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WATER SURFACE PROFILE COMPUTA USING COMPUTER PROGRAM HEC-2

VIDEO TAPE PRESENTATION

FOR FLOOD CONTROL DISTRICT PERSONNEL

Oct. 1	Basic Input Requirements for HEC-2 /	36 min.
Oct. 2	Water Surface Profile Computations Part I	69 min.
Oct. 3	Water Surface Profile Computations Part II	75 min.
Oct. 4	Data Requirements for River Models /	67 min.
Oct. 5	Capabilities of HEC-2 Program Part 1 & 2	80 min.
Oct. 9	HEC-2 Output Analysis /	60 min.
Oct. 10	Water Surface Through Bridges & Computer Requirements for Bridge Flow Part I	75 min.
Oct. 11	Water Surface Through Bridges & Computer Requirements for Bridge Flow Part II	66 min.
Oct. 12	Normal Bridge Routine Part 1 & 2	85 min.

Additional Showing Week of Oct. 15-19:

Floodway Determinations Part	69 min.

Showings will begin at 3:30 P. M. each day with the exceptions of October 1 and 9, when they will begin immediately after the staff meetings.

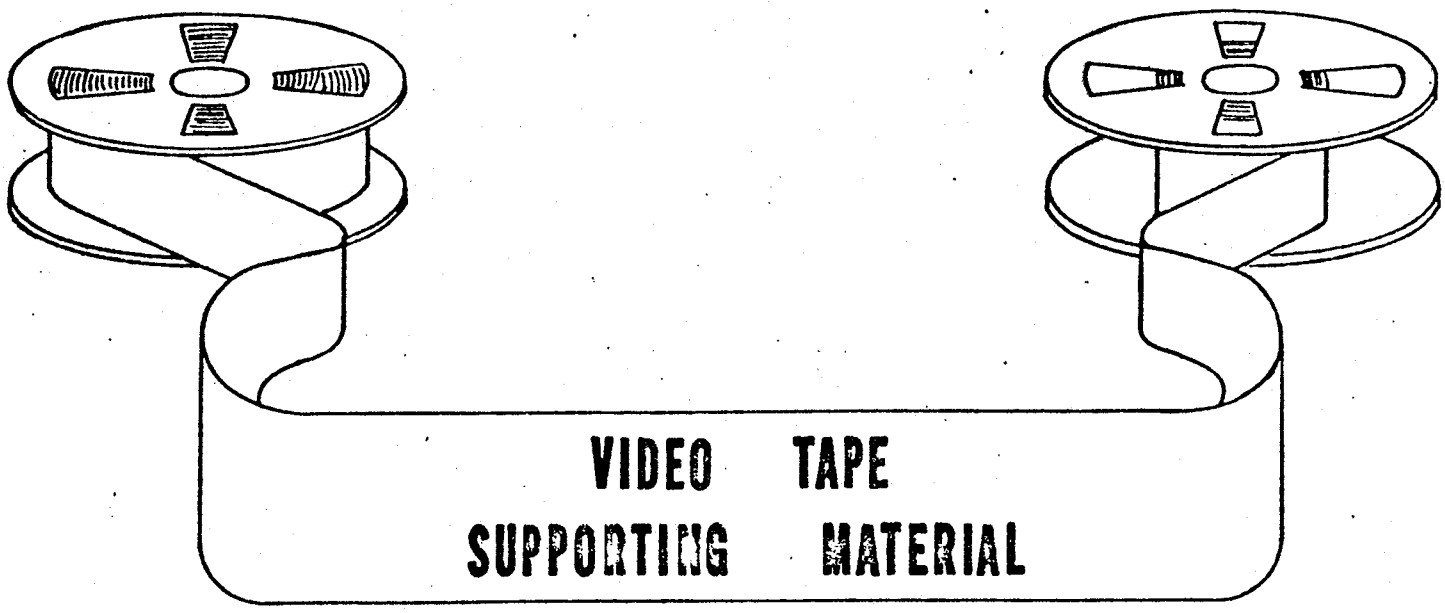
Video equipment is available all day on all dates for additional showing.

Supporting materials and references available through Hydrology section.

65B

JT

Tape No. 14,15



WATER SURFACE PROFILE COMPUTATIONS

11 JUNE 1974

THE HYDROLOGIC ENGINEERING CENTER
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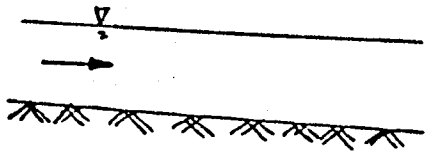
WATER SURFACE PROFILE COMPUTATION

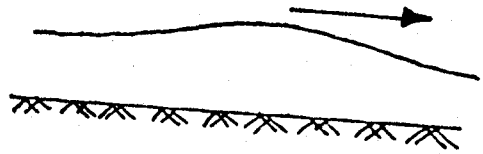
1. Classifications of Open Channel Flow

a. Steady vs unsteady



Steady Flow

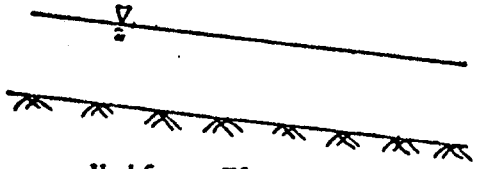
Depth and velocity at a given location do not vary with time.



Unsteady Flow

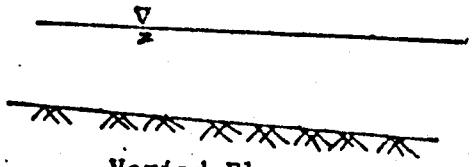
Depth and velocity vary with time at a given location.

b. Uniform vs varied



Uniform Flow

Depth and velocity are constant with distance along the channel.



Varied Flow

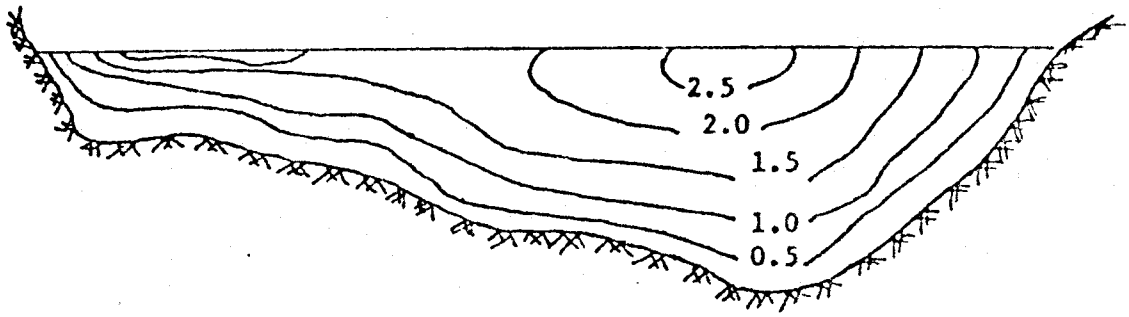
Depth and velocity vary with distance along the channel.

Gradually varied flow - depth changes gradually over a long distance.

Rapidly varied flow - depth changes abruptly over a short distance.

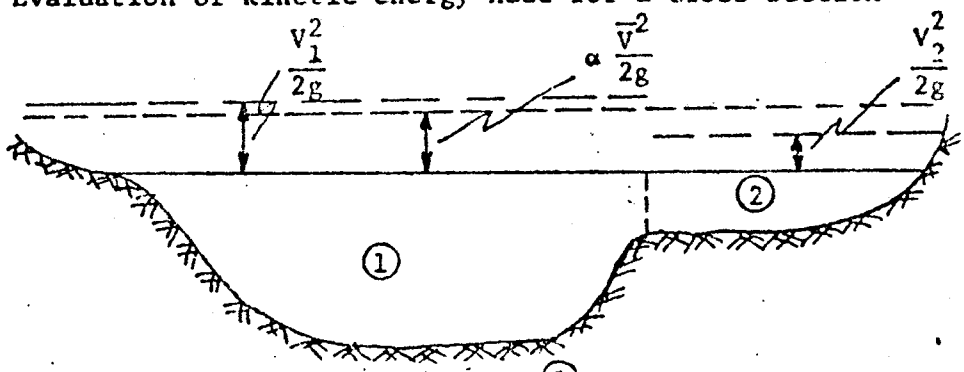
2. Velocity Distribution in a Cross Section

a. Factors influencing velocity distribution



Velocity distribution is affected by shape of cross section, roughness of boundaries, presence of bends, etc.

b. Evaluation of kinetic energy head for a cross section



V_1 = mean velocity for subarea 1

V_2 = mean velocity for subarea 2

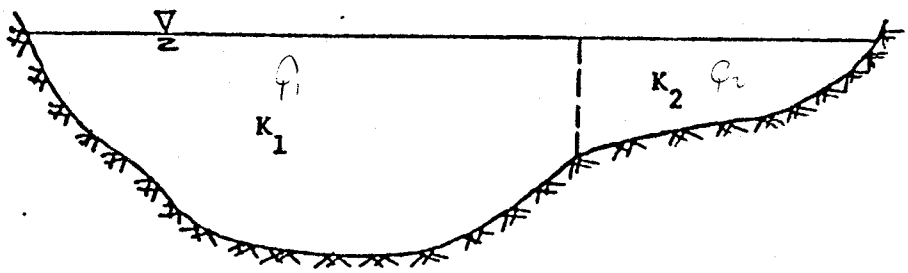
d. Determining flow distribution in a cross section

$$V = \frac{1.5}{n} R^{2/3} S_f^{1/2} \qquad \text{(Manning eq.)}$$

$$Q = VA = \left(\frac{1.5}{n} AR^{2/3}\right) S_f^{1/2}$$

Let K = conveyance $= \frac{1.5}{n} AR^{2/3}$

Then $Q = KS_f^{1/2}$



For a given water surface and total discharge, determine Q_1 and Q_2

$$S_f^{1/2} = \frac{Q}{K}$$

Assume S_f is a constant for a cross section

Then $Q_1 = K_1 S_f^{1/2}$

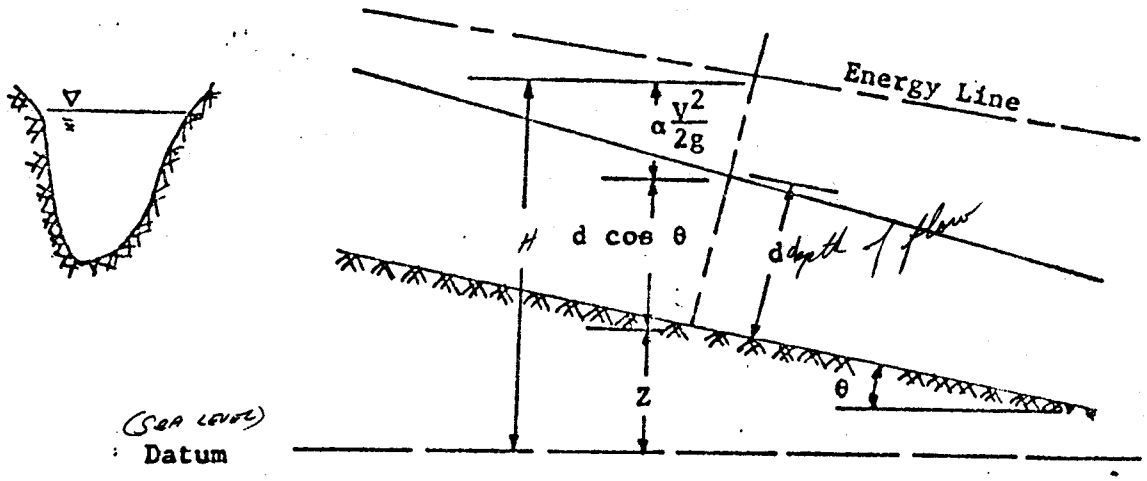
$Q_2 = K_2 S_f^{1/2}$

The pressure distribution in a still body of water is hydrostatic, which means that the pressure head is everywhere equal to the depth below the water surface.

A hydrostatic pressure distribution may be assumed to exist in a moving fluid where streamlines are approximately straight and parallel.

4. Energy Principles

a. Total energy head for a cross section



$$H = Z + d \cos\theta + \alpha\frac{V^2}{2g}$$

velocity head

For a bed slope of 1:10, $\theta = 5^{\circ}\ 40'$ and $\cos\theta = 0.99$. The $\cos\theta$ term in the energy equation is usually assumed equal to 1.

PERPENDICULAR TO FLOW

d. Energy losses

(1) Total loss

$$h_e = h_f + h_o$$

where h_e = total energy loss

h_f = energy loss due to friction

h_o = other losses

(2) Contraction and expansion losses

Contraction

$$h_o = C_c \left| \alpha_1 \frac{V_1^2}{2g} - \alpha_2 \frac{V_2^2}{2g} \right|$$

and

expansion

$$h_o = C_e \left| \alpha_1 \frac{V_1^2}{2g} - \alpha_2 \frac{V_2^2}{2g} \right|$$

where

C_c = Empirical contraction coefficient

C_e = Empirical expansion coefficient

$\alpha_1 \frac{V_1^2}{2g}$ = Upstream velocity head

$\alpha_2 \frac{V_2^2}{2g}$ = Downstream velocity head

Typical values

C_c 0.1 to 0.5

C_e 0.3 to 1.0

5. Standard Step Method

a. Computational procedure

(1) Estimate water surface elevation

(2) Calculate hydraulic properties that correspond to estimated water surface elevation

(3) Determine energy losses that correspond to estimated water surface elevation

(4) Calculate water surface elevation using energy equation and energy losses determined in (3)

(5) Compare estimated and computed water surface elevations

b. Example calculation

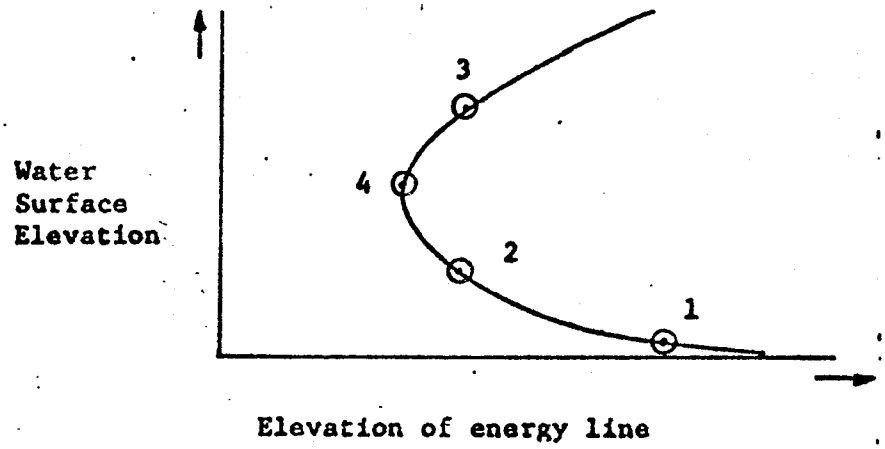
6. Critical depth and its significance

a. Definition of critical depth

The depth at which total energy head is a minimum for a given discharge.

b. Computation of critical depth in irregular channels

Minimize $Z + y + \alpha \frac{V^2}{2g}$



II

c. Controls and their significance in open channel flow

References:
a. Henderson, F. M., Open Channel Flow, MacMillan, 1966.
b. Ven Te Chow, Open Channel Hydraulics, McGraw-Hill, 1959.
c. EM 1110-2-1409, "Backwater Curves in River Channels," Corps of Engineers, 1959.
d. U. S. Army Corps of Engineers, Water Surface Profiles, IHD Volume 6, The Hydrologic Engineering Center, July 1972.

Tape No. 17

DATA REQUIREMENTS FOR RIVER MODELS

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DATA REQUIREMENTS FOR RIVER MODELS

Conference

1. What are the required data?

   a. Flow - usually a flood peak discharge estimated by statistical analysis of observed data or by rainfall-runoff calculations

   b. Flow regime - either subcritical or supercritical flow

   c. Starting water surface elevation

   d. Energy loss coefficients

   e. Cross sections

   f. Reach lengths

2. Developing the Geometric Model

   a. Cross Section Requirements

      (1) To model the geometry of river and flood plains

      (2) To model the flow boundary

(b) The distribution of flow from section to section should be reviewed to ensure reasonable flow transition from section to section.

(c) Change in conveyance from section to section could be another criterion for evaluating loss calculations.

(9) A Minnesota Proposal (Reference 3) sets the maximum reach lengths to 1/2 mile for wide flood plains and slopes less than 2 feet/mile, 1000 feet for slopes less than 3 feet/mile, and 1200 feet for slopes greater than 3 feet/mile. (Distances in valley miles.)

c. Reach lengths are measured along the flow lines between given cross sections. For HEC-2, three lengths are given to define channel and overbank flow paths. Defining the channel length based on the low flow channel assumes that flow will essentially follow the channel course even under flood flow.

d. Energy loss coefficients are one of the major sources of uncertainty in profile calculations. There are four basic sources for estimating 'n' values (Reference 3). The coefficients of contraction and expansion are not as quantified as the 'n' values.

(1) Tables of 'n' values are provided to varying degree of detail in most hydraulics texts (Ref. 1, 4, 5, and 7).

(2) Photographs with calibrated 'n' values are available to compare with field conditions (Ref. 1 & 4).

(3) Formulas have been derived to compute roughness coefficients, however, they usually require field samples of data and laboratory analysis (Ref. 3 & 4).

(2) Normal depth can be used in many cases when the stream channel is nearly uniform for a fairly long reach. HEC-2 can be used to compute normal depth by the user providing an energy slope equal to the channel slope. Other estimates of energy slope can also be used, however, the resulting water surface elevation would not be 'normal depth.'

(3) Trial and error calculations can be made assuming a range of depths. The model should have added cross sections downstream from the first cross section in the reach under study. The computed profile will converge toward the true profile, hopefully by the first section in the reach. By comparing the computed elevations for the first important section, the impact of varying starting elevations can be determined.

4. Sensitivity of water surface profile data

a. Cross section data has a direct and obvious impact on the computer results. Sensitivity tests (Ref. 3 & 6) often compare survey sections to sections derived from other sources (USGS quad, etc.). In the two referenced studies, differences in depth ranged from 1 to 4 feet.

b. Cross section spacing also has a direct impact on computed results. Reference 2 tested computed results by taking several models and removing cross sections to compare computed results before and after. Differences in computed results varied from 0.3 feet to over 4 feet.

c. Roughness coefficients are the most obvious variables in the profile calculations. When models are adjusted to fit observed data, it is the coefficients that are adjusted. The impact of 'n' value change can be easily evaluated with HEC-2 by using variable FN on the J2 card to apply a ratio to the given 'n' values.

REFERENCES

1. Barnes, H.H., Roughness Characteristics of Natural Channels, U.S. Geological Survey Water Supply Paper 1849, Government Printing Office, 1967.

2. Barr Engineering Company, The Effect of Cross Section Spacing and Cross Section Data Errors on Water Surface Profile Determination, unpublished report for the Minnesota Department of Natural Resources, Minneapolis, MN 1972.

3. Beasley, James G., An Investigation of the Data Requirements of Ohio for the HEC-2 Water Surface Profile Model, unpublished Master's Thesis at the Ohio State University, 1973.

4. Chow, V. T., Open Channel Hydraulics, McGraw-Hill, 1959.

5. HEC Training Document Water Surface Profiles - Preliminary, U.S. Army Corps of Engineers, Sacramento, CA, February 1969.

6. Sensitivity Analysis of Factors that Influence Water Surface Profiles, The Hydrologic Engineering Center, Davis, CA, October 1970.

7. Water Surface Profiles, IHD Volume 6, Draft, The Hydrologic Engineering Center, Davis, CA, 1974.

Tape No. 148

HEC-2 OUTPUT ANALYSIS

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OUTPUT ANALYSIS FOR HEC-2

Reference: HEC-2 Water Surface Profiles, Users Manual

1. Printout Sequence

   a. Data input (T1 to EJ)

   b. Computation for each section

   c. Profile plot

   d. Second profile computation

      (1) Title and job cards (T1 to J2)

      (2) Computation for each section

   e. Second profile plot - etc.

   f. Summary printout

   g. Cross section plot

2. Section Computation

   a. Variable name heading

e. Encroachment results in third summary

5. Cross section plots

a. Must be requested by section or profile

b. Total cross section or to CWSEL

c. Review input data

6. Output Review

a. Look at summary printout

(1) Computed water surface elevation (CWSEL)

(2) CWSEL difference for each discharge

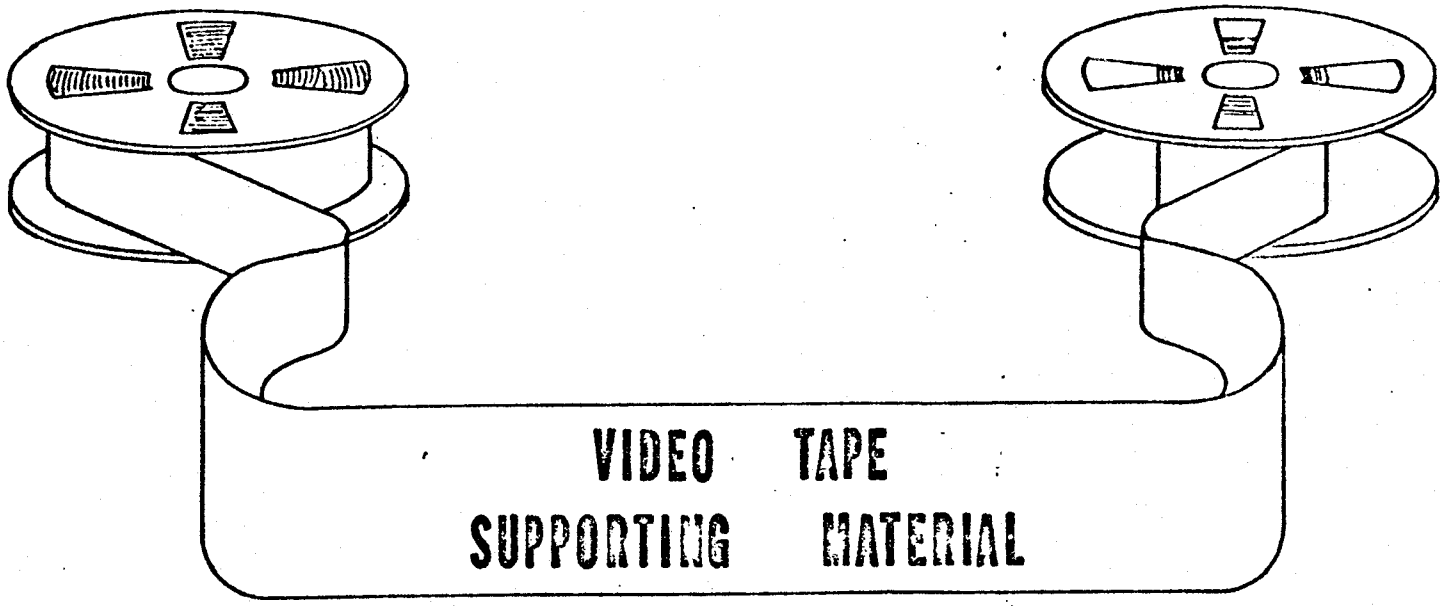
(3) CWSEL difference for each section

(4) Top width differences for each section

(5) Critical depth solutions

(6) Slopes for each section

Tape No. 18, 19



CAPABILITIES OF HEC-2 PROGRAM

12 JUNE 1974

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CAPABILITIES OF HEC-2 WATER SURFACE PROFILES PROGRAM

References:

a. "HEC-2, Water Surface Profiles," Users Manual - Feb. 72, Oct. 73. Programmers Manual - December 1971, August 1969, June 1973.

b. Eichert, Bill S., "Survey of Programs for Water Surface Profiles," paper presented at ASCE Hydraulics Division Conference, Massachusetts Institute of Technology, 21 August 1968.

1. Program Source
U. S. Army Corps of Engineers - Tulsa and HEC

2.

	Computer Version	Memory	Execution Tests
1	CDC 6600	63,000 words	15 sec
	UNIVAC 1108	52,000 words	50 sec
2	GE 437	29,000 words	5 min
3	IBM 360	70,000 words (280,000 bytes)	1.7 min

3. Program Language
Fortran IV

5. Type of Flow
Steady, gradually varied flow, subcritical and supercritical
STANDARD STEP
BACKWATER CALC.

6. Description of Problem

a. Assumption of classification or flow (subcritical or supercritical)

b. Roughness coefficients for cross section

(1) Normal - channel and two overbanks

(8) Closed conduits

(9) Proposed levees

(10) Reach lengths (3 normal)

(11) Encroachments

7. General Computational Procedure

a. Use of subsection

b. Nonuniform velocities (Coriolis effect)

c. Weighted velocity head

d. Iterative process

e. Divided flow

f. Calculate n-values directly

8. Critical Depth

   a. Always calculated for supercritical flow

   b. Calculated when requested by input

   c. Calculated when not requested if computed depth is close to critical depth

9. Bridge Flow

   a. Fixed loss (X5 card)

   b. Normal

   c. Special

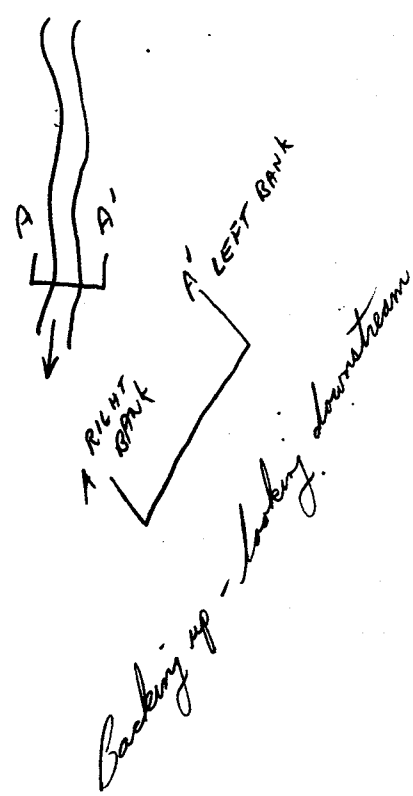
   d. Contraction and expansion losses

10. Data Editing Program Available

11. Output

   a. Normal including summary

   b. Special bridge



c. Trace

d. Special notes

e. Plotting

(1) Profiles

(2) Cross sections

12. Utility Features

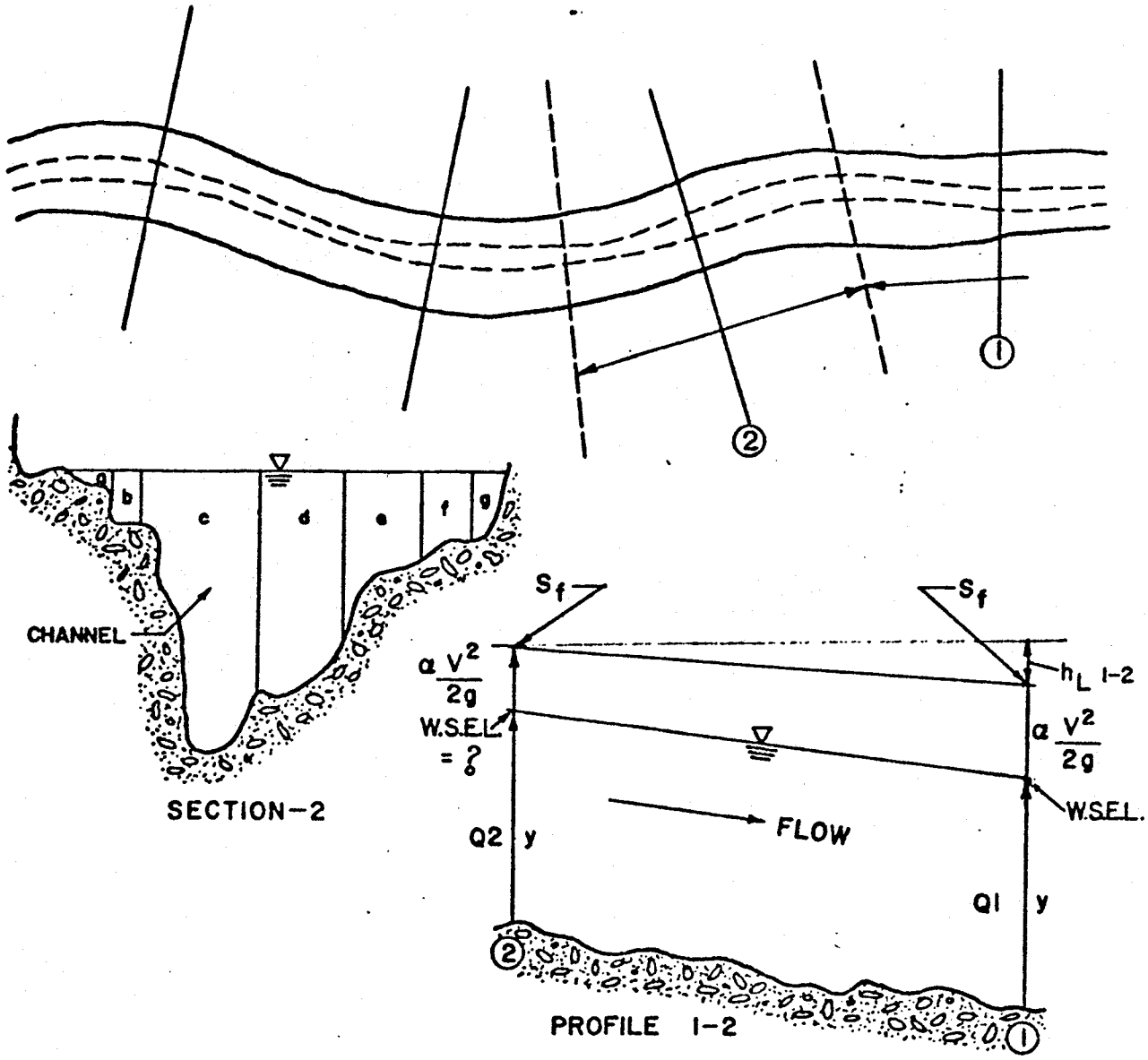
a. Multiple runs - different streams

b. Multiple runs - same stream - different Q's

c. Errors in multiple runs

d. Numerous checks - all data editing

e. Metric units



Computation Procedure

Conditions are known @ 1

- Assume WSEL (2)
- *** Compute conveyance— $K(2) = \Sigma K_a + K_b + \ldots + K_g$
  where: $K = \frac{1.49}{n} AR^{2/3}$
- *** Compute representative rate of friction loss
  $$K_{av} = \frac{K(1) + K(2)}{2} \cdot S_{av} = \frac{Q2}{K_{av}^{\ 2}}$$
- Compute WSEL(2)
  $$WSEL(2) = WSEL(1) + \alpha \frac{V_1^2}{2g} + S_{av} \cdot L_w + C \cdot \frac{|\Delta\alpha V^2|}{2g} - \alpha \frac{V_2^2}{2g}$$

Compare and repeat until criterion met.

