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Electronic Computer Program Abstract

sla
SIMONS, li & ASSOCIATES, INC.

80.0-00-1-09179

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM: COLBY PROGRAM NO.:

PREPARING AGENCY: Simons and Li Engineering

AUTHORS: R. M. Li, R. K. Simons, D. B. Simons

DATE PROGRAM COMPLETED: September, 1979

STATUS OF PROGRAM: Phase - original, Stage - operational

A. PURPOSE OF PROGRAM: To compute the total sediment transport rate in sand bed streams by Colby's method. References: (a) Colby, B. R., "Discharge of Sands and Mean Velocity Relationships in Sand Bed Streams," Professional Paper 462-A, 1964, U.S. Geological Survey; (b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

B. PROGRAM SPECIFICATIONS:

Language: ANSI Fortran (Fortran IV)

Solution Requirements: Input data

Method of Analysis: Logarithmic interpolation of Colby's graphs using a table look up scheme.

Size of Object Program: 21,411 characters

External Storage: None

Range of Quantities:

Velocity: 1 - 10 ft/sec

Hydraulic depth: 0.1 - 100 ft

Water surface width

Water temperature: 32 - 100 ^{o}F

Median bed material size: 0.1 - 0.8 mm

Fine material concentration: 0 - 150,000 ppm

Dimension System: English, except sediment sizes are input in mm.

C. METHODS: The program is written in ANSI Fortran IV. It operates in both batch and time-share processing modes.

D. EQUIPMENT DETAILS: The program was developed on the Cyber 172 computer at Colorado State University, but can operate on any compatible system. No special computer equipment is required.

E. INPUT-OUTPUT: Input data requirements are: Number of data sets to be analyzed, average velocity (ft/sec), hydraulic depth (ft), water surface width (ft), water temperature (^{o}F), median bed material size (mm), and the fine material concentration (ppm). Output includes the given data and the total sediment transport rate (tons/day).

F. ADDITIONAL REMARKS: The method is particularly applicable to the sand-bed river.

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NO.:

2. TITLE: COLBY

3. REVISION LOG: N/A

4. PURPOSE OF PROGRAM: To compute sand discharge in streams by Colby's method. References:

   a) Colby, B. R., "Discharge of Sands and Mean Velocity Relationships in Sand Bed Streams," U.S. Geological Survey Professional Paper 462-A, 1964.

   b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

5. SOLUTION:

   a) The input variables that must be supplied are:

      1 - Number of sets of data to be analyzed (NDATA)

      2 - Mean velocity (V), ft/sec

      3 - Hydraulic depth (D), ft

      4 - Width (W), ft

      5 - Water temperature (TF), ^{o}F

      6 - Median bed material size (D50), mm

      7 - Fine material load (FML), ppm

      The analysis of sand discharge by Colby's method is restricted to certain ranges of input values. These restrictions are: (1) velocity 1 - 10 ft/sec, (2) hydraulic depth 0.1 - 100 ft, (3) water temperature 32 - 100 ^{o}F, (4) median bed material size 0.1 - 0.8 mm, and (5) fine material load 0 - 150,000 ppm. Whenever the input values fall outside of these limits, a message is printed out and the analysis for that set of data stops.

b) Computation of sand discharge by Colby's method is based on logarithmic interpolation of Figures 24 and 26 in Reference a. Figure 26 is the relationship between mean velocity and sand discharge for four depths of flow (0.1, 1.0, 10, 100 ft). A three-dimensional matrix of sediment transport at 9 velocities (ft/sec) and 6 sediment sizes for the four depths (0.1, 1.0, 10, 100 ft) is provided in data statements in the program. First the program finds which digitized values of sand discharge surround the desired value based on the given hydraulic conditions. The desired value is interpolated from the matrix of sand discharge. The interpolation is performed with respect to sediment size first, then velocity, and finally depth. Subroutine SEDTRN performs these interpolations. This subroutine returns to the main program an uncorrected sand discharge in tons per day corresponding to the given depth, velocity and sediment size. Three corrections are then applied to the uncorrected value based on water temperature, fine material load and median bed material size. Subroutine TMPCOR logarithmically interpolates a depth vs. temperature matrix of correction values for the given input values of depth and temperature. This matrix of correction values comes from Figure 24 in Reference a. The subroutine returns the temperature correction value (CFT) to the main program. Subroutine FMLCOR logarithmically interpolates a depth vs. fine material load correction factor matrix for the given depth and fine material load. Again Figure 24 (Colby) provides the values for the fine material load correction (CFFML) which is returned to the main program. A final correction factor for the median bed material size is found by logarithmic

interpolation of another portion of Figure 24 (Colby). Subroutine MDCOR computes this correction factor (CFMD).

After all correction subroutines and the sediment transport subroutines have been called, the sediment transport rate (GT) is computed.

$$GT = GTUC\ (1 + (CFT \times CFFML - 1) \times CFMD) \times W$$

where GTUC is the uncorrected unit width sand discharge in tons/day/ft and CFT, CFFML and CFMD are the previously defined correction factors.

c) Logarithmic interpolation is done by a linear interpolation of logarithms. For example, let V_1 and V_2 represent values of velocity on either side of the input velocity V and G_1 and G_2 represent the respective values of sand discharge at velocities V_1 and V_2. Assume all values are for a given depth and bed material size for the interpolation matrix. Let:

$$x = \log_{10}(V)$$

$$x_1 = \log_{10}(V_1)$$

$$x_2 = \log_{10}(V_2)$$

$$y_1 = \log_{10}(G_1)$$

$$y_2 = \log_{10}(G_2)$$

$$z = y_1 + (x - x_1) \times (y_2 - y_1)/(x_2 - x_1)$$

The desired value for the sand discharge at velocity V is then

$$G = 10^z$$

6. ACCURACY: N/A

PART II: COMPUTER FUNCTIONAL DESCRIPTION

1. REVISIONAL LOG: N/A

2. FUNCTIONAL FLOW CHART: (See Figure 1)

3. EQUIPMENT AND OPERATING SYSTEM: The program was developed on a CDC Cyber 172 batch system. Normal configuration of CPU, reader and printer are necessary.

4. INPUT REQUIREMENTS: The program is written for both the batch and time-share modes. The source listing in Fig. 2 is for batch mode. Figure 3 is the interactive mode listing.

5. SECONDARY STORAGE INPUT FORMAT: None

6. INPUT DATA DESCRIPTION: The following variable names are used for input variables.

NAME	DESCRIPTION	FORMAT	
NDATA	Number of data sets to be analyzed	I5	Card 1
V	Mean velocity	F10.2	
D	Hydraulic depth	F10.2	
W	Stream width	F10.2	Card 2, 3, ..., NDATA
TF	Water temperature	F10.2	
D50	Median bed material size	F10.2	
FML	Fine material load	F10.2	

7. SUMMARY OF REQUIRED CARDS: (See 6)

8. OUTPUTS: Printed output from the program includes the input data, a comment of OK or input data out of range, and the sand discharge in tons per day.

9. OPERATOR INSTRUCTION: None

10. PROGRAM ERROR MESSAGES: None - Program stops would result from improper input data.

11. VARIABLE DEFINITIONS:

CF - Fine material load concentration at which correction factors are given

CFFML - Fine material load correction factor

CFMD - Median diameter of bed load correction factor

CFO - Overall correction factor

CFT - Temperature correction factor

D - Hydraulic depth

DF - Depth array at which sediment size correction is known (10 values)

DG - Depths at which sand discharges and temperature corrections are given

DP - Sediment sizes at which bed material size corrections are given (11 values)

D50 - Median sediment diameter

D50G - Sediment sizes at which sand discharge is known (6 values)

F - Fine material load correction factors at 10 depths and 5 concentrations

FML - Fine material load

G - Uncorrected sand discharge at 4 depths, 9 velocities, and 6 sediment sizes

GT - Sand discharge

GTUC - Uncorrected sand discharge

ID,ID1, ID2 Integers indicating which members of the depth array bound the input depth

ID50,ID501, ID502 Integers indicating which members of the median sediment size array bound the input median sediment size

IF1,IF2 - Integers indicating which members of the fine material load array bound the input fine material load

IP1,IP2 - Integers indicating which members of the sediment size array bound the input sediment diameter

IT1,IT2 - Integers indicating which members of the temperature array bound the input temperature

IV,IV1, IV2 Integers indicating which members of the velocity array bound the input velocity

NDATA - Number of data points

P - Correction factor array for sediment size at 11 sizes

REMARK - A remark on input data being OK or out of range

T - Temperature correction factor array at 7 temperatures and 4 depths

TEMP - Temperature array (7 values)

TF - Water temperature

V - Mean velocity

VG - Velocity array (9 values)

W - Stream width

12. EXAMPLE CASE:

a) Batch mode

```
COMPUTATION OF TOTAL BED MATERIAL
 TRANSPORT BY COLBYS METHOD

SET     1
AVERAGE VELOCITY                          6.63 FT./SEC.
HYDRAULIC DEPTH                           2.50 FT.
WATER SURFACE WIDTH                     170.00 FT.
TEMPERATURE                              70.00 DEG.FAHREN.
MEDIAN BED MATERIAL SIZE                  .495 MM.
FINE MATERIAL CONCENTRATION           10000.00 PPM.

BED MATERIAL TRANSPORT =    20619.8 TONS/DAY
REMARK = OK
TEMPERATURE CORRECTION FACTOR                                  .912
FINE MATERIAL LOAD CORRECTION FACTOR                          1.226
MEDIAN BED MATERIAL SIZE CORRECTION FACTOR                     .609
OVERALL CORRECTION FACTOR                                     1.072


.052 CP SECONDS EXECUTION TIME
```

b) Interactive mode

```
          COMPUTATION OF TOTAL BED MATERIAL
           TRANSPORT BY COLBYS METHOD



 START INPUT DATA IN FREE FORMAT

 ENTER THE NUMBER OF SETS OF INPUT DATA
? 1



 ENTER THE FOLLOWING INPUT DATA:

   AVERAGE VELOCITY IN FEET PER SECOND
? 6.63
   HYDRAULIC DEPTH IN FEET
? 2.5
   WATER SURFACE WIDTH IN FEET
? 170
   WATER TEMPERATURE IN DEG. FAHREN.
? 70.
   FINE MATERIAL CONCENTRATION IN  PPM. BY WEIGHT
? 10000.
   MEDIAN BED MATERIAL SIZE IN MM
? .495

     SET     1
     AVERAGE VELOCITY                    6.63 FT./SEC.
     HYDRAULIC DEPTH                     2.50 FT.
     WATER SURFACE WIDTH               170.00 FT.
     TEMPERATURE                        70.00 DEG.FAHREN.
     MEDIAN BED MATERIAL SIZE            .495 MM.
     FINE MATERIAL CONCENTRATION    10000.00 PPM.

     BED MATERIAL TRANSPORT =   20619.8 TONS/DAY
     REMARK = OK
     TEMPERATURE CORRECTION FACTOR                          .912
     FINE MATERIAL LOAD CORRECTION FACTOR                  1.226
     MEDIAN BED MATERIAL SIZE CORRECTION FACTOR             .609
     OVERALL CORRECTION FACTOR                             1.072


      .081 CP SECONDS EXECUTION TIME
```

13. JOB PROCESSING TIME:

To compile: 4.7 cpu sec

To execute: 0.05 cpu sec (batch)

0.081 cpu sec (interactive)

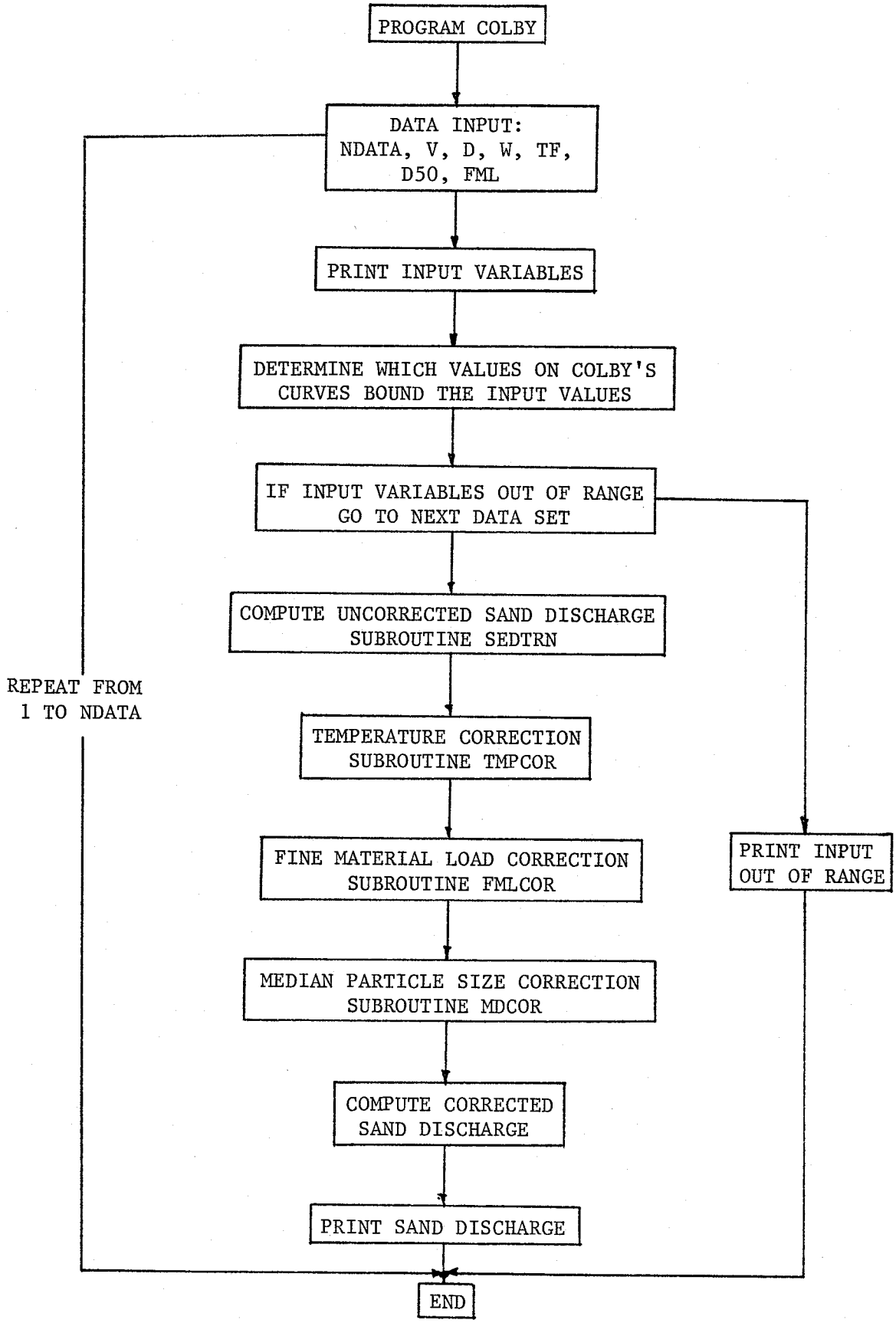

Figure 1. Flow chart of Program COLBY.

```
      PROGRAM COLBY                                                     COL 0010
     1(INPUT,OUTPUT)                                                    COL 0020
C                                                                       COL 0030
C                                                                       COL 0040
C     DEVELOPED            COLORADO STATE UNIVERSITY ENGINEERING RESEARCH  COL 0050
C                          CENTER, FORT COLLINS,COLORADO 80523          COL 0060
C     PURPOSE              COMPUTATION OF BED MATERIAL LOAD BY COLBYS   COL 0070
C                          METHOD                                       COL 0080
C     REFERENCE            COLBY,B.R., DISCHARGE OF SANDS AND MEAN VELOCITYCOL 0090
C                          RELATIONSHIPS IN SAND-BED STREAMS, PROFESSIONAL COL 0100
C                          PAPER 462-A, 1964, U.S. GEOLOGICAL SURVEY.   COL 0110
C     CORE USAGE           CDC 6400 SCOPE 3.3 SYSTEM DEFAULT VALUE,     COL 0120
C                          43000 OCTAL.                                 COL 0130
C     COMPILATION TIME     APPROXIMATELY 5 SEC.                         COL 0140
C     CENTRAL PROCESSOR                                                 COL 0150
C     TIME FOR ONE                                                      COL 0160
C     SET OF DATA          LESS THAN 0.05 SEC.                          COL 0170
C                                                                       COL 0180
C     INPUT AND OUTPUT DESCRIPTION                                      COL 0190
C                                                                       COL 0200
C     THE FIRST CARD IN THE INPUT LOGICAL RECORD SHOULD CONTAIN THE     COL 0210
C     VALUE OF NDATA, IN FORMAT I5. NDATA IS THE NUMBER OF SETS OF INPUTCOL 0220
C     DATA TO BE FED TO THE COMPUTER AT A TIME. A SET OF INPUT DATA     COL 0230
C     CONSISTS OF A GROUP OF VARIABLES NECESSARY TO SPECIFY A PROBLEM,  COL 0240
C     AS DETAILED BELOW.                                                COL 0250
C                                                                       COL 0260
C     THE FIRST CARD IN INPUT IS FOLLOWED BY THE SETS OF INPUT DATA,    COL 0270
C     TO BE PUNCHED IN FORMAT 6F10.2                                    COL 0280
C     A SET OF INPUT DATA CONSISTS OF THE FOLLOWING VARIABLES.          COL 0290
C     1) AVERAGE VELOCITY                V              F.P.S.          COL 0300
C     2) HYDRAULIC DEPTH                 D              FT.             COL 0310
C     3) WATER SURFACE WIDTH             W              FT.             COL 0320
C     4) TEMPERATURE                     TF             DEG.FAHREN.     COL 0330
C     5) MEDIAN BED MATERIAL SIZE        D50            MM.             COL 0340
C     6) FINE MATERIAL CONCENTRATION     FML            PPM.            COL 0350
C                                                                       COL 0360
C     OUTPUT CONSISTS OF THE TOTAL BED MATERIAL TRANSPORT IN TONS/DAY,  COL 0370
C     AND A REMARK ON HOW THE COMPUTATIONS WERE CARRIED OUT.            COL 0380
C     IF  REMARK= OK, THE COMPUTATIONS WERE CARRIED OUT SUCCESSFULLY.   COL 0390
C     IF  REMARK= OOR, VELOCITY, DEPTH OR BED MATERIAL SIZE IS OUT OF   COL 0400
C     RANGE.                                                            COL 0410
C     IF  REMARK= TOOR, TEMPERATURE IS OUT OR RANGE.                    COL 0420
C     IF  REMARK= FOOR, FINE MATERIAL CONCENTRATION IS OUT OF RANGE.    COL 0430
C     VARIABLE                           RANGE                          COL 0440
C     AVERAGE VELOCITY                   1-10  F.P.S.                   COL 0450
C     HYDRAULIC DEPTH                    1-100  FT.                     COL 0460
C     WATER SURFACE WIDTH                                               COL 0470
C     TEMPERATURE                        32-100  DEG.FAHREN.           COL 0480
C     MEDIAN BED MATERIAL SIZE           0.1-0.8  MM.                   COL 0490
C     FINE MATERIAL CONCENTRATION        0-150000 PPM.                  COL 0500
C                                                                       COL 0510
C                                                                       COL 0520
      COMMON /CLBY/        G(4,9,6)     , F(5,10)      , T(7,4)       ,  COL 0530
     1        P(11)       , DF(10)      , CF(5)        , DP(11)       ,  COL 0540
     2        DG(4)       , VG(9)       , D50G(6)      , TEMP(7)         COL 0550
      COMMON /I/            IV(2)       , ID(2)        , ID50(2)         COL 0560
      DATA (((G(I,J,K),I=1,4),J=1,9),K=1,3)/1.0,0.3,0.0,0.0,3.1,3.30,2.5COL 0570
     1,2.0,5.4,9.0,10.5,20.0,11.0,26.0,50.0,140.0,16.0,47.0,120.0,480.0,COL 0580
     221.0,73.0,220.0,1000.0,29.0,101.0,390.0,1600.0,42.0,160.0,700.0,23COL 0590
     300.0,59.0,220.0,1050.0,5400.0,0.38,0.0,0.0,0.0,1.6,1.2,.65,.1,3.7,COL 0600
     44.7,4.1,3.1,10.0,18.0,28.0,52.0,17.0,39.0,77.0,160.0,27.0,67.0,140COL 0610
     5.0,370.0,36.0,95.0,220.0,630.0,59.0,140.0,410.0,1200.0,81.0,215.0,COL 0620
     6610.0,2000.0,0.14,0.0,0.0,0.0,1.1,0.6,0.14,0.0,3.3,3.0,1.7,0.5,11.COL 0630
     70,14.0,15.0,13.0,19.0,32.0,47.0,68.0,31.0,60.0,100.0,150.0,43.0,85COL 0640
     8.0,140.0,240.0,71.0,135.0,280.0,500.0,100.0,202.0,400.0,710.0/    COL 0650
```

Figure 2. Batch listing, Program COLBY.

```
      DATA (((G(I,J,K),I=1,4),J=1,9),K=4,6)/0.0,0.0,0.0,0.0,0.75,0.33,0.COL 0660
     10,0.0,2.9,2.3,1.0,0.0,10.5,12.0,11.0,7.0,21.0,31.0,38.0,50.0,35.0,COL 0670
     255.0,81.0,110.0,47.0,81.0,125.0,210.0,75.0,130.0,225.0,410.0,106.0COL 0680
     3,190.0,320.0,620.0,0.0,0.0,0.0,0.0,0.0,0.5,0.0,0.0,0.0,0.0,2.8,1.8,0.6,0.0COL 0690
     4,12.0,12.0,10.0,4.5,23.0,30.0,31.0,37.0,39.0,51.0,75.0,105.0,52.0,COL 0700
     578.0,120.0,190.0,83.0,130.0,210.0,360.0,115.0,190.0,305.0,550.0,0.COL 0710
     60,0.0,0.0,0.0,0.4,0.0,0.0,0.0,0.0,2.9,1.4,0.3,0.0,13.0,11.0,7.7,3.0,25COL 0720
     7.0,29.0,30.0,30.0,41.0,50.0,70.0,93.0,57.0,75.0,110.0,160.0,91.0,1COL 0730
     830.0,200.0,330.0,125.0,190.0,290.0,510.0/                          COL 0740
      DATA ((F(I,J),I=2,5),J=1,10)/1.10,1.60,2.60,4.70,1.10,1.65,2.75,4.COL 0750
     190,1.10,1.80,3.00,5.20,1.15,1.90,3.60,7.00,1.20,2.05,4.10,8.30,1.2COL 0760
     22,2.20,5.20,11.20,1.25,2.60,7.80,22.00,1.27,3.00,9.60,29.00,1.30,3COL 0770
     3.40,12.00,41.00,1.40,4.90,22.00,110.0/                             COL 0780
      DATA (F(1,I),I=1,10)/1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0/      COL 0790
      DATA ((T(I,J),I=1,7),J=1,4)/1.20,1.15,1.05,0.96,0.90,0.85,0.82,1.3COL 0800
     15,1.25,1.12,0.92,0.86,0.80,0.75,1.55,1.40,1.20,0.90,0.80,0.71,0.65COL 0810
     2,2.00,1.60,1.25,0.84,0.71,0.62,0.55/                               COL 0820
      DATA (DF(I),I=1,10)/0.10,0.20,0.30,0.60,1.00,2.00,6.00,10.00,20.00COL 0830
     1,1.E2/,(CF(I),I=1,5)/9.0,1.E4,5.E4,1.E5,1.5E5/                     COL 0840
      DATA (P(I),I=1,11)/0.60,0.90,1.0,1.0,0.83,0.60,0.40,0.25,0.15,0.09COL 0850
     1,0.05/,(DP(I),I=1,11)/0.10,0.15,0.20,0.30,0.40,0.50,0.60,0.70,0.80COL 0860
     2,0.90,1.00/,(DG(I),I=1,4)/0.10,1.0,10.0,100.0/,(VG(I),I=1,9)/1.0,1COL 0870
     3.5,2.0,3.0,4.0,5.0,6.0,8.0,10.0/,(D50G(I),I=1,6)/0.10,0.20,0.30,0.COL 0880
     440,0.60,0.80/,(TEMP(I),I=1,7)/32.0,40.0,50.0,70.0,80.0,90.0,100.0/COL 0890
      READ 590, NDATA                                                    COL 0900
      DO 580 N = 1,NDATA                                                 COL 0910
         READ 600, V,D,W,TF,D50,FML                                      COL 0920
         PRINT 630                                                       COL 0930
         PRINT 640, N,V,D,W,TF,D50,FML                                   COL 0940
         REMARK = 5HOK                                                   COL 0950
         IF ((D50.LT.D50G(1)).OR.(D50.GT.D50G(6))) GO TO 100             COL 0960
         GO TO 110                                                       COL 0970
  100    REMARK = 5HOOR                                                  COL 0980
         GO TO 560                                                       COL 0990
C                                                                        COL 1000
C     LOCATE APPROPRIATE   V,D,D50 GRID                                  COL 1010
C                                                                        COL 1020
  110    CONTINUE                                                        COL 1030
         IF ((D.LT.DG(1)).OR.(D.GT.DG(4))) GO TO 120                     COL 1040
         GO TO 130                                                       COL 1050
  120    REMARK = 5HOOR                                                  COL 1060
         GO TO 560                                                       COL 1070
  130    IF ((V.LT.VG(1)).OR.(V.GT.VG(9))) GO TO 140                     COL 1080
         GO TO 150                                                       COL 1090
  140    REMARK = 5HOOR                                                  COL 1100
         GO TO 560                                                       COL 1110
  150    IF (TF.EQ.0.) TF = 60.                                          COL 1120
         IF (TF - 32.) 160,170,170                                       COL 1130
  160    REMARK = 5HTOOR                                                 COL 1140
         TF = 32.                                                        COL 1150
  170    IF (TF - 100) 190,190,180                                       COL 1160
  180    REMARK = 5HTOOR                                                 COL 1170
         TF = 100.                                                       COL 1180
  190    CONTINUE                                                        COL 1190
         DO 220 I = 1,3                                                  COL 1200
            IF ((D.GE.DG(I)).AND.(D.LE.DG(I + 1))) GO TO 200             COL 1210
            GO TO 210                                                    COL 1220
  200       ID1 = I                                                      COL 1230
            ID2 = I + 1                                                  COL 1240
            GO TO 230                                                    COL 1250
  210       CONTINUE                                                     COL 1260
  220    CONTINUE                                                        COL 1270
  230    CONTINUE                                                        COL 1280
         DO 270 I = 1,8                                                  COL 1290
            IF (V.EQ.VG(I + 1).AND.V.LT.VG(9)) GO TO 250                 COL 1300
            IF ((V.GE.VG(I)).AND.(V.LE.VG(I + 1))) GO TO 240             COL 1310
            GO TO 260
```

```
  240       IV1 = I                                                    COL 1330
            IV2 = I + 1                                                COL 1340
            GO TO 280                                                  COL 1350
  250       IV1 = I + 1                                                COL 1360
            IV2 = I + 2                                                COL 1370
            GO TO 280                                                  COL 1380
  260       CONTINUE                                                   COL 1390
  270    CONTINUE                                                      COL 1400
  280    CONTINUE                                                      COL 1410
         DO 310 I = 1,5                                                COL 1420
            IF ((D50.GE.D50G(I)).AND.(D50.LE.D50G(I + 1))) GO TO 290   COL 1430
            GO TO 300                                                  COL 1440
  290       ID501 = I                                                  COL 1450
            ID502 = I + 1                                              COL 1460
            GO TO 320                                                  COL 1470
  300       CONTINUE                                                   COL 1480
  310    CONTINUE                                                      COL 1490
  320    CONTINUE                                                      COL 1500
         ID(1) = ID1                                                   COL 1510
         ID(2) = ID2                                                   COL 1520
         IV(1) = IV1                                                   COL 1530
         IV(2) = IV2                                                   COL 1540
         ID50(1) = ID501                                               COL 1550
         ID50(2) = ID502                                               COL 1560
         ISTOP = 0                                                     COL 1570
C                                                                      COL 1580
C     COMPUTE UNCORRECTED SEDIMENT TRANSPORT RATE, GTUC IN TONS/DAY/FT COL 1590
C                                                                      COL 1600
         CALL SEDTRN (GTUC,IV1,IV2,ID1,ID2,ID501,ID502,V,D,D50,ISTOP)  COL 1610
         IF (ISTOP.EQ.1) GO TO 580                                     COL 1620
         IF (TF - 60.) 340,330,340                                     COL 1630
  330    CFT = 1.                                                      COL 1640
         GO TO 390                                                     COL 1650
  340    CONTINUE                                                      COL 1660
         DO 370 I = 1,6                                                COL 1670
            IF ((TF.GE.TEMP(I)).AND.(TF.LE.TEMP(I + 1))) GO TO 350     COL 1680
            GO TO 360                                                  COL 1690
  350       IT1 = I                                                    COL 1700
            IT2 = I + 1                                                COL 1710
            GO TO 380                                                  COL 1720
  360       CONTINUE                                                   COL 1730
  370    CONTINUE                                                      COL 1740
  380    CONTINUE                                                      COL 1750
C                                                                      COL 1760
C     COMPUTE TEMPERATURE CORRECTION FACTOR, CFT                       COL 1770
C                                                                      COL 1780
         CALL TMPCOR (CFT,IT1,IT2,ID1,ID2,TF,D)                        COL 1790
  390    CONTINUE                                                      COL 1800
         IF (FML - 10.) 400,400,410                                    COL 1810
  400    CFFML = 1.                                                    COL 1820
         GO TO 500                                                     COL 1830
  410    CONTINUE                                                      COL 1840
         IF (FML.GT.1.5E + 5) REMARK = 5HFOOR                          COL 1850
         DO 430 I = 1,9                                                COL 1860
            IF ((D.GE.DF(I)).AND.(D.LE.DF(I + 1))) GO TO 420           COL 1870
            GO TO 430                                                  COL 1880
  420       ID1 = I                                                    COL 1890
            ID2 = I + 1                                                COL 1900
            GO TO 440                                                  COL 1910
  430    CONTINUE                                                      COL 1920
  440    CONTINUE                                                      COL 1930
         IF (FML.LE.1.5E + 5) GO TO 450                                COL 1940
         IF1 = 4                                                       COL 1950
         IF2 = 5                                                       COL 1960
         GO TO 490                                                     COL 1970
```

```
  450     CONTINUE                                                      COL 1980
          DO 480 I = 1,4                                                COL 1990
             IF ((FML.GE.CF(I)).AND.(FML.LE.CF(I + 1))) GO TO 460       COL 2000
             GO TO 470                                                  COL 2010
  460        IF1 = I                                                    COL 2020
             IF2 = I + 1                                                COL 2030
             GO TO 490                                                  COL 2040
  470        CONTINUE                                                   COL 2050
  480     CONTINUE                                                      COL 2060
  490     CONTINUE                                                      COL 2070
C                                                                       COL 2080
C     COMPUTE FINE MATERIAL LOAD CORRECTION, CFFML                      COL 2090
C                                                                       COL 2100
          CALL FMLCOR (CFFML,IF1,IF2,ID1,ID2,D,FML)                     COL 2110
  500     CONTINUE                                                      COL 2120
          CFMD = 1.                                                     COL 2130
          IF ((D50.GT.0.20).AND.(D50.LE.0.30)) GO TO 550                COL 2140
          DO 530 I = 1,10                                               COL 2150
             IF ((D50.GE.DP(I)).AND.(D50.LE.DP(I + 1))) GO TO 510       COL 2160
             GO TO 520                                                  COL 2170
  510        IP1 = I                                                    COL 2180
             IP2 = I + 1                                                COL 2190
             GO TO 540                                                  COL 2200
  520        CONTINUE                                                   COL 2210
  530     CONTINUE                                                      COL 2220
  540     CONTINUE                                                      COL 2230
C                                                                       COL 2240
C     COMPUTE BED MATERIAL SIZE CORRECTION, CFMD                        COL 2250
C                                                                       COL 2260
          CALL MDCOR (CFMD,IP1,IP2,D50)                                 COL 2270
  550     CONTINUE                                                      COL 2280
          CFO = (1. + (CFT * CFFML - 1.) * CFMD)                        COL 2290
          GT = GTUC * CFO * W                                           COL 2300
          PRINT 650, GT,REMARK                                          COL 2310
          PRINT 610, CFT,CFFML,CFMD,CFO                                 COL 2320
          GO TO 570                                                     COL 2330
  560     CONTINUE                                                      COL 2340
          PRINT 620, REMARK                                             COL 2350
  570     CONTINUE                                                      COL 2360
C                                                                       COL 2370
  580 CONTINUE                                                          COL 2380
C                                                                       COL 2390
      STOP                                                              COL 2400
C                                                                       COL 2410
  590 FORMAT (I5)                                                       COL 2420
  600     FORMAT (6F10.2)                                               COL 2430
  610     FORMAT (5X,31HTEMPERATURE CORRECTION FACTOR  ,13X,F10.3,/,5X, COL 2440
     1 38HFINE MATERIAL LOAD CORRECTION FACTOR  ,6X,F10.3,/,5X,44HMEDIANCOL 2450
     2 BED MATERIAL SIZE CORRECTION FACTOR  ,F10.3,/,5X,   25HOVERALL COCOL 2460
     3RRECTION FACTOR,19X,F10.3,///)                                    COL 2470
  620 FORMAT (5X,38HCOMPUTATIONS COULD NOT BE CARRIED OUT ,/5X,34HDUE TOCOL 2480
     1 DATA OUT OF RANGE IN COLBYS,/5X,8HREMARK= ,R10)                  COL 2490
  630 FORMAT (//,9X,33HCOMPUTATION OF TOTAL BED MATERIAL,/10X,26HTRANSPOCOL 2500
     1RT BY COLBYS METHOD,//)                                           COL 2510
  640 FORMAT (5X,4HSET ,I5/5X,27HAVERAGE VELOCITY           ,F12.2,12H FCOL 2520
     1T./SEC.   ,/5X,27HHYDRAULIC DEPTH            ,F12.2,12H FT.      COL 2530
     2 ,/5X,27HWATER SURFACE WIDTH        ,F12.2,12H FT.        ,/5X,27HCOL 2540
     3TEMPERATURE                  ,F12.2,12H DEG.FAHREN.,/5X,27HMEDIAN BECOL 2550
     4D MATERIAL SIZE   ,F12.3,12H MM.        ,/5X,27HFINE MATERIAL CONCCOL 2560
     5ENTRATION,F12.2,12H PPM.        ,/)                               COL 2570
  650 FORMAT (5X,24HBED MATERIAL TRANSPORT =,F10.1,12H TONS/DAY   ,/5X,9COL 2580
     1HREMARK = ,R10)                                                   COL 2590
      END                                                               COL 2600
      SUBROUTINE SEDTRN (GTUC,IV1,IV2,ID1,ID2,ID501,ID502,V,D,D50,ISTOP)COL 2610
      COMMON /CLBY/          G(4,9,6)     , F(5,10)      , T(7,4)      ,  COL 2620
     1         P(11)        , DF(10)       , CF(5)        , DP(11)      ,  COL 2630
```

```
     2        DG(4)        , VG(9)        , D50G(6)      , TEMP(7)
      COMMON /I/            IV(2)        , ID(2)        , ID50(2)
      DIMENSION             GT1(2)       , GT(2)
      DO 110 I = 1,2
         IID = ID(I)
         X = ALOG10(V)
         DO 100 K = 1,2
            IID50 = ID50(K)
            X1 = ALOG10(VG(IV1))
            X2 = ALOG10(VG(IV2))
            IF (G(IID,IV1,IID50).LE.0.) GO TO 120
            Y1 = ALOG10(G(IID,IV1,IID50))
            IF (G(IID,IV2,IID50).LE.0.) GO TO 120
            Y2 = ALOG10(G(IID,IV2,IID50))
  100    GT1(K) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)
         X = ALOG10(D50)
         X1 = ALOG10(D50G(ID501))
         X2 = ALOG10(D50G(ID502))
         Y1 = GT1(1)
         Y2 = GT1(2)
  110 GT(I) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)
      X = ALOG10(D)
      X1 = ALOG10(DG(ID1))
      X2 = ALOG10(DG(ID2))
      Y1 = GT(1)
      Y2 = GT(2)
      Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)
      GTUC = 10. *  * Z
      GO TO 130
  120 ISTOP = 1
      PRINT 140
  130 RETURN
C
  140 FORMAT (10X,37HCOMPUTATION COULD NOT BE CARRIED OUT ,/10X,41HDUE T
     10 DATA OUT OF RANGE IN QS VS V GRAPH,//)
      END
      SUBROUTINE TMPCOR (CFT,IT1,IT2,ID1,ID2,TF,D)
      COMMON /CLBY/         G(4,9,6)     , F(5,10)      , T(7,4)       ,
     1        P(11)        , DF(10)       , CF(5)        , DP(11)       ,
     2        DG(4)        , VG(9)        , D50G(6)      , TEMP(7)
      DIMENSION             CF1(2)       , IT(2)
      IT(1) = IT1
      IT(2) = IT2
      X = ALOG10(D)
      DO 100 I = 1,2
         ITC = IT(I)
         X1 = ALOG10(DG(ID1))
         X2 = ALOG10(DG(ID2))
         Y1 = ALOG10(T(ITC,ID1))
         Y2 = ALOG10(T(ITC,ID2))
  100 CF1(I) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)
      X = ALOG10(TF)
      X1 = ALOG10(TEMP(IT1))
      X2 = ALOG10(TEMP(IT2))
      Y1 = CF1(1)
      Y2 = CF1(2)
      Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)
      CFT = 10. *  * Z
      RETURN
      END
      SUBROUTINE FMLCOR (CFFML,IF1,IF2,ID1,ID2,D,FML)
      COMMON /CLBY/         G(4,9,6)     , F(5,10)      , T(7,4)       ,
     1        P(11)        , DF(10)       , CF(5)        , DP(11)       ,
     2        DG(4)        , VG(9)        , D50G(6)      , TEMP(7)
      COMMON /I/            IV(2)        , ID(2)        , ID50(2)
      DIMENSION             IF(2)        , CFM(2)
```

```
      IF(2)  = IF1                                                      COL 3300
      IF(2)  = IF2                                                      COL 3310
      X = ALOG10(D)                                                     COL 3320
      DO 100 I = 1,2                                                    COL 3330
         IIF = IF(1)                                                    COL 3340
         X1 = ALOG10(DF(ID1))                                           COL 3350
         X2 = ALOG10(DF(ID2))                                           COL 3360
         Y1 = ALOG10(F(IIF,ID1))                                        COL 3370
         Y2 = ALOG10(F(IIF,ID2))                                        COL 3380
  100 CFM(I) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                      COL 3390
      X = ALOG10(FML)                                                   COL 3400
      X1 = ALOG10(CF(IF1))                                              COL 3410
      X2 = ALOG10(CF(IF2))                                              COL 3420
      Y1 = CFM(1)                                                       COL 3430
      Y2 = CFM(2)                                                       COL 3440
      Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                           COL 3450
      CFFML = 10. *  * Z                                                COL 3460
      RETURN                                                            COL 3470
      END                                                               COL 3480
      SUBROUTINE MDCOR (CFMD,IP1,IP2,D50)                               COL 3490
      COMMON /CLBY/          G(4,9,6)     , F(5,10)      , T(7,4)      ,  COL 3500
     1        P(11)        , DF(10)       , CF(5)        , DP(11)      ,  COL 3510
     2        DG(4)        , VG(9)        , D50G(6)      , TEMP(7)       COL 3520
      X = ALOG10(D50)                                                   COL 3530
      X1 = ALOG10(DP(IP1))                                              COL 3540
      X2 = ALOG10(DP(IP2))                                              COL 3550
      Y1 = ALOG10(P(IP1))                                               COL 3560
      Y2 = ALOG10(P(IP2))                                               COL 3570
      Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                           COL 3580
      CFMD = 10. *  * Z                                                 COL 3590
      RETURN                                                            COL 3600
      END                                                               COL 3610
```

```
      PROGRAM COLBYI                                                    COLI0010
     1(INPUT,OUTPUT)                                                    COLI0020
C                                                                       COLI0030
C                                                                       COLI0040
C     DEVELOPED          COLORADO STATE UNIVERSITY ENGINEERING RESEARCH COLI0050
C                        CENTER, FORT COLLINS,COLORADO 60523            COLI0060
C     PURPOSE            COMPUTATION OF BED MATERIAL LOAD BY COLBYS     COLI0070
C                        METHOD                                         COLI0080
C     REFERENCE          COLBY,B.R., DISCHARGE OF SANDS AND MEAN VELOCITYCOLI0090
C                        RELATIONSHIPS IN SAND-BED STREAMS, PROFESSIONAL COLI0100
C                        PAPER 462-A, 1964, U.S. GEOLOGICAL SURVEY.     COLI0110
C     CORE USAGE         CDC 6400 SCOPE 3.3 SYSTEM DEFAULT VALUE,       COLI0120
C                        43000 OCTAL.                                   COLI0130
C     COMPILATION TIME   APPROXIMATELY 5 SEC.                           COLI0140
C     CENTRAL PROCESSOR                                                 COLI0150
C     TIME FOR ONE                                                      COLI0160
C     SET OF DATA        LESS THAN 0.05 SEC.                            COLI0170
C                                                                       COLI0180
C     INPUT AND OUTPUT DESCRIPTION                                      COLI0190
C                                                                       COLI0200
C     THE FIRST CARD IN THE INPUT LOGICAL RECORD SHOULD CONTAIN THE     COLI0210
C     VALUE OF NDATA,IN FREE FORMAT.NDATA IS THE NUMBER OF SETS OF INPUTCOLI0220
C     DATA TO BE FED TO THE COMPUTER AT A TIME. A SET OF INPUT DATA     COLI0230
C     CONSISTS OF A GROUP OF VARIABLES NECESSARY TO SPECIFY A PROBLEM,  COLI0240
C     AS DETAILED BELOW.                                                COLI0250
C                                                                       COLI0260
C     THE FIRST CARD IN INPUT IS FOLLOWED BY THE SETS OF INPUT DATA,    COLI0270
C     TO BE PUNCHED IN FREE FORMAT                                     COCOLI0280
C     A SET OF INPUT DATA CONSISTS OF THE FOLLOWING VARIABLES.          COLI0290
C     1) AVERAGE VELOCITY                V              F.P.S.          COLI0300
C     2) HYDRAULIC DEPTH                 D              FT.             COLI0310
C     3) WATER SURFACE WIDTH             W              FT.             COLI0320
C     4) TEMPERATURE                     TF             DEG.FAHREN.     COLI0330
C     5) MEDIAN BED MATERIAL SIZE        D50            MM.             COLI0340
C     6) FINE MATERIAL CONCENTRATION     FML            PPM.            COLI0350
C                                                                       COLI0360
C     OUTPUT CONSISTS OF THE TOTAL BED MATERIAL TRANSPORT IN TONS/DAY,  COLI0370
C     AND A REMARK ON HOW THE COMPUTATIONS WERE CARRIED OUT.            COLI0380
C     IF  REMARK= OK, THE COMPUTATIONS WERE CARRIED OUT SUCCESSFULLY.   COLI0390
C     IF  REMARK= OOR, VELOCITY, DEPTH OR BED MATERIAL SIZE IS OUT OF   COLI0400
C     RANGE.                                                            COLI0410
C     IF  REMARK= TOOR, TEMPERATURE IS OUT OR RANGE.                    COLI0420
C     IF  REMARK= FOOR, FINE MATERIAL CONCENTRATION IS OUT OF RANGE.    COLI0430
C     VARIABLE                           RANGE                          COLI0440
C     AVERAGE VELOCITY                   1-10  F.P.S.                   COLI0450
C     HYDRAULIC DEPTH                    1-100  FT.                     COLI0460
C     WATER SURFACE WIDTH                                               COLI0470
C     TEMPERATURE                        32-100  DEG.FAHREN.           COLI0480
C     MEDIAN BED MATERIAL SIZE           0.1-0.8  MM.                   COLI0490
C     FINE MATERIAL CONCENTRATION        0-150000 PPM.                  COLI0500
C                                                                       COLI0510
C                                                                       COLI0520
      COMMON /CLBY/        G(4,9,6)     , F(5,10)      , T(7,4)       ,  COLI0530
     1        P(11)       , DF(10)      , CF(5)        , DP(11)       ,  COLI0540
     2        DG(4)       , VG(9)       , D50G(6)      , TEMP(7)         COLI0550
      COMMON /I/           IV(2)        , ID(2)        , ID50(2)         COLI0560
      DATA (((G(I,J,K),I=1,4),J=1,9),K=1,3)/1.0,0.3,0.0,0.0,3.1,3.30,2.5COLI0570
     1,2.0,5.4,9.0,10.5,20.0,11.0,26.0,50.0,140.0,16.0,47.0,120.0,480.0,COLI0580
     221.0,73.0,220.0,1000.0,29.0,101.0,390.0,1600.0,42.0,160.0,700.0,23COLI0590
     300.0,59.0,220.0,1050.0,5400.0,0.38,0.0,0.0,0.0,1.6,1.2,.65,.1,3.7,COLI0600
     44.7,4.1,3.1,10.0,18.0,28.0,52.0,17.0,39.0,77.0,160.0,27.0,67.0,140COLI0610
     5.0,370.0,36.0,95.0,220.0,630.0,59.0,140.0,410.0,1200.0,81.0,215.0,COLI0620
     6610.0,2000.0,0.14,0.0,0.0,0.0,1.1,0.6,0.14,0.0,3.3,3.0,1.7,0.5,11.COLI0630
     70,14.0,15.0,13.0,19.0,32.0,47.0,68.0,31.0,60.0,100.0,150.0,43.0,85COLI0640
     8.0,140.0,240.0,71.0,135.0,280.0,500.0,100.0,202.0,400.0,710.0/    COLI0650
```

