INLAND WATERS BRANCH

Some uses of a digital graph plotter in hydrology

G. W. KITE

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CANADA

SOME USES OF A DIGITAL GRAPH PLOTTER IN HYDROLOGY

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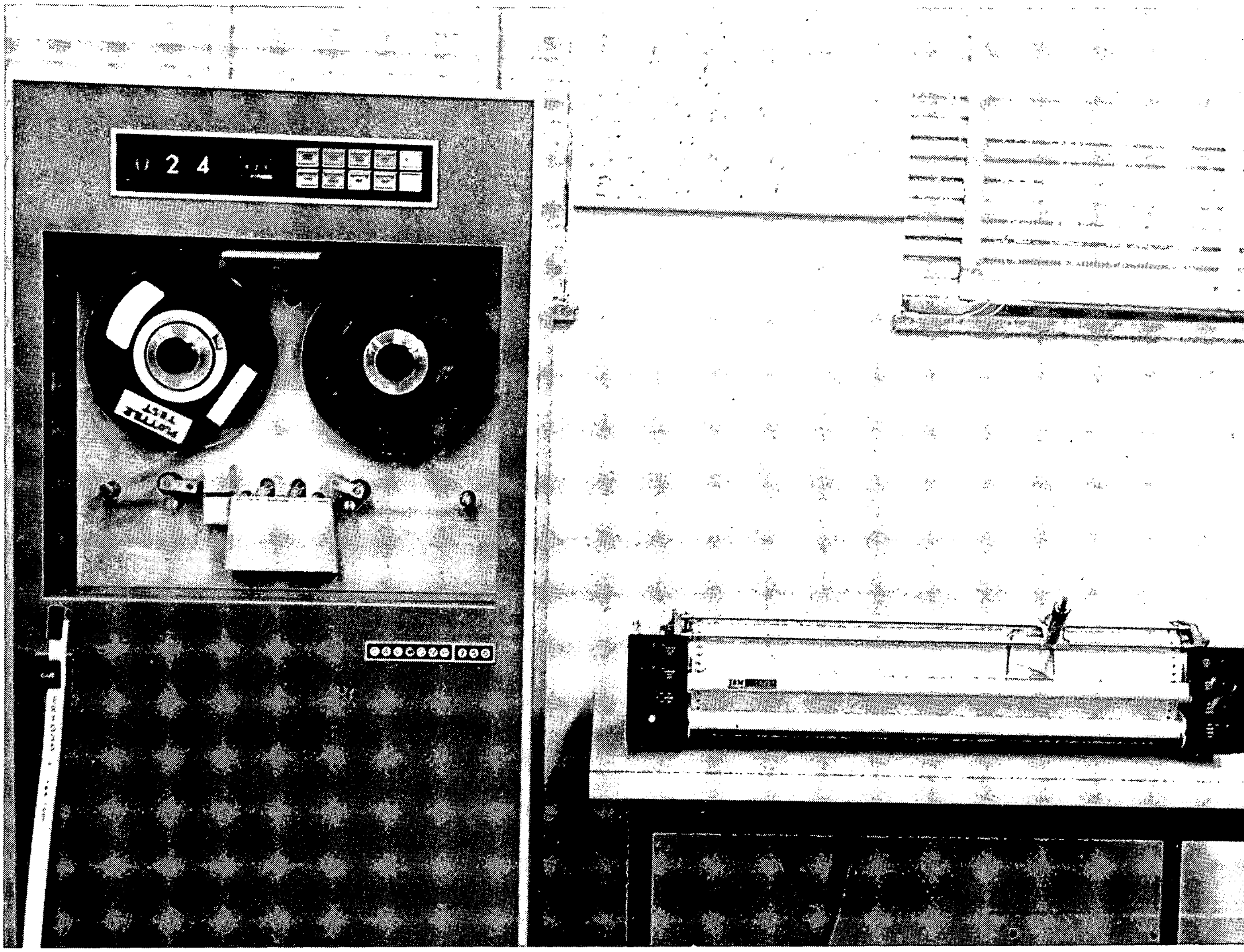
FOREWORD

This bulletin is based on a study made by the Engineering Division of the Inland Waters Branch during the period January 1967 to April 1968. The study began when it was realized, during the course of an investigation into post-glacial crustal movement in the Great Lakes region, that upwards of sixty extremely accurate graphs would be required; each graph consisting of over one hundred coordinate pairs which had to be plotted to an accuracy of three decimal places on a format suitable for a report. Since digital computers were already being used in the post-glacial crustal movement investigation, it seemed a logical extension of the work to use the computer to produce plotter output directly as well as the more usual printer output.

