TR-54

APPLICATION OF HEC-2 PROGRAMME FOR WATER SURFACE PROFILE DETERMINATION

SATISH CHANDRA
DIRECTOR

STUDY GROUP

A B PALANIAPPAN
K S RAMASASTRI

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE-247667 (UP)
INDIA

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ABSTRACT

Depth of flow at various sections are needed for different discharges under different situations. Some of the situations encountered in practice are (i) bridges in the river environment (ii) channel improvement schemes (iii) food plain encroachment etc. Some times it would be necessary to predict up to what extent the back waters would reach by downstream daming or for fixing the FRL for a dam. Also flood plain marking would be needed. In such situations water surface prifile computations are made. It is usual practice to use standard step method in such situations.

In USA and other countries a programme HEC-2 developed by Hydrologic Engineering Center, USA is extensively used for the above computations.

HEC-2 can compute water surface profiles for a gradually varied flow. The effect of obstrctions such as bridges, weirs and other structures in flood plain can be studied. In a single run upto 14 profiles using the same cross sectional data can be computed. The program can take into account the reduction of the flow carrying capacity due to encroachment of flood plain.

The data requirement includes flow regime, starting elevation, discharge, loss coefficient, i.e. subcritical, super critical etc, cross sectional geometry and reach length. The computation of water surface profile in the tributary system, if necessary can be made after the compu-

tation of the main stream. The Manning's "n" values for flood plain and channel can be varies.

The programme is implemented on VAX-II Computer of N.I.H. and tested. The program is used to compute the water surface profile for several discharges in Omar river a tributary of the river Narmada.

1.0 INTRODUCTION

Knowledge on the depth of flow for various discharge which a stream carries is essential not only to the water resources engineers, but also to navigators. The river training works modify the existing flow situation. For example construction of levees for the protection of the a village or town increases the depth of flood flow. Construction of obstructions like dams, bridges etc. change the flow regime. Release of water from reservoir requires an idea of depth of flow which the down stream river reach would encounter so that unwanted inundation is avoided. In such situations water surface profile are computed using the information on the channel geometry and roughness coefficient for the necessary discharge values. The Standarded Step Method is used for the needed computations.

A well documented and tested programme, which is often used in USA and in other countries in HEC-2. Since this programme also has number of capabilities and compute water surface profile under various situations, it has been chosen for the computations of water surface profiles. These capabilities are discussed in the following sections. The computer programme was implemented on to VAX-11 system. Because of the change of machine certain modifications were made to run the programme on UAX-11/780 Computer. The implemented programme was also tested with the test date provided in the Manual supplied by Hydrologic Engineering Centre.

For the application on to an Indian river for testing, Omar river of Narmada basin was taken up since RDSO, Lucknow made available the needed data.

The analysis and the results are discussed in the section 4.2. The results obtained include plots of water level marked on the cross sections and water surface profiles. The results were transformed to IBM PC and necessary pl,ots are made. It can be noted that this documented computed programme can be used for water surface profile computations when the flow is subcritical.

2.0 HEC-2 COMPUTER PROGRAMME

The HEC-2 programme was developed in Hydraulic Engineering Center by Bill. S. Eichert. The can comput water surface profiles for steady and gradually varied flow. This programme can be used to predict the effect of obstructions such as bridges, weirs, and other structures in the floodplain. Because of its capability to find the effect of levees and flood plain enchrochment on water surface profile, it can be used for flood plain management studies. The method used in this programme are briefly explained in the subsequent sections.

2.1 METHODOLOGY ADOPTED

The following procedure is used in HEC-2:

1. Assume a water surface elevation S_f at upstream section in the case of subcritical flow or at downstream section for supercritical flow (for e.g. assumes EL2 = El1 - length* energy slope).

2. Using the assumed elevation total conveyance K and velocity head are computed.

3. The energy slope S_f is calculated from which head loss H_e L* S_f + C $(\alpha_2 V_2^2/2*G)-(\alpha_1 V_1^2/2G)$

4. Water surface elevation WS_2 computed using the following equation

$$WS + \alpha_2(V_2^2/2g) = WS_1 + {}_1(V_1^2/2g) + H_e$$

5. A new water surface elevation is assumed as an avager of the computed value obtained from step 4 and the originally assumed value.

6. Steps 2 to 5 are repeated until assumed value agrees within 0.01 m to get a balanced water surface elevation.

Here,

K is conveyance

n is the Manning 's coefficient

r is the hydraulic radious (m)

H is the head loss (m)

L is the reach length (m)

a is the area of flow (m^2)

v is velocity (m/s)

T is top width (m)

g is acceleration due to gravity (m/sec^2)

The programme compares the calculated water surface elevation with critical depth. In the case of sub-critical flow the programme assumes the water surface elevation to be critical depth if the calculated one is below the critical. But for the case of supercritical flow, if the computed one is above critical depth the above assumption is made.

2.2 Major Options

2.2.1 Determination of critical depth

The critical water surface elevation (depth) is that elevation for which the total energy as per equation

3 is minimum.

The critical depth for a cross section will be calculated under the following situations:

(i) Optional request

(ii) Occurance of supercritical flow

(iii) Verification of critical depth because of change in flow regime while computation proceds.

(iv) Critical depth situation at the boundary.

Assuming different water surface elevation (WS) total energy is computed by equation 3. The elevation for which the total energy is minimum is assumed to be critical depth.

$$H = WS + \alpha \; (V^2/2G) \qquad \ldots(3)$$

The above iterative procedure is speeded up by parabolic interpolation after three consecutive values.

2.2.2 Friction loss equation

User can select any of the following for the computation of energy loss:

(a) average conveyance

$$S_f = (Q_1+Q_2) * (Q_1+Q_2)/(K_1+K_2) * (K_1+K_2) \qquad \ldots(4)$$

(b) average friction loss

$$S_f = (S_{f1} + S_{f2})/2 \qquad \ldots(5)$$

(Suitable for M_1, S_1, S_2 profiles)

(c) Geometric mean friction slope

$$S_f = (S_{f1} * S_{f2})^{\frac{1}{2}} \qquad \ldots(6)$$

(d) Hormonic mean friction slope

$S_f = 2\ (S_{f1} * S_{f2})/(S_{f1} + S_{f2})$ ...(7)

(most suitable for M2 profile)

(Appendix 3 explains M_1, M_2 etc. profiles)

The program user can choose any of the above equation for the computation, through a value to be given as an input data. When no option is given equation 4 will be used. It may be noted that any of the above equation will provide sufficiently accurate estimates provided the reach length is not too long. However, advantage can be taken to maximise reach length by appropriate choice of above equations.

2.2.3 Multiple profile choice

In a single run upto 14 profiles using the same cross sectional data can be computed.

2.2.4 Ineffective flow areas

Area below the specified sediment deposition depth will not be considered as an effective area of flow. This depth can be modified if opted by the user through input data.

Cross section with low lying profile over bank or with levees can be accounted by an option. Normally, areas below the water surface elevation in the main channel (c) as shown in fig. 1 is taken as area of flow, since in the portion mark (L) in the figure will contain almost stagnant water. In case the field situation is not so the user can opt as stated above. In certain situations where flow can not enter into this low lying portions due to natural or man

