DP-2

RATING CURVE ANALYSIS

S RAMASESHAN
DIRECTOR

STUDY GROUP

S M SETH
A B PALANIAPPAN

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAVAN
ROORKEE-247 667 (UP)
INDIA

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ABSTRACT

Many hydrologic analyses are made using discharge data of a river at a site. Often these discharge values are obtained from stage measurements. In order to compute the discharge from the stages a rating curve is used. A rating curve is a steady-state relation between the complex inter-relations of stages and discharges. When rating curves are available one can go in for interpolation methods. Some time physically sound rating curves may have to be established before computation of discharge is taken up. Two computer programmes for this purpose are given in this documentation.

In the case of use of available rating curves, a rating table is prepared. This table consists of stage and discharge values. After removal of data error in the table by finding first and second differences of the discharge values this table can be used as interpolating table. The Hermition method, which provides a smooth curve taking continuity of slope and curvature is used. A FORTRAN subroutine capable of interpolating discharge values for given stage values has been developed and documented.

For the establishment of rating curve from the measured discharge and the corresponding water level, after data processing, the available data is plotted on a simple graph and also on double logarithmic paper. This helps in grouping the data and to find its suitability for fitting simple curve. The grouped data is used to fit a relationship of the following form $Q = a\,(S-e)^b$ where, Q is the discharge, S is the stage and 'a','b','e' are parameters defining the relation. The well known method fitting a curve is to minimise the

sum of squares of differences between observed and computed Q using least squares criterion. Assuming a value of parameter 'e' and taking logarithms of Q and (S-e) the parameters 'a' and 'b' are found. For different values of 'e' the method is repeated and various sets of parameters 'a' and 'b' along with the sum of squares of departures are found. The set having minimum of above departure can be taken to define the relation. But a physical interpretation of the results may suggest different set of parameters.

The stage and discharge data is given as input to the programme and it gives values of parameters'a' and 'b' using least squares method Necessary flow charts, input specifications and sample output are given in the documentation. Interpretation of the physical information regarding the cross section for arriving at appropriate values of parameters 'a' and 'b' of the rating curves are also provided.

1.0 INTRODUCTION

Many hydrologic analyses are made using discharge data of a river at a site of interest. These data can be obtained by direct measurements. In case of direct measurements the data can be acquired at the expense of lot of labour and money. Sometime the observations can not be made in the time interval in which they are required. Hence alternative ways are deviced to obtain the necessary information . One of the way is to go in for measurement of water level at the required time interval which is easier and to compute the discharges from them. The computations are achieved through the use of rating curve which depicts an approximate relationship between the discharge and the stage.

While computing discharges at hourly interval from stage measurements at that interval for Narmada flood studies three different cases were categorised as follows:

1. Use of interpolation technique along with available(supplied by (the concerned field organisations) rating curves.
2. Extension of rating curve using conveyance analysis.
3. Establishment of rating curve using observed stage and corresponding discharge values together with a physical analysis.

Computer programs have been developed for dealing with the case 1 and case 3 and they are described in this documentation.

2.0 PURPOSE OF THE PROGRAM

2.1 Case 1 Interpolation

The discharge computation for a given stage is achieved by computing the particular intermediate value given by the rating table with little extrapolation if necessary. The rating table is a representation of the rating curve in a discrete form. The interpolation employed should provide smooth values(that is if plotted should form a continuous smooth curve). With this object an interpolation technique of Hermitian type(3) was used and a computer program was developed.

2.2 Case 3 Establishment of Rating Curve

The observed discharges and corresponding water stages provide the valuable information about the relationship between them. This relationship is represented in mathematical form for easy use in models. This functional representation can be developed using least squares techniques. The computer program developed for this purpose uses number of pairs of stage and discharge measurements of a particular site as input data and provide the mathematical form of the rating curve.

3.0 METHOD USED

3.1 Interpolation

Preparation of rating table:

Direct values of stage and corresponding discharge are read out from the rating curve at an equal interval of stage values. These values form the raw rating table. Smoothening of table is undertaken to remove off the possible error that would have entered in while reading the rating curve causing a deviation in the monotonic character of the relation. This is done by preparing a difference table of discharge values and adjustments are made by adding or subtracting certain small quantity to /from the discharge values so that the difference in discharge increases steadily with increase in stage. (There may be cases when the second difference is constant for one or two continuous intervals.This is acceptable).

Hermition Interpolation

In order to have a smooth continuous function the interpolaotion used here takes not only the rate of change of discharge with respect to stage(first difference) but also the rate of change of this change (second difference) into account. This type of interpolation is known as Hermitian (3)

3.2 Establishment of Rating Curve

The observed discharge and corresponding stage values are basic data used. Before using computer program a sample graphical analysis is essential.

3.2.1 Simple graphical analysis

The stage and discharge data is plotted on a simple graph sheet. This is done with two objectives(1) to identify obviously erronous data pairs which plot much away from the general trend of the scattered points,(2) to diagnose whether a single curve would be alright or to go in for more number of curves. If it is diagnosed that two or more curves are needed, the data are approximately grouped so that each group will form a single curve. In the data seperated for a single curve the identified obvious errors are removed. Moreover the same set of observations should be repeated in the data used for computer analysis.

3.2.2 Lease squares technique

The following form of the equation is used

$$Q = a\ (G-e)^{b} \qquad \ldots (1)$$

where

G is the gauge height in (m) with respect to a **datum**

Q is the discharge in (m^3/sec)

a,b and e are parameters defining the relationship.

An initial value of 'e' approximately equal to the zero of gauge of the site under consideration is assumed, thus reducing number of unknowns to two ('a','b') parameters.