This use of the digital graph plotter worked so well that it was decided to increase our experience in the use of plotters by writing more programs to give plotted output and by using other types of plotter. The results of these studies are summarized in the following pages.



Frontispiece Calcomp 563 Digital Plotter

SOME USES OF A DIGITAL GRAPH PLOTTER IN HYDROLOGY

G.W. Kite

INTRODUCTION

The useful end product from the hardware of a digital computer is generally in the form of a printout from an off-line printer. In many instances a better appreciation of the program results can be obtained if the data output is plotted. Where a large volume of data is involved it is often quicker and more convenient to receive a plot from the data processing centre than for the engineer to draw the graph from the data. However, the most efficient use of the plotter lies in "production-line plotting" where a long series of very similar plots must be produced. This type of job is wasteful of a skilled draftsman's time and can be performed very adequately by machine.

Most graph plotters are connected off-line with some form of computer; that is, they are operating on the output from a computer but because of the speed differential between the computer producing output and the plotter using the output, the link is not direct. The form of input to the plotter varies with the plotter model, usually this is 7-track magnetic tape but some plotters will accept punched cards or punched tape.

Two basic types of plotter are available. The first type to be developed, such as the EAI330D, known as a flat-bed plotter is merely an automated draftsman's table. A rectangular sheet of paper is held flat on a rigid table, usually by a vacuum device. The common sizes of paper are 31 x 34 inches and 48 x 72 inches. This type of plotter is being rapidly superseded by the drum type plotter such as the Calcomp 563 which uses a 120-foot long roll of paper in place of a sheet. The plotting width varies with the model but is commonly either 11 inches or 29½ inches.

Both types of plotter use the same drawing equipment, either a standard Rapidograph drafting pen using liquid Indian ink or a ball point pen and mounted in a vertical holder above the paper. This holder is able to move laterally across the paper, held onto two steel bars and controlled by a loop of thin wire.

On the flat-bed models there is a mechanism enabling the pen holder to move transversely along the paper, while on the drum type the paper winds off one roller, under the pen and onto a second roller. The standard incremental movement of both pen and paper is 1/100th of an inch and the rate of movement is 12,000 increments per minute, that is 2 inches per second.

The pen may be lowered onto or raised from the plotting paper at a rate of up to 600 movements per minute. The pen can move a full step (1/100th inch) or a half step in either direction on either or both axes. This implies that there are sixteen possible single movements of the pen.

The usual sequence of operations from the original recognition of the need for some form of graph output to the time when the completed plots are returned to the user would be similar to this:

(a) The programmer writes his main program to compute whatever results he wishes. On the North American continent the usual scientific programming language is FORTRAN standing for "formula translating", although other languages are available such as ALGOL, AUTOCODE, GPSS3, PL1, SIMSCRIPT and the commercial language COBOL. This main program may then utilise directly the standard plotting subroutines provided by the computing centre or the plotter manufacturer. The first plotting programs written in the Engineering Division operated in this fashion, the programs were individually written to solve their respective problems. As more experience was gained on the use of the plotter it became evident that this was an inefficient method of programming and so a series of main subroutines were written which would control the actual plotting subroutines. By using main subroutines only two CALL statements need be added to any main program to convert the program to plotter output. The necessary source or object deck subroutines are then placed between the main program and the data, the correct control cards are added and the job is sent in to the computer centre. Some centres have all the required plotting subroutines on library tapes and it is not necessary to send the subroutines as card decks with the main program.

(b) The computing centre receives the deck of cards and, after completing the accompanying paper work, places the deck in a card reader connected to a compiler. The compiler converts the FORTRAN statements into machine language and loads the machine language statements onto 9-track magnetic tape which passes to the computer proper. Assuming that the compiler detected no fatal programming errors the computer then executes the job and transfers the generated plotting instructions onto a 7-track magnetic tape. Five tracks hold the plotter instructions while the fourth and seventh tracks contain information for clock synchronisation and parity checking respectively.

(c) The plotter tape is then transferred manually to the tape transport unit of the off-line plotting unit. The tape transport looks rather like a large home tape recorder set in a vertical position, the tape coming off the left hand reel through the tape readers and onto the right hand tape reel. On the tape transport unit the operator dials the number of graphs to be plotted. The plotter can be set to draw up to 999 successive plots or the operator can order the plotter to locate and plot individual graphs.