Figure 3. Interactive listing, Program COLBY.

```
      DATA (((G(I,J,K),I=1,4),J=1,9),K=4,6)/0.0,0.0,0.0,0.0,0.75,0.33,0.COLI0660
     10,0.0,2.9,2.3,1.0,0.0,10.5,12.0,11.0,7.0,21.0,31.0,38.0,50.0,35.0,COLI0670
     255.0,81.0,110.0,47.0,81.0,125.0,210.0,75.0,130.0,225.0,410.0,106.0COLI0680
     3,190.0,320.0,620.0,0.0,0.0,0.0,0.0,0.0,0.5,0.0,0.0,0.0,0.0,2.8,1.8,0.6,0.0COLI0690
     4,12.0,12.0,10.0,4.5,23.0,30.0,31.0,37.0,39.0,51.0,75.0,105.0,52.0,COLI0700
     578.0,120.0,190.0,83.0,130.0,210.0,360.0,115.0,190.0,305.0,550.0,0.COLI0710
     60,0.0,0.0,0.0,0.4,0.0,0.0,0.0,0.0,2.9,1.4,0.3,0.0,13.0,11.0,7.7,3.0,25COLI0720
     7.0,29.0,30.0,30.0,41.0,50.0,70.0,93.0,57.0,75.0,110.0,160.0,91.0,1COLI0730
     830.0,200.0,330.0,125.0,190.0,290.0,510.0/                          COLI0740
      DATA ((F(I,J),I=2,5),J=1,10)/1.10,1.60,2.60,4.70,1.10,1.65,2.75,4.COLI0750
     190,1.10,1.80,3.00,5.20,1.15,1.90,3.60,7.00,1.20,2.05,4.10,8.30,1.2COLI0760
     22,2.20,5.20,11.20,1.25,2.60,7.80,22.00,1.27,3.00,9.60,29.00,1.30,3COLI0770
     3.40,12.00,41.00,1.40,4.90,22.00,110.0/                             COLI0780
      DATA (F(1,I),I=1,10)/1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0/      COLI0790
      DATA ((T(I,J),I=1,7),J=1,4)/1.20,1.15,1.05,0.96,0.90,0.85,0.82,1.3COLI0800
     15,1.25,1.12,0.92,0.86,0.80,0.75,1.55,1.40,1.20,0.90,0.80,0.71,0.65COLI0810
     2,2.00,1.60,1.25,0.84,0.71,0.62,0.55/                               COLI0820
      DATA (DF(I),I=1,10)/0.10,0.20,0.30,0.60,1.00,2.00,6.00,10.00,20.00COLI0830
     1,1.E2/,(CF(I),I=1,5)/9.0,1.E4,5.E4,1.E5,1.5E5/                     COLI0840
      DATA (P(I),I=1,11)/0.60,0.90,1.0,1.0,0.83,0.60,0.40,0.25,0.15,0.09COLI0850
     1,0.05/,(DP(I),I=1,11)/0.10,0.15,0.20,0.30,0.40,0.50,0.60,0.70,0.80COLI0860
     2,0.90,1.00/,(DG(I),I=1,4)/0.10,1.0,10.0,100.0/,(VG(I),I=1,9)/1.0,1COLI0870
     3.5,2.0,3.0,4.0,5.0,6.0,8.0,10.0/,(D50G(I),I=1,6)/0.10,0.20,0.30,0.COLI0880
     440,0.60,0.80/,(TEMP(I),I=1,7)/32.0,40.0,50.0,70.0,80.0,90.0,100.0/COLI0890
      PRINT 610                                                          COLI0900
      PRINT 620                                                          COLI0910
      READ   *, NDATA                                                    COLI0920
      DO 580 N = 1,NDATA                                                 COLI0930
         PRINT 630                                                       COLI0940
         READ   *, V                                                     COLI0950
         PRINT 640                                                       COLI0960
         READ   *, D                                                     COLI0970
         PRINT 650                                                       COLI0980
         READ   *, W                                                     COLI0990
         PRINT 660                                                       COLI1000
         READ   *, TF                                                    COLI1010
         PRINT 670                                                       COLI1020
         READ   *, FML                                                   COLI1030
         PRINT 680                                                       COLI1040
         READ   *, D50                                                   COLI1050
         PRINT 690, N,V,D,W,TF,D50,FML                                   COLI1060
         REMARK = 5HOK                                                   COLI1070
         IF ((D50.LT.D50G(1)).OR.(D50.GT.D50G(6))) GO TO 100             COLI1080
         GO TO 110                                                       COLI1090
  100    REMARK = 5HOOR                                                  COLI1100
         GO TO 560                                                       COLI1110
C                                                                        COLI1120
C     LOCATE APPROPRIATE   V,D,D50 GRID                                  COLI1130
C                                                                        COLI1140
  110    CONTINUE                                                        COLI1150
         IF ((D.LT.DG(1)).OR.(D.GT.DG(4))) GO TO 120                     COLI1160
         GO TO 130                                                       COLI1170
  120    REMARK = 5HOOR                                                  COLI1180
         GO TO 560                                                       COLI1190
  130    IF ((V.LT.VG(1)).OR.(V.GT.VG(9))) GO TO 140                     COLI1200
         GO TO 150                                                       COLI1210
  140    REMARK = 5HOOR                                                  COLI1220
         GO TO 560                                                       COLI1230
  150    IF (TF.EQ.0.) TF = 60.                                          COLI1240
         IF (TF - 32.) 160,170,170                                       COLI1250
  160    REMARK = 5HTOOR                                                 COLI1260
         TF = 32.                                                        COLI1270
  170    IF (TF - 100) 190,190,180                                       COLI1280
  180    REMARK = 5HTOOR                                                 COLI1290
         TF = 100.                                                       COLI1300
  190    CONTINUE                                                        COLI1310
```

```
      DO 220 I = 1,3                                                    COLI1320
         IF ((D.GE.DG(I)).AND.(D.LE.DG(I + 1))) GO TO 200               COLI1330
         GO TO 210                                                      COLI1340
200      ID1 = I                                                        COLI1350
         ID2 = I + 1                                                    COLI1360
         GO TO 230                                                      COLI1370
210      CONTINUE                                                       COLI1380
220   CONTINUE                                                          COLI1390
230   CONTINUE                                                          COLI1400
      DO 270 I = 1,8                                                    COLI1410
         IF (V.EQ.VG(I + 1).AND.V.LT.VG(9)) GO TO 250                   COLI1420
         IF ((V.GE.VG(I)).AND.(V.LE.VG(I + 1))) GO TO 240               COLI1430
         GO TO 260                                                      COLI1440
240      IV1 = I                                                        COLI1450
         IV2 = I + 1                                                    COLI1460
         GO TO 280                                                      COLI1470
250      IV1 = I + 1                                                    COLI1480
         IV2 = I + 2                                                    COLI1490
         GO TO 280                                                      COLI1500
260      CONTINUE                                                       COLI1510
270   CONTINUE                                                          COLI1520
280   CONTINUE                                                          COLI1530
      DO 310 I = 1,5                                                    COLI1540
         IF ((D50.GE.D50G(I)).AND.(D50.LE.D50G(I + 1))) GO TO 290       COLI1550
         GO TO 300                                                      COLI1560
290      ID501 = I                                                      COLI1570
         ID502 = I + 1                                                  COLI1580
         GO TO 320                                                      COLI1590
300      CONTINUE                                                       COLI1600
310   CONTINUE                                                          COLI1610
320   CONTINUE                                                          COLI1620
      ID(1) = ID1                                                       COLI1630
      ID(2) = ID2                                                       COLI1640
      IV(1) = IV1                                                       COLI1650
      IV(2) = IV2                                                       COLI1660
      ID50(1) = ID501                                                   COLI1670
      ID50(2) = ID502                                                   COLI1680
      ISTOP = 0                                                         COLI1690
C                                                                       COLI1700
C     COMPUTE UNCORRECTED SEDIMENT TRANSPORT RATE, GTUC IN TONS/DAY/FT  COLI1710
C                                                                       COLI1720
      CALL SEDTRN (GTUC,IV1,IV2,ID1,ID2,ID501,ID502,V,D,D50,ISTOP)      COLI1730
      IF (ISTOP.EQ.1) GO TO 580                                         COLI1740
      IF (TF - 60.) 340,330,340                                         COLI1750
330   CFT = 1.                                                          COLI1760
      GO TO 390                                                         COLI1770
340   CONTINUE                                                          COLI1780
      DO 370 I = 1,6                                                    COLI1790
         IF ((TF.GE.TEMP(I)).AND.(TF.LE.TEMP(I + 1))) GO TO 350         COLI1800
         GO TO 360                                                      COLI1810
350      IT1 = I                                                        COLI1820
         IT2 = I + 1                                                    COLI1830
         GO TO 380                                                      COLI1840
360      CONTINUE                                                       COLI1850
370   CONTINUE                                                          COLI1860
380   CONTINUE                                                          COLI1870
C                                                                       COLI1880
C     COMPUTE TEMPERATURE CORRECTION FACTOR, CFT                        COLI1890
C                                                                       COLI1900
      CALL TMPCOR (CFT,IT1,IT2,ID1,ID2,TF,D)                            COLI1910
390   CONTINUE                                                          COLI1920
      IF (FML - 10.) 400,400,410                                        COLI1930
400   CFFML = 1.                                                        COLI1940
      GO TO 500                                                         COLI1950
410   CONTINUE                                                          COLI1960
      IF (FML.GT.1.5E + 5) REMARK = 5HFOOR                              COLI1970
```

```
      DO 430 I = 1,9                                                    COLI1980
         IF ((D.GE.DF(I)).AND.(D.LE.DF(I + 1))) GO TO 420               COLI1990
         GO TO 430                                                      COLI2000
420      ID1 = I                                                        COLI2010
         ID2 = I + 1                                                    COLI2020
         GO TO 440                                                      COLI2030
430   CONTINUE                                                          COLI2040
440   CONTINUE                                                          COLI2050
      IF (FML.LE.1.5E + 5) GO TO 450                                    COLI2060
      IF1 = 4                                                           COLI2070
      IF2 = 5                                                           COLI2080
      GO TO 490                                                         COLI2090
450   CONTINUE                                                          COLI2100
      DO 480 I = 1,4                                                    COLI2110
         IF ((FML.GE.CF(I)).AND.(FML.LE.CF(I + 1))) GO TO 460           COLI2120
         GO TO 470                                                      COLI2130
460      IF1 = I                                                        COLI2140
         IF2 = I + 1                                                    COLI2150
         GO TO 490                                                      COLI2160
470      CONTINUE                                                       COLI2170
480   CONTINUE                                                          COLI2180
490   CONTINUE                                                          COLI2190
C                                                                       COLI2200
C     COMPUTE FINE MATERIAL LOAD CORRECTION, CFFML                      COLI2210
C                                                                       COLI2220
      CALL FMLCOR (CFFML,IF1,IF2,ID1,ID2,D,FML)                         COLI2230
500   CONTINUE                                                          COLI2240
      CFMD = 1.                                                         COLI2250
      IF ((D50.GT.0.20).AND.(D50.LE.0.30)) GO TO 550                    COLI2260
      DO 530 I = 1,10                                                   COLI2270
         IF ((D50.GE.DP(I)).AND.(D50.LE.DP(I + 1))) GO TO 510           COLI2280
         GO TO 520                                                      COLI2290
510      IP1 = I                                                        COLI2300
         IP2 = I + 1                                                    COLI2310
         GO TO 540                                                      COLI2320
520      CONTINUE                                                       COLI2330
530   CONTINUE                                                          COLI2340
540   CONTINUE                                                          COLI2350
C                                                                       COLI2360
C     COMPUTE BED MATERIAL SIZE CORRECTION, CFMD                        COLI2370
C                                                                       COLI2380
      CALL MDCOR (CFMD,IP1,IP2,D50)                                     COLI2390
550   CONTINUE                                                          COLI2400
      CFO = (1. + (CFT * CFFML - 1.) * CFMD)                            COLI2410
      GT = GTUC * CFO * W                                               COLI2420
      PRINT 700, GT,REMARK                                              COLI2430
      PRINT 590, CFT,CFFML,CFMD,CFO                                     COLI2440
      GO TO 570                                                         COLI2450
560   CONTINUE                                                          COLI2460
      PRINT 600, REMARK                                                 COLI2470
570   CONTINUE                                                          COLI2480
C                                                                       COLI2490
580 CONTINUE                                                            COLI2500
C                                                                       COLI2510
    STOP                                                                COLI2520
C                                                                       COLI2530
590    FORMAT (5X,31HTEMPERATURE CORRECTION FACTOR  ,13X,F10.3,/,5X,    COLI2540
   1 38HFINE MATERIAL LOAD CORRECTION FACTOR  ,6X,F10.3,/,5X,44HMEDIANCOLI2550
   2 BED MATERIAL SIZE CORRECTION FACTOR  ,F10.3,/,5X,   25HOVERALL COCOLI2560
   3RRECTION FACTOR,19X,F10.3,///)                                      COLI2570
600 FORMAT (5X,38HCOMPUTATIONS COULD NOT BE CARRIED OUT ,/5X,34HDUE TOCOLI2580
   1 DATA OUT OF RANGE IN COLBYS,/5X,8HREMARK= ,R10)                    COLI2590
610 FORMAT (//,9X,33HCOMPUTATION OF TOTAL BED MATERIAL,/10X,26HTRANSPOCOLI2600
   1RT BY COLBYS METHOD,//)                                             COLI2610
620 FORMAT (///, 32H START INPUT DATA IN FREE FORMAT,//, 39H ENTER THECOLI2620
```

```
     1 NUMBER OF SETS OF INPUT DATA)                                    COLI2630
   630 FORMAT (//////, 32H ENTER THE FOLLOWING INPUT DATA:,//, 38H   AVERCOLI2640
     1AGE VELOCITY IN FEET PER SECOND)                                  COLI2650
   640 FORMAT ( 26H   HYDRAULIC DEPTH IN FEET)                          COLI2660
   650 FORMAT ( 30H   WATER SURFACE WIDTH IN FEET)                      COLI2670
   660 FORMAT ( 36H   WATER TEMPERATURE IN DEG. FAHREN.)                COLI2680
   670 FORMAT ( 49H   FINE MATERIAL CONCENTRATION IN  PPM. BY WEIGHT)   COLI2690
   680 FORMAT ( 33H   MEDIAN BED MATERIAL SIZE IN MM)                   COLI2700
   690 FORMAT (/5X,4HSET ,I5/5X,27HAVERAGE VELOCITY          ,F12.2,12H COLI2710
     1FT./SEC.   ,/5X,27HHYDRAULIC DEPTH            ,F12.2,12H FT.     COLI2720
     2  ,/5X,27HWATER SURFACE WIDTH        ,F12.2,12H FT.        ,/5X,27COLI2730
     3HTEMPERATURE                ,F12.2,12H DEG.FAHREN.,/5X,27HMEDIAN BCOLI2740
     4ED MATERIAL SIZE   ,F12.3,12H MM.        ,/5X,27HFINE MATERIAL CONCOLI2750
     5CENTRATION,F12.2,12H PPM.        ,/)                              COLI2760
   700 FORMAT (5X,24HBED MATERIAL TRANSPORT =,F10.1,12H TONS/DAY   ,/5X,9COLI2770
     1HREMARK = ,R10)                                                   COLI2780
       END                                                              COLI2790
       SUBROUTINE SEDTRN (GTUC,IV1,IV2,ID1,ID2,ID501,ID502,V,D,D50,ISTOP)COLI2800
       COMMON /CLBY/          G(4,9,6)     , F(5,10)      , T(7,4)      ,  COLI2810
     1         P(11)        , DF(10)       , CF(5)        , DP(11)      ,  COLI2820
     2         DG(4)        , VG(9)        , D50G(6)      , TEMP(7)        COLI2830
       COMMON /I/             IV(2)        , ID(2)        , ID50(2)        COLI2840
       DIMENSION              GT1(2)       , GT(2)                         COLI2850
       DO 110 I = 1,2                                                     COLI2860
          IID = ID(I)                                                     COLI2870
          X = ALOG10(V)                                                   COLI2880
          DO 100 K = 1,2                                                  COLI2890
             IID50 = ID50(K)                                              COLI2900
             X1 = ALOG10(VG(IV1))                                         COLI2910
             X2 = ALOG10(VG(IV2))                                         COLI2920
             IF (G(IID,IV1,IID50).LE.0.) GO TO 120                        COLI2930
             Y1 = ALOG10(G(IID,IV1,IID50))                                COLI2940
             IF (G(IID,IV2,IID50).LE.0.) GO TO 120                        COLI2950
             Y2 = ALOG10(G(IID,IV2,IID50))                                COLI2960
  100     GT1(K) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                    COLI2970
          X = ALOG10(D50)                                                 COLI2980
          X1 = ALOG10(D50G(ID501))                                        COLI2990
          X2 = ALOG10(D50G(ID502))                                        COLI3000
          Y1 = GT1(1)                                                     COLI3010
          Y2 = GT1(2)                                                     COLI3020
  110 GT(I) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                         COLI3030
       X = ALOG10(D)                                                      COLI3040
       X1 = ALOG10(DG(ID1))                                               COLI3050
       X2 = ALOG10(DG(ID2))                                               COLI3060
       Y1 = GT(1)                                                         COLI3070
       Y2 = GT(2)                                                         COLI3080
       Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                            COLI3090
       GTUC = 10. *   * Z                                                 COLI3100
       GO TO 130                                                          COLI3110
  120 ISTOP = 1                                                           COLI3120
       PRINT 140                                                          COLI3130
  130 RETURN                                                              COLI3140
C                                                                         COLI3150
  140 FORMAT (10X,37HCOMPUTATION COULD NOT BE CARRIED OUT ,/10X,41HDUE TCOLI3160
     1O DATA OUT OF RANGE IN QS VS V GRAPH,/)                             COLI3170
       END                                                                COLI3180
       SUBROUTINE TMPCOR (CFT,IT1,IT2,ID1,ID2,TF,D)                       COLI3190
       COMMON /CLBY/          G(4,9,6)     , F(5,10)      , T(7,4)      ,  COLI3200
     1         P(11)        , DF(10)       , CF(5)        , DP(11)      ,  COLI3210
     2         DG(4)        , VG(9)        , D50G(6)      , TEMP(7)        COLI3220
       DIMENSION              CF1(2)       , IT(2)                         COLI3230
       IT(1) = IT1                                                        COLI3240
       IT(2) = IT2                                                        COLI3250
       X = ALOG10(D)                                                      COLI3260
       DO 100 I = 1,2                                                     COLI3270
          ITC = IT(I)                                                     COLI3280
          X1 = ALOG10(DG(ID1))                                            COLI3290
```

```
      X2 = ALOG10(DG(ID2))                                              COLI3300
      Y1 = ALOG10(T(ITC,ID1))                                           COLI3310
      Y2 = ALOG10(T(ITC,ID2))                                           COLI3320
  100 CF1(I) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                      COLI3330
      X = ALOG10(TF)                                                    COLI3340
      X1 = ALOG10(TEMP(IT1))                                            COLI3350
      X2 = ALOG10(TEMP(IT2))                                            COLI3360
      Y1 = CF1(1)                                                       COLI3370
      Y2 = CF1(2)                                                       COLI3380
      Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                           COLI3390
      CFT = 10. *  * Z                                                  COLI3400
      RETURN                                                            COLI3410
      END                                                               COLI3420
      SUBROUTINE FMLCOR (CFFML,IF1,IF2,ID1,ID2,D,FML)                   COLI3430
      COMMON /CLBY/          G(4,9,6)     , F(5,10)      , T(7,4)      ,  COLI3440
     1        P(11)         , DF(10)      , CF(5)        , DP(11)      ,  COLI3450
     2        DG(4)         , VG(9)       , D50G(6)      , TEMP(7)        COLI3460
      COMMON /I/             IV(2)        , ID(2)        , ID50(2)        COLI3470
      DIMENSION              IF(2)        , CFM(2)                        COLI3480
      IF(1)  = IF1                                                      COLI3490
      IF(2)  = IF2                                                      COLI3500
      X = ALOG10(D)                                                     COLI3510
      DO 100 I = 1,2                                                    COLI3520
         IIF = IF(I)                                                    COLI3530
         X1 = ALOG10(DF(ID1))                                           COLI3540
         X2 = ALOG10(DF(ID2))                                           COLI3550
         Y1 = ALOG10(F(IIF,ID1))                                        COLI3560
         Y2 = ALOG10(F(IIF,ID2))                                        COLI3570
  100 CFM(I) = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                      COLI3580
      X = ALOG10(FML)                                                   COLI3590
      X1 = ALOG10(CF(IF1))                                              COLI3600
      X2 = ALOG10(CF(IF2))                                              COLI3610
      Y1 = CFM(1)                                                       COLI3620
      Y2 = CFM(2)                                                       COLI3630
      Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                           COLI3640
      CFFML = 10. *  * Z                                                COLI3650
      RETURN                                                            COLI3660
      END                                                               COLI3670
      SUBROUTINE MDCOR (CFMD,IP1,IP2,D50)                               COLI3680
      COMMON /CLBY/          G(4,9,6)     , F(5,10)      , T(7,4)      ,  COLI3690
     1        P(11)         , DF(10)      , CF(5)        , DP(11)      ,  COLI3700
     2        DG(4)         , VG(9)       , D50G(6)      , TEMP(7)        COLI3710
      X = ALOG10(D50)                                                   COLI3720
      X1 = ALOG10(DP(IP1))                                              COLI3730
      X2 = ALOG10(DP(IP2))                                              COLI3740
      Y1 = ALOG10(P(IP1))                                               COLI3750
      Y2 = ALOG10(P(IP2))                                               COLI3760
      Z = Y1 + (X - X1) * (Y2 - Y1)/(X2 - X1)                           COLI3770
      CFMD = 10. *  * Z                                                 COLI3780
      RETURN                                                            COLI3790
      END                                                               COLI3800
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM: EINSTN PROGRAM NO.:

PREPARING AGENCY: Simons and Li Engineering

AUTHORS: R. M. Li, R. K. Simons, D. B. Simons

DATE PROGRAM COMPLETED: September, 1979

STATUS OF PROGRAM: Phase - original, Stage - operational

A. PURPOSE OF PROGRAM: To compute bed load by Einstein's method.

References: (a) Einstein, H. A., "The Bed-Load Function for Sediment Transportation in Open Channel Flow," Technical Bulletin 1026, U.S. Department of Agriculture, September, 1950; (b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

B. PROGRAM SPECIFICATIONS:

Language: ANSI Fortran IV

Solution Requirements: Input data

Method of Analysis: Computer application of Einstein's bed load function

Size of Object Program: 21,654 characters

External Storage: None

Restrictions: None

General Equations: See reference

Range of Quantities: Unlimited

Accuracy: N/A

Dimension System: English except sediment sizes are read in mm then converted to feet in the program.

C. METHODS: The program is written in Fortran IV in both batch or time-share processing modes. All stops would be unprogrammed, resulting from improper input variable.

D. EQUIPMENT DETAILS: The program was developed on a CDC Cyber 172 but can operate on any compatible system without special equipment. Normal configuration of CPU, reader and printer are necessary to run the program in batch mode.

E. INPUT-OUTPUT: Input requirements are: Number of data sets, number of sediment size fractions, type of sediment size distribution (log-normal or specified as input), frequency of sediment data input, discharge (cfs), mean velocity (ft/sec), hydraulic depth (ft), stream width (ft), energy slope (ft/ft), kinematic viscosity (ft^2/sec), median bed material size (mm), gradation coefficient, sediment sizes (mm) and corresponding percentages if the sediment size distribution was to be specified, D_{65} and D_{35} (mm). Output includes input data and bed material transport rate.

F. ADDITIONAL REMARKS: Complete documentation of this program is available and the method can be used for design purposes.

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NUMBER:

2. TITLE: EINSTN - Bed load transport in rivers by Einstein's method

3. REVISION LOG: N/A

4. PURPOSE OF PROGRAM: To compute bed load transport in rivers by Einstein's method. References:

   a) Einstein, H. A., "The Bed-Load Function for Sediment Transportation in Open Channel Flow," Technical Bulletin 1026, U.S. Department of Agriculture, September, 1950.

   b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

5. STEP SOLUTION:

   a) The input variables that must be supplied are:

      1 - Number of data sets (NDATA)

      2 - Type of sediment size distribution (IDIST)

      if IDIST = 0, size distribution is read in

      if IDIST = 1, a lognormal size distribution is assumed

      3 - Frequency of sediment data input (ISED)

      if ISED = 0, the same size distribution is used for all flow conditions

      if ISED = 1, a new distribution is read in or computed for each set of data.

      4 - Discharge (DISCH), cfs

      5 - Initial estimate of hydraulic radius (RT), ft

      6 - Stream width (W), ft

      7 - Energy slope (SS), ft/ft

8 - Kinematic viscosity of water (VK), ft^2/sec

9 - Median bed material size (D50M), mm, if IDIST = 1

10 - Gradation coefficient (SIGMA), if IDIST = 1

11 - Number of sediment sizes (NSIZ), if IDIST = 0

12 - Upper bound of sediment size in each size fraction (DRU), if IDIST = 0

13 - Lower bound of sediment size in each size fraction (DRL), if IDIST = 0

14 - Sediment percentages (PB), decimal fractions if IDIST = 0

15 - D_{35} (D35), mm, if IDIST = 0

16 - D_{65} (D65), mm, if IDIST = 0

Variables (4) through (8) are read in from 1 to the number of data sets. Variables (9) and (10) are read in if IDIST = 1. Variables (11) through (16) are read in if IDIST = 0. If ISED is 1, variables (9) and (10), or (11) through (16), are also read in from 1 to the number of data sets. After input of data for each data set, computation of sediment transport by Einstein's method can begin.

b) Determine the hydraulic radius with respect to the grain (RBP), the hydraulic radius for channel irregularities (RBPP), and the average velocity of the flow (VELAV) by an iterative incremental search method. This involves subroutine FIG4 and FIG5 in the search loop. The search balances the resistance along the two hydraulic radii and the computed velocity in such a way that the input discharge value is maintained. Subroutine FIG4 computes the parameters for rough-smooth transition and FIG5 is used in computing the shear velocity for channel irregularities.

c) Calculate the apparent roughness diameter, DELT, and the ratio of DELT/DELTA. Determine the characteristic grain size of the mixture based on this ratio.

d) Compute the ratio of D65 to the laminar sublayer thickness, X8. Call subroutine FIG8, which returns the value of the pressure correction for rough-smooth transition, Y8.

e) Compute the logarithmic function, BETAX, and the parameter of total transport, PP.

f) In a do-loop from 1 to the number of sediment sizes, compute the following:

1 - The ratio of the individual grain size D (I) to the characteristic grain size of the mixture, CAPX; X7.

2 - Call subroutine FIG7 which returns the value of the hiding factor for grains in a mixture, Y7.

3 - Compute the intensity of shear for individual particles, PSIS.

4 - Call subroutine FIG10 which returns the value of the intensity of transport for individual grain size, Y10.

5 - Using Y10 compute the bed load transport of the bed material for each size.

6 - Compute the settling velocity using Rubey's equation SETV and the exponent of suspended distribution, Z.

7 - Using the ratio of the bed-layer thickness to the water depth, A and Z. Call subroutine POWER which returns and evaluates Einstein's integrals XI1, XI2, XJ1, XJ2.

8 - Compute the total transport (suspended and bed load) of bed material for each size, TSD.

g) Sum transport of individual dizes to obtain total transport.

g) Print input data and sediment transport by sizes and in total.

6. ACCURACY: N/A

PART II: COMPUTER FUNCTION DESCRIPTION

1. REVISION LOG: N/A

2. FUNCTIONAL FLOW CHART: (See Figure 1)

3. EQUIPMENT AND OPERATING SYSTEM: The program was developed on a CDC Cyber 172. Normal configuration of CPU, reader and printer are necessary to run the program in the batch mode.

4. INPUT REQUIREMENTS: The program is written for either the time-share or batch processing mode. The source listing (Fig. 2) is for batch. Figure 3 is the interactive mode listing. Input data for batch are described below. For time share mode the user is prompted for necessary inputs.

5. SECONDARY STORAGE INPUT FORMAT: None

6. INPUT DATA DESCRIPTION: The following variable names are used for input variables:

NAME	DESCRIPTION	FORMAT	
NDATA	Number of data sets	I5	Card 1
IDIST	Type of sediment size distribution. If IDIST = 0, size distribution is read in; if IDIST = 1, a lognormal distribution is computed.	I5	Card 2
ISED	Frequency of sediment data input. If ISED = 0 one size distribution is used for all data sets; if ISED = 1, a new size distribution is read in for each data set.	I5	Card 2
DISCH	Water discharge, cfs	F10.2	Card 3

NAME	DESCRIPTION	FORMAT		
RT	Hydraulic radius, ft	F10.2	Card 3	
W	Stream width, ft	F10.2	Card 3	
SS	Energy slope, ft/ft	E10.4	Card 3	
VK	Kinematic viscosity, ft^2/sec	E10.4	Card 3	
D50M	Median sediment size, mm	F10.4	Card 4	If IDIST = 1
SIGMA	Gradation coefficient	F10.4	Card 4	
NSIZ	Number of sediment sizes	I5	Card 4	If IDIST = 0
DRU	Upper bound sediment size, mm	F10.4	If IDIST = 0	
DRL	Lower bound sediment size, mm	F10.4	Card 5 through 5+ NSIZ	
PB	Sediment percentage array	F10.4		
D35	Sediment size for which 35% of sample is finer, mm	F10.4	Card 5 + NSIZ + 1 if IDIST = 0	
D65	Sediment size for which 65% of sample is finer, mm	F10.4		

Repeat Card 3 from 1 to NDATA after sediment data cards if IDIST = 0 and ISED = 0.

Repeat Cards 3 through 5 + NSIZ + 1 from 1 to NDATA if IDIST = 0 and ISED = 1.

7. SUMMARY OF REQUIRED CARDS: (See 6)

8. OUTPUTS: Printed output generated by Program EINSTN includes the input data and a table of five columns containing sediment fractions percentage, geometric mean size for that fraction, bed load, suspended load and total load. Also the sum of the individual bed loads, suspended loads and total loads are printed out.

9. OPERATOR INSTRUCTIONS: None

10. PROGRAM ERROR MESSAGES: None - Program stops would result from improper data input.

11. VARIABLE DEFINITIONS:

A - Ratio of bed layer thickness to water depth

BD - Bed load in each size fraction, tons/day

BETAX - A logarithmic function

CAPX - Characteristic grain size of mixture, ft

D - Bed material sizes, ft

DELT - Apparent roughness diamter, ft

DELTA - Thickness of the laminar sublayer, ft

DISCH - Water discharge, cfs

DRL - Lower limit of sediment size in each fraction, mm

DRU - Upper limit of sediment size in each fraction, mm

D35 - Particle diameter for which 35% of the sample is finer, mm.

D50M - Median particle diameter, mm. Convert to ft

D65 - Particle diameter for which 65% of the sample is finer, mm.

G - Acceleration of gravity, ft/sec^2

IDIST - Sediment size distribution type

NDATA - Number of data sets

NSIZ - Number of size fractions

PB - Bed material percentages (decimal fractions)

PP - Parameter of total transport

PSIS - Intensity of shear for individual grain size

RATIO - Ratio of DELT/DELTA

RBP - Hydraulic radius with respect to the grain

RBPP - The difference between RT and RBP, or RT-RBP.

RT - Hydraulic radius of total section, ft

SD - Suspended bed load by fractions, tons/day

SDB - Total bed material load, tons/day

SDS - Total suspended bed material load, tons/day

SDT - Total sediment load, tons/day

SETV - Settling velocity, ft/sec

SIGMA - Gradation coefficient

SIP - Intensity of shear on representative particle, lb/ft^2

SS - Energy slope, ft/ft

SVP - Shear velocity with respect to the grain, ft/sec

SUPP - Shear velocity for channel irregularities, ft/sec

TSD - Total sediment load by sizes, tons/day

VELAV - Mean velocity, ft/sec

VK - Kinematic viscosity of water, ft^2/sec

W - Stream width, ft

X - Sediment diameter, mm

XI1 - Value of integral I1

XI2 - Value of integral I2

XJ1 - Value of integral J1

XJ2 - Value of integral J2

XM - Ratio of bed layer thickness to water depth

X4 - Ratio of roughness diameter to the laminar sublayer thickness

X7 - Ratio of sediment diameter to characteristic grain size of the mixture

X8 - Ratio of D65 to the laminar sublayer thickness

X10 - Intensity of shear for individual grain size

Y4 - Parameter for rough-smooth transition

Y7 - "Hiding factor" for grains in a mixture

Y10 - Intensity of transport for individual grain size

Z - Exponent of suspended distribution

12. EXAMPLE CASE:

a) Batch Mode

```
        COMPUTATION OF TOTAL BED MATERIAL
         LOAD BY THE EINSTEIN BED-LOAD FUNCTION

SET     1

    WATER DISCHARGE                          2820.00 C.F.S
    INITIAL GUESS OF HYDRAULIC RADIUS           2.50 FT.
    WATER SURFACE WIDTH                       170.00 FT.
    ENERGY GRADIENT                         .0010500 FT./FT.
    KINEMATIC VISCOSITY                     .0000106 SQ.FT./SEC.
    D35                                        .290 MM.      D65
```

INCREMENT	UPPER BOUND MM	LOWER BOUND MM	INCREMENT FRACTION	BED LOAD TRANSPORT RATE TONS/DAY	TOTAL BED MATERIAL TRANS. RATE TONS/DAY
1	.5890	.4170	.1780	.8974E+03	.2063E+04
2	.4170	.2950	.4020	.1745E+04	.6330E+04
3	.2950	.2080	.3200	.1064E+04	.1061E+05
4	.2080	.1470	.0580	.1228E+03	.6895E+04

```
TOTAL BED LOAD =     .3829E+04 TONS/DAY
TOTAL BED MATERIAL LOAD =     .2590E+05 TONS/DAY
DEPTH =    2.45889 FT
MEAN VELOCITY =    6.74616 FT/SEC
```

b) Interactive mode

```
        COMPUTATION OF TOTAL BED MATERIAL
         LOAD BY THE EINSTEIN BED-LOAD FUNCTION


 START INPUT DATA IN FREE FORMAT

 ENTER THE NUMBER OF SETS OF INPUT DATA
? 1


 SET SIZE DISTRIBUTION TYPE, IDIST = 0 OR 1
   ENTER 0 IF THE SEDIMENT SIZES AND PERCENTAGES DEFINING THE SEDIMENT SIZE DISTRIBUTION ARE TO BE READ IN
   ENTER 1 IF THE LOG-NORMAL SEDIMENT SIZE DISTRIBUTION IS TO BE EVALUATED
? 0


 ENTER 0 IF SEDIMENT DATA WILL NOT BE CHANGED FOR DIFFERENT HYDRAULIC CONDITION
 ENTER 1 IF THE SEDIMENT DATA ARE TO BE READ OR COMPUTED FOR EACH HYDRAULIC CONDITION
? 0




 ENTER THE FOLLOWING HYDRAULIC DATA:

   WATER DISCHARGE IN CUBIC FEET PER SECOND
? 2820.
   INITIAL GUESS OF HYDRAULIC RADIUS IN FEET
? 2.5
   WATER SURFACE WIDTH IN FEET
? 170.
   ENERGY SLOPE IN FEET/FEET
? .00105
   KINEMATIC VISCOSITY IN SQ.FT./SEC.
? .0000106


 IDIST=0 ENTER THE FOLLOWING BED MATERIAL DATA:

   NUMBER OF SEDIMENT SIZE FRACTIONS, NSIZ, MAX. OF 20
? 4
   THE UPPER BOUND SIZE AND LOWER BOUND SIZE IN MM, AND
   THE PERCENT WEIGHT OF EACH SEDIMENT FRACTION
        (DRU(I),DRL(I),PB(I),I=1,NSIZ)
? .589,.417,.178
? .417,.295,.402
? .295,.208,.320
? .208,.147,.058
   THE 35% AND 65% FINER DIAMETERS IN MM, D35 AND D65
? .29,.37
```

SET 1

WATER DISCHARGE	2820.00	C.F.S
INITIAL GUESS OF HYDRAULIC RADIUS	2.50	FT.
WATER SURFACE WIDTH	170.00	FT.
ENERGY GRADIENT	.0010500	FT./FT.
KINEMATIC VISCOSITY	.0000106	SQ.FT./SEC.
D35	.290	MM.

D65 .370 MM.

INCREMENT	UPPER BOUND MM	LOWER BOUND MM	INCREMENT FRACTION	BED LOAD TRANSPORT RATE TONS/DAY	TOTAL BED MATERIAL TRANS. RATE TONS/DAY
1	.5890	.4170	.1780	.8974E+03	.2063E+04
2	.4170	.2950	.4020	.1745E+04	.6330E+04
3	.2950	.2080	.3200	.1064E+04	.1061E+05
4	.2080	.1470	.0580	.1228E+03	.6895E+04

TOTAL BED LOAD = .3829E+04 TONS/DAY
TOTAL BED MATERIAL LOAD = .2590E+05 TONS/DAY
DEPTH = 2.45889 FT
MEAN VELOCITY = 6.74616 FT/SEC

.173 CP SECONDS EXECUTION TIME

13. JOB PROCESSING TIME:

To compile: 6.9 cpu sec

To execute: 0.126 cpu sec (batch)

0.173 cpu sec (interactive)

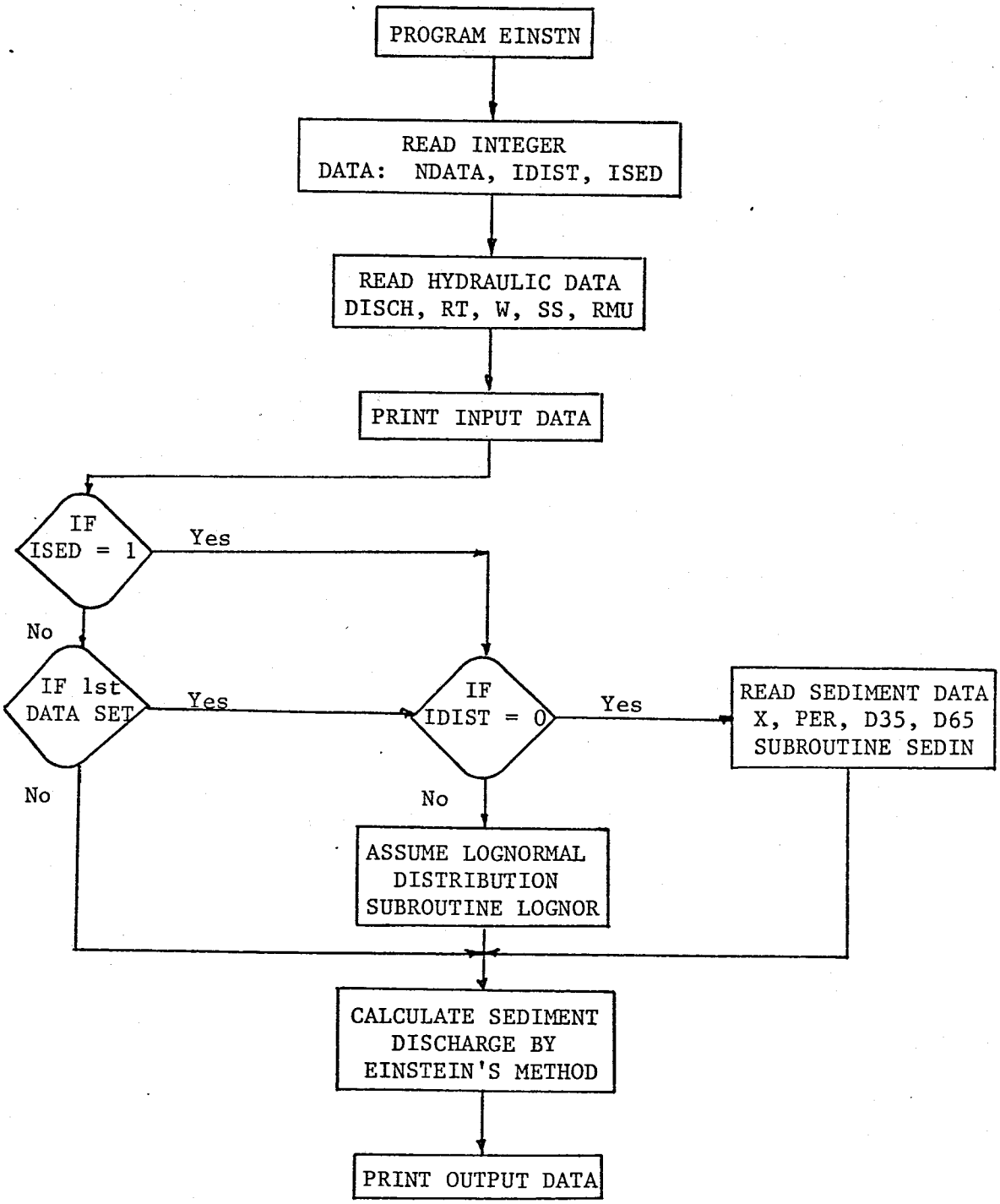

Figure 1. Flow chart of program EINSTN.

```
      PROGRAM EINSTN                                                    EIN 0010
     1(INPUT,OUTPUT)                                                    EIN 0020
C                                                                       EIN 0030
C     DEVELOPED          COLORADO STATE UNIVERSITY ENGINEERING RESEARCH EIN 0040
C                        CENTER, FORT COLLINS, COLORADO 80523.          EIN 0050
C     PURPOSE            COMPUTATION OF BED MATERIAL LOAD BY EINSTEINS  EIN 0060
C                        METHOD.                                        EIN 0070
C     REFERENCE          EINSTEIN, H.A., THE BED-LOAD FUNCTION FOR      EIN 0080
C                        SEDIMENT TRANSPORTATION IN OPEN CHANNEL FLOW,  EIN 0090
C                        TECHNICAL BULLETIN 1026, SEPTEMBER 1950,       EIN 0100
C                        UNITED STATES DEPARTMENT OF AGRICULTURE        EIN 0110
C     CORE USAGE         CDC 6400 SCOPE 3.3 SYSTEM DEFAULT VALUE,       EIN 0120
C                        43000 OCTAL.                                   EIN 0130
C     COMPILATION TIME   APPROXIMATELY 7.0 SEC.                         EIN 0140
C     CENTRAL PROCESSOR                                                 EIN 0150
C     TIME FOR ONE                                                      EIN 0160
C     SET OF DATA        LESS THAN 0.1 SEC.                             EIN 0170
C                                                                       EIN 0180
C                                                                       EIN 0190
C     INPUT AND OUTPUT DESCRIPTION                                      EIN 0200
C                                                                       EIN 0210
C     THE FIRST CARD IN THE INPUT LOGICAL RECORD SHOULD CONTAIN THE     EIN 0220
C     VALUE OF NDATA, IN FORMAT I5. NDATA IS THE NUMBER OF SETS OF INPUTEIN 0230
C     DATA TO BE FED TO THE COMPUTER AT A TIME. A SET OF INPUT DATA     EIN 0240
C     CONSISTS OF A GROUP OF VARIABLES NECESSARY TO SPECIFY A PROBLEM,  EIN 0250
C     AS DETAILED BELOW.                                                EIN 0260
C                                                                       EIN 0270
C     THE SECOND CARD CONTAINS THE VALUE OF IDIST AND ISED IN           EIN 0280
C     FORMAT 2I5                                                        EIN 0290
C     IDIST = SEDIMENT SIZE DISTRIBUTION TYPE                           EIN 0300
C             IF IDIST = 0, READ SEDIMENT SIZE AND PERCENTAGE ARRAYS    EIN 0310
C                           AND D35 AND D65                             EIN 0320
C             IF IDIST = 1, COMPUTE LOG-NORMAL SIZE DISTRIBUTION        EIN 0330
C     ISED = FREQUENCY OF SEDIMENT DATA INPUT                           EIN 0340
C             IF ISED  = 0, SAME SEDIMENT DATA IS USED IN ALL           EIN 0350
C                           CALCULATIONS                                EIN 0360
C             IF ISED  = 1, READ OR COMPUTE SEDIMENT DATA FOR EACH      EIN 0370
C                           HYDRAULIC CONDITION                         EIN 0380
C                                                                       EIN 0390
C     HYDRAULIC DATA FOLLOW                                             EIN 0400
C     A SET OF HYDRAULIC DATA CONSISTS OF THE FOLLOWING VARIABLES,      EIN 0410
C     IN FORMAT(3F10.2,2E10.4)                                          EIN 0420
C                                       FORTRAN NAME        UNITS       EIN 0430
C     1) WATER DISCHARGE                QW                  C.F.S.      EIN 0440
C     2) INITIAL GUESS OF                                               EIN 0450
C        HYDRAULIC RADIUS               RT                  FT.         EIN 0460
C     3) WATER SURFACE WIDTH            W                   FT.         EIN 0470
C     4) ENERGY GRADIENT                SS                  FT./FT.     EIN 0480
C     6) KINEMATIC VISCOSITY            VK                  SQ.FT./SEC. EIN 0490
C                                                                       EIN 0500
C                                                                       EIN 0510
C     SEDIMENT DATA FOLLOW                                              EIN 0520
C                                                                       EIN 0530
C     IF IDIST = 0 READ SEDIMENT SIZES AND PERCENTAGES DEFINING THE     EIN 0540
C     SEDIMENT SIZE DISTRIBUTION OF THE BED MATERIAL.  ALSO READ IN     EIN 0550
C     NUMBER OF SEDIMENT SIZE FRACTIONS AND D35 AND D65                 EIN 0560
C     1) NO OF SEDIMENT SIZE FRACTION   NSIZ                            EIN 0570
C     2) SEDIMENT SIZE OF THE                                           EIN 0580
C        UPPER BOUND                    DRU                 MM          EIN 0590
C     3) SEDIMENT SIZE OF THE                                           EIN 0600
C        LOWER BOUND                    DRL                 MM          EIN 0610
C     3) SEDIMENT  PERCENTAGE           PB                              EIN 0620
C     4) D35                            D35                 MM          EIN 0630
C     5) D65                            D65                 MM          EIN 0640
C                                                                       EIN 0650
```

Figure 2. Batch listing, Program EINSTN.

197

```
C     IF IDIST=1 READ THE MEDIAN BED MATERIAL SIZE AND THE GRADATION
C     COEFFICIENT
C     1) MEDIAN BED MATERIAL SIZE        D50M                    MM
C     2) GRADATION COEFFICIENT           SIGMA
C
C     THESE VARIABLES ARE READ IN IN FORMAT(3F10.4)
C
C     OUTPUT CONSISTS OF FIVE COLUMNS, AS FOLLOWS
C     1) UPPER BOUND SEDIMENT SIZE IN MM
C     2) LOWER BOUND SEDIMENT SIZE IN MM
C     3) SEDIMENT FRACTION PERCENTAGE
C     4) BED LOAD, IN TONS/DAY
C     5) TOTAL BED MATERIAL LOAD, IN TONS/DAY
C
C
      COMMON /SED/          NSIZ        , IDIST       , DRU(20)     ,
     1        DRL(20)      , PB(20)      , D50M        , SIGMA       ,
     2        D35          , D65
      DIMENSION             D(20)       , FV(20)      , CGB(20)     ,
     1        SD(20)       , STR(20)
      PRINT 320
      PRINT 330
      READ 300, NDATA
      READ 300, IDIST,ISED
      DO 220 L = 1,NDATA
         READ 310, QW,RT,W,SS,VK
         IF (L.GT.1.AND.ISED.EQ.0) GO TO 100
         CALL SEDIN
100      CONTINUE
         PRINT 260, L
         PRINT 270, QW,RT,W,SS,VK
         IF (IDIST.EQ.1) PRINT 290, D50M,SIGMA
         PRINT 280, D35,D65
         D65 = D65/304.8
         D35 = D35/304.8
         DO 110 I = 1,NSIZ
            D(I) = (DRU(I) * DRL(I)) *   * 0.5/304.8
            FV(I) = ((2./3. * 32.2 * 1.65 * D(I) *   * 3 + 36. * VK * VK)
     1        *   * 0.5 - 6. * VK)/D(I)
110      CGB(I) = 4.84 * D(I)
         AKP = 0.4
         AA = 0.1
         XK = 0.1 * RT
         XR = 0.0
120      DO 130 II = 1,10
            XI = II
            RBP = XR + XI * XK
            SIP = (1.68 * D35)/(RBP * SS)
            SVP = SQRT(32.2 * RBP * SS)
            DELTA = 11.6 * VK/SVP
            X4 = D65/DELTA
            IF (X4.LT.0.1) GO TO 210
            CALL FIG4 (X4,Y4)
            AJKP = 2.3/AKP
            VELAV = SVP * (AJKP * ALOG10(12.27 * RBP * Y4/D65))
            X5 = SIP
            CALL FIG5 (X5,Y5)
            SVPP = VELAV/Y5
            RBPP = SVPP *   * 2/(32.2 * SS)
            RT = RBP + RBPP
            QT = RT * W * VELAV
            IF (ABS(QT - QW).LE.AA) GO TO 150
            IF (QT.GT.QW.AND.XK.GT.0.0) GO TO 140
            IF (QT.LT.QW.AND.XK.LT.0.0) GO TO 140
130      CONTINUE
```

```
      GO TO 210                                                         EIN 1310
140   XR = RBP                                                          EIN 1320
      XK =  - XK/10.0                                                   EIN 1330
      GO TO 120                                                         EIN 1340
C                                                                       EIN 1350
C     COMPUTATION OF SEDIMENT DISCHARGE BED LOAD                        EIN 1360
C                                                                       EIN 1370
150   DELT = D65/Y4                                                     EIN 1380
      RATIO = DELT/DELTA                                                EIN 1390
      IF (RATIO.LT.1.80) GO TO 160                                      EIN 1400
      CAPX = 0.77 * DELT                                                EIN 1410
      GO TO 170                                                         EIN 1420
160   CAPX = 1.39 * DELTA                                               EIN 1430
170   X8 = D65/DELTA                                                    EIN 1440
      CALL FIG8 (X8,Y8)                                                 EIN 1450
      BETAX = ALOG10(10.6 * CAPX/DELT)                                  EIN 1460
      PP = 2.304 * ALOG10(30.2 * Y4 * RT/D65)                           EIN 1470
      SSD = 0.                                                          EIN 1480
      SSTR = 0.                                                         EIN 1490
      DO 200 I = 1,NSIZ                                                 EIN 1500
         X7 = D(I)/CAPX                                                 EIN 1510
         CALL FIG7 (X7,Y7)                                              EIN 1520
         PSIS = Y7 * Y8 * (1.025/BETAX) *  * 2 * (1.68 * D(I)/(RBP * EIN 1530
    1    SS))                                                           EIN 1540
         X10 = PSIS                                                     EIN 1550
         CALL FIG10 (X10,Y10)                                           EIN 1560
         SD(I) = Y10 * 1205.0 * (D(I) *  * 1.5) * PB(I)                 EIN 1570
         XM = 2.0 * D(I)/RT                                             EIN 1580
         SETV = FV(I)                                                   EIN 1590
         ZZ = SETV/(AKP * SVP)                                          EIN 1600
         IF (ZZ.LT.5.5) GO TO 180                                       EIN 1610
         STR(I) = SD(I)                                                 EIN 1620
         GO TO 190                                                      EIN 1630
180      CALL POWJ (ZZ,XM,XI1,XI2,0.01)                                 EIN 1640
         STR(I) = SD(I) * (PP * XI1 + XI2 + 1.0)                        EIN 1650
190      CONTINUE                                                       EIN 1660
         SD(I) = SD(I) * W * 43.2                                       EIN 1670
         STR(I) = STR(I) * W * 43.2                                     EIN 1680
         SSD = SSD + SD(I)                                              EIN 1690
         SSTR = SSTR + STR(I)                                           EIN 1700
200   CONTINUE                                                          EIN 1710
C                                                                       EIN 1720
      PRINT 230, (I,DRU(I),DRL(I),PB(I),SD(I),STR(I),I = 1,NSIZ)        EIN 1730
      PRINT 240, SSD,SSTR,RT,VELAV                                      EIN 1740
      GO TO 220                                                         EIN 1750
210   PRINT 250                                                         EIN 1760
220 CONTINUE                                                            EIN 1770
C                                                                       EIN 1780
C                                                                       EIN 1790
C                                                                       EIN 1800
230 FORMAT (////, 66H INCREMENT    UPPER     LOWER    INCREMENT  BED LEIN 1810
   1OAD     TOTAL BED,/14X, 35HBOUND     BOUND    FRACTION   TRANS, 16EIN 1820
   2HPORT     MATERIAL,/15X,  2HMM,8X,  2HMM,17X, 18H  RATE      TRANS.EIN 1830
   3,  5H RATE,/43X,2(  9H TONS/DAY,5X)//(1X,I5,F13.4,2F10.4,1X,2E13.4EIN 1840
   4))                                                                  EIN 1850
240 FORMAT (///, 17H TOTAL BED LOAD =,E13.4,  9H TONS/DAY,/, 26H TOTALEIN 1860
   1 BED MATERIAL LOAD =,E13.4,  9H TONS/DAY,/,  8H DEPTH =,F10.5,  3HEIN 1870
   2 FT,/, 16H MEAN VELOCITY =,F10.5,  7H FT/SEC,///)                   EIN 1880
250 FORMAT (///, 26H PROGRAM FAILS TO CONVERGE,///)                     EIN 1890
260 FORMAT (//,  7H SET  ,I3/)                                          EIN 1900
270 FORMAT (5X,34HWATER DISCHARGE                    ,F12.2,12H C.F.S   EIN 1910
   1    ,/5X,34HINITIAL GUESS OF HYDRAULIC RADIUS ,F12.2,12H FT.       EIN 1920
   2  ,/5X,34HWATER SURFACE WIDTH                ,F12.2,12H FT.         EIN 1930
   3,/5X,34HENERGY GRADIENT                   ,F12.7,12H FT./FT.    ,/EIN 1940
   45X,34HKINEMATIC VISCOSITY                ,F12.7,12H SQ.FT./SEC.)   EIN 1950
280 FORMAT (5X,34HD35                          ,F12.3,4H MM.,5X,3EIN 1960
   14HD65                                  ,F12.3,4H MM.,//)          EIN 1970
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  290 FORMAT (5X,34HMEDIAN BED MATERIAL SIZE                    ,F12.3,13H MM.      EIN 1980
     1      ,/5X,34HGRADATION COEFFICIENT                     ,F12.2,)             EIN 1990
  300 FORMAT (2I5)                                                                  EIN 2000
  310 FORMAT (3F10.2,2E10.4)                                                        EIN 2010
  320 FORMAT (1H1)                                                                  EIN 2020
  330 FORMAT (//9X,33HCOMPUTATION OF TOTAL BED MATERIAL,/,10X,38HLOAD BYEIN 2030
     1 THE EINSTEIN BED-LOAD FUNCTION,/)                                            EIN 2040
      END                                                                           EIN 2050
      SUBROUTINE SEDIN                                                              EIN 2060
      COMMON /SED/          NSIZ        , IDIST       , DRU(20)     ,             EIN 2070
     1        DRL(20)      , PB(20)      , D50M        , SIGMA       ,             EIN 2080
     2        D35          , D65                                                   EIN 2090
C                                                                                   EIN 2100
C     THIS SUBROUTINE READS SEDIMENT SIZE DISTRIBUTION DATA                         EIN 2110
C                                                                                   EIN 2120
      IF (IDIST.EQ.1) GO TO 100                                                     EIN 2130
      READ 110, NSIZ                                                                EIN 2140
      READ 120, (DRU(I),DRL(I),PB(I),I = 1,NSIZ)                                    EIN 2150
      READ 120, D35,D65                                                             EIN 2160
      RETURN                                                                        EIN 2170
  100 CALL LOGNOR                                                                   EIN 2180
      RETURN                                                                        EIN 2190
C                                                                                   EIN 2200
  110 FORMAT (I5)                                                                   EIN 2210
  120 FORMAT (3F10.4)                                                               EIN 2220
      END                                                                           EIN 2230
      SUBROUTINE LOGNOR                                                             EIN 2240
      COMMON /SED/          NSIZ        , IDIST       , DRU(20)     ,             EIN 2250
     1        DRL(20)      , PB(20)      , D50M        , SIGMA       ,             EIN 2260
     2        D35          , D65                                                   EIN 2270
C                                                                                   EIN 2280
C     THIS SUBROUTINE COMPUTES A LOG-NORMAL SIZE DISTRIBUTION                       EIN 2290
C                                                                                   EIN 2300
      READ 110, D50M,SIGMA                                                          EIN 2310
C                                                                                   EIN 2320
      NSIZ = 10                                                                     EIN 2330
C                                                                                   EIN 2340
      D05 = D50M/SIGMA *  * 1.645                                                   EIN 2350
      D10 = D50M/SIGMA *  * 1.285                                                   EIN 2360
      D20 = D50M/SIGMA *  * 0.845                                                   EIN 2370
      D30 = D50M/SIGMA *  * 0.525                                                   EIN 2380
      D40 = D50M/SIGMA *  * 0.255                                                   EIN 2390
      D50 = D50M                                                                    EIN 2400
      D60 = D50M * SIGMA *  * 0.255                                                 EIN 2410
      D70 = D50M * SIGMA *  * 0.525                                                 EIN 2420
      D80 = D50M * SIGMA *  * 0.845                                                 EIN 2430
      D90 = D50M * SIGMA *  * 1.285                                                 EIN 2440
      D95 = D50M * SIGMA *  * 1.645                                                 EIN 2450
      DRL(1) = D05                                                                  EIN 2460
      DRU(1) = DRL(1)                                                               EIN 2470
      DRU(2) = D20                                                                  EIN 2480
      DRL(2) = D10                                                                  EIN 2490
      DRU(3) = D30                                                                  EIN 2500
      DRL(3) = D20                                                                  EIN 2510
      DRU(4) = D40                                                                  EIN 2520
      DRL(4) = D30                                                                  EIN 2530
      DRU(5) = D50                                                                  EIN 2540
      DRL(5) = D40                                                                  EIN 2550
      DRU(6) = D60                                                                  EIN 2560
      DRL(6) = D50                                                                  EIN 2570
      DRU(7) = D70                                                                  EIN 2580
      DRL(7) = D60                                                                  EIN 2590
      DRU(8) = D80                                                                  EIN 2600
      DRL(8) = D70                                                                  EIN 2610
      DRU(9) = D90                                                                  EIN 2620
```