The currently approved analytical method of fitting curves to scattered points is to minimise(R)the sum of square of departures $(DQ)_i=(Q_i-Q_c)$,where Q_i refers to the scattered data and Qc refers to the calculated value by equation 1. This equation can be written in the form

$$\log Q = \log a + b \log (G-e) \qquad \ldots (2)$$

which is equivalent to

$$\bar{Q}_i = \bar{a} + b\,\bar{G}_i \qquad \ldots (3)$$

Let there be N pairs of stage and discharge and the logarithmic values of (G-e) of each of them represented by $\bar{G}_i$ and Q_i by $\bar{Q}_i$. In order that the curve given by 1 or 3 may have minimum of $\Sigma(DQ)_i^2$, all partial derivaties of this sum with respect to the parameters $\bar{a}$,b.

$$R = \sum_{i=1}^{N} (D\,Q_i)^2 \qquad \ldots (4a)$$

$$\partial R/\partial \bar{a} = 0 \qquad \ldots 4b)$$

$$\partial R/\partial b = 0 \qquad \ldots (4c)$$

The equations 4a, b and c lead to the following

$$N\,\bar{a} + b\sum_{i=1}^{N}\bar{G}_i = \sum_{i=1}^{N}\bar{Q}_i \qquad \ldots (5a)$$

$$\bar{a}\sum_{i=1}^{N}\bar{G}_i + b\sum_{i=1}^{N}(\bar{G}_i)^2 = \sum_{i=1}^{N}\bar{Q}_i\,\bar{G}_i \qquad \ldots (5b)$$

These two equations 5a and 5b form the simultaneous equations to solve for $\bar{a}$ and b, and $\bar{a}$ can be converted to a by antilogarithms.

For different values of 'e' different sets of parameters a,b are obtained. The value of 'e' are varied by desired increments. For each of the value 'e' different sets of parameters are computed along with their respective sum of squares of departures (i.e.,function R). After a number of trials the set of parameters which produce the minimum value of R can be chosen as the parameters providing best fit.

The computer program (LSF) does these computations and tabulates all the sets of values of parameters obtained in trials along with corresponding value of function R. The program also calculates Error and Shifts as given by

$$\text{Error} = \left[\frac{\bar{Q}_c - Q_c}{Q_i}\right] \times 100$$

Shift = S_i - (Stage calculated for the Q_i from fitted relation)

These are tabulated in the order of magnitude of discharge and in the sequence of observations. If these values are random, they indicate no systematic error is present in grouping of the data. In case of any systematic error a different grouping of data is to be done and different rating curve equations are obtained for each.

3.2.3 Physical reasoning

From among the tabulated parameters and corresponding values of R the best curve may not be the one chosen by computer based on least value of R from the point of view of physically realistic values of parameters. One may have to go in for the second best or third best depending upon the parameter values being physically realistic as explained in section 5.2.

This choice is done by judgement using computer results and range of parameter values obtained by physical analysis.

4.0 COMPUTER PROGRAMME

4.1 Interpolation INTPOL

The computer program INTPOL is capable of interpolating from a given equal interval table. It picks up the interval in which the specified node lines. However, it sets the interval not to be lesser than the second and not to be greater than the last but one interval. In other words it finds the value of J which will never be less than 2 or greater than N-1 where N is the length of the table, since the interpolation method uses second difference also. If X is the specified node and S(J) and Q(J) are the table values,then the ordinate to be computed Y, will be

$$Y = Q(J) + \frac{(X-S(J))}{2H}\left[Q(J+1)-Q(j-1)\right] + (X-S(J))^2\left[\frac{Q(j+1)-2Q(j)+Q(j-1)}{2H^2}\right]$$

where H is the equal interval of the table.

4.1 Least Squares Fit (LSF)

The computer programme LSF is capable of giving a rating analysis. The program takes daily gauge and discharge values together with dates. The program needs an initial value of 'e' as specified in the input. It accepts a maximum of 30 iterations. Applying least squares technique it finds the two parameters of equation 1 for each of the initerations and stores them. The program prints the parameters and the corresponding sum of squared errors and picks up those parameters for which the error is minimum and prints them. The table of stage,discharge observed and also as calculated using the above picked parameters are printed. The 'Shifts' and the Error as explained are also calculated and printed.

5.0 INPUT SPECIFICATION

5.1 INTPOL (Program for interpolation)

This is a subroutine requiring a table of stage and discharge (rating table). Also required is the value of stage which is to be converted to discharge. The call of this subroutine provides back the values of stage, discharge and also the original rating table to the calling program.

5.2 LSF (Program for least square fit)

SNo.	Name	Description	Format
1	SNA(I)	Station name	30A1
2	IWRIT	Index '1' cause to write all the tables as per text. Other values cause to print only coefficients.	Free format
3	HD(1) DHD NIT N	initial guess of 'e' increment of trial Number of trials Number of pairs in in the stage & discharge.	Free format
4	H,Q,DATE	Stage,discharge and date respectively N sets of values.	Free format

5.3 Output Specification

5.3.1 INTPOL (Program for interpolation)

The output of this subroutine goes into the calling program. The computed discharge, the stage and the rating table are sent back to the calling program.

5.3.2 LSF (Program for least square fit)

1. The name of the site is printed as read by the program.
2. A table of trials and error.
3. A table of coefficients found in each one of the trials.
4. Best set of parameter as per Mathematical Criteria.

   If IWRIT is equal to 1 the following are also printed.
5. A table of stage, observed and computed discharge.
6. A table of stage, discharge, Error,shift in its time sequence (as given).
7. A table of stage, discharge, Error and shift in the order of magnitude of discharge.

6.0 EXAMPLE CALCULATION

6.1 INTPOL

SITE : GADARWARA

RIVER : SHAKKAR

STAGE (m)	Q (m^3/s)	Q	^2Q
1	2	3	4
323.0	10		
		40	
323.5	50		30
		70	
324.0	120		35
		105	
324.5	225		35
		140	
325.0	365		40
		180	
325.5	545		45
		225	
326.0	770		55
		280	
326.5	1050		55
		335	
327.0	1385		60
		395	
327.5	1780		85
		480	
328.0	2260		

DIFFERENCE TABLE

RATING TABLE

SITE : GADARWARA

RIVER : SHAKKAR

YEAR : 1979

S.No.	Stage	Discharge(Cumecs)
1.	323.0	10
2.	323.5	50
3.	324.0	120
4.	324.5	225
5.	325.0	365
6.	325.5	545
7.	326.0	770
8.	326.5	1050
9.	327.0	1385
10.	327.5	1780
11.	328.0	2260

6.2 Example calculation (for Program LSF)

Physical Analysis and Related Calculations

The rating analysis should be verified by physical analysis. Each item of equation(1) can be explained as follows:

Manning's equation as a basis:

The physical analysis is based on Manning equation.

$$Q = \frac{1}{n} AR^{2/3} S^{1/2} \qquad \ldots (2)$$

where,

Q is discharge in cumecs

n is Manning's coefficient

A is wetted cross sectional area in sq.m.