Fig. 4. Schematic of Computation Procedure

(2) Horizontal and vertical changes

(3) Fixed ratio

c. Beginning conditions (known water surface, slope/area, critical depth)

d. Shock losses ($h_s = c * | \Delta HV |$)

e. Change of discharge - at any cross section

f. Description of cross section

(1) By coordinates

(2) By using previous or current cross section

(3) Automatic insertion of additional cross section

(4) Adding additional points in cross section

(5) Effective area

(6) Raising cross section ends

(7) Channel improvements to natural cross section

b. Look at profile plots

c. Look at the profile computations

(1) Special notes

(2) Bridge routines

(3) Velocities

(4) Discharges in the cross section

(5) Interpolated cross sections

d. Look at data first for source of errors

(1) Same spatial locations as data for each section

(2) Variables defined in Exhibit 9 of the Users Manual

b. Special notes

(1) Indicate different inputs

(2) Show computational difficulties

(3) Defined in Exhibit 7 of the Users Manual

3. Profile Plot

a. Basic data review

b. Computed results

4. Summary Printout

a. Must be requested

b. Choice of variables available

c. Computed results in first summary

d. Differences in computed results in second summary

d. The coefficients of contraction and expansion and the coefficients for the bridge routines in HEC-2 are relatively insensitive when compared to the previous items (Ref. 3). However, for high velocity streams, contraction and expansion coefficients may become important.

e. Changes in discharge may not have a major impact on computed profiles. This can be tested with HEC-2 using variable FQ on the J1 card to ratio the discharge values given in the model.

(4) Using observed water surface profile data would be the best estimate for 'n' values. With HEC-2, the 'n' values can be computed if water surface elevations are available for every cross section. If only scattered points are known, the computed profiles should be checked with the known elevations.

(5) Contraction and expansion coefficients are provided in HEC-2 to account for losses associated with changes in the shape of cross sections. A range of values are given in the HEC-2 Users Manual. Because the coefficients are applied to the change in velocity head, they may not be significant if stream velocities or changes in velocity are small.

3. Starting conditions for the model

a. Flows are provided by the hydrologic analysis, which is a separate topic.

b. Flow regime is generally not a problem. For most natural streams, the flow is subcritical. If HEC-2 is used and the flow regime is incorrectly defined, the program would assume critical depth because the calculations are not permitted to cross critical depth.

c. Starting water surface elevations must be provided for every discharge profile.

(1) Known water surface elevations would be the first choice. These can be lake levels, sea level, or control sections such as a gage or critical depth sections. HEC-2 can be used to compute critical depth to start a profile calculation.

(3) To satisfy the requirements of the analytical method

b. Guidelines for locating sections (Ref. 3, 5, & 7)

(1) Cross sections should be taken where there is an appreciable change in cross sectional area, roughness, and slope

(2) Cross sections should be taken normal to the flow lines

(3) Detailed cross sections should be taken above, below, and within bridges

(4) Cross sections should be located at the head and tail of levees

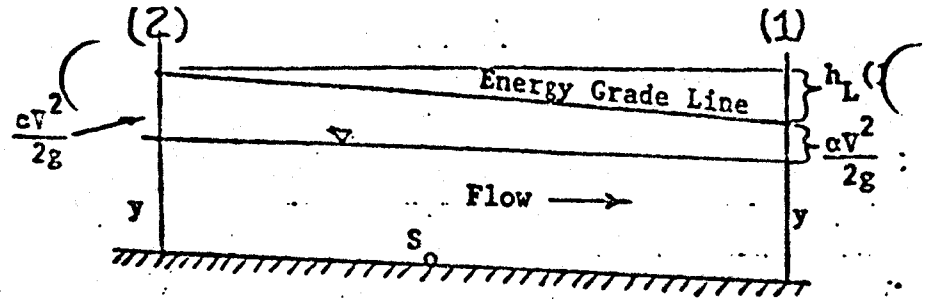
(5) Cross sections are needed at all control sections

(6) Cross sections are required immediately below a confluence on a main stream and above the confluence on the tributary

(7) In general, more cross sections are needed to define energy losses in urban areas as opposed to rural areas, where steeper slopes are encountered, and on smaller streams

(8) Cross section spacing is initially controlled by the physical requirements for locating cross sections (items 1-7). A review of the computed results is required to insure spacing is adequate to provide for the analytical method.

(a) Change in energy slope can be used as a basis for evaluating spacing. If the slope decreases by more than 50% or increases more than 100%, the reach length may be too long for accurate loss calculations.



$z_u + y_u + \alpha_2 \frac{V_2^2}{2g} = z_d + y_d + \alpha \frac{V_1^2}{2g} + h_L$

$WS_u + \alpha_2 \frac{V_2^2}{2g} = WS_d + \alpha \frac{V_1^2}{2g} + h_L$

$h_e = C \left| \alpha \frac{V_1^2}{2g} - \alpha \frac{V_2^2}{2g} \right| + L \left[\frac{Q}{K_1 + K_2} \right]$

PAGE _____ OF _____

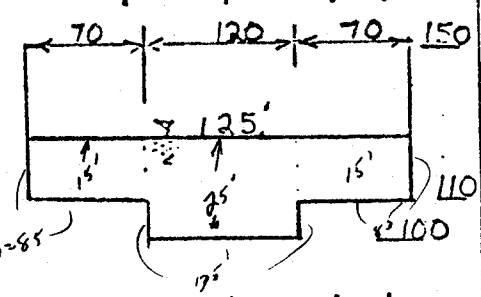
COMPUTED BY _____ DATE _____

CHECKED BY _____ DATE _____

RIVER MILE	WS ELEVATION ASMD	WS ELEVATION CMPT	A	R	$R^{2/3}$	n	L	K = x 10^3	$\bar{K}$ x 10^3	h_f	$K(K/A)^2$ x 10^9	α	V	$\frac{\alpha V^2}{2g}$	$\Delta\frac{\alpha V^2}{2g}$	h_o	ΔWS
1.0	125.0		1050	12.35	5.35	.04		209.0			8.3						
Q	= 11,000		3000	21.4	7.70	.02		1730.0			575.4						
			1050	12.35	5.35	.04		209.0			8.4						
		Total	5100				K_t	2148.0		K_t	582.8	1.53	2.16	.11			
1.5	126.1	125.06	666	9.37	4.41	.045	2640	97.0			2.05						
Q	= 10500		2426	18.0	6.85	.025	2640	988.0			163.90						
			666	9.37	4.41	.045	2640	97.0			2.05						
		Total	3758					1182.0	1665	.10	168.00	1.44	2.79	.17	-.06	.02	+.06
	125.0	125.04	600	8.6	4.2	.045	2640	83.0			1.58						
			2300	17.0	6.1	.025	2640	911.6			144.60						
			600	8.6	4.2	.045	2640	83.0			1.58						
		Total	3500					1077.6	1612.8	.11	147.76	1.47	3.02	.20	-.09	.02	+.04

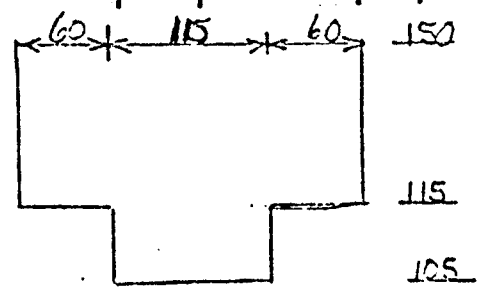
RM 1.0
Q = 11,000
Nch = .02
Nob = .04

Ce = .3
Cc = .1



RM 1.5
Q = 10,500
Nch = .025
Nob = .045

L = 2640'



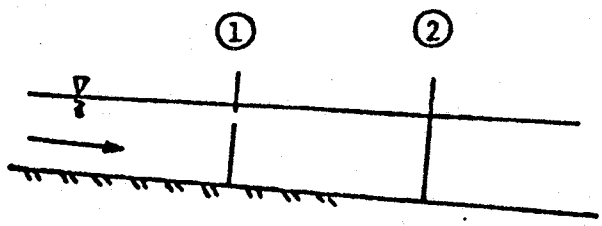
$WS_u = WS_d + \Delta WS$ $\quad A_t = \Sigma A$ $\quad \bar{K} = \frac{K_d + K_u}{2}$ $\quad \alpha = \frac{\Sigma[K(K/A)^2]}{K_t(K_t/A_t)^2}$ $\quad V = Q/A_t$ $\quad$ if Δh_v − ; $h_o = C_e\,|\Delta h_v|$

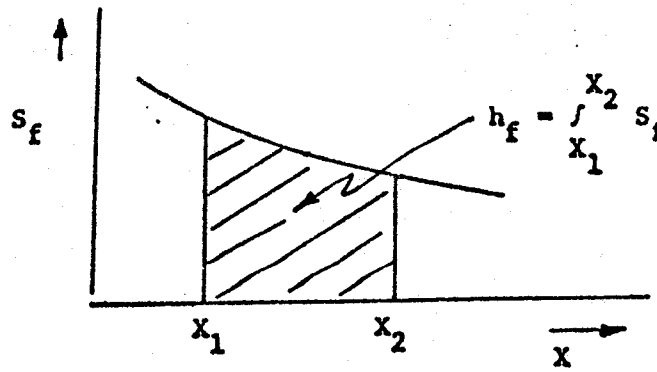
$h_v = \frac{\alpha V^2}{2g}$ $\quad$ if Δh_v + ; $h_o = C_c\,|\Delta h_v|$

u = upstream section $K_t = \Sigma K$

d[redacted]tio[redacted] $K = \frac{1.486}{n} A R^{2/3}$ [redacted] [redacted] $\Delta h_v = h_{vd} - h_{vu}$ $\quad \Delta WS = h_f + \Delta h_v + h_o$ [redacted]

(3) Determining friction loss in a channel reach





$$h_f = \int_{X_1}^{X_2} S_f \, dx$$

slope energy line

$S_f = \frac{dH}{dx}$

$dH = S_f \, dx$

Let $$\int_{X_1}^{X_2} S_f \, dx = \bar{S}_f \, L \qquad (1)$$

where $\bar{S}_f$ = representative friction slope

L = reach length

Approximations for $\bar{S}_f$

$$\bar{S}_f = \frac{S_{f_1} + S_{f_2}}{2} \qquad (2)$$

or

$S_f = \left(\frac{Q}{K}\right)^2$

$$\bar{S}_f = \left[\frac{Q}{\frac{K_1 + K_2}{2}}\right]^2 \qquad (3)$$

K = conveyance

substituting (3) in (1)

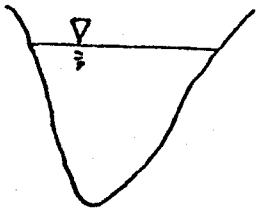
$$h_f = L \left[\frac{2Q}{K_1 + K_2}\right]^2$$

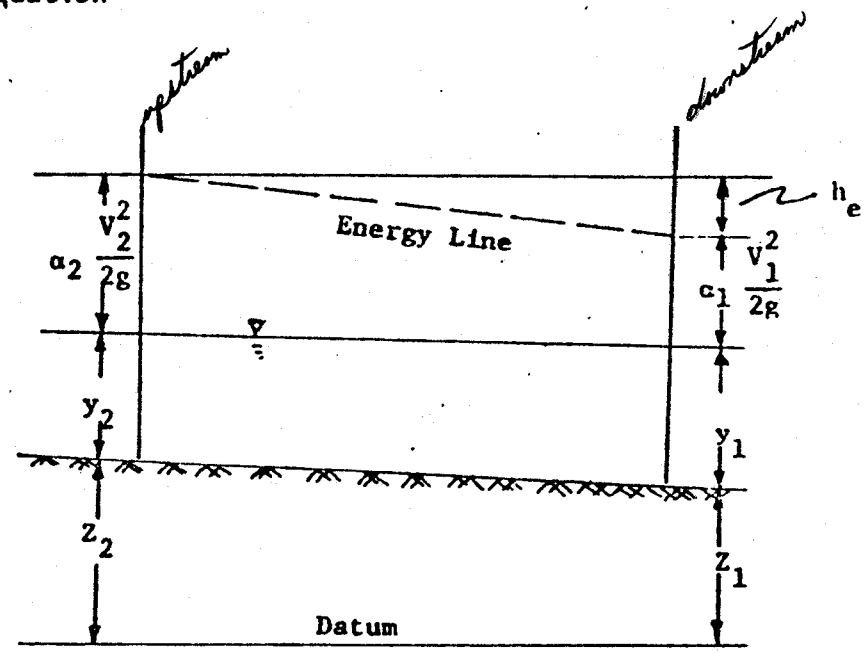
M1 PROFILE

water surface profiles

5-08

b. The energy equation





$$Z_2 + y_2 + \alpha_2 \frac{V_2^2}{2g} = Z_1 + y_1 + \alpha_1 \frac{V_1^2}{2g} + h_e$$

Let $H = Z + y + \alpha \frac{V^2}{2g}$

$$H_2 = H_1 + h_e$$

c. Limitation of energy equation

✓(1) Steady flow

✓(2) One dimensional flow

✓(3) Gradually varied flow (hydrostatic pressure distribution assumed)

✓(4) Channels of small slope (<1:10)

Or in general

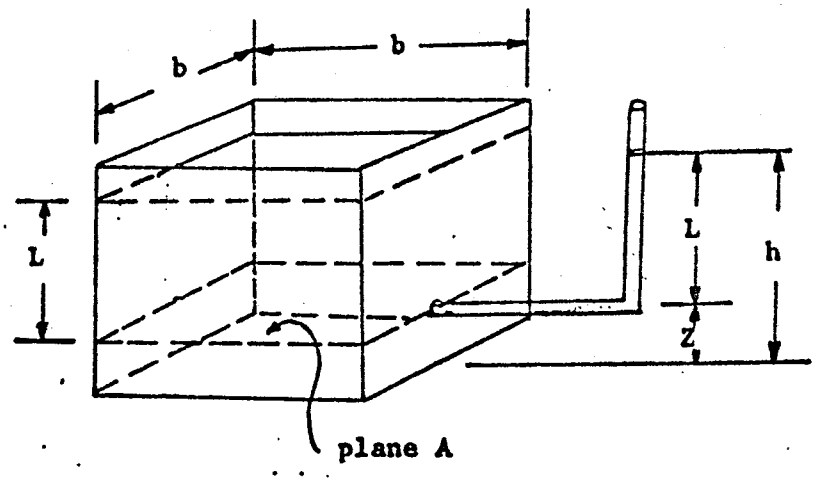
$$Q_i = K_i \, S_f^{1/2}$$

where i designates subsection number

If this eq. is combined with the equation for α, there results

$$\alpha = \frac{(\Sigma A_i)^2 \;\; \Sigma(K_i^3 / A_i^2)}{(\Sigma K_i)^3}$$

3. **Pressure Distribution in a Channel Section**



Pressure on plane A $= \dfrac{b \; b \; L \; \gamma}{b \; b} = \gamma L$ **(+ atmos. pressure)**

Pressure head $= \dfrac{\text{pressure}}{\gamma} = \dfrac{\gamma L}{\gamma} = L$

Piezometric head = Z + pressure head = Z + L = h

Kinetic energy head = discharge-weighted velocity head

$$= \frac{Q_1 \left(\frac{V_1^2}{2g}\right) + Q_2 \left(\frac{V_2^2}{2g}\right)}{Q_1 + Q_2} = \alpha \frac{\overline{V}^2}{2g}$$

$$\alpha = \frac{2g \left[Q_1 \left(\frac{V_1^2}{2g}\right) + Q_2 \left(\frac{V_2^2}{2g}\right)\right]}{(Q_1 + Q_2)\ \overline{V}^2}$$

$$\alpha = \frac{Q_1 V_1^2 + Q_2 V_2^2}{(Q_1 + Q_2)\ \overline{V}^2}$$

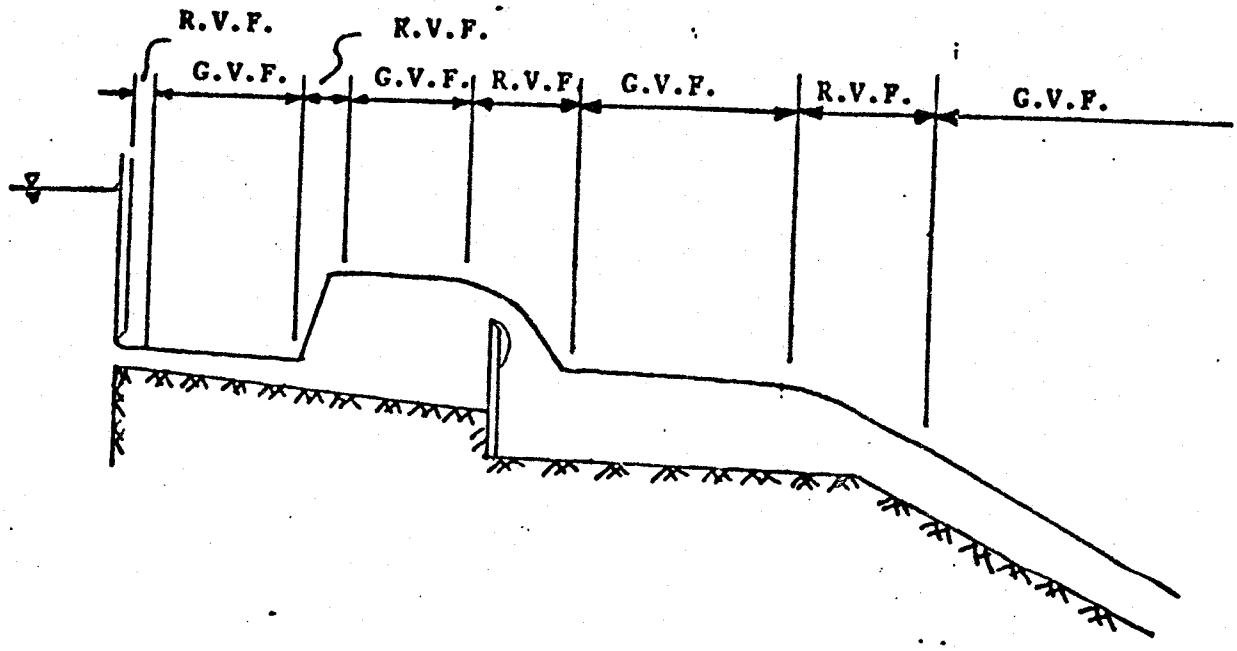
in general

$$\alpha = \frac{[Q_1 V_1^2 + Q_2 V_2^2 + Q_3 V_3^2 + \ldots + Q_N V_N^2]}{Q\ (\overline{V}^2)}$$

c. Typical values of velocity coefficient, α

Channel Type	Value of α		
	Min.	Avg.	Max.
Regular channels, flumes, spillways	1.10	1.15	1.20
Natural streams	1.15	1.30	1.50
Rivers under ice cover	1.20	1.50	2.00
River valleys, overflooded	1.50	1.75	2.00

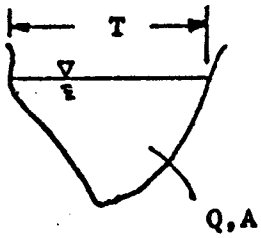
From Chow, Open Channel Hydraulics



c. Subcritical vs supercritical

Effect of gravitational forces relative to inertial forces represented by the Froude No., a dimensionless ratio.

$$Fr = \frac{V}{\sqrt{gD}}$$



where Fr = Froude No.

V = mean velocity = Q/A

g = gravitational acceleration

D = hydraulic mean depth = A/T

This definition of Froude No. applies only where a uniform velocity distribution can be assumed.

For	Fr < 1	flow is subcritical
	Fr = 1	flow is critical
	Fr > 1	flow is supercritical

TAPE No. 222, 22

NORMAL BRIDGE ROUTINE

THE HYDROLOGIC ENGINEERING CENTER
CORPS OF ENGINEERS, U.S. ARMY
609 SECOND STREET
DAVIS, CALIFORNIA 95616
(916) 449-3292

Tape No. 222,223

NORMAL BRIDGE ROUTINE - HEC-2

ge routine in HEC-2 is a standard step calculation
djustment in the conveyance calculation to account for
he bridge is modeled by defining cross sections through
e.

the bridge deck below the water surface elevation is
total area.

erimeter is increased where water is in contact with
e.

efined by:

low chord and top of road elevation on the X2 card.

roadway stations and elevations and corresponding low
BT cards.

- Training Document No. 6, Page 44.

using the X2 card. Training Document No. 6, Page 37
ing Sample Section)

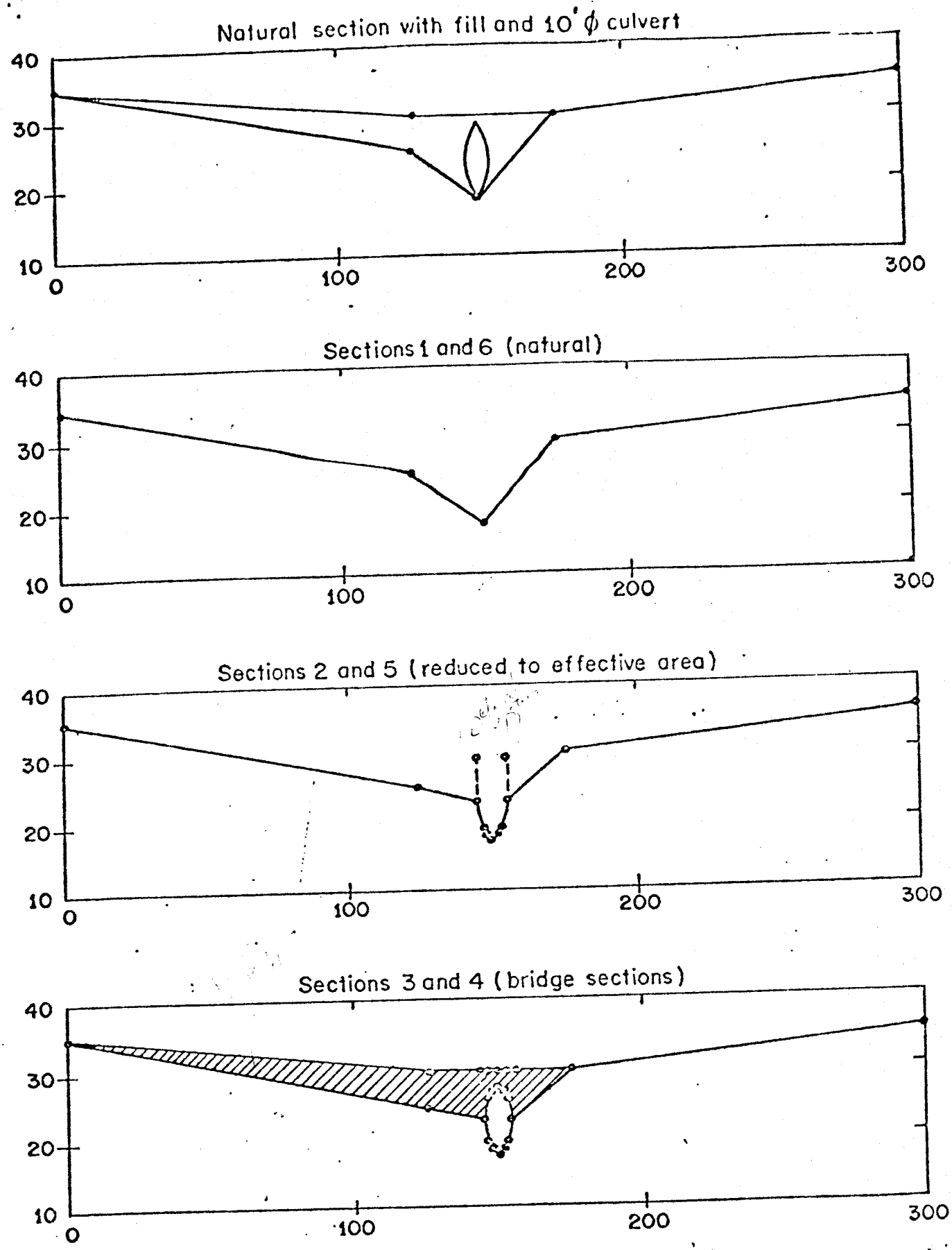


Figure 10. Normal Bridge Routine Section

L 117

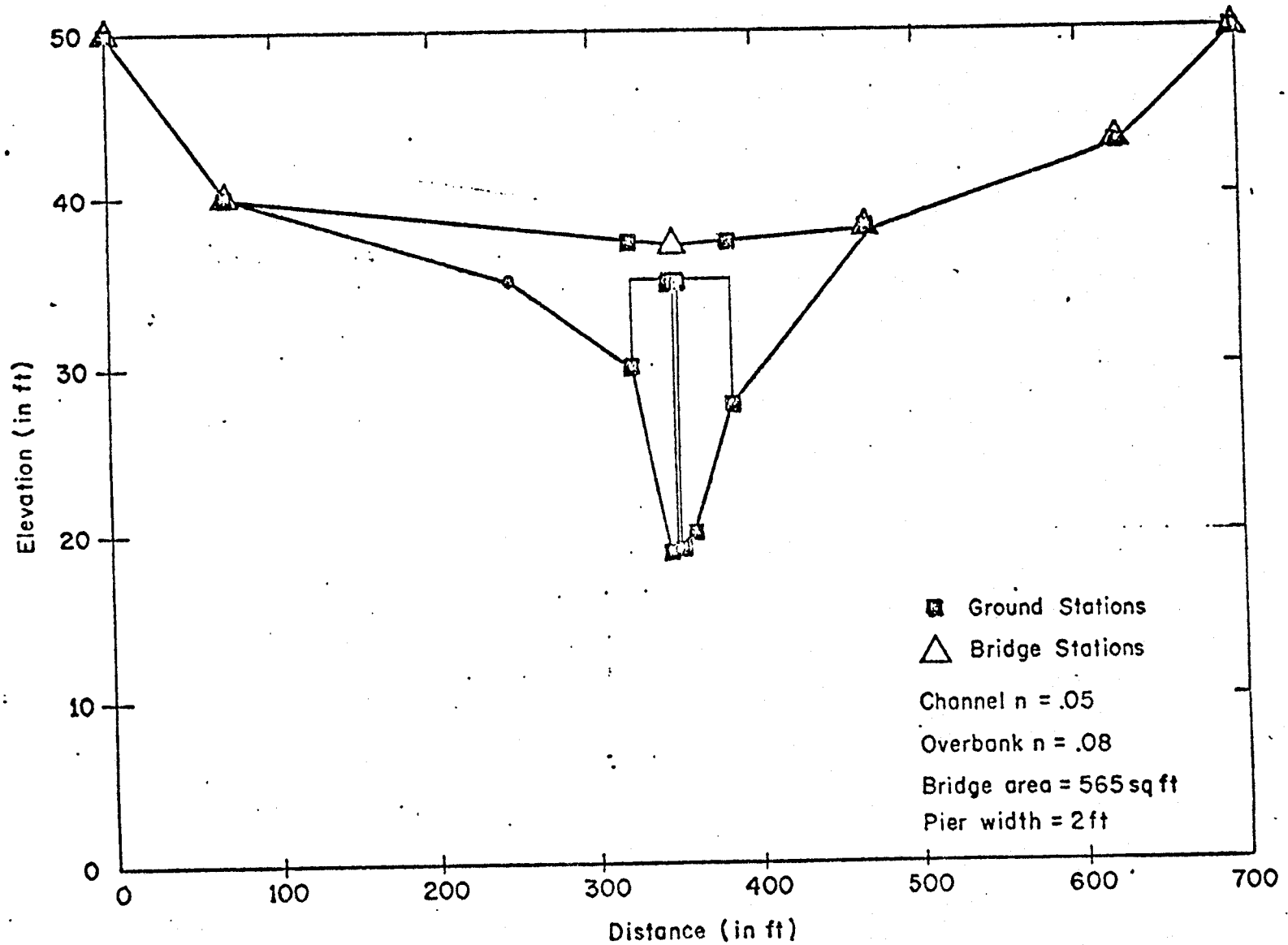


Figure 8. Special Bridge Routine Sample Section

CORRECTIONS 01,02,03,04,05,06,07,08,09
MODIFICATIONS 52,53,54,55,56,57,58
****

T1 NORMAL BRIDGE EXAMPLE WITH X2 CARD
T2 SPECIAL BRIDGE PROBLEM
T3

J1	ICHECK	INQ	NINV	IDIN	STRT	METRIC	MVINS	Q	WSEL	FW
	=0	2.	=0	=0	=0	=0	=0	=0	30,000	=0

NC	.080	.080	.050	.300	.500	=0	=0	=0	=0	=0
WT	3,000	2000,000	4500,000	6000,000	=0	=0	=0	=0	=0	=0
X1	1,000	10,000	325,000	375,000	=0	=0	=0	=0	=0	=0
GR	50,000	0	40,000	75,000	35,000	250,000	30,000	325,000	19,000	345,000
GR	20,000	360,000	28,000	375,000	38,000	475,000	43,000	625,000	50,000	700,000
X1	2,000	=0	=0	=0	300,000	300,000	300,000	=0	=0	=0
X3	10,000	=0	=0	=0	=0	=0	=0	36,000	36,000	=0
X1	2,100	15,000	325,000	375,000	10,000	10,000	10,000	=0	=0	=0
X2	=0	=0	=0	35,000	37,000	=0	=0	=0	=0	=0
GR	50,000	0	40,000	75,000	37,500	325,000	30,000	325,000	19,000	345,000
GR	19,000	350,000	35,000	350,000	35,000	352,000	19,500	352,000	20,000	360,000
GR	28,000	375,000	37,000	375,000	38,000	475,000	43,000	625,000	50,000	700,000
X1	2,900	=0	=0	=0	60,000	60,000	60,000	=0	=0	=0
X2	=0	=0	=0	35,000	37,000	=0	=0	=0	=0	=0
X1	3,000	10,000	325,000	375,000	10,000	10,000	10,000	=0	=0	=0
X3	10,000	=0	=0	=0	=0	=0	=0	37,000	37,000	=0
GR	50,000	0	40,000	75,000	35,000	250,000	30,000	325,000	19,000	345,000
GR	20,000	360,000	28,000	375,000	38,000	475,000	43,000	625,000	50,000	700,000
X1	4,000	=0	=0	=0	75,000	75,000	75,000	=0	=0	=0
EJ	=0	=0	=0	=0	=0	=0	=0	=0	=0	=0

