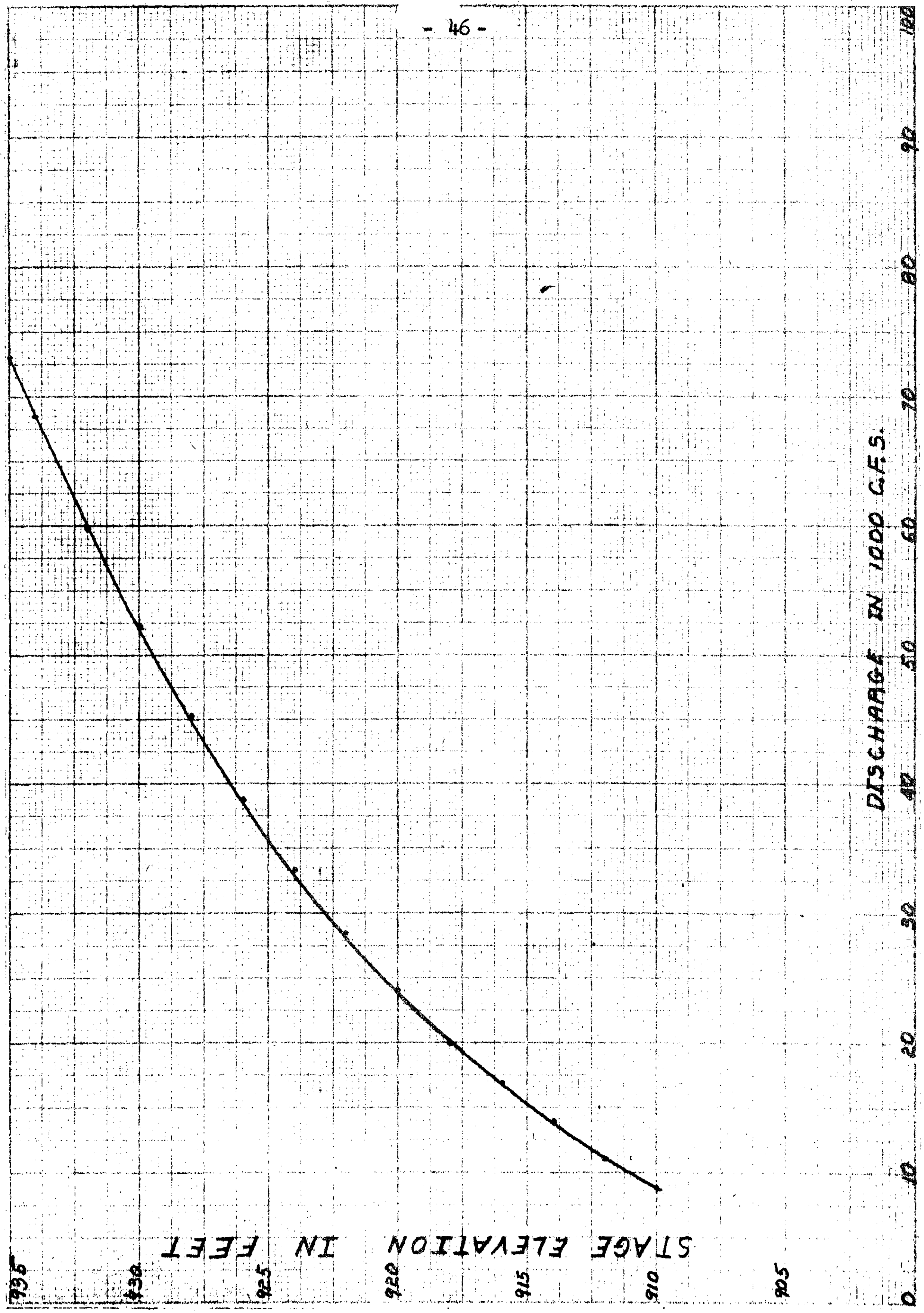
TOTAL AREA # 8950.00
TOTAL CONVEYANCE # 3439948.70
TOTAL DISCHARGE # 72972.33

BRIDGE INFORMATION INPUT

ABUTMENT TYPE # 6
ABUTMENT CURVE NO. # 5
SKEW ANGLE # 0
CURVE USED ON FIGURE 7A # 8
CURVE USED ON FIGURE 7B # 1
NO. OF BENTS # 2

CALCULATED INFORMATION

QA # 4896.68
PORTION OF DISCHARGE THRU OPENING - QB # 58712.92
QC # 9362.73
AN2 # 5789.58
VN2 # 12.60
DISCHARGE RATIO - M # .804
RATIO OF AREAS - RTIOJ # .047
TOTAL COEFFICIENT - K # .293
BACKWATER APPROXIMATION NO.1 # .723
BACKWATER APPROXIMATION NO.2 # .881
BACKWATER APPROXIMATION NO.3 # .913


DISCHARGE IN 1000 C.F.S.
0
10
20
30
40
50
60
70
80
90
100
STAGE ELEVATION IN FEET
935
930
925
920
915
910
905