R is hydraulic radius.

S is engery slope.

A rating that follows manning's equation will plot as a straight line on a logarithmic paper since the equation(2) is of the form

$$Q = aH^{b}$$

Taking logarithms on both the sides

$$\text{Log } Q = \text{Log } a + b \text{ Log } H$$

where,

$H = G-e$

G is the gauge height

e is the effective zero flow

If R is approximately taken equal to H the equation 3 turns out to be

$$\text{Log } Q = \text{Log } \frac{1}{n} AR^{2/3}S^{1/2}$$

$$= \text{Log} \frac{1}{n} AH^{2/3}S^{1/2}$$

$$= \text{Log } \frac{1}{n} WHH^{2/3} S^{1/2}$$

$$\doteq \text{Log } \frac{1}{n} WS^{1/2} + \text{Log } H^{5/3}$$

$$= \text{Log } a + b \text{ Log } H$$

The parameter 'a'

The parameter a is approximated by

$$a = \frac{1}{n} WS^{1/2}$$

The Manning's 'n'

This is estimated from photographs/site visits, or by experience. Generally n will vary with depth for unsteady flow. But for rating analysis a single value is adopted. A wide range of values are expected. The value varies from 0.017 for alluvial stream with no vegetation to 0.05 for mountain stream with rocky beds with vegetation on the bank.

The width 'W'

The width varies with stage. However, this is determined at approximately mean annual flood. This is surface width.

The slope 'S'

This is computed from topographic map. The bottom slope is often irregular. The slope used here is effective slope sustaining the flow. One easy measure could be water surface slope at low flow or peak flow.

The parameter 'b'

This is often approximated to 5/3 or slightly more. Actually this parameter depends on the side slope of the channel. The hydraulic radius 'R' seldom equals the depth 'H'. For trapezoidal channel the increase in area as a result of increase in width as stage rises, causes the discharge 'Q' to increase rapidly than for a rectangular section. In this case 'b' varies from 1.67 to 1.9. For parabolic channels 'b' is approximated to 2. For a triangular channel 'b' equals 2.5. Most of the natural channel sections vary between trapezoidal to parabolic in shape.

The parameter 'e'

This is a level by which the elevations(water level) are to be reduced. This represents an effective zero flow. Approximately this is equal to zero of gauge of the site. Estimation can be made by

$$e = G - A/(W + 2A/W)$$

for a mean annual flow.

Log Plots:

As the next analysis, plotting of daily stage discharge pairs are taken up.

A smooth curve is drawn by visual estimation on rectangular coordinate system after plotting Q and H. Three values of discharges Q_1, Q_2 and Q_3 are selected from the smooth curve drawn, such that $Q_2^2 = Q_1 Q_3$. If the corresponding values of the stages are H_1, H_2 and H_3 the equation (1) will yield

$$e = \frac{H_1 H_3 - H_2^2}{H_1 + H_3 - 2H_2}$$

Now plotting on Log-Log scale is taken up. The gauge height is shifted by a depth 'e'. Now the shifts in 'e' on Log Log scale are in easy control. Choose a series of measurements from a peak as high as possible downward on a recession. Plot measurements sequentially as long as they form a smooth curve. Stop when a group of measurements begins to depart consistently from the curve. Draw in the trend line with a curve. By trial and error determine the change in shift required to obtain a straight line rating (Δ e). Lower discharge measurements may not fit the curve if a section control exists for lower stages, similarly higher discharge may not fit if over bank flow exists or if a back water condition is caused by a downstream constriction. A single rating can be adopted over that range of flow where similar section control do exist. The coefficients of the equation are determined as follows:

1. The gauge height required to straighten the curve determines 'e'

2. The discharge for the gauge height (G-e=1) is equal to 'a'.

3. $b = \dfrac{\text{Log } Q_1 - \text{Log } Q_2}{\text{Log}(G_1 - e) - \text{Log}(G_2 - e)}$

where Q_1 is greater Q_2

6.3 Application of physical analysis

Site: Mandeleshwar of the river Narmada

Width(W) = 600 M - 650 M (Figure 1 & 2)

Slope(S) = 0.00046

$S^{1/2}$ = 0.0215

$S^{1/2}$ = approximately

$a = \dfrac{WS^{1/2}}{n} = 400$

a is in the range of 400 to 450

Effective zero flow - 138.7 to 139.0

b - 1.7 to 1.8

Rating analysis:

A plot in rectangular coordinates is enclosed. The point marked ⊙ are removed from the analysis and rest of the daily gauge & discharge were fed to LSF.FOR The results are enclosed.