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

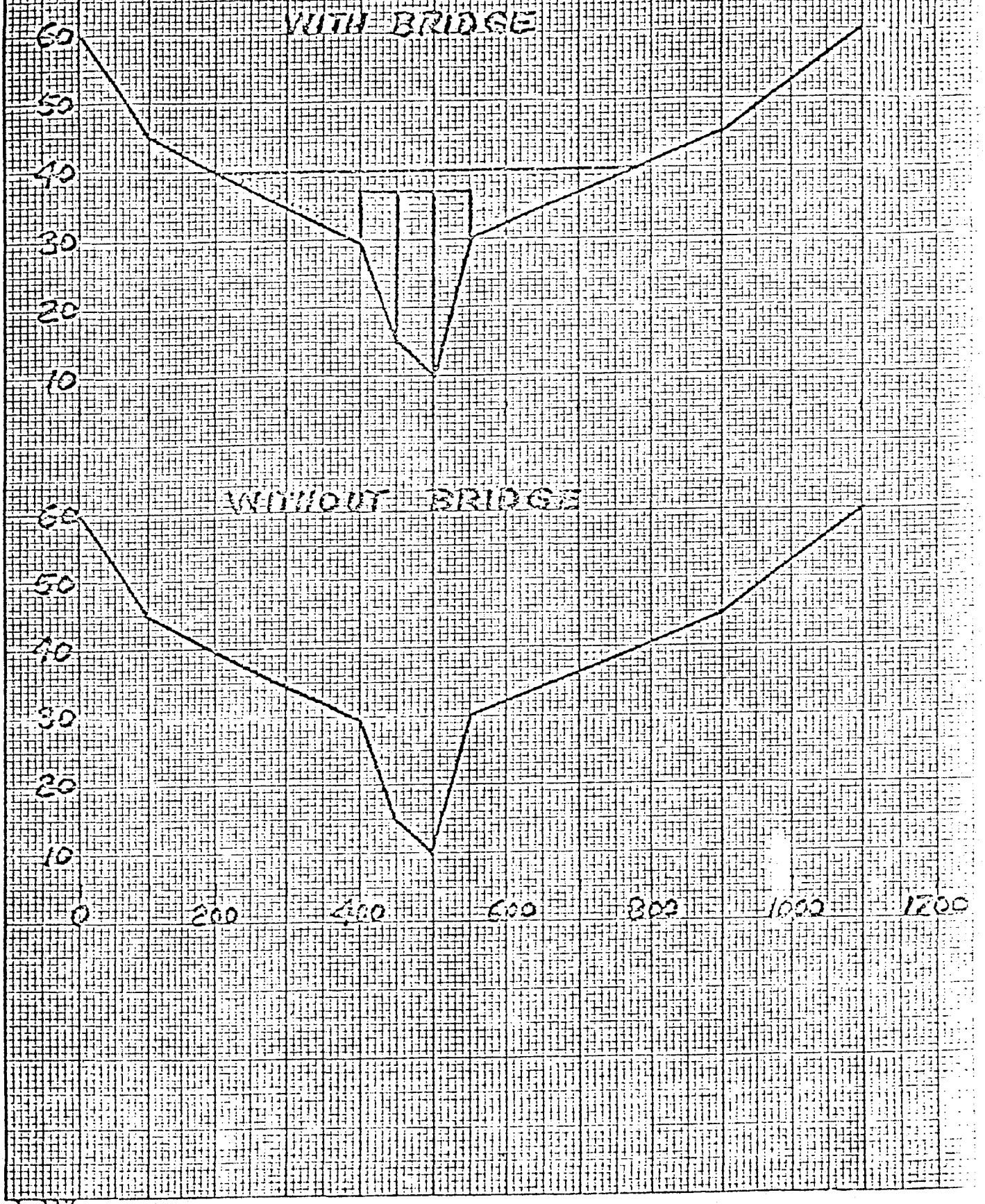
PROGRAM | DATE

REQUESTED BY | PREPARED BY | CHECKED BY | PAGE | OF

	1	2	3	4	5	6	7	8	9	10
T1	SPECIAL BRIDGE EXAMPLE									
T2										
T3	EASY CREEK									
J1		2							32	
NC	.08	.08	.04	.3	.5					
QT		10000	15000	20000	30000					
X1	1	8	400	550	0	0	0			
GR	60	0	45	100	30	400	15	450	10	500
GR	30	550	45	900	60	1100				
X1	2				500	500	500			
X3	10							38	38	
SB	1.05	1.5	2.5		50	4	2800	2	13	13
X1	3				100	100	100			
X2			1	37	40					
X3	10							40	40	
BT	6	0	60		100	45		200	40	
BT	780	40		900	45		1100	60		
X1	4				150	150	150			
ET										

FIGURE 2.

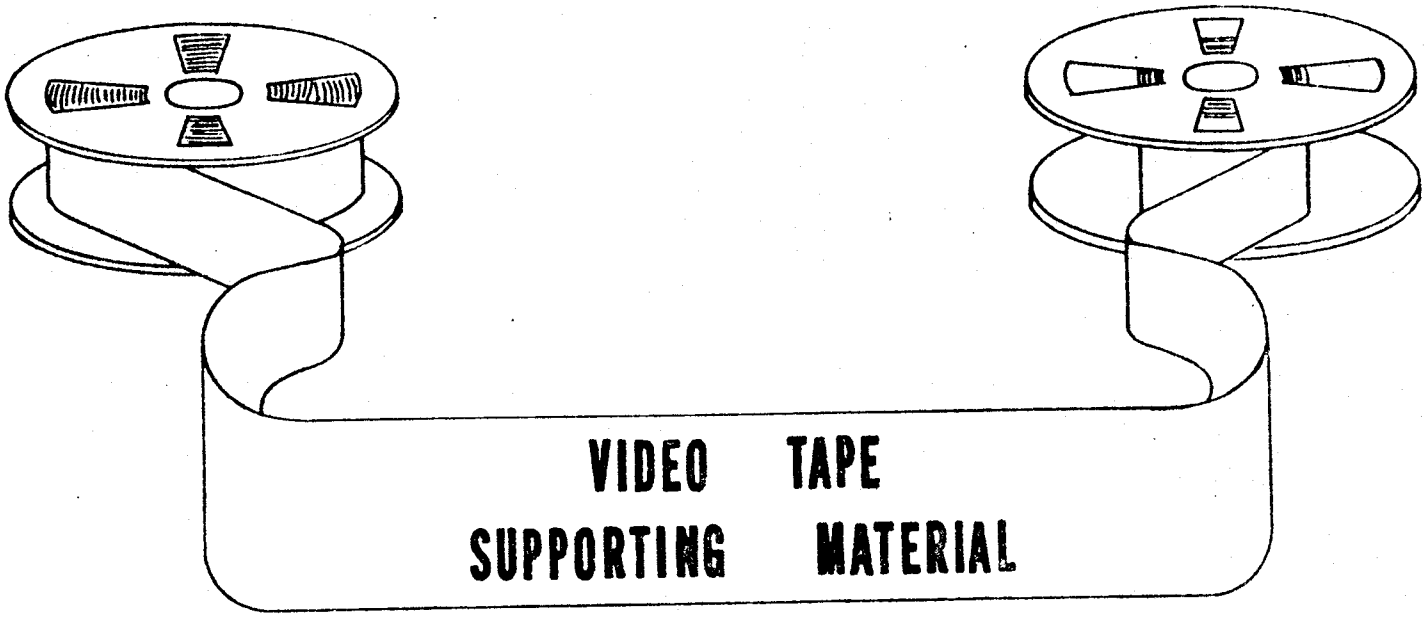
EXAMPLE SECTION



KEUFFEL & ESSER CO.

TRAM

Tape No. 23



FLOODWAY DETERMINATIONS

14 JUNE 1974

THE HYDROLOGIC ENGINEERING CENTER
CORPS OF ENGINEERS, U.S. ARMY
609 SECOND STREET
DAVIS, CALIFORNIA 95616
(916) 449-3292

The views and conclusions expressed on video tapes are those of the individual instructors and are not intended to modify or replace official guidance or directives such as Engineering Regulations, Manuals, Circulars, or Technical Letters issued by the Office of the Chief of Engineers.

FLOODWAY DETERMINATION

1. Natural Floodway: The channel of a water course and those portions of the adjoining flood plain which are reasonably required to carry a selected probability flood.

2. Designated Floodway: The channel of a water course and those portions of the adjoining flood plain required to provide for the passage of a selected flood with an small increase in flood stage above that of natural conditions.

3. General Guidelines

   a. Hydrology and hydraulics will be based on existing conditions.

   b. Discharge based on a one percent exceedence frequency.

   c. Flood plain divided into Designated Floodway and a Floodway Fringe.

      (1) Designated Floodway will pass the selected flood discharge without raising the water surface more than one foot above that of the natural floodway.

      (2) Floodway Fringe will be assumed filled solid for the purpose of hydraulic computations.

5. Flow Distribution (J2 card, ITRACE = 15)

   a. Horizontal distribution of percent discarge, area, and velocity

   b. Applies to entire profile

   c. Distribution only applies to the overbank; channel is treated as a unit.

   d. If there are more than 12 incremental overbank areas, the program will sum the areas to 3% of the flow

6. Method 4 encroachment (J3 and ET cards)

   a. First profile must be a natural profile to provide a basis for computation

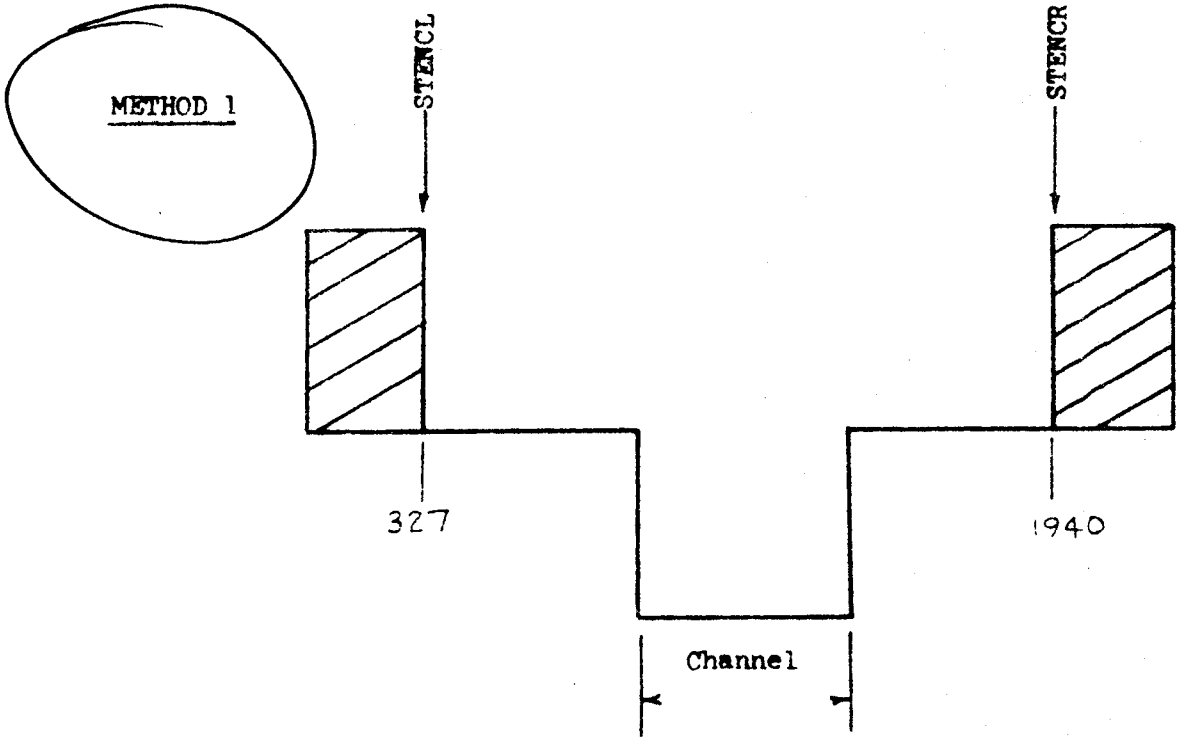
   b. J3 card is used to call the variables needed in program storage for subsequent calcualtions.

   c. Second and/or subsequent profiles call the method and the change in water surface elevation times 10 (i.e. 5.4 means method 4 with a 0.5 ft rise in water elevation)

   d. Program will try for equal conveyance reduction on the two overbank areas, but will not go into the channel to set encroachments.

   e. The encroachment procedure is applied to every cross section using the same criteria unless the method or criteria is changed by another ET card.

FLOODWAY DETERMINATION WITH HEC-2



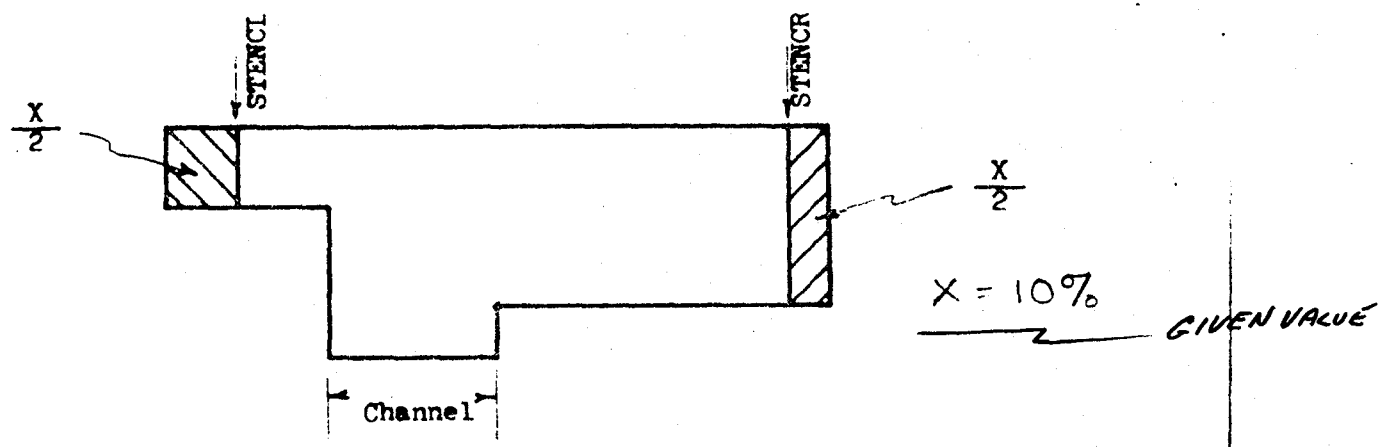
Encroachment stations STENCL and STENCR are specified on X3 or ET cards

1	2	3	4	5	6	7	8	9	10
J1		3.							
ET	7.1	9.1					1800	327	1940

MULTIPLE PROFILE APPROACH

THIS SPECIFIC DEVELOPMENTS OR LOCATIONS

METHOD 3

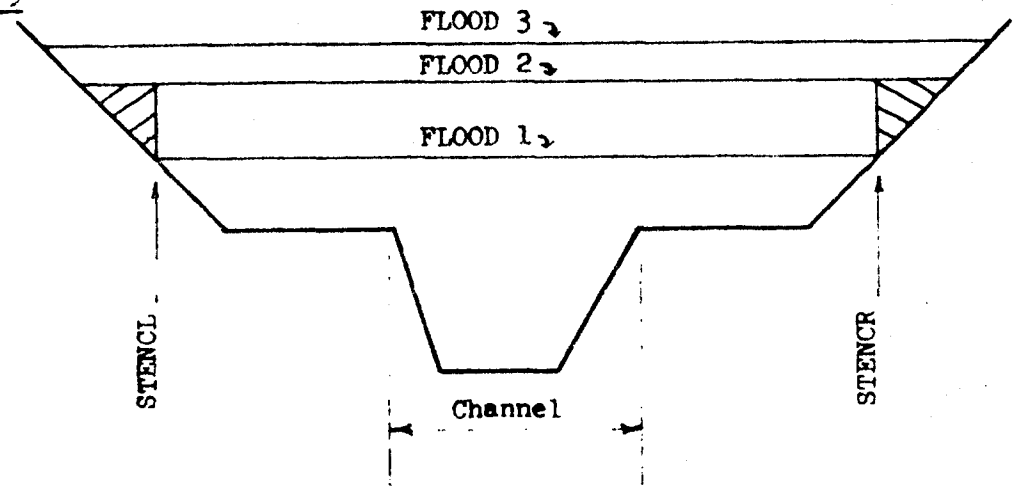


Encroachment stations are determined from the percent (X) reduction in conveyance specified on the ET card such that the total conveyance for each cross-section of the natural profile is reduced by "X" percent if possible. One-half the reduction is made on each side (if possible) as long as the encroachments do not infringe on the main channel. The flow area will be limited to the channel if the percentage X requires a greater reduction than is available from the natural overbanks.

1	2	3	4	5	6	7	8	9	10
J3	1	36	3	4	27	28	9		
J1		4							
ET			10.3						

NATURAL PROFILE FIRST

METHOD 5



Encroachment stations for Floods 2 and 3 are determined from the topwidth limits of the profile for Flood 1. The elevation for Flood 2 becomes the elevation of encroachment for the profile for Flood 3. The J1 and J3 cards are used to request this method.

1	2	3	4	5	6	7	8	9	10
J1		-202							
J3	27	28	31	32	1	4	9		
J1		-203							
J1		-204							

GENERAL GUIDELINES FOR DEVELOPMENT OF FLOODWAY DATA

1. DEFINITIONS.

a. *NATURAL FLOODWAY* is the channel of a watercourse and those portions of the adjoining flood plain which are reasonably required to carry and discharge the floodwaters of a selected probability-of-occurrence flood.

b. *DESIGNATED FLOODWAY* is the channel of a watercourse and that portion of the adjoining flood plain required to provide for the passage of a selected flood with an insignificant increase in flood stage above that of natural conditions. Normally, the 100-year flood (one that has a 1-percent chance of occurrence in any given year) should be considered as the selected flood. An "insignificant increase" is normally considered to be no greater than 1 foot unless a smaller increase is established by State or local regulation.

2. PURPOSE OF DESIGNATING FLOODWAY. Designation of a floodway by establishing identifiable limits and the control of land use in and adjacent to the floodway serve to conserve an unobstructed area for the passage of floodwaters while providing for the appropriate use of lands based on knowledgeable awareness of, and consistent with, the flood hazards.

3. POLICY. To establish a uniform approach to floodway determinations, the following guidelines are to be used in the initial developmental stage, unless State or local governmental regulations have more restrictive requirements:

a. The capacity of the *Designated Floodway* will be based on the discharge of the flood that has a 1-percent chance of occurrence in any given year.

b. The flood plain of the selected flood, under existing conditions, will be divided into two zones (see Figure 1): a *Designated Floodway* and a *Floodway Fringe*.

c. The *Designated Floodway*, to be reserved by zoning or encroachment lines, will be designed to pass the selected flood discharge without raising the water surface more than 1 foot above that of the natural floodflow (unless other criteria apply).

f. Individuals developing floodway data should be alert for special conditions involving the area under consideration and the criteria used which may affect the application of the floodway concept. For example, the resulting increase in water surface may greatly enlarge the zone area affected by the selected flood an unreasonable distance beyond its natural flood plain. This condition can exist when the overbank area is very flat and more than an insignificant increase in the water surface is permitted. The additional increase then suggests the need to project the horizontal controls beyond the natural selected flood plain into areas not otherwise affected, which would constitute an unnecessary and uneconomical restriction on the use of the land.

5. COORDINATION. Some States, cities, and other governmental units have adopted floodway criteria which is inconsistent with the 1-percent-chance and 1-foot-stage-increase formula. Since any regulation, ordinance, or other floodway control measure must be adopted and enforced by the local entity, determination of the floodway must necessarily conform with local criteria and enabling legislative authority. State and local officials should be contacted as early as possible in the floodway determination process to coordinate possible alinements with future development planning. Programs of other Federal agencies may overlap the study area, and any previous work by them should be considered before implementing an extensive floodway determination. Also, follow-up coordination should be maintained with local officials after presentation of the floodway design data. Many problems and pressures will surface after the initial alinement is made public, and some reanalysis must be expected where conflicts in location dictate alinement shifts.

6. PROCEDURES. As local interests will actually implement the final designation of the floodway, the initial determination of required widths should normally be based on the engineering factor of the most "hydraulically efficient" area of the flood plain. This will result in the minimum width required for the maximum conveyance capability. In some cases, this may also produce a floodway located symmetrically about the channel; but the advantages of symmetry, as a prime objective, must be weighed against the more narrow, hydraulically-efficient section. Procedures in developing floodway data would include the following:

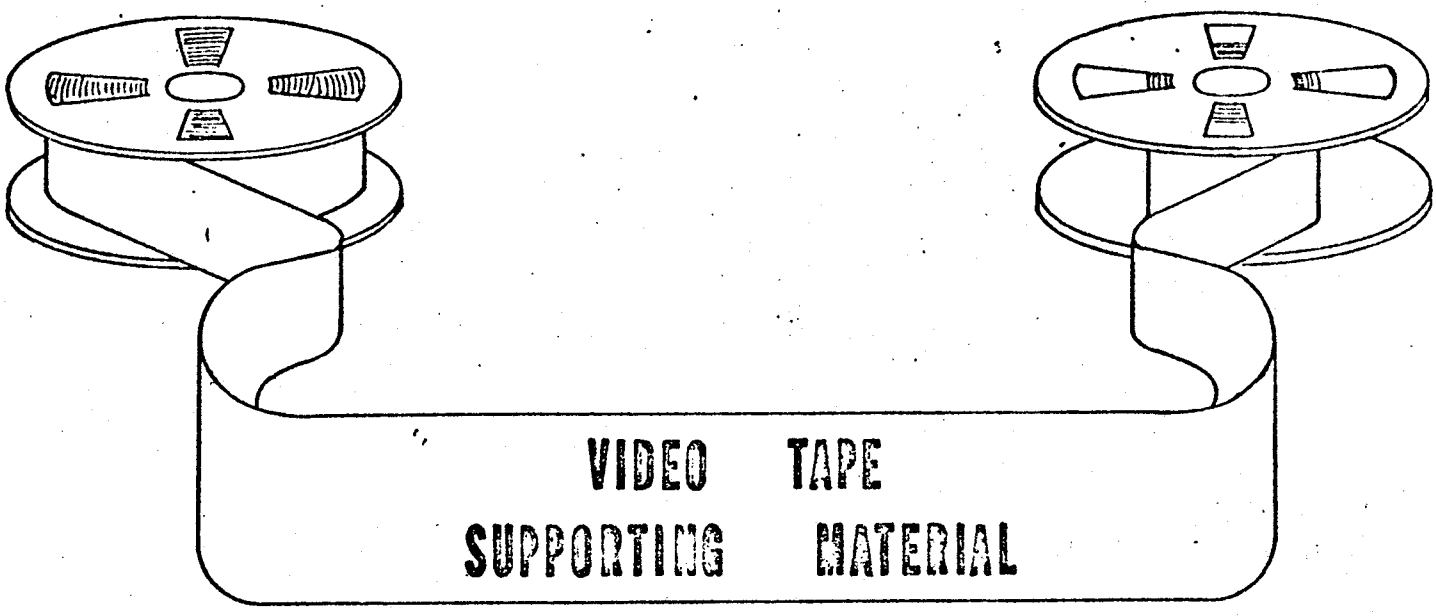
a. Derive the water surface profile for the selected flood under existing conditions and relate the elevations to the cross sections.

b. Using the cross section "picture," estimate the floodway width for each section considering the distribution of conveyance, depth of flow in the floodway fringe area, velocities, and variations in "n" values.

(5) Using the conveyance printout, the flow distribution can be adjusted to smooth out the floodway boundaries. The revised encroachment boundaries are inserted in the Method 1 procedure; the backwater program is then again run to determine if the resulting water surface conforms to the specified criteria.

7. DATA FURNISHED TO REQUESTER. The final floodway alinement should be plotted on maps at such scale that local officials can readily identify the floodway limits with known locations. The concerned agency may also request copies of the cross sections with the floodway delineated.

Tape No. 20, 21, 2



WATER SURFACE PROFILES THROUGH BRIDGES AND COMPUTER REQUIREMENTS FOR BRIDGE FLOW

13 JUNE 1974

THE HYDROLOGIC ENGINEERING CENTER
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This packet contains material used during the presentation of two lectures on the application of the HEC-2 bridge routines.

The first blue lecture outline covers the material presented in tapes 20 and 21, while the second outline covers tape 22. Also included is a copy of a workshop problem with its solution (white pages) illustrating the bridge calculations performed in the Special Bridge Routine. The problem is referenced in the lectures.

Following the handout is a workshop problem (yellow pages) introduced at the end of tape 22. The problem calls for coding input for the HEC-2 Special Bridge Routine. A solution (green pages) showing program input and output is also provided. New program users are encouraged to code the workshop problem before looking at the solution.

Additional information on the HEC-2 bridge routines is presented in Training Document No. 6, "Application of the HEC-2 Bridge Routines," which is available from The Hydrologic Engineering Center.

WATER SURFACE PROFILES THROUGH BRIDGES

1. Nature of Flow Through Bridges

   a. Laurson's four flow zones

   b. Classes of flow

2. Approaches to Bridge Loss Computation

   a. Ordinary standard step computations

   b. Apply energy or momentum equations to evaluate pier losses and standard step method for remaining losses

   c. Apply energy equation between sections located in zones of gradually varied flow to account for all bridge losses

3. Methods Available in HEC-2

   a. Normal bridge routine

      - Ordinary water surface profile calculations with provision for reduced flow area and increased wetted perimeter due to bridge

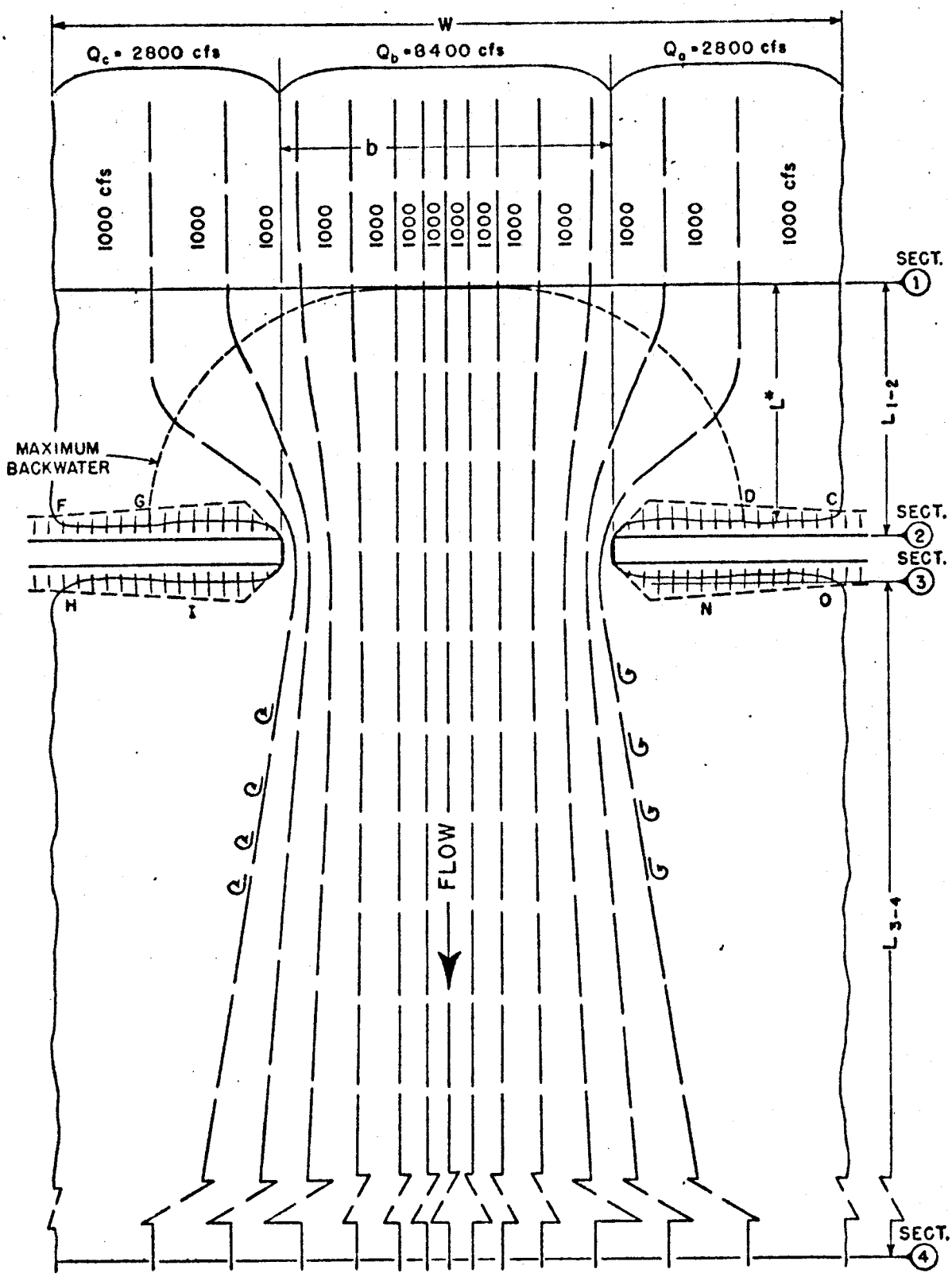


Figure 1.—Flow lines for typical normal crossing.