```
      DRL(9) = D80                                                      EIN 2630
      DRL(10) = D95                                                     EIN 2640
      DRU(10) = DRL(10)                                                 EIN 2650
      DO 100 I = 1,NSIZ                                                 EIN 2660
  100 PB(I) = 0.1                                                       EIN 2670
      D35 = D50M/SIGMA *   * .385                                       EIN 2680
      D65 = D50M * SIGMA *   * .385                                     EIN 2690
C                                                                       EIN 2700
C                                                                       EIN 2710
      RETURN                                                            EIN 2720
C                                                                       EIN 2730
  110 FORMAT (3F10.4)                                                   EIN 2740
      END                                                               EIN 2750
      SUBROUTINE FIG4 (X,Y)                                             EIN 2760
C                                                                       EIN 2770
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 4 SERIES OF EQNS.      EIN 2780
C                                                                       EIN 2790
      IF (X.LE.0.40) GO TO 100                                          EIN 2800
      GO TO 110                                                         EIN 2810
  100 Y = 1.769 * ALOG10(X/0.080)                                       EIN 2820
      GO TO 260                                                         EIN 2830
  110 IF (X.GT.0.40.AND.X.LE.0.56) GO TO 120                            EIN 2840
      GO TO 130                                                         EIN 2850
  120 Y = 1.495 * ALOG10(X/0.059)                                       EIN 2860
      GO TO 260                                                         EIN 2870
  130 IF (X.GT.0.56.AND.X.LE.0.76) GO TO 140                            EIN 2880
      GO TO 150                                                         EIN 2890
  140 Y = 0.92 * ALOG10(X/0.0145)                                       EIN 2900
      GO TO 260                                                         EIN 2910
  150 IF (X.GT.0.76.AND.X.LE.0.96) GO TO 160                            EIN 2920
      GO TO 170                                                         EIN 2930
  160 Y = 0.292 * ALOG10(X/2.9E - 06)                                   EIN 2940
      GO TO 260                                                         EIN 2950
  170 IF (X.GT.0.96.AND.X.LE.1.35) GO TO 180                            EIN 2960
      GO TO 190                                                         EIN 2970
  180 Y = 0.277 * ALOG10(632000.0/X)                                    EIN 2980
      GO TO 260                                                         EIN 2990
  190 IF (X.GT.1.35.AND.X.LE.3.00) GO TO 200                            EIN 3000
      GO TO 210                                                         EIN 3010
  200 Y = 1.115 * ALOG10(34.4/X)                                        EIN 3020
      GO TO 260                                                         EIN 3030
  210 IF (X.GT.3.00.AND.X.LE.4.00) GO TO 220                            EIN 3040
      GO TO 230                                                         EIN 3050
  220 Y = 0.725 * ALOG10(128.0/X)                                       EIN 3060
      GO TO 260                                                         EIN 3070
  230 IF (X.GT.4.00.AND.X.LE.6.70) GO TO 240                            EIN 3080
      GO TO 250                                                         EIN 3090
  240 Y = 0.399 * ALOG10(2160.0/X)                                      EIN 3100
      GO TO 260                                                         EIN 3110
  250 IF (X.GT.6.70) Y = 1.0                                            EIN 3120
  260 RETURN                                                            EIN 3130
C                                                                       EIN 3140
      END                                                               EIN 3150
      SUBROUTINE FIG5 (X,Y)                                             EIN 3160
C                                                                       EIN 3170
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 5 BY A SERIES OF EQNS. EIN 3180
C                                                                       EIN 3190
      IF (X.LE.1.0) GO TO 100                                           EIN 3200
      GO TO 110                                                         EIN 3210
  100 Y = 40.0 * X *   * ( - 1.288)                                     EIN 3220
      GO TO 180                                                         EIN 3230
  110 IF (X.GT.1.0.AND.X.LE.2.0) GO TO 120                              EIN 3240
      GO TO 130                                                         EIN 3250
  120 Y = 40.0 * X *   * ( - 0.982)                                     EIN 3260
      GO TO 180                                                         EIN 3270
  130 IF (X.GT.2.0.AND.X.LE.4.0) GO TO 140                              EIN 3280
      GO TO 150                                                         EIN 3290
```

```
  140 Y = 31.1 * X *   * ( - 0.618)                                    EIN 3300
      GO TO 180                                                        EIN 3310
  150 IF (X.GT.4.0.AND.X.LE.8.0) GO TO 160                             EIN 3320
      GO TO 170                                                        EIN 3330
  160 Y = 26.0 * X *   * ( - 0.486)                                    EIN 3340
      GO TO 180                                                        EIN 3350
  170 IF (X.GT.8.0) Y = 21.4 * X *   * ( - 0.394)                      EIN 3360
  180 RETURN                                                           EIN 3370
C                                                                      EIN 3380
      END                                                              EIN 3390
      SUBROUTINE FIG7 (X,Y)                                            EIN 3400
C                                                                      EIN 3410
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 7 BY A SERIES OF EQNS. EIN 3420
C                                                                      EIN 3430
      IF (X.LE.0.20) Y = (X/1.090) *   * ( - 2.088)                    EIN 3440
      IF (X.GT.0.20.AND.X.LE.0.40) Y = (X/0.877) *   * ( - 2.402)      EIN 3450
      IF (X.GT.0.40.AND.X.LE.0.65) Y = (X/0.832) *   * ( - 2.582)      EIN 3460
      IF (X.GT.0.65.AND.X.LE.0.80) Y = (X/0.990) *   * ( - 1.515)      EIN 3470
      IF (X.GT.0.80.AND.X.LE.1.00) Y = (X/1.185) *   * ( - 0.826)      EIN 3480
      IF (X.GT.1.00.AND.X.LE.1.45) Y = (X/1.450) *   * ( - 0.375)      EIN 3490
      IF (X.GT.1.45) Y = 1.0                                           EIN 3500
      RETURN                                                           EIN 3510
C                                                                      EIN 3520
      END                                                              EIN 3530
      SUBROUTINE FIG8 (X,Y)                                            EIN 3540
C                                                                      EIN 3550
C     THIS SUBROUTINE ESTIMATES EINSTEINS FIG 8 BY A SERIES OF EQNS.   EIN 3560
C                                                                      EIN 3570
      IF (X.LT.0.66) Y = (X/1.005) *   * 1.178                         EIN 3580
      IF (X.GT.0.66.AND.X.LE.0.84) Y = (X/1.104) *   * (0.957)         EIN 3590
      IF (X.GT.0.84.AND.X.LE.1.10) Y = (X/1.940) *   * (0.310)         EIN 3600
      IF (X.GT.1.10.AND.X.LE.1.30) Y = (X/0.475) *   * ( - 0.208)      EIN 3610
      IF (X.GT.1.30.AND.X.LE.2.20) Y = (X/0.930) *   * ( - 0.633)      EIN 3620
      IF (X.GT.2.20.AND.X.LE.3.10) Y = (X/0.278) *   * ( - 0.266)      EIN 3630
      IF (X.GT.3.10) Y = 0.530                                         EIN 3640
      RETURN                                                           EIN 3650
C                                                                      EIN 3660
      END                                                              EIN 3670
      SUBROUTINE POWJ (Z,A,XJ1,XJ2,CONV)                               EIN 3680
      N = 1                                                            EIN 3690
      XJ1 = 0.                                                         EIN 3700
      XJ2 = 0.                                                         EIN 3710
      ALG = ALOG(A)                                                    EIN 3720
      C = 1.                                                           EIN 3730
      D =  - Z                                                         EIN 3740
      E = D + 1.                                                       EIN 3750
      FN = 1.                                                          EIN 3760
      AEX = A *   * E                                                  EIN 3770
      GO TO 110                                                        EIN 3780
  100 N = N + 1                                                        EIN 3790
      C = C * D/FN                                                     EIN 3800
      D = E                                                            EIN 3810
      E = D + 1.                                                       EIN 3820
      FN = FLOAT(N)                                                    EIN 3830
      AEX = A *   * E                                                  EIN 3840
  110 IF (ABS(E).LE.0.001) GO TO 120                                   EIN 3850
      XJ1 = XJ1 + C * (1. - AEX)/E                                     EIN 3860
      XJ2 = XJ2 + C * ((AEX - 1.)/E *   * 2 - AEX * ALG/E)             EIN 3870
      GO TO 130                                                        EIN 3880
  120 XJ1 = XJ1 - C * ALG                                              EIN 3890
      XJ2 = XJ2 - 0.5 * C * ALG *   * 2                                EIN 3900
  130 IF (N.EQ.1) GO TO 140                                            EIN 3910
      CJ1 = ABS(1. - FJ1/XJ1)                                          EIN 3920
      CJ2 = ABS(1. - FJ2/XJ2)                                          EIN 3930
      IF (CJ1.LE.CONV.AND.CJ2.LE.CONV) GO TO 150                       EIN 3940
```

```
  140 FJ1 = XJ1                                                         EIN 3950
      FJ2 = XJ2                                                         EIN 3960
      GO TO 100                                                         EIN 3970
  150 FACT = 0.216 * (A *  * (Z - 1.))/((1. - A) *  * Z)                EIN 3980
      XJ1 = FACT * XJ1                                                  EIN 3990
      XJ2 = FACT * XJ2                                                  EIN 4000
      RETURN                                                            EIN 4010
C                                                                       EIN 4020
      END                                                               EIN 4030
      SUBROUTINE FIG10 (X,Y)                                            EIN 4040
C                                                                       EIN 4050
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 10 BY A SERIES OF EQNS.EIN 4060
C                                                                       EIN 4070
      IF (X.LT..4) Y = 8.106078 * X *  * ( - 0.989002)                  EIN 4080
      IF (X.LE.1..AND.X.GE..4) Y = 7.473444 * X *  * ( - 1.067367)      EIN 4090
      IF (X.LT.2..AND.X.GT.1.) Y = 7.512081 * X *  * ( - 1.182832)      EIN 4100
      IF (X.LE.3..AND.X.GE.2.) Y = 9.151968 * X *  * ( - 1.472483)      EIN 4110
      IF (X.LT.5..AND.X.GT.3.) Y = 16.025332 * X *  * ( - 1.972806)     EIN 4120
      IF (X.LE.7..AND.X.GE.5.) Y = 41.421873 * X *  * ( - 2.578713)     EIN 4130
      IF (X.LT.10..AND.X.GT.7.) Y = 130.2209 * X *  * ( - 3.165102)     EIN 4140
      IF (X.LE.13..AND.X.GE.10.) Y = 584.560594 * X *  * ( - 3.818249)  EIN 4150
      IF (X.LT.17..AND.X.GT.13.) Y = 3543.989886 * X *  * ( - 4.522935) EIN 4160
      IF (X.LE.20..AND.X.GE.17.) Y = 1690645.945 * X *  * ( - 6.703904) EIN 4170
      IF (X.LT.23..AND.X.GT.20.) Y = 5188257832. * X *  * ( - 9.381815) EIN 4180
      IF (X.GE.23.) Y = 3.134987996E15 * X *  * ( - 13.597547)          EIN 4190
      RETURN                                                            EIN 4200
C                                                                       EIN 4210
      END                                                               EIN 4220
```

```
      PROGRAM EINSTNI                                                   EINI0010
     1(INPUT,OUTPUT)                                                    EINI0020
C                                                                       EINI0030
C     DEVELOPED          COLORADO STATE UNIVERSITY ENGINEERING RESEARCH EINI0040
C                        CENTER, FORT COLLINS, COLORADO 80523.          EINI0050
C     PURPOSE            COMPUTATION OF BED MATERIAL LOAD BY EINSTEINS  EINI0060
C                        METHOD.                                        EINI0070
C     REFERENCE          EINSTEIN, H.A., THE BED-LOAD FUNCTION FOR      EINI0080
C                        SEDIMENT TRANSPORTATION IN OPEN CHANNEL FLOW,  EINI0090
C                        TECHNICAL BULLETIN 1026, SEPTEMBER 1950,       EINI0100
C                        UNITED STATES DEPARTMENT OF AGRICULTURE        EINI0110
C     CORE USAGE         CDC 6400 SCOPE 3.3 SYSTEM DEFAULT VALUE,       EINI0120
C                        43000 OCTAL.                                   EINI0130
C     COMPILATION TIME   APPROXIMATELY 7.0 SEC.                         EINI0140
C     CENTRAL PROCESSOR                                                 EINI0150
C     TIME FOR ONE                                                      EINI0160
C     SET OF DATA        LESS THAN 0.1 SEC.                             EINI0170
C                                                                       EINI0180
C                                                                       EINI0190
C     INPUT AND OUTPUT DESCRIPTION                                      EINI0200
C                                                                       EINI0210
C     THE FIRST CARD IN THE INPUT LOGICAL RECORD SHOULD CONTAIN THE     EINI0220
C     VALUE OF NDATA,IN FREE FORMAT.NDATA IS THE NUMBER OF SETS OF INPUTEINI0230
C     DATA TO BE FED TO THE COMPUTER AT A TIME. A SET OF INPUT DATA     EINI0240
C     CONSISTS OF A GROUP OF VARIABLES NECESSARY TO SPECIFY A PROBLEM,  EINI0250
C     AS DETAILED BELOW.                                                EINI0260
C                                                                       EINI0270
C     THE SECOND AND THIRD CARDS CONTAIN THE VALUE OF IDIST AND ISED IN EINI0280
C     FREE FORMAT                                                       EINI0290
C     IDIST = SEDIMENT SIZE DISTRIBUTION TYPE                           EINI0300
C             IF IDIST = 0, READ SEDIMENT SIZE AND PERCENTAGE ARRAYS    EINI0310
C                           AND D35 AND D65                             EINI0320
C             IF IDIST = 1, COMPUTE LOG-NORMAL SIZE DISTRIBUTION        EINI0330
C     ISED = FREQUENCY OF SEDIMENT DATA INPUT                           EINI0340
C             IF ISED  = 0, SAME SEDIMENT DATA IS USED IN ALL           EINI0350
C                           CALCULATIONS                                EINI0360
C             IF ISED  = 1, READ OR COMPUTE SEDIMENT DATA FOR EACH      EINI0370
C                           HYDRAULIC CONDITION                         EINI0380
C                                                                       EINI0390
C     HYDRAULIC DATA FOLLOW                                             EINI0400
C     A SET OF HYDRAULIC DATA CONSISTS OF THE FOLLOWING VARIABLES,      EINI0410
C     IN FREE FORMAT                                                    EINI0420
C                                       FORTRAN NAME        UNITS       EINI0430
C     1) WATER DISCHARGE                QW                  C.F.S.      EINI0440
C     2) INITIAL GUESS OF                                               EINI0450
C        HYDRAULIC RADIUS               RT                  FT.         EINI0460
C     3) WATER SURFACE WIDTH            W                   FT.         EINI0470
C     4) ENERGY GRADIENT                SS                  FT./FT.     EINI0480
C     6) KINEMATIC VISCOSITY            VK                  SQ.FT./SEC. EINI0490
C                                                                       EINI0500
C                                                                       EINI0510
C     SEDIMENT DATA FOLLOW                                              EINI0520
C                                                                       EINI0530
C     IF IDIST = 0 READ SEDIMENT SIZES AND PERCENTAGES DEFINING THE     EINI0540
C     SEDIMENT SIZE DISTRIBUTION OF THE BED MATERIAL.  ALSO READ IN     EINI0550
C     NUMBER OF SEDIMENT SIZE FRACTIONS AND D35 AND D65                 EINI0560
C     1) NO OF SEDIMENT SIZE FRACTION   NSIZ                            EINI0570
C     2) SEDIMENT SIZE OF THE                                           EINI0580
C        UPPER BOUND                    DRU                 MM          EINI0590
C     3) SEDIMENT SIZE OF THE                                           EINI0600
C        LOWER BOUND                    DRL                 MM          EINI0610
C     3) SEDIMENT  PERCENTAGE           PB                              EINI0620
C     4) D35                            D35                 MM          EINI0630
C     5) D65                            D65                 MM          EINI0640
```

Figure 3. Interactive listing, Program EINSTN

```
C                                                                       EINI0650
C     IF IDIST=1 READ THE MEDIAN BED MATERIAL SIZE AND THE GRADATION    EINI0660
C     COEFFICIENT                                                       EINI0670
C     1) MEDIAN BED MATERIAL SIZE        D50M                  MM       EINI0680
C     2) GRADATION COEFFICIENT           SIGMA                          EINI0690
C                                                                       EINI0700
C     THESE VARIABLES ARE READ IN IN FREE FORMAT                        EINI0710
C                                                                       EINI0720
C     OUTPUT CONSISTS OF FIVE COLUMNS, AS FOLLOWS                       EINI0730
C     1) UPPER BOUND SEDIMENT SIZE IN MM                                EINI0740
C     2) LOWER BOUND SEDIMENT SIZE IN MM                                EINI0750
C     3) SEDIMENT FRACTION PERCENTAGE                                   EINI0760
C     4) BED LOAD, IN TONS/DAY                                          EINI0770
C     5) TOTAL BED MATERIAL LOAD, IN TONS/DAY                           EINI0780
C                                                                       EINI0790
C                                                                       EINI0800
      COMMON /SED/          NSIZ        , IDIST       , DRU(20)      ,  EINI0810
     1        DRL(20)      , PB(20)      , D50M        , SIGMA        ,  EINI0820
     2        D35          , D65                                        EINI0830
      DIMENSION             D(20)       , FV(20)      , CGB(20)      ,  EINI0840
     1        SD(20)       , STR(20)                                    EINI0850
      PRINT 380                                                         EINI0860
      PRINT 390                                                         EINI0870
      PRINT 300                                                         EINI0880
      READ   *, NDATA                                                   EINI0890
      PRINT 310                                                         EINI0900
      READ   *, IDIST                                                   EINI0910
      PRINT 320                                                         EINI0920
      READ   *, ISED                                                    EINI0930
      DO 220 L = 1,NDATA                                                EINI0940
         PRINT 330                                                      EINI0950
         READ   *, QW                                                   EINI0960
         PRINT 340                                                      EINI0970
         READ   *, RT                                                   EINI0980
         PRINT 350                                                      EINI0990
         READ   *, W                                                    EINI1000
         PRINT 360                                                      EINI1010
         READ   *, SS                                                   EINI1020
         PRINT 370                                                      EINI1030
         READ   *, VK                                                   EINI1040
         IF (L.GT.1.AND.ISED.EQ.0) GO TO 100                            EINI1050
         CALL SEDIN                                                     EINI1060
 100     CONTINUE                                                       EINI1070
         PRINT 260, L                                                   EINI1080
         PRINT 270, QW,RT,W,SS,VK                                       EINI1090
         IF (IDIST.EQ.1) PRINT 290, D50M,SIGMA                          EINI1100
         PRINT 280, D35,D65                                             EINI1110
         D65 = D65/304.8                                                EINI1120
         D35 = D35/304.8                                                EINI1130
         DO 110 I = 1,NSIZ                                              EINI1140
            D(I) = (DRU(I) * DRL(I)) *   * 0.5/304.8                    EINI1150
            FV(I) = ((2./3. * 32.2 * 1.65 * D(I) *   * 3 + 36. * VK * VK)EINI1160
     1       *   * 0.5 - 6. * VK)/D(I)                                  EINI1170
 110     CGB(I) = 4.84 * D(I)                                           EINI1180
         AKP = 0.4                                                      EINI1190
         AA = 0.1                                                       EINI1200
         XK = 0.1 * RT                                                  EINI1210
         XR = 0.0                                                       EINI1220
 120     DO 130 II = 1,10                                               EINI1230
            XI = II                                                     EINI1240
            RBP = XR + XI * XK                                          EINI1250
            SIP = (1.68 * D35)/(RBP * SS)                               EINI1260
            SVP = SQRT(32.2 * RBP * SS)                                 EINI1270
            DELTA = 11.6 * VK/SVP                                       EINI1280
            X4 = D65/DELTA                                              EINI1290
            IF (X4.LT.0.1) GO TO 210                                    EINI1300
            CALL FIG4 (X4,Y4)                                           EINI1310
```

```
            AJKP = 2.3/AKP                                              EINI1320
            VELAV = SVP * (AJKP * ALOG10(12.27 * RBP * Y4/D65))         EINI1330
            X5 = SIP                                                    EINI1340
            CALL FIG5 (X5,Y5)                                           EINI1350
            SVPP = VELAV/Y5                                             EINI1360
            RBPP = SVPP *  * 2/(32.2 * SS)                              EINI1370
            RT = RBP + RBPP                                             EINI1380
            QT = RT * W * VELAV                                         EINI1390
            IF (ABS(QT - QW).LE.AA) GO TO 150                           EINI1400
            IF (QT.GT.QW.AND.XK.GT.0.0) GO TO 140                       EINI1410
            IF (QT.LT.QW.AND.XK.LT.0.0) GO TO 140                       EINI1420
  130     CONTINUE                                                      EINI1430
          GO TO 210                                                     EINI1440
  140     XR = RBP                                                      EINI1450
          XK =  - XK/10.0                                               EINI1460
          GO TO 120                                                     EINI1470
C                                                                       EINI1480
C     COMPUTATION OF SEDIMENT DISCHARGE BED LOAD                        EINI1490
C                                                                       EINI1500
  150     DELT = D65/Y4                                                 EINI1510
          RATIO = DELT/DELTA                                            EINI1520
          IF (RATIO.LT.1.80) GO TO 160                                  EINI1530
          CAPX = 0.77 * DELT                                            EINI1540
          GO TO 170                                                     EINI1550
  160     CAPX = 1.39 * DELTA                                           EINI1560
  170     X8 = D65/DELTA                                                EINI1570
          CALL FIG8 (X8,Y8)                                             EINI1580
          BETAX = ALOG10(10.6 * CAPX/DELT)                              EINI1590
          PP = 2.304 * ALOG10(30.2 * Y4 * RT/D65)                       EINI1600
          SSD = 0.                                                      EINI1610
          SSTR = 0.                                                     EINI1620
          DO 200 I = 1,NSIZ                                             EINI1630
             X7 = D(I)/CAPX                                             EINI1640
             CALL FIG7 (X7,Y7)                                          EINI1650
             PSIS = Y7 * Y8 * (1.025/BETAX) *  * 2 * (1.68 * D(I)/(RBP * EINI1660
     1       SS))                                                       EINI1670
             X10 = PSIS                                                 EINI1680
             CALL FIG10 (X10,Y10)                                       EINI1690
             SD(I) = Y10 * 1205.0 * (D(I) *  * 1.5) * PB(I)             EINI1700
             XM = 2.0 * D(1)/RT                                         EINI1710
             SETV = FV(I)                                               EINI1720
             ZZ = SETV/(AKP * SVP)                                      EINI1730
             IF (ZZ.LT.5.5) GO TO 180                                   EINI1740
             STR(I) = SD(I)                                             EINI1750
             GO TO 190                                                  EINI1760
  180        CALL POWJ (ZZ,XM,XI1,XI2,0.01)                             EINI1770
             STR(I) = SD(I) * (PP * XI1 + XI2 + 1.0)                    EINI1780
  190        CONTINUE                                                   EINI1790
             SD(I) = SD(I) * W * 43.2                                   EINI1800
             STR(I) = STR(I) * W * 43.2                                 EINI1810
             SSD = SSD + SD(I)                                          EINI1820
             SSTR = SSTR + STR(I)                                       EINI1830
  200     CONTINUE                                                      EINI1840
C                                                                       EINI1850
          PRINT 230, (I,DRU(I),DRL(I),PB(I),SD(I),STR(I),I = 1,NSIZ)    EINI1860
          PRINT 240, SSD,SSTR,RT,VELAV                                  EINI1870
          GO TO 220                                                     EINI1880
  210     PRINT 250                                                     EINI1890
  220 CONTINUE                                                          EINI1900
C                                                                       EINI1910
C                                                                       EINI1920
C                                                                       EINI1930
  230 FORMAT (////, 66H INCREMENT    UPPER     LOWER    INCREMENT  BED LEINI1940
     1OAD     TOTAL BED,/14X, 35HBOUND     BOUND    FRACTION   TRANS, 16EINI1950
     2HPORT     MATERIAL,/15X,  2HMM,8X,  2HMM,17X, 18H  RATE      TRANS.EINI1960
     3,  5H RATE,/43X,2(  9H TONS/DAY,5X)//(1X,I5,F13.4,2F10.4,1X,2E13.4EINI1970
     4))                                                                EINI1980
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```
  240 FORMAT (///, 17H TOTAL BED LOAD =,E13.4,  9H TONS/DAY,/, 26H TOTALEINI1990
     1 BED MATERIAL LOAD =,E13.4,  9H TONS/DAY,/,  8H DEPTH =,F10.5,  3HEINI2000
     2 FT,/, 16H MEAN VELOCITY =,F10.5,  7H FT/SEC,///)                EINI2010
  250 FORMAT (///, 26H PROGRAM FAILS TO CONVERGE,///)                  EINI2020
  260 FORMAT (//,  7H SET   ,I3/)                                      EINI2030
  270 FORMAT (5X,34HWATER DISCHARGE                    ,F12.2,12H C.F.S  EINI2040
     1    ,/5X,34HINITIAL GUESS OF HYDRAULIC RADIUS ,F12.2,12H FT.     EINI2050
     2  ,/5X,34HWATER SURFACE WIDTH                ,F12.2,12H FT.      EINI2060
     3,/5X,34HENERGY GRADIENT                  ,F12.7,12H FT./FT.    ,/EINI2070
     45X,34HKINEMATIC VISCOSITY                ,F12.7,12H SQ.FT./SEC.) EINI2080
  280 FORMAT (5X,34HD35                              ,F12.3,4H MM.,5X,3EINI2090
     14HD65                                ,F12.3,4H MM.,//)           EINI2100
  290 FORMAT (5X,34HMEDIAN BED MATERIAL SIZE           ,F12.3,13H MM.   EINI2110
     1     ,/5X,34HGRADATION COEFFICIENT             ,F12.2,)           EINI2120
  300 FORMAT (//, 32H START INPUT DATA IN FREE FORMAT,//, 39H ENTER THE EINI2130
     1NUMBER OF SETS OF INPUT DATA)                                    EINI2140
  310 FORMAT (//, 43H SET SIZE DISTRIBUTION TYPE, IDIST = 0 OR 1,/, 62H EINI2150
     1  ENTER 0 IF THE SEDIMENT SIZES AND PERCENTAGES DEFINING THE , 44HEINI2160
     2SEDIMENT SIZE DISTRIBUTION ARE TO BE READ IN,/, 59H   ENTER 1 IF TEINI2170
     3HE LOG-NORMAL SEDIMENT SIZE DISTRIBUTION IS , 16HTO BE EVALUATED )EINI2180
  320 FORMAT (//, 46H ENTER 0 IF SEDIMENT DATA WILL NOT BE CHANGED , 33HEINI2190
     1FOR DIFFERENT HYDRAULIC CONDITION,/, 57H ENTER 1 IF THE SEDIMENT DEINI2200
     2ATA ARE TO BE READ OR COMPUTED , 28HFOR EACH HYDRAULIC CONDITION) EINI2210
  330 FORMAT (//////, 36H ENTER THE FOLLOWING HYDRAULIC DATA:,//, 43H   EINI2220
     1WATER DISCHARGE IN CUBIC FEET PER SECOND)                        EINI2230
  340 FORMAT ( 44H   INITIAL GUESS OF HYDRAULIC RADIUS IN FEET)        EINI2240
  350 FORMAT ( 30H   WATER SURFACE WIDTH IN FEET)                      EINI2250
  360 FORMAT ( 28H   ENERGY SLOPE IN FEET/FEET)                        EINI2260
  370 FORMAT ( 37H   KINEMATIC VISCOSITY IN SQ.FT./SEC.)               EINI2270
  380 FORMAT (1H1)                                                     EINI2280
  390 FORMAT (//9X,33HCOMPUTATION OF TOTAL BED MATERIAL,/,10X,38HLOAD BYEINI2290
     1 THE EINSTEIN BED-LOAD FUNCTION,/)                               EINI2300
      END                                                              EINI2310
      SUBROUTINE SEDIN                                                 EINI2320
      COMMON /SED/          NSIZ        , IDIST       , DRU(20)     ,  EINI2330
     1        DRL(20)      , PB(20)      , D50M        , SIGMA       ,  EINI2340
     2        D35          , D65                                       EINI2350
C                                                                      EINI2360
C     THIS SUBROUTINE READS SEDIMENT SIZE DISTRIBUTION DATA            EINI2370
C                                                                      EINI2380
      IF (IDIST.EQ.1) GO TO 100                                        EINI2390
      PRINT 110                                                        EINI2400
      READ   *, NSIZ                                                   EINI2410
      PRINT 120                                                        EINI2420
      READ   *, (DRU(I),DRL(I),PB(I),I = 1,NSIZ)                       EINI2430
      PRINT 130                                                        EINI2440
      READ   *, D35,D65                                                EINI2450
      RETURN                                                           EINI2460
  100 CALL LOGNOR                                                      EINI2470
      RETURN                                                           EINI2480
C                                                                      EINI2490
  110 FORMAT (//, 48H IDIST=0 ENTER THE FOLLOWING BED MATERIAL DATA: ,//EINI2500
     1, 54H   NUMBER OF SEDIMENT SIZE FRACTIONS, NSIZ, MAX. OF 20)     EINI2510
  120 FORMAT ( 55H   THE UPPER BOUND SIZE AND LOWER BOUND SIZE IN MM, ANEINI2520
     1D,/, 47H   THE PERCENT WEIGHT OF EACH SEDIMENT FRACTION,/, 38H   EINI2530
     2    (DRU(I),DRL(I),PB(I),I=1,NSIZ))                             EINI2540
  130 FORMAT ( 53H   THE 35% AND 65% FINER DIAMETERS IN MM, D35 AND D65)EINI2550
      END                                                              EINI2560
      SUBROUTINE LOGNOR                                                EINI2570
      COMMON /SED/          NSIZ        , IDIST       , DRU(20)     ,  EINI2580
     1        DRL(20)      , PB(20)      , D50M        , SIGMA       ,  EINI2590
     2        D35          , D65                                       EINI2600
C                                                                      EINI2610
C     THIS SUBROUTINE COMPUTES A LOG-NORMAL SIZE DISTRIBUTION          EINI2620
C                                                                      EINI2630
```

```
      PRINT 110                                                         EINI2640
      READ   *, D50M,SIGMA                                              EINI2650
C                                                                       EINI2660
      NSIZ = 10                                                         EINI2670
C                                                                       EINI2680
      D05 = D50M/SIGMA *  * 1.645                                       EINI2690
      D10 = D50M/SIGMA *  * 1.285                                       EINI2700
      D20 = D50M/SIGMA *  * 0.845                                       EINI2710
      D30 = D50M/SIGMA *  * 0.525                                       EINI2720
      D40 = D50M/SIGMA *  * 0.255                                       EINI2730
      D50 = D50M                                                        EINI2740
      D60 = D50M * SIGMA *  * 0.255                                     EINI2750
      D70 = D50M * SIGMA *  * 0.525                                     EINI2760
      D80 = D50M * SIGMA *  * 0.845                                     EINI2770
      D90 = D50M * SIGMA *  * 1.285                                     EINI2780
      D95 = D50M * SIGMA *  * 1.645                                     EINI2790
      DRL(1) = D05                                                      EINI2800
      DRU(1) = DRL(1)                                                   EINI2810
      DRU(2) = D20                                                      EINI2820
      DRL(2) = D10                                                      EINI2830
      DRU(3) = D30                                                      EINI2840
      DRL(3) = D20                                                      EINI2850
      DRU(4) = D40                                                      EINI2860
      DRL(4) = D30                                                      EINI2870
      DRU(5) = D50                                                      EINI2880
      DRL(5) = D40                                                      EINI2890
      DRU(6) = D60                                                      EINI2900
      DRL(6) = D50                                                      EINI2910
      DRU(7) = D70                                                      EINI2920
      DRL(7) = D60                                                      EINI2930
      DRU(8) = D80                                                      EINI2940
      DRL(8) = D70                                                      EINI2950
      DRU(9) = D90                                                      EINI2960
      DRL(9) = D80                                                      EINI2970
      DRL(10) = D95                                                     EINI2980
      DRU(10) = DRL(10)                                                 EINI2990
      DO 100 I = 1,NSIZ                                                 EINI3000
  100 PB(I) = 0.1                                                       EINI3010
      D35 = D50M/SIGMA *  * .385                                        EINI3020
      D65 = D50M * SIGMA *  * .385                                      EINI3030
C                                                                       EINI3040
C                                                                       EINI3050
      RETURN                                                            EINI3060
C                                                                       EINI3070
  110 FORMAT (//, 50H IDIST=1 ENTER THE MEDIAN BED MATERIAL SIZE IN MM ,EINI3080
     1 29HAND THE GRADATION COEFFICIENT)                                EINI3090
      END                                                               EINI3100
      SUBROUTINE FIG4 (X,Y)                                             EINI3110
C                                                                       EINI3120
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 4 SERIES OF EQNS.      EINI3130
C                                                                       EINI3140
      IF (X.LE.0.40) GO TO 100                                          EINI3150
      GO TO 110                                                         EINI3160
  100 Y = 1.769 * ALOG10(X/0.080)                                       EINI3170
      GO TO 260                                                         EINI3180
  110 IF (X.GT.0.40.AND.X.LE.0.56) GO TO 120                            EINI3190
      GO TO 130                                                         EINI3200
  120 Y = 1.495 * ALOG10(X/0.059)                                       EINI3210
      GO TO 260                                                         EINI3220
  130 IF (X.GT.0.56.AND.X.LE.0.76) GO TO 140                            EINI3230
      GO TO 150                                                         EINI3240
  140 Y = 0.92 * ALOG10(X/0.0145)                                       EINI3250
      GO TO 260                                                         EINI3260
  150 IF (X.GT.0.76.AND.X.LE.0.96) GO TO 160                            EINI3270
      GO TO 170                                                         EINI3280
  160 Y = 0.292 * ALOG10(X/2.9E - 06)                                   EINI3290
```

```
      GO TO 260                                                         EINI3300
  170 IF (X.GT.0.96.AND.X.LE.1.35) GO TO 180                            EINI3310
      GO TO 190                                                         EINI3320
  180 Y = 0.277 * ALOG10(632000.0/X)                                    EINI3330
      GO TO 260                                                         EINI3340
  190 IF (X.GT.1.35.AND.X.LE.3.00) GO TO 200                            EINI3350
      GO TO 210                                                         EINI3360
  200 Y = 1.115 * ALOG10(34.4/X)                                        EINI3370
      GO TO 260                                                         EINI3380
  210 IF (X.GT.3.00.AND.X.LE.4.00) GO TO 220                            EINI3390
      GO TO 230                                                         EINI3400
  220 Y = 0.725 * ALOG10(128.0/X)                                       EINI3410
      GO TO 260                                                         EINI3420
  230 IF (X.GT.4.00.AND.X.LE.6.70) GO TO 240                            EINI3430
      GO TO 250                                                         EINI3440
  240 Y = 0.399 * ALOG10(2160.0/X)                                      EINI3450
      GO TO 260                                                         EINI3460
  250 IF (X.GT.6.70) Y = 1.0                                            EINI3470
  260 RETURN                                                            EINI3480
C                                                                       EINI3490
      END                                                               EINI3500
      SUBROUTINE FIG5 (X,Y)                                             EINI3510
C                                                                       EINI3520
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 5 BY A SERIES OF EQNS. EINI3530
C                                                                       EINI3540
      IF (X.LE.1.0) GO TO 100                                           EINI3550
      GO TO 110                                                         EINI3560
  100 Y = 40.0 * X *  * ( - 1.288)                                      EINI3570
      GO TO 180                                                         EINI3580
  110 IF (X.GT.1.0.AND.X.LE.2.0) GO TO 120                              EINI3590
      GO TO 130                                                         EINI3600
  120 Y = 40.0 * X *  * ( - 0.982)                                      EINI3610
      GO TO 180                                                         EINI3620
  130 IF (X.GT.2.0.AND.X.LE.4.0) GO TO 140                              EINI3630
      GO TO 150                                                         EINI3640
  140 Y = 31.1 * X *  * ( - 0.618)                                      EINI3650
      GO TO 180                                                         EINI3660
  150 IF (X.GT.4.0.AND.X.LE.8.0) GO TO 160                              EINI3670
      GO TO 170                                                         EINI3680
  160 Y = 26.0 * X *  * ( - 0.486)                                      EINI3690
      GO TO 180                                                         EINI3700
  170 IF (X.GT.8.0) Y = 21.4 * X *  * ( - 0.394)                        EINI3710
  180 RETURN                                                            EINI3720
C                                                                       EINI3730
      END                                                               EINI3740
      SUBROUTINE FIG7 (X,Y)                                             EINI3750
C                                                                       EINI3760
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 7 BY A SERIES OF EQNS. EINI3770
C                                                                       EINI3780
      IF (X.LE.0.20) Y = (X/1.090) *  * ( - 2.088)                      EINI3790
      IF (X.GT.0.20.AND.X.LE.0.40) Y = (X/0.877) *  * ( - 2.402)        EINI3800
      IF (X.GT.0.40.AND.X.LE.0.65) Y = (X/0.832) *  * ( - 2.582)        EINI3810
      IF (X.GT.0.65.AND.X.LE.0.80) Y = (X/0.990) *  * ( - 1.515)        EINI3820
      IF (X.GT.0.80.AND.X.LE.1.00) Y = (X/1.185) *  * ( - 0.826)        EINI3830
      IF (X.GT.1.00.AND.X.LE.1.45) Y = (X/1.450) *  * ( - 0.375)        EINI3840
      IF (X.GT.1.45) Y = 1.0                                            EINI3850
      RETURN                                                            EINI3860
C                                                                       EINI3870
      END                                                               EINI3880
      SUBROUTINE FIG8 (X,Y)                                             EINI3890
C                                                                       EINI3900
C     THIS SUBROUTINE ESTIMATES EINSTEINS FIG 8 BY A SERIES OF EQNS.    EINI3910
C                                                                       EINI3920
      IF (X.LT.0.66) Y = (X/1.005) *  * 1.178                           EINI3930
      IF (X.GT.0.66.AND.X.LE.0.84) Y = (X/1.104) *  * (0.957)           EINI3940
      IF (X.GT.0.84.AND.X.LE.1.10) Y = (X/1.940) *  * (0.310)           EINI3950
```

```
      IF (X.GT.1.10.AND.X.LE.1.30) Y = (X/0.475) *  * ( - 0.208)
      IF (X.GT.1.30.AND.X.LE.2.20) Y = (X/0.930) *  * ( - 0.633)
      IF (X.GT.2.20.AND.X.LE.3.10) Y = (X/0.278) *  * ( - 0.266)
      IF (X.GT.3.10) Y = 0.530
      RETURN
C
      END
      SUBROUTINE POWJ (Z,A,XJ1,XJ2,CONV)
      N = 1
      XJ1 = 0.
      XJ2 = 0.
      ALG = ALOG(A)
      C = 1.
      D =  - Z
      E = D + 1.
      FN = 1.
      AEX = A *  * E
      GO TO 110
  100 N = N + 1
      C = C * D/FN
      D = E
      E = D + 1.
      FN = FLOAT(N)
      AEX = A *  * E
  110 IF (ABS(E).LE.0.001) GO TO 120
      XJ1 = XJ1 + C * (1. - AEX)/E
      XJ2 = XJ2 + C * ((AEX - 1.)/E *  * 2 - AEX * ALG/E)
      GO TO 130
  120 XJ1 = XJ1 - C * ALG
      XJ2 = XJ2 - 0.5 * C * ALG *  * 2
  130 IF (N.EQ.1) GO TO 140
      CJ1 = ABS(1. - FJ1/XJ1)
      CJ2 = ABS(1. - FJ2/XJ2)
      IF (CJ1.LE.CONV.AND.CJ2.LE.CONV) GO TO 150
  140 FJ1 = XJ1
      FJ2 = XJ2
      GO TO 100
  150 FACT = 0.216 * (A *  * (Z - 1.))/((1. - A) *  * Z)
      XJ1 = FACT * XJ1
      XJ2 = FACT * XJ2
      RETURN
C
      END
      SUBROUTINE FIG10 (X,Y)
C
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIG 10 BY A SERIES OF EQNS.
C
      IF (X.LT..4) Y = 8.106078 * X *  * ( - 0.989002)
      IF (X.LE.1..AND.X.GE..4) Y = 7.473444 * X *  * ( - 1.067367)
      IF (X.LT.2..AND.X.GT.1.) Y = 7.512081 * X *  * ( - 1.182832)
      IF (X.LE.3..AND.X.GE.2.) Y = 9.151968 * X *  * ( - 1.472483)
      IF (X.LT.5..AND.X.GT.3.) Y = 16.025332 * X *  * ( - 1.972806)
      IF (X.LE.7..AND.X.GE.5.) Y = 41.421873 * X *  * ( - 2.578713)
      IF (X.LT.10..AND.X.GT.7.) Y = 130.2209 * X *  * ( - 3.165102)
      IF (X.LE.13..AND.X.GE.10.) Y = 584.560594 * X *  * ( - 3.818249)
      IF (X.LT.17..AND.X.GT.13.) Y = 3543.989886 * X *  * ( - 4.522935)
      IF (X.LE.20..AND.X.GE.17.) Y = 1690645.945 * X *  * ( - 6.703904)
      IF (X.LT.23..AND.X.GT.20.) Y = 5188257832. * X *  * ( - 9.381815)
      IF (X.GE.23.) Y = 3.134987996E15 * X *  * ( - 13.597547)
      RETURN
C
      END
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM: MODEIN PROGRAM NO.:

PREPARING AGENCY: Simons and Li Engineering

AUTHORS: R. M. Li, R. K. Simons, D. B. Simons

DATE PROGRAM COMPLETED: September, 1979

STATUS OF PROGRAM: Phase - Original, Stage - Operational

A. PURPOSE OF PROGRAM: To compute total sediment discharge by the Modified Einstein procedure. References: (a) U.S. Bureau of Reclamation, Sedimentation Section of the Hydrology Branch, "Step Method for Computing Total Sediment Load by the Modified Einstein Procedure," July, 1955, revised; (b) U.S. Bureau of Reclamation, Sedimentation Section of the Hydrology Branch, "Computation of Z's for Use in the Modified Einstein Procedure," June, 1966; (c) Simons, D. B. and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

B. PROGRAM SPECIFICATIONS:

Language: Fortran IV

Solution Requirements: Input data

Method of Analysis: Computer application of the Modified Einstein Procedure

Size of Object Program: 23,120 characters

External Storage: None

Restrictions: None

General Equations: See reference

Range of Quantities: Unlimited

Accuracy: N/A

Dimension System: English

C. METHODS: The program is written in Fortran IV in both time-share and batch modes. All stops would be unprogrammed, resulting from improper input variables.

D. EQUIPMENT DETAILS: The program was developed on a CDC Cyber 172 but can operate on any compatible system. No special computer equipment is required. A normal configuration of reader, CPU and printer is required to run the program in batch mode.

E. INPUT-OUTPUT: Input requirements are: The number of data sets, mean velocity (ft/sec), hydraulic depth (ft), water surface width (ft), water temperature (^{o}F), kinematic viscosity (ft^{2}/sec), D_{65} (ft), D_{35} (ft), average sediment concentration (ppm), portion of depth not sampled (ft), average depth of sampling (ft), integer selectors to determine sediment input data, and detail of output and sediment sizes and percentage.

F. ADDITIONAL REMARKS: The method can be used to estimate the total bed material load but cannot be used for design purposes.

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NUMBER:

2. TITLE: MODEINS

3. REVISION LOG: N/A

4. PURPOSE OF PROGRAM: To compute total sediment discharge by the Modified Einstein Procedure. References:

   a) U.S. Bureau of Reclamation, Sedimentation Section of the Hydrology Branch, "Step Method for Computing Total Sediment Load by the Modified Einstein Procedure," July, 1955, Revised.

   b) U.S. Bureau of Reclamation, Sedimentation Section of the Hydrology Branch, "Computation of Z's for Use in the Modified Einstein Procedure," June, 1966.

   c) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

5. STEP SOLUTION:

   a) The input variables that must be supplied are:

      1 - Number of data sets (NDATA)

      2 - Mean velocity (UAVE), ft/sec

      3 - Hydraulic depth (DEPTH), ft

      4 - Water surface width (W), ft

      5 - Water temperature (TEMP), ^{o}F

      6 - Kinematic viscosity (XNU), ft^2/sec

      7 - D_{65} (D65), ft

      8 - D_{35} (D35), ft

      9 - Average concentration (CONC), ppm

      10 - Portion of depth not sampled (DN), ft

      11 - Average depth of sampling (DS), ft

12 - Integer selector (JIN)

If JIN = 1, the size fraction used by the USBR in Reference a will be used except the third value will be deleted. Number of size fractions = 10.

If JIN = 2, the size fractions used by the USBR will be used except the first 2 size fractions will be deleted and the third used instead. Number of size fractions = 9.

JIN = 1		JIN = 2	
DRL	DRU	DRL	DRU
.000	.0156	.002	.0625
.0156	.0625	.0625	.125
.0625	.125	.125	.250
.125	.250	.250	.500
.250	.500	.500	1.00
.500	1.00	1.00	2.00
1.00	2.00	2.00	4.00
2.00	4.00	4.00	8.00
4.00	8.00	8.00	16.00
8.00	16.00		

If JIN = 3, the user specifies the number of size fractions (up to 10), sizes and percentages.

13 - Integer selector (JOUT)

If JOUT = 1, the output will consist of the general input date, a check on the convergence of Z prime and 20 columns of final results (see Reference a).

If JOUT = 2, sediment data and columns 1, 4, 5, 6 and 20 of the table output will be printed.

14 - If JIN = 1, the percent of bed material in size fractions (FB) and the percent of suspended load in size fractions (FS) for 10 size fractions are read in.

If JIN = 2, same as if JIN = 1 except only 9 values are input.

If JIN = 3, read in the number of size fractions (ND); the lower limit of sediment size in a given range (DRL), mm; the upper limit of sediment size in a given range (DRU), mm; the percentage of bed material in that size (FB); the percentage of suspended material in that size (FS).

(Note that size fractions should be punched in order of increasing size)

b) Compute the value of RS by iteration, subroutine RSCOM and subroutine PLATE3.

c) Compute the percentage of flow through the sampled zone, subroutine PLATE4.

d) Compute the intensity of shear on particles (subroutine PLATE5)

e) Compute the constant P, the distance of lower limit of integration above the sampling depth, and the distance of lower limit of integration above the stream bed divided by the depth.

f) Compute number of size fractions for which there are both bed and suspended discharge (subroutine SDR)

g) Compute the multipliers from plate 7 (subroutine MULCOM) and the exponent for vertical distribution of sediment (subroutine ZPCOM)

h) Compute a least squares fit of the exponent of vertical sediment distribution and settling velocity (subroutine LSZPVS)

i) Compute sediment load and suspended load (subroutine POWER)

j) Print results

6. ACCURACY: N/A

PART II: COMPUTER FUNCTIONAL DESCRIPTION

1. REVISION LOG: N/A

2. FUNCTIONAL FLOW CHART: (see Figure 1)

3. EQUIPMENT AND OPERATING SYSTEM: The program was developed on a CDC Cyber 172 but can operate on any compatible system. Normal configuration of CPU, reader and printer are necessary to run the program in batch mode.

4. INPUT REQUIREMENTS: The program is written for either the time-share or batch processing mode. The source listing is for the batch mode (Figure 2). Figure 3 is the interactive mode listing. The program in the time-share mode prompts the user for input data.