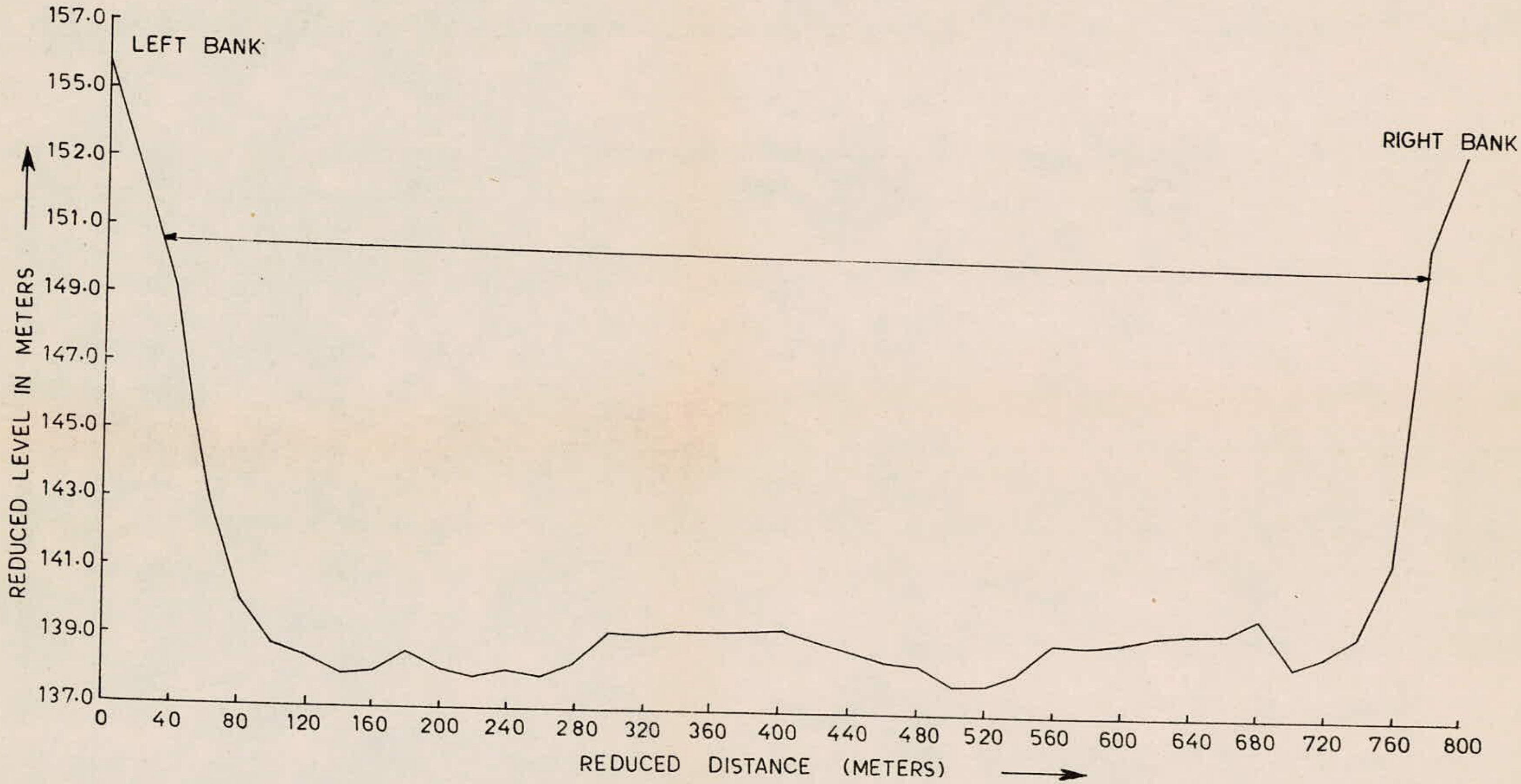


FIGURE 1- CROSS SECTION OF THE RIVER NARMADA AT MANDALESHWAR

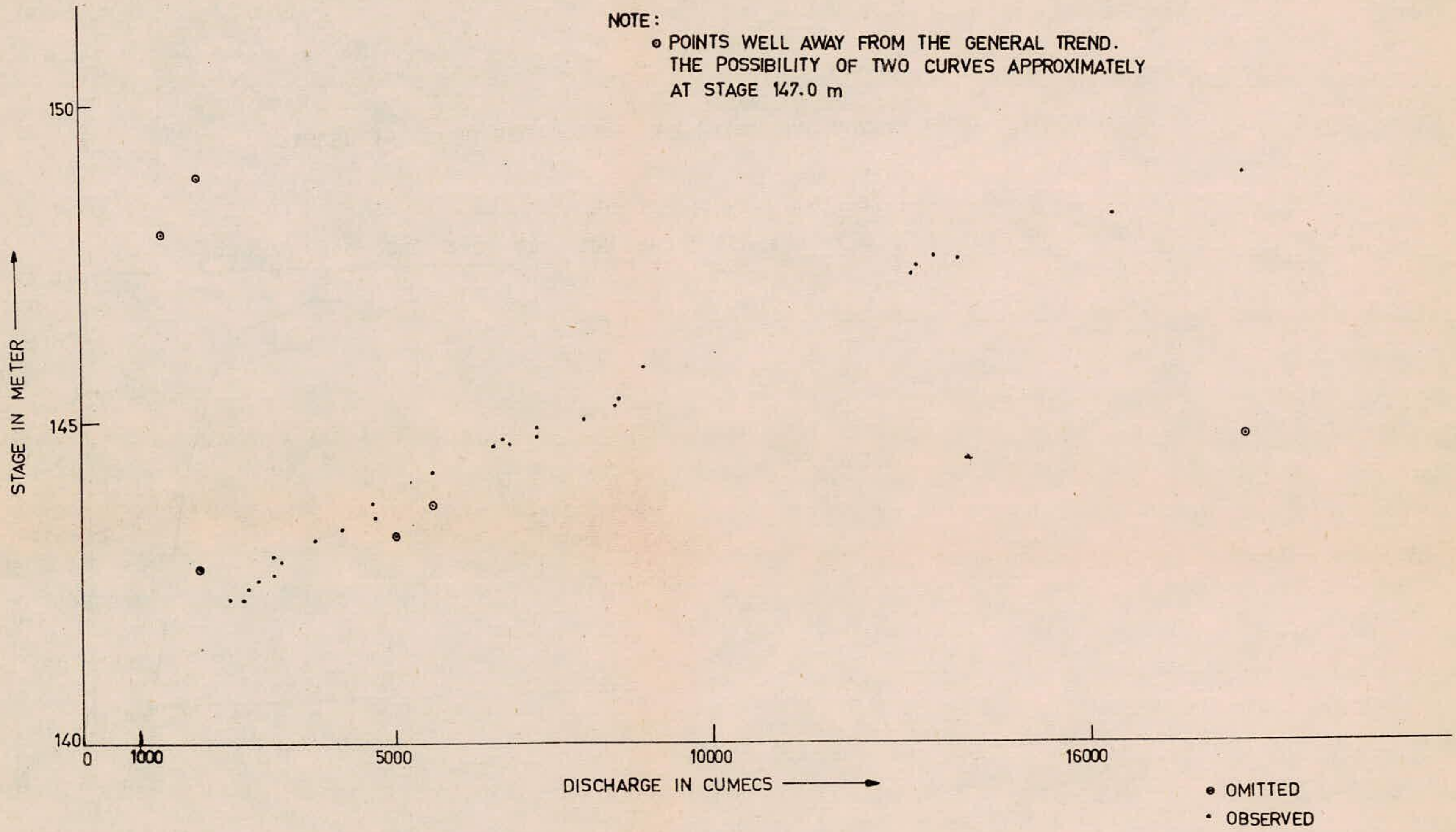


FIGURE 2 - STAGE-DISCHARGE PLOT

ESTIMATION OF PARAMETERS FROM LOG LOG PLOT

$$b = \frac{\log Q_1 - \log Q_2}{\log (G_1 - e) - \log (G_2 - e)}$$

(From Figure 3)