(after Bur. of Public Roads, Ref. b)

b. Special bridge routine

(1) Low flow

- Transfers to normal bridge routine if bridge does not have piers

- Uses Yarnell equation for Class A low flow (for bridge with piers)

- Uses momentum principles for Class B or Class C low flow

Calculations for low flow with bridge piers are based on a bridge opening that is trapezoidal in shape

(2) Pressure flow

$Q = A\sqrt{2gH/K}$ {ORIFICE EQUATION}

Typical value of K for bridge openings is 1.5

(3) Weir flow

$Q = CLH^{3/2}$

- Incorporates correction for submergence based on Ogee-shaped weir

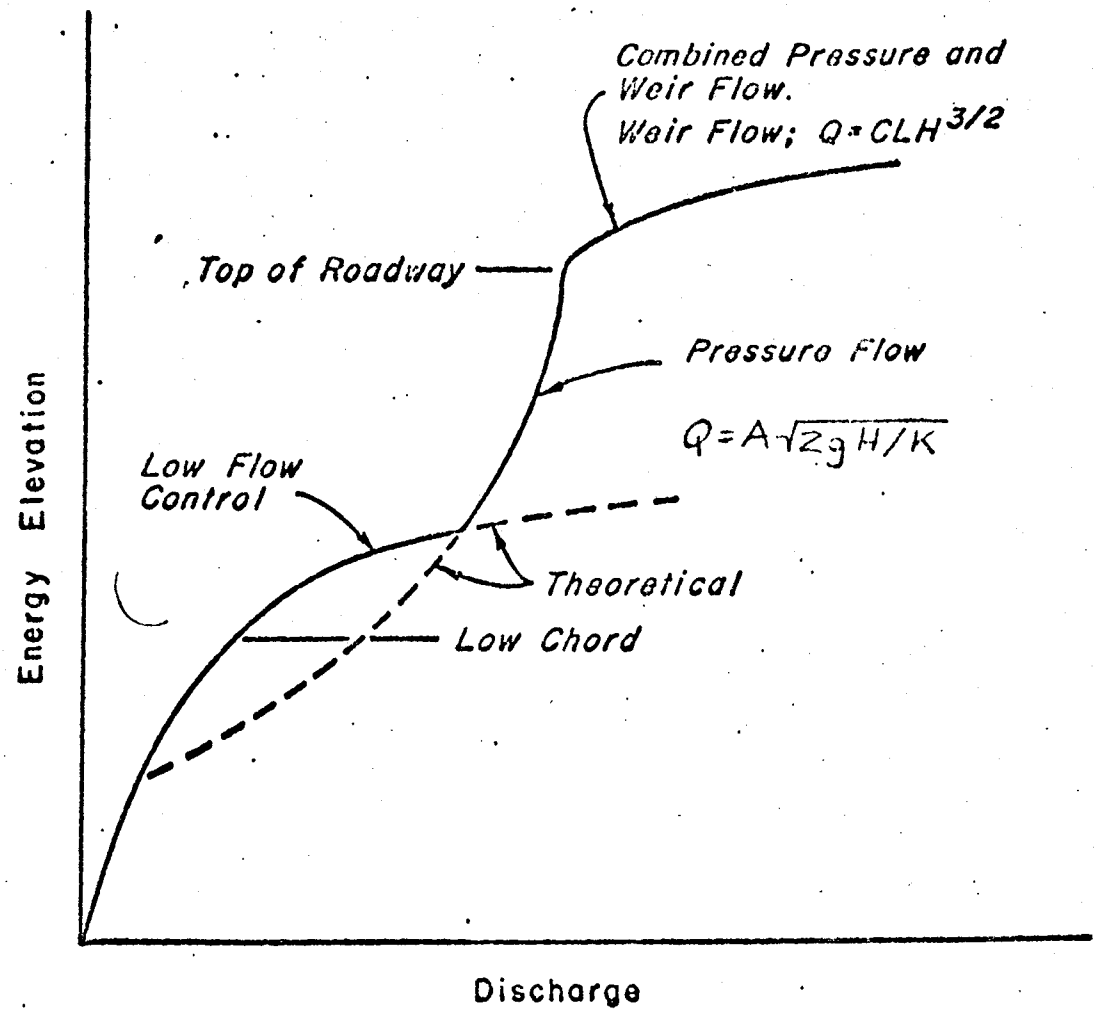
(4) Combination of flow types

c. Input bridge loss

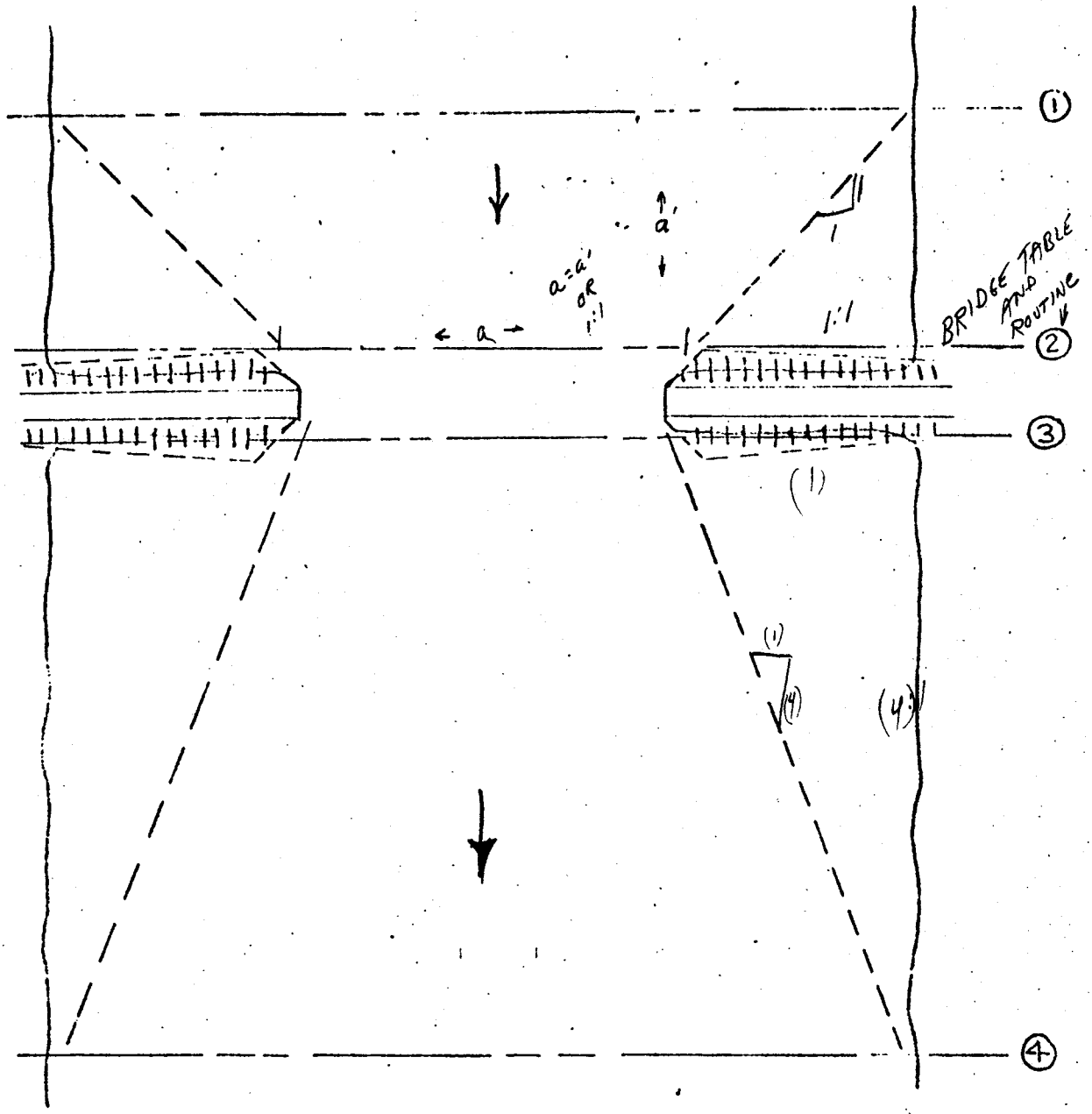
4. Selection of Method for Determining Losses

a. Accuracy required

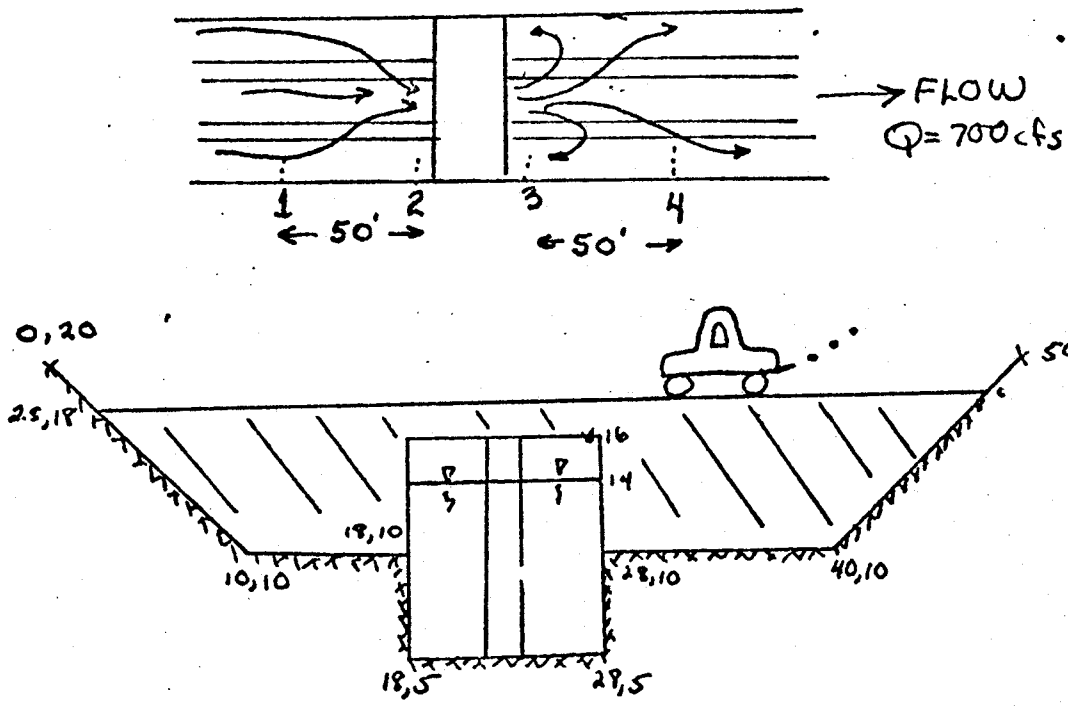
$H_3 = 2K(K + \frac{10}{g_3} V$



TYPICAL DISCHARGE RATING CURVE FOR BRIDGE CULVERT



1:4 EXPANSION



ENERGY LOSSES

Section	Friction Loss	Contraction or Expansion Loss	Pier Obstruction Loss
1 - 2	.12	.23	--
2 - 3	--	--	.52
3 - 4	.18	.42	--
Σ = 1.47	Σ = .30	Σ = .65	Σ = .52

COMPUTER REQUIREMENTS FOR BRIDGE FLOW

Reference: HEC-2, Computer Program Water Surface Profiles, Users Manual.

1. Cross Section Locations

   a. Downstream cross section represents fully expanded flow. (Section 1, figure 1)

      (1) Section location can be located downstream of the bridge around 4 times the average side contraction caused by the bridge.

      (2) May want to locate left and right bank stations consistent with bridge abutments if the section is to be repeated upstream.

   b. Immediately downstream of the bridge represents the effective flow area just coming out of the bridge. (Section 2, figure 1)

      (1) Effective area option used to confine flow to the bridge opening for low flow and pressure flow solutions. (X3 card with 10 in field 1)

      (2) The elevations for the effective area option are extended to the estimated elevation where weir flow would be expected. (X3 card, fields 8 and 9)

      (3) Expansion losses would be calculated at this section.

   c. Bridge is modeled by either Special or Normal Bridge routines between Sections 2 and 3.

(3) COFQ is the coefficient used in the weir equation. For bridge structures, a value around 2.5 would be used, and for roadway approaches (trapezoidal shape), a value around 3.0 is suggested.

(4) RDLEN is the length of a fixed elevation weir which can be used instead of using BT cards to describe a variable elevation weir.

(5) BWC is the bottom width of the trapezoidal approximation of the bridge opening for low flow calculations.

(6) BWP is the total width of piers in the bridge opening.

Σ_{SUM}

(7) BAREA is the net opening of the actual bridge. This area will be used for orifice calculations.

(8) SS is the side slope of the trapezoidal approximation of tne bridge.

(9) ELCHU is the invert elevation of the trapezoidal approximation on the upstream side of the bridge.

(10) ELCHD is the invert elevation of the trapezoid on the downstream side.

b. X2 card is required with Section 3.

(1) Special bridge routine is called with a 1 in the third field.

(1) RDST are the road stations on the BT cards and they must be the same as ground stations on the GR cards.

(2) RDEL are the road elevations accross the bridge.

(3) XLCEL are the low chord elevations accross the bridge. For the road approach sections, the low chord elevation is usually given as the ground elevation.

c. Standard step solutions will be made through the bridge based on the bridge sections given.

4. Fixed Bridge Loss

a. A bridge loss can be read in between any two sections using the X5 card.

b. Change in water surface elevation or a fixed water surface elevation can be read in the card.

c. Variable INQ (J1 field 2) tells the program which field of the X5 card to read for any profile.

BRIDGE LOSS COMPUTATIONS -
SPECIAL BRIDGE ROUTINE

PROBLEM DESCRIPTION

Figure 1 shows the profile and cross sections for a rectangular concrete lined channel with a single bridge. Water surface profiles were computed through the bridge from Sections 2 to 3 for three cases using computer program HEC-2 and the special bridge routine. The results of these computations are shown in Exhibits 1 to 3.

For each case the water surface elevation at Section 2 is 1215.00 and flow is subcritical. The type of flow through the bridge, low chord elevation, and top of roadway elevation for each case are tabulated in Table 1 below.

TABLE 1

Case	Flow Type	Elevation Low Chord	Elevation Top Roadway
1	Low Flow	1220.0	1225.0
2	Pressure Flow	1210.0	1225.0
3	Pressure and Weir Flow	1210.0	1212.0

PROBLEM

a. Check the computer computations for energy slope (SLOPE), friction loss (HL), elevation of the energy grade line (EG), and computed water surface elevation at cross section 3, for each of the three cases.

b. Prepare the necessary input data to make the computer computations given.

c. What effect would a bridge with closed abutments, extending 20 feet into the channel from each side, have on the losses through the bridge?

1 CASE NO 2 SPECIAL BRIDGE ROUTINE-PRESSURE FLOW CONTROLLING

2 RECTANGULAR CHANNEL

3 FLAT CREEK (HEC-2 TEST NO 3)

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OTHER LOSS
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID
2.00	15.00	1215.00	1209.23	1215.00	1216.77	1.77	0.00	-0.00
16000.	0.	16000.	0.	0.	1500.	0.	0.	0.
0.00	0.00	10.67	0.00	0.015	0.015	0.015	0.000	1200.00
0.000445	0.	0.	0.	0	13	1	-0.00	100.00

PRESSURE FLOW

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	ELLC	ELTRD	CLASS
1221.13	1217.14	0.48	0.	16000.	900.	1210.00	1225.00	10.00
3.00	20.16	1220.16	1209.26	0.00	1221.13	0.98	4.37	-0.00
16000.	0.	16000.	0.	0.	2016.	0.	0.	0.
0.00	0.00	7.94	0.00	0.015	0.015	0.015	0.000	1200.00
0.000184	0.	0.	0.	3	0	1	-0.00	100.00

BRIDGE LOSS COMPUTATIONS

SPECIAL BRIDGE ROUTINE

PROBLEM DESCRIPTION

Figure 1 shows the plan, thalweg profile, and a bridge cross section in a natural stream channel. The channel cross section at the bridge is considered representative of the reach. The bridge has two square piers, each two feet wide. The remaining bridge area is 2250 square feet. The channel 'n' value is 0.04 and overbank 'n' is 0.08.

PROBLEM

1. Prepare the necessary input data using the special bridge routine option and operate HEC-2 to compute water surface profiles through the bridge. Start with a natural cross section at River Station 100 and operate the model to a natural cross section upstream of the bridge. The three discharges and the associated starting water surface elevations to be used are shown below.

Discharge	WSEL
8,000	525
10,000	530
25,000	532

2. For the 8,000 cfs discharge, what are the five computed components of loss through the bridge?

WATER SURFACE PROFILE COMPUTATION USING HEC-2

SPECIAL BRIDGE ROUTINE
PROBLEM SOLUTION

PS-18

7 PAGES

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**************************
SEPT 1971 VERSION UPDATED AUG 1974
ERROR CORRECTIONS 01,02,03,04,05,06,07,08
MODIFICATIONS 52,53,54,55,56,57
**************************
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```
T1      FLOOD PLAIN HYDROLOGY WORKSHOP
T2              SPECIAL BRIDGE
T3
```

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	2.	0.	0.	.000000	.00	.0	0.	525.000	.000

NC	.080	.080	.040	.300	.500	.000	.000	.000	.000	.000
NT	3.000	8000.000	10000.000	25000.000	.000	.000	.000	.000	.000	.000
X1	1.000	10.000	400.000	550.000	.000	.000	.000	.000	4.500	.000
GR	540.000	100.000	532.000	260.000	521.000	400.000	511.000	440.000	510.000	485.000
GR	512.000	510.000	518.000	550.000	526.000	650.000	533.000	720.000	540.000	930.000
X1	2.000	.000	.000	.000	500.000	500.000	500.000	.000	4.500	.000
X3	10.000	.000	.000	.000	.000	.000	.000	531.000	531.000	.000
SB	1.250	1.500	2.500	.000	70.000	4.000	2250.000	3.500	511.000	511.000
X1	3.000	.000	.000	.000	50.000	50.000	50.000	.000	.000	.000
X2	.000	.000	1.000	528.500	531.000	.000	.000	.000	.000	.000
X3	10.000	.000	.000	.000	.000	.000	.000	531.000	531.000	.000
BT	6.000	100.000	540.000	.000	260.000	532.000	.000	275.000	531.000	.000
BT	700.000	531.000	.000	720.000	533.000	.000	930.000	540.000	.000	.000
X1	4.000	.000	.000	.000	150.000	150.000	150.000	.000	.000	.000
EJ	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

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SEPT 1971 VERSION UPDATED AUG 1974
ERROR CORRECTIONS 01,02,03,04,05,06,07,08
MODIFICATIONS S2,S3,S4,S5,S6,S7
**************************
```

T1 FLOOD PLAIN HYDROLOGY WORKSHOP
T2 SPECIAL BRIDGE
T3

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	3.	0.	0.	.000000	.00	-1.0	0.	530.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	2.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

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**************************
SEPT 1971 VERSION UPDATED AUG 1974
ERROR CORRECTIONS 01,02,03,04,05,06,07,08
MODIFICATIONS 52,53,54,55,56,57
**************************
```

T1 FLOOD PLAIN HYDROLOGY WORKSHOP
T2 SPECIAL BRIDGE
T3

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	4.	0.	0.	.000000	.00	-1.0	0.	532.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	15.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

SUMMARY PRINTOUT FOR MULTIPLE PROFILES

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	CRIWS	EG	TOPWID	10K*S	TIME	VOL
1.00	.00	.00	.00	505.50	8000.00	525.00	.00	525.12	393.18	1.50	.00	.00
1.00	.00	.00	.00	505.50	10000.00	530.00	.00	530.08	555.00	.78	.00	.00
1.00	.00	.00	.00	505.50	25000.00	532.00	.00	532.36	655.00	3.32	.00	.00
2.00	500.00	.00	.00	510.00	8000.00	525.03	.00	525.35	150.00	5.69	.03	31.42
2.00	500.00	.00	.00	510.00	10000.00	529.98	.00	530.23	150.00	2.80	.03	48.86
2.00	500.00	.00	.00	510.00	25000.00	532.06	.00	532.80	451.86	8.16	.02	68.89
3.00	50.00	531.00	528.50	510.00	8000.00	525.05	.00	525.37	150.00	5.65	.03	33.45
3.00	50.00	531.00	528.50	510.00	10000.00	530.20	.00	530.44	150.00	2.68	.04	51.76
3.00	50.00	531.00	528.50	510.00	25000.00	533.24	.00	533.85	492.26	6.33	.02	74.71
4.00	150.00	.00	.00	510.00	8000.00	525.20	.00	525.46	293.35	4.87	.04	40.34
4.00	150.00	.00	.00	510.00	10000.00	530.35	.00	530.50	412.42	1.91	.05	63.11
4.00	150.00	.00	.00	510.00	25000.00	533.35	.00	533.95	497.69	6.19	.03	93.22

SECTION NUMBER	DISCHARGE CFS	CWSEL	CWSEL DIFF EACH Q	CWSEL DIFF EACH SECTION	CWSEL-WSELK	TOPWID	T.W. DIFF	LENGTH
1.000	8000.000	525.000	.000	.000	.000	393.182	.000	.000
1.000	10000.000	530.000	5.000	.000	.000	555.000	-161.818	.000
1.000	25000.000	532.000	2.000	.000	.000	655.000	-261.818	.000
2.000	8000.000	525.030	.000	.030	.000	150.000	.000	500.000
2.000	10000.000	529.983	4.954	-.017	.000	150.000	.000	500.000
2.000	25000.000	532.062	2.079	.062	.000	451.863	-301.863	500.000
3.000	8000.000	525.053	.000	.023	.000	150.000	.000	50.000
3.000	10000.000	530.203	5.150	.220	.000	150.000	.000	50.000
3.000	25000.000	533.243	3.040	1.181	.000	492.261	-342.261	50.000
4.000	8000.000	525.196	.000	.143	.000	293.352	.000	150.000
4.000	10000.000	530.346	5.150	.143	.000	412.416	-119.064	150.000
4.000	25000.000	533.351	3.005	.108	.000	497.694	-204.342	150.000

DATA FOR LAST CROSS SECTION

PROFILE	TYPE ENC	TARGET	TOP WIDTH AREA-ACRES	TOP WIDTH AREA-DIFF
1	.000	.000	4.053	.000
2	.000	.000	5.187	1.134
3	.000	.000	8.599	4.546

CEHV= .300 CEHV= .500

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XCL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
1.00	26.50	532.00	.00	532.00	532.36	.36	.00	.00	516.50
25000.	2312.	19081.	3607.	1602.	3487.	2124.	0.	0.	513.50
.00	1.44	5.47	1.70	.080	.040	.080	.000	505.50	170.00
.000332	0.	0.	0.	0	0	1	.00	655.00	825.00
2.00	22.06	532.06	.00	.00	532.80	.74	.25	.19	521.00
25000.	1294.	21019.	2687.	779.	2822.	1190.	69.	6.	518.00
.02	1.66	7.45	2.26	.080	.040	.080	.040	510.00	258.76
.000816	500.	500.	500.	2	0	1	.00	451.86	710.62

SPECIAL BRIDGE

SB	XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
	1.25	1.50	2.50	.00	70.00	4.00	2250.00	3.50	511.00	511.00

PRESSURE AND WEIR FLOW

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	ELLC	ELTRD	CLASS
534.94	532.85	.05	5379.	19705.	2250.	528.50	531.00	30.00
3.00	23.24	533.24	.00	.00	533.85	.61	1.05	.00	521.00
25000.	1578.	20495.	2927.	940.	2999.	1388.	75.	7.	518.00
.02	1.04	6.83	2.11	.080	.040	.080	.040	510.00	235.10
.000633	50.	50.	50.	2	0	2	.00	492.26	727.36
4.00	23.35	533.35	.00	.00	533.95	.59	.09	.00	521.00
25000.	1603.	20446.	2951.	978.	3016.	1407.	93.	9.	518.00
.03	1.04	6.78	2.10	.080	.040	.080	.040	510.00	232.92
.000619	150.	150.	150.	0	0	1	.00	497.69	730.62

```
CCHV=    .300 CEHV=    .500
  SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS    BANK ELEV
  Q        ULOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA      LEFT/RIGHT
  TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN    SSTA
  SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID   ENDST

     1.00    24.50   530.00      .00   530.00   530.08      .08      .00      .00   516.50
    10000.     747.    7977.    1277.    1182.    3187.    1634.       0.       0.   513.50
      .00      .63     2.50      .78     .080     .040     .080     .000   505.50   210.00
  .000078       0.       0.       0.        0        0        1      .00   555.00   765.00

OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      531.00 ELREA=      531.00

     2.00    19.98   529.98      .00      .00   530.23      .25      .07      .08   521.00
    10000.       0.   10000.       0.       0.    2510.       0.      49.       4.   518.00
      .03      .00     3.98      .00     .080     .040     .080     .040   510.00   400.00
  .000280     500.     500.     500.        2        0        1      .00   150.00   550.00

SPECIAL BRIDGE

SB  XK      XKOR     CDFQ     RDLEN    BWC      BWP      BAREA    SS       ELCHV    ELCHD
     1.25     1.50     2.50      .00    70.00     4.00  2250.00     3.50   511.00   511.00

PRESSURE FLOW

  EGPRS    EGLWC    H3       QWEIR    QPR      BAREA    ELLC     ELTRD    CLASS

   530.44   530.24      .01       0.    10000.    2250.   528.50   531.00    10.00

OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      531.00 ELREA=      531.00

     3.00    20.20   530.20      .00      .00   530.44      .24      .21      .00   521.00
    10000.       0.   10000.       0.       0.    2543.       0.      52.       4.   518.00
      .04      .00     3.93      .00     .080     .040     .080     .040   510.00   400.00
  .000268       50.      50.      50.        2        0        1      .00   150.00   550.00

     4.00    20.35   530.35      .00      .00   530.50      .16      .03      .03   521.00
    10000.     399.    8680.     921.     556.    2564.     929.      63.       5.   518.00
      .05      .72     3.38      .99     .080     .040     .080     .040   510.00   281.05
  .000191     150.     150.     150.        2        0        1      .00   412.42   693.46
```

```
CCHV=    .300 CEHV=    .500
   SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS    BANK ELEV
   Q        OLCH     QCH      QROB     ALOH     ACH      AROB     VOL      TWA      LEFT/RIGHT
   TIME     VLOH     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN    SSTA
   SLOPE    XLOBL    XLCH     XLOBR    IIRIAL   IDC      ICONT    CORAR    TOPWID   ENDST

     1.00    19.50   525.00      .00   525.00   525.12      .12      .00      .00   516.50
    8000.      274.    7054.     672.     460.    2437.     811.       0.       0.   513.50
      .00      .60     2.89      .83     .080     .040     .080     .000   505.50   291.82
  .000150       0.       0.       0.        0        0        1      .00   393.18   685.00

OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      531.00 ELREA=      531.00

     2.00    15.03   525.03      .00      .00   525.35      .32      .13      .10   521.00
    8000.       0.    8000.       0.       0.    1767.       0.      31.       3.   518.00
      .03      .00     4.53      .00     .080     .040     .080     .040   510.00   400.00
  .000569     500.     500.     500.        2        0        1      .00   150.00   637.87

SPECIAL BRIDGE

SB  XK      XKOR     COFQ     RDLEN    BWC      BWP      BAREA    SS       ELCHU    ELCHD
    1.25     1.50     2.50       .00    70.00     4.00  2250.00     3.50   511.00   511.00

CLASS A LOW FLOW

BRIDGE W.S.=    525.00  BRIDGE VELOCITY=      4.97

  EGPRS    EGLWC    W3       OWEIR    QPR      BAREA    ELLC     ELTRD    CLASS

     .00   525.37     .02       0.    8000.    2250.   528.50   531.00     1.00

OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      531.00 ELREA=      531.00

     3.00    15.05   525.05      .00      .00   525.37      .32      .02      .00   521.00
    8000.       0.    8000.       0.       0.    1770.       0.      33.       3.   518.00
      .03      .00     4.52      .00     .080     .040     .080     .040   510.00   400.00
  .000565      50.      50.      50.        0        0        1      .00   150.00   638.16