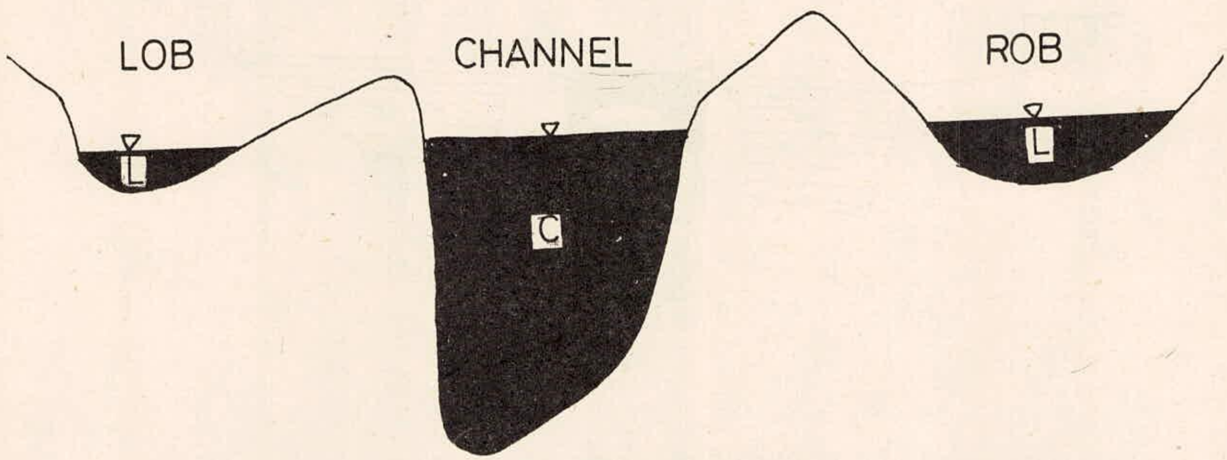
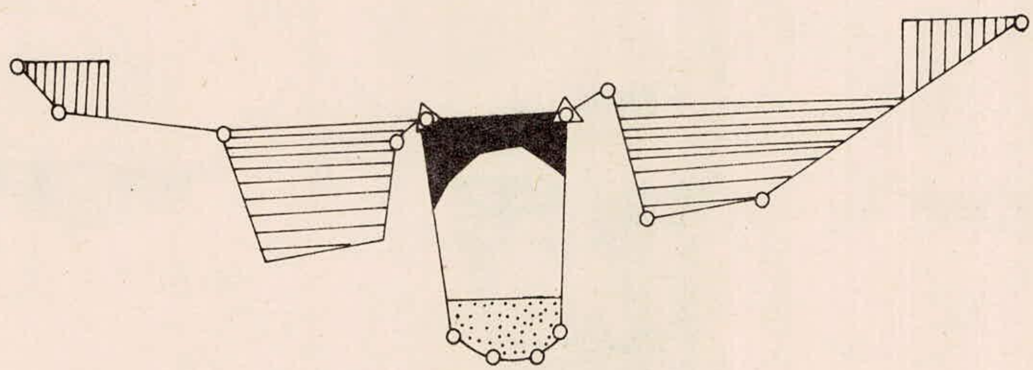


FIG. 1 : AREA OF FLOW NORMALLY USED

made levees, the areas marked 'L' should not be included in the area of flow computations. When user specified option X3.1 is 10, so long as the water surface elevation is less than levees (or bank) elevation the flow area of channel 'C' only will be taken. When the water surface elevation raises above the bank or levees the rea outside the main channel will be included. However, a computational imbalance would occur with regard to water surface elevation just below and just above the banks. If this computed and assumed elevation do not match. The elevation closest to the balanced will be printed out. Some of the ineffective areas of flow are as shown in Fig. 2.



EFFECTIVE FLOW AREA

FLOOD PLAIN ENCROACHMENT

FLOW BELOW BANK ELEVATION

SEDIMENT DEPOSITION

BRIDGE DECK

FIG. 2: INEFFECTIVE FLOW AREAS

2.2.5 Loss at the bridge structure

Energy loss due to expansion or due to contraction on either side of the bridge is calculated and used in the standard step method. A loss due to the structure is also accounted either through a normal bridge or through special bridge method.

In the normal bridge method, the ineffective area of deck as shown in Fig. 2 is subtracted from the total area and the wetted perimeter is increased when required (where water surface elevation exceed the lowest chord). This method is suitable for bridges without piers, low flow through circular or arch culvert and for bridges under high submergence.

The special bridge method is used for bridge with piers. This method can also be used for any bridge. The special bridge method computes losses through the structure for low flow, weir flow, and pressure flow or for any combination of these using hydraulic formulae. Explanation of HEC-2 bridge capabilities can be seen in Appendix IV of the USER'S MANNUAL.

2.2.6 Floodplain encroachment

Encroachments reduce the flow carying capacity. This can be specified by station and elevation values on either side of the bank through input data. Six options are permitted. For example, fixed top width, encroachment in the form of % of conveyance etc. This programme can also compute limit of encroachment in the flood plain, such that the required flow (100 years flood) is with in a higher elevation specified.

2.2.7 Channel improvement

Various channel improvements can be studied modifying cross section data automatically through options. New reach length (revised L), Left/right side bank slope, new roughness coefficient 'n', center line location etc. can be specified.

2.2.8 Interpolation of cross section

It may be necessary to give additional cross sections between the specified ones in order to accurately determine energy gradient. User can specify maximum allowable changes in velocity head exceeding which additional cross sections are interpolated (up to three) between the given cross sections if so opted. Interpolated cross sections are determined by raising or lowering and expanding or contracting the current cross sections shape. In the following cases interpolation will not be done (a) reach length is less than fifty feet, (b) encroachment have been encountered, (c) previous section is a special bridge cross section.

2.2.9 Tributary system profile

The computation of water surgace profile in the tributary system, if necessary can be made after the computation of the main stream form the starting elevation for the tributary. A tributary to a tributary can also be considered. Tributary stream profile can not be calculated simultaneously with encroachment calculations.

2.2.10 Roughness coefficient 'n'

If the Manning's 'n' value is not specified through NC card, this can be computed for the second or subsequent sections. The ratio of 'n' between channel and the flood plain is given for the first or other sections also. High water marks are given through J1 card. Average friction slope equation 1-b is used for 'n'. When an adverse slope is encountered computations are restarted using previous section 'n' value.

Another method used in HEC-2 is to specify the discharge and an assumed set of 'n' values and have the programme to compute the water surface profile to compare high water markings. A variation in 'n' can be assumed for next or subsequent profile trials.

2.3 Data Requirements

The data need include : flow regime, starting elevation, discharge, loss coefficient, cross sectional geometry and reach lengths.

Subcritical and supercritical flow will be identified by input data. Normally, a change in flow regime is not permitted in the programme except for certain bridge analysis. Computation proceeds upstream for subcritical flow. When the flow change the regime profile need to be computed twice.

Starting elevation may be specified as (1) critical depth (2) as known elevation (3) by the slope area method, through input data. At sections of rapids, weirs waterfall etc. critical depth can be specified. An approximate energy slope value is given for estimate of starting elevation.

Discharge may be specified for a single profile run. This discharge can be changed at any cross section. A table of discharge can be given as an input data.

Energy loss coefficients are given through the Manning's 'n' values, contraction or expansion or transition losses and bridge loss coefficients. Horizontal variation in the Manning's 'n' can be given. A variation of 'n' with respect to elevation can be given. Expansion and contraction loss can be given. They will be typically of the order of 0.3, 0.1 respectively. The bridge loss coefficient are treated separately.

Cross section geometry is defined by reduced distance and reduced level along with the reach length. Cross section should include the entire flood plain and should be perpendicular to the flow. Cross sections are required at representative locations throughout a stream. They should clearly provide a picture of the changes occur in the discharge, slope, shape or roughness. They should be representative of leevee reach, weir, bridges. Where abrupt changes occur, several sections should be used irrespective of the distance. The purpose of the study also affects the spacing of cross sections. For example, navigational studies requires a close spacing of about five hundred feet, where as for sedimentation studies to determine deposition in reservoir a 5 to 10 miles spacing are sufficient. Maximum spacing can be used with average friction slope equation for M1 profile and with hormonic mean friction slope equation for M2 profiles. Upto 100 data points can be given to describe a cross section geometry. Data are arranged left to right looking downstream.

The distance between cross sections is referred to as reach length. The reach length between left over bank, righ over bank and channel can be specified. Overbank rach length can be taken as an anticipated flow path.

3.0 DATA

Data of Omar river a mountain stream in the eastern Madhya Pradesh has been used for the purpose of this study. Information on cross-section of the river at 12 sites at an interval of 1645m was obtained from the records of RDSO, Lucknow. Slope of the river was obtained from the L section of the river made available by RDSO.