$G_1 = 148.0$ $\qquad$ $G_1 = 16{,}000$

$G_2 = 141.2$ $\qquad$ $G_2 = 1300$

$$b = \frac{\log 16000 - \log 1900}{\log(148 - 138.8) - \log(141.2 - 138.8)}$$

$$b = \frac{4.20412 - 3.11394}{.963787 - 0.3}$$

$= 1.868$

$a = 400$

$e = 139$

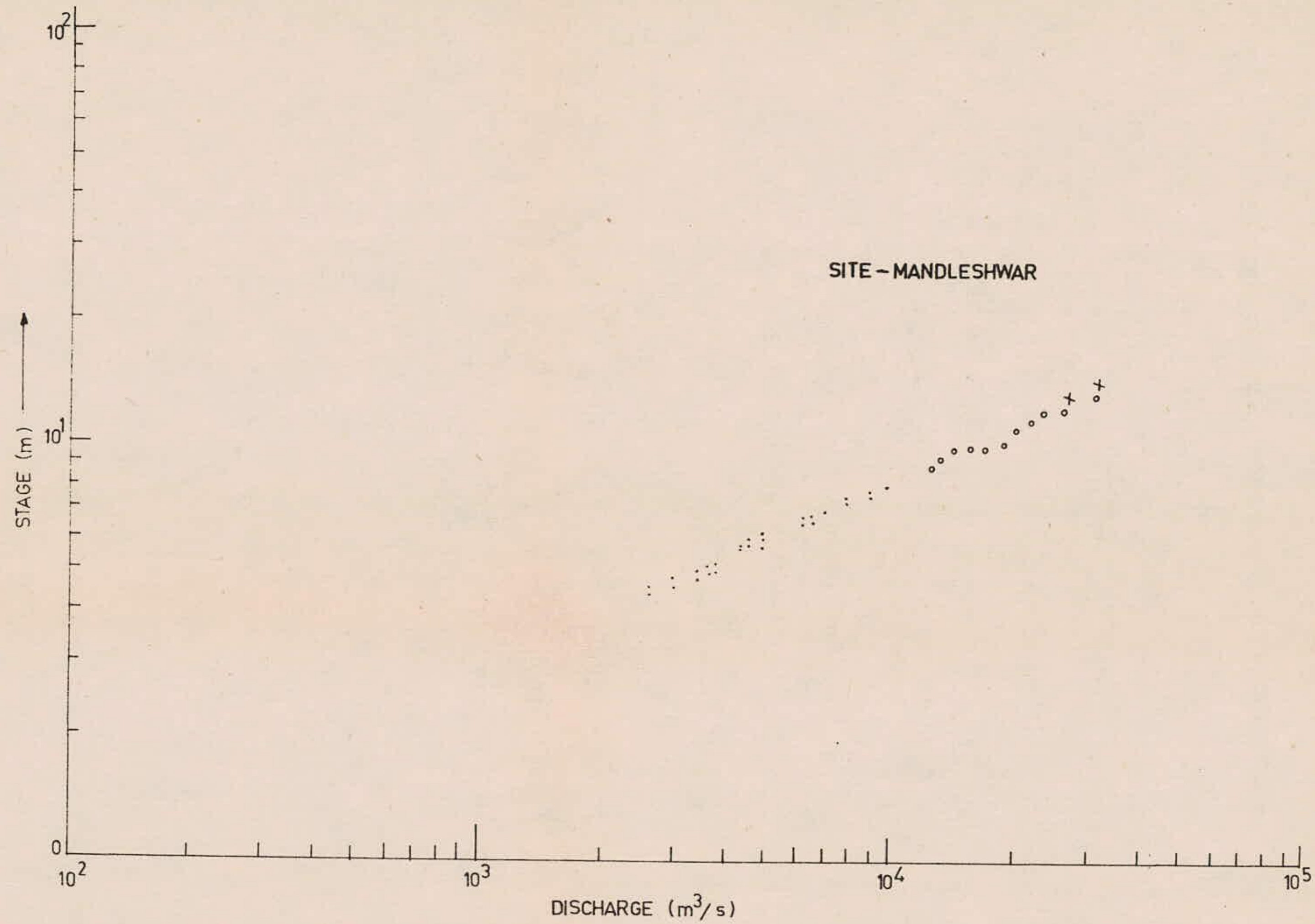


FIGURE 3- DOUBLE LOG PLOT OF STAGE AND DISCHARGE

7.0 APPLICATION OF THE PROGRAMME

7.1 Sample Input (LSF)

```
NANDALESHWAR
0
138.5  0.1  10  18
142.29  2310.   29.0675
142.24  2480.   11.0775
142.16  2592.   17.0775
143.41  4922.   19.0775
142.52  2846.   20.0775
142.28  2520.   22.0775
143.59  4711.   31.0775
142.34  2600.    1.0875
142.08  2274.    7.0875
143.37  4150.   10.0875
147.51 13559.   13.0875
148.23 16400.   14.0875
147.32 13120.   16.0875
145.83  8990.   17.0875
143.73  5558.   18.0875
144.94  7146.   23.0875
147.56 15943.   25.0875
147.43 13232.   26.0875
```

7.2 Sample Output

Name of the site : M A N D A L E S H W A R

Table of Datum VS Sum of Squares of Errors and coeff. of corr.