     4.00    15.20   525.20      .00      .00   525.46      .27      .08      .01   521.00
    8000.      75.    7614.     311.     112.    1792.     324.      40.       4.   518.00
      .04      .67     4.25      .96     .080     .040     .080     .040   510.00   346.60
  .000487     150.     150.     150.        2        0        1      .00   293.35   639.95
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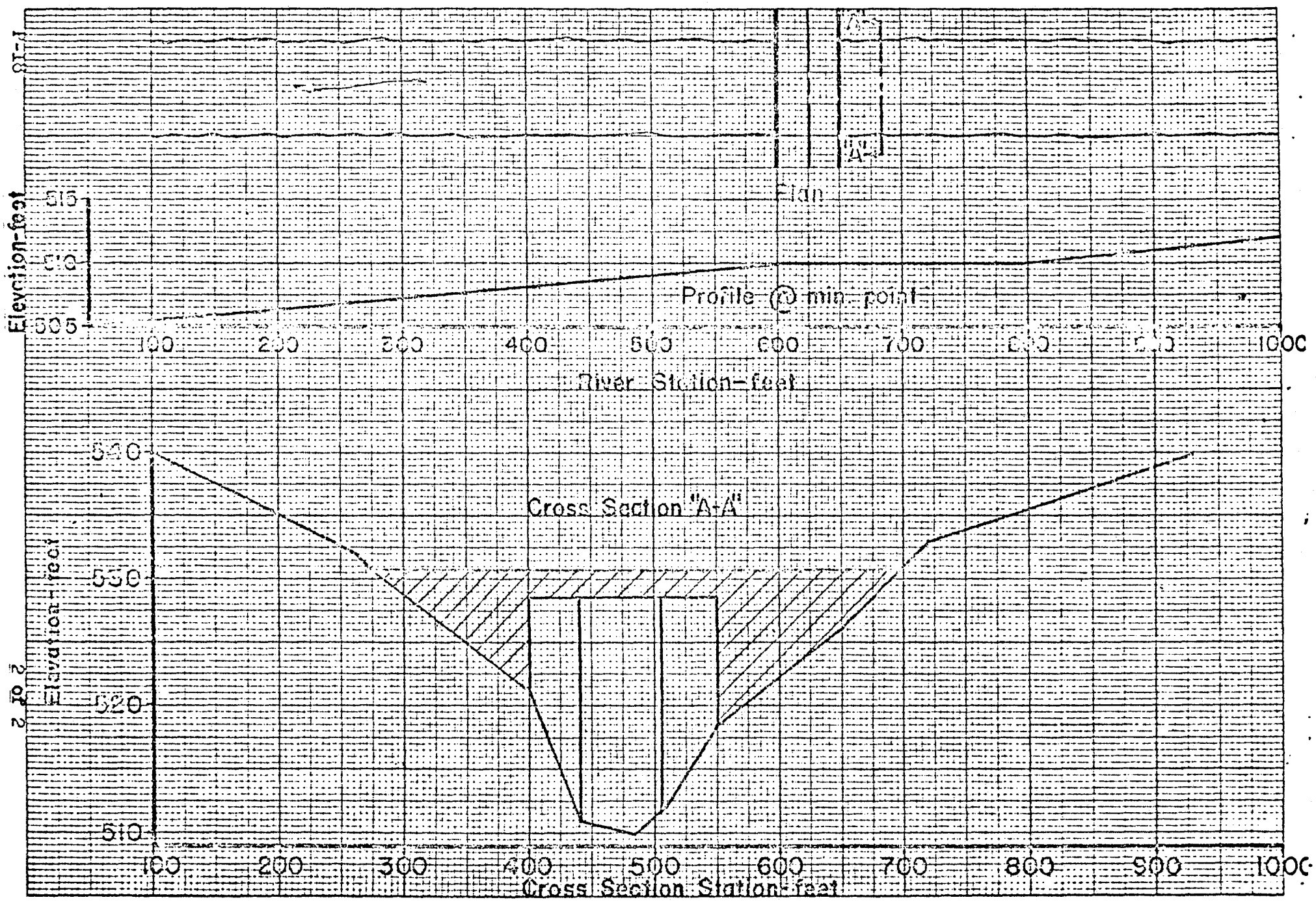
2 OF 7


Plan
A
A
Profile @ min. point
Elevation-feet
515
510
505
100
200
300
400
500
600
700
800
900
1000
River Station-feet
Cross Section "A-A"
Elevation-feet
540
530
520
510
100
200
300
400
500
600
700
800
900
1000
Cross Section Station-feet

T1 CASE NO 3 SPECIAL BRIDGE ROUTINE-PRESSURE AND WEIR FLOW CONTROLLING
T2 RECTANGULAR CHANNEL
T3 FLAT CREEK

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OTHER LOSS
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID
2.00	15.00	1215.00	1209.23	1215.00	1216.77	1.77	0.	0.
16000	0	16000	0	0	1500	0	0	0
0.	0.	10.67	0.	.015	.015	.015	0.	1200.00
.000445	0	0	0	0	13	1	0.	100.00

PRESSURE AND WEIR FLOW

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	ELLC	ELTRD	CLASS
1221.13	1217.14	.48	4573	11432	900	1210.00	1212.00	30.00
3.00	16.71	1216.71	1209.36	0.	1218.13	1.42	1.37	0.
16000	0	16000	0	0	1670	0	0	0
0.	0.	9.58	0.	.015	.015	.015	0.	1200.00
.000321	0	0	0	4	5	2	0.	100.00

1 CASE NO 1 SPECIAL BRIDGE ROUTINE-CLASS A LOW FLOW CONTROLLING

2 RECTANGULAR CHANNEL

3 FLAT CREEK (HEC-2 TEST NO 1)

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OTHER LOSS
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID
2.00	15.00	1215.00	1209.23	1215.00	1216.77	1.77	0.00	-0.00
16000.	0.	16000.	0.	0.	1500.	0.	0.	0.
0.00	0.00	10.67	0.00	0.015	0.015	0.015	0.000	1200.00
0.000445	0.	0.	0.	0	13	1	-0.00	100.00

CLASS A LOW FLOW

BRIDGE W.S.= 1214.36 BRIDGE VELOCITY= 12.38

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	ELLC	ELTRD	CLASS
0.00	1217.14	0.48	0.	16000.	1350.	1220.00	1225.00	1.00
3.00	15.48	1215.48	1209.26	0.00	1217.14	1.66	0.37	-0.00
16000.	0.	16000.	0.	0.	1548.	0.	0.	0.
0.00	0.00	10.34	0.00	0.015	0.015	0.015	0.000	1200.00
0.000404	0.	0.	0.	0	0	1	-0.00	100.00

Exhibit 1

(2) Test elevation for calculating pressure flow can be read in on field four. (Usually the maximum low chord elevation)

(3) Test elevation for calculating weir flow can be read in on field five. (Usually the minimum elevation on the road or weir)

c. BT cards are located with the upstream section 3 to define the top of road (or weir) for the Special bridge routine.

(1) Cards are located after the X3 card and before the GR cards, if any are used.

(2) The minimum number of road stations and elevations can be used to define the weir if the bridge has a pier width indicated on the SB card.

(3) Without a pier width, the program would use standard step calculations for low flow solutions. Then the road stations on the BT card must be consistent with GR stations and low chord elevations would be required. (See Normal Bridge Routine)

3. Normal Bridge Routine

a. Between sections 2 and 3, one or more sections are added to define the bridge opening.

b. Sections defining the bridge are normally ground sections (like Sections 2 and 3) with BT cards used to define the bridge structure.

d. Immediately upstream of the bridge represents the effective flow area going into the bridge. (Section 3)

(1) Often this section is a repeat of Section 2 geometry.

(2) Effective area option is used the same as Section 2 except the elevation is usually set to the weir elevation.

e. The upstream section represents the full flow section before the flow starts contracting to pass through the bridge. (Sec. 4)

(1) Section can be located by placing the section upstream a length equal to the bridge opening or by using a length equal to the average contraction width.

(2) Contraction losses would be calculated at this section.

f. Added sections could be placed between Sections 1 and 2, and between Sections 3 and 4 if the reach lengths were too long.

2. Special Bridge routine.

a. SB card would be added between Sections 2 and 3 to model the bridge structure.

(1) XK is the pier shape coefficient for the Yarnell equation. Values are given in Exhibit 2.

(2) XKOR is the coefficient for orifice flow calculations. For most bridges, a value of 1.5 can be used and for long culverts, a value can be calculated as shown in Exhibit 2.

References:

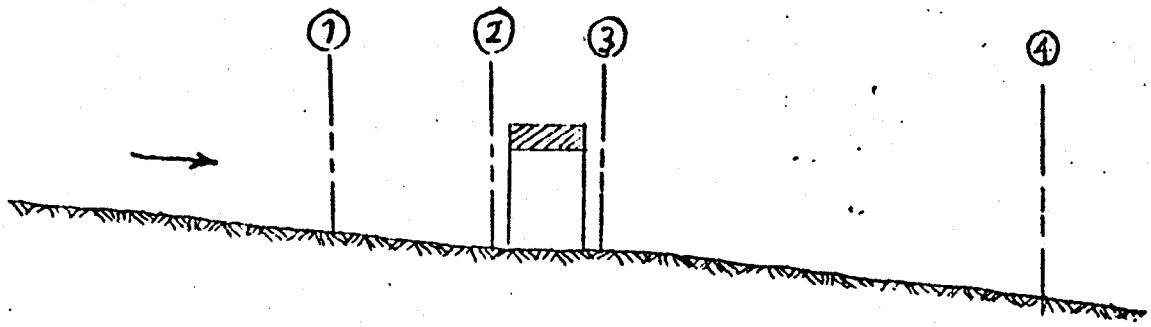
a. Laursen, Emmett, M., "Bridge Backwater in Wide Valleys," ASCE, J. Hyd. Div., Vol. 96, No. HY 4, April 1970.

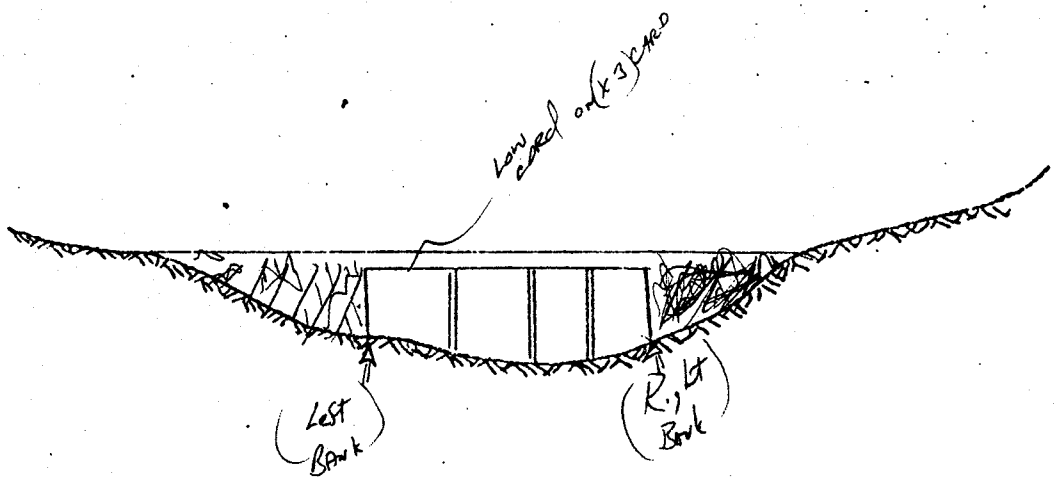
b. Bureau of Public Roads, Hydraulics of Bridge Waterways, Hydraulic Design Series, No. 1, Second Edition, 1970.

c. Computer Program HEC-2, Water Surface Profiles, Users Manual, February 1972.

d. Eichert, B. S., and Peters, J., Computer Determination of Flow Through Bridges, ASCE, J. Hyd. Div., Vol. 96, No. HY7, July 1970.

e. U. S. Army Corps of Engineers, Water Surface Profiles, IHD Volume 6, The Hydrologic Engineering Center, July 1972.





Fields 8+9 extend centers for effective pers

CROSS SECTIONS 2 & 3.

FOR LOW FLOW

b. Normal bridge routine

(1) Use for low flow where flow area cannot be approximated by a trapezoid

(2) Use for low flow in long culverts

(3) Use where bridge (including abutments) is a small obstruction to the flow

(4) Use for bridges under high submergence

(5) Will not permit profile to cross critical depth line

c. Special bridge routine

(1) Determines class of flow

(2) Uses hydraulic formulae

(3) Suitable for pressure flow through culverts

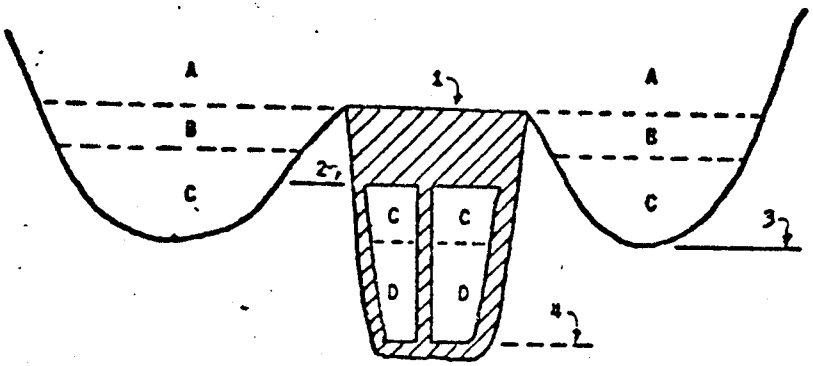
5. Modeling the Flow Boundaries

a. Positioning cross sections

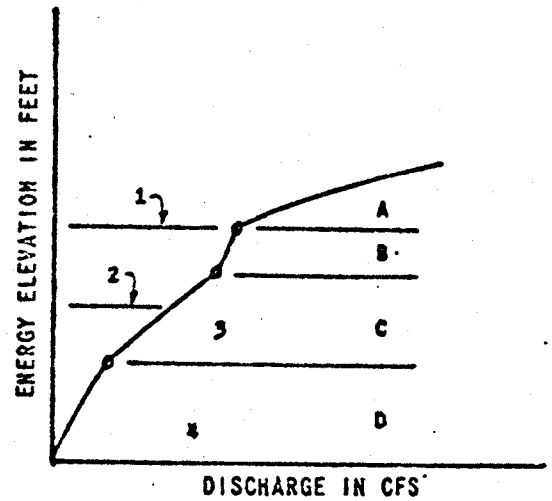
b. Specifying effective flow areas

6. Components of Bridge Losses

- Contraction loss, upstream friction loss, "structure" loss, expansion loss, downstream friction loss



BRIDGE CROSS SECTION



BRIDGE RATING CURVE

ELEVATIONS

1 Top of Roadway

2 Low Chord

3 Roadway Approach

4 Channel Invert

FLOW CONDITION

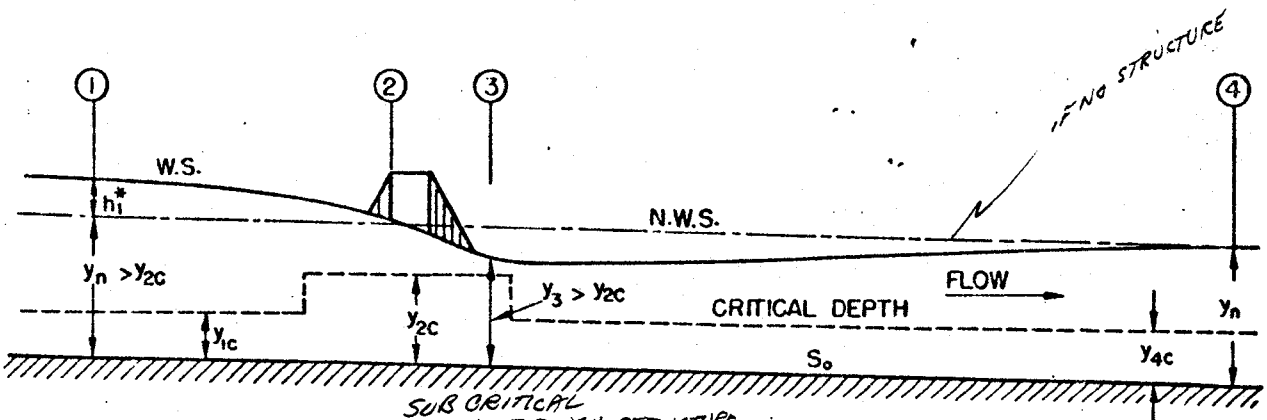
A - Combined pressure under bridge, weir in over banks, weir over bridge

B - Combined pressure under bridge, weir in overbanks

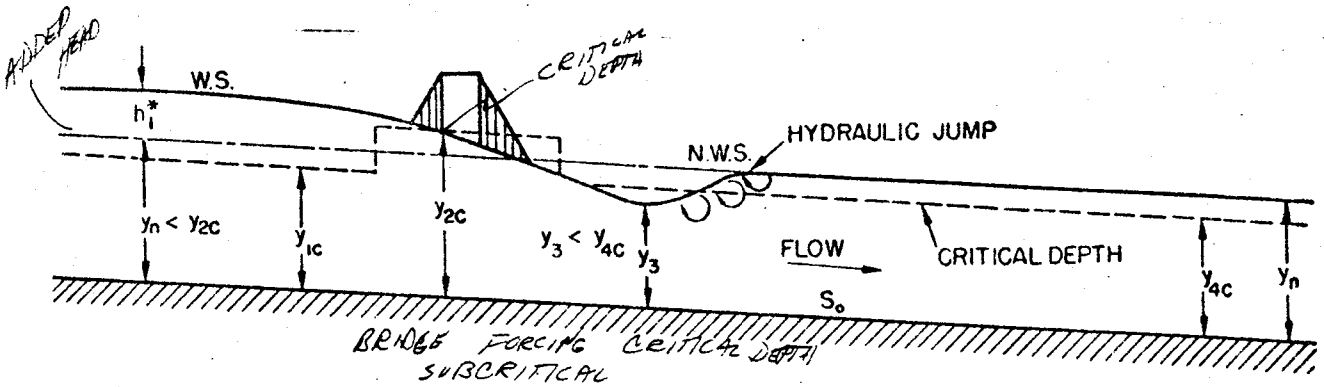
C - Combined low flow under bridge, weir in overbanks

D - Low flow under bridge

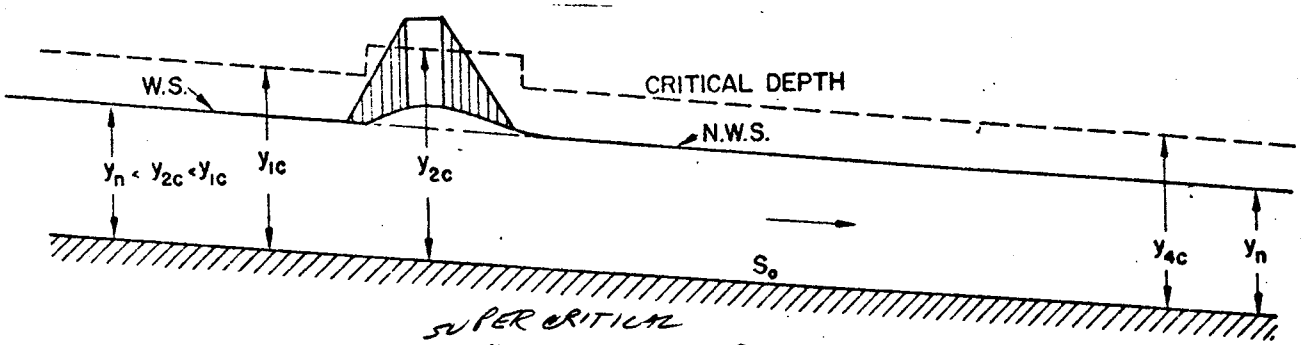
ILLUSTRATION OF BRIDGE FLOW TYPES



SUB CRITICAL
ENTIRELY THROUGH STRUCTURE
CLASS A

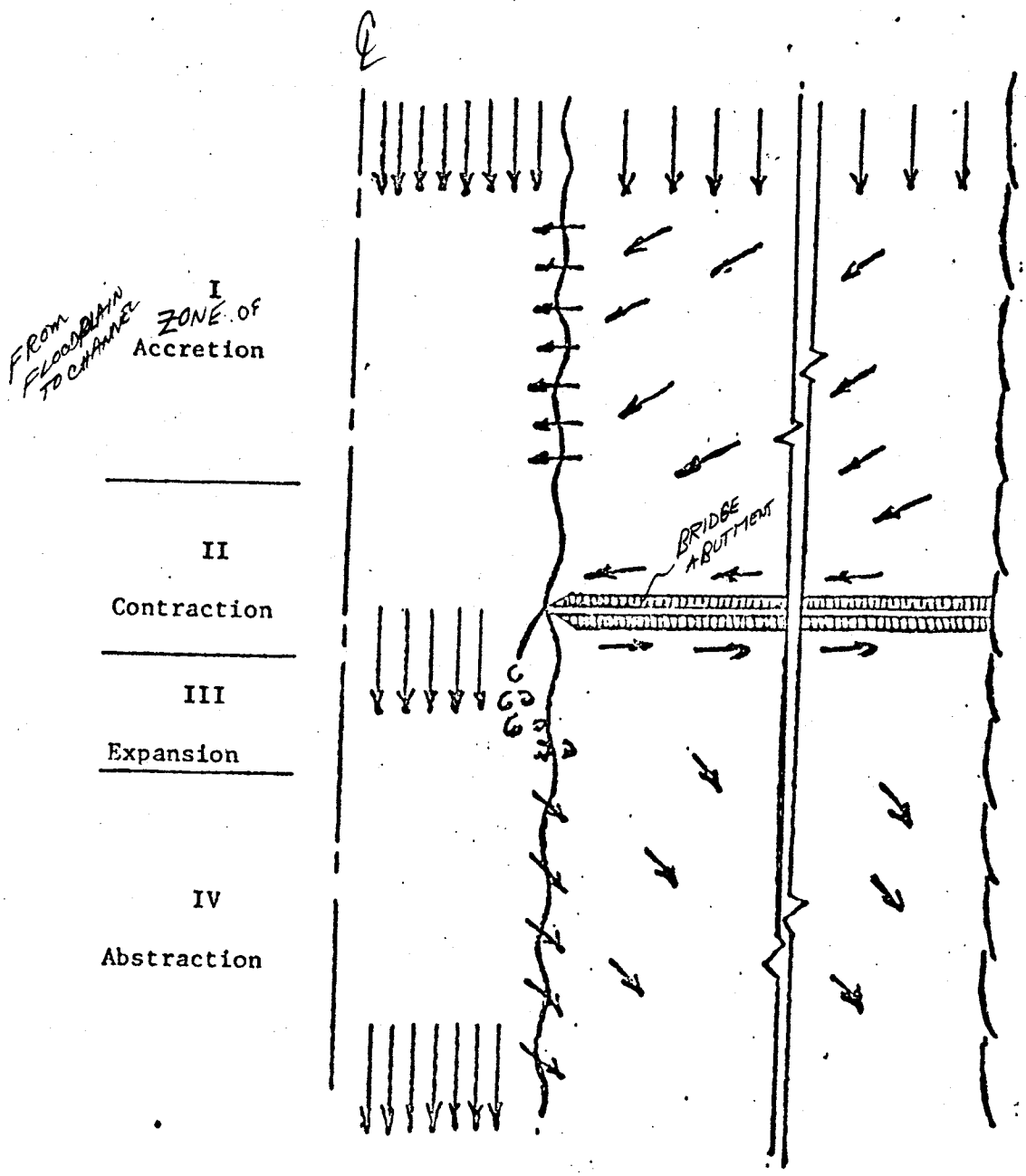


BRIDGE FORCING CRITICAL DEPTH
SUBCRITICAL
CLASS B



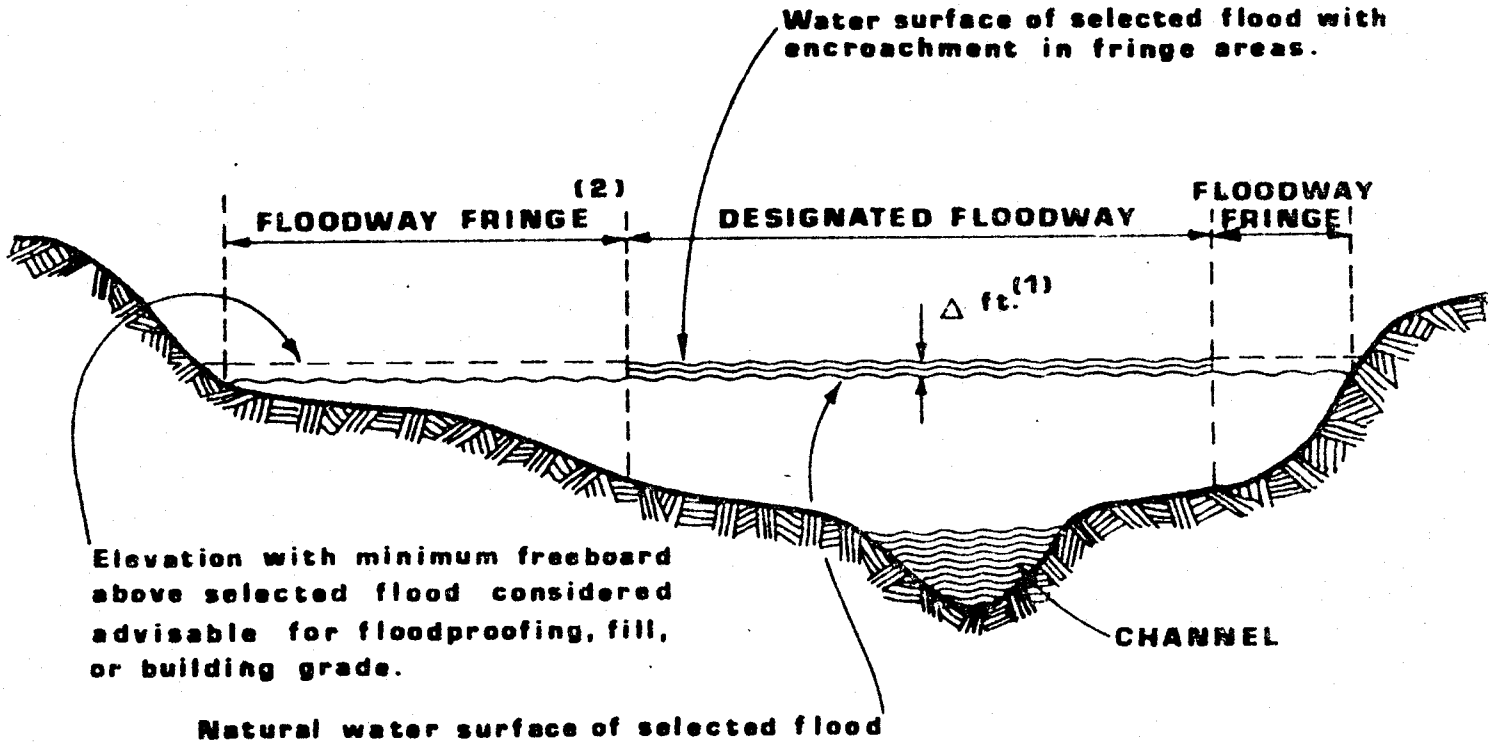
SUPER CRITICAL
THROUGH ENTIRE REACH
CLASS C

(after Bur. of Public Roads, Ref. b)



Four Flow Zones (After Laursen)

[Ref A]



(1) Maximum of 1 foot or less if so established by State or local regulations.

(2) The floodway fringe should normally be considered as the area between the designated floodway limit and the limit of the natural selected flood as long as the encroachment results in only an insignificant increase (less than 1 foot) in the water surface of the selected flood.

Figure 1

c. Based on the estimated widths, run backwater calculations to determine the revised water surface profile to verify if the confined floodway and rise in water surface elevations are within the parameters allowed.

d. Analyze the first trial computation and make necessary adjustments in floodway boundaries to approximate the required water surface elevations. Subsequent finite adjustments to reach an exact elevation should not be attempted as parameter variations along the study reach preclude the need for such detailed analysis.

e. Additional adjustments may be required for loss of valley storage, excessive velocities, unreasonable depths in the floodway fringe area, and floodway configuration to maintain smooth transitions between various reaches of the floodway.

f. Computerized Procedure: The above described procedures have been incorporated in Computer Program 723-X6-L202A, "Water Surface Profiles," Hydrologic Engineering Center, Davis, California. This program, commonly known as HEC-2, was revised in September 1971 to be used on either CDC6600 or GE400 series computers.

(1) Water surface profiles are readily available from the program, including analysis for bridges, culverts, and other restrictions or obstructions.

(2) Using floodway determination Method Number 4, the incremental increase in water surface is added to the elevation based on existing conditions. The program then analyzes the conveyance capacity of the flood plain cross section and establishes encroachment boundaries for the floodway that are based on removing an equal amount of conveyance from each side of the flood plain.

(3) In addition to providing a printout of the resulting floodway dimensions, a tabulation is printed of the cross section conveyance distribution. The subareas of flow in each overbank are based on conveyance units of 3 percent of the total flow.

(4) The floodway derived by the above computer method satisfies the engineering data requirements. However, the need to provide smooth floodway boundaries, rather than the undulations provided by Method 4, requires a reanalysis of the floodway. Method 1 of the HEC-2 program provides this capability.

d. The *Floodway Fringe* will normally be considered as that portion of the flood plain between the floodway and the natural outline of the selected flood. (This land can be considered for development, provided the area is either filled to a required elevation or other floodproofing measures are applied to protect against the flood hazard condition.)

e. For purposes of hydraulic computations, it will be assumed that the *Floodway Fringe* area is filled solid and has no overbank storage nor floodflow capacity.

f. The hydrology and hydraulics for floodways will be based on existing conditions unless future flood control works are under construction and scheduled for operation within 2 years.

g. Since inclusion of the *Designated Floodway* in land use regulations is a non-Federal responsibility, the Corps' role is to provide sufficient data and guidance to enable the local officials to select the appropriate limits.

4. SPECIAL CONSIDERATIONS.

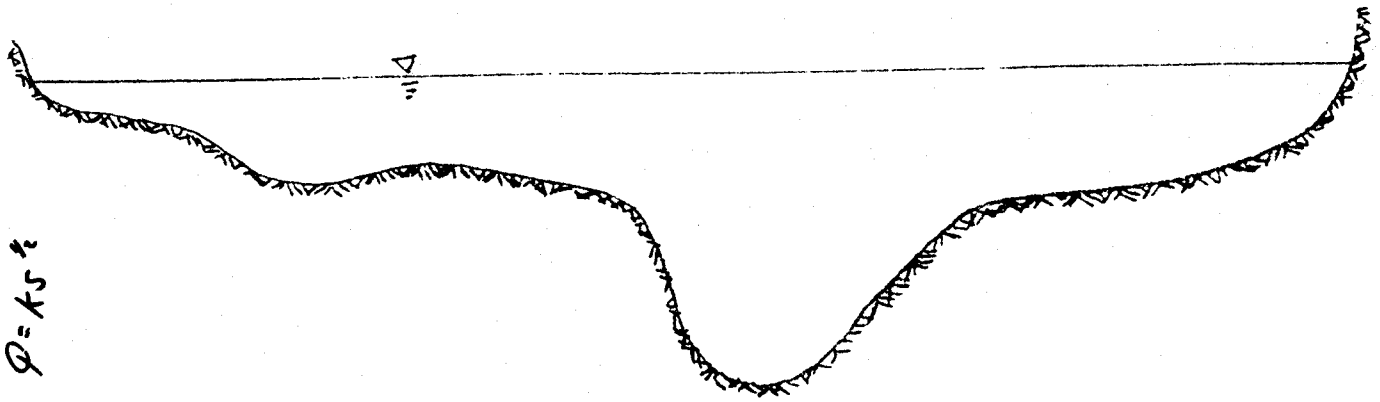
a. The effect of existing development within the floodway should be considered if it is sufficient to alter flow capacity or location of the floodway limits.

b. The loss of valley storage by confinement of the flow to the *Designated Floodway* can be significant. If such losses accumulate to where the flow increase exceeds 10 percent of the initial flow, it should be accounted for in determining the floodway's areal requirements.

c. Floodway delineations are not applicable in all cases, such as for inland sheet flow areas or coastal areas.

d. Variations in "n" values should be considered in individual segments of floodways. Composite "n" values in overbank areas can give misleading results; they should be used only when detailed refinement is not justified.

e. In situations where encroachment into the *Floodway Fringe* area causes excessive velocities to develop, particularly in those rare cases where the water surface elevation drops, other criteria should be selected to limit the extent of encroachment.