The tape readers in the transport unit transmit the taped instructions to the actual plotter, which is about the shape and size of a large typewriter table. The operator must fit the required type, size (mm) and colour of pen into the vertical holder, feed the roll of paper forward, pass the pen to provide sufficient margin in case the plot moves backwards from the origin, and set the pen part way across the paper. On some types of plotter the programmer has no control over the positioning of the origin of his plot on the paper, this is left up to the operator's good judgement. On other plotters, instructions can be built into the program which will position the plot origin at any required distance from the edge of the paper.

After these preliminary settings have been completed, the operator presses the START button and the tape readers start a search for the first block address on the magnetic tape. Two block addresses are placed on the tape by the plotter subroutines at the start of every individual plot. When the block address has been found in the rapid forward search, the block address is read again, as a check, slowly in reverse direction. If the match is confirmed the plot instructions are carried out and the required drawing produced.

(d) The finished plot is cut from the paper roll, put with the programmer's card deck and returned to him. In our case this whole sequence of operations usually takes between 24 and 48 hours, involving on average a time of 3 minutes on an IBM 360/65 digital computer and about 10 minutes per plot on a Calcomp 663 plotter. For smaller computers this time would be greater and for larger numbers of plots the computer time would also increase, although not linearly.

The most common plotting system in the Calcomp, although other systems are available such as the Benson-Lehner and the EAI. In Ottawa, three graph plotters were available to the Inland Waters Branch:

1) Calcomp 563 at EMR Departmental Computing Centre

2) Calcomp 663 at CDPSB

3) EAI 3500 at NRC

The first two plotter programs written by the division were designed for use on the Calcomp 563 at EMR Computing Centre in conjunction with their CDC 3100 computer. Later, because of the small storage capacity of the 3100, the programs were written to suit the FORTRAN level of the IBM 360/65 at CDPSB with their Calcomp 663 plotter. The Calcomp 663 is reportedly a faster plotter than the 563. Because of the somewhat different programming technique used between the one-job programs used on the CDC 3100-Calcomp 563 combination and the multi-use subroutines used on the IBM 360/65 Calcomp 663, the programs are described in separate sections of this report.

Job Set-up IBM 360

Column 1 — Column 16 — Column 72

```
//J               EMR40. (Job card prepared by CDPSB)
//                PROGRAMMER'S NAME
//                EXEC FORTGCLG, PARM. FORT = BCD
//FORT.SYSIN *

Source Deck

/ *
//LKED.SYSIN DD UNIT = 9TRACK, DSNAME = PLTRTNS, VOLUME = SER = BU1537,       X
//                DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 80),               X
//                DISP = OLD
//             DD *

Oject Deck

/ *
//GO.PLOTTAPE DD UNIT = 7TRACK, DISP = (NEW, KEEP)                            X
//                VOLUME = PRIVATE, DSNAME = PLTRTAPE
//GO.SYSIN  DD *

Input Data for Main.

Plot Control Cards.

/ *
```

CDPSB Job Submission Form

JOB IN	195601	JOB OUT	JOB IN	195601	JOB OUT

JOB RETURN LABEL

G.W. Kite
F 224
8 Temporary Building

SPOOL RETURN LABEL

DECOLLATE ☐ BURST ☐

G.W. Kite
F. 224
8 Temporary Building

CENTRAL DATA PROCESSING
SERVICE BUREAU

CENTRAL DATA PROCESSING
SERVICE BUREAU

DATE & TIME IN | JOB SUBMISSION NUMBER J 195601 | ACCOUNT NUMBER E M R 4 0 . P L O T | DATE & TIME OUT

NAME OF CONTACT (PLEASE PRINT) G. LATHAM | PHONE NO. 994-9444 | ADDITIONAL INSTRUCTION SHEET INCLUDED [x]

SPECIAL INSTRUCTIONS	SIMPLE DSNAME OR VOLUME SERIAL	RING IN	NL	K/R
Input	BU1537			
~~To be plotted~~	PLTRTAPE			K
	7track			
	scratch			
	labelled			

EST. MAX. CORE (K BYTES)	1 0 0
EST. JOB TIME (MINUTES)	0 0 5
TAPE DRIVES REQUIRED	0 1 1
SCRATCH DISK TRACKS	0 0 0 0
PRIVATE DISK DRIVES REQ'D.	0 0
SERVICE REQUIRED (DAYS)	0 0
RENTED DISK SPACE REQUIRED	0
EST. CARD OUTPUT	0 0 0 0