DATUM	SUM OF SQUARES OF ERRORS	COEFFIENT OF CORRELATION	RMS
138.500	0.012	0.997	0.026
138.600	0.012	0.997	0.025
138.700	0.011	0.997	0.025
138.800	0.011	0.997	0.025
138.900	0.011	0.997	0.025
139.000	0.011	0.997	0.024
139.100	0.011	0.997	0.024
139.200	0.010	0.997	0.024
139.300	0.010	0.997	0.024
139.400	0.010	0.997	0.024

A	HD	B
197.622	138.500	1.934
217.382	138.600	1.900
239.033	138.700	1.866
262.746	138.800	1.831
288.710	138.900	1.797
317.125	139.000	1.763
348.213	139.100	1.728
382.212	139.200	1.693
419.382	139.300	1.658
460.004	139.400	1.623

The datum is : 139.100

THE VARIANCE IS 0.096

The rating equation is : Q =348.213 * (H - 139.100) ** 1.728

The coefficient of correlation is : 0.99695

8.0 RECOMMENDATIONS

A combined analysis of the river cross-section and flow data provides useful physical basis for development of rating curves. Two programmes for specific cases of development/use of rating curves have been described above. The Hermitian interpolation is found to be the best suited for interpolation using available rating curves. The LSF progoramme along with physical analysis provides a useful method for the establishment of rating curves.

REFERENCES

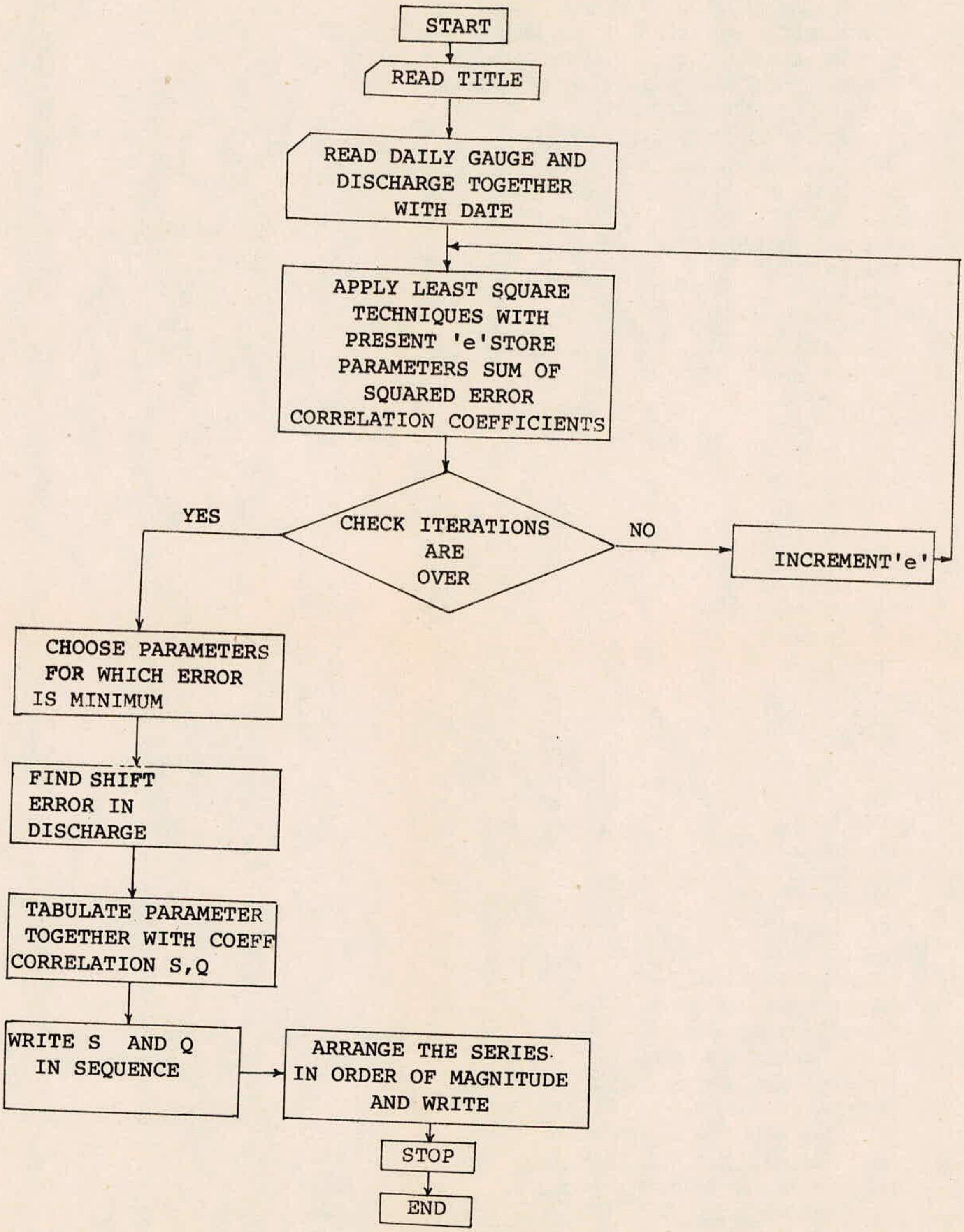
1. Dawdy, D.R.(1983)," Consultant Report No.2", National Institute of Hydrology,Roorkee.

2. Granino A.Korn and Theresa M. Korn,(1968)," Mathematical Hand Book for Scientist and Engineers", McGraw Hill Book Company.

3. Henderson, F.M.,(1966)," Open Channel Flow", Mac Millian Company, New York.

APPENDIX I

THE PROGRAMME LSF AND INTPOL



THE PROGRAMME (LSF)