PERCENT CONVEYANCE $Q = KS^{1/2}$

FLOW DISTRIBUTION

MAIN CHANNEL

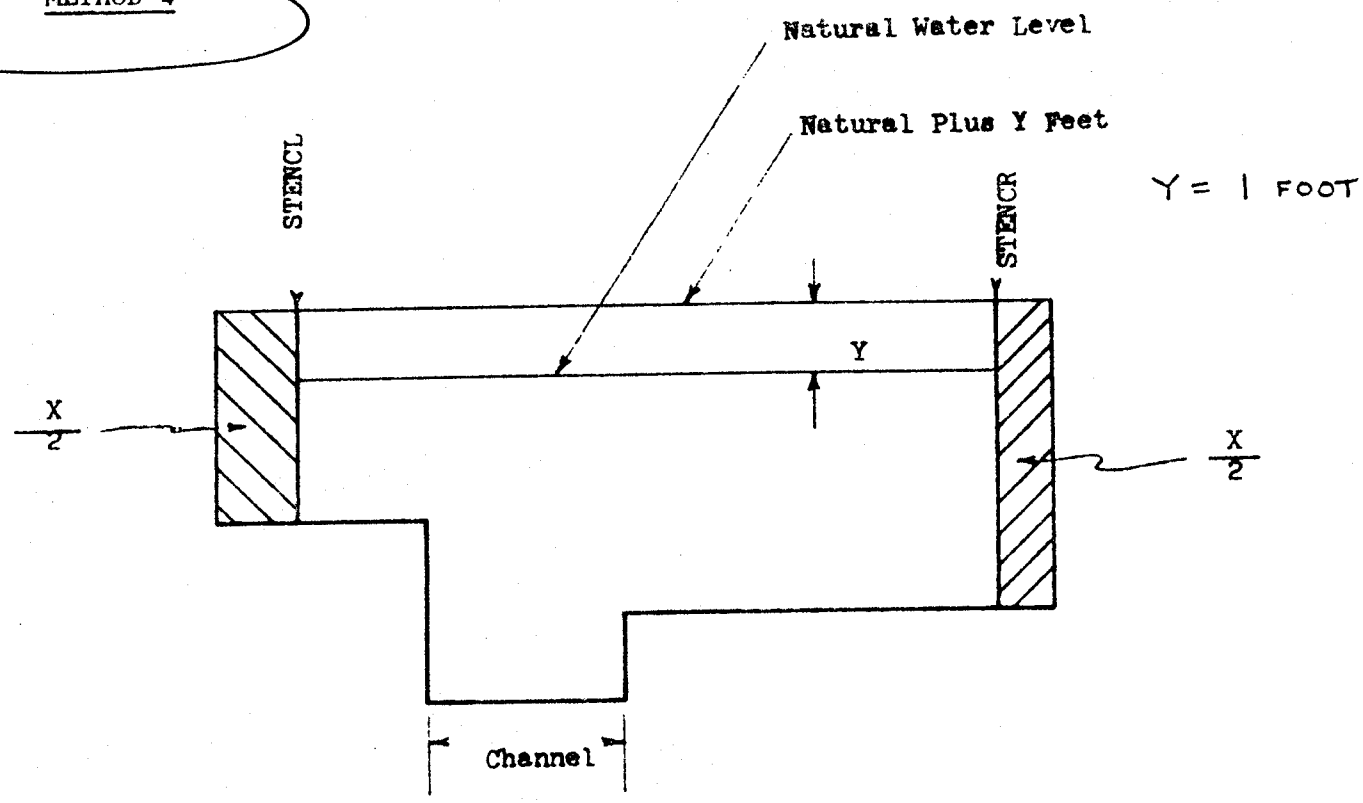
STA=	164.	200.	265.	270.	280.	420.	470.	500.	521.
PER Q=	2.2	4.0	.5	1.2	73.5	7.3	6.5	4.9	
AREA=	149.5	358.3	37.6	80.1	1889.1	375.6	285.3	197.5	
VEL=	2.8	2.2	2.6	2.8	7.6	3.8	4.4	4.9	

1	2	3	4	5	6	7	8	9	10
J2									15

INPUT TO ALLOW TO GET FLOW DISTRIBUTION

WILL GET FLOW DISTRIBUTION

METHOD 4



Encroachment stations are determined, when requested by the ET card, so that the conveyance of the cross section with encroachments and a water level Y feet above the natural profile is the same as the conveyance of the unmodified cross-section for the natural water level.

LAST EXHIBIT PAGE # 1136 (CODE # DISCRIPTION VARIABLES) (1+34 ARE MANDATORY)

MUST GO IN WITH ORIGINAL DATA

	1	2	3	4	5	6	7	8	9	10
J3	1	34	36	4	27	28	9			
J1		5								
ET					10.4					

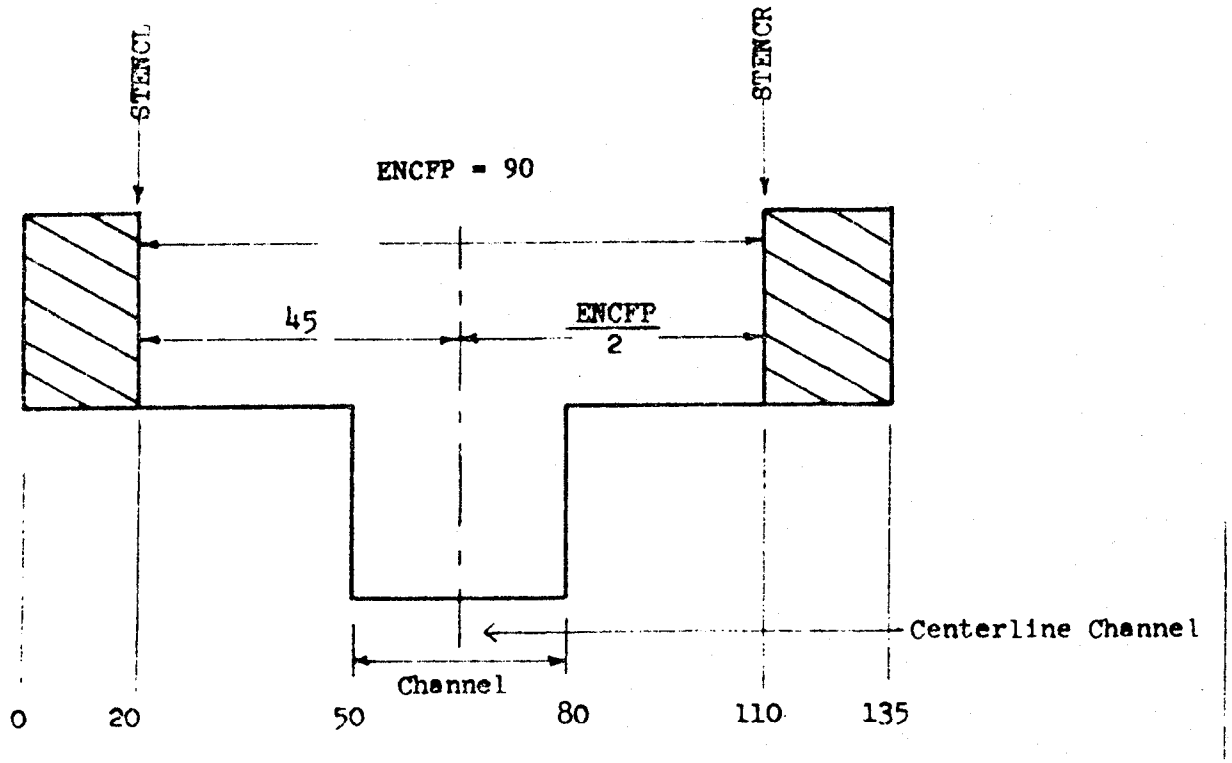
READ FIELDS OF ET CARD

SCALE

EQUALS 1 FOOT

METHOD 4

METHOD 2



Encroachment stations are computed from the width ENCFP which is centered on the midpoint of the left and right bank stations. ENCFP is read on the X3 or ET card

1	2	3	4	5	6	7	8	9	10
X1	6								
ET					90.2				

7. Method 1

   a. Input station and elevation on the X3 card

   b. Input station only on the ET card

   c. Multiple profile capability on the ET card

   d. Method 1 input applies only to the next cross section

   e. Can be used to stop encroachments by another method during any profile.

8. Other encroachment methods

   a. Method 2 is an input topwidth placed at each cross section by centering the encroachment width on the channel.

   b. Method 3 is an input reduction in conveyance expressed as a ratio

   c. Method 5 sets the limits of encroachment based on a natural floodway. Elevation limits can be set by running a profile through the encroached sections

9. Input-Output

   a. Exhibit 9A of the HEC-2 User's Manual describes methods, input and output

   b. Standard Test T in Exhibit 8 of the User's Manual shows an example of Methods 2, 3, and 4

4. Computer Procedures

a. Determine natural water surface profile using the flow-distribution option.

b. Run subsequent profiles using method 4 with limiting change in water surface elevation.

c. Analyze the first trial computations and make necessary adjustment required by:

(1) Excessive changes in water surface elevation.

(2) Significant increases in velocities.

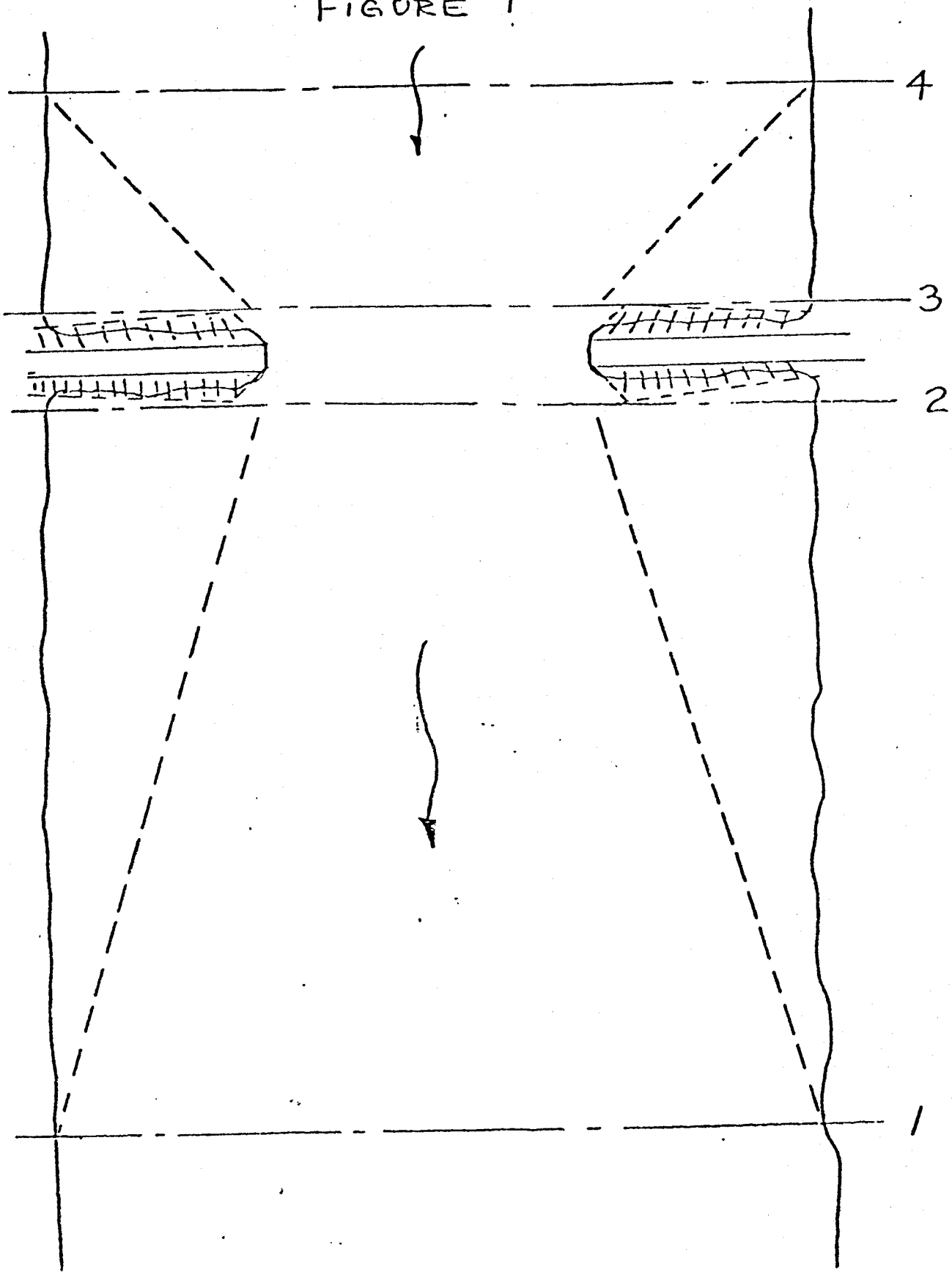
(3) Unreasonable depths in floodway fringe.

(4) Undulating top widths

(5) Results inconsistent with local needs

d. Compute water surface profile based on adjustments to ensure desired results.

FIGURE 1



```
 ,300 CLEAR=   ,300
 SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS    BANK ELEV
 Q        OLOB     OCH      QROB     ALOB     ACH      AROB     VOL      TWA      LEFT/RIGHT
 TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN    SSTA
 SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CURAR    TOPWID   ENDST

    1,00    11,00    30,00        0    30,00    30,47      ,47        0        0    30,00
   2000,        0    1980,      20,        0     358,      20,        0        0    28,00
       0        0     5,50      ,99     ,080     ,050     ,080        0    19,00   325,00
  ,002853      =0       =0       =0        0        0        1        0    70,00   395,00

 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      36,00 ELREA=      36,00

    2,00    11,82    30,82        0        0    31,22      ,39      ,72      ,02    30,00
   2000,        0    2000,        0        0     399,        0        3,        0,   28,00
     ,02        0     5,02        0     ,080     ,050     ,080     ,050    19,00   325,00
  ,002043     300,     300,     300,        2        0        1        0    50,00   403,25

 3265 DIVIDED FLOW

 NORMAL BRIDGE,NRD= 0 MIN ELTRD=  37,00 MAX ELLC=  35,00

    2,10    11,83    30,83        0        0    31,27      ,44      ,03      ,02    37,50
   2000,        0    2000,        0        0     377,        0        3,        0,   37,00
     ,02        0     5,30        0     ,080     ,050     ,080     ,050    19,00   325,00
  ,004001      10,      10,      10,        1        0        1        0    48,00   375,00

 3265 DIVIDED FLOW

 NORMAL BRIDGE,NRD= 0 MIN ELTRD=  37,00 MAX ELLC=  35,00

    2,90    12,09    31,09        0        0    31,50      ,41      ,23      ,01    37,50
   2000,        0    2000,        0        0     390,        0        3,        0,   37,00
     ,02        0     5,13        0     ,080     ,050     ,080     ,050    19,00   325,00
  ,003659      60,      60,      60,        2        0        1        0    48,00   375,00

 SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS    BANK ELEV
 Q        OLOB     OCH      QROB     ALOB     ACH      AROB     VOL      TWA      LEFT/RIGHT
 TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN    SSTA
 SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CURAR    TOPWID   ENDST

 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      37,00 ELREA=      37,00

    3,00    12,19    31,19        0        0    31,54      ,36      ,02      ,02    30,00
   2000,        0    2000,        0        0     417,        0        3,        1,   28,00
     ,02        0     4,80        0     ,080     ,050     ,080     ,049    19,00   325,00
  ,001770      10,      10,      10,        2        0        1        0    50,00   406,86

    4,00    12,37    31,37        0        0    31,68      ,31      ,12      ,01    30,00
   2000,        8,     1934,      58,       14,     427,      57,        4,        1,   28,00
     ,03      ,56     4,53     1,02     ,080     ,050     ,080     ,049    19,00   304,28
  ,001510      75,      75,      75,        1        0        1        0   104,53   408,81
```

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM HEC-2 DATE

REQUESTED BY BOINNER PREPARED BY CHECKED BY PAGE 1 OF 1

	1	2	3	4	5	6	7	8	9	10
T1	NORMAL BRIDGE EXAMPLE WITH X2 CARD									
T2	SPECIAL BRIDGE PROBLEM									
T3										
J1		2							30.0	
NC	.08	.08	.05	.3	.5					
QT	3	2000	4500	6000						
X1	1	10	325	375						
GR	50	0	40	75	35	250	30	325	19	345
GR	20	360	28	375	38	475	43	625	50	700
X1	2				300	300	300			
X3	10	effects are opt.						36	36	
X1	2.1	15	325	375	10	10	10			
X2				35	37					
GR	50	0	40	75	37.5	325	30	325	19	345
GR	19	350	35	350	35	352	19.5	352	20	360
GR	28	375	37	375	38	475	43	625	50	700
X1	2.9				60	60	60			
X2				35	37					
X1	3	10	325	375	10	10	10			
X3	10							37	37	
GR	50	0	40	75	35	250	30	325	19	345
GR	20	360	28	375	38	475	43	625	50	700
X1	4				75	75	75			
EJ										

GENERAL PURPOSE DATA FORM

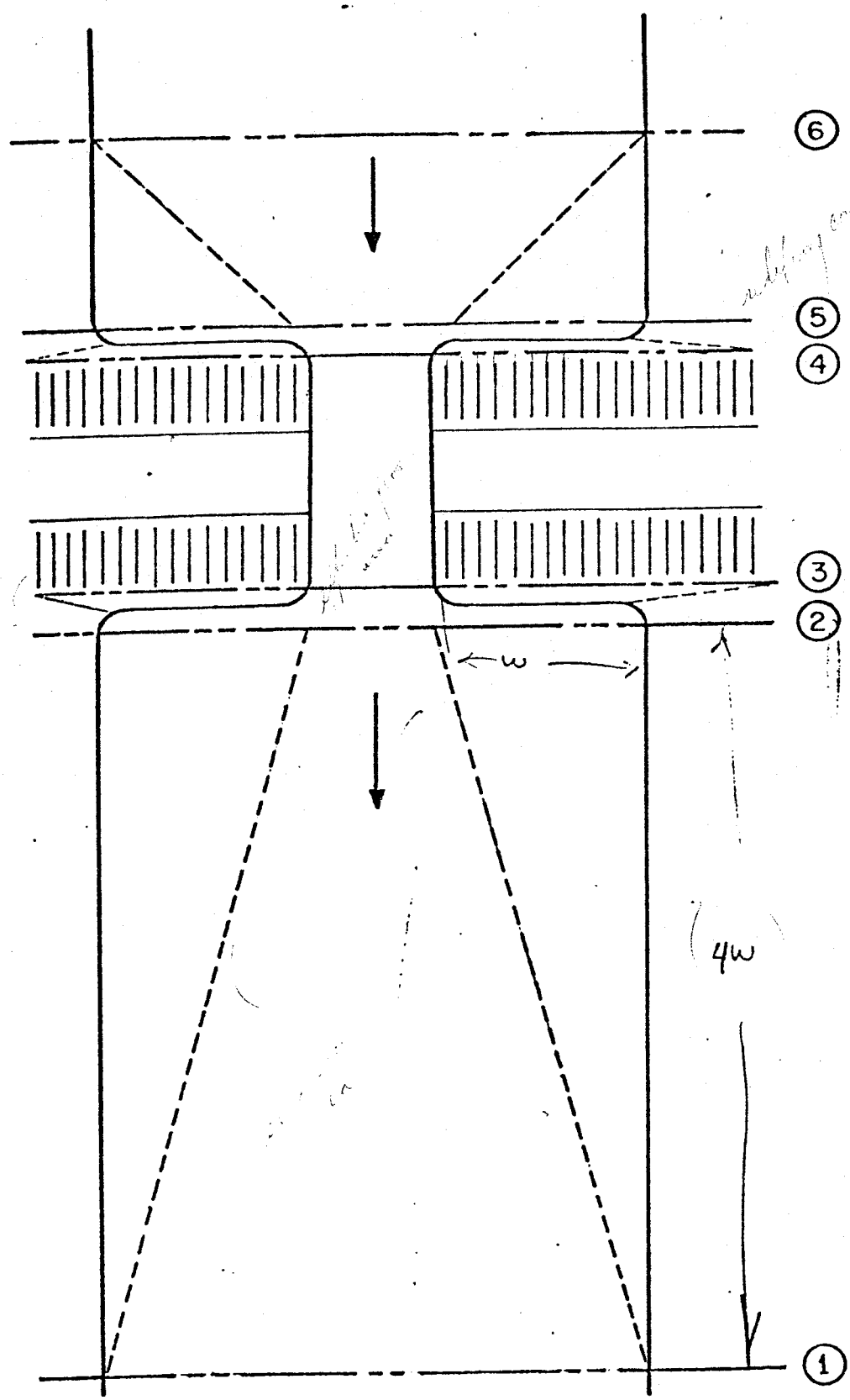
(8 COLUMN FIELDS)

PROGRAM HEC-2 DATE

REQUESTED BY BONNER PREPARED BY CHECKED BY PAGE 1 OF 1

	1	2	3	4	5	6	7	8	9	10
T1	NORMAL BRIDGE ROUTINE EXAMPLE									
T2		CIRCULAR CULVERT								
T3										
J1								450	25	
NC	.08	.08	.03	.3	.5					
X1	1	5	125	175	0	0	0			
GR	35	0	25	125	18	150	30	175	35	300
X1	2	11	145	155	100	100	100			
X3	10							29	29	
GR	35	0	25	125	23	145	19.5	145.5	18.5	147.5
GR	18	150	18.5	152.5	19.5	154.5	23	155	30	175
GR	35	300								
NC			.012							
X1	3				10	10	10			
BT	11	0	35	35	125	30	25	145	30	23
BT	145.5	30	25.5	147.5	30	27.5	150	30	28	152.5
BT	30	27.5	154.5	30	25.5	155	30	23	175	30
BT	30	300	35							
X1	4				100	100	100			
X2							1			
NC			.03							
X1	5				10	10	10			
X3	10							30	30	
X1	6	5	125	175	25	25	25			
GR	35	0	25	125	18	150	30	175	35	300
EJ										

Figure [illegible] Normal Bridge Example



NORMAL BRIDGE CROSS SECTION LOCATIONS

TAPE No. 224

LEARNING PACKAGE – INTRODUCTION TO HEC-2

THE HYDROLOGIC ENGINEERING CENTER
CORPS OF ENGINEERS, U.S. ARMY
609 SECOND STREET
DAVIS, CALIFORNIA 95616
(916) 449-3292

The views and conclusions expressed on video tapes are those of the individual instructors and are not intended to modify or replace official guidance or directives such as Engineering Regulations, Manuals, Circulars, or Technical Letters issued by the Office of the Chief of Engineers.

INTRODUCTION

The information provided in this learning package is intended to supplement a 36-minute video tape entitled "Basic Input Requirements for HEC-2". The package consists of

(1) a reading assignment for materials that should be read prior to viewing the tape,

(2) a detailed outline of material covered by the tape (including visuals used in the taped presentation),

(3) a problem to be solved after viewing the tape,

(4) a problem solution, and

(5) a questionnaire for recording your evaluation of this learning package.

Because of the large amount of information contained on the tape, you may find it desirable to view the tape twice.

This is the first tape and learning package that the Center has put together. If the demand warrants continued development of this media for providing instruction in the use of computer programs, more tapes will be made in the future. Please complete and return the questionnaire supplied with the learning package. Any constructive criticism that you provide will be very much appreciated.

OUTLINE FOR VIDEO TAPE

"BASIC INPUT REQUIREMENTS FOR HEC-2"

I. Video Tape Content

A. Introduction

B. General overview of program capabilities

C. Input requirements for water surface profile calculation

D. Workshop problem introduction

II. Overview of Program Capabilities

A. Calculate steady, gradually varied water surface profiles in channels of any geometry for subcritical or supercritical flow.

1. Steady flow: depth and velocity do not vary with time.

2. Gradually varied flow: depth and velocity vary gradually with distance. (The pressure distribution at each cross section is assumed to be hydrostatic.)

3. Subcritical flow is where the flow depth is everywhere above critical depth, while supercritical flow occurs at depths less than critical depth. The program will not allow the water surface profile to pass through critical depth during a profile calculation. Separate runs would be required for subcritical and supercritical reaches.

III. Program Input Requirements

A. Sample problem showing basic input.

Compute subcritical water surface profiles for a discharge of 200 cfs starting at elevation 13 feet and a discharge of 500 cfs starting at elevation 15 feet. The discharge between sections 2 and 3 is reduced 10%. Use an expansion coefficient of 0.3 and a contraction coefficient of 0.1. Reach lengths are shown in the plan view and Manning's "n" values are shown with the cross sections.

B. Input Cards (See Exhibit 10 for description)

1. Data Card Format

   a. Data card has 80 columns

   b. Card divided into 10 fields of 8 columns each

   c. First two card columns reserved for card identification and called field 0 in Users Manual.

   d. Data can be read anywhere within a field, but a decimal point is required unless the data is written to the far right of the field (right justified)

   e. A blank data field is the same as a zero input

2. Title Cards (T1, T2, T3) required to start the job.

   a. Identify job for user -

   b. Not used in computation

   c. T3 card (Fields 2, 3, 4 give titles to plots and tables)

c. Do not read left and right bank stations (Fields 3 and 4)

d. Reach lengths (Fields 5, 6, and 7)

e. Ratio of previous section's width (Field 8)

f. Elevation adjustment + or - for entire cross section (Field 9)

g. Items e and f are permanent changes to the section.

8. Manning's "n" values vary across section (NH card)

a. Number of "n" values (Field 1)

b. First "n" value starting on the left side of the section (Field 2)

c. Last station to the right of the first "n" value (Field 3)

d. Second "n" value and station - etc. (Fields 4 and 5, etc.)