5. SECONDARY STORAGE INPUT FORMAT: None

6. INPUT DATA DESCRIPTION:

NAME	DESCRIPTION	FORMAT	
NDATA	Number of data sets	I5	Card 1
UAVE	Mean velocity, ft/sec	F10.0	Card 2
DEPTH	Hydraulic depth, ft	F10.0	Card 2
W	Water surface width, ft	F10.0	Card 2
TEMP	Water temperature, ^{o}F	F10.0	Card 2
XNU	Kinematic viscosity, ft^2/sec	F10.0	Card 2
D65	Sediment size for which 65% of sample is finer, ft	F10.0	Card 2
D35	Sediment size for which 35% of sample is finer, ft	F10.0	Card 3
CONC	Average concentration, ppm	F10.0	Card 3

NAME	DESCRIPTION	FORMAT	
DN	Portion of depth not sampled, ft	F10.0	Card 3
DS	Average depth of sampling, ft	F10.0	Card 3
JIN	Integer input selector code	I1	Card 4
JOUT	Integer output selector code	I1	Card 4

If JIN = 1 the sediment size used by the USBR in Reference (a) is used except for the third value (D(j), J=1,10) = .0056, .0312, .0884, .117, .354, .707, 1.41, 2.85, 5.66, 11.32 (mm)

FB	Decimal percentage of bed material in size fractions	F10.0	Cards 5-14
FS	Decimal percentage of suspended material in size fractions	F10.0	Cards 5-14

If JIN = 2 the following sediment sizes are used: (D(J), J=1,9) = .011, .0884, .177, .354, .707, 1.41, 2.83, 5.66, 11.32 (mm)

FB	Decimal percentage of bed material in size fraction	F10.0	Cards 5-13
FS	Decimal percentage of suspended material in size fraction	F10.0	Cards 5-13

If JIN = 3 the user supplies the sediment sizes and percentages.

ND	Number of sediment sizes	I1	Card 5
DRL	Lower limit of sediment size in each fraction	F10.0	Cards 6-14
DRU	Upper limit of sediment size in each fraction	F10.0	Cards 6-14
FB	Decimal percentage of bed material in size fraction	F10.0	Cards 6-14
FS	Decimal percentage of suspended material in size fraction	F10.0	Cards 6-14

7. SUMMARY OF REQUIRED CARDS: (See 6)

8. OUTPUTS: JOUT selects the type of output desired. If JOUT = 1, output will consist of the general data, check on convergence of Z prime, and the final results in 20 columns, as follows.

1 - Geometric mean diameter, ft

2 - PSI

3 - PHI shear

4 - Percentage of bed material in size fraction

5 - Bed load transport, tons/day

6 - Percentage of suspended load in size fraction

7 - Sampled transport in size fraction

8 - Multipliers

9 - Z prime values

10 - A doulbe prime values

11 - Geometric mean diameter, in ft

12 - J one prime

13 - J two prime

14 - J one double prime

15 - J two double prime

16 - Product of JS

17 - I one double prime

18 - I two double prime

19 - Product of IS

20 - Computed load, in tons/day

If JOUT = 2 is selected, most of the 20 columns will be omitted in the printout, and instead only columns 1, 4, 5, 6 and 20 will be printed. Additionally, DRL(J) and DRU(J), lower and upper limits

of the size fraction range, in mm, will be printed to the left of the 5 columns previously mentioned.

9. OPERATOR INSTRUCTION: None

10. PROGRAM ERROR MESSAGES: None. Program stops would result from improper input data.

11. VARIABLE DEFINITIONS:

A - Coefficient in least squares fit equation

AP - Ratio of the depth not sampled to the average sampling depth

APP - Ratio of 2 x grain diameter to the depth

AREA - Cross-sectional area of flow, ft^2

COL16 - $J_2' = \int_{A'}^{1} [(1-y)/(y)]^{z'} dy$

COL17 - $J_2' = \int_{A'}^{1} [(1-y)/(y)]^{z'} \ln(y)\, dy$

COL18 - $J_1'' = \int_{A''}^{1} [(1-y)/(y)]^{z'} dy$

COL19 - $J_2'' = \int_{A''}^{1} [(1-y)/(y)]^{z'} \ln(y)\, dy$

COL20 - A factor containing P and Einstein's integral J_1', J_1'', J_2', J_2''

COL21 - I_1'' = Mathematical abbreviation which contains J_1'' that is associated with the total depth through which suspended sediment is discharged.

COL22 - I_2'' - Mathematical abbreviation which contains J_2'' that is associated with the total depth through which suspended sediment is discharged.

COL23 - The factor that is multiplied times the bed load to determine total load in each size fraction

CONC - Sediment concentration, ppm

D - Sediment size, ft

DEPTH - Hydraulic depth, ft

DISCH - Water discharge, cfs

DN - Portion of depth not sampled, ft

DRL - Lower limit of sediment size in each size fraction, mm

DRU - Upper limit of sediment size in each size fraction, mm

DS - Average sampling depth, ft

DXKS - A parameter used in computing P

D35 - Sediment size for which 35% of the sample is finer, ft

D65 - Sediment size for which 65% of the sample is finer, ft

FB - Decimal percentages of bed material in each size fraction

FQL - Total sediment load in each size fraction

FS - Decimal percentages of suspended material in each size fraction

JIN - Integer code for type of input data

JOUT - Integer code for output

NDATA - Number of data sets

P - A parameter

PFS - Percentage of streamflow sampled

PHISH - Intensity of bed load transport

PSI - Function for correlating effect of flow with intensity of sediment transport

QSM - Sampled suspended load, tons/day

QSP - Sediment discharge in sampling zone for each size, tons/day

QSPT - Sediment discharge in sampling zone, tons/day

RS - Hydraulic radius times energy slope, ft

TBL - Total bed load, tons/day

TEMP - Water temperature, ^{o}F

TQL - Total bed material load, tons/day

TSL - Total suspended load, tons/day

UAVE - Mean velocity, ft/sec

VS - Settling velocity, ft/sec

W - Stream width, ft

XIBQB - Bed load transport in each size fraction, ton/sday

XKS - D65, ft

XMULT - Multiplier

XNU - Kinematic viscosity of water, ft^2/sec

XPSI - Intensity of shear on particles

YPSI - Intensity of shear on particles

ZP - Exponent for vertical distribution of sediment

12. EXAMPLE CASE:

a) Batch mode (See pgs. 13 and 14.)

b) Interactive mode (See pgs. 15-18.)

13. JOB PROCESSING TIME:

To compile: 10.4 cpu sec

To execute: 0.31 cpu sec (batch)

0.44 cpu sec (interactive)

Example case, batch mode.

COMPUTATION OF TOTAL SEDIMENT LOAD BY THE MODIFIED EINSTEIN PROCEDURE

DATA INPUT

SET 1		
WATER DISCHARGE	230.34	C.F.S.
AVERAGE VELOCITY	2.08	FT./SEC.
HYDRAULIC DEPTH	.98	FT.
WATER SURFACE WIDTH	113.00	FT.
AREA	110.74	SQ.FT.
TEMPERATURE	64.00	DEG.FAHREN.
KINEMATIC VISCOSITY	.0000114	SQ.FT./SEC.
D65	.001050	FT.
D35	.000750	FT.
AVERAGE CONCENTRATION	262.00	PPM.
SAMPLED SUSPENDED LOAD	162.9420	TONS/DAY
PORTION OF DEPTH NOT SAMPLED	.30	FT.
AVERAGE DEPTH AT SAMPLING	1.22	FT.

CONVERGENCE OF SUBROUTINE ZPCOM IS CHECKED BY PRINTING OUT VALUES INVOLVED

ITER.	ZTRY	RQSP	CRQSP	DCRQ
1	.65698	19.13742	17.15951	-1.97791
2	.64217	19.13742	19.17448	.03706

J	ZP(J)	VS(J)
1	.013859	.000087
2	.154001	.002709
3	.642172	.020833
4	1.464188	.067624
5	2.581648	.152040
6	3.743757	.258550
7	4.998487	.390728
8	6.476593	.565719
9	8.302996	.806727
10	10.604473	1.144244

J	D(J)	PSI(J)	PHISH(J)	FB(J)	XIBQB(J)	FS(J)	QSP(J)	XMULT(J)	ZP(J)	APP(J)
1	.000018	5.489	.51332	0.000	0.000	.220	28.282	.022	.014	.000037
2	.000102	5.489	.51332	0.000	0.000	.250	32.139	.240	.154	.000209
3	.000290	5.489	.51332	.380	2.821	.420	53.993	1.000	.642	.000592
4	.000580	5.489	.51332	.500	10.500	.110	14.141	2.280	1.464	.001184
5	.001160	5.489	.51332	.050	2.970	0.000	0.000	4.020	2.582	.002367
6	.002320	6.791	.29644	.010	.970	0.000	0.000	5.830	3.744	.004734
7	.004640	13.582	.02662	.010	.246	0.000	0.000	7.784	4.998	.009469
8	.009280	27.163	.00010	0.000	0.000	0.000	0.000	10.085	6.477	.018938
9	.018559	54.327	.00000	0.000	0.000	0.000	0.000	12.930	8.303	.037876
10	.037118	108.654	.00000	0.000	0.000	0.000	0.000	16.513	10.604	.075752

J	D(J)	COL16(J)	COL17(J)	COL18(J)	COL19(J)	COL20(J)	COL21(J)	COL22(J)	COL23(J)	COMP.LOAD
1	.000018	.753	-.411	1.007	-1.024	1.275	0.000	0.000	0.000	36.0515
2	.000102	.705	-.421	1.064	-1.332	1.411	0.000	0.000	0.000	45.3410
3	.000290	0.000	0.000	0.000	0.000	0.000	6.366	-16.785	52.193	147.2529
4	.000580	0.000	0.000	0.000	0.000	0.000	.423	-2.140	3.372	35.4099
5	.001160	0.000	0.000	0.000	0.000	0.000	.135	-.734	1.710	5.0787
6	.002320	0.000	0.000	0.000	0.000	0.000	.078	-.389	1.443	1.3999
7	.004640	0.000	0.000	0.000	0.000	0.000	.053	-.235	1.333	.3285
8	.009280	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
9	.018559	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
10	.037118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000

TOTAL BED LOAD 17.5 TONS/DAY
TOTAL SUSPENDED LOAD 253.4 TONS/DAY
TOTAL LOAD 270.9 TONS/DAY
.312 CP SECONDS EXECUTION TIME

Example case, interactive mode

```
                    COMPUTATION OF TOTAL SEDIMENT LOAD BY THE MODIFIED  EINSTEIN PROCEDURE



  START INPUT DATA IN FREE FORMAT

 ENTER NUMBER OF DATA SETS, NDATA=
? 1
  ENTER INOPT=1 TO READ IN ALL THE MAJOR VARIABLES IN ONE STRING,
        OTHERWISE INPUT DATA ONE BY ONE
? 0



  ENTER FOLLOWING INPUT DATA (10 VARIABLES):

  AVERAGE VELOCITY IN FPS, UAVE=
? 2.08
  HYDRAULIC DEPTH IN FT., DEPTH=
? 0.98
  WATER SURFACE WIDTH IN FT., W=
? 113.
  TEMPERATURE IN DEG. FARENH., TEMP=
? 64.
  KINEMATIC VISCOSITY IN SQ.FT./SEC., XNU=
? .0000114
  D65 IN FT.=
? .00105
  D35 IN FT.=
? .00075
  AVERAGE CONCENTRATION IN PPM BY WEIGHT, CONC=
? 262.
  PORTION OF DEPTH NOT SAMPLED IN FT. DN=
? .3
  AVERAGE DEPTH OF SAMPLING IN FT., DS=
? 1.22


  SEDIMENT SIZE DATA INPUT OPTION
      JIN=1 FOR 10 DEFINED SIZE FRACTIONS
      JIN=2 FOR  9 DEFINED SIZE FRACIONS,
      JIN=3 USER PROVIDES SIZE FRACTIONS AND DATA
```

```
              JIN=1                          JIN=2
        DRL          DRU                DRL          DRU
      (LOWER)      (UPPER)            (LOWER)      (UPPER)
       .0020 -      .0156
       .0156 -      .0625
                                       .0020 -      .0625
       .0625 -      .1250             .0625 -      .1250
       .1250 -      .2500             .1250 -      .2500
       .2500 -      .5000             .2500 -      .5000
       .5000 -     1.0000             .5000 -     1.0000
      1.0000 -     2.0000            1.0000 -     2.0000
      2.0000 -     4.0000            2.0000 -     4.0000
      4.0000 -     8.0000            4.0000 -     8.0000
      8.0000 -    16.0000            8.0000 -    16.0000
  ENTER JIN=
? 2
  OUTPUT OPTION: JOUT=1 FOR FULL PRINTOUT

                 =2 FOR THE INPUT PARAMETERS AND THE RESULTS ONLY
      ENTER JOUT=
? 1
  NUMBER OF SIZE FRACTIONS ND=     9

  ENTER THE SIZE FRACTIONS OF BED MATERIAL FB( ) AND
                              SUSP. MAT.   FS( )  AS
       AS FOLLOWING:
  ENTER  FB( 1 )   FS( 1 )
? 0.00,0.22
  ENTER  FB( 2 )   FS( 2 )
? 0.00,0.25
  ENTER  FB( 3 )   FS( 3 )
? 0.38,0.42
  ENTER  FB( 4 )   FS( 4 )
? 0.50,0.11
  ENTER  FB( 5 )   FS( 5 )
? 0.05,0.00
  ENTER  FB( 6 )   FS( 6 )
? 0.01,0.00
  ENTER  FB( 7 )   FS( 7 )
? 0.01,0.00
  ENTER  FB( 8 )   FS( 8 )
? 0.00,0.00
  ENTER  FB( 9 )   FS( 9 )
? 0.00,0.00
```

DATA INPUT

SET 1		
WATER DISCHARGE	230.34	C.F.S.
AVERAGE VELOCITY	2.08	FT./SEC.
HYDRAULIC DEPTH	.98	FT.
WATER SURFACE WIDTH	113.00	FT.
AREA	110.74	SQ.FT.
TEMPERATURE	64.00	DEG.FAHREN.
KINEMATIC VISCOSITY	.0000114	SQ.FT./SEC.
D65	.001050	FT.
D35	.000750	FT.
AVERAGE CONCENTRATION	262.00	PPM.
SAMPLED SUSPENDED LOAD	162.6812	TONS/DAY
PORTION OF DEPTH NOT SAMPLED	.30	FT.
AVERAGE DEPTH AT SAMPLING	1.22	FT.

CONVERGENCE OF SUBROUTINE ZPCOM IS CHECKED BY PRINTING OUT VALUES INVOLVED

ITER.	ZTRY	RQSP	CRQSP	DCRQ
1	.80622	6.75527	4.96658	-1.78869
2	.75430	6.75527	7.04099	.28571
3	.76053	6.75527	6.75159	-.00368

J	ZP(J)	VS(J)
1	.019018	.000348
2	.333555	.020833
3	.760525	.067624
4	1.340954	.152040
5	1.944574	.258550
6	2.596603	.390728
7	3.364057	.565719
8	4.312724	.806727
9	5.508152	1.144244

J	D(J)	PSI(J)	PHISH(J)	FB(J)	XIBQB(J)	FS(J)	QSP(J)	XMULT(J)	ZP(J)	GPP(J)
1	.000037	5.489	.51332	0.000	0.000	.220	28.237	.025	.019	.000075
2	.000290	5.489	.51332	0.000	0.000	.250	32.087	.439	.334	.000592
3	.000580	5.489	.51332	.380	7.980	.420	53.907	1.000	.761	.001184
4	.001160	5.489	.51332	.500	29.698	.110	14.118	1.763	1.341	.002367
5	.002320	6.791	.29644	.050	4.851	0.000	0.000	2.557	1.945	.004734
6	.004640	13.582	.02662	.010	.246	0.000	0.000	3.414	2.596	.009469
7	.009280	27.163	.00010	.010	.003	0.000	0.000	4.423	3.364	.018938
8	.018559	54.327	.00000	0.000	0.000	0.000	0.000	5.671	4.313	.037876
9	.037118	108.654	.00000	0.000	0.000	0.000	0.000	7.243	5.508	.075752

J	D(J)	COL16(J)	COL17(J)	COL18(J)	COL19(J)	COL20(J)	COL21(J)	COL22(J)	COL23(J)	COMP.LOAD
1	.000037	.750	-.411	1.010	-1.033	1.283	0.000	0.000	0.000	36.2368
2	.000290	.659	-.439	1.222	-2.015	1.673	0.000	0.000	0.000	53.6813
3	.000580	0.000	0.000	0.000	0.000	0.000	2.908	-8.519	23.535	187.8088
4	.001160	0.000	0.000	0.000	0.000	0.000	.503	-2.141	4.234	125.7459
5	.002320	0.000	0.000	0.000	0.000	0.000	.218	-.962	2.366	11.4774
6	.004640	0.000	0.000	0.000	0.000	0.000	.131	-.532	1.863	.4590
7	.009280	0.000	0.000	0.000	0.000	0.000	.087	-.312	1.621	.0042
8	.018559	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
9	.037118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000

TOTAL BED LOAD 42.8 TONS/DAY
TOTAL SUSPENDED LOAD 372.6 TONS/DAY
TOTAL LOAD 415.4 TONS/DAY
.441 CP SECONDS EXECUTION TIME

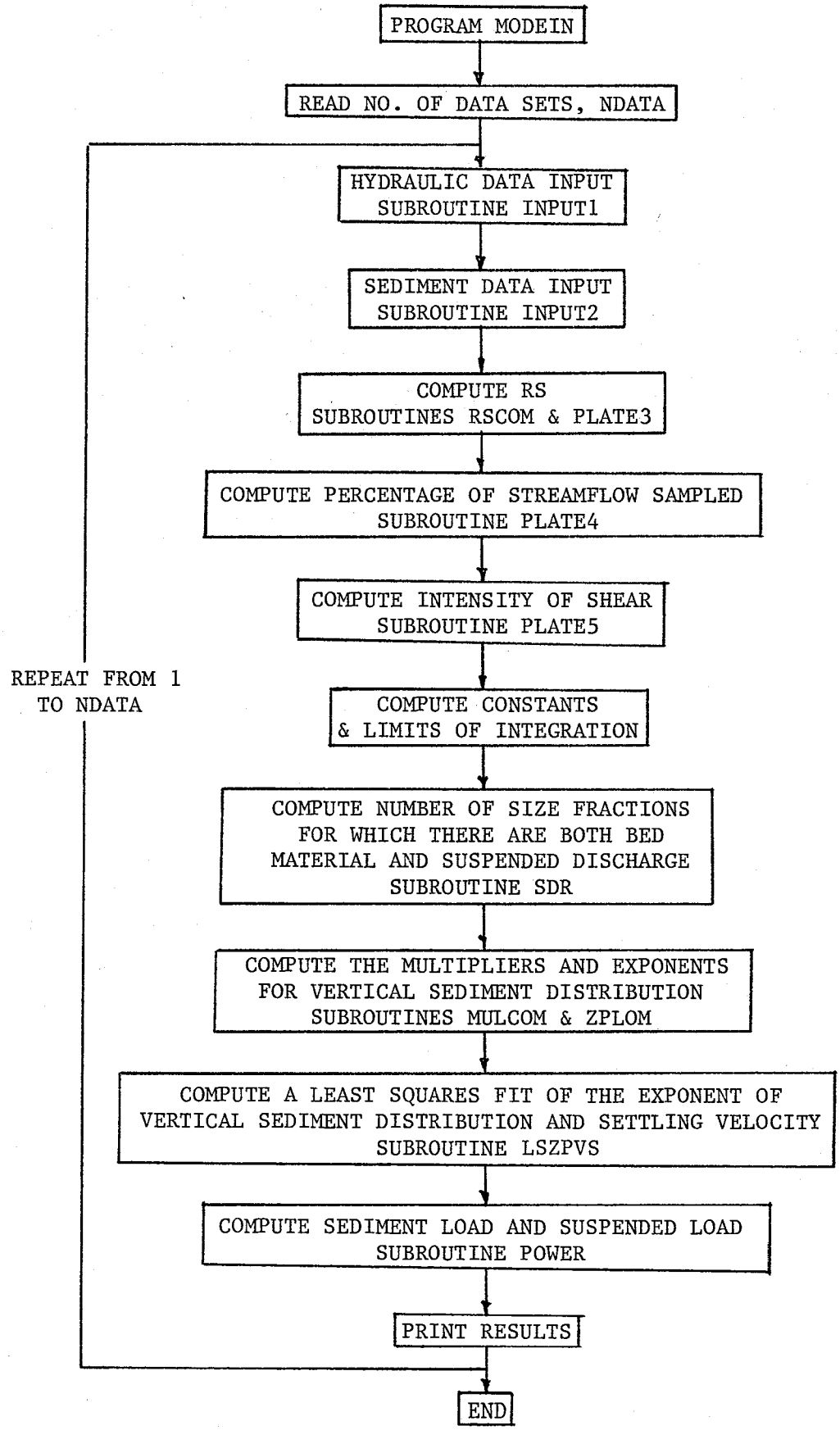

Figure 1. Flow chart for the Modified Einstein Procedure.

```
      PROGRAM MODEIN                                                    MOD 0010
     1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)                           MOD 0020
C                                                                       MOD 0030
C                                                                       MOD 0040
C     DEVELOPED          COLORADO STATE UNIVERSITY ENGINEERING RESEARCH MOD 0050
C                        CENTER, FORT COLLINS, COLORADO, 80523.         MOD 0060
C     PURPOSE            COMPUTATION OF TOTAL SEDIMENT LOAD BY          MOD 0070
C                        THE MODIFIED EINSTEIN PROCEDURE.               MOD 0080
C     REFERENCES         U.S. BUREAU OF RECLAMATION PUBLICATION         MOD 0090
C                        STEP METHOD FOR COMPUTING TOTAL SEDIMENT LOAD  MOD 0100
C                        BY THE MODIFIED EINSTEIN PROCEDURE, JULY 1955  MOD 0110
C                        (REVISED) AND ADDENDUM  COMPUTATION OF Z FOR USEMOD 0120
C                        IN THE MODIFIED EINSTEIN PROCEDURE, JUNE 1966. MOD 0130
C     CORE USAGE         CDC 6400 SCOPE 3.3 SYSTEM DEFAULT VALUE,       MOD 0140
C                        43000 OCTAL.                                   MOD 0150
C     COMPILATION TIME   APPROXIMATELY 8 SEC.                           MOD 0160
C     CENTRAL PROCESSOR                                                 MOD 0170
C     TIME FOR ONE                                                      MOD 0180
C     SET OF DATA        APPROXIMATELY 1 SEC.                           MOD 0190
C                                                                       MOD 0200
C                                                                       MOD 0210
C     INPUT AND OUTPUT DESCRIPTION                                      MOD 0220
C                                                                       MOD 0230
C     THE FIRST CARD IN THE INPUT LOGICAL RECORD SHOULD CONTAIN         MOD 0240
C     THE VALUE OF NDATA, IN FORMAT I5.  NDATA IS THE NUMBER OF SETS    MOD 0250
C     OF INPUT DATA TO BE FED TO THE COMPUTER AT A TIME.  A SET OF INPUTMOD 0260
C     DATA CONSISTS OF A GROUP OF VARIABLES NECESSARY TO SPECIFY        MOD 0270
C     A PROBLEM, AS DETAILED BELOW.                                     MOD 0280
C                                                                       MOD 0290
C     THE FIRST CARD IS TO BE FOLLOWED BY THE NUMBER OF SETS OF INPUT   MOD 0300
C     DATA, EACH ONE CONSISTING OF THE FOLLOWING, IN THE ORDER SHOWN    MOD 0310
C     (ORDER IS THE SAME AS THAT USED IN REFERENCE 8)                   MOD 0320
C                                                                       MOD 0330
C     1) GENERAL DATA, 13 VARIABLES TO BE PUNCHED IN FORMAT (8F10.0)    MOD 0340
C        FOLLOWING IS A LIST OF THE VARIABLES, FORTRAN NAME AND UNITS.  MOD 0350
C        AVERAGE VELOCITY                    UAVE          FT./SEC.     MOD 0360
C        HYDRAULIC DEPTH                     DEPTH         FT.          MOD 0370
C        WATER SURFACE WIDTH                 W             FT.          MOD 0380
C        TEMPERATURE                         TEMP          DEG.FARENH.  MOD 0390
C        KINEMATIC VISCOSITY                 XNU           SQ.FT./SEC.  MOD 0400
C        65 PERCENT FINER DIAMETER                                      MOD 0410
C             FOR BED-MATERIAL               D65           FT.          MOD 0420
C        35 PERCENT FINER DIAMETER                                      MOD 0430
C             FOR BED-MATERIAL               D35           FT.          MOD 0440
C        AVERAGE CONCENTRATION               CONC          PPM.         MOD 0450
C        PORTION OF DEPTH NOT SAMPLED        DN            FT.          MOD 0460
C        AVERAGE DEPTH OF SAMPLING           DS            FT.          MOD 0470
C                                                                       MOD 0480
C     2) INTEGER SELECTORS JIN AND JOUT, TO BE PUNCHED IN FORMAT 2I1.   MOD 0490
C        JIN SELECTS THE NUMBER AND RANGE IN THE COMPUTATIONAL          MOD 0500
C        SIZE FRACTIONS. ND IS THE NUMBER OF SIZE FRACTIONS.            MOD 0510
C        IF JIN=1, THE SIZE FRACTIONS IN THE USBR PUBLICATION WILL BE   MOD 0520
C        USED. THE FIRST TWO SIZE FRACTIONS WILL BE USED AND THE THIRD  MOD 0530
C        DELETED, RESULTING IN ND= 10                                   MOD 0540
C        IF JIN=2, THE SIZE FRACTIONS IN THE USBR PUBLICATION WILL BE   MOD 0550
C        USED. IN THIS CASE THE FIRST TWO SIZE FRACTIONS WILL BE DELETEDMOD 0560
C        AND THE THIRD USED INSTEAD, RESULTING IN ND=9                  MOD 0570
C        IF JIN=3, THE USER HAS THE OPTION OF SPECIFYING THE NUMBER AND MOD 0580
C        RANGE OF COMPUTATIONAL SIZE FRACTIONS. IF THIS OPTION IS       MOD 0590
C        CHOSEN, ND SHOULD BE READ IN THE CARD IMMEDIATELY FOLLOWING,   MOD 0600
C        IN FORMAT I1.                                                  MOD 0610
C        JOUT SELECTS THE TYPE OF OUTPUT DESIRED.                       MOD 0620
C        IF JOUT=1, OUTPUT WILL CONSIST OF THE GENERAL DATA, CHECK ON   MOD 0630
C        CONVERGENCE OF Z PRIME, AND THE FINAL RESULTS IN 20 COLUMNS,   MOD 0640
C        AS FOLLOWS.                                                    MOD 0650
```

Figure 2. Batch listing, Program MODEIN.

```
C
C        1) GEOMETRIC MEAN DIAMETER, IN FT.                                MOD 0660
C        2) PSI                                                            MOD 0670
C        3) PHI SHEAR                                                      MOD 0680
C        4) PERCENTAGE OF BED MATERIAL IN SIZE FRACTION                    MOD 0690
C        5) BED LOAD TRANSPORT, TONS/DAY                                   MOD 0700
C        6) PERCENTAGE OF SUSPENDED LOAD IN SIZE FRACTION                  MOD 0710
C        7) SAMPLED TRANSPORT IN SIZE FRACTION                             MOD 0720
C        8) MULTIPLIERS                                                    MOD 0730
C        9) Z PRIME VALUES                                                 MOD 0740
C        10) A DOUBLE PRIME VALUES                                         MOD 0750
C        11) GEOMETRIC MEAN DIAMETER, IN FT                                MOD 0760
C        12) J ONE PRIME                                                   MOD 0770
C        13) J TWO PRIME                                                   MOD 0780
C        14) J ONE DOUBLE PRIME                                            MOD 0790
C        15) J TWO DOUBLE PRIME                                            MOD 0800
C        16) PRODUCT OF JS                                                 MOD 0810
C        17) I ONE DOUBLE PRIME                                            MOD 0820
C        18) I TWO DOUBLE PRIME                                            MOD 0830
C        19) PRODUCT OF IS                                                 MOD 0840
C        20) COMPUTED LOAD, IN TONS/DAY                                    MOD 0850
C        IF JOUT=2 IS SELECTED, MOST OF THE 20 COLUMNS WILL BE OMITTED     MOD 0860
C        IN THE PRINTOUT, AND INSTEAD ONLY COLUMNS 1,4,5,6 AND 20 WILL     MOD 0870
C        BE PRINTED. ADDITIONALLY, DRL(J) AND DRU(J), LOWER AND UPPER      MOD 0880
C        LIMITS OF THE SIZE FRACTION RANGE, IN MM, WILL BE PRINTED TO      MOD 0890
C        THE LEFT OF THE 5 COLUMNS PREVIOUSLY MENTIONED.                   MOD 0900
C                                                                          MOD 0910
C     3) DATA ARRAYS.                                                      MOD 0920
C        IF JIN=1, THE PERCENT OF BED MATERIAL INSIZE FRACTIONS FB(10),    MOD 0930
C        AND PERCENT OF SUSPENDED LOAD IN SIZE FRACTIONS FS(10)            MOD 0940
C        SHOULD BE PUNCHED IN FORMAT 2F10.0                                MOD 0950
C        IF JIN=2, FB(9) AND FS(9) SHOULD BE PUNCHED IN FORMAT 2F10.0      MOD 0960
C        IF JIN=3, THE RANGE OF COMPUTATIONAL SIZE FRACTIONS SHOULD BE     MOD 0970
C        SPECIFIED IN ADDITION TO THE PERCENTAGES FB AND FS.               MOD 0980
C        IF THIS OPTION IS CHOSEN, DRL(ND), DRU(ND), FB(ND) AND FS(ND)     MOD 0990
C        SHOULD BE PUNCHED IN FORMAT 4F10.0                                MOD 1000
C        DRL(J) AND DRU(J) ARE THE LOWER AND UPPER LIMITS OF THE SIZE      MOD 1010
C        FRACTION RANGE, IN MM, RESPECTIVELY. NOTE THAT SIZE FRACTIONS     MOD 1020
C        SHOULD BE PUNCHED IN ORDER OF INCREASING SIZE.                    MOD 1030
C                                                                          MOD 1040
C                                                                          MOD 1050
                                                                           MOD 1060
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,      MOD 1070
     1        W            , AREA        , TEMP        , XNU         ,      MOD 1080
     2        D65          , D35         , CONC        , QSM         ,      MOD 1090
     3        DN           , DS                                             MOD 1100
      COMMON /ALLB/         D(11)       , VS(11)      , FB(10)      ,      MOD 1110
     1        FS(10)       , XMULT(10)   , JIN         , JOUT        ,      MOD 1120
     2        ND           , ND1         , ND2                              MOD 1130
      COMMON /ALLC/         QSP(10)     , XIBQB(10)   , FQL(10)             MOD 1140
      COMMON /ALLD/         P           , AP          , APP(10)     ,      MOD 1150
     1        ZP(10)                                                        MOD 1160
      COMMON /ALLE/         DRL(11)     , DRU(11)                           MOD 1170
      COMMON /CEF/          CJ0(2)      , CJ1(2)      , CJ2(2)      ,      MOD 1180
     1        CJ3(2)       , CJ(2)       , C1(2)       , C2(2)       ,      MOD 1190
     2        C3(2)        , C4(2)                                          MOD 1200
      DIMENSION             COL16(10)   , COL17(10)   , COL18(10)   ,      MOD 1210
     1        COL19(10)    , COL20(10)   , COL21(10)   , COL22(10)   ,      MOD 1220
     2        COL23(10)    , PSI(10)     , PHISH(10)                        MOD 1230
      READ (5,300) NDATA                                                   MOD 1240
      DO 280 L = 1,NDATA                                                   MOD 1250
         IDZ = 0                                                           MOD 1260
         WRITE (6,350)                                                     MOD 1270
         WRITE (6,360)                                                     MOD 1280
         CALL INPUT1                                                       MOD 1290
         CALL INPUT2                                                       MOD 1300
         WRITE (6,370)                                                     MOD 1310
```

```
      WRITE (6,380) L,DISCH,UAVE,DEPTH,W,AREA,TEMP,XNU,D65,D35,CONC,QMOD 1320
     1 SM,DN,DS                                                         MOD 1330
C                                                                       MOD 1340
C     CALCULATING HYDRAULIC RADIUS*SLOPE RS, PERCENTAGE OF FLOW SAMPLED MOD 1350
C     PFS, AND SEDIMENT DISCHARGE THROUGH THE SAMPLED ZONE QSPT         MOD 1360
C                                                                       MOD 1370
      CALL RSCOM (X,RS)                                                 MOD 1380
      CALL PLATE4 (X,PFS,XKS)                                           MOD 1390
      QSPT = QSM * PFS                                                  MOD 1400
C                                                                       MOD 1410
C     CALCULATING PSI(J)                                                MOD 1420
C                                                                       MOD 1430
      DO 110 J = 1,ND                                                   MOD 1440
         XPSI = 1.65 * D35/RS                                           MOD 1450
         YPSI = 0.66 * D(J)/RS                                          MOD 1460
         XYPSI = XPSI - YPSI                                            MOD 1470
         IF (XYPSI.LT.0) GO TO 100                                      MOD 1480
         PSI(J) = XPSI                                                  MOD 1490
         GO TO 110                                                      MOD 1500
  100    PSI(J) = YPSI                                                  MOD 1510
  110 CONTINUE                                                          MOD 1520
C                                                                       MOD 1530
C     CALCULATING BED LOAD DISCHARGE XIBQB(J) AND PERCENTAGE OF         MOD 1540
C     SUSPENDED MATERIAL IN VARIOUS SIZE FRACTIONS QSP(J)               MOD 1550
C                                                                       MOD 1560
      DO 120 J = 1,ND                                                   MOD 1570
         XX = PSI(J)                                                    MOD 1580
         CALL PLATE5 (XX,YY)                                            MOD 1590
         PHISH(J) = YY                                                  MOD 1600
         XIBQB(J) = 43.2 * W * 1200. * PHISH(J)/2. * D(J) *  * 1.5 * MOD 1610
     1   FB(J)                                                          MOD 1620
         QSP(J) = FS(J) * QSPT                                          MOD 1630
  120 CONTINUE                                                          MOD 1640
C                                                                       MOD 1650
C     CALCULATING P, APRIME AP, AND A DOUBLE PRIME APP(J)               MOD 1660
C                                                                       MOD 1670
      DXKS = 30.2 * X * DEPTH/XKS                                       MOD 1680
      P = 2.303 * ALOG10(DXKS)                                          MOD 1690
      AP = DN/DS                                                        MOD 1700
      DO 130 J = 1,ND                                                   MOD 1710
         APP(J) = 2 * D(J)/DEPTH                                        MOD 1720
  130 CONTINUE                                                          MOD 1730
      CALL SDR (N,K)                                                    MOD 1740
      N1 = N + 1                                                        MOD 1750
      NK = N + K                                                        MOD 1760
      WRITE (6,290)                                                     MOD 1770
C                                                                       MOD 1780
C     IF K IS GREATER THAN 2, CONTROL BRANCHES TO STATEMENT 160         MOD 1790
C     CALCULATING MULTIPLIERS XMULT(J) , AND ZPRIME ZP(J)               MOD 1800
C                                                                       MOD 1810
      IF (K.GT.2) GO TO 150                                             MOD 1820
      CALL MULCOM (K,N1,NK,KK)                                          MOD 1830
      CALL ZPCOM (KK,IDZ)                                               MOD 1840
      IF (IDZ.EQ.1) GO TO 280                                           MOD 1850
      DO 140 J = 1,ND                                                   MOD 1860
         ZP(J) = ZP(KK) * XMULT(J)                                      MOD 1870
  140 CONTINUE                                                          MOD 1880
      GO TO 190                                                         MOD 1890
C                                                                       MOD 1900
C     CALCULATING ZP AND VS ARRAYS TO BE FED TO LEAST SQUARE SUBROUTINE MOD 1910
C     LSZPVS                                                            MOD 1920
C                                                                       MOD 1930
  150 CONTINUE                                                          MOD 1940
      DO 160 J = N1,NK                                                  MOD 1950
         CALL ZPCOM (J,IDZ)                                             MOD 1960
         IF (IDZ.EQ.1) GO TO 280                                        MOD 1970
```

```
  160     CONTINUE                                                      MOD 1980
          IF (JOUT.EQ.2) GO TO 170                                      MOD 1990
          WRITE (6,310)                                                 MOD 2000
          WRITE (6,330)                                                 MOD 2010
          WRITE (6,340) (J,ZP(J),VS(J),J = N1,NK)                       MOD 2020
  170     CONTINUE                                                      MOD 2030
          CALL LSZPVS (N1,NK,K,VS,ZP,A,B)                               MOD 2040
          A = EXP(A)                                                    MOD 2050
          DO 180 J = 1,ND                                               MOD 2060
             XMULT(J) = 0.0                                             MOD 2070
             ZP(J) = A * VS(J) *  * B                                   MOD 2080
  180     CONTINUE                                                      MOD 2090
C                                                                       MOD 2100
C     CALCULATING SEDIMENT LOAD BY USING MODIFIED EINSTEINS INTEGRAL    MOD 2110
C     CHARTS 9,10,11 AND 12                                             MOD 2120
C                                                                       MOD 2130
  190     CONTINUE                                                      MOD 2140
          IF (JOUT.EQ.2) GO TO 210                                      MOD 2150
          IF (K.LT.3) GO TO 200                                         MOD 2160
          WRITE (6,320)                                                 MOD 2170
  200     CONTINUE                                                      MOD 2180
          IF (JOUT.EQ.2) GO TO 210                                      MOD 2190
          WRITE (6,330)                                                 MOD 2200
          WRITE (6,340) (J,ZP(J),VS(J),J = 1,ND)                        MOD 2210
  210     CONTINUE                                                      MOD 2220
          TQL = 0                                                       MOD 2230
          TBL = 0                                                       MOD 2240
          DO 250 I = 1,ND                                               MOD 2250
             XM = APP(I)                                                MOD 2260
             ZM = ZP(I)                                                 MOD 2270
             IF (FB(I).LT.0.01.AND.FS(I).LT.0.01) GO TO 230             MOD 2280
             IF (FB(I).LT.0.01) GO TO 220                               MOD 2290
             CALL POWER (ZM,XM,COL21(I),COL22(I),DUM1,DUM2,0.01)        MOD 2300
             COL23(I) = P * COL21(I) + COL22(I) + 1.                    MOD 2310
             FQL(I) = XIBQB(I) * COL23(I)                               MOD 2320
             COL16(I) = 0.                                              MOD 2330
             COL17(I) = 0.                                              MOD 2340
             COL18(I) = 0.                                              MOD 2350
             COL19(I) = 0.                                              MOD 2360
             COL20(I) = 0.                                              MOD 2370
             GO TO 240                                                  MOD 2380
  220        CONTINUE                                                   MOD 2390
             CALL POWER (ZM,AP,DUM1,DUM2,COL16(I),COL17(I),0.01)        MOD 2400
             CALL POWER (ZM,XM,DUM3,DUM4,COL18(I),COL19(I),0.01)        MOD 2410
             COL20(I) = (P * COL18(I) + COL19(I))/(P * COL16(I) + COL17(IMOD 2420
     1       ))                                                         MOD 2430
             FQL(I) = QSP(I) * COL20(I)                                 MOD 2440
             COL21(I) = 0.                                              MOD 2450
             COL22(I) = 0.                                              MOD 2460
             COL23(I) = 0.                                              MOD 2470
             GO TO 240                                                  MOD 2480
  230        CONTINUE                                                   MOD 2490
             FQL(I) = 0.0                                               MOD 2500
             COL16(I) = 0.                                              MOD 2510
             COL17(I) = 0.                                              MOD 2520
             COL18(I) = 0.                                              MOD 2530
             COL19(I) = 0.                                              MOD 2540
             COL20(I) = 0.                                              MOD 2550
             COL21(I) = 0.                                              MOD 2560
             COL22(I) = 0.                                              MOD 2570
             COL23(I) = 0.                                              MOD 2580
  240        CONTINUE                                                   MOD 2590
             TQL = TQL + FQL(I)                                         MOD 2600
             TBL = TBL + XIBQB(I)                                       MOD 2610
  250     CONTINUE                                                      MOD 2620
          TSL = TQL - TBL                                               MOD 2630
```

```
C     PRINTING OUTPUT
C
      WRITE (6,390)
      IF (JOUT.EQ.2) GO TO 260
      WRITE (6,400)
      WRITE (6,410) (J,D(J),PSI(J),PHISH(J),FB(J),XIBQB(J),FS(J),QSP(
     1 J),XMULT(J),ZP(J),APP(J),J = 1,ND)
      WRITE (6,420)
      WRITE (6,430) (J,D(J),COL16(J),COL17(J),COL18(J),COL19(J),COL20
     1 (J),COL21(J),COL22(J),COL23(J),FQL(J),J = 1,ND)
      GO TO 270
  260 CONTINUE
      WRITE (6,440)
      WRITE (6,450) (DRL(J),DRU(J),D(J),FB(J),XIBQB(J),FS(J),FQL(J),J
     1  = 1,ND)
  270 CONTINUE
      WRITE (6,460) TBL,TSL,TQL
  280 CONTINUE
C
C     FORMAT STATEMENTS
C
      STOP
C
C
C
  290 FORMAT (//,10X,75H CONVERGENCE OF SUBROUTINE ZPCOM IS CHECKED BY P
     1RINTING OUT VALUES INVOLVED,//)
  300 FORMAT (I5)
  310 FORMAT (//,10X,41H ARRAYS ZP AND VS BEFORE LEAST SQUARE FIT,/)
  320 FORMAT (//,10X,40H ARRAYS ZP AND VS AFTER LEAST SQUARE FIT,/)
  330 FORMAT (//,10X,35H            J       ZP(J)        VS(J),/)
  340 FORMAT (10X,I12,2F12.6)
  350 FORMAT (1H1)
  360 FORMAT (40X,70HCOMPUTATION OF TOTAL SEDIMENT LOAD BY THE MODIFIED
     1 EINSTEIN PROCEDURE,///)
  370 FORMAT (32X,10HDATA INPUT,//)
  380 FORMAT (10X,4HSET ,I5,/10X,34HWATER DISCHARGE                  ,F
     112.2,13H C.F.S.       ,/10X,34HAVERAGE VELOCITY                 ,F
     212.2,13H FT./SEC.     ,/10X,34HHYDRAULIC DEPTH                  ,F
     312.2,13H FT.          ,/10X,34HWATER SURFACE WIDTH              ,F
     412.2,13H FT.          ,/10X,34HAREA                             ,F
     512.2,13H SQ.FT.       ,/10X,34HTEMPERATURE                      ,F
     612.2,13H DEG.FAHREN.  ,/10X,34HKINEMATIC VISCOSITY              ,F
     712.7,13H SQ.FT./SEC.  ,/10X,34HD65                              ,F
     812.6,13H FT.          ,/10X,34HD35                              ,F
     912.6,13H FT.          ,/10X,34HAVERAGE CONCENTRATION            ,F
     012.2,13H PPM.         ,/10X,34HSAMPLED SUSPENDED LOAD           ,F
     112.4,13H TONS/DAY     ,/10X,34HPORTION OF DEPTH NOT SAMPLED     ,F
     212.2,13H FT.          ,/10X,34HAVERAGE DEPTH AT SAMPLING        ,F
     312.2,4H FT.)
  390 FORMAT (//)
  400 FORMAT (5X,1HJ,11X,4HD(J),7X,6HPSI(J),5X,8HPHISH(J),7X,5HFB(J),4X,
     18HXIBQB(J),7X,5HFS(J),6X,6HQSP(J),4X,8HXMULT(J),7X,5HZP(J),5X,6HAP
     2P(J)/)
  410 FORMAT (4X,I2,4X,F12.6,F12.3,F12.5,6F12.3,F12.6)
  420 FORMAT (//5X,1HJ,11X,4HD(J),6X,8HCOL16(J),4X,8HCOL17(J),4X,8HCOL18
     1(J),4X,8HCOL19(J),4X,8HCOL20(J),4X,8HCOL21(J),4X,8HCOL22(J),4X,8HC
     2OL23(J),4X,9HCOMP.LOAD/)
  430 FORMAT (4X,I2,4X,F12.6,8F12.3,F12.4)
  440 FORMAT (10X,84H       DRL(J)       DRU(J)        D(J)         FB(J)
     1 XIBQB(J)        FS(J)        FQL(J),/)
  450 FORMAT (10X,6F12.6,F12.3)
  460 FORMAT (///,5X,34HTOTAL BED LOAD                        ,F16.1,9H TONS
     1/DAY,/5X,34HTOTAL SUSPENDED LOAD                  ,F16.1,9H TONS/DAY,/
     25X,34HTOTAL LOAD                          ,F16.1,9H TONS/DAY)
```

```
      END                                                               MOD 3300
      SUBROUTINE INPUT1                                                 MOD 3310
C                                                                       MOD 3320
C     THIS SUBROUTINE READS IN THE BASIC VARIABLES OF THE PROBLEM       MOD 3330
C                                                                       MOD 3340
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,   MOD 3350
     1        W            , AREA        , TEMP        , XNU         ,   MOD 3360
     2        D65          , D35         , CONC        , QSM         ,   MOD 3370
     3        DN           , DS                                        MOD 3380
      READ (5,100) UAVE,DEPTH,W,TEMP,XNU,D65,D35,CONC,DN,DS             MOD 3390
      AREA = DEPTH * W                                                  MOD 3400
      DISCH = UAVE * AREA                                               MOD 3410
      QSM = DISCH * CONC * .0027                                         MOD 3420
      RETURN                                                            MOD 3430
C                                                                       MOD 3440
C                                                                       MOD 3450
C                                                                       MOD 3460
  100 FORMAT (8F10.0)                                                   MOD 3470
      END                                                               MOD 3480
      SUBROUTINE INPUT2                                                 MOD 3490
C                                                                       MOD 3500
C     THIS SUBROUTINE READS IN ADDITIONAL INPUT AND FINDS THE VALUE OF  MOD 3510
C     ND, THE NUMBER OF SIZE FRACTIONS TO BE USED IN THE COMPUTATION    MOD 3520
C                                                                       MOD 3530
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,   MOD 3540
     1        W            , AREA        , TEMP        , XNU         ,   MOD 3550
     2        D65          , D35         , CONC        , QSM         ,   MOD 3560
     3        DN           , DS                                        MOD 3570
      COMMON /ALLB/         D(11)       , VS(11)      , FB(10)      ,   MOD 3580
     1        FS(10)       , XMULT(10)   , JIN         , JOUT        ,   MOD 3590
     2        ND           , ND1         , ND2                         MOD 3600
      COMMON /ALLE/         DRL(11)     , DRU(11)                     MOD 3610
      DRL(1) = .002                                                     MOD 3620
      DRL(2) = .0156                                                    MOD 3630
      DRL(3) = .002                                                     MOD 3640
      DRL(4) = .0625                                                    MOD 3650
      DRL(5) = .125                                                     MOD 3660
      DRL(6) = .25                                                      MOD 3670
      DRL(7) = .5                                                       MOD 3680
      DRL(8) = 1.                                                       MOD 3690
      DRL(9) = 2.                                                       MOD 3700
      DRL(10) = 4.                                                      MOD 3710
      DRL(11) = 8.                                                      MOD 3720
      DRU(1) = .0156                                                    MOD 3730
      DRU(2) = .0625                                                    MOD 3740
      DRU(3) = .0625                                                    MOD 3750
      DRU(4) = .125                                                     MOD 3760
      DRU(5) = .25                                                      MOD 3770
      DRU(6) = .5                                                       MOD 3780
      DRU(7) = 1.                                                       MOD 3790
      DRU(8) = 2.                                                       MOD 3800
      DRU(9) = 4.                                                       MOD 3810
      DRU(10) = 8.                                                      MOD 3820
      DRU(11) = 16.                                                     MOD 3830
      READ (5,180) JIN,JOUT                                             MOD 3840
      IF (JIN.EQ.3) GO TO 150                                           MOD 3850
      DO 100 J = 1,11                                                   MOD 3860
         D(J) = (DRL(J) * DRU(J)) *   * 0.5/304.8                       MOD 3870
         VS(J) = ((2./3. * 32.17 * 1.65 * D(J) *   * 3. + 36. * XNU *   * MOD 3880
     1   2.) *   * 0.5 - 6. * XNU)/D(J)                                 MOD 3890
  100 CONTINUE                                                          MOD 3900
      ND1 = 10                                                          MOD 3910
      ND2 = 9                                                           MOD 3920
      IF (JIN.EQ.2) GO TO 120                                           MOD 3930
      DO 110 J = 3,ND1                                                  MOD 3940
         D(J) = D(J + 1)                                                MOD 3950
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      VS(J) = VS(J + 1)                                                 MOD 3960
  110 CONTINUE                                                          MOD 3970
      ND = ND1                                                          MOD 3980
      GO TO 140                                                         MOD 3990
  120 DO 130 J = 1,ND2                                                  MOD 4000
      D(J) = D(J + 2)                                                   MOD 4010
      VS(J) = VS(J + 2)                                                 MOD 4020
  130 CONTINUE                                                          MOD 4030
      ND = ND2                                                          MOD 4040
  140 CONTINUE                                                          MOD 4050
      READ (5,190) (FB(J),FS(J),J = 1,ND)                               MOD 4060
      GO TO 170                                                         MOD 4070
  150 CONTINUE                                                          MOD 4080
      READ (5,200) ND                                                   MOD 4090
      READ (5,210) (DRL(J),DRU(J),FB(J),FS(J),J = 1,ND)                 MOD 4100
      DO 160 J = 1,ND                                                   MOD 4110
      D(J) = (DRU(J) * DRL(J)) *  * 0.5/304.8                           MOD 4120
      VS(J) = ((2./3. * 32.17 * 1.65 * D(J) *  * 3. + 36. * XNU *  *    MOD 4130
     1 2.) *  * 0.5 - 6. * XNU)/D(J)                                    MOD 4140
  160 CONTINUE                                                          MOD 4150
  170 CONTINUE                                                          MOD 4160
      RETURN                                                            MOD 4170
C                                                                       MOD 4180
C                                                                       MOD 4190
C                                                                       MOD 4200
  180 FORMAT (2I1)                                                      MOD 4210
  190 FORMAT (2F10.0)                                                   MOD 4220
  200 FORMAT (I1)                                                       MOD 4230
  210 FORMAT (4F10.0)                                                   MOD 4240
      END                                                               MOD 4250
      SUBROUTINE RSCOM (X,RS)                                           MOD 4260
C                                                                       MOD 4270
C     THIS SUBROUTINE COMPUTES THE VALUE OF RS BY ITERATION             MOD 4280
C                                                                       MOD 4290
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,   MOD 4300
     1        W            , AREA        , TEMP        , XNU         ,   MOD 4310
     2        D65          , D35         , CONC        , QSM         ,   MOD 4320
     3        DN           , DS                                          MOD 4330
      X = 1.6                                                           MOD 4340
      TOL = 0.001                                                       MOD 4350
      XKS = D65                                                         MOD 4360
  100 XDKS = 12.27 * X * DEPTH/XKS                                      MOD 4370
      SRRS = UAVE/(32.63 * ALOG10(XDKS))                                MOD 4380
      USHP = SRRS * 5.68                                                MOD 4390
      DEL = 11.6 * XNU/USHP                                             MOD 4400
      DELKS = XKS/DEL                                                   MOD 4410
      CALL PLATE3 (DELKS,X2)                                            MOD 4420
      DELX = X - X2                                                     MOD 4430
      IF (ABS(DELX).LT.TOL) GO TO 110                                   MOD 4440
      X = X2                                                            MOD 4450
      GO TO 100                                                         MOD 4460
  110 CONTINUE                                                          MOD 4470
      XDKS = 12.27 * X * DEPTH/XKS                                      MOD 4480
      SRRS = UAVE/(32.63 * ALOG10(XDKS))                                MOD 4490
      RS = SRRS * SRRS                                                  MOD 4500
      RETURN                                                            MOD 4510
C                                                                       MOD 4520
      END                                                               MOD 4530
      SUBROUTINE PLATE4 (X,PFS,XKS)                                     MOD 4540
C                                                                       MOD 4550
C     THIS SUBROUTINE SUBSTITUTES PLATE FOUR FOR THE ANALYTICAL         MOD 4560
C     EXPRESSION OF PFS                                                 MOD 4570
C                                                                       MOD 4580
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,   MOD 4590
     1        W            , AREA        , TEMP        , XNU         ,   MOD 4600
```

```
     2          D65          , D35          , CONC         , QSM          ,
     3          DN           , DS
      XKS = D65
      A = 30.2 * X/XKS
      YDS = DS * ALOG(A * DS) - DS
      YDN = DN * ALOG(A * DN) - DN
      PFS = (YDS - YDN)/YDS
      RETURN
C
      END
      SUBROUTINE SDR (N,K)
C
C     THIS SUBROUTINE COUNTS THE NUMBER OF SIZE FRACTIONS K FOR WHICH
C     THERE IS BOTH BED AND SUSPENDED DISCHARGE, AND THE NUMBER OF SIZE
C     FRACTIONS N SMALLER THAN FIRST K.
C
      COMMON /ALLB/          D(11)        , VS(11)       , FB(10)       ,
     1          FS(10)       , XMULT(10)  , JIN          , JOUT         ,
     2          ND           , ND1        , ND2
      J = 0
      K = 0
      N = 0
  100 CONTINUE
      IF (FB(J + 1).GT.0.00.AND.FS(J + 1).GT.0.00) GO TO 120
      IF (K.NE.0) GO TO 110
      N = N + 1
  110 J = J + 1
      IF (J.EQ.ND) RETURN
      GO TO 100
  120 CONTINUE
      K = K + 1
      J = J + 1
      IF (J.EQ.ND) RETURN
      GO TO 100
C
      END
      SUBROUTINE LSZPVS (N1,NK,K,X,Y,A,B)
C
C     THIS SUBROUTINE CALCULATES A LEAST SQUARE FIT FOR ZPRIME ZP(K) AND
C     VS(K)
C
      DIMENSION              X(11)        , Y(10)
      SUMX = 0.
      SUMY = 0.
      SUMXY = 0.
      SUMX2 = 0.
      DO 100 J = N1,NK
         XL = ALOG(X(J))
         SUMX = SUMX + XL
         YL = ALOG(Y(J))
         SUMY = SUMY + YL
         XY = XL * YL
         SUMXY = SUMXY + XY
         X2 = XL * XL
         SUMX2 = SUMX2 + X2
  100 CONTINUE
      XMEAN = SUMX/K
      YMEAN = SUMY/K
      B = (SUMXY - SUMX * SUMY/K)/(SUMX2 - SUMX * SUMX/K)
      A = YMEAN - B * XMEAN
      RETURN
C
      END
      SUBROUTINE MULCOM (K,N1,NK,KK)
C
C     THIS SUBROUTINE CALCULATES THE MULTIPLIERS XMULT(J)
C
```

```
      COMMON /ALLB/          D(11)        , VS(11)       , FB(10)       ,   MOD 5280
     1        FS(10)        , XMULT(10)    , JIN          , JOUT         ,   MOD 5290
     2        ND            , ND1          , ND2                             MOD 5300
      DIMENSION              SBS(9)                                           MOD 5310
      IF (K.EQ.0) GO TO 150                                                   MOD 5320
      IF (K.EQ.2) GO TO 100                                                   MOD 5330
      KK = N1                                                                 MOD 5340
      GO TO 130                                                               MOD 5350
  100 CONTINUE                                                                MOD 5360
      DO 110 J = N1,NK                                                        MOD 5370
         SBS(J) = FB(J) + FS(J)                                               MOD 5380
  110 CONTINUE                                                                MOD 5390
      IF (SBS(N1).GT.SBS(NK)) GO TO 120                                       MOD 5400
      KK = NK                                                                 MOD 5410
      GO TO 130                                                               MOD 5420
  120 KK = N1                                                                 MOD 5430
  130 CONTINUE                                                                MOD 5440
      DO 140 J = 1,ND                                                         MOD 5450
         XMULT(J) = (VS(J)/VS(KK)) *  * 0.7                                   MOD 5460
  140 CONTINUE                                                                MOD 5470
      GO TO 160                                                               MOD 5480
  150 WRITE (6,170)                                                           MOD 5490
  160 CONTINUE                                                                MOD 5500
      RETURN                                                                  MOD 5510
C                                                                             MOD 5520
C                                                                             MOD 5530
C                                                                             MOD 5540
  170 FORMAT (10X,97HBECAUSE NO SIZE FRACTION CONTAINS BOTH BED AND SUSPMOD 5550
     1ENDED DISCHARGE, THE COMPUTATIONS ARE ABORTED.)                         MOD 5560
      END                                                                     MOD 5570
      SUBROUTINE PLATE8 (X,Y)                                                 MOD 5580
C                                                                             MOD 5590
C     THIS SUBROUTINE APPROXIMATES PLATE 8 BY A LINE IN LOG-LOG PAPER         MOD 5600
C                                                                             MOD 5610
      Y =  - 0.33 * ALOG10(X) + 1.08                                          MOD 5620
      RETURN                                                                  MOD 5630
C                                                                             MOD 5640
      END                                                                     MOD 5650
      SUBROUTINE ZPCOM (J,IDZ)                                                MOD 5660
C                                                                             MOD 5670
C     THIS SUBROUTINE COMPUTES ZPRIME ZP BY ITERATION                         MOD 5680
C     FIRST, ATRIAL VALUE OF ZP IS CALCULATED, AND THEN, WITH ANOTHER         MOD 5690
C     TRIAL, A LINEAR INTERPOLATION IS MADE. CONVERGENCE IS VERY FAST.        MOD 5700
C                                                                             MOD 5710
      COMMON /ALLB/          D(11)        , VS(11)       , FB(10)       ,   MOD 5720
     1        FS(10)        , XMULT(10)    , JIN          , JOUT         ,   MOD 5730
     2        ND            , ND1          , ND2                             MOD 5740
      COMMON /ALLC/          QSP(10)      , XIBQB(10)    , FQL(10)          MOD 5750
      COMMON /ALLD/          P            , AP           , APP(10)      ,   MOD 5760
     1        ZP(10)                                                           MOD 5770
      XM = APP(J)                                                             MOD 5780
      RQSP = QSP(J)/XIBQB(J)                                                  MOD 5790
      IF (RQSP.LT.1873.) GO TO 100                                            MOD 5800
      IDZ = 1                                                                 MOD 5810
      WRITE (6,150)                                                           MOD 5820
      RETURN                                                                  MOD 5830
  100 CALL PLATE8 (RQSP,ZTRY)                                                 MOD 5840
      STEP = 0.01                                                             MOD 5850
      WRITE (6,160)                                                           MOD 5860
      KOUNT = 0                                                               MOD 5870
  110 CONTINUE                                                                MOD 5880
      KOUNT = KOUNT + 1                                                       MOD 5890
      IF (KOUNT.GT.10) GO TO 130                                              MOD 5900
      CALL POWER (ZTRY,XM,XI1PP,DUM1,XJ1PP,DUM2,0.01)                         MOD 5910
      CALL POWER (ZTRY,AP,DUM3,DUM4,XJ1P,XJ2P,0.01)                           MOD 5920
      CRQSP = XI1PP/XJ1PP * (P * XJ1P + XJ2P)                                 MOD 5930
```