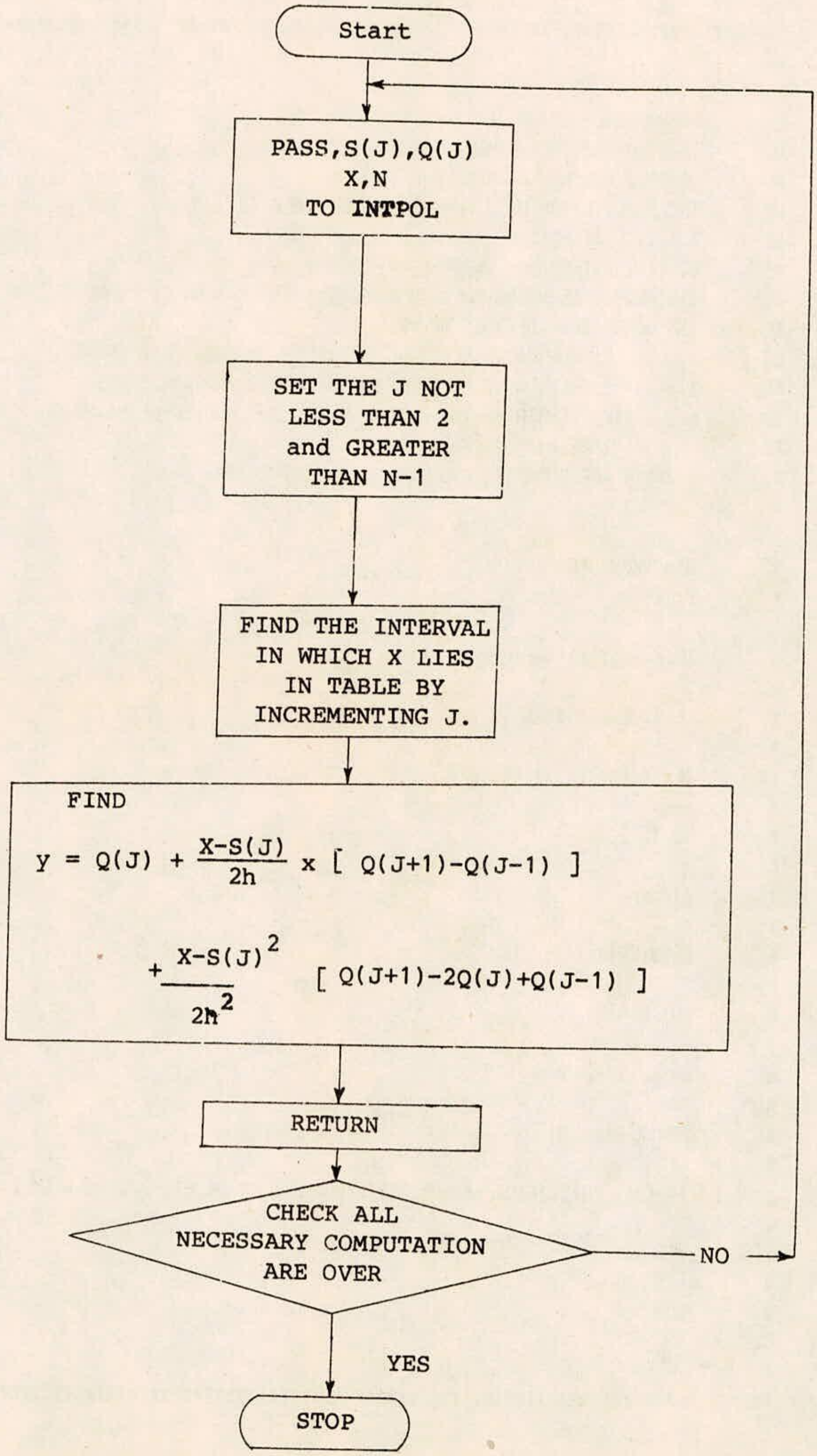
```
C     PROGRAM FOR CURVE FITTING
C     TYPE OF CURVE FITTED: Q = A * (H- HO) **B
      DIMENSION Q(500),H(500),X(500),Y(500),DX(500),DY(500),ERR(30)
     1,Q1(500),QCA(30,500),A(30),B(30),SNA(30),HO(31),R(30)
      DIMENSION SHIFT(500),RSIDL(500),ER0(300),ER1(30,300)
      DIMENSION  RMS(30),DATE(500)
      OPEN(UNIT=5,FILE='CUU.DAT',STATUS='OLD')
      OPEN(UNIT=9,FILE='CUU.OUT',STATUS='NEW')
      DO 1 I=1,30
 1    SNA(I)=' '
      READ(5,5)(SNA(I),I=2,30)
      READ(5,*) IWRITE
      IK=0
 5    FORMAT(30A1)
      READ(5,*)HO(1),DHO,NIT,N
      READ(5,*)(H(I),Q(I),DATE(I),I=1,N)
      SUMY=0
      SUMYSQ=0
      DO 10 I=1,N
      Y(I)=ALOG10(Q(I))
 10   SUMY=SUMY+Y(I)
      YBAR=SUMY/N
      DO 8 I=1,N
      DY(I)=Y(I)-YBAR
 8    SUMYSQ=SUMYSQ+DY(I)**2
      VAR=SUMYSQ/N
      DO 100 J=1,NIT
      SUMX=0
      SUMXY=0
      SUMXSQ=0
      ERR(J)=0.0
      ER0(J)=0.0
      DO 15 I=1,N
      X(I)=ALOG10(H(I)-HO(J))
 15   SUMX=SUMX+X(I)
      XBAR=SUMX/N
      DO 11 I=1,N
      DX(I)=X(I)-XBAR
      SUMXSQ=SUMXSQ+DX(I)**2
 11   SUMXY-SUMXY+DX(I)*DY(I)
      B(J)=SUMXY/SUMXSQ
      A(J)=10.0**(YBAR-B(J)*XBAR)
      R(J)=SUMXY/(SQRT(SUMXSQ*SUMYSQ))
      DO 85 I=1,N
      QCA(J,I)=A(J)*(H(I)-HO(J))**B(J)
      ERR(J)=ERR(J)+(ALOG10(QCA(J,I))-Y(I))**2
      ER1(J,I)=(QCA(J,I)-Q(I))**2
      ER0(J)-ER0(J)+ER1(J,I)
 85   CONTINUE
      RMS(J)=(ERR(J)/N)**0.5
```

```
100 HD(J+1)=HD(J)+DHD
    ISA=1
    AMIN=ERO(1)
    IF(NIT.EQ.1)GO TO 130
    DO 120 I=2,NIT
    IF(ERO(I).GT.AMIN) GO TO 120
    AMIN=ERO(I)
    ISA=I
120 CONTINUE
    DO 145 I=1,N
    HCA=(Q(I)/A(ISA))**(1./B(ISA)) +HD(ISA)
    SHIFT(I)=H(I)-HCA
    RSIDL(I)=((Q(I)-QCA(ISA,I))*100.)/QCA(ISA,I)
145    CONTINUE
130 WRITE(9,90)(SNA(I),I=1,28)
90  FORMAT(///,20X,'Name of the site : '30A1)
    WRITE(9,95)(HD(I),ERR(I),R(I),RMS(I),I=1,NIT)
    WRITE(9,96)
    WRITE(9,98)(A(I),HD(I),B(I),I=1,NIT)
98  FORMAT(23X,'A',18X,'HD',17X,'B'/30(20X,F9.3,10X,F9.3,10X,F9.3/))
95  FORMAT(///20X,'Table of Datum VS Sum of Squares of Errors and
    1coeff. of corr.'//20X,67('_')/20X'!  ','DATUM'10X'SUM OF
    2 SQUARES'10X'COEFFIENT OF'6X,'RMS   !'/,20X,'!'19X,'OF ERRORS'
    313X'CORRELATION'13X,'!'/20X,67('-')/
    3(20X,'!'F8.3,7X,F15.3,10X,F9.3),8X,F6.3,2X,'!')
96  FORMAT(20X,67('-')///)
    WRITE(9,101)HD(ISA),VAR,A(ISA),HD(ISA),B(ISA),R(ISA)
    IF(IWRITE.NE.1)STOP
    WRITE(9,102)(I,H(I),Q(I),QCA(ISA,I),I=1,N)
101 FORMAT(20X,'The datum is : 'F9.3,/20X,'THE VARIANCE IS',
    1F9.3,/20X,'The rating equation is : Q ='
    1 F7.3,' * ( H - 'F8.3,') **'F7.3,//20X,'The
    2coefficient of correlation is : 'F8.5/)
102 FORMAT(1X,129('-')/3(' ! S.N.  STAGE   OBS. DISCH.  CALC. DI
    1SCH.')'!'/1X,129('-')/,3(' !'41X),'!'/(3(1X,'!'I5,2X,F7.3,2X,
    2F10.3,F13.3,2X)'!'))
    WRITE(9,121)
121 FORMAT(1X,129('-'))
    WRITE (9,122)
122 FORMAT(2(10X,'NBR  DATE    STAGE    DISCH    %ERR   SHIFT',20X))
    MD=N/2
    DO 158 I=1,MD
    MI=I+MD
158 WRITE(9,123) I,DATE(I),H(I),Q(I),RSIDL(I),SHIFT(I),
    1           MI,DATE(MI),H(MI),Q(MI),RSIDL(MI),SHIFT(MI)
    IF(2*MD.NE.N)WRITE(9,126)N,DATE(N),H(N),Q(N),RSIDL(N),SHIFT(N)
    IS=1
123 FORMAT(2(7X,I5,1X,F7.4,1X,F7.2,2X,F7.0,3X,F7.2,1X,F7.2,20X))
126 FORMAT(7X,I5,1X,F7.4,1X,F7.2,2X,F7.0,3X,F7.2,1X,F7.2)
    WRITE(9,125)
```

```
125 FORMAT(///'                    THE TABLE  IN THE ORDER OF MAGNITUDE'/)
    CUME=0.0
154 CHCK=0.0
    DO 155 I=1,N
    IF (QCA(ISA,I).LT.CHCK)GO TO 155
    CHCK=QCA(ISA,I)
    IMX=I
155 CONTINUE
    CUME=ER1(ISA,IMX)/1000000.+CUME
    WRITE(9,128) IS,DATE(IMX),H(IMX),QCA(ISA,IMX),RSIDL(IMX),SHIFT(IMX)
    1,CUME
128 FORMAT(7X,I5,1X,F7.4,1X,F7.2,2X,F6.0,3X,F6.0,1X,F8.2,1X,F8.2)
    QCA(ISA,IMX)=0.0
    IS=IS+1
    IF(IS.LE.N)GOTO 154
    WRITE(9,195)
195 FORMAT(10X,31('*')/10X,'*ERR'10X,'ERO'13X,'*')
    WRITE(9,156)(ERR(I),ERO(I),I=1,NIT)
156 FORMAT(10X,'*',F8.4,1X,F15.0,8X,'*')
    WRITE(9,157)
157 FORMAT(10X,31('*'))
    STOP
    END
```