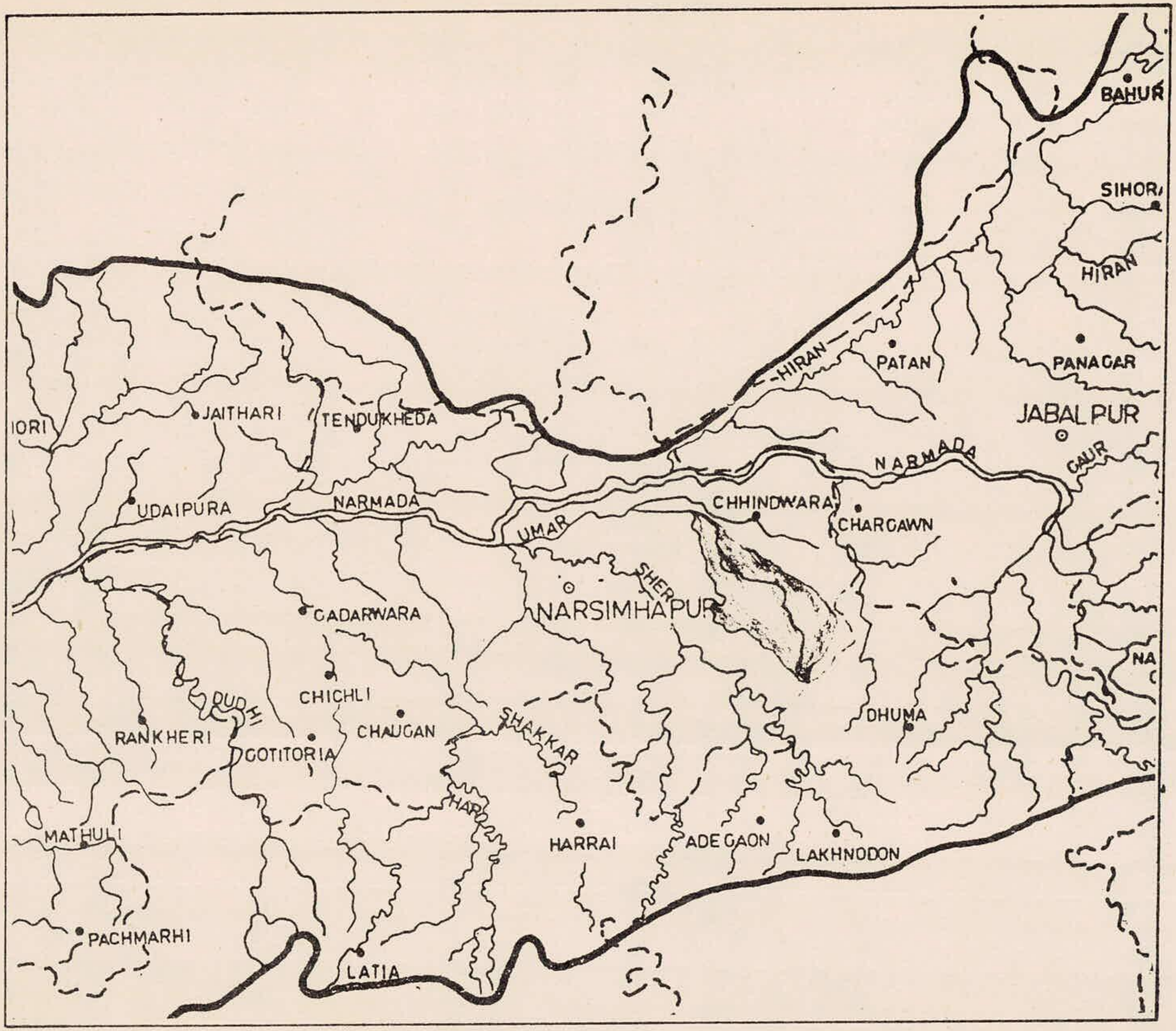


FIG. 3. INDEX MAP

4.0 APPLICATION

The following is a sample application made using the above described programme.

4.1 Description of the Study Area

The Omar river is a small tributary of the river which joins the river Narmada downstream of Jabalpur. The Railway bridge no. 153, is located on the Itarsi-Jabalpur route of Central Railway (figure 3). This mountainous catchment is situated on the northern slopes of Satpura ranges in Seoni district of Madhya Pradesh.

4.2 Analysis and Results

The observed discharge and the computed Manning's 'n' from velocity measurements are plotted as shown in Fig.4. This Figure shows two different pattern of variation; one for discharge less than 60 cumecs and the other for higher discharges. This plot is used to estimate the Manning's 'n' to be input to the programme. The cross section drawings were discretised and the necessary reduced distances, reduced levels were tabulated. They were given as input to the programme in the required format as shown in the Appendix-1.

The profiels were computed for discharges 50 m^3/s and 150 m^3/s. The results obtained are depth of flow at various sections along the river, cross section plots as opted and also water surface profile plot. The results were transfered to IBM PC and plots were made. These plots are shown in Figures Some of the direct outputs of HEC-2 are also show in Appendix 2 as a sample output.

The results show that critical flow occurs in the river at the chainage 38624.25 m from the bridge and also at another section for a discharge of 150 m^3/s. The cross sections are narrow at these places. The occurrance of critical flow could not be verified since field data are not available. However for an actual problem verification of the information on the cross section and also the flow situation are needed.