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      DCRQ = CRQSP - RQSP                                               MOD 5940
      IF (JOUT.EQ.2) GO TO 120                                          MOD 5950
      WRITE (6,180) KOUNT,ZTRY,RQSP,CRQSP,DCRQ                          MOD 5960
  120 CONTINUE                                                          MOD 5970
      TOL = 0.01 * RQSP                                                 MOD 5980
      IF (ABS(DCRQ).LT.TOL) GO TO 140                                   MOD 5990
      IF (CRQSP.LT.RQSP) ZTRY1 = ZTRY - STEP                            MOD 6000
      IF (CRQSP.GT.RQSP) ZTRY1 = ZTRY + STEP                            MOD 6010
      CALL POWER (ZTRY1,XM,XI1PP,DUM1,XJ1PP,DUM2,0.01)                  MOD 6020
      CALL POWER (ZTRY1,AP,DUM3,DUM4,XJ1P,XJ2P,0.01)                    MOD 6030
      CRQSP1 = XI1PP/XJ1PP * (P * XJ1P + XJ2P)                          MOD 6040
      TEMP = (RQSP - CRQSP) * STEP/(CRQSP1 - CRQSP)                     MOD 6050
      IF (CRQSP.LT.RQSP) ZTRY = ZTRY - TEMP                             MOD 6060
      IF (CRQSP.GT.RQSP) ZTRY = ZTRY + TEMP                             MOD 6070
      GO TO 110                                                         MOD 6080
  130 CONTINUE                                                          MOD 6090
      WRITE (6,170)                                                     MOD 6100
  140 CONTINUE                                                          MOD 6110
      ZP(J) = ZTRY                                                      MOD 6120
      RETURN                                                            MOD 6130
C                                                                       MOD 6140
C                                                                       MOD 6150
C                                                                       MOD 6160
  150 FORMAT (///,10X,88HRQSP OUT OF PERMISSIBLE RANGE IN THIS SET OF DAMOD 6170
     1TA.CALCULATIONS FOR THIS SET ARE ABORTED.)                        MOD 6180
  160 FORMAT (//,20X,5HITER.,5X,5HZTRY ,6X,4HRQSP,8X,5HCRQSP,7X,4HDCRQ) MOD 6190
  170 FORMAT (/10X,76HZPCOM DOES NOT CONVERGE WITH 10 ITERATIONS, LAST VMOD 6200
     1ALUE OF ZP(J) WILL BE USED,/)                                     MOD 6210
  180 FORMAT (/10X,I12,4F12.5)                                          MOD 6220
      END                                                               MOD 6230
      SUBROUTINE PLATE3 (X,Y)                                           MOD 6240
C                                                                       MOD 6250
C     THIS SUBROUTINE APPROXIMATES PLATE 3 BY A SERIES OF EQUATIONS     MOD 6260
C                                                                       MOD 6270
      IF (X.LE.0.40) GO TO 100                                          MOD 6280
      GO TO 110                                                         MOD 6290
  100 Y = 1.769 * ALOG10(X/0.080)                                       MOD 6300
      GO TO 260                                                         MOD 6310
  110 IF (X.GT.0.40.AND.X.LE.0.56) GO TO 120                            MOD 6320
      GO TO 130                                                         MOD 6330
  120 Y = 1.495 * ALOG10(X/0.059)                                       MOD 6340
      GO TO 260                                                         MOD 6350
  130 IF (X.GT.0.56.AND.X.LE.0.76) GO TO 140                            MOD 6360
      GO TO 150                                                         MOD 6370
  140 Y = 0.92 * ALOG10(X/0.0145)                                       MOD 6380
      GO TO 260                                                         MOD 6390
  150 IF (X.GT.0.76.AND.X.LE.0.96) GO TO 160                            MOD 6400
      GO TO 170                                                         MOD 6410
  160 Y = 0.292 * ALOG10(X/2.9E - 06)                                   MOD 6420
      GO TO 260                                                         MOD 6430
  170 IF (X.GT.0.96.AND.X.LE.1.35) GO TO 180                            MOD 6440
      GO TO 190                                                         MOD 6450
  180 Y = 0.277 * ALOG10(632000.0/X)                                    MOD 6460
      GO TO 260                                                         MOD 6470
  190 IF (X.GT.1.35.AND.X.LE.3.00) GO TO 200                            MOD 6480
      GO TO 210                                                         MOD 6490
  200 Y = 1.115 * ALOG10(34.4/X)                                        MOD 6500
      GO TO 260                                                         MOD 6510
  210 IF (X.GT.3.00.AND.X.LE.4.00) GO TO 220                            MOD 6520
      GO TO 230                                                         MOD 6530
  220 Y = 0.725 * ALOG10(128.0/X)                                       MOD 6540
      GO TO 260                                                         MOD 6550
  230 IF (X.GT.4.00.AND.X.LE.6.70) GO TO 240                            MOD 6560
      GO TO 250                                                         MOD 6570
  240 Y = 0.399 * ALOG10(2160.0/X)                                      MOD 6580
      GO TO 260                                                         MOD 6590
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  250 IF (X.GT.6.70) Y = 1.0                                            MOD 6600
  260 RETURN                                                            MOD 6610
C                                                                       MOD 6620
      END                                                               MOD 6630
      SUBROUTINE PLATE5 (X,Y)                                           MOD 6640
C                                                                       MOD 6650
C     THIS SUBROUTINE APPROXIMATES PLATE 5 BY A SERIES OF EQUATIONS     MOD 6660
C                                                                       MOD 6670
C                                                                       MOD 6680
      IF (X.LT..4) Y = 8.106078 * X *  * ( - 0.989002)                  MOD 6690
      IF (X.LE.1..AND.X.GE..4) Y = 7.473444 * X *  * ( - 1.067367)      MOD 6700
      IF (X.LT.2..AND.X.GT.1.) Y = 7.512081 * X *  * ( - 1.182832)      MOD 6710
      IF (X.LE.3..AND.X.GE.2.) Y = 9.151968 * X *  * ( - 1.472483)      MOD 6720
      IF (X.LT.5..AND.X.GT.3.) Y = 16.025332 * X *  * ( - 1.972806)     MOD 6730
      IF (X.LE.7..AND.X.GE.5.) Y = 41.421873 * X *  * ( - 2.578713)     MOD 6740
      IF (X.LT.10..AND.X.GT.7.) Y = 130.2209 * X *  * ( - 3.165102)     MOD 6750
      IF (X.LE.13..AND.X.GE.10.) Y = 584.560594 * X *  * ( - 3.818249)  MOD 6760
      IF (X.LT.17..AND.X.GT.13.) Y = 3543.989886 * X *  * ( - 4.522935) MOD 6770
      IF (X.LE.20..AND.X.GE.17.) Y = 1690645.945 * X *  * ( - 6.703904) MOD 6780
      IF (X.LT.23..AND.X.GT.20.) Y = 5188257832. * X *  * ( - 9.381815) MOD 6790
      IF (X.GE.23.) Y = 3.134987996E15 * X *  * ( - 13.597547)          MOD 6800
      RETURN                                                            MOD 6810
C                                                                       MOD 6820
      END                                                               MOD 6830
      SUBROUTINE POWER (Z,A,XI1,XI2,XJ1,XJ2,CONV)                       MOD 6840
C                                                                       MOD 6850
C     THIS SUBROUTINE EVALUATES I1 I2 J1 AND J2 INTEGRALS               MOD 6860
C     NOTATIONS                                                         MOD 6870
C     XI1 = VALUE OF I1 INTEGRAL                                        MOD 6880
C     XI2 = VALUE OF I2 INTEGRAL                                        MOD 6890
C     XJ1 = VALUE OF J1 INTEGRAL                                        MOD 6900
C     XJ2 = VALUE OF J2 INTEGRAL                                        MOD 6910
C     N = ORDER OF APPROXIMATION + 1                                    MOD 6920
C     CONV = CONVERGENCE CRITERION                                      MOD 6930
C                                                                       MOD 6940
      N = 1                                                             MOD 6950
      FACT = 0.216 * A *  * (Z - 1.)/(1. - A) *  * Z                    MOD 6960
      XI1 = 0.                                                          MOD 6970
      XI2 = 0.                                                          MOD 6980
      XJ1 = 0.                                                          MOD 6990
      XJ2 = 0.                                                          MOD 7000
      ALG = ALOG(A)                                                     MOD 7010
      C = 1.                                                            MOD 7020
      D =  - Z                                                          MOD 7030
      E = D + 1.                                                        MOD 7040
      FN = 1.                                                           MOD 7050
      AEX = A *  * E                                                    MOD 7060
      GO TO 110                                                         MOD 7070
  100 N = N + 1                                                         MOD 7080
      C = C * D/FN                                                      MOD 7090
      D = E                                                             MOD 7100
      E = D + 1.                                                        MOD 7110
      FN = FLOAT(N)                                                     MOD 7120
      AEX = A *  * E                                                    MOD 7130
  110 IF (ABS(E).LE.0.001) GO TO 120                                    MOD 7140
      XJ1 = XJ1 + C * (1. - AEX)/E                                      MOD 7150
      XJ2 = XJ2 + C * ((AEX - 1.)/E *  * 2 - AEX * ALG/E)               MOD 7160
      GO TO 130                                                         MOD 7170
  120 XJ1 = XJ1 - C * ALG                                               MOD 7180
      XJ2 = XJ2 - 0.5 * C * ALG *  * 2                                  MOD 7190
  130 IF (N.EQ.1) GO TO 140                                             MOD 7200
      CJ1 = ABS(1. - FJ1/XJ1)                                           MOD 7210
      CJ2 = ABS(1. - FJ2/XJ2)                                           MOD 7220
      IF (CJ1.LE.CONV.AND.CJ2.LE.CONV) GO TO 150                        MOD 7230
  140 FJ1 = XJ1                                                         MOD 7240
      FJ2 = XJ2                                                         MOD 7250
      GO TO 100                                                         MOD 7260
  150 XI1 = FACT * XJ1                                                  MOD 7270
      XI2 = FACT * XJ2                                                  MOD 7280
      RETURN                                                            MOD 7290
C                                                                       MOD 7300
      END                                                               MOD 7310
```

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      PROGRAM MODEINI                                                   MODI0010
     1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)                           MODI0020
C                                                                       MODI0030
C                                                                       MODI0040
C     DEVELOPED          COLORADO STATE UNIVERSITY ENGINEERING RESEARCH MODI0050
C                        CENTER, FORT COLLINS, COLORADO, 80523.         MODI0060
C     PURPOSE            COMPUTATION OF TOTAL SEDIMENT DISCHARGE BY     MODI0070
C                        THE MODIFIED EINSTEIN PROCEDURE.               MODI0080
C     REFERENCES         U.S. BUREAU OF RECLAMATION PUBLICATION         MODI0090
C                        STEP METHOD FOR COMPUTING TOTAL SEDIMENT LOAD  MODI0100
C                        BY THE MODIFIED EINSTEIN PROCEDURE, JULY 1955  MODI0110
C                        (REVISED) AND ADDENDUM  COMPUTATION OF Z FOR USEMODI0120
C                        IN THE MODIFIED EINSTEIN PROCEDURE, JUNE 1966. MODI0130
C     CORE USAGE         CDC 6400 SCOPE 3.3 SYSTEM DEFAULT VALUE,       MODI0140
C                        43000 OCTAL.                                   MODI0150
C     COMPILATION TIME   APPROXIMATELY 8 SEC.                           MODI0160
C     CENTRAL PROCESSOR                                                 MODI0170
C     TIME FOR ONE                                                      MODI0180
C     SET OF DATA        APPROXIMATELY 1 SEC.                           MODI0190
C                                                                       MODI0200
C                                                                       MODI0210
C     INPUT AND OUTPUT DESCRIPTION                                      MODI0220
C                                                                       MODI0230
C     THE FIRST CARD IN THE INPUT LOGICAL RECORD SHOULD CONTAIN         MODI0240
C     THE VALUE OF NDATA,IN FREE FORMAT. NDATA IS THE NUMBER OF SETS    MODI0250
C     OF INPUT DATA TO BE FED TO THE COMPUTER AT A TIME.  A SET OF INPUTMODI0260
C     DATA CONSISTS OF A GROUP OF VARIABLES NECESSARY TO SPECIFY        MODI0270
C     A PROBLEM, AS DETAILED BELOW.                                     MODI0280
C                                                                       MODI0290
C     THE FIRST CARD IS TO BE FOLLOWED BY THE NDATA SETS OF INPUT       MODI0300
C     DATA, EACH ONE CONSISTING OF THE FOLLOWING, IN THE ORDER SHOWN    MODI0310
C     (ORDER IS THE SAME AS THAT USED IN REFERENCE 8)                   MODI0320
C                                                                       MODI0330
C     1) GENERAL DATA, 10 VARIABLES TO BE ENTERED IN FREE FORMAT        MODI0340
C        FOLLOWING IS A LIST OF THE VARIABLES, FORTRAN NAME AND UNITS.  MODI0350
C        AVERAGE VELOCITY                    UAVE          FT./SEC.     MODI0360
C        HYDRAULIC DEPTH                     DEPTH         FT.          MODI0370
C        WATER SURFACE WIDTH                 W             FT.          MODI0380
C        TEMPERATURE                         TEMP          DEG.FARENH.  MODI0390
C        KINEMATIC VISCOSITY                 XNU           SQ.FT./SEC.  MODI0400
C        65 PERCENT FINER DIAMETER                                      MODI0410
C             FOR BED-MATERIAL               D65           FT.          MODI0420
C        35 PERCENT FINER DIAMETER                                      MODI0430
C             FOR BED-MATERIAL               D35           FT.          MODI0440
C        AVERAGE CONCENTRATION               CONC          PPM.         MODI0450
C        PORTION OF DEPTH NOT SAMPLED        DN            FT.          MODI0460
C        AVERAGE DEPTH OF SAMPLING           DS            FT.          MODI0470
C                                                                       MODI0480
C     2) INTEGER SELECTORS JIN AND JOUT, TO BE ENTERED IN FREE FORMAT   MODI0490
C        JIN SELECTS THE NUMBER AND RANGE IN THE COMPUTATIONAL          MODI0500
C        SIZE FRACTIONS. ND IS THE NUMBER OF SIZE FRACTIONS.            MODI0510
C        IF JIN=1, THE SIZE FRACTIONS IN THE USBR PUBLICATION WILL BE   MODI0520
C        USED. THE FIRST TWO SIZE FRACTIONS WILL BE USED AND THE THIRD  MODI0530
C        DELETED, RESULTING IN ND= 10                                   MODI0540
C        IF JIN=2, THE SIZE FRACTIONS IN THE USBR PUBLICATION WILL BE   MODI0550
C        USED. IN THIS CASE THE FIRST TWO SIZE FRACTIONS WILL BE DELETEDMODI0560
C        AND THE THIRD USED INSTEAD, RESULTING IN ND=9                  MODI0570
C        IF JIN=3, THE USER HAS THE OPTION OF SPECIFYING THE NUMBER AND MODI0580
C        RANGE OF COMPUTATIONAL SIZE FRACTIONS. IF THIS OPTION IS       MODI0590
C        CHOSEN, ND SHOULD BE READ IN THE CARD IMMEDIATELY FOLLOWING,   MODI0600
C        IN FORMAT I1.                                                  MODI0610
C        JOUT SELECTS THE TYPE OF OUTPUT DESIRED.                       MODI0620
C        IF JOUT=1, OUTPUT WILL CONSIST OF THE GENERAL DATA, CHECK ON   MODI0630
C        CONVERGENCE OF Z PRIME, AND THE FINAL RESULTS IN 20 COLUMNS,   MODI0640
C        AS FOLLOWS.                                                    MODI0650
```

Figure 3. Interactive listing, Program MODEIN.

```
C
C        1) GEOMETRIC MEAN DIAMETER, IN FT.                                MODI0670
C        2) PSI                                                            MODI0680
C        3) PHI SHEAR                                                      MODI0690
C        4) PERCENTAGE OF BED MATERIAL IN SIZE FRACTION                    MODI0700
C        5) BED LOAD TRANSPORT, TONS/DAY                                   MODI0710
C        6) PERCENTAGE OF SUSPENDED LOAD IN SIZE FRACTION                  MODI0720
C        7) SAMPLED TRANSPORT IN SIZE FRACTION                             MODI0730
C        8) MULTIPLIERS                                                    MODI0740
C        9) Z PRIME VALUES                                                 MODI0750
C        10) A DOUBLE PRIME VALUES                                         MODI0760
C        11) GEOMETRIC MEAN DIAMETER, IN FT                                MODI0770
C        12) J ONE PRIME                                                   MODI0780
C        13) J TWO PRIME                                                   MODI0790
C        14) J ONE DOUBLE PRIME                                            MODI0800
C        15) J TWO DOUBLE PRIME                                            MODI0810
C        16) PRODUCT OF JS                                                 MODI0820
C        17) I ONE DOUBLE PRIME                                            MODI0830
C        18) I TWO DOUBLE PRIME                                            MODI0840
C        19) PRODUCT OF IS                                                 MODI0850
C        20) COMPUTED LOAD, IN TONS/DAY                                    MODI0860
C        IF JOUT=2 IS SELECTED, MOST OF THE 20 COLUMNS WILL BE OMITTED     MODI0870
C        IN THE PRINTOUT, AND INSTEAD ONLY COLUMNS 1,4,5,6 AND 20 WILL     MODI0880
C        BE PRINTED. ADDITIONALLY, DRL(J) AND DRU(J), LOWER AND UPPER      MODI0890
C        LIMITS OF THE SIZE FRACTION RANGE, IN MM, WILL BE PRINTED TO      MODI0900
C        THE LEFT OF THE 5 COLUMNS PREVIOUSLY MENTIONED.                   MODI0910
C                                                                          MODI0920
C     3) DATA ARRAYS.                                                      MODI0930
C        IF JIN=1, THE PERCENT OF BED MATERIAL IN SIZE FRACTIONS FB(10),MODI0940
C        AND PERCENT OF SUSPENDED LOAD IN SIZE FRACTIONS FS(10)            MODI0950
C        SHOULD BE ENTERED IN FREE FORMAT                                  MODI0960
C        IF JIN=2, FB(9) AND FS(9) SHOULD BE ENTERED IN FREE FORMAT        MODI0970
C        IF JIN=3, THE RANGE OF COMPUTATIONAL SIZE FRACTIONS SHOULD BE     MODI0980
C        SPECIFIED IN ADDITION TO THE PERCENTAGES FB AND FS.               MODI0990
C        IF THIS OPTION IS CHOSEN, DRL(ND), DRU(ND), FB(ND) AND FS(ND)     MODI1000
C        SHOULD BE ENTERED IN FREE FORMAT                                  MODI1010
C        DRL(J) AND DRU(J) ARE THE LOWER AND UPPER LIMITS OF THE SIZE      MODI1020
C        FRACTION RANGE, IN MM, RESPECTIVELY. NOTE THAT SIZE FRACTIONS     MODI1030
C        SHOULD BE ENTERED IN ORDER OF INCREASING SIZE.                    MODI1040
C                                                                          MODI1050
C                                                                          MODI1060
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,    MODI1070
     1        W            , AREA        , TEMP        , XNU         ,    MODI1080
     2        D65          , D35         , CONC        , QSM         ,    MODI1090
     3        DN           , DS                                           MODI1100
      COMMON /ALLB/         D(11)       , VS(11)      , FB(10)      ,    MODI1110
     1        FS(10)       , XMULT(10)   , JIN         , JOUT        ,    MODI1120
     2        ND           , ND1         , ND2                            MODI1130
      COMMON /ALLC/         QSP(10)     , XIBQB(10)   , FQL(10)          MODI1140
      COMMON /ALLD/         P           , AP          , APP(10)     ,    MODI1150
     1        ZP(10)                                                     MODI1160
      COMMON /ALLE/         DRL(11)     , DRU(11)                        MODI1170
      COMMON /CEF/          CJ0(2)      , CJ1(2)      , CJ2(2)      ,    MODI1180
     1        CJ3(2)       , CJ(2)       , C1(2)       , C2(2)       ,    MODI1190
     2        C3(2)        , C4(2)                                        MODI1200
      DIMENSION             COL16(10)   , COL17(10)   , COL18(10)   ,    MODI1210
     1        COL19(10)    , COL20(10)   , COL21(10)   , COL22(10)   ,    MODI1220
     2        COL23(10)    , PSI(10)     , PHISH(10)                      MODI1230
      COMMON /RUNSEQ/       L                                            MODI1240
      WRITE (6,350)                                                      MODI1250
      WRITE (6,360)                                                      MODI1260
      PRINT 290                                                          MODI1270
      READ   *, NDATA                                                    MODI1280
      DO 280 L = 1,NDATA                                                 MODI1290
         IDZ = 0                                                         MODI1300
         CALL INPUT1                                                     MODI1310
```