9. Cross section with low overbank

a. X1 card same as Item 6 above

b. Effective area option required if flow should be contained in the channel until bank elevations are exceeded (X3 card)

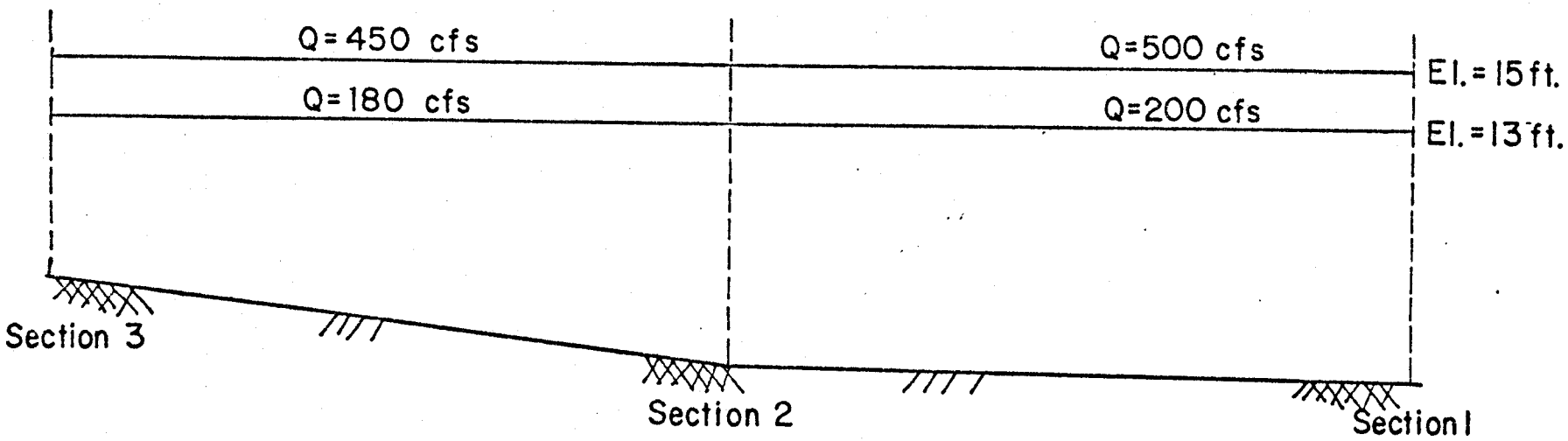
(1) X3 card with 10 in first field calls the effective area option

(2) Works off the designated left and right bank stations

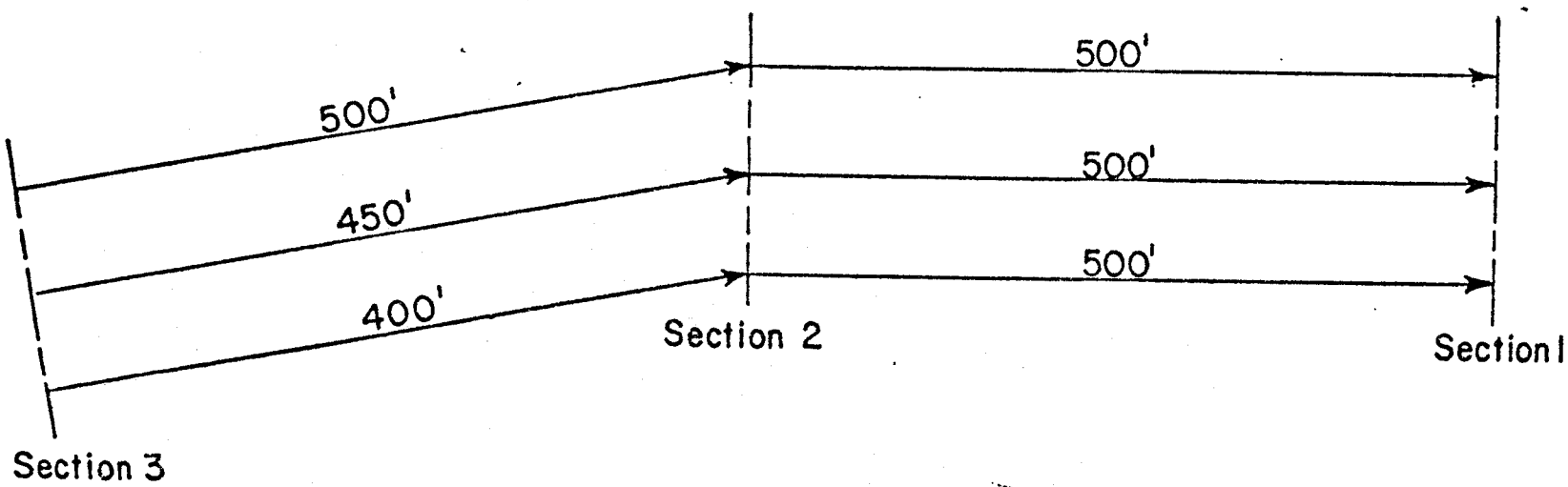
(3) Flow is kept in the channel until bank elevation is exceeded

10. End of data (EJ card)

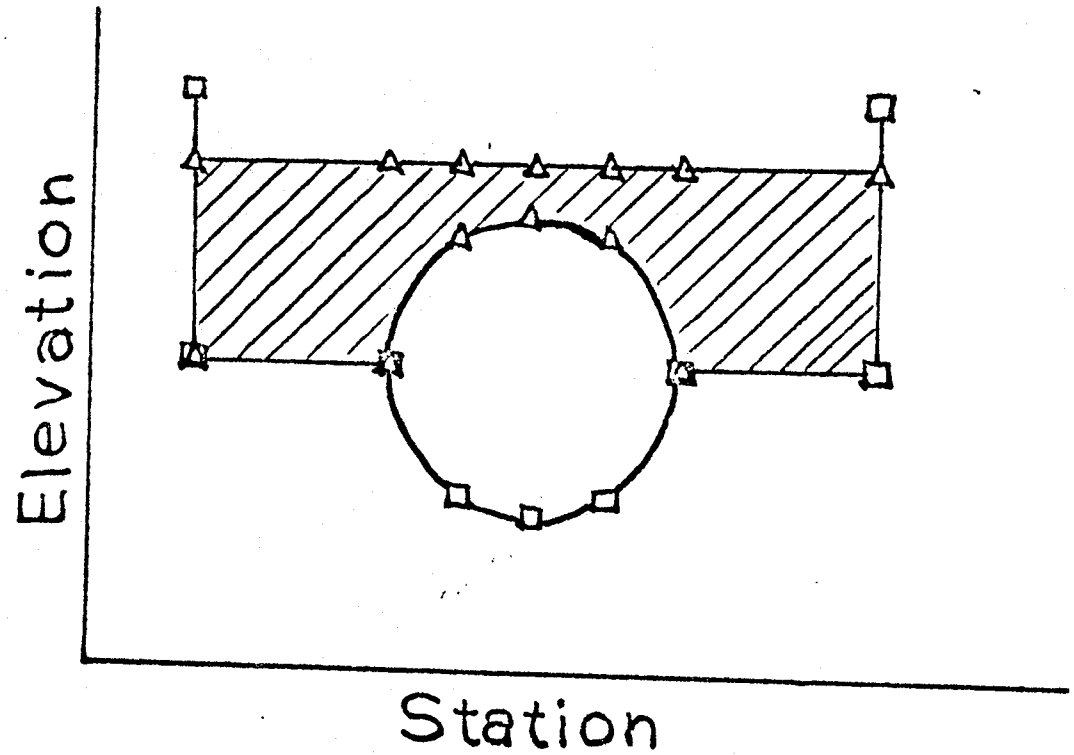
PROFILE VIEW



PLAN VIEW



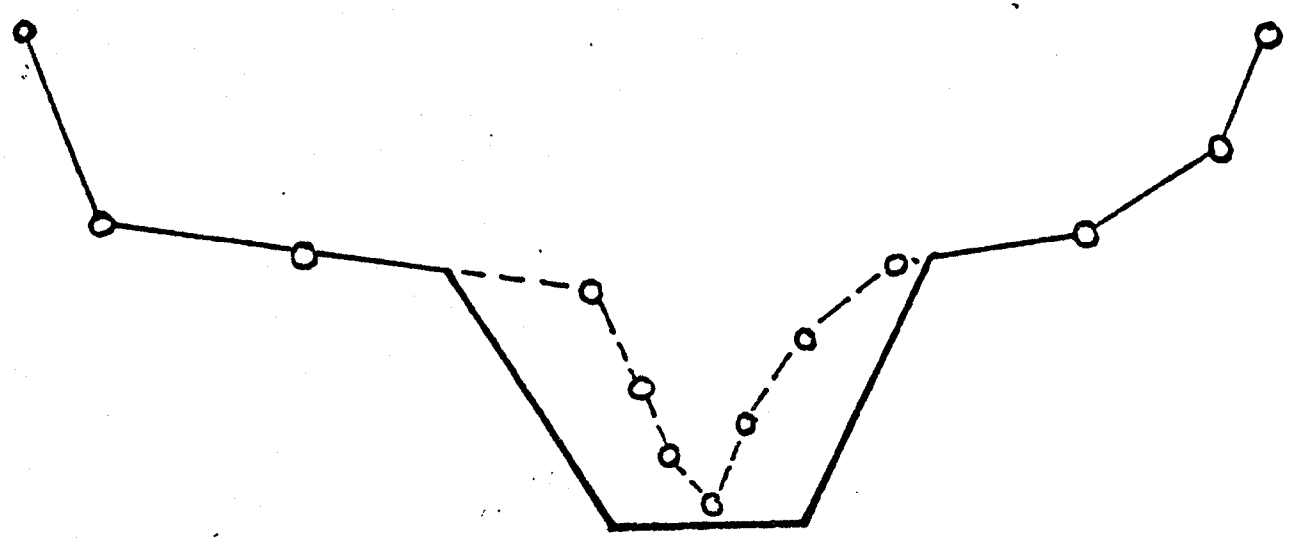
POINTS FOR CULVERTS



△ BRIDGE TABLE

□ CROSS SECTION

CHANNEL IMPROVEMENT ROUTINE



— CHIMP TEMPLATE

o—o STANDARD CROSS SECTION

FUNCTIONAL USE INDEX

Task	Cards Used
1. Basic Applications	T1, T2, T3, J1(4-9), NC, X1(1-9) GR, EJ, ER*
2. Multiple Profiles, Summary Printout	J2(1), J3
3. Optional Cards for Roughness Description	J2(6), NH, NV
4. Optional Cards for Specifying Discharge	J1(2,10), X2(1), QT
5. Bridge Losses	X2(3,9), BT, SB
6. Specification of Ineffective Flow Areas	X3, ET
7. Direct Solution for Manning's n	J1(3), X2(2)
8. Additional Ground Points	X4
9. Plots of Cross Sections and Profiles	J2(2-5), X1(10)
10. Traces and Data Printout	J1(1), X2(10), J2(10)
11. Data Comment Cards	C_
12. Critical Depth Option	J2(7)
13. Channel Modification Due to Excavation	J2(8,9), CI
14. Storage-Discharge Output	J4

*Numbers in parentheses refer to card fields 1-10.

10.0 10 0

0 1 2 3 4 5 6 7 8 9 10

GLOBE 604441

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM | DATE

REQUESTED BY | PREPARED BY | CHECKED BY | PAGE | OF

	1	2	3	4	5	6	7	8	9	10
T1	SAMPLE PROBLEM HEC-2									
T2	FIRST PROFILE									
T3	SAMPLE CREEK									

SPK

CARD J1 (cont)

REQUIRED BASIC DATA

Field	Variable	Value	Description
4	IDIR	0	Subcritical flow. Cross sectional data (GR cards) are read starting at the downstream end.
		1	Supercritical flow. Cross sectional data are read starting at the upstream end.
5	STRT	-1	Start computations at critical depth.
		0	Start with known water surface elevation. Enter WSEL in field 9.
		+	Start by slope-area method. Enter estimated energy slope here.
6	METRIC	0	Input and output in English units.
		1	Input and output in Metric units.
7	HVINS	-1	No interpolated cross sections to be inserted by computer.
		0	Interpolated cross sections will be automatically inserted by computer when the change in velocity head between cross sections exceeds 0.5 feet.
		+	Enter maximum allowable change in velocity head between cross sections. If this value is exceeded, interpolated cross sections will be inserted by computer.
8	Q	0	Only if INQ(J1.2) is 2 or greater.
		+	Starting river flow.
9	WSEL	+	If STRT(J1.5) is zero enter known starting water surface elevation. If STRT is + or - enter approximate water surface elevation.

OPTION FOR CHANGING JOB DISCHARGES

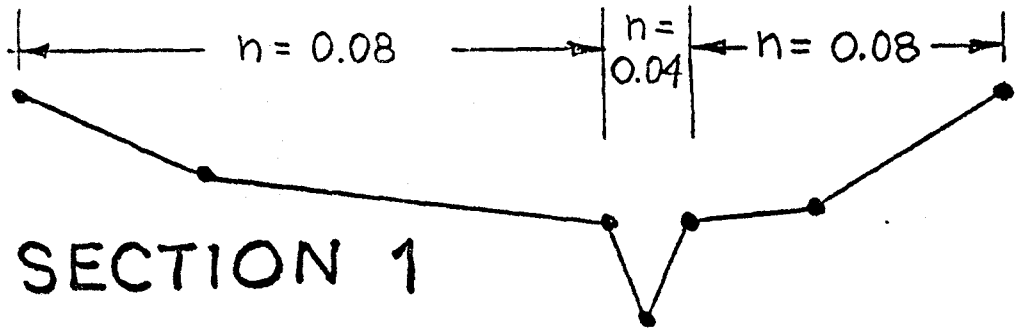
Field	Variable	Value	Description
10	FQ	0	A factor of 1.0 will be used.
		+	Factor to multiply all flows by.

CROSS SECTION 2

REPEAT SECTION 1

EXPAND SECTION 10%

RAISE SECTION 0.4 ft.



SECTION 1

1	2	3	4	5	6	7	8	9	10
X1	2			500	500	500	1.1	0.4	

DATA

TWO PROFILES:	(1)	(2) ✓
FLOW REGIME:	SUBCRITICAL	SUBCRITICAL
STARTING Q:	200 cfs	500 cfs
STARTING WSEL:	13 ft	15 ft

	1	2	3	4	5	6	7	8	9	10
T1		SAMPLE PRØBLEM HEC-2								
T2		SECØND PRØFILE								
T3		SAMPLE CREEK								
J1		3							15	
J2	15									
ER										

WATER SURFACE PROFILES - COMPUTER COMPUTATION

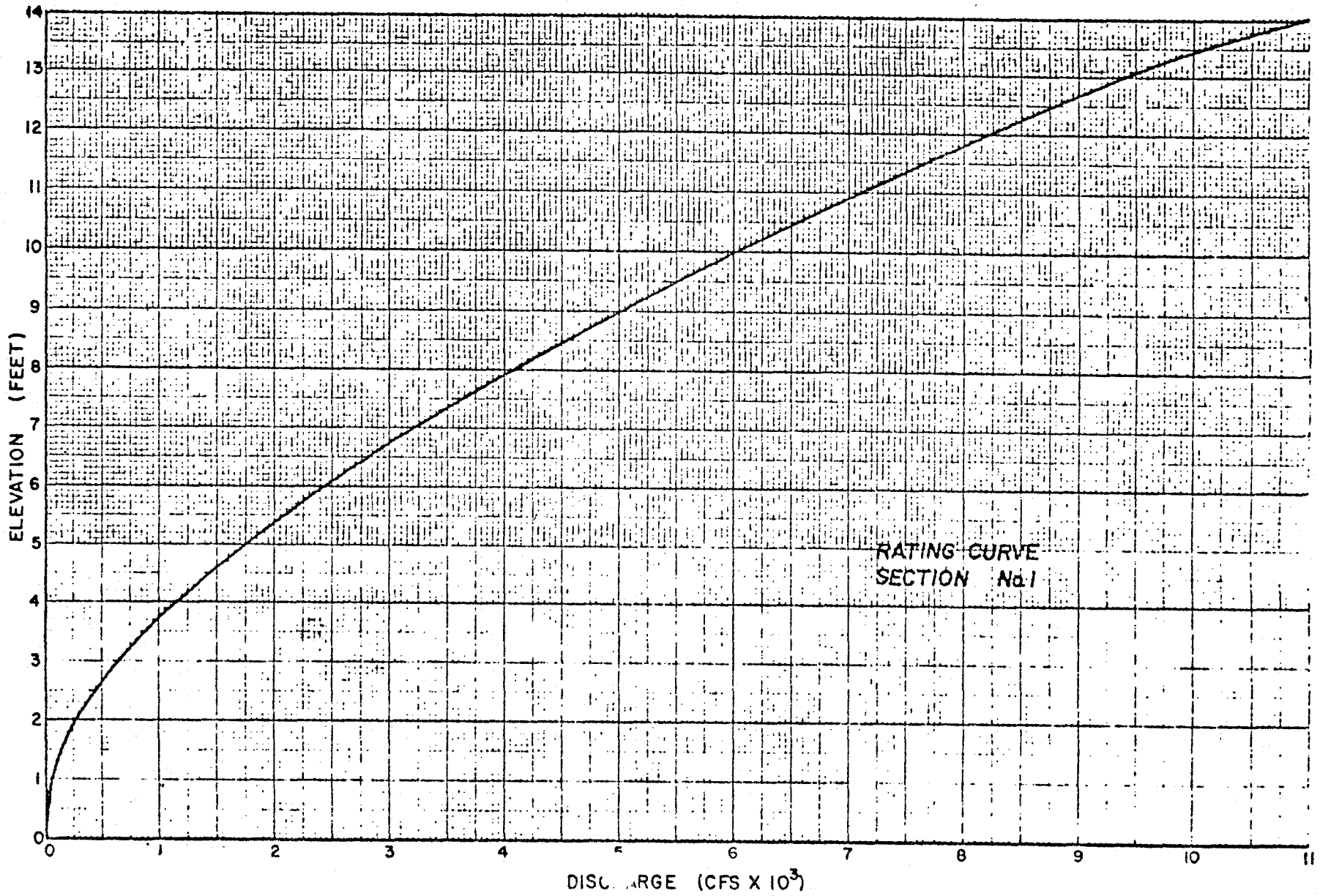
PROBLEM DESCRIPTION

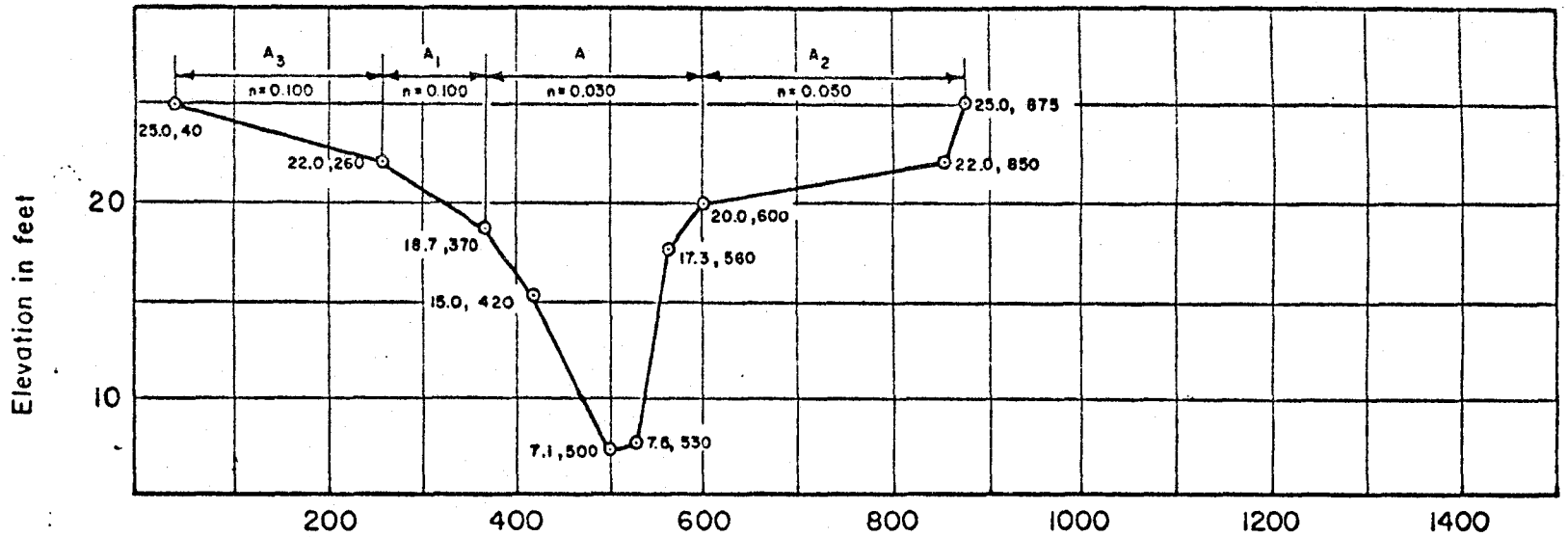
A plan view of the Red Fox River is shown in figure 1. Plots of cross sections are shown in figures 2 through 5. A rating curve for cross section 1 is shown in figure 6. Channel distances between cross sections are as follows:

Section	Distance Feet
1	
	500
2	
	400
3	
	475
4	

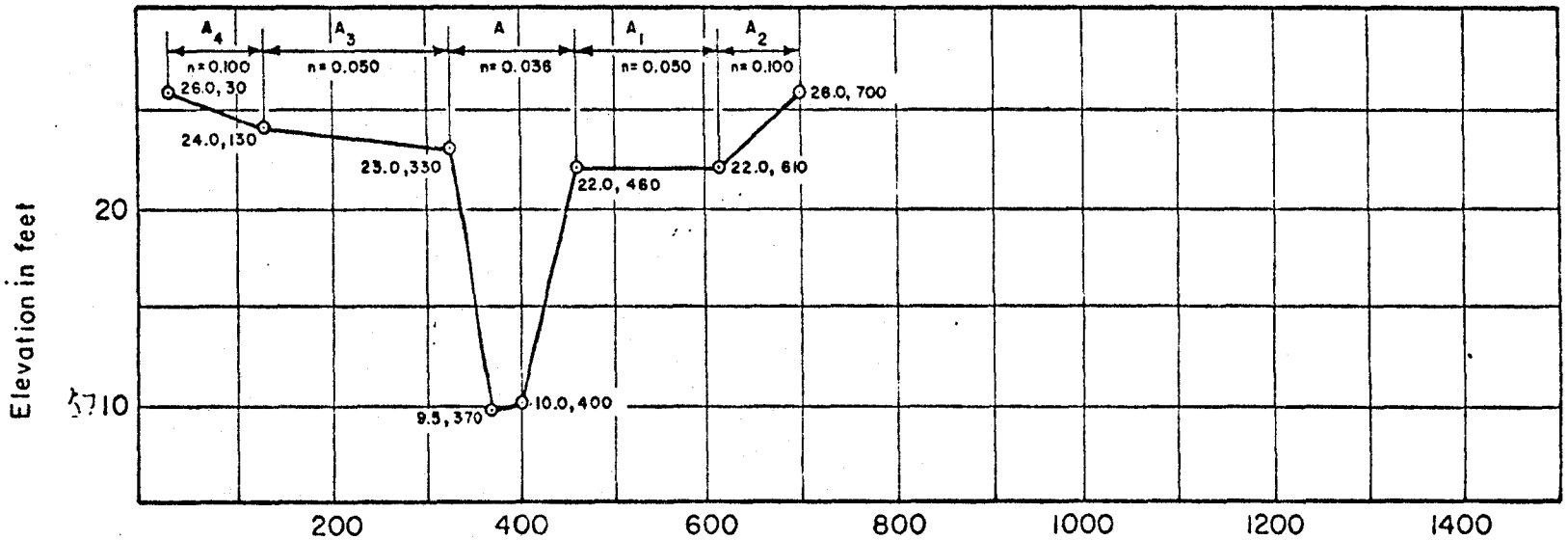
PROBLEM

Prepare complete input data and operate computer program HEC-2 to determine water surface profiles for discharges of 1000, 5000, and 10,000 cfs. Specify expansion and contraction coefficients of 0.3 and 0.1 respectively. Assume overbank reach lengths are equal to the channel distances.


RATING CURVE
SECTION No 1
ELEVATION (FEET)
DISCHARGE (CFS X 10³)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14



Cross section No. 3



Cross section No. 4

RED FOX RIVER, COLORADO

RED FOX RIVER PROFILES

PROBLEM SOLUTION

```
**************************
SEPT 1971 VERSION UPDATED JUNE 1974
ERROR CORRECTIONS 01,02,03,04,05,06,07
MODIFICATIONS 52,53,54,55,56,57
**************************
```

```
T1    WATER SURFACE PROFILES WORKSHOP
T2
T3    RED FOX RIVER

J1  ICHECK   INQ    NINV   IDIR   STRT   METRIC  HVINS   Q      WSEL   FQ
     0.      2.     0.     0.   .000000   .00     .0     0.    3.800  .000

QT   3.000  1000.000 5000.000 10000.000  .000    .000   .000   .000   .000   .000
NC    .000   .000    .000    .100    .300    .000   .000   .000   .000   .000
NH   5.000   .100   415.000   .050  650.000   .030  710.000  .050  1020.000 .100
NH 1635.000  .000     .000    .000    .000    .000   .000   .000   .000   .000

X1   1.000  11.000  650.000  710.000  .000    .000   .000   .000   .000   .000
GR  25.000  20.000   18.000  110.000  17.000  415.000  14.000  650.000  1.000  675.000
GR   .000  690.000   1.000  710.000  13.000  710.000  14.000  1020.000  14.000  1590.000
GR  25.000 1635.000   .000    .000    .000    .000    .000   .000   .000   .000
NH   4.000   .100   415.000   .050  575.000   .030  640.000  .100  1250.000  .000

X1   2.000  10.000  575.000  640.000  500.000  500.000  500.000  .000   .000   .000
GR  25.000  30.000   20.000  110.000  20.000  200.000  17.000  415.000  10.000  575.000
GR   4.000  580.000   4.000  615.000  18.000  640.000  18.000  1195.000  25.000  1250.000
NC   .100   .050    .030    .000    .000    .000    .000   .000   .000   .000

X1   3.000  10.000  370.000  600.000  400.000  400.000  400.000  .000   .000   .000
GR  25.000  40.000   22.000  260.000  18.700  370.000  15.000  420.000  7.100  500.000
GR   7.500  530.000  17.300  560.000  20.000  600.000  22.000  850.000  25.000  875.000
NH   5.000   .100   130.000   .050  330.000   .036  460.000  .050  610.000  .100
NH 700.000   .000    .000    .000    .000    .000    .000   .000   .000   .000

X1   4.000   8.000  330.000  460.000  475.000  475.000  475.000  .000   .000   .000
GR  26.000  30.000   24.000  130.000  23.000  330.000  9.500  370.000  10.000  400.000
GR  22.000  460.000  22.000  610.000  26.000  700.000  .000   .000   .000   .000
EJ   .000   .000    .000    .000    .000    .000    .000   .000   .000   .000
```

```
****************************
SEPT 1971 VERSION UPDATED JUNE 1974
ERROR CORRECTIONS 01,02,03,04,05,06,07
MODIFICATIONS 52,53,54,55,56,57
****************************

T1      WATER SURFACE PROFILES WORKSHOP
T2
T3      RED FOX RIVER
J1  ICHECK   INQ    NINV   IDIR   STRT   METRIC  HVINS   Q     WSEL   FQ
     0.      3.      0.     0.   .000000   .00     .0     0.   9.000  .000
J2  NPROF   IPLOT   PRFVS  XSECV  XSECH   FN     ALLDC   IBW   CHNIM  ITRACE
   2.000    .000    .000   .000   .000   .000   .000   .000   .000   .000
```

```
**************************
SEPT 1971 VERSION UPDATED JUNE 1974
ERROR CORRECTIONS 01,02,03,04,05,06,07
MODIFICATIONS 52,53,54,55,56,57
**************************
```

```
T1    WATER SURFACE PROFILES WORKSHOP
T2
T3    RED FOX RIVER
J1  ICHECK   INQ    NINV   IDIR   STRT   METRIC  HVINS   Q     WSEL   FD
       0.     4.     0.     0.  .000000   .00     .0     0.   13.400  .000
J2  NPROF   IPLOT   PRFVS  XSECV  XSECH   FN    ALLOC   IBW   CHNIM  ITRACE
     15.000  .000   .000   .000   .000   .000   .000   .000   .000   .000
```

SUMMARY PRINTOUT FOR MULTIPLE PROFILES

RED FOX RIVER

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	CRIWS	EG	TOPWID	10K*8	TIME	VOL
1.00	.00	.00	.00	.00	1000.00	3.80	.00	4.83	40.38	64.06	.00	.00
1.00	.00	.00	.00	.00	5000.00	9.00	.00	12.01	50.38	66.38	.00	.00
1.00	.00	.00	.00	.00	10000.00	15.42	15.42	16.91	1056.65	22.12	.00	.00
2.00	500.00	.00	.00	4.00	1000.00	7.09	.00	8.16	43.09	68.75	.02	1.40
2.00	500.00	.00	.00	4.00	5000.00	12.46	12.04	14.81	111.31	45.76	.01	4.68
2.00	500.00	.00	.00	4.00	10000.00	16.05	15.71	18.67	199.75	37.93	.01	18.46
3.00	400.00	.00	.00	7.10	1000.00	10.23	.00	10.93	70.05	67.99	.03	2.64
3.00	400.00	.00	.00	7.10	5000.00	15.49	.00	16.28	141.28	24.78	.03	10.00
3.00	400.00	.00	.00	7.10	10000.00	19.06	.00	19.94	228.25	20.82	.03	29.23
4.00	475.00	.00	.00	9.50	1000.00	13.29	.00	13.94	57.67	59.08	.05	4.29
4.00	475.00	.00	.00	9.50	5000.00	16.75	16.75	19.15	85.26	101.89	.04	16.02
4.00	475.00	.00	.00	9.50	10000.00	19.78	19.78	22.98	109.34	91.86	.04	40.28

SECTION NUMBER	DISCHARGE CFS	CWSEL	CWSEL DIFF EACH Q	CWSEL DIFF EACH SECTION	CWSEL-WSELK	TOPWID	T.W. DIFF	LENGTH
1.000	1000.000	3.800	.000	.000	.000	40.385	.000	.000
1.000	5000.000	9.000	5.200	.000	.000	50.385	-10.000	.000
1.000	10000.000	15.415	6.415	.000	.000	1056.648	-1016.264	.000
2.000	1000.000	7.087	.000	3.287	.000	43.087	.000	500.000
2.000	5000.000	12.458	5.371	3.458	.000	111.314	-68.227	500.000
2.000	10000.000	16.047	3.589	.632	.000	199.746	-156.659	500.000
3.000	1000.000	10.227	.000	3.140	.000	70.054	.000	400.000
3.000	5000.000	15.494	5.266	3.036	.000	141.276	-71.221	400.000
3.000	10000.000	19.064	3.570	3.017	.000	228.249	-158.195	400.000
4.000	1000.000	13.289	.000	3.061	.000	57.673	.000	475.000
4.000	5000.000	16.754	3.465	1.260	.000	85.262	-27.589	475.000
4.000	10000.000	19.777	3.023	.713	.000	109.336	-51.663	475.000

DATA FOR LAST CROSS SECTION

PROFILE	TYPE ENC	TARGET	TOP WIDTH AREA-ACRES	TOP WIDTH AREA-DIFF
1	.000	.000	1.695	.000
2	.000	.000	3.323	1.628
3	.000	.000	11.016	9.321

Tape No. 2

June 1974

LEARNING PACKAGE

INTRODUCTION TO HEC-2

The Hydrologic Engineering Center
609 Second Street
Davis, California 95616

READING ASSIGNMENT

Prior to viewing the video tape "Basic Input Requirements for HEC-2," please read the following:

1. IHD Volume 6, "Water Surface Profiles," Chapters 1 through 5.

2. HEC-2 "Users Manual," Pages 1-7 and 13-17, and Exhibit 10.

In addition, preliminary review of the Outline for Video Tape may help viewers follow the presentation.

B. Bridge routines for calculating profiles through bridges and over weirs and small dams.

1. Special bridge routine is available to calculate flow through bridges for a wide variety of conditions. (SB card)
2. Closed conduits can be modeled using the BT cards to provide the top portion of the cross section.

C. Encroachment Option (ET card)

1. Five methods are available in the program to set limits on floodway, including a procedure to locate encroachments based on a specified change in water surface elevation.
2. Exhibit 9A in Users Manual describes methods, input, and output.

D. Channel modifying routine

1. Input trapezoidal section (CI card) within given cross section and program modifies the section to reflect excavation of trapezoid.
2. Multiple profiles can be run with different bottom widths for the trapezoidal section.

E. Printer plots of profiles and cross sections

F. Functional Use Index (Exhibit 10 in Users Manual)

1. Determine which cards are required.
2. Determine which variables are needed to accomplish desired result.
3. Arrange cards in proper sequence (see "Summary in Input Cards" at end of Users Manual).