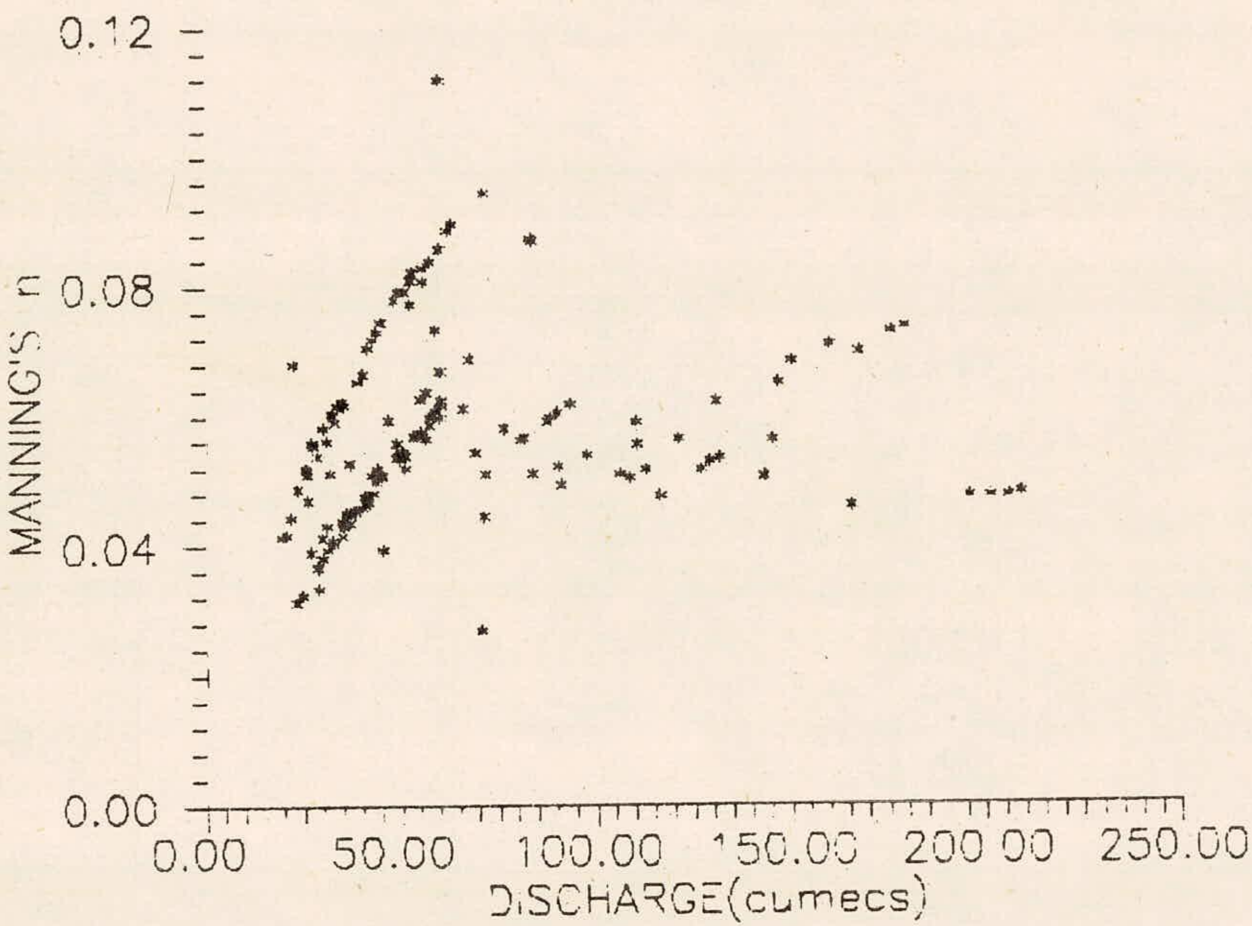
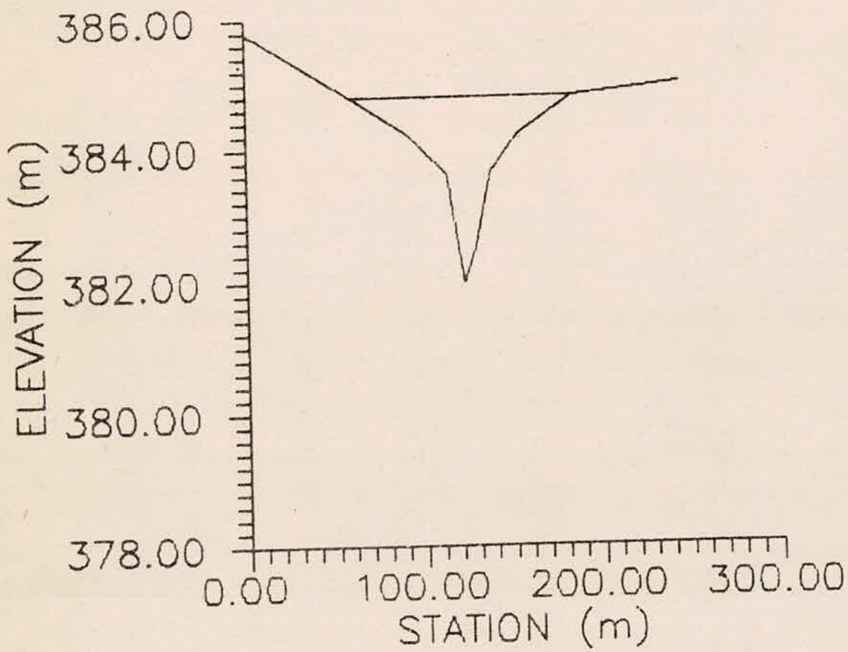
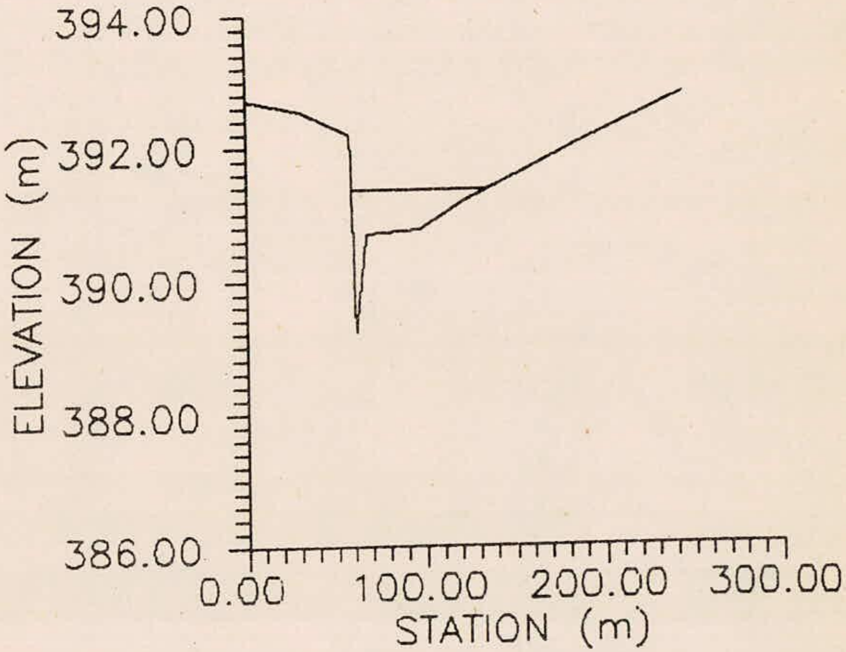


Fig. 4. VARIATION OF MANNING'S n WITH DISCHARGE OF THE RIVER OMAR AT RLY.BRIDGE

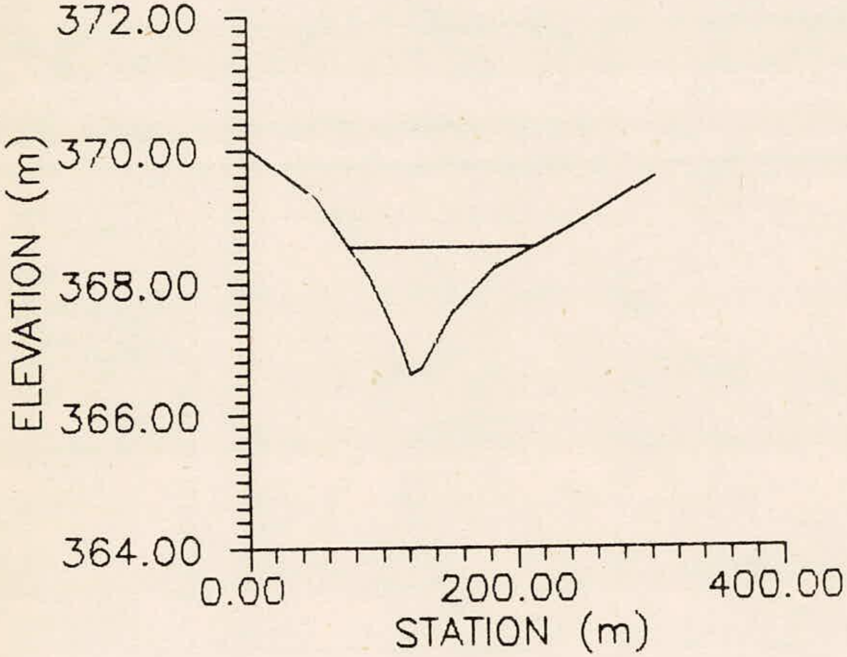


CROSS SECTION OF OMAR RIVER
AT 37014.91 m

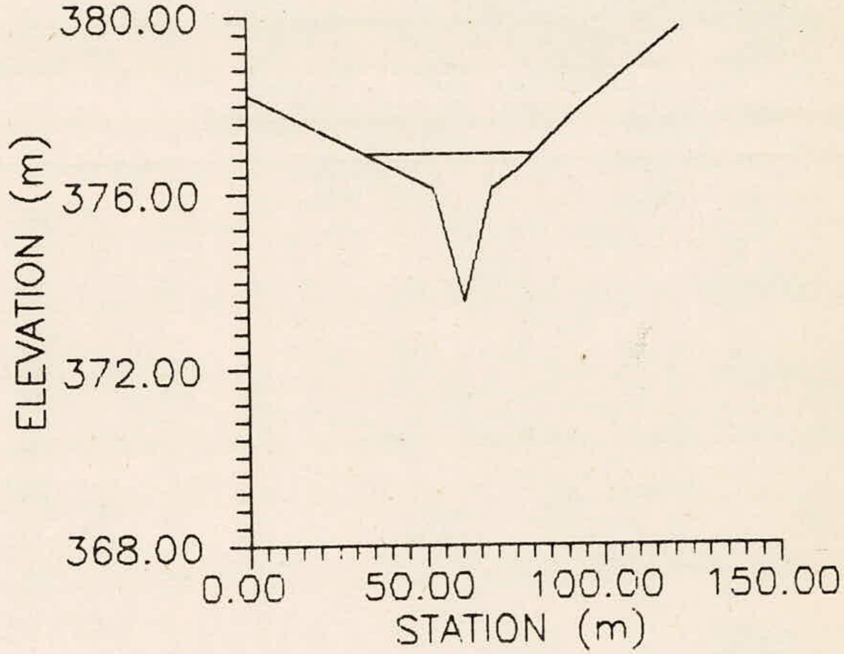


CROSS SECTION OF OMAR RIVER
AT 38624.25 m

Fig. 5. a-1.