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      CALL INPUT2                                                       MODI1320
      WRITE (6,370)                                                     MODI1330
      WRITE (6,380) L,DISCH,UAVE,DEPTH,W,AREA,TEMP,XNU,D65,D35,CONC,QMODI1340
     1 SM,DN,DS                                                         MODI1350
C                                                                       MODI1360
C     CALCULATING HYDRAULIC RADIUS*SLOPE RS, PERCENTAGE OF FLOW SAMPLED MODI1370
C     PFS, AND SEDIMENT DISCHARGE THROUGH THE SAMPLED ZONE QSPT         MODI1380
C                                                                       MODI1390
      CALL RSCOM (X,RS)                                                 MODI1400
      CALL PLATE4 (X,PFS,XKS)                                           MODI1410
      QSPT = QSM * PFS                                                  MODI1420
C                                                                       MODI1430
C     CALCULATING PSI(J)                                                MODI1440
C                                                                       MODI1450
      DO 110 J = 1,ND                                                   MODI1460
         XPSI = 1.65 * D35/RS                                           MODI1470
         YPSI = 0.66 * D(J)/RS                                          MODI1480
         XYPSI = XPSI - YPSI                                            MODI1490
         IF (XYPSI.LT.0) GO TO 100                                      MODI1500
         PSI(J) = XPSI                                                  MODI1510
         GO TO 110                                                      MODI1520
  100    PSI(J) = YPSI                                                  MODI1530
  110 CONTINUE                                                          MODI1540
C                                                                       MODI1550
C     CALCULATING BED LOAD DISCHARGE XIBQB(J) AND PERCENTAGE OF         MODI1560
C     SUSPENDED MATERIAL IN VARIOUS SIZE FRACTIONS QSP(J)               MODI1570
C                                                                       MODI1580
      DO 120 J = 1,ND                                                   MODI1590
         XX = PSI(J)                                                    MODI1600
         CALL PLATE5 (XX,YY)                                            MODI1610
         PHISH(J) = YY                                                  MODI1620
         XIBQB(J) = 43.2 * W * 1200. * PHISH(J)/2. * D(J) *  * 1.5 *    MODI1630
     1   FB(J)                                                          MODI1640
         QSP(J) = FS(J) * QSPT                                          MODI1650
  120 CONTINUE                                                          MODI1660
C                                                                       MODI1670
C     CALCULATING P, APRIME AP, AND A DOUBLE PRIME APP(J)               MODI1680
C                                                                       MODI1690
      DXKS = 30.2 * X * DEPTH/XKS                                       MODI1700
      P = 2.303 * ALOG10(DXKS)                                          MODI1710
      AP = DN/DS                                                        MODI1720
      DO 130 J = 1,ND                                                   MODI1730
         APP(J) = 2 * D(J)/DEPTH                                        MODI1740
  130 CONTINUE                                                          MODI1750
      CALL SDR (N,K)                                                    MODI1760
      N1 = N + 1                                                        MODI1770
      NK = N + K                                                        MODI1780
      WRITE (6,300)                                                     MODI1790
C                                                                       MODI1800
C     IF K IS GREATER THAN 2, CONTROL BRANCHES TO STATEMENT 160         MODI1810
C     CALCULATING MULTIPLIERS XMULT(J) , AND ZPRIME ZP(J)               MODI1820
C                                                                       MODI1830
      IF (K.GT.2) GO TO 150                                             MODI1840
      CALL MULCOM (K,N1,NK,KK)                                          MODI1850
      CALL ZPCOM (KK,IDZ)                                               MODI1860
      IF (IDZ.EQ.1) GO TO 280                                           MODI1870
      DO 140 J = 1,ND                                                   MODI1880
         ZP(J) = ZP(KK) * XMULT(J)                                      MODI1890
  140 CONTINUE                                                          MODI1900
      GO TO 190                                                         MODI1910
C                                                                       MODI1920
C     CALCULATING ZP AND VS ARRAYS TO BE FED TO LEAST SQUARE SUBROUTINE MODI1930
C     LSZPVS                                                            MODI1940
C                                                                       MODI1950
  150 CONTINUE                                                          MODI1960
      DO 160 J = N1,NK                                                  MODI1970
```

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            CALL ZPCOM (J,IDZ)                                          MODI1980
            IF (IDZ.EQ.1) GO TO 280                                     MODI1990
  160     CONTINUE                                                      MODI2000
          IF (JOUT.EQ.2) GO TO 170                                      MODI2010
          WRITE (6,310)                                                 MODI2020
          WRITE (6,330)                                                 MODI2030
          WRITE (6,340) (J,ZP(J),VS(J),J = N1,NK)                       MODI2040
  170     CONTINUE                                                      MODI2050
          CALL LSZPVS (N1,NK,K,VS,ZP,A,B)                               MODI2060
          A = EXP(A)                                                    MODI2070
          DO 180 J = 1,ND                                               MODI2080
             XMULT(J) = 0.0                                             MODI2090
             ZP(J) = A * VS(J) *  * B                                   MODI2100
  180     CONTINUE                                                      MODI2110
C                                                                       MODI2120
C     CALCULATING SEDIMENT LOAD BY USING MODIFIED EINSTEINS INTEGRAL    MODI2130
C     CHARTS 9,10,11 AND 12                                             MODI2140
C                                                                       MODI2150
  190     CONTINUE                                                      MODI2160
          IF (JOUT.EQ.2) GO TO 210                                      MODI2170
          IF (K.LT.3) GO TO 200                                         MODI2180
          WRITE (6,320)                                                 MODI2190
  200     CONTINUE                                                      MODI2200
          IF (JOUT.EQ.2) GO TO 210                                      MODI2210
          WRITE (6,330)                                                 MODI2220
          WRITE (6,340) (J,ZP(J),VS(J),J = 1,ND)                        MODI2230
  210     CONTINUE                                                      MODI2240
          TQL = 0                                                       MODI2250
          TBL = 0                                                       MODI2260
          DO 250 I = 1,ND                                               MODI2270
             XM = APP(I)                                                MODI2280
             ZM = ZP(I)                                                 MODI2290
             IF (FB(I).LT.0.01.AND.FS(I).LT.0.01) GO TO 230             MODI2300
             IF (FB(I).LT.0.01) GO TO 220                               MODI2310
             CALL POWER (ZM,XM,COL21(I),COL22(I),DUM1,DUM2,0.01)        MODI2320
             COL23(I) = P * COL21(I) + COL22(I) + 1.                    MODI2330
             FQL(I) = XIBQB(I) * COL23(I)                               MODI2340
             COL16(I) = 0.                                              MODI2350
             COL17(I) = 0.                                              MODI2360
             COL18(I) = 0.                                              MODI2370
             COL19(I) = 0.                                              MODI2380
             COL20(I) = 0.                                              MODI2390
             GO TO 240                                                  MODI2400
  220        CONTINUE                                                   MODI2410
             CALL POWER (ZM,AP,DUM1,DUM2,COL16(I),COL17(I),0.01)        MODI2420
             CALL POWER (ZM,XM,DUM3,DUM4,COL18(I),COL19(I),0.01)        MODI2430
             COL20(I) = (P * COL18(I) + COL19(I))/(P * COL16(I) + COL17(IMODI2440
     1       ))                                                         MODI2450
             FQL(I) = QSP(I) * COL20(I)                                 MODI2460
             COL21(I) = 0.                                              MODI2470
             COL22(I) = 0.                                              MODI2480
             COL23(I) = 0.                                              MODI2490
             GO TO 240                                                  MODI2500
  230        CONTINUE                                                   MODI2510
             FQL(I) = 0.0                                               MODI2520
             COL16(I) = 0.                                              MODI2530
             COL17(I) = 0.                                              MODI2540
             COL18(I) = 0.                                              MODI2550
             COL19(I) = 0.                                              MODI2560
             COL20(I) = 0.                                              MODI2570
             COL21(I) = 0.                                              MODI2580
             COL22(I) = 0.                                              MODI2590
             COL23(I) = 0.                                              MODI2600
  240        CONTINUE                                                   MODI2610
             TQL = TQL + FQL(I)                                         MODI2620
             TBL = TBL + XIBQB(I)                                       MODI2630
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          TBL = TBL + XIBQB(I)                                          MODI2630
  250     CONTINUE                                                      MODI2640
          TSL = TQL - TBL                                               MODI2650
C                                                                       MODI2660
C     PRINTING OUTPUT                                                   MODI2670
C                                                                       MODI2680
          WRITE (6,390)                                                 MODI2690
          IF (JOUT.EQ.2) GO TO 260                                      MODI2700
          WRITE (6,400)                                                 MODI2710
          WRITE (6,410) (J,D(J),PSI(J),PHISH(J),FB(J),XIBQB(J),FS(J),QSP(MODI2720
     1    J),XMULT(J),ZP(J),APP(J),J = 1,ND)                            MODI2730
          WRITE (6,420)                                                 MODI2740
          WRITE (6,430) (J,D(J),COL16(J),COL17(J),COL18(J),COL19(J),COL20MODI2750
     1    (J),COL21(J),COL22(J),COL23(J),FQL(J),J = 1,ND)               MODI2760
          GO TO 270                                                     MODI2770
  260     CONTINUE                                                      MODI2780
          WRITE (6,440)                                                 MODI2790
          WRITE (6,450) (DRL(J),DRU(J),D(J),FB(J),XIBQB(J),FS(J),FQL(J),JMODI2800
     1     = 1,ND)                                                      MODI2810
  270     CONTINUE                                                      MODI2820
          WRITE (6,460) TBL,TSL,TQL                                     MODI2830
  280 CONTINUE                                                          MODI2840
C                                                                       MODI2850
C     FORMAT STATEMENTS                                                 MODI2860
C                                                                       MODI2870
      STOP                                                              MODI2880
C                                                                       MODI2890
C                                                                       MODI2900
C                                                                       MODI2910
  290 FORMAT (///, 33H  START INPUT DATA IN FREE FORMAT,//, 34H ENTER NUMODI2920
     1MBER OF DATA SETS, NDATA=)                                        MODI2930
  300 FORMAT (//,10X,75H CONVERGENCE OF SUBROUTINE ZPCOM IS CHECKED BY PMODI2940
     1RINTING OUT VALUES INVOLVED,//)                                   MODI2950
  310 FORMAT (//,10X,41H ARRAYS ZP AND VS BEFORE LEAST SQUARE FIT,/)    MODI2960
  320 FORMAT (//,10X,40H ARRAYS ZP AND VS AFTER LEAST SQUARE FIT,/)     MODI2970
  330 FORMAT (//,10X,35H            J       ZP(J)        VS(J),/)       MODI2980
  340 FORMAT (10X,I12,2F12.6)                                           MODI2990
  350 FORMAT (1H1)                                                      MODI3000
  360 FORMAT (40X,70HCOMPUTATION OF TOTAL SEDIMENT LOAD BY THE MODIFIED MODI3010
     1 EINSTEIN PROCEDURE,///)                                          MODI3020
  370 FORMAT (32X,10HDATA INPUT,//)                                     MODI3030
  380 FORMAT (10X,4HSET ,I5,/10X,34HWATER DISCHARGE                    ,FMODI3040
     112.2,13H C.F.S.       ,/10X,34HAVERAGE VELOCITY                  ,FMODI3050
     212.2,13H FT./SEC.     ,/10X,34HHYDRAULIC DEPTH                   ,FMODI3060
     312.2,13H FT.          ,/10X,34HWATER SURFACE WIDTH               ,FMODI3070
     412.2,13H FT.          ,/10X,34HAREA                              ,FMODI3080
     512.2,13H SQ.FT.       ,/10X,34HTEMPERATURE                       ,FMODI3090
     612.2,13H DEG.FAHREN.  ,/10X,34HKINEMATIC VISCOSITY               ,FMODI3100
     712.7,13H SQ.FT./SEC.  ,/10X,34HD65                               ,FMODI3110
     812.6,13H FT.          ,/10X,34HD35                               ,FMODI3120
     912.6,13H FT.          ,/10X,34HAVERAGE CONCENTRATION             ,FMODI3130
     012.2,13H PPM.         ,/10X,34HSAMPLED SUSPENDED LOAD            ,FMODI3140
     112.4,13H TONS/DAY     ,/10X,34HPORTION OF DEPTH NOT SAMPLED      ,FMODI3150
     212.2,13H FT.          ,/10X,34HAVERAGE DEPTH AT SAMPLING         ,FMODI3160
     312.2,4H FT.)                                                      MODI3170
  390 FORMAT (//)                                                       MODI3180
  400 FORMAT (5X,1HJ,11X,4HD(J),7X,6HPSI(J),5X,8HPHISH(J),7X,5HFB(J),4X,MODI3190
     18HXIBQB(J),7X,5HFS(J),6X,6HQSP(J),4X,8HXMULT(J),7X,5HZP(J),5X,6HAPMODI3200
     2P(J)/)                                                            MODI3210
  410 FORMAT (4X,I2,4X,F12.6,F12.3,F12.5,6F12.3,F12.6)                  MODI3220
  420 FORMAT (//5X,1HJ,11X,4HD(J),6X,8HCOL16(J),4X,8HCOL17(J),4X,8HCOL18MODI3230
     1(J),4X,8HCOL19(J),4X,8HCOL20(J),4X,8HCOL21(J),4X,8HCOL22(J),4X,8HCMODI3240
     2OL23(J),4X,9HCOMP.LOAD/)                                          MODI3250
  430 FORMAT (4X,I2,4X,F12.6,8F12.3,F12.4)                              MODI3260
  440 FORMAT (10X,84H       DRL(J)       DRU(J)        D(J)         FB(J)   MODI3270
     1 XIBQB(J)        FS(J)       FQL(J),/)                            MODI3280
  450 FORMAT (10X,6F12.6,F12.3)                                         MODI3290
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  460 FORMAT (///,5X,34HTOTAL BED LOAD                    ,F16.1,9H TONSMODI3300
     1/DAY,/5X,34HTOTAL SUSPENDED LOAD                ,F16.1,9H TONS/DAY,/MODI3310
     25X,34HTOTAL LOAD                            ,F16.1,9H TONS/DAY)       MODI3320
      END                                                                   MODI3330
      SUBROUTINE INPUT1                                                     MODI3340
C                                                                           MODI3350
C     THIS SUBROUTINE READS IN THE BASIC VARIABLES OF THE PROBLEM           MODI3360
C                                                                           MODI3370
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,       MODI3380
     1        W            , AREA        , TEMP        , XNU         ,      MODI3390
     2        D65          , D35         , CONC        , QSM         ,      MODI3400
     3        DN           , DS                                             MODI3410
      COMMON /RUNSEQ/       L           , INOPT                            MODI3420
      IF (L.EQ.1) PRINT 130                                                 MODI3430
      IF (L.EQ.1) READ   *, INOPT                                           MODI3440
      IF (INOPT.EQ.1) GO TO 110                                             MODI3450
      PRINT 140                                                             MODI3460
      PRINT 150                                                             MODI3470
      READ   *, UAVE                                                        MODI3480
      PRINT 160                                                             MODI3490
      READ   *, DEPTH                                                       MODI3500
      PRINT 170                                                             MODI3510
      READ   *, W                                                           MODI3520
      PRINT 180                                                             MODI3530
      READ   *, TEMP                                                        MODI3540
      PRINT 190                                                             MODI3550
      READ   *, XNU                                                         MODI3560
      PRINT 200                                                             MODI3570
      READ   *, D65                                                         MODI3580
      PRINT 210                                                             MODI3590
      READ   *, D35                                                         MODI3600
      PRINT 220                                                             MODI3610
      READ   *, CONC                                                        MODI3620
      PRINT 230                                                             MODI3630
      READ   *, DN                                                          MODI3640
      PRINT 240                                                             MODI3650
      READ   *, DS                                                          MODI3660
  100 CONTINUE                                                              MODI3670
C                                                                           MODI3680
C     CALCULATE AREA(SQ.FT),DISCHARGE(CFS) AND SAMPLED SUSPENDED LOAD(T/MODI3690
C                                                                           MODI3700
      AREA = DEPTH * W                                                      MODI3710
      DISCH = AREA * UAVE                                                   MODI3720
      QSM = (43.2 * 62.4 * 1E - 6) * DISCH * CONC                           MODI3730
      RETURN                                                                MODI3740
  110 CONTINUE                                                              MODI3750
      PRINT 250                                                             MODI3760
      READ   *, UAVE,DEPTH,W,TEMP,XNU,D65,D35,CONC,DN,DS                    MODI3770
      IF (D65.LE.D35) GO TO 120                                             MODI3780
      GO TO 100                                                             MODI3790
  120 WRITE (6,260) D65,D35                                                 MODI3800
      READ   *, UAVE,DEPTH,W,TEMP,XNU,D65,D35,CONC,DN,DS                    MODI3810
      GO TO 100                                                             MODI3820
C                                                                           MODI3830
C                                                                           MODI3840
C                                                                           MODI3850
  130 FORMAT ( 50H  ENTER INOPT=1 TO READ IN ALL THE MAJOR VARIABLES, 15MODI3860
     1H IN ONE STRING,,/, 39H        OTHERWISE INPUT DATA ONE BY ONE)      MODI3870
  140 FORMAT (////, 44H  ENTER FOLLOWING INPUT DATA (10 VARIABLES):,/)      MODI3880
  150 FORMAT ( 32H  AVERAGE VELOCITY IN FPS, UAVE=)                         MODI3890
  160 FORMAT ( 32H  HYDRAULIC DEPTH IN FT., DEPTH=)                         MODI3900
  170 FORMAT ( 32H  WATER SURFACE WIDTH IN FT., W=)                         MODI3910
  180 FORMAT ( 36H  TEMPERATURE IN DEG. FARENH., TEMP=)                     MODI3920
  190 FORMAT ( 42H  KINEMATIC VISCOSITY IN SQ.FT./SEC., XNU=)               MODI3930
  200 FORMAT ( 13H  D65 IN FT.=)                                            MODI3940
  210 FORMAT ( 13H  D35 IN FT.=)                                            MODI3950
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  220 FORMAT ( 47H  AVERAGE CONCENTRATION IN PPM BY WEIGHT, CONC=)-------MODI3960
  230 FORMAT ( 41H  PORTION OF DEPTH NOT SAMPLED IN FT. DN=)             MODI3970
  240 FORMAT ( 39H  AVERAGE DEPTH OF SAMPLING IN FT., DS=)               MODI3980
  250 FORMAT ( 54H  ENTER FOLLOWING INPUT DATA (10 VARIABLES) IN ENGLISHMODI3990
     1,  7H UNITS:,/, 42H   UAVE,DEPTH,W,TEMP,VISCO.,D65,D35,CONC.(, 20HMODI4000
     2PPM BY WEIGHT),DN,DS)                                              MODI4010
  260 FORMAT (/,5X, 29HCHECK YOUR INPUT DATA IF D65=,F10.6, 15H FT.  .GTMODI4020
     1. D35=,F10.6,  4H FT.,/,5X, 31HENTER DATA IN THIS STRING AGAIN,/) MODI4030
      END                                                                MODI4040
      SUBROUTINE INPUT2                                                  MODI4050
C                                                                        MODI4060
C     THIS SUBROUTINE READS IN ADDITIONAL INPUT AND FINDS THE VALUE OF  MODI4070
C     ND, THE NUMBER OF SIZE FRACTIONS TO BE USED IN THE COMPUTATION    MODI4080
C                                                                        MODI4090
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,   MODI4100
     1        W            , AREA       , TEMP        , XNU         ,   MODI4110
     2        D65          , D35        , CONC        , QSM         ,   MODI4120
     3        DN           , DS                                         MODI4130
      COMMON /ALLB/         D(11)       , VS(11)      , FB(10)      ,   MODI4140
     1        FS(10)       , XMULT(10)  , JIN         , JOUT        ,   MODI4150
     2        ND           , ND1        , ND2                          MODI4160
      COMMON /ALLE/         DRL(11)     , DRU(11)                      MODI4170
      COMMON /RUNSEQ/       L                                          MODI4180
      IF (L.GE.2) GO TO 220                                              MODI4190
      DRL(1) = .002                                                      MODI4200
      DRL(2) = .0156                                                     MODI4210
      DRL(3) = .002                                                      MODI4220
      DRL(4) = .0625                                                     MODI4230
      DRL(5) = .125                                                      MODI4240
      DRL(6) = .25                                                       MODI4250
      DRL(7) = .5                                                        MODI4260
      DRL(8) = 1.                                                        MODI4270
      DRL(9) = 2.                                                        MODI4280
      DRL(10) = 4.                                                       MODI4290
      DRL(11) = 8.                                                       MODI4300
      DRU(1) = .0156                                                     MODI4310
      DRU(2) = .0625                                                     MODI4320
      DRU(3) = .0625                                                     MODI4330
      DRU(4) = .125                                                      MODI4340
      DRU(5) = .25                                                       MODI4350
      DRU(6) = .5                                                        MODI4360
      DRU(7) = 1.                                                        MODI4370
      DRU(8) = 2.                                                        MODI4380
      DRU(9) = 4.                                                        MODI4390
      DRU(10) = 8.                                                       MODI4400
      DRU(11) = 16.                                                      MODI4410
  100 CONTINUE                                                           MODI4420
      PRINT 230                                                          MODI4430
      PRINT 240                                                          MODI4440
      DO 110 J = 1,11                                                    MODI4450
         IF (J.LE.2) PRINT 250, DRL(J),DRU(J)                            MODI4460
         IF (J.EQ.3) PRINT 260, DRL(J),DRU(J)                            MODI4470
         IF (J.GT.3) PRINT 250, DRL(J),DRU(J),DRL(J),DRU(J)              MODI4480
  110 CONTINUE                                                           MODI4490
      PRINT 270                                                          MODI4500
      READ   *, JIN                                                      MODI4510
      PRINT 280                                                          MODI4520
      READ   *, JOUT                                                     MODI4530
      IF (JIN.EQ.3) GO TO 180                                            MODI4540
      DO 120 J = 1,11                                                    MODI4550
         D(J) = (DRL(J) * DRU(J)) *  * 0.5/304.8                         MODI4560
         VS(J) = ((2./3. * 32.17 * 1.65 * D(J) *  * 3. + 36. * XNU *  * MODI4570
     1   2.) *  * 0.5 - 6. * XNU)/D(J)                                   MODI4580
  120 CONTINUE                                                           MODI4590
      ND1 = 10                                                           MODI4600
      ND2 = 9                                                            MODI4610
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      IF (JIN.EQ.2) GO TO 140                                           MODI4620
      DO 130 J = 3,ND1                                                  MODI4630
         D(J) = D(J + 1)                                                MODI4640
         VS(J) = VS(J + 1)                                              MODI4650
  130 CONTINUE                                                          MODI4660
      ND = ND1                                                          MODI4670
      GO TO 160                                                         MODI4680
  140 DO 150 J = 1,ND2                                                  MODI4690
         D(J) = D(J + 2)                                                MODI4700
         VS(J) = VS(J + 2)                                              MODI4710
  150 CONTINUE                                                          MODI4720
      ND = ND2                                                          MODI4730
  160 CONTINUE                                                          MODI4740
      PRINT 290, ND                                                     MODI4750
      DO 170 J = 1,ND                                                   MODI4760
         PRINT 300, J,J                                                 MODI4770
         READ   *, FB(J),FS(J)                                          MODI4780
  170 CONTINUE                                                          MODI4790
      GO TO 210                                                         MODI4800
  180 CONTINUE                                                          MODI4810
      PRINT 310                                                         MODI4820
      READ   *, ND                                                      MODI4830
      PRINT 320                                                         MODI4840
      DO 190 J = 1,ND                                                   MODI4850
         PRINT 330, J,J,J,J                                             MODI4860
         READ   *, DRL(J),DRU(J),FB(J),FS(J)                            MODI4870
  190 CONTINUE                                                          MODI4880
      DO 200 J = 1,ND                                                   MODI4890
         D(J) = (DRU(J) * DRL(J)) *  * 0.5/304.8                        MODI4900
         VS(J) = ((2./3. * 32.17 * 1.65 * D(J) *  * 3. + 36. * XNU *  * MODI4910
     1   2.) *  * 0.5 - 6. * XNU)/D(J)                                  MODI4920
  200 CONTINUE                                                          MODI4930
  210 CONTINUE                                                          MODI4940
      OLDD65 = D65                                                      MODI4950
      OLDD35 = D35                                                      MODI4960
      RETURN                                                            MODI4970
  220 CONTINUE                                                          MODI4980
      IF (OLDD65.NE.D65.OR.OLDD35.NE.D35) GO TO 100                     MODI4990
      PRINT 340                                                         MODI5000
      READ   *, IFSDATA                                                 MODI5010
      IF (IFSDATA.EQ.1) RETURN                                          MODI5020
      PRINT 350, ND                                                     MODI5030
      READ   *, (FS(J),J = 1,ND)                                        MODI5040
      RETURN                                                            MODI5050
C                                                                       MODI5060
C                                                                       MODI5070
C                                                                       MODI5080
  230 FORMAT(//33H  SEDIMENT SIZE DATA INPUT OPTION/,41H      JIN=1 FOR MODI5090
     110 DEFINED SIZE FRACTIONS,/, 41H      JIN=2 FOR  9 DEFINED SIZE FRMODI5100
     2ACIONS,/, 49H      JIN=3 USER PROVIDES SIZE FRACTIONS AND DATA,/) MODI5110
  240 FORMAT (/11X, 11H      JIN=1,18X,  5HJIN=2,/10X,2( 17H   DRL      MODI5120
     1 DRU ,8X),/10X,2( 18H (LOWER)   (UPPER),7X))                      MODI5130
  250 FORMAT (10X,2(F7.4,  3H - ,F7.4,8X))                              MODI5140
  260 FORMAT (35X,F7.4,  3H - ,F7.4)                                    MODI5150
  270 FORMAT ( 12H  ENTER JIN=)                                         MODI5160
  280 FORMAT ( 41H  OUTPUT OPTION: JOUT=1 FOR FULL PRINTOUT,/, 52H      MODI5170
     1                =2 FOR THE INPUT PARAMETERS AND, 17H THE RESULTS ONMODI5180
     2LY,/, 18H        ENTER JOUT=)                                    MODI5190
  290 FORMAT ( 30H  NUMBER OF SIZE FRACTIONS ND=,I5,//, 52H  ENTER THE SMODI5200
     1IZE FRACTIONS OF BED MATERIAL FB( ) AND,/, 53H                    MODI5210
     2          SUSP. MAT.   FS( )  AS ,/, 21H        AS FOLLOWING:)    MODI5220
  300    FORMAT ( 12H  ENTER  FB(,I2,  8H )   FS(,I2,  2H ))           MODI5230
  310 FORMAT ( 40H  ENTER THE NUMBER OF SIZE FRACTIONS ND=)             MODI5240
  320 FORMAT (12X, 49HLOWER LIMIT   UPPER LIMIT  FRAC. OF BED AND SUSP.)MODI5250
  330    FORMAT ( 17H    ENTER    DRL(,I2, 11H )     DRU(,I2, 10H )    MODI5260
     1FB(,I2, 10H )     FS(,I2,  2H ))                                 MODI5270
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  340 FORMAT (/, 49H  THE BED MATERIAL DISTRIBUTION IS THE SAME AS IN, 1MODI5280
     15H THE FIRST SET.,//, 52H  ENTER IFSDATA=1 IF SIZE FRACTIONS OF THMODI5290
     2E SUSPENDED, 39H LOAD ARE THE SAME AS IN THE FIRST SET,,/, 31H    MODI5300
     3    OTHERWISE READ IN FS( ))                                      MODI5310
  350 FORMAT ( 18H  ENTER FS(J),J=1,,I3,  2H ))                         MODI5320
      END                                                               MODI5330
      SUBROUTINE RSCOM (X,RS)                                           MODI5340
C                                                                       MODI5350
C     THIS SUBROUTINE COMPUTES THE VALUE OF RS BY ITERATION             MODI5360
C                                                                       MODI5370
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,   MODI5380
     1        W            , AREA       , TEMP        , XNU         ,   MODI5390
     2        D65          , D35        , CONC        , QSM         ,   MODI5400
     3        DN           , DS                                         MODI5410
      X = 1.6                                                           MODI5420
      TOL = 0.001                                                       MODI5430
      XKS = D65                                                         MODI5440
  100 XDKS = 12.27 * X * DEPTH/XKS                                      MODI5450
      SRRS = UAVE/(32.63 * ALOG10(XDKS))                                MODI5460
      USHP = SRRS * 5.68                                                MODI5470
      DEL = 11.6 * XNU/USHP                                             MODI5480
      DELKS = XKS/DEL                                                   MODI5490
      CALL PLATE3 (DELKS,X2)                                            MODI5500
      DELX = X - X2                                                     MODI5510
      IF (ABS(DELX).LT.TOL) GO TO 110                                   MODI5520
      X = X2                                                            MODI5530
      GO TO 100                                                         MODI5540
  110 CONTINUE                                                          MODI5550
      XDKS = 12.27 * X * DEPTH/XKS                                      MODI5560
      SRRS = UAVE/(32.63 * ALOG10(XDKS))                                MODI5570
      RS = SRRS * SRRS                                                  MODI5580
      RETURN                                                            MODI5590
C                                                                       MODI5600
      END                                                               MODI5610
      SUBROUTINE PLATE4 (X,PFS,XKS)                                     MODI5620
C                                                                       MODI5630
C     THIS SUBROUTINE SUBSTITUTES PLATE FOUR FOR THE ANALYTICAL         MODI5640
C     EXPRESSION OF PFS                                                 MODI5650
C                                                                       MODI5660
      COMMON /ALL/          DISCH       , UAVE        , DEPTH       ,   MODI5670
     1        W            , AREA       , TEMP        , XNU         ,   MODI5680
     2        D65          , D35        , CONC        , QSM         ,   MODI5690
     3        DN           , DS                                         MODI5700
      XKS = D65                                                         MODI5710
      A = 30.2 * X/XKS                                                  MODI5720
      YDS = DS * ALOG(A * DS) - DS                                      MODI5730
      YDN = DN * ALOG(A * DN) - DN                                      MODI5740
      PFS = (YDS - YDN)/YDS                                             MODI5750
      RETURN                                                            MODI5760
C                                                                       MODI5770
      END                                                               MODI5780
      SUBROUTINE SUR (N,K)                                              MODI5790
C                                                                       MODI5800
C     THIS SUBROUTINE COUNTS THE NUMBER OF SIZE FRACTIONS K FOR WHICH   MODI5810
C     THERE IS BOTH BED AND SUSPENDED DISCHARGE, AND THE NUMBER OF SIZE MODI5820
C     FRACTIONS N SMALLER THAN FIRST K.                                 MODI5830
C                                                                       MODI5840
      COMMON /ALLB/         D(11)       , VS(11)      , FB(10)      ,   MODI5850
     1        FS(10)       , XMULT(10)  , JIN         , JOUT        ,   MODI5860
     2        ND           , ND1        , ND2                          MODI5870
      J = 0                                                             MODI5880
      K = 0                                                             MODI5890
      N = 0                                                             MODI5900
  100 CONTINUE                                                          MODI5910
      IF (FB(J + 1).GT.0.00.AND.FS(J + 1).GT.0.00) GO TO 120            MODI5920
      IF (K.NE.0) GO TO 110                                             MODI5930
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      N = N + 1                                                         MODI5940
  110 J = J + 1                                                         MODI5950
      IF (J.EQ.ND) RETURN                                               MODI5960
      GO TO 100                                                         MODI5970
  120 CONTINUE                                                          MODI5980
      K = K + 1                                                         MODI5990
      J = J + 1                                                         MODI6000
      IF (J.EQ.ND) RETURN                                               MODI6010
      GO TO 100                                                         MODI6020
C                                                                       MODI6030
      END                                                               MODI6040
      SUBROUTINE LSZPVS (N1,NK,K,X,Y,A,B)                               MODI6050
C                                                                       MODI6060
C     THIS SUBROUTINE CALCULATES A LEAST SQUARE FIT FOR ZPRIME ZP(K) ANDMODI6070
C     VS(K)                                                             MODI6080
C                                                                       MODI6090
      DIMENSION              X(11)        , Y(10)                      MODI6100
      SUMX = 0.                                                         MODI6110
      SUMY = 0.                                                         MODI6120
      SUMXY = 0.                                                        MODI6130
      SUMX2 = 0.                                                        MODI6140
      DO 100 J = N1,NK                                                  MODI6150
         XL = ALOG(X(J))                                                MODI6160
         SUMX = SUMX + XL                                               MODI6170
         YL = ALOG(Y(J))                                                MODI6180
         SUMY = SUMY + YL                                               MODI6190
         XY = XL * YL                                                   MODI6200
         SUMXY = SUMXY + XY                                             MODI6210
         X2 = XL * XL                                                   MODI6220
         SUMX2 = SUMX2 + X2                                             MODI6230
  100 CONTINUE                                                          MODI6240
      XMEAN = SUMX/K                                                    MODI6250
      YMEAN = SUMY/K                                                    MODI6260
      B = (SUMXY - SUMX * SUMY/K)/(SUMX2 - SUMX * SUMX/K)               MODI6270
      A = YMEAN - B * XMEAN                                             MODI6280
      RETURN                                                            MODI6290
C                                                                       MODI6300
      END                                                               MODI6310
      SUBROUTINE MULCOM (K,N1,NK,KK)                                    MODI6320
C                                                                       MODI6330
C     THIS SUBROUTINE CALCULATES THE MULTIPLIERS XMULT(J)               MODI6340
C                                                                       MODI6350
      COMMON /ALLB/          D(11)        , VS(11)       , FB(10)       ,MODI6360
     1        FS(10)       , XMULT(10)    , JIN          , JOUT         ,MODI6370
     2        ND           , ND1          , ND2                         MODI6380
      DIMENSION              SBS(9)                                     MODI6390
      IF (K.EQ.0) GO TO 150                                             MODI6400
      IF (K.EQ.2) GO TO 100                                             MODI6410
      KK = N1                                                           MODI6420
      GO TO 130                                                         MODI6430
  100 CONTINUE                                                          MODI6440
      DO 110 J = N1,NK                                                  MODI6450
         SBS(J) = FB(J) + FS(J)                                         MODI6460
  110 CONTINUE                                                          MODI6470
      IF (SBS(N1).GT.SBS(NK)) GO TO 120                                 MODI6480
      KK = NK                                                           MODI6490
      GO TO 130                                                         MODI6500
  120 KK = N1                                                           MODI6510
  130 CONTINUE                                                          MODI6520
      DO 140 J = 1,ND                                                   MODI6530
         XMULT(J) = (VS(J)/VS(KK)) *  * 0.7                             MODI6540
  140 CONTINUE                                                          MODI6550
      GO TO 160                                                         MODI6560
  150 WRITE (6,170)                                                     MODI6570
  160 CONTINUE                                                          MODI6580
      RETURN                                                            MODI6590
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C                                                                       MODI6600
C                                                                       MODI6610
C                                                                       MODI6620
  170 FORMAT (10X,97HBECAUSE NO SIZE FRACTION CONTAINS BOTH BED AND SUSPMODI6630
     1ENDED DISCHARGE, THE COMPUTATIONS ARE ABORTED.)                   MODI6640
      END                                                               MODI6650
      SUBROUTINE PLATE8 (X,Y)                                           MODI6660
C                                                                       MODI6670
C     THIS SUBROUTINE APPROXIMATES PLATE 8 BY A LINE IN LOG-LOG PAPER   MODI6680
C                                                                       MODI6690
      Y =  - 0.33 * ALOG10(X) + 1.08                                    MODI6700
      RETURN                                                            MODI6710
C                                                                       MODI6720
      END                                                               MODI6730
      SUBROUTINE ZPCOM (J,IDZ)                                          MODI6740
C                                                                       MODI6750
C     THIS SUBROUTINE COMPUTES ZPRIME ZP BY ITERATION                   MODI6760
C     FIRST, ATRIAL VALUE OF ZP IS CALCULATED, AND THEN, WITH ANOTHER   MODI6770
C     TRIAL, A LINEAR INTERPOLATION IS MADE. CONVERGENCE IS VERY FAST.  MODI6780
C                                                                       MODI6790
      COMMON /ALLB/          D(11)        , VS(11)       , FB(10)       ,  MODI6800
     1        FS(10)       , XMULT(10)    , JIN          , JOUT         ,  MODI6810
     2        ND           , ND1          , ND2                            MODI6820
      COMMON /ALLC/          QSP(10)      , XIBQB(10)    , FQL(10)        MODI6830
      COMMON /ALLD/          P            , AP           , APP(10)      ,  MODI6840
     1        ZP(10)                                                     MODI6850
      XM = APP(J)                                                       MODI6860
      RQSP = QSP(J)/XIBQB(J)                                            MODI6870
      IF (RQSP.LT.1873.) GO TO 100                                      MODI6880
      IDZ = 1                                                           MODI6890
      WRITE (6,150)                                                     MODI6900
      RETURN                                                            MODI6910
  100 CALL PLATE8 (RQSP,ZTRY)                                           MODI6920
      STEP = 0.01                                                       MODI6930
      WRITE (6,160)                                                     MODI6940
      KOUNT = 0                                                         MODI6950
  110 CONTINUE                                                          MODI6960
      KOUNT = KOUNT + 1                                                 MODI6970
      IF (KOUNT.GT.10) GO TO 130                                        MODI6980
      CALL POWER (ZTRY,XM,XI1PP,DUM1,XJ1PP,DUM2,0.01)                   MODI6990
      CALL POWER (ZTRY,AP,DUM3,DUM4,XJ1P,XJ2P,0.01)                     MODI7000
      CRQSP = XI1PP/XJ1PP * (P * XJ1P + XJ2P)                           MODI7010
      DCRQ = CRQSP - RQSP                                               MODI7020
      IF (JOUT.EQ.2) GO TO 120                                          MODI7030
      WRITE (6,180) KOUNT,ZTRY,RQSP,CRQSP,DCRQ                          MODI7040
  120 CONTINUE                                                          MODI7050
      TOL = 0.01 * RQSP                                                 MODI7060
      IF (ABS(DCRQ).LT.TOL) GO TO 140                                   MODI7070
      IF (CRQSP.LT.RQSP) ZTRY1 = ZTRY - STEP                            MODI7080
      IF (CRQSP.GT.RQSP) ZTRY1 = ZTRY + STEP                            MODI7090
      CALL POWER (ZTRY1,XM,XI1PP,DUM1,XJ1PP,DUM2,0.01)                  MODI7100
      CALL POWER (ZTRY1,AP,DUM3,DUM4,XJ1P,XJ2P,0.01)                    MODI7110
      CRQSP1 = XI1PP/XJ1PP * (P * XJ1P + XJ2P)                          MODI7120
      TEMP = (RQSP - CRQSP) * STEP/(CRQSP1 - CRQSP)                     MODI7130
      IF (CRQSP.LT.RQSP) ZTRY = ZTRY - TEMP                             MODI7140
      IF (CRQSP.GT.RQSP) ZTRY = ZTRY + TEMP                             MODI7150
      GO TO 110                                                         MODI7160
  130 CONTINUE                                                          MODI7170
      WRITE (6,170)                                                     MODI7180
  140 CONTINUE                                                          MODI7190
      ZP(J) = ZTRY                                                      MODI7200
      RETURN                                                            MODI7210
C                                                                       MODI7220
C                                                                       MODI7230
C                                                                       MODI7240
  150 FORMAT (///,10X,88HRQSP OUT OF PERMISSIBLE RANGE IN THIS SET OF DAMODI7250
```

```
     1TA.CALCULATIONS FOR THIS SET ARE ABORTED.)                        MODI7260
  160 FORMAT (//,20X,5HITER.,5X,5HZTRY ,6X,4HRQSP,8X,5HCRQSP,7X,4HDCRQ) MODI7270
  170 FORMAT (/10X,76HZPCOM DOES NOT CONVERGE WITH 10 ITERATIONS, LAST VMODI7280
     1ALUE OF ZP(J) WILL BE USED,/)                                     MODI7290
  180 FORMAT (/10X,I12,4F12.5)                                          MODI7300
      END                                                               MODI7310
      SUBROUTINE PLATE3 (X,Y)                                           MODI7320
C                                                                       MODI7330
C     THIS SUBROUTINE APPROXIMATES PLATE 3 BY A SERIES OF EQUATIONS     MODI7340
C                                                                       MODI7350
      IF (X.LE.0.40) GO TO 100                                          MODI7360
      GO TO 110                                                         MODI7370
  100 Y = 1.769 * ALOG10(X/0.080)                                       MODI7380
      GO TO 260                                                         MODI7390
  110 IF (X.GT.0.40.AND.X.LE.0.56) GO TO 120                            MODI7400
      GO TO 130                                                         MODI7410
  120 Y = 1.495 * ALOG10(X/0.059)                                       MODI7420
      GO TO 260                                                         MODI7430
  130 IF (X.GT.0.56.AND.X.LE.0.76) GO TO 140                            MODI7440
      GO TO 150                                                         MODI7450
  140 Y = 0.92 * ALOG10(X/0.0145)                                       MODI7460
      GO TO 260                                                         MODI7470
  150 IF (X.GT.0.76.AND.X.LE.0.96) GO TO 160                            MODI7480
      GO TO 170                                                         MODI7490
  160 Y = 0.292 * ALOG10(X/2.9E - 06)                                   MODI7500
      GO TO 260                                                         MODI7510
  170 IF (X.GT.0.96.AND.X.LE.1.35) GO TO 180                            MODI7520
      GO TO 190                                                         MODI7530
  180 Y = 0.277 * ALOG10(632000.0/X)                                    MODI7540
      GO TO 260                                                         MODI7550
  190 IF (X.GT.1.35.AND.X.LE.3.00) GO TO 200                            MODI7560
      GO TO 210                                                         MODI7570
  200 Y = 1.115 * ALOG10(34.4/X)                                        MODI7580
      GO TO 260                                                         MODI7590
  210 IF (X.GT.3.00.AND.X.LE.4.00) GO TO 220                            MODI7600
      GO TO 230                                                         MODI7610
  220 Y = 0.725 * ALOG10(128.0/X)                                       MODI7620
      GO TO 260                                                         MODI7630
  230 IF (X.GT.4.00.AND.X.LE.6.70) GO TO 240                            MODI7640
      GO TO 250                                                         MODI7650
  240 Y = 0.399 * ALOG10(2160.0/X)                                      MODI7660
      GO TO 260                                                         MODI7670
  250 IF (X.GT.6.70) Y = 1.0                                            MODI7680
  260 RETURN                                                            MODI7690
C                                                                       MODI7700
      END                                                               MODI7710
      SUBROUTINE PLATE5 (X,Y)                                           MODI7720
C                                                                       MODI7730
C     THIS SUBROUTINE APPROXIMATES PLATE 5 BY A SERIES OF EQUATIONS     MODI7740
C                                                                       MODI7750
C                                                                       MODI7760
      IF (X.LT..4) Y = 8.106078 * X *  * ( - 0.989002)                  MODI7770
      IF (X.LE.1..AND.X.GE..4) Y = 7.473444 * X *  * ( - 1.067367)      MODI7780
      IF (X.LT.2..AND.X.GT.1.) Y = 7.512081 * X *  * ( - 1.182832)      MODI7790
      IF (X.LE.3..AND.X.GE.2.) Y = 9.151968 * X *  * ( - 1.472483)      MODI7800
      IF (X.LT.5..AND.X.GT.3.) Y = 16.025332 * X *  * ( - 1.972806)     MODI7810
      IF (X.LE.7..AND.X.GE.5.) Y = 41.421873 * X *  * ( - 2.578713)     MODI7820
      IF (X.LT.10..AND.X.GT.7.) Y = 130.2209 * X *  * ( - 3.165102)     MODI7830
      IF (X.LE.13..AND.X.GE.10.) Y = 584.560594 * X *  * ( - 3.818249)  MODI7840
      IF (X.LT.17..AND.X.GT.13.) Y = 3543.989886 * X *  * ( - 4.522935) MODI7850
      IF (X.LE.20..AND.X.GE.17.) Y = 1690645.945 * X *  * ( - 6.703904) MODI7860
      IF (X.LT.23..AND.X.GT.20.) Y = 5188257832. * X *  * ( - 9.381815) MODI7870
      IF (X.GE.23.) Y = 3.134987996E15 * X *  * ( - 13.597547)          MODI7880
      RETURN                                                            MODI7890
C                                                                       MODI7900
      END                                                               MODI7910
```

```
      SUBROUTINE POWER (Z,A,XI1,XI2,XJ1,XJ2,CONV)                       MODI7920
C                                                                       MODI7930
C     THIS SUBROUTINE EVALUATES I1 I2 J1 AND J2 INTEGRALS               MODI7940
C     NOTATIONS                                                         MODI7950
C     XI1 = VALUE OF I1 INTEGRAL                                        MODI7960
C     XI2 = VALUE OF I2 INTEGRAL                                        MODI7970
C     XJ1 = VALUE OF J1 INTEGRAL                                        MODI7980
C     XJ2 = VALUE OF J2 INTEGRAL                                        MODI7990
C     N = ORDER OF APPROXIMATION + 1                                    MODI8000
C     CONV = CONVERGENCE CRITERION                                      MODI8010
C                                                                       MODI8020
      N = 1                                                             MODI8030
      FACT = 0.216 * A *  * (Z - 1.)/(1. - A) *  * Z                    MODI8040
      XI1 = 0.                                                          MODI8050
      XI2 = 0.                                                          MODI8060
      XJ1 = 0.                                                          MODI8070
      XJ2 = 0.                                                          MODI8080
      ALG = ALOG(A)                                                     MODI8090
      C = 1.                                                            MODI8100
      D =  - Z                                                          MODI8110
      E = D + 1.                                                        MODI8120
      FN = 1.                                                           MODI8130
      AEX = A *  * E                                                    MODI8140
      GO TO 110                                                         MODI8150
  100 N = N + 1                                                         MODI8160
      C = C * D/FN                                                      MODI8170
      D = E                                                             MODI8180
      E = D + 1.                                                        MODI8190
      FN = FLOAT(N)                                                     MODI8200
      AEX = A *  * E                                                    MODI8210
  110 IF (ABS(E).LE.0.001) GO TO 120                                    MODI8220
      XJ1 = XJ1 + C * (1. - AEX)/E                                      MODI8230
      XJ2 = XJ2 + C * ((AEX - 1.)/E *  * 2 - AEX * ALG/E)               MODI8240
      GO TO 130                                                         MODI8250
  120 XJ1 = XJ1 - C * ALG                                               MODI8260
      XJ2 = XJ2 - 0.5 * C * ALG *  * 2                                  MODI8270
  130 IF (N.EQ.1) GO TO 140                                             MODI8280
      CJ1 = ABS(1. - FJ1/XJ1)                                           MODI8290
      CJ2 = ABS(1. - FJ2/XJ2)                                           MODI8300
      IF (CJ1.LE.CONV.AND.CJ2.LE.CONV) GO TO 150                        MODI8310
  140 FJ1 = XJ1                                                         MODI8320
      FJ2 = XJ2                                                         MODI8330
      GO TO 100                                                         MODI8340
  150 XI1 = FACT * XJ1                                                  MODI8350
      XI2 = FACT * XJ2                                                  MODI8360
      RETURN                                                            MODI8370
C                                                                       MODI8380
      END                                                               MODI8390
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM: MPM PROGRAM NO.:

PREPARING AGENCY: Simons and Li Engineering

AUTHORS: R. K. Simons, R. M. Li and D. B. Simons

DATE PROGRAM COMPLETED: September, 1979

STATUS OF PROGRAM: Phase - original, Stage - operational

A. PURPOSE OF PROGRAM: To compute the bed-load transport rate by Meyer-Peter, Muller's method. (Note: suspended bed material is not computed by this method.) References: (a) Meyer-Peter, E., and R. Muller, "Formulas for Bed-Load Transport," Proceedings of the Third Meeting of International Association for Hydraulic Research, Stockholm, 1948; (b) U.S. Bureau of Reclamation, "Investigation of Meyer-Peter, Muller Bedload Formulas," Sedimentation Section, Hydrology Branch, Division of Project Investigations, U.S. Department of the Interior, Bureau of Reclamation, 1960; (c) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

B. PROGRAM SPECIFICATIONS:

Language: Fortran IV

Solution Requirements: Input data

Method of Analysis: Computer application of Meyer-Peter, Muller's bed-load equations

Size of Object Program: 17,541 characters

External Storage: None

Restrictions: None

General Equations: Meyer-Peter, Muller's bed-load equation:

$$Q_s = \frac{8W}{\sqrt{\rho}\ \gamma_s'} = (\tau - \tau_c)^{1.5}$$

where W is the stream width, ρ is the density of the water (γ/g), γ_s' is the specific weight of submerged sediment, τ is the tractive force on the bed, and τ_c is the critical shear stress.

Range of Quantities: Unlimited

Accuracy: N/A

Dimension System: English except sediment size is read in mm then converted to ft.

C. METHODS: The program is written in Fortran IV in both time-share and batch processing modes. All stops would be unprogrammed, resulting from introduction of improper input variables.

D. EQUIPMENT DETAILS: The program was developed on a CDC Cyber 172 but can operate on any compatible system. No special computer equipment is required. Normal configuration of CPU, reader and printer are required to run the program in batch mode.

E. INPUT-OUTPUT: Input requirements are: Number of data sets, mean velocity (ft/sec), hydraulic depth (ft), stream width (ft), median sediment diameter (mm), energy slope (ft/ft), and kinematic viscosity of water (ft^2/sec).

F. ADDITIONAL REMARKS: The method computes bed load only and assumes the effective shear stress is equal to the total shear stress. This method is particularly useful for the gravel and boulder bed streams.

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NO.:

2. TITLE: MPM

3. REVISION LOG: N/A

4. PURPOSE OF PROGRAM: To compute bed-load transport rate by Meyer-Peter, Muller's Method. References:

   a) Meyer-Peter, E., and R. Muller, "Formulas for Bed-Load Transport," Proceedings of the Third Meeting of the International Association for Hydraulic Research, Stockholm, 1948.

   b) U.S. Bureau of Reclamation, "Investigation of Meyer-Peter, Muller Bedload Formulas," Sedimentation Section, Hydrology Branch, Division of Project Investigations, U.S. Department of the Interior, Bureau of Reclamation, 1960.

   c) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

5. STEP SOLUTION:

   a) The input variables that must be supplied upon request are:

      1 - Number of data sets (NDATA)

      2 - Mean velocity (V), ft/sec

      3 - Hydraulic depth (D), ft

      4 - Stream width (W), ft

      5 - Median sediment diameter (DM), mm

      6 - Energy slope (S), ft/ft

      7 - Kinematic viscosity of water (SNU), ft^2/sec

   b) After the number of data sets is read in, a set of hydraulic data is read in and Meyer-Peter, Muller's bed-load equation is applied

in a do loop from 1 to the number of data sets in the following manner:

c) Compute the shear stress, τ

$$\tau = \sqrt{gDS}$$

d) Compute the critical shear, τ_c

$$\tau_c = 0.047\ \gamma_s'\ DM$$

e) If $\tau - \tau_c$ is less than zero, the bed-load is set to zero; if not, Meyer-Peter, Muller's equation is used.

f) Calculate bed-load transport rate in lbs/ft^3

$$Q_s = \frac{8W}{\sqrt{\rho}\ \gamma_s'} (\tau - \tau_c)^{1.5}$$

and convert from lb/ft^3 to T/D

$$Q_s = 43.2\ Q_s$$

g) Print input data and output of results.

6. ACCURACY: N/A

PART II: COMPUTER FUNCTIONAL DESCRIPTION

1. REVISION LOG: N/A

2. FUNCTIONAL FLOW CHART: (See Figure 1)

3. EQUIPMENT AND OPERATING SYSTEM: The program was developed on a CDC Cyber 172. Normal configuration of CPU, reader and printer is required to run the program in batch mode.

4. INPUT REQUIREMENTS: The program is written for either the time share or batch processing mode. The source listing in Fig. 2 is for the batch mode. Fig. 3 is the interactive mode listing. Input requirements are given below. For the time share mode the user is prompted for input values.

5. SECONDARY STORAGE INPUT FORMAT: None

6. INPUT DATA DESCRIPTION:

NAME	DESCRIPTION	FORMAT	
NDATA	Number of data sets	I5	Card 1
V	Mean velocity, ft/sec	F10.2	
D	Hydraulic depth, ft	F10.2	
W	Stream width, ft	F10.2	Card 2, 3, ..., NDATA
DM	Median particle diameter, mm	F10.3	
S	Energy slope, ft/ft	F10.7	
SNU	Kinematic viscosity, ft^2/sec	E10.3	

7. SUMMARY OF REQUIRED CARDS: (See 6)

8. OUTPUTS: Printed output generated by the program includes the given input data and the bed-load transport rate in tons/day.

9. OPERATOR INSTRUCTIONS: None

10. PROGRAM ERROR MESSAGES: None. Program stops would result from improper input data.

11. VARIABLE DEFINITIONS:

D - Hydraulic depth, ft

DM - Median sediment size, mm

NDATA - Number of data sets

QS - Bed-load transport rate, tons/day

RHO - Density of water, slugs/ft^3

S - Energy slope, ft/ft

SNU - Kinematic viscosity, ft^2/sec

T - (TAU - TCR), lbs/ft^2

TAU - Shear stress on the bed, lbs/ft^2

TCR - Critical shear stress, lbs/ft^2

V - Mean velocity, ft/sec

W - Stream width, ft

12. EXAMPLE CASE:

a) Batch mode

```
COMPUTATION OF TOTAL SEDIMENT DISCHARGE
BY MEYER-PETER AND MULLERS METHOD

   SET     1
   MEAN VELOCITY                    6.63 FT/SEC
   HYDRAULIC DEPTH                  2.50 FT
   STREAM WIDTH                   170.00 FT
   MEDIAN SEDIMENT DIAMETER         .495 MM
   ENERGY SLOPE                 .0010500 FT/FT
   KINEMATIC VISCOSITY          .106E-04 FT**2/SEC

   BED MATERIAL DISCHARGE  =       25. TONS/DAY

   .037 CP SECONDS EXECUTION TIME
```

b) Interactive mode

```
COMPUTATION OF TOTAL SEDIMENT DISCHARGE
    BY MEYER-PETER AND MULLERS METHOD



START INPUT DATA IN FREE FORMAT

ENTER THE NUMBER OF SETS OF INPUT DATA
? 1



ENTER THE FOLLOWING HYDRAULIC DATA:

  AVERAGE VELOCITY IN FEET PER SECOND
? 6.63
  HYDRAULIC DEPTH IN FEET
? 2.5
  STREAM WIDTH IN FEET
? 170.
  ENERGY SLOPE IN FEET/FEET
? .00105
  KINEMATIC VISCOSITY IN SQ.FT./SEC.
? .0000106
  MEDIAN BED MATERIAL SIZE IN MM
? .495

    SET     1
    MEAN VELOCITY                    6.63 FT/SEC
    HYDRAULIC DEPTH                  2.50 FT
    STREAM WIDTH                   170.00 FT
    MEDIAN SEDIMENT DIAMETER         .495 MM
    ENERGY SLOPE                 .0010500 FT/FT
    KINEMATIC VISCOSITY          .106E-04 FT**2/SEC

    BED MATERIAL DISCHARGE  =       25. TONS/DAY


     .064 CP SECONDS EXECUTION TIME
```

13. JOB PROCESSING TIME:

To compile: 0.6 cpu sec

To execute: 0.04 cpu sec (batch)

0.062 cpu sec (interactive)

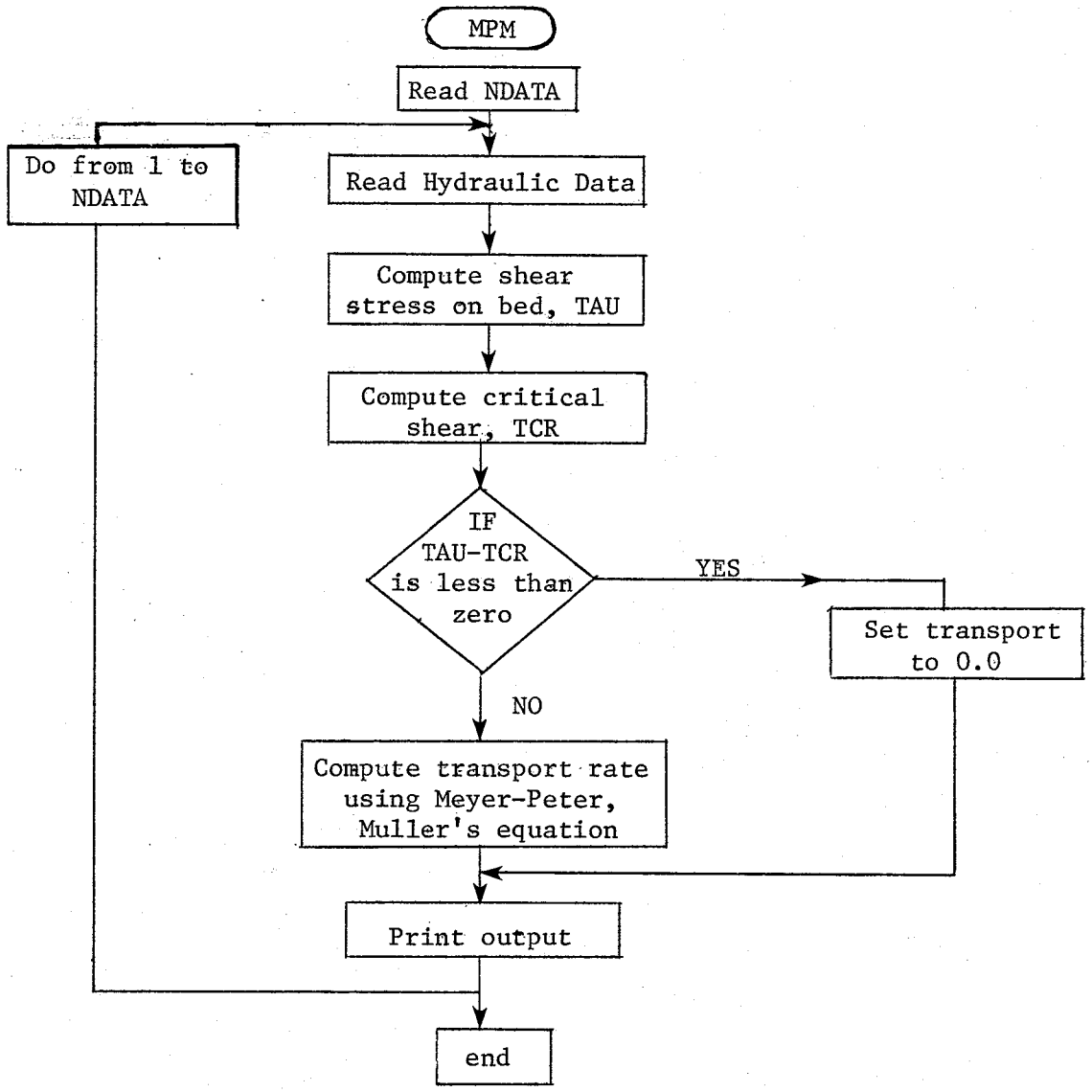

Figure 1. Flow chart of Program MPM.

```
      PROGRAM MPM                                                       MPM 0010
     1(INPUT,OUTPUT)                                                    MPM 0020
C                                                                       MPM 0030
C     DEVELOPED                                                         MPM 0040
C                                                                       MPM 0050
C                                                                       MPM 0060
C     PURPOSE              COMPUTATION OF BED MATERIAL DISCHARGE       MPM 0070
C                          IN RIVERS BY MEYER-PETER, MULLER METHOD     MPM 0080
C                                                                       MPM 0090
C     REFERENCE            MEYER-PETER, E. AND MULLER, R., "FORMULAS   MPM 0100
C                          FOR BED LOAD TRANSPORT," PROCEEDINGS OF     MPM 0110
C                          THIRD MEETING OF INTERNATIONAL ASSOCIATION  MPM 0120
C                          FOR HYDRAULIC RESEARCH, STOCKHOLM, 1948     MPM 0130
C                                                                       MPM 0140
C     CORE USAGE                                                        MPM 0150
C                                                                       MPM 0160
C     COMPILER TIME        LESS THAN 0.6 SEC                           MPM 0170
C                                                                       MPM 0180
C     CENTRAL PROCESSOR                                                 MPM 0190
C     TIME FOR ONE SET                                                  MPM 0200
C     OF DATA              LESS THAN 0.03 SEC                          MPM 0210
C                                                                       MPM 0220
C     INPUT DATA                                                        MPM 0230
C                                                                       MPM 0240
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FORMAT I5.          MPM 0250
C     NDATA = NUMBER OF DATA SETS TO BE ANALYZED                        MPM 0260
C                                                                       MPM 0270
C     THE SECOND AND SUCCEEDING CARDS CONTAIN THE HYDRAULIC AND         MPM 0280
C     SEDIMENT DATA SETS IN THE FOLLOWING FORMAT:                       MPM 0290
C     (3F10.2,F10.3,F10.7,E10.3)                                        MPM 0300
C     V     = MEAN VELOCITY (FT/SEC)                                    MPM 0310
C     D     = HYDRAULIC DEPTH (FT)                                      MPM 0320
C     W     = STREAM WIDTH (FT)                                         MPM 0330
C     DM    = MEDIAN SEDIMENT DIAMETER (MM)                             MPM 0340
C     S     = ENERGY SLOPE OF STREAM (FT/FT)                            MPM 0350
C     SNU   = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                  MPM 0360
C                                                                       MPM 0370
      PRINT 130                                                         MPM 0380
      READ 140, NDATA                                                   MPM 0390
      RHO = 62.4/32.2                                                   MPM 0400
      DO 120 I = 1,NDATA                                                MPM 0410
         READ 150, V,D,W,DM,S,SNU                                       MPM 0420
         PRINT 160, I,V,D,W,DM,S,SNU                                    MPM 0430
         DM = DM/304.8                                                  MPM 0440
         TAU = 62.4 * D * S                                             MPM 0450
         TCR = 0.047 * 1.65 * 62.4 * DM                                 MPM 0460
         T = TAU - TCR                                                  MPM 0470
         IF (T.LE.0.) GO TO 100                                         MPM 0480
         QS = W * 8./SQRT(RHO)/(1.65 * 62.4) * T *  * 1.5               MPM 0490
         QS = QS * 43.2                                                 MPM 0500
         GO TO 110                                                      MPM 0510
  100    QS = 0.                                                        MPM 0520
  110    CONTINUE                                                       MPM 0530
         PRINT 170, QS                                                  MPM 0540
  120 CONTINUE                                                          MPM 0550
      STOP                                                              MPM 0560
C                                                                       MPM 0570
  130 FORMAT (1H1///, 41H  COMPUTATION OF TOTAL SEDIMENT DISCHARGE,/, 35MPM 0580
     1H  BY MEYER-PETER AND MULLERS METHOD,//)                          MPM 0590
  140 FORMAT (I5)                                                       MPM 0600
  150    FORMAT (3F10.2,F10.3,F10.7,E10.3)                              MPM 0610
  160    FORMAT (5X,4HSET ,I5/,5X,25HMEAN VELOCITY            ,F12.2,   MPM 0620
     17H FT/SEC/,5X,25HHYDRAULIC DEPTH          ,F12.2,3H FT/,5X,25HSTREMPM 0630
     2AM WIDTH              ,F12.2,3H FT/,5X,   25HMEDIAN SEDIMENT DIAMETMPM 0640
     3ER ,F12.3,3H MM/,5X,   25HENERGY SLOPE             ,F12.7,6H FT/FTMPM 0650
     4/,  5X,25HKINEMATIC VISCOSITY          ,E12.3,10H FT**2/SEC//)    MPM 0660
  170 FORMAT (5X,25HBED MATERIAL DISCHARGE  =,F10.0,9H TONS/DAY///)     MPM 0670
      END                                                               MPM 0680
```

Figure 2. Batch listing, Program MPM.

```
      PROGRAM MPMI                                                      MPMI0010
     1(INPUT,OUTPUT)                                                    MPMI0020
C                                                                       MPMI0030
C     DEVELOPED                                                         MPMI0040
C                                                                       MPMI0050
C                                                                       MPMI0060
C     PURPOSE            COMPUTATION OF BED MATERIAL DISCHARGE          MPMI0070
C                        IN RIVERS BY MEYER-PETER, MULLER METHOD        MPMI0080
C                                                                       MPMI0090
C     REFERENCE          MEYER-PETER, E. AND MULLER, R., "FORMULAS      MPMI0100
C                        FOR BED LOAD TRANSPORT," PROCEEDINGS OF        MPMI0110
C                        THIRD MEETING OF INTERNATIONAL ASSOCIATION     MPMI0120
C                        FOR HYDRAULIC RESEARCH, STOCKHOLM, 1948        MPMI0130
C                                                                       MPMI0140
C     CORE USAGE                                                        MPMI0150
C                                                                       MPMI0160
C     COMPILER TIME      LESS THAN 0.6 SEC                              MPMI0170
C                                                                       MPMI0180
C     CENTRAL PROCESSOR                                                 MPMI0190
C     TIME FOR ONE SET                                                  MPMI0200
C     OF DATA            LESS THAN 0.03 SEC                             MPMI0210
C                                                                       MPMI0220
C     INPUT DATA                                                        MPMI0230
C                                                                       MPMI0240
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FREE FORMAT.        MPMI0250
C     NDATA = NUMBER OF DATA SETS TO BE ANALYZED                        MPMI0260
C                                                                       MPMI0270
C     THE SECOND AND SUCCEEDING CARDS CONTAIN THE HYDRAULIC AND         MPMI0280
C     SEDIMENT DATA SETS IN FREE FORMAT                                 MPMI0290
C     V     = MEAN VELOCITY (FT/SEC)                                    MPMI0300
C     D     = HYDRAULIC DEPTH (FT)                                      MPMI0310
C     W     = STREAM WIDTH (FT)                                         MPMI0320
C     DM    = MEDIAN SEDIMENT DIAMETER (MM)                             MPMI0330
C     S     = ENERGY SLOPE OF STREAM (FT/FT)                            MPMI0340
C     SNU   = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                  MPMI0350
C                                                                       MPMI0360
      PRINT 130                                                         MPMI0370
      RHO = 62.4/32.2                                                   MPMI0380
      PRINT 140                                                         MPMI0390
      READ   *, NDATA                                                   MPMI0400
      DO 120 I = 1,NDATA                                                MPMI0410
         PRINT 150                                                      MPMI0420
         READ   *, V                                                    MPMI0430
         PRINT 160                                                      MPMI0440
         READ   *, D                                                    MPMI0450
         PRINT 170                                                      MPMI0460
         READ   *, W                                                    MPMI0470
         PRINT 180                                                      MPMI0480
         READ   *, S                                                    MPMI0490
         PRINT 190                                                      MPMI0500
         READ   *, SNU                                                  MPMI0510
         PRINT 200                                                      MPMI0520
         READ   *, DM                                                   MPMI0530
         PRINT 210, I,V,D,W,DM,S,SNU                                    MPMI0540
         DM = DM/304.8                                                  MPMI0550
         TAU = 62.4 * D * S                                             MPMI0560
         TCR = 0.047 * 1.65 * 62.4 * DM                                 MPMI0570
         T = TAU - TCR                                                  MPMI0580
         IF (T.LE.0.) GO TO 100                                         MPMI0590
         QS = W * 8./SQRT(RHO)/(1.65 * 62.4) * T *  * 1.5               MPMI0600
         QS = QS * 43.2                                                 MPMI0610
         GO TO 110                                                      MPMI0620
  100    QS = 0.                                                        MPMI0630
  110    CONTINUE                                                       MPMI0640
         PRINT 220, QS                                                  MPMI0650
```

Figure 3. Interactive listing, Program MPM.

```
  120 CONTINUE                                                          MPMI0660
      STOP                                                              MPMI0670
C                                                                       MPMI0680
  130 FORMAT (1H1///, 41H  COMPUTATION OF TOTAL SEDIMENT DISCHARGE,/, 39MPMI0690
     1H       BY MEYER-PETER AND MULLERS METHOD,//)                     MPMI0700
  140 FORMAT (///, 32H START INPUT DATA IN FREE FORMAT,//, 39H ENTER THEMPMI0710
     1 NUMBER OF SETS OF INPUT DATA)                                    MPMI0720
  150 FORMAT (//////, 36H ENTER THE FOLLOWING HYDRAULIC DATA:,//, 38H   MPMI0730
     1AVERAGE VELOCITY IN FEET PER SECOND)                              MPMI0740
  160 FORMAT ( 26H   HYDRAULIC DEPTH IN FEET)                           MPMI0750
  170 FORMAT ( 23H   STREAM WIDTH IN FEET)                              MPMI0760
  180 FORMAT ( 28H   ENERGY SLOPE IN FEET/FEET)                         MPMI0770
  190 FORMAT ( 37H   KINEMATIC VISCOSITY IN SQ.FT./SEC.)                MPMI0780
  200 FORMAT ( 33H   MEDIAN BED MATERIAL SIZE IN MM)                    MPMI0790
  210 FORMAT (//5X,4HSET ,I5/,5X,25HMEAN VELOCITY            ,F12.2,7H FMPMI0800
     1T/SEC/,5X,25HHYDRAULIC DEPTH          ,F12.2,3H FT/,5X,25HSTREAM WMPMI0810
     2IDTH              ,F12.2,3H FT/,5X,25HMEDIAN SEDIMENT DIAMETER ,F12MPMI0820
     3.3,3H MM/,5X,25HENERGY SLOPE              ,F12.7,6H FT/FT/,5X,25HKIMPMI0830
     4NEMATIC VISCOSITY       ,E12.3,10H FT**2/SEC//)                   MPMI0840
  220 FORMAT (5X,25HBED MATERIAL DISCHARGE  =,F10.0,9H TONS/DAY///)     MPMI0850
      END                                                               MPMI0860
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM: SHENHNG PROGRAM NO.:

PREPARING AGENCY: Simons and Li Engineering

AUTHORS: R. M. Li, R. K. Simons, D. B. Simons

DATE PROGRAM COMPLETED: September, 1979

STATUS OF PROGRAM: Phase - original, Stage - operational

A. PURPOSE OF PROGRAM: To compute sediment discharge in rivers by Shen and Hung's method. References: (a) Shen, H. W., and C. S. Hung, "An Engineering Approach to Total Bed Material Load by Regression Analysis," Proceedings, Sedimentation Symposium, Berkeley, 1971; (b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

B. PROGRAM SPECIFICATIONS:

Language: ANSI Fortran IV

Solution Requirements: Input data

Method of Analysis: Computer application of Shen and Hung's equation

Size of Object Program: 17,574 characters

External Storage: None

Restrictions: None

General Equation: Shen and Hung's sediment concentration equation:

$$\log C = -107404.459 + 324214.747X - 326309.589X^2 + 109503.872X^3$$

where C is the sediment concentration in parts per million and X is:

$$X = \left(\frac{V\ S^{0.57}}{W^{0.32}}\right)^{0.0075}$$

and V is the mean velocity, S is the energy slope and W is the fall velocity.

Range of Quantities: Unlimited

Accuracy: N/A

Dimension System: English (except input sediment diameter is in mm)

C. METHODS: The program is written in Fortran IV in both batch and time-share modes. All stops would be unprogrammed resulting from improper input variables.

D. EQUIPMENT DETAILS: The program was developed on a CDC Cyber 172 but can operate on any compatible system. No special computer equipment required. Normal configuration of CPU, reader and printer is necessary to run the program in batch mode.

E. INPUT-OUTPUT: Input requirements are: Number of data sets to be analyzed (NDATA), mean velocity (ft/sec), hydraulic depth (ft), stream width (ft), median bed material diameter (mm), energy slope (ft/ft), kinematic viscosity of water (ft^2/sec). Output includes the given data and sediment concentration and transport rate.

F. ADDITIONAL REMARKS: The method indicates that the sediment concentration is independent of flow depth and is applicable to small streams.