3. Job card (J1) - See Page 6 of 36, Exhibit 10 of Users Manual for description.

   a. Read discharge table (Field 2)

   b. Flow regime (Field 4)

   c. Starting condition (Field 5)

   d. Starting WSEL (Field 9)

4. Discharge Table (QT)

   a. Number of values to be read (Field 1)

   b. Discharges for each profile in each card field (Fields 2, 3, etc.)

5. Manning's "n" values (NC)

   a. Left bank, right bank, and channel "n" values

   b. Contraction and expansion coefficients (optional)

6. Cross Sections (X1 and GR cards)

   a. Section Number (X1 Field 1)

   b. Number of X-Y coordinates on GR cards (X1 Field 2)

   c. Left and right bank Stations (X1 Fields 3 and 4)

   d. Reach lengths to next downstream section (left bank, right bank, channel; (X1 Fields 5, 6, and 7)

   e. Elevations and stations across the channel section from left to right (GR cards). Section stations should be positive.

7. Repeated Cross Section (X1 and <u>NO</u> GR cards)

   a. Section number (Field 1)

   b. Number of X-Y coordinates specified as zero (Field 2 = 0)

11. Second profile

    a. Title cards (T1, T2, T3) used as in Item 2

    b. Job card (J1) used as in Item 3

    c. Job card (J2)

        (1) Required for second and subsequent profiles

        (2) Number of profile (Field 1) for second profile would be 2, and 3 for third, etc.

        (3) Value of 15 can be read on last profile to ask for summary printout (J2 Field 1 = 15)

    d. Only above 5 cards are required and allowed for second and subsequent profiles

12. End of run (ER card)

    a. Three blank cards after last J2 card

    b. ER card tells program end of run

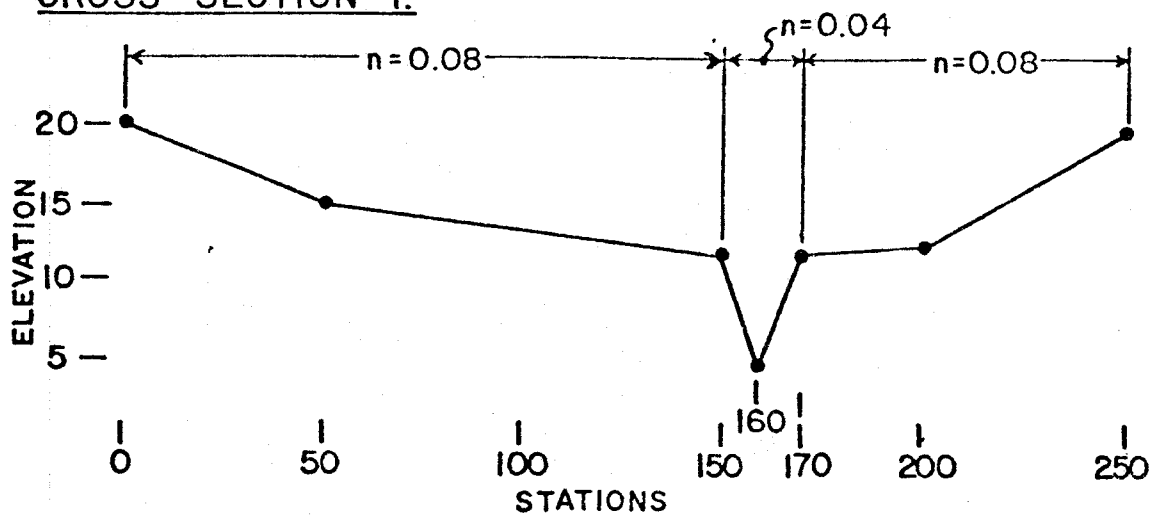
IV. Workshop Problem

A. A problem similar to the sample problem is provided in the following yellow pages.

B. The solution is provided in the green pages for comparison purposes.

C. Please code and run the workshop problem.

CROSS SECTION 1.

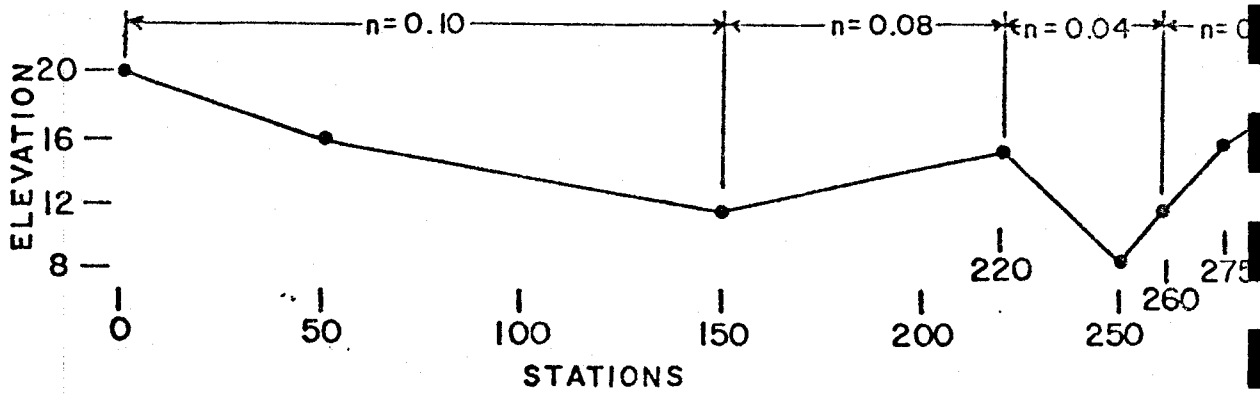


CROSS SECTION 2. (NOT SURVEYED)

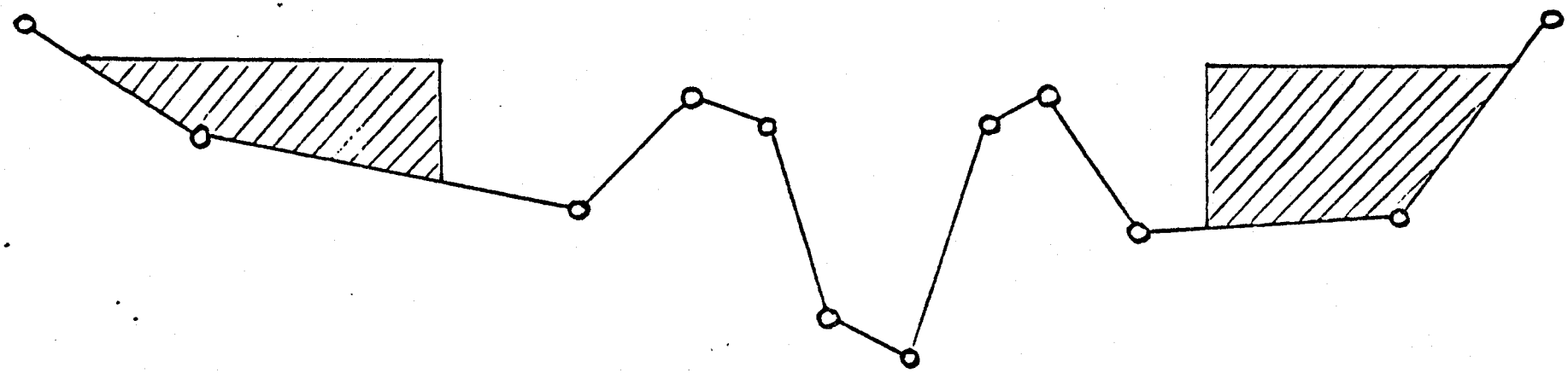
Based on U.S.G.S. quad assume:

Section 2 is 10% wider and 0.4 ft. higher than Section 1.

CROSS SECTION 3.



ENCROACH ON CROSS SECTION



```
T1        SAMPLE PROBLEM  HEC-2
T2        FIRST PROFILE
T3        SAMPLE CREEK
J1              2                0        0                                13
QT      2     200      500
NC    .08     .08      .04      .1       .3
X1      1       7      150     170        0        0        0
GR     20       0       15      50       12      150        5      160       12      170
GR     15     200       20     250
X1      2                                500      500      500      1.1       .4
NH      4     .10      150     .08      220      .04      260      .08      300
QT      2     180      450
X1      3       8      220     260      400      500      450
X3     10
GR     20       0       16      50       12      150       16      220        8      250
GR     12     260       16     275       20      300
EJ
T1        SAMPLE PROBLEM HEC-2
T2        SECOND PROFILE
T3        SAMPLE CREEK
J1              3                                                          15
J2     15

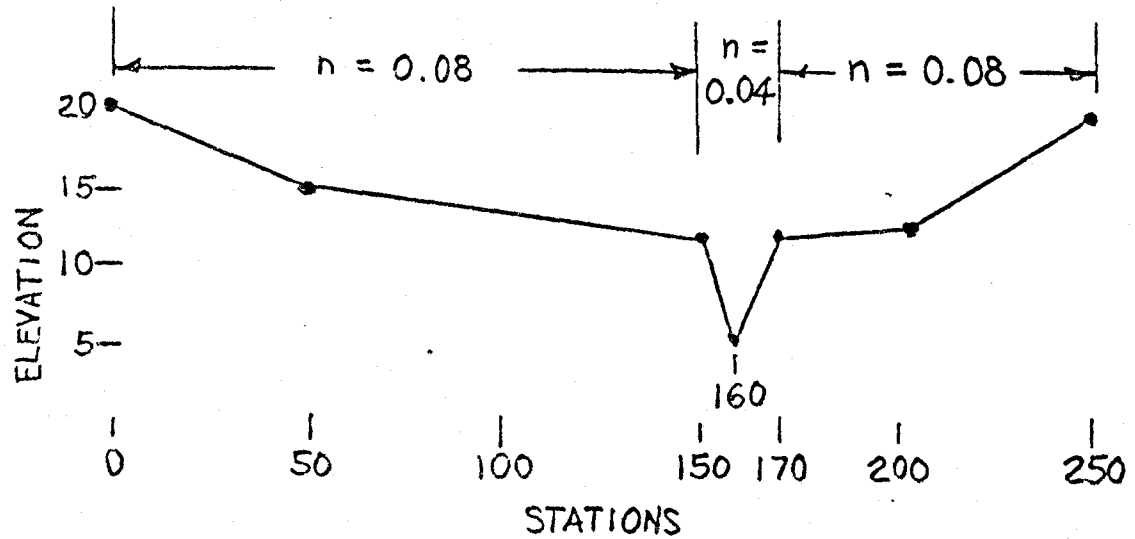

ER
```

DATA

TWO PROFILES:	(1) ✓	(2)
FLOW REGIME:	SUBCRITICAL	SUBCRITICAL
STARTING Q:	200 cfs	500 cfs
STARTING WSEL:	13 ft	15 ft

1	2	3	4	5	6	7	8	9	10
JT		2		0	0				13
QT	2	200	500						

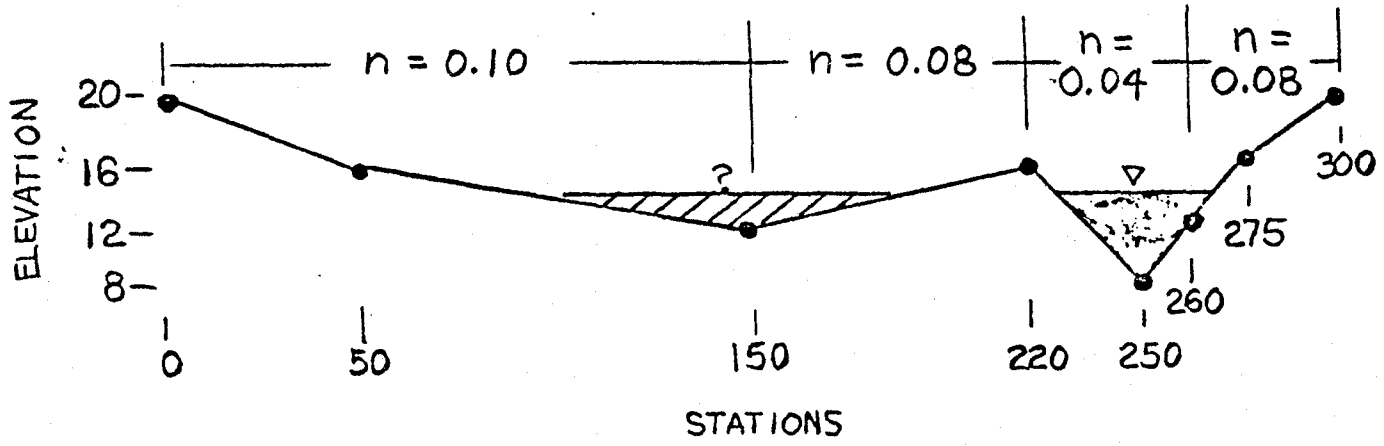
CROSS SECTION 1



1	2	3	4	5	6	7	8	9	10
NC .08	.08	.04	.1	.3					
XI 1	7	150	170	0	0	0			
GR 20	0	15	50	12	150	5	160	12	170
GR 15	200	20	250						

CROSS SECTION 3

DECREASE Q BY 10%



	1	2	3	4	5	6	7	8	9	10
NH	4	.10	150	.08	220	.04	260	.08	300	
QT	2	180	450							
X1	3	8	220	260	400	500	450			
X3	10									
GR	20	0	16	50	12	150	16	220	8	250
GR	12	260	16	275	20	300				
EJ										

GENERAL PURPOSE DATA FORM

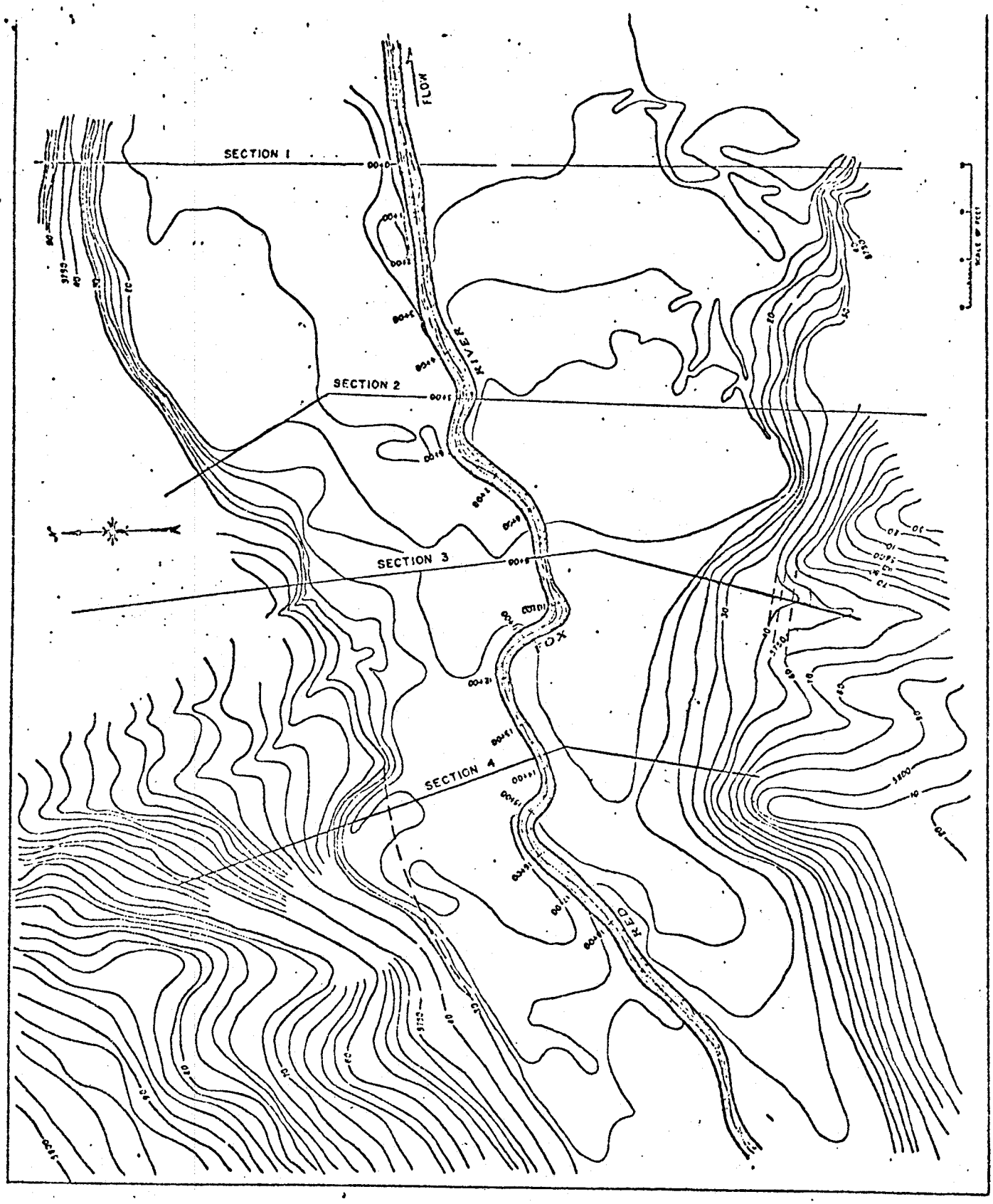
(8 COLUMN FIELDS)

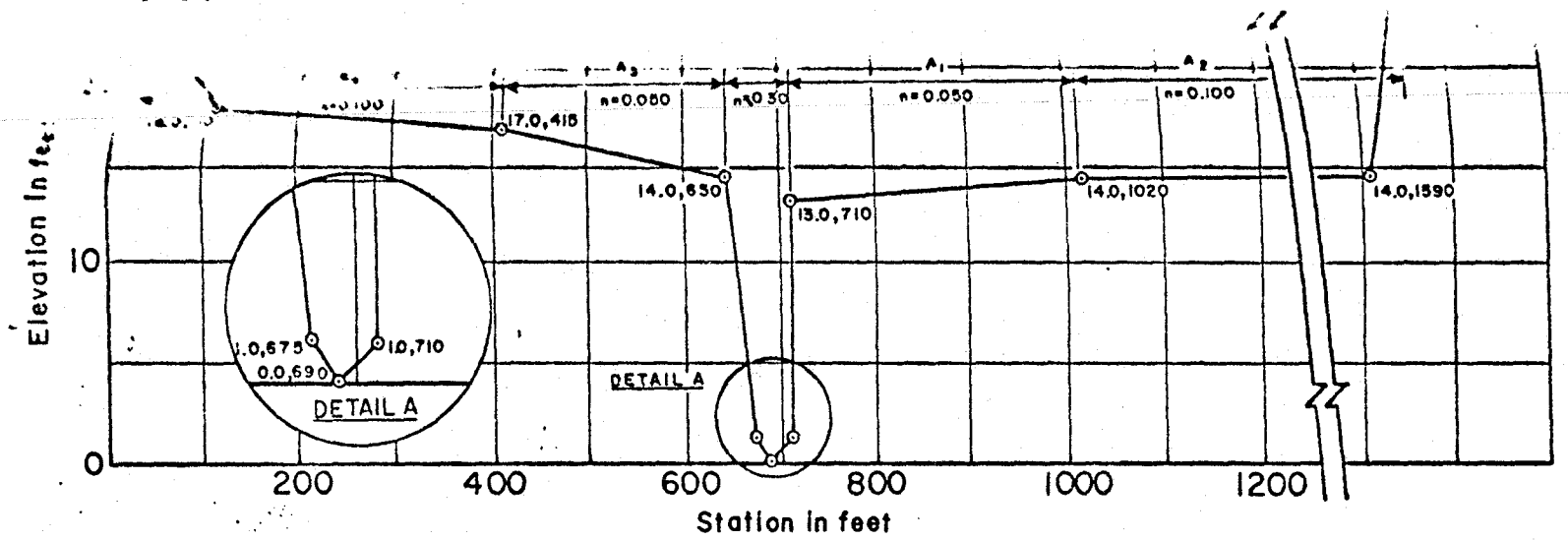
PROGRAM HEC-2 DATE 23 OCT 73

REQUESTED BY PREPARED BY VRB CHECKED BY PAGE 1 OF 1

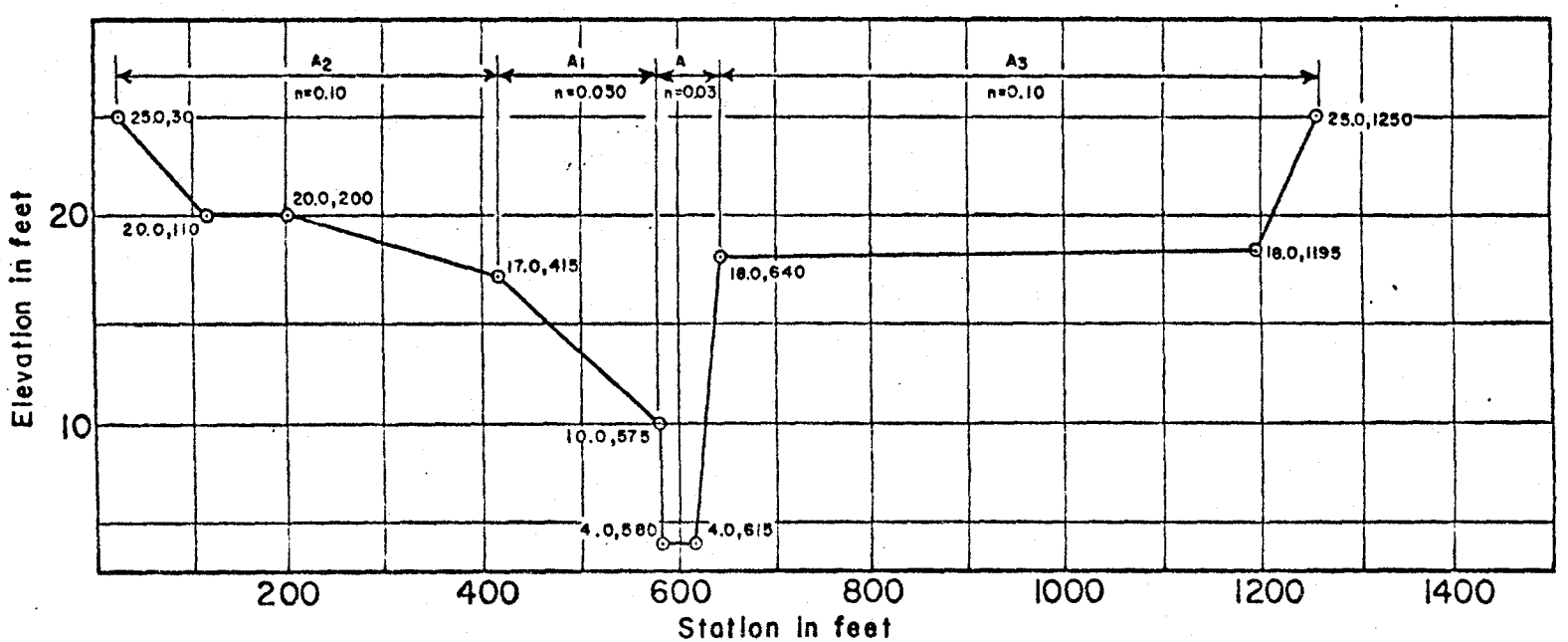
	1	2	3	4	5	6	7	8	9	10
T1	SAMPLE PROBLEM HEC-2									
T2	FIRST PROFILE									
T3	SAMPLE CREEK									
J1		2		0	0				13	
QT	2	200	500							
NC	.08	.08	.04	.1	.3					
X1	1	7	150	170	0	0	0			
GR	20	0	15	50	12	150	5	160	12	170
GR	15	200	20	250						
X1	2				500	500	500	1.1	.4	
NH	4	.10	150	.08	220	.04	260	.08	300	
QT	2	180	450							
X1	3	8	220	260	400	500	450			
X3	10									
GR	20	0	16	50	12	150	16	220	8	250
GR	12	260	16	275	20	300				
EJ										
T1	SAMPLE PROBLEM HEC-2									
T2	SECOND PROFILE									
T3	SAMPLE CREEK									
J1		3							15	
J2	15									
ER										

SPK FOR 29 JUN 321a


FLOW
SECTION 1
SECTION 2
SECTION 3
SECTION 4
RIVER
FOX
RED



Cross section No. I



Cross section No. 2

CCHV= .100 CEHV= .300

1490 NH CARD USED

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	BSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
1.00	3.80	3.80	.00	3.80	4.83	1.03	.00	.00	14.00
1000.	.0.	1000.	.0.	.0.	123.	.0.	.0.	.0.	13.00
.00	.00	8.13	.00	.000	.030	.000	.000	.00	669.62
.006406	0.	0.	0.	0	0	1	.00	40.38	710.00

1490 NH CARD USED

2.00	3.09	7.09	.00	.00	8.16	1.07	3.32	.01	10.00
1000.	.0.	1000.	.0.	.0.	121.	.0.	.1.	.0.	18.00
.02	.00	8.30	.00	.000	.030	.000	.000	4.00	577.43
.006875	500.	500.	500.	2	0	1	.00	43.09	620.51
3.00	3.13	10.23	.00	.00	10.93	.70	2.73	.04	18.70
1000.	.0.	1000.	.0.	.0.	149.	.0.	.3.	.1.	20.00
.03	.00	6.72	.00	.100	.030	.050	.013	7.10	468.30
.006799	400.	400.	400.	2	0	1	.00	70.05	538.36

1490 NH CARD USED

4.00	3.79	13.29	.00	.00	13.94	.65	3.01	.00	23.00
1000.	.0.	1000.	.0.	.0.	154.	.0.	.4.	.2.	22.00
.05	.00	6.47	.00	.100	.036	.050	.019	9.50	358.77
.005908	475.	475.	475.	2	0	1	.00	57.67	416.45

CCHV= .100 CEHV= .300

1490 NH CARD USED

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	QLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
1.00	9.00	9.00	.00	9.00	12.01	3.01	.00	.00	14.00
5000.	.0.	5000.	.0.	.0.	359.	0.	0.	.0.	13.00
.00	.00	13.93	.00	.000	.030	.000	.000	.00	659.62
.006638	0.	0.	0.	0	0	1	.00	50.38	710.00

1490 NH CARD USED

3301 HV CHANGED MORE THAN HVINS

2.00	8.46	12.46	12.04	.00	14.81	2.35	2.73	.07	10.00
5000.	159.	4841.	.0.	.49.	387.	0.	5.	1.	18.00
.01	2.31	12.50	.00	.050	.030	.000	.000	4.00	518.79
.004576	500.	500.	500.	4	11	1	.00	111.31	630.11

3301 HV CHANGED MORE THAN HVINS

3.00	8.39	15.49	.00	.00	16.28	.79	1.32	.16	18.70
5000.	.0.	5000.	.0.	.0.	702.	0.	.10.	.2.	20.00
.03	.00	7.12	.00	.100	.030	.050	.013	7.10	413.22
.002478	400.	400.	400.	2	0	1	.00	1-1.28	554.50

1490 NH CARD USED

7185 MIN SPECIFIC ENERGY

3720 ASSUMED CRITICAL DEPTH

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	QLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
4.00	7.25	16.75	16.75	.00	19.15	2.40	2.11	.00	23.00
5000.	.0.	5000.	.0.	.0.	402.	0.	16.	3.	22.00
.04	.00	12.43	.00	.100	.036	50	.019	9.50	348.51
.010189	475.	475.	475.	4	15	1	.00	85.26	433.77

CCHV= .100 CEHV= .300
1490 NH CARD USED

3720 ASSUMED CRITICAL DEPTH

SECNO / Q / TIME / SLOPE	DEPTH / QLOB / VLOB / XLOBL	CWSEL / QCH / VCH / XLCH	CRIWS / QROB / VROB / XLOBR	WSELK / ALOB / XNL / ITRIAL	EG / ACH / XNCH / IDC	HV / AROB / XNR / ICONT	HL / VOL / WTN / CORAR	QLOSS / TWA / ELMIN / TOPWID	BANK ELEV LEFT/RIGHT / SSTA / ENDST
1.00	15.42	15.42	15.42	13.40	16.91	1.50	.00	.00	14.00
10000.	87.	7920.	1993.	.78.	720.	1404.	0.	0.	13.00
.00	1.11	11.00	1.42	.050	.030	.068	.000	.00	539.14
.002212	0.	0.	0.	0	8	1	.00	1056.65	1595.79

1490 NH CARD USED

3301 HV CHANGED MORE THAN HVINS

2.00	12.05	16.05	15.71	.00	18.67	2.62	1.42	.34	10.00
10000.	1599.	8401.	0.	418.	597.	0.	.18.	.7.	18.00
.01	3.83	14.08	.00	.050	.030	.100	.000	4.00	436.77
.003793	500.	500.	500.	6	13	1	.00	199.75	636.51

3301 HV CHANGED MORE THAN HVINS

3.00	11.96	19.06	.00	.00	19.94	.88	1.10	.17	18.70
10000.	0.	10000.	0.	2.	1328.	0.	.29.	9.	20.00
.03	.22	7.53	.00	.100	.030	.050	.013	7.10	357.88
.002082	400.	400.	400.	4	0	1	.00	228.25	586.13

1490 NH CARD USED
3685 20 TRIALS USED WSEL,CWSEL

7185 MIN SPECIFIC ENERGY

3720 ASSUMED CRITICAL DEPTH

SECNO / Q / TIME / SLOPE	DEPTH / QLOB / VLOB / XLOBL	CWSEL / QCH / VCH / XLCH	CRIWS / QROB / VROB / XLOBR	WSELK / ALOB / XNL / ITRIAL	EG / ACH / XNCH / IDC	HV / AROB / XNR / ICONT	HL / VOL / WTN / CORAR	QLOSS / TWA / ELMIN / TOPWID	BANK ELEV LEFT/RIGHT / SSTA / ENDST
4.00	10.28	19.78	19.78	.00	22.98	3.20	1.82	.00	23.00
10000.	0.	10000.	0.	0.	696.	0.	40.	11.	22.00
.04	.00	14.36	.00	.100	.036	051	.019	9.50	339.55
.009186	475.	475.	475.	30	9	1	.00	109.34	448.89