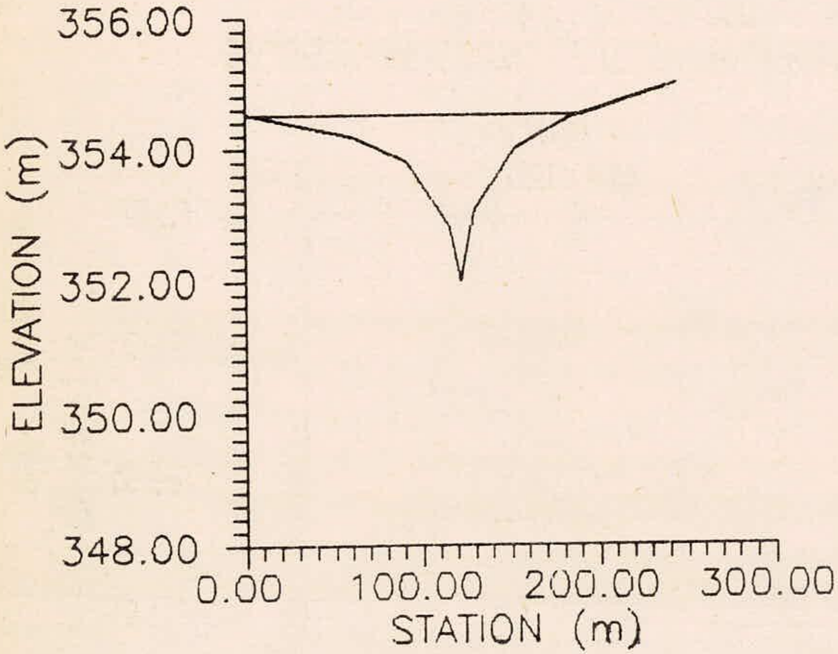


CROSS SECTION OF OMAR RIVER
AT 33796.22 m

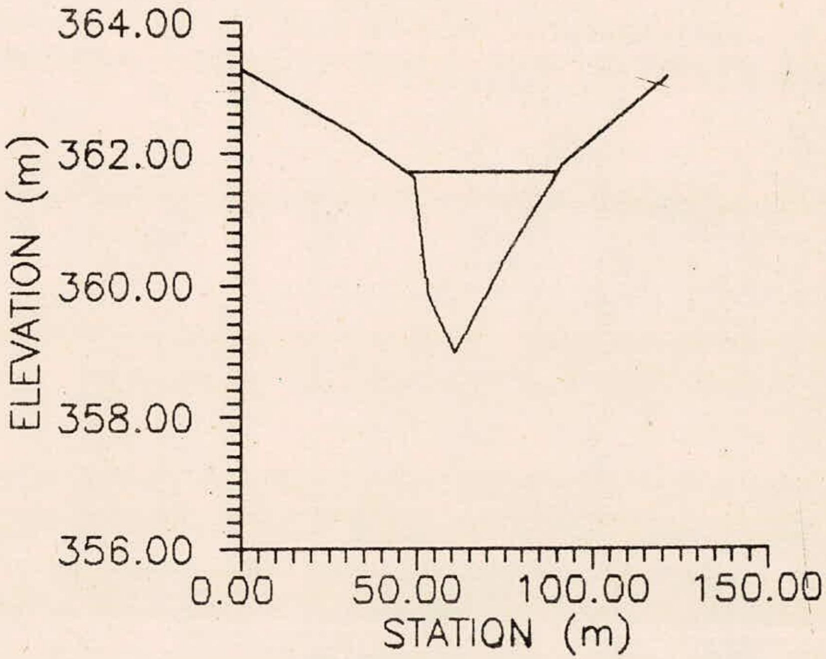


CROSS SECTION OF OMAR RIVER
AT 35405.56 m

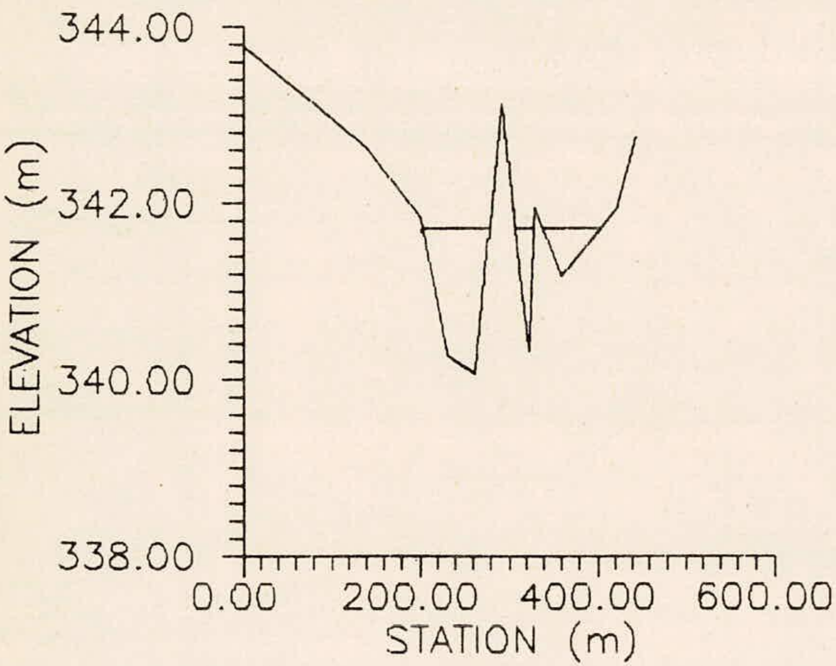
Fig. a-2.



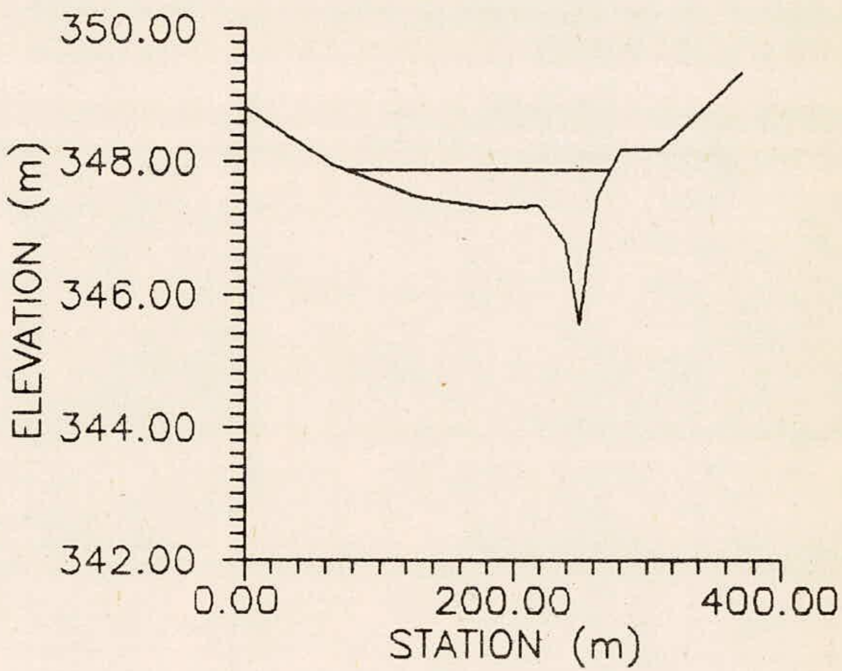
a-3. CROSS SECTION OF OMAR RIVER
AT 30577.53 m