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NUMBER:

2. TITLE: SHENHNG

3. REVISION LOG: N/A

4. PURPOSE OF PROGRAM: To compute sediment discharge in rivers by Shen and Hung's method. References:

   a) Shen, H. W., and C. S. Hung, "An Engineering Approach to Total Bed Material Load by Regression Analysis," Proceedings, Sedimentation Symposium, Berkeley, 1971.

   b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

5. STEP SOLUTION:

   a) The input variables that must be supplied are:

      1 - Number of data sets (NDATA)

      2 - Mean velocity (V), ft/sec

      3 - Hydraulic depth (D), ft

      4 - Stream width (W), ft

      5 - Median bed material diameter (DM), mm

      6 - Energy slope (S), ft/ft

      7 - Kinematic viscosity of water (SNU), ft^2/sec

   b) After data input and conversion of the bed material to feet, the fall velocity of the median bed material is calculated using Rubey's equation (Simons and Sentürk, 1977).

   c) Next the factor X in Shen and Hung's equation is determined from the above calculation and the input data.

$$X = \left(\frac{V\ S^{0.57}}{W^{0.32}}\right)^{0.0075}$$

   where W is the fall velocity.

d) The value obtained for X is then plugged into the regression equation of the log of sediment concentration in ppm.

$$\log C = -107404.459 + 324214.747X - 326309.589X^2 + 109503.872X^3$$

The concentration is then the antilog of the value computed for log C.

e) The sediment discharge is then the water discharge (Q = VxDxW) times a number of factors to convert to tons per day.

$$Qs = 62.4 \times 43.2 \times 10^{-6} \times C \times Q$$

6. ACCURACY: N/A

PART II: COMPUTER FUNCTIONAL DESCRIPTION

1. REVISION LOG: N/A

2. FUNCTIONAL FLOW CHART: (See Figure 1)

3. EQUIPMENT AND OPERATING SYSTEM: The program was developed on a CDC Cyber 172. Normal configuration of CPU, reader and printer are necessary to run the program in batch mode.

4. INPUT REQUIREMENTS: The program was written for either the time share or batch processing mode. The source listing (Figure 2) is for the batch mode. Figure 3 is the interactive mode listing.

5. SECONDARY STORAGE INPUT FORMAT: None

6. INPUT DATA DESCRIPTION: The following variable names are used for the input variables:

NAME	DESCRIPTION	FORMAT	
NDATA	Number of data sets	I5	Card 1
V	Mean velocity	F10.2	
D	Hydraulic depth	F10.2	
W	Stream width	F10.2	Card 2, 3, ..., NDATA
DM	Bed material size	F10.3	
S	Energy slope	F10.7	
SNU	Kinematic viscosity of water	E10.3	

7. SUMMARY OF REQUIRED CARDS: (See 6)

8. OUTPUTS: Printed output generated by Program SHENHNG consists of the input data and sediment concentration and transport rate.

9. OPERATOR INSTRUCTIONS: None

10. PROGRAM ERROR MESSAGES: None. Program stops would result from improper input data.

11. VARIABLE DEFINITIONS:

C - Sediment concentration, ppm

CL - Log of sediment concentration

D - Hydraulic depth, ft

DM - Median bed material size, mm

Q - Water discharge, cfs

QS - Sediment discharge, tons/day

S - Energy slope, ft/ft

SNU - Kinematic viscosity, ft^2/sec

V - Mean velocity, ft/sec

VF - Fall velocity, ft/sec

W - Stream width, ft

X - Temporary variable

12. EXAMPLE CASE:

a) Batch Mode

```
COMPUTATION OF TOTAL SEDIMENT DISCHARGE
BY SHEN AND HUNGS METHOD

   SET      1
   MEAN VELOCITY                    6.63 FT/SEC
   HYDRAULIC DEPTH                  2.50 FT
   STREAM WIDTH                   170.00 FT
   MEDIAN SEDIMENT DIAMETER         .495 MM
   ENERGY SLOPE                 .0010500 FT/FT
   KINEMATIC VISCOSITY          .106E-04 FT**2/SEC

TOTAL SEDIMENT CONCENTRATION =     3073. PPM BY WEIGHT
TOTAL SEDIMENT DISCHARGE     =    23339. TONS/DAY

    .042 CP SECONDS EXECUTION TIME
```

b) Interactive Mode

```
COMPUTATION OF TOTAL SEDIMENT DISCHARGE
     BY SHEN AND HUNGS METHOD



START INPUT DATA IN FREE FORMAT

ENTER THE NUMBER OF SETS OF INPUT DATA
? 1



ENTER THE FOLLOWING HYDRAULIC DATA:

  AVERAGE VELOCITY IN FEET PER SECOND
? 6.63
  HYDRAULIC DEPTH IN FEET
? 2.5
  STREAM WIDTH IN FEET
? 170.
  ENERGY SLOPE IN FEET/FEET
? .00105
  KINEMATIC VISCOSITY IN SQ.FT./SEC.
? .0000106
  MEDIAN BED MATERIAL SIZE IN MM
? .495

    SET      1
    MEAN VELOCITY                    6.63 FT/SEC
    HYDRAULIC DEPTH                  2.50 FT
    STREAM WIDTH                   170.00 FT
    MEDIAN SEDIMENT DIAMETER         .495 MM
    ENERGY SLOPE                 .0010500 FT/FT
    KINEMATIC VISCOSITY          .106E-04 FT**2/SEC

TOTAL SEDIMENT CONCENTRATION =     3073. PPM BY WEIGHT
TOTAL SEDIMENT DISCHARGE     =    23339. TONS/DAY


    .062 CP SECONDS EXECUTION TIME
```

13. JOB PROCESSING TIME:

To compile: 0.7 cpu sec

To execute: 0.04 cpu sec (batch)

0.064 cpu sec (interactive)

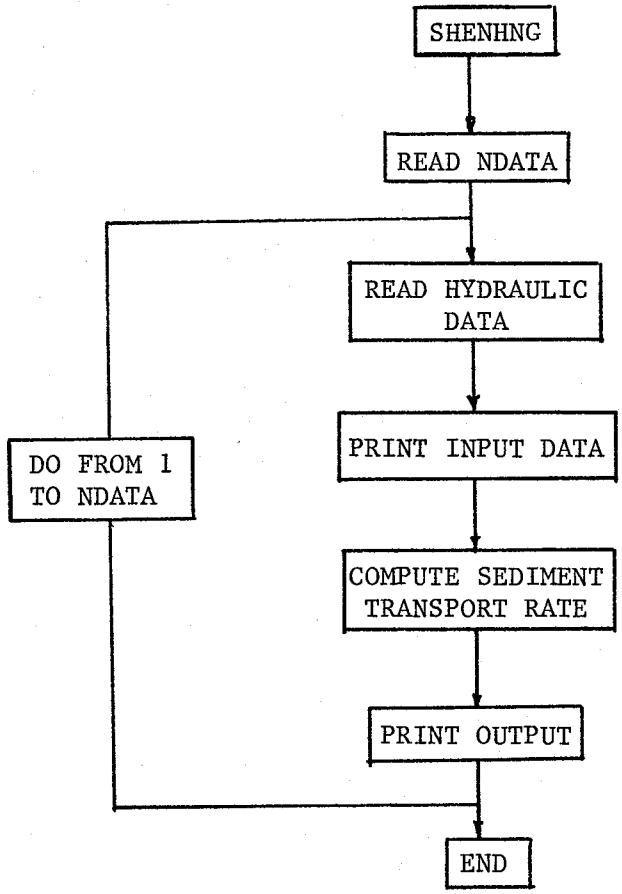

Figure 1. Flow chart of Program SHENHNG.

```
      PROGRAM SHENHU                                                    SH  0010
     1(INPUT,OUTPUT)                                                    SH  0020
C                                                                       SH  0030
C     DEVELOPED                                                         SH  0040
C                                                                       SH  0050
C     PURPOSE            COMPUTATION OF SEDIMENT DISCHARGE IN           SH  0060
C                        RIVERS BY SHEN AND HUNGS METHOD                SH  0070
C                                                                       SH  0080
C     REFERENCE          SHEN, H.W. AND HUNG, C.S., "AN ENGINEERING     SH  0090
C                        APPROACH TO TOTAL BED MATERIAL LOAD BY         SH  0100
C                        REGRESSION ANALYSIS," PROCEEDINGS, SEDI-       SH  0110
C                        MENTATION SYMPOSIUM, BERKELEY, 1971            SH  0120
C                                                                       SH  0130
C     CORE USAGE                                                        SH  0140
C                                                                       SH  0150
C     COMPILATION TIME   APPROXIMATELY 0.7 SEC                          SH  0160
C                                                                       SH  0170
C     CENTRAL PROCESSOR                                                 SH  0180
C     TIME FOR ONE SET                                                  SH  0190
C     OF DATA            LESS THAN 0.3 SEC                              SH  0200
C                                                                       SH  0210
C     INPUT DATA                                                        SH  0220
C                                                                       SH  0230
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FORMAT I5.          SH  0240
C     NDATA = NUMBER OF DATA SETS TO BE ANALYZED                        SH  0250
C                                                                       SH  0260
C     THE SECOND AND SUCCEEDING CARDS CONTAIN THE HYDRAULIC AND         SH  0270
C     SEDIMENT DATA SETS IN THE FOLLOWING FORMAT:                       SH  0280
C     (3F10.2,F10.3,F10.7,E10.3)                                        SH  0290
C     V     = MEAN VELOCITY (FT/SEC)                                    SH  0300
C     D     = HYDRAULIC DEPTH (FT)                                      SH  0310
C     W     = STREAM WIDTH (FT)                                         SH  0320
C     DM    = MEDIAN SEDIMENT DIAMETER (MM)                             SH  0330
C     S     = ENERGY SLOPE OF STREAM (FT/FT)                            SH  0340
C     SNU   = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                  SH  0350
C                                                                       SH  0360
      PRINT 110                                                         SH  0370
      READ 120, NDATA                                                   SH  0380
      DO 100 I = 1,NDATA                                                SH  0390
         READ 130, V,D,W,DM,S,SNU                                       SH  0400
         PRINT 140, I,V,D,W,DM,S,SNU                                    SH  0410
         DM = DM/304.8                                                  SH  0420
         VF = (SQRT(2./3. * 32.2 * 1.65 * DM *  * 3. + 36. * SNU *  * 2.SH  0430
     1   ) - 6. * SNU)/DM                                               SH  0440
         X = (V * S *  * 0.57/VF *  * 0.32) *  * 0.0075                 SH  0450
         CL =  - 107404.459 + 324214.747 * X - 326309.589 * X *  * 2. + SH  0460
     1   109503.872 * X *  * 3.                                         SH  0470
         C = 10. *  * CL                                                SH  0480
         Q = V * D * W                                                  SH  0490
         QS = C * 1.E - 6 * Q * 62.4 * 43.2                             SH  0500
         PRINT 150, C,QS                                                SH  0510
  100 CONTINUE                                                          SH  0520
      STOP                                                              SH  0530
C                                                                       SH  0540
  110 FORMAT (1H1//, 41H  COMPUTATION OF TOTAL SEDIMENT DISCHARGE,/, 26HSH  0550
     1  BY SHEN AND HUNGS METHOD,//)                                    SH  0560
  120 FORMAT (I5)                                                       SH  0570
  130    FORMAT (3F10.2,F10.3,F10.7,E10.3)                              SH  0580
  140    FORMAT (5X,4HSET ,I5/,5X,25HMEAN VELOCITY            ,F12.2,   SH  0590
     17H FT/SEC/,5X,25HHYDRAULIC DEPTH          ,F12.2,3H FT/,5X,25HSTRESH  0600
     2AM WIDTH                ,   F12.2,3H FT/,5X,25HMEDIAN SEDIMENT DIAMETSH  0610
     3ER ,   F12.3,3H MM/,5X,25HENERGY SLOPE              ,F12.7,6H FT/FTSH  0620
     4/,5X,   25HKINEMATIC VISCOSITY       ,E12.3,10H FT**2/SEC//)      SH  0630
  150 FORMAT (2X,30HTOTAL SEDIMENT CONCENTRATION =,F10.0,14H PPM BY WEIGSH  0640
     1HT/2X,30HTOTAL SEDIMENT DISCHARGE      =,F10.0,9H TONS/DAY///)    SH  0650
      END                                                               SH  0660
```

Figure 2. Batch listing, Program SHENHNG.

```
      PROGRAM SHENHU1                                                   SHI 0010
     1(INPUT,OUTPUT)                                                    SHI 0020
C                                                                       SHI 0030
C     DEVELOPED                                                         SHI 0040
C                                                                       SHI 0050
C     PURPOSE            COMPUTATION OF SEDIMENT DISCHARGE IN           SHI 0060
C                        RIVERS BY SHEN AND HUNGS METHOD                SHI 0070
C                                                                       SHI 0080
C     REFERENCE          SHEN, H.W. AND HUNG, C.S., "AN ENGINEERING     SHI 0090
C                        APPROACH TO TOTAL BED MATERIAL LOAD BY         SHI 0100
C                        REGRESSION ANALYSIS," PROCEEDINGS, SEDI-       SHI 0110
C                        MENTATION SYMPOSIUM, BERKELEY, 1971            SHI 0120
C                                                                       SHI 0130
C     CORE USAGE                                                        SHI 0140
C                                                                       SHI 0150
C     COMPILATION TIME   APPROXIMATELY 0.7 SEC                          SHI 0160
C                                                                       SHI 0170
C     CENTRAL PROCESSOR                                                 SHI 0180
C     TIME FOR ONE SET                                                  SHI 0190
C     OF DATA            LESS THAN 0.3 SEC                              SHI 0200
C                                                                       SHI 0210
C     INPUT DATA                                                        SHI 0220
C                                                                       SHI 0230
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FREE FORMAT.        SHI 0240
C     NDATA = NUMBER OF DATA SETS TO BE ANALYZED                        SHI 0250
C                                                                       SHI 0260
C     THE SECOND AND SUCCEEDING CARDS CONTAIN THE HYDRAULIC AND         SHI 0270
C     SEDIMENT DATA SETS IN FREE FORMAT                                 SHI 0280
C     V     = MEAN VELOCITY (FT/SEC)                                    SHI 0290
C     D     = HYDRAULIC DEPTH (FT)                                      SHI 0300
C     W     = STREAM WIDTH (FT)                                         SHI 0310
C     DM    = MEDIAN SEDIMENT DIAMETER (MM)                             SHI 0320
C     S     = ENERGY SLOPE OF STREAM (FT/FT)                            SHI 0330
C     SNU   = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                  SHI 0340
C                                                                       SHI 0350
      PRINT 110                                                         SHI 0360
      PRINT 120                                                         SHI 0370
      READ   *, NDATA                                                   SHI 0380
      DO 100 I = 1,NDATA                                                SHI 0390
         PRINT 130                                                      SHI 0400
         READ   *, V                                                    SHI 0410
         PRINT 140                                                      SHI 0420
         READ   *, D                                                    SHI 0430
         PRINT 150                                                      SHI 0440
         READ   *, W                                                    SHI 0450
         PRINT 160                                                      SHI 0460
         READ   *, S                                                    SHI 0470
         PRINT 170                                                      SHI 0480
         READ   *, SNU                                                  SHI 0490
         PRINT 180                                                      SHI 0500
         READ   *, DM                                                   SHI 0510
         PRINT 190, I,V,D,W,DM,S,SNU                                    SHI 0520
         DM = DM/304.8                                                  SHI 0530
         VF = (SQRT(2./3. * 32.2 * 1.65 * DM *  * 3. + 36. * SNU *  * 2.SHI 0540
     1   ) - 6. * SNU)/DM                                               SHI 0550
         X = (V * S *  * 0.57/VF *  * 0.32) *  * 0.0075                 SHI 0560
         CL =  - 107404.459 + 324214.747 * X - 326309.589 * X *  * 2. + SHI 0570
     1   109503.872 * X *  * 3.                                         SHI 0580
         C = 10. *  * CL                                                SHI 0590
         Q = V * D * W                                                  SHI 0600
         QS = C * 1.E - 6 * Q * 62.4 * 43.2                             SHI 0610
         PRINT 200, C,QS                                                SHI 0620
  100 CONTINUE                                                          SHI 0630
C                                                                       SHI 0640
C                                                                       SHI 0650
```

Figure 3. Interactive listing, Program SHENHNG.

```
      STOP                                                              SHI 0660
C                                                                       SHI 0670
  110 FORMAT (1H1//, 41H  COMPUTATION OF TOTAL SEDIMENT DISCHARGE,/, 31HSHI 0680
     1        BY SHEN AND HUNGS METHOD,//)                              SHI 0690
  120 FORMAT (///, 32H START INPUT DATA IN FREE FORMAT,//, 39H ENTER THESHI 0700
     1 NUMBER OF SETS OF INPUT DATA)                                    SHI 0710
  130 FORMAT (//////, 36H ENTER THE FOLLOWING HYDRAULIC DATA:,//, 38H   SHI 0720
     1AVERAGE VELOCITY IN FEET PER SECOND)                              SHI 0730
  140 FORMAT ( 26H   HYDRAULIC DEPTH IN FEET)                           SHI 0740
  150 FORMAT ( 23H   STREAM WIDTH IN FEET)                              SHI 0750
  160 FORMAT ( 28H   ENERGY SLOPE IN FEET/FEET)                         SHI 0760
  170 FORMAT ( 37H   KINEMATIC VISCOSITY IN SQ.FT./SEC.)                SHI 0770
  180 FORMAT ( 33H   MEDIAN BED MATERIAL SIZE IN MM)                    SHI 0780
  190 FORMAT (//5X,4HSET ,I5/,5X,25HMEAN VELOCITY            ,F12.2,7H FSHI 0790
     1T/SEC/,5X,25HHYDRAULIC DEPTH          ,F12.2,3H FT/,5X,25HSTREAM WSHI 0800
     2IDTH              ,F12.2,3H FT/,5X,25HMEDIAN SEDIMENT DIAMETER ,F12SHI 0810
     3.3,3H MM/,5X,25HENERGY SLOPE              ,F12.7,6H FT/FT/,5X,25HKISHI 0820
     4NEMATIC VISCOSITY       ,E12.3,10H FT**2/SEC//)                  SHI 0830
  200 FORMAT (2X,30HTOTAL SEDIMENT CONCENTRATION =,F10.0,14H PPM BY WEIGSHI 0840
     1HT/2X,30HTOTAL SEDIMENT DISCHARGE     =,F10.0,9H TONS/DAY///)     SHI 0850
      END                                                               SHI 0860
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM: TOFLTI PROGRAM NO.:

PREPARING AGENCY: Simons and Li Engineering

AUTHORS: R. M. Li, R. K. Simons, D. B. Simons

DATE PROGRAM COMPLETED: September, 1979

STATUS OF PROGRAM: Phase - original, Stage - operational

A. PURPOSE OF PROGRAM: To compute sand discharge in rivers by Toffaleti's Method. References: (a) Toffaleti, F. B., "Definitive Computations of Sand Discharge in Rivers," ASCE Journal of the Hydraulics Division, January, 1969; (b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

B. PROGRAM SPECIFICATIONS:

Language: ANSI Fortran IV

Solution Requirements: Input data

Method of Analysis: Computer application of Toffaleti's method

Size of Object Program: 21,060 characters

External Storage: None

Restrictions: None

General Equations: (See Reference)

Range of Quantities: Unlimited

Accuracy: N/A

Dimension System: English (except for input sediment size)

C. METHODS: The program is written in Fortran IV in both batch and time-share modes. Program stops would be unprogrammed resulting from improper input variables.

D. EQUIPMENT DETAILS: The program was developed on a CDC Cyber 172, but can operate on any compatible system. No special computer equipment is required. Normal configuration of CPU, reader and printer are necessary to run the program in the batch mode.

E. INPUT-OUTPUT: Inpur requirements are: The number of data sets, number of sediment size fractions, size distribution type, frequency of sediment data input parameter, mean velocity (ft/sec), hydraulic depth (ft), stream width (ft), water temperature (^{o}F), sediment particle size for which 65 percent of the sample is finer (mm), energy slope (ft/ft), kinematic viscosity of water (ft^2/sec), either sediment sizes (mm) and their respective percentages or a median particle size (mm) and a gradation coefficient.

F. ADDITIONAL REMARKS: Comparison of approximately 600 cases of computed versus measured loads that covered a very wide range of conditions shows that the Toffaleti procedure is consistently satisfactory for the conditions tested (Simons and Sentürk, 1977).

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NO.:

2. TITLE: TOFLTI

3. REVISION LOG: N/A

4. PURPOSE OF PROGRAM: To compute sand discharge by Toffaleti's method.

   References:

   a) Toffaleti, F. B., "Definitive Computation of Sand Discharge in Rivers," ASCE Journal of the Hydraulics Division, January, 1969.

   b) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

5. STEP SOLUTION:

   a) The input variables are:

      1 - Number of data sets (NDATA)

      2 - Number of sediment size fractions (NSED)

      3 - Sediment size distribution type (IDIST)

      if IDIST = 0, read in sizes and percentages. Also read in D_{65}, the sediment size for which 65% of the sample is finer.

      if IDIST = 1, a lognormal distribution is assumed. Read in median particle size and gradation coefficient.

      4 - Sediment input frequency parameter (ISED)

      if ISED = 0, same sediment distribution is used for all flow conditions

      if ISED = 1, a different size distribution is used for each flow condition

      5 - Mean velocity (V), ft/sec

      6 - Hydraulic depth (HR), ft

      7 - Hydraulic width (W), ft

8 - Water temperature (TDF), ^{o}F

9 - Energy slope (S), ft/ft

10 - Kinematic viscosity of water (SNU), ft^2/sec

EITHER 11 - An array of sediment sizes (DM), mm

12 - A percentage array corresponding to sizes (ZI), decimal fractions)

13 - The 65% finer sediment size (D65), mm

OR 11 - Median sediment size (D50), mm

12 - Gradation coefficient (SIGMA)

b) After input of required data computations of sand discharge begins by steps as given in Toffaleti (see Reference a).

<u>Step 1</u>. Compute:

$$YA = \frac{HR}{11.24}$$

$$YB = \frac{HR}{2.5}$$

(SI) = SS x HR x CZ (CZ from Figure 3, Toffaleti)

$$U_2 = \frac{V}{\sqrt{G \cdot D65 \cdot S}}$$

$$U_3 = \frac{V^3}{\sqrt{G \cdot SNU \cdot S}}$$

Find U_1 from Toffaleti's Figure 4 (subroutine TFIG4)

$$U_*' = \frac{V}{U_1} \quad ; \quad \overline{AM} = 10\ U_*'$$

$$\overline{PAM} = \frac{P^{1/3}}{\overline{AM}} \quad ; \quad (P = 10^5\ SNU, \quad SNU \text{ in } ft^2/sec)$$

From Figure 1 (Toffaleti), evaluate A.

(In the program, Figure 1 is approximated by a series of equations)

Steps 2 - 10 require separate computation for each sediment size

(DD = 2* particle diameter)

Step 2.

$$ZOM = \frac{VF \times V}{(SI)}$$ (VF is the fall velocity computed by Rubey's Equation. See Simons and Sentürk, 1977)

Check point: If $ZOM < 1.5\ Z_V$, use $ZOM = 1.5\ Z_V$

($Z_V = 0.1198 + 0.00048$ TDF, where TDF is water temperature)

$ZOL = 0.756\ ZOM$

$ZOU = 1.5\ ZOM$

$ZOL - Z_V = F1$

$ZOM - Z_V = F2$

$ZOU - Z_V = F3$

$1 - F1 = F4$

$1 - F2 = F5$

$1 - F3 = F6$

Step 3.

$$GF(I) = \frac{0.6}{\left(\frac{T\ A_c\ DM(I)}{V^2 \times 0.0058}\right)^{5/3}} \quad ;$$

$T = 1.10\ G\ (0.00158 + 0.0000028\ TDF)$

Step 4.

$$XC = \frac{F4\ GF(I)}{(YA)^{F4} - DD^{F4}}$$

Step 5.

$C = ZI(I)\ WX$; $ZI(I)$ = fraction of material in ith size,

W = stream width

Step 6.

$$\text{Bedload} = C\ DD^{F4}$$

$$UD = Cv\ V\left(\frac{DD}{HR}\right)^{Z_V} \quad ; \quad Cv = 1 + Z_V$$

$$UBL = \frac{XC}{43.2\ UD\ DD^{F1}}$$

If UBL > 100 pcf, the bed load is adjusted.

$$\text{Bedload} = \text{Bedload}\ (100/UBL)$$

Step 7.

$$\text{For } Y \Big]_{0}^{YA}\ GA = \frac{C}{F4}\left(YA^{F4} - DD^{F4}\right) + \text{Bedload}\ , \quad 0 \leq Y \leq YA$$

or

$$GA = GF(I)\ ZI(I)\ W + \text{Bedload}$$

Step 8.

$$\text{For } Y \Big]_{YA}^{YB}\ GB = (C/F5)\ YA^{F2-F1}\ \left(YB^{F5} - YA^{F5}\right)$$

Step 9.

$$\text{For } Y \Big]_{YB}^{HR}\ GC = (C/F6)\ YA^{F2-F1}\ YB^{F3-F2}\ \left(HR^{F6} - YB^{F6}\right)$$

Step 10.

$$\text{For } Y \Big]_{0}^{HR}\ GT = GA + GB + CC$$

6. ACCURACY: N/A

PART II: COMPUTER FUNCTIONAL DESCRIPTION

1. REVISION LOG: N/A

2. FUNCTIONAL FLOW CHART: (See Figure 1)

3. EQUIPMENT AND OPERATING SYSTEM: The program was developed on a CDC Cyber 172. Normal configuration of CPU, reader and printer are necessary to run the program in batch mode.

4. INPUT REQUIREMENTS: The program is written for either time-share or batch processing mode. The source listing (Figure 2) is for the batch mode. Figure 3 is the interactive mode listing.

5. SECONDARY STORAGE INPUT FORMAT: None

6. INPUT DATA DESCRIPTION: The following variable names are used for the input variables.

NAME	DESCRIPTION	FORMAT	
NDATA	Number of data sets	F5	Card 1
NDED	Number of sediment size fractions	I5	Card 2
IDIST	Sediment size distribution type	I5	Card 2
ISED	Frequency of sediment data input	I5	Card 2
V	Mean velocity (ft/sec)	F10.3	Card 3
HR	Hydraulic depth (ft)	F10.3	Card 3
W	Stream width (ft)	F10.3	Card 3
TDF	Water temperature (^{o}F)	F10.3	Card 3
S	Energy slope (ft/ft)	F10.7	Card 3
SNU	Kinematic viscosity of water (ft^2/sec)	E10.3	Card 3

EITHER IDIST = 0

DM(I)	Array of sediment sizes (mm)	10F8.4	Card 4
ZI(I)	Corresponding percentages (decimal fraction)	10F8.4	Card 5
D65	The 65% finer bed material size (mm)	F8.4	Card 6

OR IDIST = 1

D50	Median sediment size (mm)	F10.5	Card 4
SIGMA	Gradation coefficient	F10.5	Card 4

7. SUMMARY OF REQUIRED CARDS: See 6

8. OUTPUTS: Printed output generated by the program includes the pertinent input data and the sediment transport rate.

9. OPERATOR INSTRUCTIONS: None

10. PROGRAM ERROR MESSAGES: None - Program stops would result from improper data input.

11. VARIABLE DEFINITIONS:

AC	correction factor
ACOR	correction factor for models
AM	10 U_*' where U_*' = particle shear velocity
BQL	bed load (tons/day)
C	ZI*W*XC
CEF	a parameter used in evaluating U_1
CV	velocity distribution parameter, CV=1+ZV
CZ	temperature related parameter
C1	parameter used in evaluating U_1
C2	parameter used in evaluating U_1
DD	2*DM (ft)
DM	input bed material sizes (mm converted to ft in program)
D05-D95	bed material sizes for which 0 5 - 95% of the sample is finer

D65	bed material size for which 65% of the sample is finer
FQL	total sediment load
F1,F2,F3	exponents in point load equations for lower, middle and upper zone, respectively
F4,F5,F6	exponents in integrated load equations for lower, middle and upper zones, respectively
G	acceleration of gravity (ft/sec^2)
GA	sand load in lower zone (tons/day)
GB	sand load in middle zone (tons/day)
GC	sand load in upper zone (tons/day)
GF	nucleus load computed for a unit width in lower zone assuming bed composed entirely of one size fraction (tons/day/ft)
HR	hydraulic depth (ft)
IDIST	sediment size distribution type
ISED	frequency of sediment data input parameter
NDATA	number of data sets
NSED	number of sediment size fractions
P	kinematic viscosity of water times 10^5
PAM	parameter used to evaluate AC
S	energy slope (ft/ft)
SI	parameter used in evaluation of ZDM
SIGMA	gradation coefficient
SNU	kinematic viscosity of water (ft^2/sec)
SQL	suspended load in each size fraction
SQLP	middle and upper zone loads for each size fraction
TBQL	total bed load (tons/day)
TC	expansion of TP to include weight and shape factors

TDF	water temperature (°F)
TP	a parameter including constants and shear forces dependent on temperature
TQL	total load (tons/day)
TSQL	total suspended load (tons/day)
TSQLP	sum of middle and upper zone loads (tons/day)
UBL	concentration of bed load assuming bed material all one size (lbs/ft^3)
UD	point velocity at point 2 grain diameters from bed (ft/sec)
U1	correlation of velocity and shear velocity as a function of U2 and U3
U2,U3	parameters for evaluating shear velocity
U3L,U3R,U3X	parameters in evaluating U1
V	mean velocity (ft/sec)
VF	fall velocity (ft/sec)
VSP	ratio of mean velocity to U1
W	stream width (ft)
XC	product of factors included in formulation for zonal point loads
YA	distance to upper limit of lower zone $(\frac{HR}{11.24})$, (ft)
YB	distance to upper limit of middle zone $(\frac{HR}{2.5})$, (ft)
ZI	size fraction percentage array
ZOL	exponent in sand concentration distribution equation in lower zone
ZOM	exponent in sand concentration distribution equation in middle zone
ZOU	exponent in sand concentration distribution equation in upper zone
ZV	exponent of velocity distribution

12. EXAMPLE CASE:

a) Batch mode

```
    COMPUTATION OF SAND DISCHARGE
    BY TOFFALETIS METHOD//
SET     1
AVERAGE VELOCITY                    6.63FT/SEC,
HYDRAULIC DEPTH                     2.50 FT
WATER SURFACE WIDTH                170.00 FT
WATER TEMPERATURE                   70.00 DEG F
D65                                  .370 MM
ENERGY SLOPE                     .00105000 FT/FT
KINEMATIC VISCOSITY                .11E-04 FT**2/SEC

SEDIMENT SIZE        FRACTION        BED LOAD        SUSPENDED LOAD      TOTAL LOAD
   (MM)                             (TONS/DAY)        (TONS/DAY)         (TONS/DAY)

 .4950                .18              264.3             384.9              649.2
 .3510                .40              520.8            1707.8             2228.7
 .2480                .32              266.1            3371.6             3637.7
 .1750                .06               23.8            2007.6             2031.4

TOTAL BED LOAD =    1075.   SUS LOAD =    7472.   TOTAL BED-MATERIAL LOAD =    8547. TONS/DAY
   .081 CP SECONDS EXECUTION TIME
```

b) Interactive mode (see pages 12 and 13).

13. JOB PROCESSING TIME:

To Compile: 4.1 cpu sec

To Execute: 0.08 cpu sec (batch)

0.147 cpu sec (interactive)

Example case, interactive mode.

```
          COMPUTATION OF SAND DISCHARGE
               BY TOFFALETIS METHOD


 START INPUT DATA IN FREE FORMAT

 ENTER THE NUMBER OF SETS OF INPUT DATA
? 1


 SET SIZE DISTRIBUTION TYPE, IDIST = 0 OR 1
   ENTER 0 IF THE SEDIMENT SIZES AND PERCENTAGES DEFINING THE SEDIMENT SIZE DISTRIBUTION ARE TO BE READ IN
   ENTER 1 IF THE LOG-NORMAL SEDIMENT SIZE DISTRIBUTION IS TO BE EVALUATED
? 0


 ENTER 0 IF SEDIMENT DATA WILL NOT BE CHANGED FOR DIFFERENT HYDRAULIC CONDITION
 ENTER 1 IF THE SEDIMENT DATA ARE TO BE READ OR COMPUTED FOR EACH HYDRAULIC CONDITION
? 0



 ENTER THE FOLLOWING HYDRAULIC DATA:

   AVERAGE VELOCITY IN FEET PER SECOND
? 6.63
   HYDRAULIC RADIUS IN FEET
? 2.5
   WATER SURFACE WIDTH IN FEET
? 170
   WATER TEMPERATURE IN DEG. FAHRENHEIT
? 70.
   ENERGY SLOPE IN FEET/FEET
? .00105
   KINEMATIC VISCOSITY IN SQ.FT./SEC.
? .0000106
```

```
IDIST=0 ENTER THE FOLLOWING BED MATERIAL DATA:

  NUMBER OF SEDIMENT SIZE FRACTIONS, NSED
? 4
  GEO MEAN SIZE IN MM REPRESENTING THE ITH FRACTION AND THE PERCENT WEIGHT OF THE ITH FRACTION
      (DM(I),ZI(I),I=1,NSED)
? .495,.178
? .351,.402
? .248,.320
? .175,.058
  THE 65% FINER DIAMETER IN MM, D65
? .37

  SET     1
  AVERAGE VELOCITY                    6.63 FT/SEC
  HYDRAULIC DEPTH                     2.50 FT
  WATER SURFACE WIDTH               170.00 FT
  WATER TEMPERATURE                  70.00 DEG F
  D65                                 .370 MM
  ENERGY SLOPE                  .00105000 FT/FT
  KINEMATIC VISCOSITY             .11E-04 FT**2/SEC

SEDIMENT SIZE        FRACTION        BED LOAD       SUSPENDED LOAD     TOTAL LOAD
   (MM)                             (TONS/DAY)       (TONS/DAY)       (TONS/DAY)

  .4950                .18            264.3            384.9            649.2
  .3510                .40            520.8           1707.8           2228.7
  .2480                .32            266.1           3371.6           3637.7
  .1750                .06             23.8           2007.6           2031.4

TOTAL BED LOAD =    1075.   SUS LOAD =    7472.   TOTAL BED-MATERIAL LOAD =    8547. TONS/DAY
   .147 CP SECONDS EXECUTION TIME
```

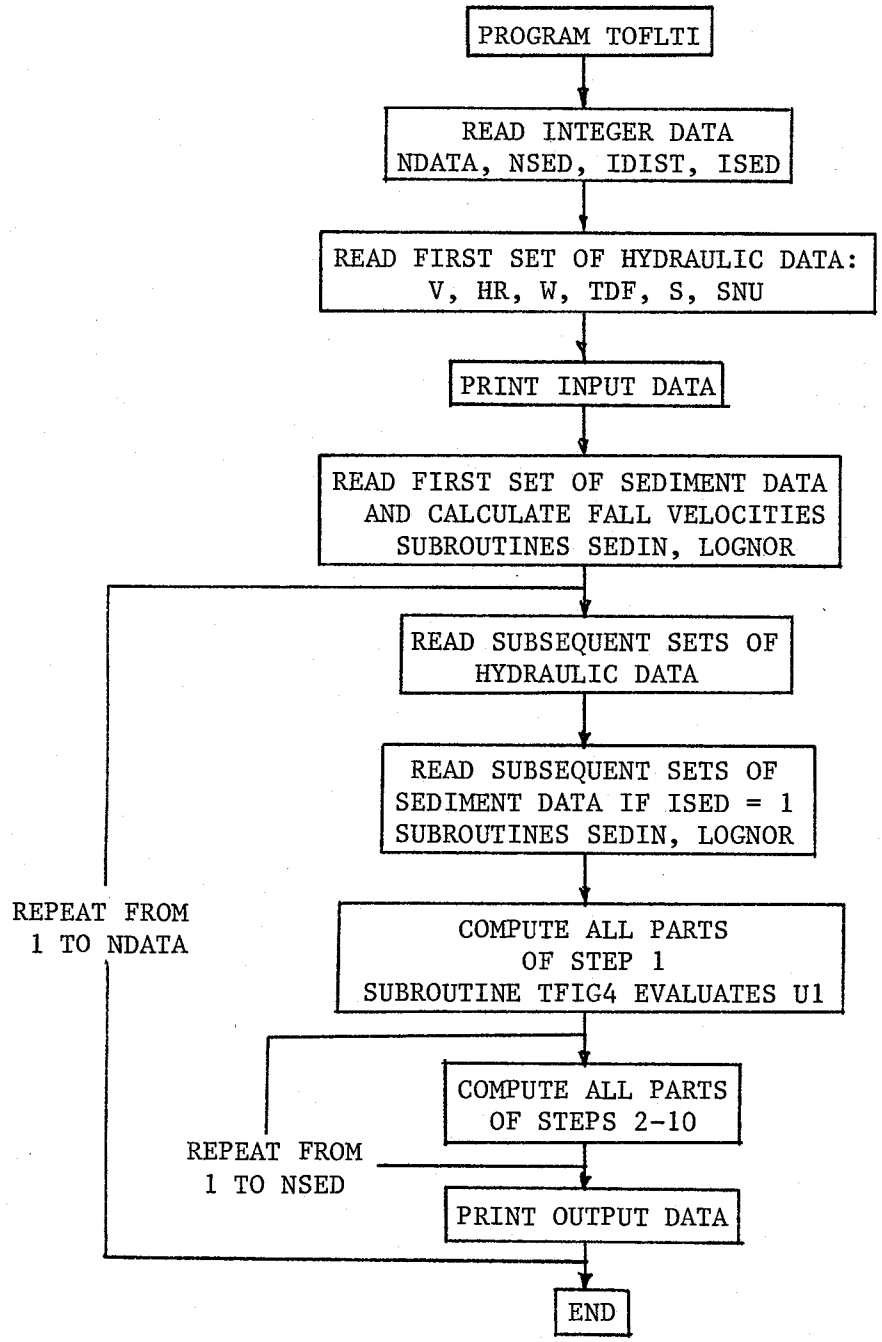

Figure 1. Flow chart of Program TOFLTI.

```
      PROGRAM TOFLTI                                                    TOF 0010
     1(INPUT,OUTPUT)                                                    TOF 0020
C                                                                       TOF 0030
C     DEVELOPED                                                         TOF 0040
C                                                                       TOF 0050
C     PURPOSE              COMPUTATION OF SAND DISCHARGE IN RIVERS BY  TOF 0060
C                          TOFFALETIS METHOD                           TOF 0070
C                                                                       TOF 0080
C     REFERENCE            TOFFALETI, FRED B., "DEFINITIVE COMPUTATIONS TOF 0090
C                          OF SAND DISCHARGE IN RIVERS," ASCE JOURNAL  TOF 0100
C                          OF THE HYDRAULICS DIVISION, JAN., 1969      TOF 0110
C                                                                       TOF 0120
C     CORE USAGE                                                        TOF 0130
C                                                                       TOF 0140
C     COMPILATION TIME     APPROXIMATELY 4.1 SEC                       TOF 0150
C                                                                       TOF 0160
C     CENTRAL PROCESSOR                                                 TOF 0170
C     TIME FOR ONE SET                                                  TOF 0180
C     OF DATA              APPROXIMATELY 0.12 SEC                      TOF 0190
C                                                                       TOF 0200
C     INPUT DATA                                                        TOF 0210
C                                                                       TOF 0220
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FORMAT I5.  NDATA   TOF 0230
C     IS THE NUMBER OF SETS OF INPUT DATA TO BE ANALYZED BY TOFFALETI'S TOF 0240
C     METHOD.                                                           TOF 0250
C                                                                       TOF 0260
C     THE SECOND CARD CONTAINS THE VALUES OF NSED,IDIST, AND ISED IN    TOF 0270
C     FORMAT 3I5.                                                       TOF 0280
C     NSED = THE NUMBER OF SEDIMENT SIZE FRACTIONS                      TOF 0290
C     IDIST = THE SEDIMENT SIZE DISTRIBUTION TYPE                       TOF 0300
C             IF IDIST = 0 READ IN SEDIMENT PARTICLE SIZES AND          TOF 0310
C             CORRESPONDING PERCENTAGES (10F8.4) AND D65(MM) (F8.4)     TOF 0320
C             IF IDIST = 1 A LOGNORMAL DISTRIBUTION IS ASSUMED          TOF 0330
C             READ IN D50 (MM) AND THE GRADATION COEFFICIENT,           TOF 0340
C             SIGMA (2F10.5)                                            TOF 0350
C     ISED = FREQUENCY OF SEDIMENT DATA INPUT PARAMETER                 TOF 0360
C             IF ISED = 0 THE SAME SEDIMENT SIZE DISTRIBUTION IS        TOF 0370
C             USED FOR ALL FLOW CONDITIONS BEING ANALYZED               TOF 0380
C             IF ISED = 1 A DIFFERENT SEDIMENT SIZE DISTRIBUTION        TOF 0390
C             IS USED FOR EACH FLOW CONDITION                           TOF 0400
C                                                                       TOF 0410
C     HYDRAULIC DATA (5F10.3,F10.7,E10.3)                               TOF 0420
C                                                                       TOF 0430
C     V     = MEAN VELOCITY (FT/SEC)                                    TOF 0440
C     HR    = HYDRAULIC DEPTH (FT)                                      TOF 0450
C     W     = STREAM WIDTH (FT)                                         TOF 0460
C     TDF   = WATER TEMPERATURE (DEG. FAHRENHEIT)                       TOF 0470
C     S     = FRICTION SLOPE                                            TOF 0480
C     SNU   = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                  TOF 0490
C                                                                       TOF 0500
      COMMON /SED/          NSED        , IDIST       , DM(20)       ,  TOF 0510
     1        ZI(20)       , VF(20)      , SNU         , D65             TOF 0520
      DIMENSION             GF(20)      , BQL(20)     , SQL(20)      ,  TOF 0530
     1        FQL(20)      , SQLP(20)                                   TOF 0540
C                                                                       TOF 0550
C     COMPUTATION OF THE SEDIMENT LOAD (TONS/DAY) BY TOFFALETIS METHOD  TOF 0560
C                                                                       TOF 0570
      PRINT 150                                                         TOF 0580
      READ 160, NDATA                                                   TOF 0590
      READ 170, NSED,IDIST,ISED                                         TOF 0600
      READ 180, V,HR,W,TDF,S,SNU                                        TOF 0610
      CALL SEDIN                                                        TOF 0620
      DO 140 IDATA = 1,NDATA                                            TOF 0630
         IF (IDATA.EQ.1) GO TO 100                                      TOF 0640
```

Figure 2. Batch listing, Program TOFLTI.

```
      READ 180, V,HR,W,TDF,S,SNU                                        TOF 0650
      IF (ISED.EQ.0) GO TO 100                                          TOF 0660
      CALL SEDIN                                                        TOF 0670
100   CONTINUE                                                          TOF 0680
      PRINT 190, IDATA,V,HR,W,TDF,D65,S,SNU                             TOF 0690
C                                                                       TOF 0700
C     STEP 1                                                            TOF 0710
C                                                                       TOF 0720
      D65 = D65/304.8                                                   TOF 0730
      G = 32.17                                                         TOF 0740
      YA = HR/11.24                                                     TOF 0750
      YB = HR/2.5                                                       TOF 0760
      CZ = 260.67 - 0.667 * TDF                                         TOF 0770
      SI = S * HR * CZ                                                  TOF 0780
      U2 = V/SQRT(G * D65 * S)                                          TOF 0790
      U3 = V *  * 3/(G * SNU * S)                                       TOF 0800
      CALL TFIG4 (U1,U2,U3)                                             TOF 0810
      VSP = V/U1                                                        TOF 0820
      AM = 10. * VSP                                                    TOF 0830
      P = SNU * 10. *  * 5                                              TOF 0840
      PAM = P *  * (1./3.)/AM                                           TOF 0850
      ZV = 0.1198 + 0.00048 * TDF                                       TOF 0860
      CV = 1. + ZV                                                      TOF 0870
      IF (PAM.LE.0.5) AC = 9.86/(PAM) *  * 1.51                         TOF 0880
      IF (PAM.LE.0.67.AND.PAM.GT.0.5) AC = 39.1 * PAM *  * 0.482        TOF 0890
      IF (PAM.LE.0.72.AND.PAM.GE.0.67) AC = 338. * PAM *  * 5.87        TOF 0900
      IF (PAM.LE.1.28.AND.PAM.GT.0.72) AC = 49.                         TOF 0910
      IF (PAM.GT.1.28) AC = 24.8 * PAM *  * 2.76                        TOF 0920
      FAC = PAM * S * D65 * 10. *  * 5                                  TOF 0930
C                                                                       TOF 0940
C     CHECK POINT                                                       TOF 0950
C                                                                       TOF 0960
      IF (FAC.LE.0.25) GO TO 110                                        TOF 0970
      IF (FAC.GT.0.25.AND.FAC.LT.0.35) ACOR = 5.08 * FAC *  * 1.16      TOF 0980
      IF (FAC.GE.0.35) ACOR = 0.5/FAC *  * 1.05                         TOF 0990
      AC = AC * ACOR                                                    TOF 1000
      IF (AC.LT.16.) AC = 16.                                           TOF 1010
110   CONTINUE                                                          TOF 1020
      TBQL = 0.                                                         TOF 1030
      TSQL = 0.                                                         TOF 1040
      TQL = 0.                                                          TOF 1050
      TSQLP = 0.                                                        TOF 1060
      DO 120 I = 1,NSED                                                 TOF 1070
C                                                                       TOF 1080
C     STEP 2                                                            TOF 1090
C                                                                       TOF 1100
        ZOM = VF(I) * V/SI                                              TOF 1110
C                                                                       TOF 1120
C     CHECK POINT                                                       TOF 1130
C                                                                       TOF 1140
        IF (ZOM.LT.(1.5 * ZV)) ZOM = 1.5 * ZV                           TOF 1150
        ZOL = 0.756 * ZOM                                               TOF 1160
        ZOU = 1.5 * ZOM                                                 TOF 1170
        F1 = ZOL - ZV                                                   TOF 1180
        F2 = ZOM - ZV                                                   TOF 1190
        F3 = ZOU - ZV                                                   TOF 1200
        F4 = 1. - F1                                                    TOF 1210
        F5 = 1. - F2                                                    TOF 1220
        F6 = 1. - F3                                                    TOF 1230
        DD = 2. * DM(I)                                                 TOF 1240
        TP = G * (0.00158 + 0.0000028 * TDF)                            TOF 1250
        TC = 1.10 * TP                                                  TOF 1260
C                                                                       TOF 1270
C     STEP 3                                                            TOF 1280
C                                                                       TOF 1290
        GF(I) = 0.600/(TC * AC * DM(I)/(V *  * 2 * 0.00058)) *  * (5TOF 1300
```

```
     1        ./3.)                                                    TOF 1310
C                                                                      TOF 1320
C     STEP 4                                                           TOF 1330
C                                                                      TOF 1340
            XC = F4 * GF(I)/(YA *  * F4 - DD *  * F4)                  TOF 1350
C                                                                      TOF 1360
C     STEP5                                                            TOF 1370
C                                                                      TOF 1380
            C = ZI(I) * W * XC                                         TOF 1390
C                                                                      TOF 1400
C     STEP 6                                                           TOF 1410
C                                                                      TOF 1420
            BQL(I) = C * DD *  * F4                                    TOF 1430
            UD = CV * V * (DD/HR) *  * ZV                              TOF 1440
            UBL = XC/(43.2 * UD * DD *  * F1)                          TOF 1450
C                                                                      TOF 1460
C     CHECK POINT                                                      TOF 1470
C                                                                      TOF 1480
            IF (UBL.GT.100.) BQL(I) = BQL(I) * 100./UBL                TOF 1490
C                                                                      TOF 1500
C     COMPUTATION OF THE SEDIMENT LOAD                                 TOF 1510
C                                                                      TOF 1520
C     STEP 7                                                           TOF 1530
C                                                                      TOF 1540
            GA = GF(I) * ZI(I) * W                                     TOF 1550
C                                                                      TOF 1560
C     STEP 8                                                           TOF 1570
C                                                                      TOF 1580
            GB = C * YA *  * (F2 - F1) * (YB *  * F5 - YA *  * F5)/F5  TOF 1590
C                                                                      TOF 1600
C     STEP 9                                                           TOF 1610
C                                                                      TOF 1620
            GC = C * YA *  * (F2 - F1) * YB *  * (F3 - F2) * (HR *  * F6TOF 1630
     1       - YB *  * F6)/F6                                          TOF 1640
C                                                                      TOF 1650
C     STEP 10                                                          TOF 1660
C                                                                      TOF 1670
            SQL(I) = GA + GB + GC                                      TOF 1680
            FQL(I) = SQL(I) + BQL(I)                                   TOF 1690
            SQLP(I) = GB + GC                                          TOF 1700
            TSQLP = TSQLP + SQLP(I)                                    TOF 1710
            TBQL = TBQL + BQL(I)                                       TOF 1720
            TSQL = TSQL + SQL(I)                                       TOF 1730
            TQL = TQL + FQL(I)                                         TOF 1740
  120     CONTINUE                                                     TOF 1750
          PRINT 200                                                    TOF 1760
          DO 130 I = 1,NSED                                            TOF 1770
            DM(I) = DM(I) * 304.8                                      TOF 1780
            PRINT 220, DM(I),ZI(I),BQL(I),SQL(I),FQL(I)                TOF 1790
  130     CONTINUE                                                     TOF 1800
          PRINT 210, TBQL,TSQL,TQL                                     TOF 1810
  140 CONTINUE                                                         TOF 1820
      STOP                                                             TOF 1830
C                                                                      TOF 1840
  150 FORMAT (1H1///9X,29HCOMPUTATION OF SAND DISCHARGE/9X,22HBY TOFFALETOF 1850
     1TIS METHOD//)                                                    TOF 1860
  160 FORMAT (I5)                                                      TOF 1870
  170 FORMAT (3I5)                                                     TOF 1880
  180 FORMAT (4F10.3,F10.7,E10.3)                                      TOF 1890
  190     FORMAT (5X,4HSET ,I5/5X,27HAVERAGE VELOCITY          ,F12.2,  TOF 1900
     1  7HFT/SEC,/5X,27HHYDRAULIC DEPTH            ,F12.2,3H FT,/5X,   2TOF 1910
     27HWATER SURFACE WIDTH        ,F12.2,3H FT,/5X,27HWATER TEMPERATURETOF 1920
     3              ,F12.2,6H DEG F,/5X,27HD65                       ,  TOF 1930
     4 F12.3,3H MM,/5X,27HENERGY SLOPE              ,F12.8,6H FT/FT,/5XTOF 1940
     5   ,27HKINEMATIC VISCOSITY        ,E12.2,10H FT**2/SEC/)         TOF 1950
```