PROGRAM INTPOL

FLOW CHART



```
               ****************
               *   INTPOL.    *
               ****************
*******************************************************************************
*                                                                             *
*                                                                             *
*       SUBROUTINE  INTPOL ( S , Q , X , Y , N )                              *
*C      THIS SUBROUTINE IS MENT FOR USE WITH RATING TABLE                     *
*C      TO CALCLATE DISCHARGES FROM STAGS.                                    *
*C      THE COMPUTATION USES HERMITTON INTERPOLATION.                         *
*C      S...... RATINGTABLE VARIABLE STAGE.                                   *
*C      Q...... RAINGTABLE VARIABLE DISCHARGE.                                *
*C      S,Q SHOULD BE DMENSIONED TO A VALUE GREATER THAN OR EQUAL TO          *
*C      THE VALUE OF N DEFINED BELOW.                                         *
*C      X...... SINGLE VALUE OF STAGE FOR WHICH DISCHARGE IS NEEDED.          *
*C      Y...... SINGLE VALUE OF DISCHARGE COMPUTED FOR THE STAGE.             *
*C      N......THE LENGTH OF THE RATING TABLE (THE NUMBER OF PAIRS OF         *
*C             STAGE AND DISCHARGE                                            *
*C      S,Q,X,N ARE SUPPLIED FROM THE CALLING PROGRAM.                        *
*                                                                             *
*                                                                             *
*       DIMENSON S(N) , Q(N)                                                  *
*       Y=Q(1)                                                                *
*                                                                             *
*       IF(X.EQ.S(1)) RETURN                                                  *
*                                                                             *
*       IF(X.LE.S(2)) GO TO 2                                                 *
*                                                                             *
*4      IF(S(J+1).LT.X) GO TO 3                                               *
*                                                                             *
*       GO TO 2                                                               *
*                                                                             *
*3      J=J+1                                                                 *
*                                                                             *
*       IF(J.EQ.N-1) GO TO 2                                                  *
*                                                                             *
*       GO TO 4                                                               *
*                                                                             *
*2      H=S(J+1)-S(J)                                                         *
*                                                                             *
*       PQ=(X-S(J))/H                                                         *
*                                                                             *
*       Y=Q(J)+(PQ/2.)*(Q(J+1)-Q(J-1))+(PQ*PQ/2.)*(Q(J+1)-2.*Q(J)+Q(J-1))*
*                                                                             *
*       RETURN                                                                *
*                                                                             *
*       END                                                                   *
*                                                                             *
*                                                                             *
*******************************************************************************
```