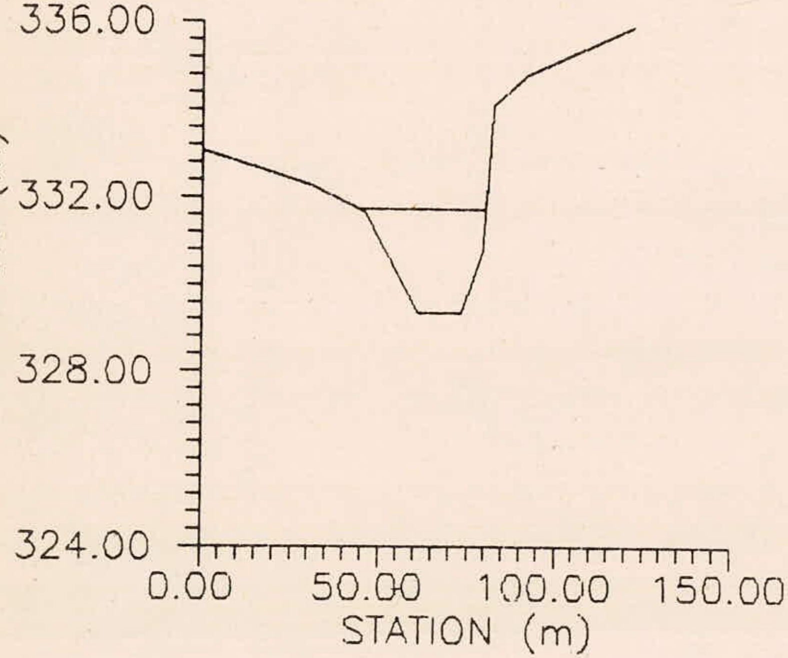
a-4. CROSS SECTION OF OMAR RIVER
AT 32186.88 m



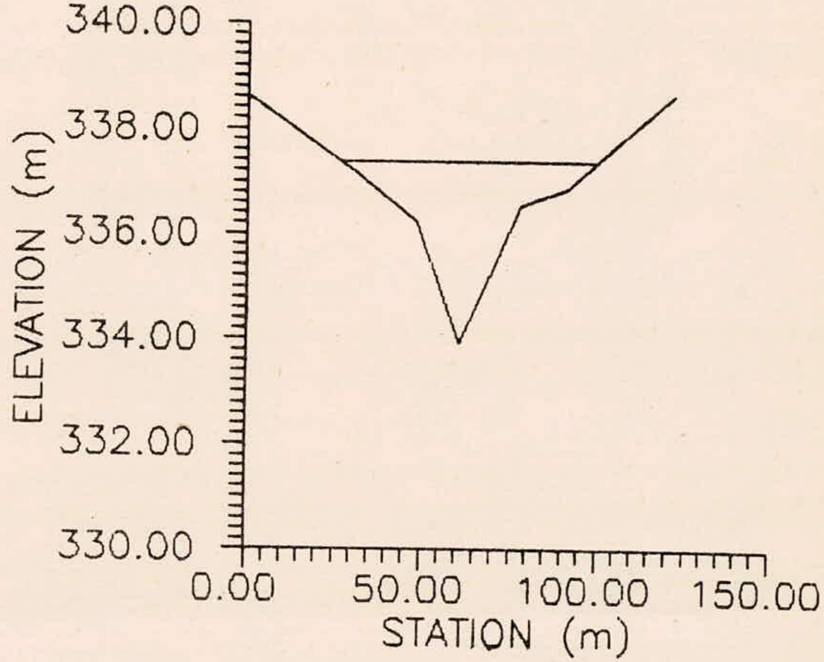
a-5. CROSS SECTION OF OMAR RIVER
AT 27358.84 m



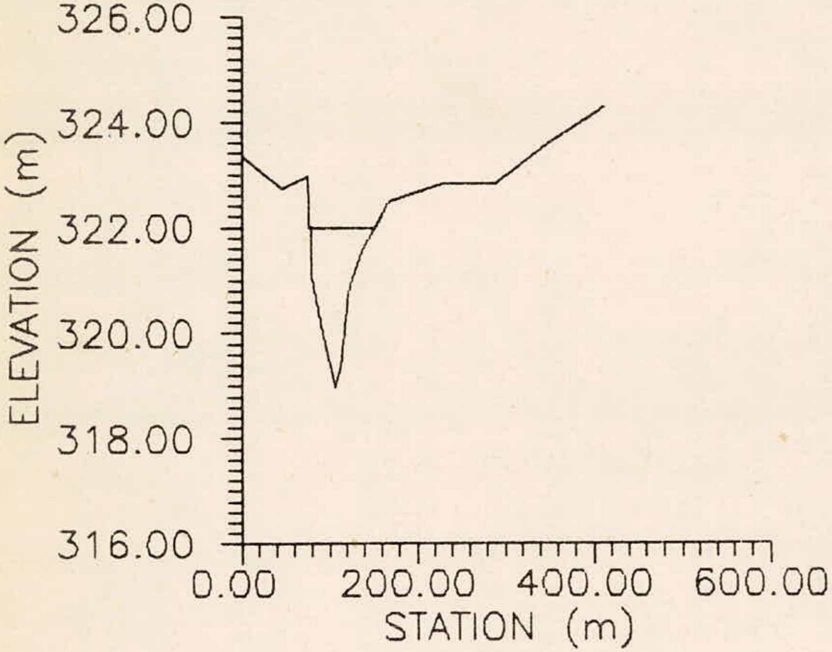
a-6. CROSS SECTION OF OMAR RIVER
AT 28968.19 m



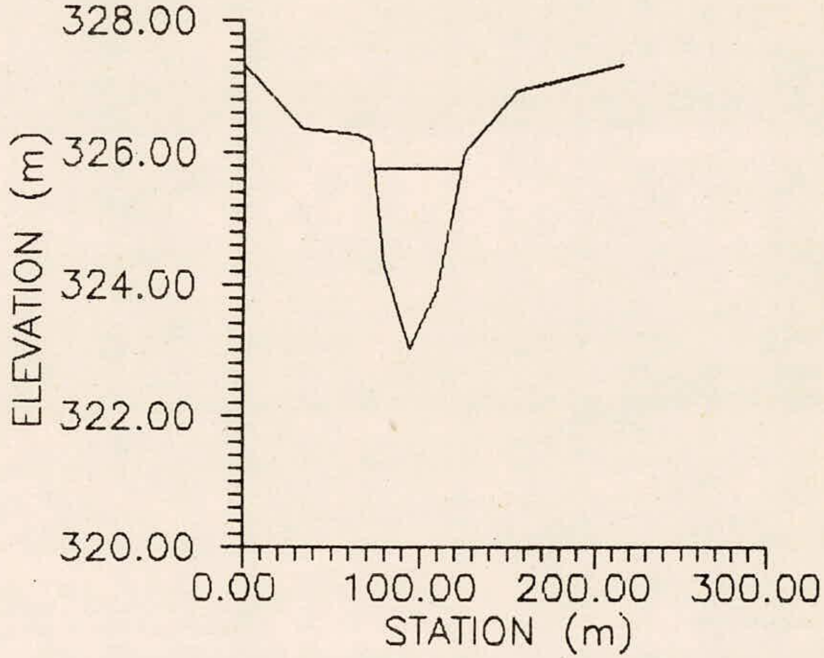
a-7. CROSS SECTION OF OMAR RIVER AT 24140.16 m



a-8. CROSS SECTION OF OMAR RIVER AT 25749.50 m



a).9. CROSS SECTION OF OMAR RIVER AT 20921.47 m



a).10. CROSS SECTION OF OMAR RIVER AT 22530.81 m

5.0 REMARKS

The programme HEC-2 was implemented on VAX 11/780 computed system and applied on to a small river Omar in Narmada basin, is capable of computing water levels at various sections along a river. In this process pertinent hydrolic parameters determined are depth of flow, water surface width, elevation of total energy line, friction slope, flow velocity, critical depth and volume beneath the computed profile.

Flow at a bridge is a complex hydraulic process, which is approximated by one dimensional equations and certain discharge coefficients. However, HEC-2 manual claims that this complex situation is handled successfully by two SUBROUTINES. This needs to be tested for such flow situation in Indian rivers.