```
  200 FORMAT (3X,13HSEDIMENT SIZE,8X,8HFRACTION,10X,8HBED LOAD,7X,14HSUSTOF 1960
     1PENDED LOAD,5X,10HTOTAL LOAD,/6X,4H(MM),31X,10H(TONS/DAY),7X,10H(TTOF 1970
     2ONS/DAY),9X,10H(TONS/DAY),/)                                      TOF 1980
  210 FORMAT (/3X,16HTOTAL BED LOAD =,F9.0,3X,10HSUS LOAD =,F9.0,3X, 25HTOF 1990
     1TOTAL BED-MATERIAL LOAD =,F9.0,  9H TONS/DAY)                     TOF 2000
  220 FORMAT (2X,F8.4,F19.2,3F19.1)                                     TOF 2010
      END                                                               TOF 2020
=TOF
      SUBROUTINE SEDIN                                                  TOF 2030
      COMMON /SED/          NSED        , IDIST       , DM(20)      ,   TOF 2040
     1        ZI(20)       , VF(20)      , SNU         , D65             TOF 2050
      IF (IDIST.EQ.0) GO TO 100                                         TOF 2060
      NSED = 10                                                         TOF 2070
      READ 130, D50,SIGMA                                               TOF 2080
      CALL LOGNOR (D50,SIGMA)                                           TOF 2090
      GO TO 110                                                         TOF 2100
  100 READ 140, (DM(I),I = 1,NSED)                                      TOF 2110
      READ 140, (ZI(I),I = 1,NSED)                                      TOF 2120
      READ 140, D65                                                     TOF 2130
  110 CONTINUE                                                          TOF 2140
C                                                                       TOF 2150
C     CALCULATE FALL VELOCITY USING RUBEY@S EQ.(SEE SIMONS&SENTURK)     TOF 2160
C                                                                       TOF 2170
      DO 120 I = 1,NSED                                                 TOF 2180
         DM(I) = DM(I)/304.8                                            TOF 2190
  120 VF(I) = (SQRT(2./3. * 32.2 * (2.65 - 1.) * DM(I) *  * 3. + 36. * STOF 2200
     1NU *  * 2.) - 6. * SNU)/DM(I)                                     TOF 2210
      RETURN                                                            TOF 2220
C                                                                       TOF 2230
  130 FORMAT (2F10.5)                                                   TOF 2240
  140 FORMAT (10F8.4)                                                   TOF 2250
      END                                                               TOF 2260
=TOF
      SUBROUTINE LOGNOR (D50,SIGMA)                                     TOF 2270
      COMMON /SED/          NSED        , IDIST       , DM(20)      ,   TOF 2280
     1        ZI(20)       , VF(20)      , SNU         , D65             TOF 2290
      D95 = D50 * SIGMA *  * 1.645                                      TOF 2300
      D90 = D50 * SIGMA *  * 1.285                                      TOF 2310
      D80 = D50 * SIGMA *  * 0.845                                      TOF 2320
      D70 = D50 * SIGMA *  * 0.525                                      TOF 2330
      D60 = D50 * SIGMA *  * 0.255                                      TOF 2340
      D40 = D50/SIGMA *  * 0.255                                        TOF 2350
      D30 = D50/SIGMA *  * 0.525                                        TOF 2360
      D20 = D50/SIGMA *  * 0.845                                        TOF 2370
      D10 = D50/SIGMA *  * 1.285                                        TOF 2380
      D05 = D50/SIGMA *  * 1.645                                        TOF 2390
      DM(1) = SQRT(D05 * D10)                                           TOF 2400
      DM(2) = SQRT(D10 * D20)                                           TOF 2410
      DM(3) = SQRT(D20 * D30)                                           TOF 2420
      DM(4) = SQRT(D30 * D40)                                           TOF 2430
      DM(5) = SQRT(D40 * D50)                                           TOF 2440
      DM(6) = SQRT(D50 * D60)                                           TOF 2450
      DM(7) = SQRT(D60 * D70)                                           TOF 2460
      DM(8) = SQRT(D70 * D80)                                           TOF 2470
      DM(9) = SQRT(D80 * D90)                                           TOF 2480
      DM(10) = SQRT(D90 * D95)                                          TOF 2490
      DO 100 I = 1,10                                                   TOF 2500
  100 ZI(I) = 0.1                                                       TOF 2510
      D65 = D50 * SIGMA *  * .385                                       TOF 2520
      RETURN                                                            TOF 2530
      END                                                               TOF 2540
=TOF
      SUBROUTINE TFIG4 (U1,U2,U3)                                       TOF 2550
C                                                                       TOF 2560
C     THIS SUBROUTINE APPROXIMATES FIG.4 OF TOFFALETIS SAND DISCHARGE   TOF 2570
C         COMPUTATION                                                   TOF 2580
C                                                                       TOF 2590
```

```
      IF (U2.LT.500.) GO TO 100                                         TOF 2600
      CEF = 1.0                                                         TOF 2610
      GO TO 110                                                         TOF 2620
  100 CEF = 0.92                                                        TOF 2630
  110 C = 21.9 + 9.7 * ALOG10((U2/500.) *  * CEF)                       TOF 2640
      U3L = 2.16 + 0.23 * C                                             TOF 2650
      U3R = 3.32 + 0.23 * C                                             TOF 2660
      U3X = ALOG10(U3)                                                  TOF 2670
      IF (U3X.GT.U3R) GO TO 120                                         TOF 2680
      IF (U3X.LT.U3L) GO TO 130                                         TOF 2690
      C1 =  - ((U3R - U3L)/2.) *  * 2                                   TOF 2700
      C2 = (U3R + U3L)/2.                                               TOF 2710
      U1 = (U3X - C2) *  * 2/C1 + (1. + C)                              TOF 2720
      GO TO 140                                                         TOF 2730
  120 U1 = C                                                            TOF 2740
      GO TO 140                                                         TOF 2750
  130 U1 = (U3X - 2.17)/0.23                                            TOF 2760
  140 RETURN                                                            TOF 2770
      END                                                               TOF 2780
```

```
      PROGRAM TOFLTII                                                   TOFI0010
     1(INPUT,OUTPUT)                                                    TOFI0020
C                                                                       TOFI0030
C     DEVELOPED                                                         TOFI0040
C                                                                       TOFI0050
C     PURPOSE              COMPUTATION OF SAND DISCHARGE IN RIVERS BY  TOFI0060
C                          TOFFALETIS METHOD                           TOFI0070
C                                                                       TOFI0080
C     REFERENCE            TOFFALETI, FRED B., "DEFINITIVE COMPUTATIONS TOFI0090
C                          OF SAND DISCHARGE IN RIVERS," ASCE JOURNAL  TOFI0100
C                          OF THE HYDRAULICS DIVISION, JAN., 1969      TOFI0110
C                                                                       TOFI0120
C     CORE USAGE                                                        TOFI0130
C                                                                       TOFI0140
C     COMPILATION TIME     APPROXIMATELY 4.1 SEC                       TOFI0150
C                                                                       TOFI0160
C     CENTRAL PROCESSOR                                                 TOFI0170
C     TIME FOR ONE SET                                                  TOFI0180
C     OF DATA              APPROXIMATELY 0.12 SEC                      TOFI0190
C                                                                       TOFI0200
C     INPUT DATA                                                        TOFI0210
C                                                                       TOFI0220
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FREE FORMAT.  NDATA TOFI0230
C     IS THE NUMBER OF SETS OF INPUT DATA TO BE ANALYZED BY TOFFALETI'S TOFI0240
C     METHOD.                                                           TOFI0250
C                                                                       TOFI0260
C     THE SECOND AND THIRD CARDS CONTAINS THE VALUES OF IDIST AND ISED ITOFI0270
C     FREE FORMAT.                                                      TOFI0280
C     IDIST = THE SEDIMENT SIZE DISTRIBUTION TYPE                       TOFI0290
C             IF IDIST = 0 READ IN SEDIMENT PARTICLE SIZES AND          TOFI0300
C             CORRESPONDING PERCENTAGES                                 TOFI0310
C             IF IDIST = 1 A LOGNORMAL DISTRIBUTION IS ASSUMED          TOFI0320
C             READ IN D50 (MM) AND THE GRADATION COEFFICIENT,           TOFI0330
C             SIGMA                                                     TOFI0340
C     ISED = FREQUENCY OF SEDIMENT DATA INPUT PARAMETER                 TOFI0350
C             IF ISED = 0 THE SAME SEDIMENT SIZE DISTRIBUTION IS        TOFI0360
C             USED FOR ALL FLOW CONDITIONS BEING ANALYZED               TOFI0370
C             IF ISED = 1 A DIFFERENT SEDIMENT SIZE DISTRIBUTION        TOFI0380
C             IS USED FOR EACH FLOW CONDITION                           TOFI0390
C                                                                       TOFI0400
C     HYDRAULIC DATA                                                    TOFI0410
C                                                                       TOFI0420
C     V      = MEAN VELOCITY (FT/SEC)                                   TOFI0430
C     HR     = HYDRAULIC DEPTH (FT)                                     TOFI0440
C     W      = STREAM WIDTH (FT)                                        TOFI0450
C     TDF    = WATER TEMPERATURE (DEG. FAHRENHEIT)                      TOFI0460
C     D65    = SEDIMENT PARTICLE SIZE FOR WHICH 65% OF THE SAMPLE       TOFI0470
C              IS FINER (MM)                                            TOFI0480
C     S      = FRICTION SLOPE                                           TOFI0490
C     SNU    = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                 TOFI0500
C                                                                       TOFI0510
      COMMON /SED/          NSED        , IDIST       , DM(20)       ,  TOFI0520
     1        ZI(20)       , VF(20)      , SNU         , D65            TOFI0530
      DIMENSION             GF(20)      , BQL(20)     , SQL(20)      ,  TOFI0540
     1        FQL(20)      , SQLP(20)                                   TOFI0550
C                                                                       TOFI0560
C     COMPUTATION OF THE SEDIMENT LOAD (TONS/DAY) BY TOFFALETIS METHOD  TOFI0570
C                                                                       TOFI0580
      PRINT 150                                                         TOFI0590
      PRINT 160                                                         TOFI0600
      READ   *, NDATA                                                   TOFI0610
      PRINT 170                                                         TOFI0620
      READ   *, IDIST                                                   TOFI0630
      PRINT 180                                                         TOFI0640
      READ   *, ISED                                                    TOFI0650
```

Figure 3. Interactive listing, Program TOFLTI.

```
      DO 140 IDATA = 1,NDATA                                            TOFI0660
         PRINT 190                                                      TOFI0670
         READ   *, V                                                    TOFI0680
         PRINT 200                                                      TOFI0690
         READ   *, HR                                                   TOFI0700
         PRINT 210                                                      TOFI0710
         READ   *, W                                                    TOFI0720
         PRINT 220                                                      TOFI0730
         READ   *, TDF                                                  TOFI0740
         PRINT 230                                                      TOFI0750
         READ   *, S                                                    TOFI0760
         PRINT 240                                                      TOFI0770
         READ   *, SNU                                                  TOFI0780
         IF (IDATA.GE.2.AND.ISED.EQ.0) GO TO 100                        TOFI0790
         CALL SEDIN                                                     TOFI0800
  100    CONTINUE                                                       TOFI0810
         PRINT 250                                                      TOFI0820
         PRINT 260, IDATA,V,HR,W,TDF,D65,S,SNU                          TOFI0830
C                                                                       TOFI0840
C     STEP 1                                                            TOFI0850
C                                                                       TOFI0860
         D65 = D65/304.8                                                TOFI0870
         G = 32.17                                                      TOFI0880
         YA = HR/11.24                                                  TOFI0890
         YB = HR/2.5                                                    TOFI0900
         CZ = 260.67 - 0.667 * TDF                                      TOFI0910
         SI = S * HR * CZ                                               TOFI0920
         U2 = V/SQRT(G * D65 * S)                                       TOFI0930
         U3 = V *  * 3/(G * SNU * S)                                    TOFI0940
         CALL TFIG4 (U1,U2,U3)                                          TOFI0950
         VSP = V/U1                                                     TOFI0960
         AM = 10. * VSP                                                 TOFI0970
         P = SNU * 10. *  * 5                                           TOFI0980
         PAM = P *  * (1./3.)/AM                                        TOFI0990
         ZV = 0.1198 + 0.00048 * TDF                                    TOFI1000
         CV = 1. + ZV                                                   TOFI1010
         IF (PAM.LE.0.5) AC = 9.86/(PAM) *  * 1.51                      TOFI1020
         IF (PAM.LE.0.67.AND.PAM.GT.0.5) AC = 39.1 * PAM *  * 0.482     TOFI1030
         IF (PAM.LE.0.72.AND.PAM.GE.0.67) AC = 338. * PAM *  * 5.87     TOFI1040
         IF (PAM.LE.1.28.AND.PAM.GT.0.72) AC = 49.                      TOFI1050
         IF (PAM.GT.1.28) AC = 24.8 * PAM *  * 2.76                     TOFI1060
         FAC = PAM * S * D65 * 10. *  * 5                               TOFI1070
C                                                                       TOFI1080
C     CHECK POINT                                                       TOFI1090
C                                                                       TOFI1100
         IF (FAC.LE.0.25) GO TO 110                                     TOFI1110
         IF (FAC.GT.0.25.AND.FAC.LT.0.35) ACOR = 5.08 * FAC *  * 1.16   TOFI1120
         IF (FAC.GE.0.35) ACOR = 0.5/FAC *  * 1.05                      TOFI1130
         AC = AC * ACOR                                                 TOFI1140
         IF (AC.LT.16.) AC = 16.                                        TOFI1150
  110    CONTINUE                                                       TOFI1160
         TBQL = 0.                                                      TOFI1170
         TSQL = 0.                                                      TOFI1180
         TQL = 0.                                                       TOFI1190
         TSQLP = 0.                                                     TOFI1200
         DO 120 I = 1,NSED                                              TOFI1210
C                                                                       TOFI1220
C     STEP 2                                                            TOFI1230
C                                                                       TOFI1240
            ZOM = VF(I) * V/SI                                          TOFI1250
C                                                                       TOFI1260
C     CHECK POINT                                                       TOFI1270
C                                                                       TOFI1280
            IF (ZOM.LT.(1.5 * ZV)) ZOM = 1.5 * ZV                       TOFI1290
            ZOL = 0.756 * ZOM                                           TOFI1300
            ZOU = 1.5 * ZOM                                             TOFI1310
```

```
      F1 = ZOL - ZV                                                     TOFI1320
      F2 = ZOM - ZV                                                     TOFI1330
      F3 = ZOU - ZV                                                     TOFI1340
      F4 = 1. - F1                                                      TOFI1350
      F5 = 1. - F2                                                      TOFI1360
      F6 = 1. - F3                                                      TOFI1370
      DD = 2. * DM(I)                                                   TOFI1380
      TP = G * (0.00158 + 0.0000028 * TDF)                              TOFI1390
      TC = 1.10 * TP                                                    TOFI1400
C                                                                       TOFI1410
C     STEP 3                                                            TOFI1420
C                                                                       TOFI1430
      GF(I) = 0.600/(TC * AC * DM(I)/(V *  * 2 * 0.00058)) *  * (5TOFI1440
     1 ./3.)                                                            TOFI1450
C                                                                       TOFI1460
C     STEP 4                                                            TOFI1470
C                                                                       TOFI1480
      XC = F4 * GF(I)/(YA *  * F4 - DD *  * F4)                         TOFI1490
C                                                                       TOFI1500
C     STEP5                                                             TOFI1510
C                                                                       TOFI1520
      C = ZI(I) * W * XC                                                TOFI1530
C                                                                       TOFI1540
C     STEP 6                                                            TOFI1550
C                                                                       TOFI1560
      BQL(I) = C * DD *  * F4                                           TOFI1570
      UD = CV * V * (DD/HR) *  * ZV                                     TOFI1580
      UBL = XC/(43.2 * UD * DD *  * F1)                                 TOFI1590
C                                                                       TOFI1600
C     CHECK POINT                                                       TOFI1610
C                                                                       TOFI1620
      IF (UBL.GT.100.) BQL(I) = BQL(I) * 100./UBL                       TOFI1630
C                                                                       TOFI1640
C     COMPUTATION OF THE SEDIMENT LOAD                                  TOFI1650
C                                                                       TOFI1660
C     STEP 7                                                            TOFI1670
C                                                                       TOFI1680
      GA = GF(I) * ZI(I) * W                                            TOFI1690
C                                                                       TOFI1700
C     STEP 8                                                            TOFI1710
C                                                                       TOFI1720
      GB = C * YA *  * (F2 - F1) * (YB *  * F5 - YA *  * F5)/F5         TOFI1730
C                                                                       TOFI1740
C     STEP 9                                                            TOFI1750
C                                                                       TOFI1760
      GC = C * YA *  * (F2 - F1) * YB *  * (F3 - F2) * (HR *  * F6TOFI1770
     1  - YB *  * F6)/F6                                                TOFI1780
C                                                                       TOFI1790
C     STEP 10                                                           TOFI1800
C                                                                       TOFI1810
      SQL(I) = GA + GB + GC                                             TOFI1820
      FQL(I) = SQL(I) + BQL(I)                                          TOFI1830
      SQLP(I) = GB + GC                                                 TOFI1840
      TSQLP = TSQLP + SQLP(I)                                           TOFI1850
      TBQL = TBQL + BQL(I)                                              TOFI1860
      TSQL = TSQL + SQL(I)                                              TOFI1870
      TQL = TQL + FQL(I)                                                TOFI1880
  120 CONTINUE                                                          TOFI1890
      PRINT 270                                                         TOFI1900
      DO 130 I = 1,NSED                                                 TOFI1910
      DM(I) = DM(I) * 304.8                                             TOFI1920
      PRINT 290, DM(I),ZI(I),BQL(I),SQL(I),FQL(I)                       TOFI1930
  130 CONTINUE                                                          TOFI1940
      PRINT 280, TBQL,TSQL,TQL                                          TOFI1950
  140 CONTINUE                                                          TOFI1960
      STOP                                                              TOFI1970
```

```
150     FORMAT (1H1///9X,29HCOMPUTATION OF SAND DISCHARGE/14X,22HBY TOFTOFI1990
   1FALETIS METHOD  //)                                                TOFI2000
160     FORMAT (////, 32H START INPUT DATA IN FREE FORMAT,//, 39H ENTERTOFI2010
   1 THE NUMBER OF SETS OF INPUT DATA)                                 TOFI2020
170     FORMAT (//, 43H SET SIZE DISTRIBUTION TYPE, IDIST = 0 OR 1,/,  TOFI2030
   1  62H   ENTER 0 IF THE SEDIMENT SIZES AND PERCENTAGES DEFINING THETOFI2040
   2  ,   44HSEDIMENT SIZE DISTRIBUTION ARE TO BE READ IN,/,    59H   TOFI2050
   3ENTER 1 IF THE LOG-NORMAL SEDIMENT SIZE DISTRIBUTION IS ,    16HTOTOFI2060
   4 BE EVALUATED )                                                    TOFI2070
180     FORMAT (//, 46H ENTER 0 IF SEDIMENT DATA WILL NOT BE CHANGED , TOFI2080
   133HFOR DIFFERENT HYDRAULIC CONDITION,/,    57H ENTER 1 IF THE SEDITOFI2090
   2MENT DATA ARE TO BE READ OR COMPUTED ,    28HFOR EACH HYDRAULIC COTOFI2100
   3NDITION)                                                           TOFI2110
190     FORMAT (//////, 36H ENTER THE FOLLOWING HYDRAULIC DATA:,//,    TOFI2120
   138H   AVERAGE VELOCITY IN FEET PER SECOND)                         TOFI2130
200     FORMAT ( 27H   HYDRAULIC RADIUS IN FEET)                        TOFI2140
210     FORMAT ( 30H   WATER SURFACE WIDTH IN FEET)                     TOFI2150
220     FORMAT ( 39H   WATER TEMPERATURE IN DEG. FAHRENHEIT)            TOFI2160
230     FORMAT ( 28H   ENERGY SLOPE IN FEET/FEET)                       TOFI2170
240     FORMAT ( 37H   KINEMATIC VISCOSITY IN SQ.FT./SEC.)              TOFI2180
250     FORMAT (////)                                                   TOFI2190
260     FORMAT (5X,4HSET ,I5/5X,27HAVERAGE VELOCITY            ,F12.2,  TOFI2200
   1 7H FT/SEC,/5X,27HHYDRAULIC DEPTH              ,F12.2,3H FT,/5X,   2TOFI2210
   27HWATER SURFACE WIDTH          ,F12.2,3H FT,/5X,27HWATER TEMPERATURETOFI2220
   3           ,F12.2,6H DEG F,/5X,   27HD65                          ,F1TOFI2230
   42.3,   3H MM,/5X,27HENERGY SLOPE                ,F12.8,6H FT/FT,/5XTOFI2240
   5,27HKINEMATIC VISCOSITY          ,E12.2,10H FT**2/SEC/)            TOFI2250
270 FORMAT (3X,13HSEDIMENT SIZE,8X,8HFRACTION,10X,8HBED LOAD,7X,14HSUSTOFI2260
   1PENDED LOAD,5X,10HTOTAL LOAD,/6X,4H(MM),31X,10H(TONS/DAY),7X,10H(TTOFI2270
   20NS/DAY),9X,10H(TONS/DAY),/)                                       TOFI2280
280 FORMAT (/3X,16HTOTAL BED LOAD =,F9.0,3X,10HSUS LOAD =,F9.0,3X, 25HTOFI2290
   1TOTAL BED-MATERIAL LOAD =,F9.0,  9H TONS/DAY)                      TOFI2300
290 FORMAT (2X,F8.4,F19.2,3F19.1)                                      TOFI2310
    END                                                                TOFI2320
    SUBROUTINE SEDIN                                                   TOFI2330
    COMMON /SED/          NSED        , IDIST       , DM(20)       ,   TOFI2340
   1        ZI(20)       , VF(20)      , SNU         , D65              TOFI2350
    IF (IDIST.EQ.0) GO TO 100                                          TOFI2360
    NSED = 10                                                          TOFI2370
    PRINT 130                                                          TOFI2380
    READ   *, D50,SIGMA                                                TOFI2390
    CALL LOGNOR (D50,SIGMA)                                            TOFI2400
    GO TO 110                                                          TOFI2410
100 CONTINUE                                                           TOFI2420
    PRINT 140                                                          TOFI2430
    READ   *, NSED                                                     TOFI2440
    PRINT 150                                                          TOFI2450
    READ   *, (DM(I),ZI(I),I = 1,NSED)                                 TOFI2460
    PRINT 160                                                          TOFI2470
    READ   *, D65                                                      TOFI2480
110 CONTINUE                                                           TOFI2490
C                                                                      TOFI2500
C   CALCULATE FALL VELOCITY USING RUBEY@S EQ.(SEE SIMONS&SENTURK)      TOFI2510
C                                                                      TOFI2520
    DO 120 I = 1,NSED                                                  TOFI2530
       DM(I) = DM(I)/304.8                                             TOFI2540
120 VF(I) = (SQRT(2./3. * 32.2 * (2.65 - 1.) * DM(I) *   * 3. + 36. * STOFI2550
   1NU *   * 2.) - 6. * SNU)/DM(I)                                     TOFI2560
    RETURN                                                             TOFI2570
C                                                                      TOFI2580
130 FORMAT(//55H IDIST=1 ENTER THE MEDIAN BED MATERIAL SIZE,D50 IN MM,TOFI2590
   1,32H   AND THE GRADATION COEFFICIENT)                              TOFI2600
140 FORMAT (//, 48H IDIST=0 ENTER THE FOLLOWING BED MATERIAL DATA: ,//TOFI2610
   1, 42H   NUMBER OF SEDIMENT SIZE FRACTIONS, NSED)                   TOFI2620
150 FORMAT ( 36H   GEO MEAN SIZE IN MM REPRESENTING , 59HTHE ITH FRACTTOFI2630
   1ION AND THE PERCENT WEIGHT OF THE ITH FRACTION,/, 30H   ------ (DM(ITOFI2640
   2),ZI(I),I=1,NSED))                                                 TOFI2650
```

```
  160 FORMAT ( 36H   THE 65% FINER DIAMETER IN MM, D65)                TOFI2660
      END                                                              TOFI2670
      SUBROUTINE LOGNOR (D50,SIGMA)                                    TOFI2680
      COMMON /SED/          NSED        , IDIST       , DM(20)       ,  TOFI2690
     1        ZI(20)       , VF(20)       , SNU         , D65           TOFI2700
      D95 = D50 * SIGMA *  * 1.645                                     TOFI2710
      D90 = D50 * SIGMA *  * 1.285                                     TOFI2720
      D80 = D50 * SIGMA *  * 0.845                                     TOFI2730
      D70 = D50 * SIGMA *  * 0.525                                     TOFI2740
      D60 = D50 * SIGMA *  * 0.255                                     TOFI2750
      D40 = D50/SIGMA *  * 0.255                                       TOFI2760
      D30 = D50/SIGMA *  * 0.525                                       TOFI2770
      D20 = D50/SIGMA *  * 0.845                                       TOFI2780
      D10 = D50/SIGMA *  * 1.285                                       TOFI2790
      D05 = D50/SIGMA *  * 1.645                                       TOFI2800
      DM(1) = SQRT(D05 * D10)                                          TOFI2810
      DM(2) = SQRT(D10 * D20)                                          TOFI2820
      DM(3) = SQRT(D20 * D30)                                          TOFI2830
      DM(4) = SQRT(D30 * D40)                                          TOFI2840
      DM(5) = SQRT(D40 * D50)                                          TOFI2850
      DM(6) = SQRT(D50 * D60)                                          TOFI2860
      DM(7) = SQRT(D60 * D70)                                          TOFI2870
      DM(8) = SQRT(D70 * D80)                                          TOFI2880
      DM(9) = SQRT(D80 * D90)                                          TOFI2890
      DM(10) = SQRT(D90 * D95)                                         TOFI2900
      DO 100 I = 1,10                                                  TOFI2910
  100 ZI(I) = 0.1                                                      TOFI2920
      D65 = D50 * SIGMA *  * .385                                      TOFI2930
      RETURN                                                           TOFI2940
      END                                                              TOFI2950
      SUBROUTINE TFIG4 (U1,U2,U3)                                      TOFI2960
C                                                                      TOFI2970
C     THIS SUBROUTINE APPROXIMATES FIG.4 OF TOFFALETIS SAND DISCHARGE  TOFI2980
C         COMPUTATION                                                  TOFI2990
C                                                                      TOFI3000
      IF (U2.LT.500.) GO TO 100                                        TOFI3010
      CEF = 1.0                                                        TOFI3020
      GO TO 110                                                        TOFI3030
  100 CEF = 0.92                                                       TOFI3040
  110 C = 21.9 + 9.7 * ALOG10((U2/500.) *  * CEF)                      TOFI3050
      U3L = 2.16 + 0.23 * C                                            TOFI3060
      U3R = 3.32 + 0.23 * C                                            TOFI3070
      U3X = ALOG10(U3)                                                 TOFI3080
      IF (U3X.GT.U3R) GO TO 120                                        TOFI3090
      IF (U3X.LT.U3L) GO TO 130                                        TOFI3100
      C1 =  - ((U3R - U3L)/2.) *  * 2                                  TOFI3110
      C2 = (U3R + U3L)/2.                                              TOFI3120
      U1 = (U3X - C2) *  * 2/C1 + (1. + C)                             TOFI3130
      GO TO 140                                                        TOFI3140
  120 U1 = C                                                           TOFI3150
      GO TO 140                                                        TOFI3160
  130 U1 = (U3X - 2.17)/0.23                                           TOFI3170
  140 RETURN                                                           TOFI3180
      END                                                              TOFI3190
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM: YANG PROGRAM NO.:

PREPARING AGENCY: Simons and Li Engineering

AUTHORS: R. M. Li, R. K. Simons, D. B. Simons

DATE PROGRAM COMPLETED: September, 1979

STATUS OF PROGRAM: Phase - original, Stage - operational

A. PURPOSE OF PROGRAM: To compute the sediment discharge in rivers by Yang's Method. References: (a) Yang, C. T., "Incipient Motion and Sediment Transport," ASCE Journal of the Hydraulics Division, October, 1973; (b) Yang, C. T., "Minimum Unit Stream Power and Fluvial Hydraulics," ASCE Journal of the Hydraulics Division, July, 1976; (c) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

B. PROGRAM SPECIFICATIONS:

Language: ANSI Fortran IV

Solution Requirements: Input data

Methods of Analysis: Computer form of Yang's method

Size of Object Program: 17,650 characters

External Storage: None

Restrictions: None

General Equations: Yang's sediment concentration equation

$$\log C = 5.435 - 0.286 \log \frac{wd}{\nu} - 0.457 \log \frac{U_*}{w}$$

$$+ \left(1.799 - 0.409 \log \frac{wd}{\nu} - 0.314 \log \frac{U_*}{w}\right) \log \left(\frac{VS}{w} - \frac{V_{cr}S}{w}\right)$$

where C is the sediment concentration by weight, w is the fall velocity of median sediment particle, d is the particle diameter,

ν is the kinematic viscosity, U_* is the shear velocity, VS is the unit stream power, V is the velocity, S is the energy slope, V_{cr} is the average critical velocity at incipient motion.

Range of Quantities: Unlimited within physical reason

Accuracy: N/A

Dimension System: English, except input sediment diameter is in mm.

C. METHODS: The program is written in both batch and time-share models in Fortran IV.

D. EQUIPMENT DETAILS: The program was developed on a CDC Cyber 172 but can operate on any compatible system. Normal configuration of CPU, reader and printer is necessary to run the program in batch mode.

E. INPUT-OUTPUT: Input requirements are: Number of data sets to be analyzed, mean velocity (ft/sec), hydraulic depth (ft), stream width (ft), median sediment diameter (mm), energy slope of river (ft/ft), kinematic viscosity of water (ft^2/sec). Output includes the input data and total sediment concentration and discharge.

F. ADDITIONAL REMARKS: This method often underestimates the sediment concentration.

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NUMBER:

2. TITLE: YANG

3. REVISION LOG: N/A

4. PURPOSE OF PROGRAM: To compute total sediment discharge in rivers by Yang's method. References:

   a) Yang, C. T., "Incipient Motion and Sediment Transport," ASCE Journal of the Hydraulics Division, October, 1973.

   b) Yang, C. T., "Minimum Unit Stream Power and Fluvial Hydraulics," ASCE Journal of the Hydraulics Division, July, 1976.

   c) Simons, D. B., and F. Sentürk, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

5. SOLUTION:

   a) The input variables are:

      1 - The number of data sets to be analyzed

      2 - Mean velocity (ft/sec)

      3 - Hydraulic depth (ft)

      4 - Stream width (ft)

      5 - Median sediment diameter (mm)

      6 - Energy slope of stream (ft/ft)

      7 - Kinematic viscosity of water (ft^2/sec)

   b) After the input of necessary data for each set computation of the hydraulic parameters in Yang's equation is begun, the median particle size is converted to ft for unit consistency, and its fall velocity (w) is computed by Rubey's equation. The critical velocity (V_{cr}) at incipient motion and the shear velocity (U_*) are

determined. These values are then used in Yang's equation.

$$\log C = 5.435 - 0.286 \log \frac{wd}{\nu} - 0.457 \log \frac{U_*}{w}$$

$$+ \left(1.799 - 0.409 \log \frac{wd}{\nu} - 0.314 \log \frac{U_*}{w}\right) \log \left(\frac{VS}{w} - \frac{V_{cr}S}{w}\right)$$

The sediment concentration by weight is obtained by taking the antilog of the previously obtained value. If the mean velocity is less than the critical velocity, the concentration is zero. Sediment discharge is found by

$$Q_s = C \times 10^{-6} \times V \times D \times W \times K$$

where K is a conversion factor from ft^3/sec of sediment discharge to tons per day (K = 62.4 x 43.2).

6. ACCURACY: N/A

PART II: COMPUTER FUNCTIONAL DESCRIPTION

1. REVISION LOG: N/A

2. FUNCTION FLOW CHART: See Figure 1

3. EQUIPMENT AND OPERATING SYSTEM: The pgoram was developed on a CDC Cyber 172. Normal configuration of CPU, reader and printer are necessary to run the program in batch mode.

4. INPUT REQUIREMENTS: The program is written for either batch or time-share modes. The source listing (Figure 2) is for the batch mode. Figure 3 is the interactive mode listing.

5. SECONDARY STORAGE INPUT FORMAT: None

6. INPUT DATA DESCRIPTION: The following variable names are used for input variables:

NAME	DESCRIPTION	FORMAT	
NDATA	Number of data sets	I5	Card 1
V	Mean velocity	F10.2	
D	Hydraulic depth	F10.2	
W	Stream width	F10.2	Card 2, 3, ..., NDATA
DM	Median sediment diameter	F10.3	
S	Energy slope of stream	F10.7	
SNU	Kinematic viscosity of water	E10.3	

7. SUMMARY OF REQUIRED INPUT CARDS: (See 6)

8. OUTPUT: Printed output generated by the program includes the input data and the sediment concentration and discharge.

9. OPERATOR INSTRUCTIONS: None

10. PROGRAM ERROR MESSAGES: None - Program stop would result from improper input data.

11. VARIABLE DEFINITIONS:

CS - Sediment concentration by weight (ppm)

CT - Log of CS

D - Hydraulic depth (ft)

DM - Median bed material size (mm)

NDATA - Number of data sets

Q - Water discharge (cfs)

QS - Sediment discharge (tons/day)

REY - Reynolds number using shear velocity

REYP - Particle Reynolds number using fall velocity

S - Energy slope (ft/ft)

SNU - Kinematic viscosity of water (ft^2/sec)

US - Shear velocity divided by fall velocity

USTAR - Shear velocity (ft/sec)

V - Mean velocity (ft/sec)

VCROVF - Critical velocity at incipient motion divided by fall velocity

VF - Fall velocity (ft/sec)

VSW - Dimensionless effective unit stream power

W - Stream width (ft)

12. EXAMPLE CASE:

a) Batch mode

```
COMPUTATION OF TOTAL SEDIMENT DISCHARGE
BY YANGS METHOD

   SET      1
   MEAN VELOCITY                    6.63FT/SEC/     HYDRAULIC DEPTH                2.50 FT
   STREAM WIDTH                   170.00 FT
   MEDIAN SEDIMENT DIAMETER         .495 MM
   ENERGY SLOPE                 .0010500 FT/FT
   KINEMATIC VISCOSITY          .106E-04 FT**2/SEC
```

```
TOTAL SEDIMENT CONCENTRATION =     1702. PPM BY WEIGHT
TOTAL SEDIMENT DISCHARGE     =    12928. TONS/DAY


     .040 CP SECONDS EXECUTION TIME
```

b) Interactive mode

```
COMPUTATION OF TOTAL SEDIMENT DISCHARGE
     BY YANGS METHOD



START INPUT DATA IN FREE FORMAT

ENTER THE NUMBER OF SETS OF INPUT DATA
? 1



ENTER THE FOLLOWING HYDRAULIC DATA:

  AVERAGE VELOCITY IN FEET PER SECOND
? 6.63
  HYDRAULIC DEPTH IN FEET
? 2.5
  STREAM WIDTH IN FEET
? 170.
  ENERGY SLOPE IN FEET/FEET
? .00105
  KINEMATIC VISCOSITY IN SQ.FT./SEC.
? .0000106
  MEDIAN BED MATERIAL SIZE IN MM
? .495

    SET     1
    MEAN VELOCITY                    6.63 FT/SEC
    HYDRAULIC DEPTH                  2.50 FT
    STREAM WIDTH                   170.00 FT
    MEDIAN SEDIMENT DIAMETER         .495 MM
    ENERGY SLOPE                 .0010500 FT/FT
    KINEMATIC VISCOSITY          .106E-04 FT**2/SEC

TOTAL SEDIMENT CONCENTRATION =     1702. PPM BY WEIGHT
TOTAL SEDIMENT DISCHARGE     =    12928. TONS/DAY


    .064 CP SECONDS EXECUTION TIME
```

13. JOB PROCESSING TIME

To compile:	0.9	cpu sec
To execute:	0.04	cpu sec (batch)
	0.064	cpu sec (interactive)

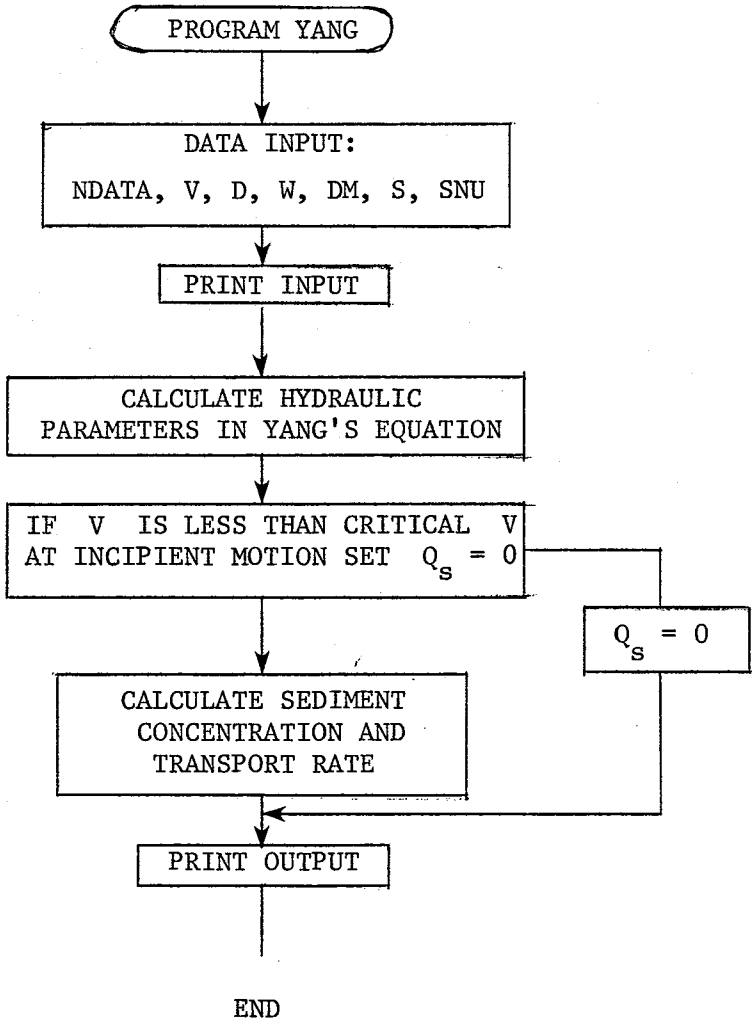

Figure 1. Flow chart of program YANG.

```
      PROGRAM YANG                                                      YAN 0010
     1(INPUT,OUTPUT)                                                    YAN 0020
C                                                                       YAN 0030
C     DEVELOPED                                                         YAN 0040
C                                                                       YAN 0050
C     PURPOSE            COMPUTATION OF SEDIMENT DISCHARGE IN           YAN 0060
C                        RIVERS BY YANGS METHOD                         YAN 0070
C                                                                       YAN 0080
C     REFERENCE          YANG, C.T., "INCIPIENT MOTION AND SEDIMENT     YAN 0090
C                        TRANSPORT," ASCE JOURNAL OF THE HYDRAULICS     YAN 0100
C                        DIVISION, OCT., 1973                           YAN 0110
C                        AND                                            YAN 0120
C                        YANG, C.T., "MINIMUM UNIT STREAM POWER         YAN 0130
C                        AND FLUVIAL HYDRAULICS," ASCE JOURNAL OF       YAN 0140
C                        THE HYDRAULICS DIVISION, JULY, 1976            YAN 0150
C                                                                       YAN 0160
C     CORE USAGE                                                        YAN 0170
C                                                                       YAN 0180
C     COMPILATION TIME   APPROXIMATELY 0.9 SEC                          YAN 0190
C                                                                       YAN 0200
C     CENTRAL PROCESSOR                                                 YAN 0210
C     TIME FOR ONE SET                                                  YAN 0220
C     OF DATA            LESS THAN 0.03 SEC                             YAN 0230
C                                                                       YAN 0240
C     INPUT DATA                                                        YAN 0250
C                                                                       YAN 0260
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FORMAT I5.          YAN 0270
C     NDATA = NUMBER OF DATA SETS TO BE ANALYZED                        YAN 0280
C                                                                       YAN 0290
C     THE SECOND AND SUCCEEDING CARDS CONTAIN THE HYDRAULIC AND         YAN 0300
C     SEDIMENT DATA SETS IN THE FOLLOWING FORMAT:                       YAN 0310
C     (3F10.2,F10.3,F10.7,E10.3)                                        YAN 0320
C     V     = MEAN VELOCITY (FT/SEC)                                    YAN 0330
C     D     = HYDRAULIC DEPTH (FT)                                      YAN 0340
C     W     = STREAM WIDTH (FT)                                         YAN 0350
C     DM    = MEDIAN SEDIMENT DIAMETER (MM)                             YAN 0360
C     S     = ENERGY SLOPE OF STREAM (FT/FT)                            YAN 0370
C     SNU   = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                  YAN 0380
C                                                                       YAN 0390
      PRINT 140                                                         YAN 0400
      READ 150, NDATA                                                   YAN 0410
      DO 130 I = 1,NDATA                                                YAN 0420
         READ 160, V,D,W,DM,S,SNU                                       YAN 0430
         PRINT 170, I,V,D,W,DM,S,SNU                                    YAN 0440
         DM = DM/304.8                                                  YAN 0450
         VF = (SQRT(2./3. * 32.2 * 1.65 * DM *  * 3. + 36. * SNU *  * 2.YAN 0460
     1   ) - 6. * SNU)/DM                                               YAN 0470
         USTAR = SQRT(32.2 * D * S)                                     YAN 0480
         REY = USTAR * DM/SNU                                           YAN 0490
         VCROVF = 2.05                                                  YAN 0500
         IF (REY.LT.70.) VCROVF = 2.5/(ALOG10(REY) - 0.06) + 0.66       YAN 0510
         IF (VCROVF.LT.0.) VCROVF = 0.                                  YAN 0520
         REYP = VF * DM/SNU                                             YAN 0530
         US = USTAR/VF                                                  YAN 0540
         VSW = S * (V/VF - VCROVF)                                      YAN 0550
         IF (VSW.GT.0.) GO TO 100                                       YAN 0560
         CS = 0.                                                        YAN 0570
         GO TO 110                                                      YAN 0580
  100    CT = 5.435 - 0.286 * ALOG10(REYP) - 0.457 * ALOG10(US) + (1.799YAN 0590
     1    - 0.409 * ALOG10(REYP) - 0.314 * ALOG10(US)) * ALOG10(VSW)    YAN 0600
         CS = 10. *  * CT                                               YAN 0610
         GO TO 120                                                      YAN 0620
  110    CS = 0.                                                        YAN 0630
  120    Q = V * D * W                                                  YAN 0640
         QS = CS * 1.E - 6 * Q * 62.4 * 43.2                            YAN 0650
```

Figure 2. Batch listing, Program YANG.

```
      PRINT 180, CS,QS                                                  YAN 0660
  130 CONTINUE                                                          YAN 0670
      STOP                                                              YAN 0680
C                                                                       YAN 0690
  140 FORMAT (1H1///, 41H  COMPUTATION OF TOTAL SEDIMENT DISCHARGE,/, 17YAN 0700
     1H  BY YANGS METHOD,//)                                            YAN 0710
  150 FORMAT (I5)                                                       YAN 0720
  160    FORMAT (3F10.2,F10.3,F10.7,E10.3)                              YAN 0730
  170    FORMAT (5X,4HSET ,I5/,5X,25HMEAN VELOCITY            ,F12.2,  1YAN 0740
     1 7HFT/SEC/,5X,25HHYDRAULIC DEPTH          ,F12.2,3H FT/,5X,25HSTREYAN 0750
     2AM WIDTH              ,   F12.2,3H FT/,5X,25HMEDIAN SEDIMENT DIAMETYAN 0760
     3ER ,   F12.3,3H MM/,5X,25HENERGY SLOPE              ,F12.7,6H FT/FTYAN 0770
     4/,   5X,25HKINEMATIC VISCOSITY      ,E12.3,10H FT**2/SEC//)        YAN 0780
  180 FORMAT (2X,30HTOTAL SEDIMENT CONCENTRATION =,F10.0,14H PPM BY WEIGYAN 0790
     1HT/2X,30HTOTAL SEDIMENT DISCHARGE     =,F10.0,9H TONS/DAY///)      YAN 0800
      END                                                               YAN 0810
```

```
      PROGRAM YANGI                                                     YANI0010
     1(INPUT,OUTPUT)                                                    YANI0020
C                                                                       YANI0030
C     DEVELOPED                                                         YANI0040
C                                                                       YANI0050
C     PURPOSE            COMPUTATION OF SEDIMENT DISCHARGE IN           YANI0060
C                        RIVERS BY YANGS METHOD                         YANI0070
C                                                                       YANI0080
C     REFERENCE          YANG, C.T., "INCIPIENT MOTION AND SEDIMENT     YANI0090
C                        TRANSPORT," ASCE JOURNAL OF THE HYDRAULICS     YANI0100
C                        DIVISION, OCT., 1973                           YANI0110
C                        AND                                            YANI0120
C                        YANG, C.T., "MINIMUM UNIT STREAM POWER         YANI0130
C                        AND FLUVIAL HYDRAULICS," ASCE JOURNAL OF       YANI0140
C                        THE HYDRAULICS DIVISION, JULY, 1976            YANI0150
C                                                                       YANI0160
C     CORE USAGE                                                        YANI0170
C                                                                       YANI0180
C     COMPILATION TIME   APPROXIMATELY 0.9 SEC                          YANI0190
C                                                                       YANI0200
C     CENTRAL PROCESSOR                                                 YANI0210
C     TIME FOR ONE SET                                                  YANI0220
C     OF DATA            LESS THAN 0.03 SEC                             YANI0230
C                                                                       YANI0240
C     INPUT DATA                                                        YANI0250
C                                                                       YANI0260
C     THE FIRST CARD CONTAINS THE VALUE OF NDATA IN FREE FORMAT.        YANI0270
C     NDATA = NUMBER OF DATA SETS TO BE ANALYZED                        YANI0280
C                                                                       YANI0290
C     THE SECOND AND SUCCEEDING CARDS CONTAIN THE HYDRAULIC AND         YANI0300
C     SEDIMENT DATA SETS IN FREE FORMAT                                 YANI0310
C     V     = MEAN VELOCITY (FT/SEC)                                    YANI0320
C     D     = HYDRAULIC DEPTH (FT)                                      YANI0330
C     W     = STREAM WIDTH (FT)                                         YANI0340
C     DM    = MEDIAN SEDIMENT DIAMETER (MM)                             YANI0350
C     S     = ENERGY SLOPE OF STREAM (FT/FT)                            YANI0360
C     SNU   = KINEMATIC VISCOSITY OF WATER (FT**2/SEC)                  YANI0370
C                                                                       YANI0380
      PRINT 140                                                         YANI0390
      PRINT 150                                                         YANI0400
      READ   *, NDATA                                                   YANI0410
      DO 130 I = 1,NDATA                                                YANI0420
         PRINT 160                                                      YANI0430
         READ   *, V                                                    YANI0440
         PRINT 170                                                      YANI0450
         READ   *, D                                                    YANI0460
         PRINT 180                                                      YANI0470
         READ   *, W                                                    YANI0480
         PRINT 190                                                      YANI0490
         READ   *, S                                                    YANI0500
         PRINT 200                                                      YANI0510
         READ   *, SNU                                                  YANI0520
         PRINT 210                                                      YANI0530
         READ   *, DM                                                   YANI0540
         PRINT 220, I,V,D,W,DM,S,SNU                                    YANI0550
         DM = DM/304.8                                                  YANI0560
         VF = (SQRT(2./3. * 32.2 * 1.65 * DM *  * 3. + 36. * SNU *  * 2.YANI0570
     1   ) - 6. * SNU)/DM                                               YANI0580
         USTAR = SQRT(32.2 * D * S)                                     YANI0590
         REY = USTAR * DM/SNU                                           YANI0600
         VCROVF = 2.05                                                  YANI0610
         IF (REY.LT.70.) VCROVF = 2.5/(ALOG10(REY) - 0.06) + 0.66       YANI0620
         IF (VCROVF.LT.0.) VCROVF = 0.                                  YANI0630
         REYP = VF * DM/SNU                                             YANI0640
         US = USTAR/VF                                                  YANI0650
```

Figure 3. Interactive listing, Program YANG.

```
      VSW = S * (V/VF - VCROVF)                                         YANI0660
      IF (VSW.GT.0.) GO TO 100                                          YANI0670
      CS = 0.                                                           YANI0680
      GO TO 110                                                         YANI0690
100   CT = 5.435 - 0.286 * ALOG10(REYP) - 0.457 * ALOG10(US) + (1.799YANI0700
     1  - 0.409 * ALOG10(REYP) - 0.314 * ALOG10(US)) * ALOG10(VSW)     YANI0710
      CS = 10. *  * CT                                                  YANI0720
      GO TO 120                                                         YANI0730
110   CS = 0.                                                           YANI0740
120   Q = V * D * W                                                     YANI0750
      QS = CS * 1.E - 6 * Q * 62.4 * 43.2                               YANI0760
      PRINT 230, CS,QS                                                  YANI0770
130 CONTINUE                                                            YANI0780
    STOP                                                                YANI0790
C                                                                       YANI0800
140 FORMAT (1H1///, 41H  COMPUTATION OF TOTAL SEDIMENT DISCHARGE,/, 22YANI0810
   1H        BY YANGS METHOD,//)                                       YANI0820
150 FORMAT (///, 32H START INPUT DATA IN FREE FORMAT,//, 39H ENTER THEYANI0830
   1 NUMBER OF SETS OF INPUT DATA)                                      YANI0840
160 FORMAT (//////, 36H ENTER THE FOLLOWING HYDRAULIC DATA:,//, 38H    YANI0850
   1AVERAGE VELOCITY IN FEET PER SECOND)                                YANI0860
170 FORMAT ( 26H   HYDRAULIC DEPTH IN FEET)                             YANI0870
180 FORMAT ( 23H   STREAM WIDTH IN FEET)                                YANI0880
190 FORMAT ( 28H   ENERGY SLOPE IN FEET/FEET)                           YANI0890
200 FORMAT ( 37H   KINEMATIC VISCOSITY IN SQ.FT./SEC.)                  YANI0900
210 FORMAT ( 33H   MEDIAN BED MATERIAL SIZE IN MM)                      YANI0910
220 FORMAT (//5X,4HSET ,I5/,5X,25HMEAN VELOCITY            ,F12.2,7H FYANI0920
   1T/SEC/,5X,25HHYDRAULIC DEPTH          ,F12.2,3H FT/,5X,25HSTREAM WYANI0930
   2IDTH              ,F12.2,3H FT/,5X,25HMEDIAN SEDIMENT DIAMETER ,F12YANI0940
   3.3,3H MM/,5X,25HENERGY SLOPE              ,F12.7,6H FT/FT/,5X,25HKIYANI0950
   4NEMATIC VISCOSITY      ,E12.3,10H FT**2/SEC//)                    YANI0960
230 FORMAT (2X,30HTOTAL SEDIMENT CONCENTRATION =,F10.0,14H PPM BY WEIGYANI0970
   1HT/2X,30HTOTAL SEDIMENT DISCHARGE     =,F10.0,9H TONS/DAY///)      YANI0980
    END                                                                 YANI0990
```