A secondary purpose of HEC-2 is to calculate the permissible encroachment width for specified discharges. This capability also needs testing so that use can be made for flood plain zoning with additional information from topografic maps.

A proper sediment transport routines can be linked to HEC-2 and can be used for alluvial rivers also. Such attempts were made (PALANIAPPAN 1987) by Simon and Li at CSU, USA, in developing HEC-2SR. They need proper modifications to account the sediment transport. Further: i) The programme is very long contain 8000 statementss (ii) Computations using this general purpose programme is high for simple water surface profile computations. (iii) The input data preparation is time consuming and error prone which could be avoided by proper changes in the programme. However, no such change is made herein.

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NATIONAL INSTITUTE OF HYDROLOGY

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

COMPUTER WORDS USING ... DATE 30.3.88

PREPARED BY A.B PALANIAPPAN CHECKED BY PAGE 1 OF

	1	2	3	4	5	6	7	8	9	10
T 1	PROFILE FOR THE RIVER OMAR									
T 2	A TRIBUTARY OF HIRAN, IN NARMADA BASIN									
T 3	ASSUMED DISCHARGE									
J 1								50.0	2.0	
J 2	1 -1	1								
J 3	38	8	4	25	1	2				
N C	.06	.06	.06							
X 1	1	15	76.20	167.64	1609.34	1609.34	1609.34			
G R	323.36	0	322.74	45.72	322.95	76.20	321.06	78.63	320.05	91.44
G R	318.99	106.68	319.18	109.72	319.39	112.77	320.88	121.92	321.57	137.16
E J	322.48	167.64	322.81	228.6	322.83	289.56	323.61	350.52	324.57	411.48
X 1	2	11	71.62	155.44	1609.35	1609.35	1609.35			
G R	327.32	0	326.34	33.52	326.25	64.0	326.17	71.62	324.31	79.24
G R	323.04	94.48	323.89	109.72	326.00	124.96	326.92	155.44	327.32	216.40
X 1	3	9	45.72	82.29	1609.35	1609.35	1609.35			
1 2										
G R	333.05	0	332.24	30.48	331.66	45.72	329.36	60.96	329.36	73.15
G R	330.77	79.24	334.08	82.29	334.80	91.44	335.90	121.92		
X 1	4	7	48.76	78.02	1609.34	1609.34	1609.34			
G R	338.64	0	337.21	30.48	336.23	48.76	333.93	60.96	336.55	78.02
G R	336.87	91.44	338.66	121.92						
X 1	5	13	292.6	330.09	1609.35	1609.35	1609.35			
G R	343.78	0	343.15	79.24	342.63	140.29	341.82	201.16	340.28	231.64
G R	340.07	262.12	343.12	292.6	341.23	312.4	340.33	323.08	341.95	330.09
G R	341.18	360.57	341.93	421.53	342.75	445.0				
X 1	6	11	219.45	280.41	1609.35	1609.35	1609.35			
G R	348.82	0	347.93	67.05	347.46	128.01	347.28	188.97	347.33	219.45
G R	346.78	239.26	345.54	249.93	347.47	262.73	348.18	280.41	348.16	310.89
G R	349.32	371.85								
X 1	7	9	91.44	182.88	1609.35	1609.35	1609.35			
G R	354.52	0	354.17	60.80	353.80	91.44	352.81	115.21	351.99	121.92
1 3										

SURFACE WATER ANALYSIS AND MODELLING DIVISION

NATIONAL INSTITUTE OF HYDROLOGY

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PREPARED BY A.B. PALANIAPPAN CHECKED BY DATE 30.3.88 PAGE 2

	1	2	3	4	5	6	7	8	9	10
GR	353.05	129.54	353.99	152.40	354.45	182.88	354.97	243.84		
X1	8	8	49.37	91.44	1609.35	1609.35	1609.35			
GR	363.28	0	362.33	30.48	361.62	49.37	359.83	53.34	358.96	60.96
GR	360.45	75.89	361.81	91.44	363.14	121.92				
X1	9	9	51.81	182.88	1609.34	1609.34	1609.34			
GR	370.03	0	369.26	51.81	368.07	91.44	367.06	114.30	366.6	121.92
GR	366.69	130.45	367.52	152.40	368.18	182.88	368.86	243.84	369.56	304.80
X1	10	9	45.72	68.88	1609.34	1609.34	1609.34			
GR	378.23	0	376.98	30.48	376.35	45.72	376.10	52.42	373.53	60.96
GR	376.13	68.88	376.53	76.20	377.74	91.44	379.72	121.92		
X1	11	11	112.77	137.16	1609.35	1609.35	1609.35			
GR	385.79	0	385.10	39.62	384.20	91.44	383.59	112.77	382.58	118.26
GR	381.97	121.92	382.44	128.01	383.63	137.16	384.20	152.40	384.77	182.88
GR	384.94	243.84								
X1	12	9	57.91	67.05						
GR	392.7	0	392.53	30.48	392.18	57.91	389.23	60.96	390.67	67.05
GR	390.75	97.53	391.18	121.92	391.99	182.88	392.74	243.84		
EJ										
ER										

SURFACE WATER ANALYSIS AND MODELLING DIVISION

```
*****************************************************
*  WATER SURFACE PROFILES                           *
*  VERSION OF NOVEMBER 1976                         *
*  UPDATED APRIL 1980                               *
*                                                   *
*  RUN DATE  19-MAY-88 TIME   12:55:14              *
*****************************************************
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****************************************
*  U.S. ARMY CORPS OF ENGINEERS        *
*  THE HYDROLOGIC ENGINEERING CENTER   *
*  609 SECOND STREET, SUITE D          *
*  DAVIS, CALIFORNIA 95616             *
*  (916) 440-2105 (FTS) 448-2105       *
****************************************
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X     X XXXXXXX  XXXXX           XXXXX
X     X X       X     X         X     X
X     X X       X                     X
XXXXXXX XXXX    X         XXXXX  XXXXX
X     X X       X               X
X     X X       X     X         X
X     X XXXXXXX  XXXXX          XXXXXXX
```

PROFILE FOR STREAM   NARMADA BASIN

PLOTTED POINTS (BY PRIORITY)-E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L
-LEFT BANK,R-RIGHT BANK,M-LOWER END STA

```
ELEVATION  310.      320.      330.      340.      350.      360.      370.      380.      390.      400.
    SECNO  CUMDIS

   1.00     0.  C        I.  EL     .         .         .         .         .         .         .         .         .
          200.  C        I.  ELM    .         .         .         .         .         .         .         .         .
          400.  C         I   EL    .         .         .         .         .         .         .         .         .
          600.  C         I   ELM   .         .         .         .         .         .         .         .         .
          800.  C         .I   EL   .         .         .         .         .         .         .         .         .
         1000.  C         . I ELM   .         .         .         .         .         .         .         .         .
         1200.  C         . I  ER   .         .         .         .         .         .         .         .         .
         1400.  C         .  I ELM  .         .         .         .         .         .         .         .         .
         1600.  C         .  I  ER  .         .         .         .         .         .         .         .         .
   2.00  1800.  C         .  I  ER  .         .         .         .         .         .         .         .         .
         2000.  C         .   I WER .         .         .         .         .         .         .         .         .
         2200.  C         .    I ELR.         .         .         .         .         .         .         .         .
         2400.  C         .    I  EMR         .         .         .         .         .         .         .         .
         2600.  C         .     I  ER         .         .         .         .         .         .         .         .
         2800.  C         .      I WER        .         .         .         .         .         .         .         .
         3000.  C         .       I E R       .         .         .         .         .         .         .         .
         3200.  C         .        I.EMR      .         .         .         .         .         .         .         .
   3.00  3400.  .         .        I.CEMR     .         .         .         .         .         .         .         .
         3600.  C         .         I WER     .         .         .         .         .         .         .         .
         3800.  C         .         I  EMR    .         .         .         .         .         .         .         .
         4000.  C         .         .I LER    .         .         .         .         .         .         .         .
         4200.  C         .         . I LEM   .         .         .         .         .         .         .         .
         4400.  C         .         . I LERM  .         .         .         .         .         .         .         .
         4600.  C         .         .  I LEM  .         .         .         .         .         .         .         .
         4800.  C         .         .  I  LEM .         .         .         .         .         .         .         .
   4.00  5000.  C         .         .   I LE M.         .         .         .         .         .         .         .
         5200.  C         .         .    I LEM.         .         .         .         .         .         .         .
         5400.  C         .         .    I  WEM         .         .         .         .         .         .         .
         5600.  C         .         .     I  EM         .         .         .         .         .         .         .
         5800.  C         .         .      I REM        .         .         .         .         .         .         .
         6000.  C         .         .       I EL        .         .         .         .         .         .         .
         6200.  C         .         .        I.EM       .         .         .         .         .         .         .
         6400.  C         .         .        I.EL       .         .         .         .         .         .         .
   5.00  6600.  C         .         .         I EL      .         .         .         .         .         .         .
         6800.  C         .         .         .IWEL     .         .         .         .         .         .         .
         7000.  C         .         .         .I EL     .         .         .         .         .         .         .
         7200.  C         .         .         . I EL    .         .         .         .         .         .         .
         7400.  C         .         .         .  I EM   .         .         .         .         .         .         .
         7600.  C         .         .         .  I  EM  .         .         .         .         .         .         .
         7800.  C         .         .         .   I ER  .         .         .         .         .         .         .
         8000.  C         .         .         .    I EM .         .         .         .         .         .         .
   6.00  8200.  .         .         .         .     ICEM.         .         .         .         .         .         .
         8400.  C         .         .         .     I LEM         .         .         .         .         .         .

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        8600.  C          .          .         .      I LE          .         .           .         .         .          .
        8800.  C          .          .         .       I ER         .         .           .         .         .          .
        9000.  C          .          .         .        I.EM        .         .           .         .         .          .
        9200.  C          .          .         .         ILE        .         .           .         .         .          .
        9400.  C          .          .         .         I LE       .         .           .         .         .          .
        9600.  C          .          .         .         .I LE      .         .           .         .         .          .
 7.00   9800.  C          .          .         .         . I LE     .         .           .         .         .          .
       10000.  C          .          .         .         .  I EM    .         .           .         .         .          .
       10200.  C          .          .         .         .   I EM   .         .           .         .         .          .
       10400.  C          .          .         .         .    I EM  .         .           .         .         .          .
       10600.  C          .          .         .         .     I  EM.         .           .         .         .          .
       10800.  C          .          .         .         .     I  EM          .           .         .         .          .
       11000.  C          .          .         .         .      I  EM         .           .         .         .          .
       11200.  C          .          .         .         .       I .EM        .           .         .         .          .
 8.00  11400.  C          .          .         .         .        I. EM       .           .         .         .          .
       11600.  C          .          .         .         .         I  EM      .           .         .         .          .
       11800.  C          .          .         .         .         .I ELM     .           .         .         .          .
       12000.  C          .          .         .         .          . I EM    .           .         .         .          .
       12200.  C          .          .         .         .          . I EM    .           .         .         .          .
       12400.  C          .          .         .         .          .  I EM   .           .         .         .          .
       12600.  C          .          .         .         .          .   I E   .           .         .         .          .
       12800.  C          .          .         .         .          .    IRE  .           .         .         .          .
 9.00  13000.  C          .          .         .         .          .     IRE .           .         .         .          .
       13200.  C          .          .         .         .          .     I RE.           .         .         .          .
       13400.  C          .          .         .         .          .      I RE           .         .         .          .
       13600.  C          .          .         .         .          .       I.R E         .         .         .          .
       13800.  C          .          .         .         .          .        I  REM       .         .         .          .
       14000.  C          .          .         .         .          .        .I  REM      .         .         .          .
       14200.  C          .          .         .         .          .         .  I REM    .         .         .          .
       14400.  C          .          .         .         .          .         .   I LEM   .         .         .          .
10.00  14600.  C          .          .         .         .          .         .    I LEM  .         .         .          .
       14800.  C          .          .         .         .          .         .     I LEM..         .         .          .
       15000.  C          .          .         .         .          .         .      I LEM.         .         .          .
       15200.  C          .          .         .         .          .         .       I LEM         .         .          .
       15400.  C          .          .         .         .          .         .        I LEM        .         .          .
       15600.  C          .          .         .         .          .         .         I.LE        .         .          .
       15800.  C          .          .         .         .          .         .          I LE       .         .          .
       16000.  C          .          .         .         .          .         .           .I LE     .         .          .
11.00  16200.  C          .          .         .         .          .         .           . I LE    .         .          .
12.00  16400.  .          .          .         .         .          .         .           .      IWE.M        .          .
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3

DAUD:(PALANI. HEJHEC2.OUT;23 4-MAY-1988

4-MAY-88 11:38:45

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HEC2 RELEASE DATED NOV. 76 UPDATED APRIL 1980
ERROR CORR - 01,02,03,04
MODIFICATION - 50,51,52,53,54

****

NOTE - ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY

NARMADA BASIN

SUMMARY PRINTOUT

SECNO	DEPTH	TOPWID	AREA	CWSEL	CRIWS
1.000	2.01	45.18	47.40	321.00	0.00
2.000	1.64	37.72	36.43	324.68	0.00
3.000	0.94	5812	31.06	332.60	0.00
4.000	2.75	43.25	46.43	336.68	0.00
5.000	0.80	58.72	29.96	340.87	0.00
6.000	2.03	150.83	59.42	347.57	0.00
7.000	1.70	51.05	31.88	353.69	0.00
8.000	2.04	31.36	34.64	361.00	0.00
9.000	1.15	64.16	37.04	367.75	0.00
10.000	2.86	29.01	27.63	376.39	0.00
11.000	1.88	39.40	29.29	383.85	0.00
12.000	1.76	51.77	17.89	390.99	390.99

5-MAY-86 09:59:10

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HEC2 RELEASE DATA NOV. 76 UPDATED APRL 1980

ERROR CORR - 01,02,03,04

MODIFICATION - 50,51,52,53,54

****

NOTE - ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY

NARMADA BASIN

SUMMARY PRINTOUT

SECNO	DEPTH	TOPWID	AREA	CWSEL	CRIWS
1.000	3.01	74.14	105.99	322.00	0.00
2.000	2.71	49.82	83.20	325.75	0.00
3.000	2.37	36.32	58.21	331.73	330.71
4.000	3.44	72.89	87.43	337.37	0.00
5.000	1.64	161.42	113.19	341.71	0.00
6.000	2.31	195.88	109.93	347.85	347.49
7.000	2.52	188.70	116.11	354.51	0.00
8.000	2.75	43.52	60.89	361.71	0.00
9.000	1.93	138.50	112.52	368.53	0.00
10.000	3.36	48.32	47.25	376.89	0.00
11.000	2.80	125.24	99.90	384.77	0.00
12.000	2.12	76.32	41.21	391.35	391.35

13-MAY-88 14:43:51

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HEC2 RELEASE DATED NOV. 76 UPDATED APRL 1980
ERROR CORR - 01,02,03,04
MODIFICATION - 50,51,53,54
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NOTE - ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY

NARMADA BASIN

SUMMARY PRINTOUT

SECNO	DEPTH	TOPWID	AREA	CWSEL	CRIWS
1.000	6.01	411.48	980.29	325.00	0.00
2.000	2.34	45.61	65.47	325.38	325.38
3.000	4.67	82.24	213.13	334.03	331.79
4.000	4.31	106.45	165.92	338.24	0.00
5.000	2.61	298.94	339.40	342.68	0.00
6.000	2.70	271.64	196.39	348.24	0.00
7.000	3.31	243.84	295.50	355.30	0.00
8.000	3.55	82.52	110.02	362.51	0.00
9.000	2.93	210.00	292.23	369.53	0.00
10.000	3.93	69.02	80.11	377.46	377.46
11.000	3.78	241.31	302.57	385.75	0.00
12.000	2.69	119.61	96.80	391.92	391.92