DATE & TIME IN | SPOOL SUBMISSION NUMBER S 195601 | ACCOUNT NUMBER E M R 4 0 . P L O T | DATE & TIME OUT

NAME OF CONTACT (PLEASE PRINT) G. LATHAM | PHONE NO. 994-9444 | ADDITIONAL INSTRUCTION SHEET INCLUDED [x]

FROM	TO	RECORD LENGTH	BF IN	BF OUT	COUNT (THOUSAND)	REC.	NL	ASA/SS	PLY	K/R	DSNAME	VOLUME SERIAL	JOB NUMBER CREATED UNDER	COMP.
TA														
DK	From	TA to	PL							K	PLTRTAPE			
CR														
CP														
PR														
PL														

CENTRAL DATA PROCESSING SERVICE BUREAU

Plotting Instruction Sheet

CENTRAL DATA PROCESSING SERVICE BUREAU

PLOTTER INSTRUCTIONS

ACCOUNT NUMBER: E M R 4 0 . P L O T		JOB SERIAL NUMBER 5 2 8 3 2	
PROGRAMMER'S NAME: G.W. Kite		TELEPHONE NUMBER: 4-9444	DATE 22nd January 1968
ADDRESS: F-224, 8 Temp. Bldg.			
ESTIMATED TIME TO PLOT 10 MINUTES	INPUT TAPE	DS NAME PLTRTAPE NO. OF PLOTS 3	
OUTPUT	PAPER STANDARD 11" [ ] 30" [X]	PEN BALL POINT [X] LIQUIDINK [ ]	INK GREEN [ ] RED [ ] BLACK [X] BLUE [ ]

Special Instructions:

Operator's Remarks

PLOTTING TIME: ____________ Mins ____________ OPERATOR: ____________ SIGNATURE

BUR-50 (4-68)

Description of Plotter Subroutines

Four subroutines were written to control the use of the standard Calcomp subroutines. All are written in FORTRAN IV G language and are suitable for the IBM 360-65.

The two main subroutines are XYREAD and XYPLOT.

XYREAD

Subroutine XYREAD is the first of the two main subroutines called by the main program. It reads in, from data cards, all the information required to carry out the detail plotting such as titles, axes, grids, frames, identification, plot series numbers, etc. The information is read in in the format given in the table entitled "List of Graph Plot Variables".

The first plot information card contains data defining the core storage area required on the plotter. The next seven cards hold the ordinate and abscissa of the lower left hand characters of the plot titles and also the size of the characters to be drawn and the angle relative to horizontal. Then, on seven further cards, the plot titles are read in in alphameric form. Card 16 holds information required to scale the data to fit the plot size. Calcomp provides a standard scale subroutine which will do this scaling, but the subroutine does not always provide minimum and interval values which are convenient to use. Subroutine XYREAD provides the programmer with an option, he can either use the standard SCALE subroutine or he can himself provide the minimum and interval values corresponding to the variables. Cards 17 to 20 provide the data necessary to locate the origin of each axis, the angles at which the axes are to be drawn, the angles at which the interval values of each variable are to be plotted and the titles to be drawn alongside each axis. From cards 21 to 23 information describing each plot is read in, the numbers of points to be plotted, the type of line to be drawn and the style of symbol to be used. Calcomp provides 128 characters which can be used to distinguish between different lines on the same plot.

Data card 24 contains the most important information. On this card are eight parameters which completely control the action of the second subroutine, XYPLOT. Control is maintained by this card over the number of lines of title to be drawn, whether straight line or smooth curve plots are required, the size of frame to be drawn around the plot, whether a grid is required and the number of lines to be drawn on each plot. Three further cards control the grid size and the character size of other titles. An explanation of each variable in the subroutine is given on comment cards in the computer listing of the subroutine.

After subroutine XYREAD has been read in control is returned to the main program which can then create the arrays to be plotted and pass control to subroutine XYPLOT.

XYPLOT

Subroutine XYPLOT carries out the actual plotting, calling minor subroutines as required. This subroutine fixes the plot origin at a given distance from the edge of the paper, writes the plot titles, draws the axes, carries out the point plotting, draws the frame and adds the grid. With the present subroutine, up to seven lines of title can be written; usually four lines of main title, a plot sequence number and two lines of plot identification. Up to three plots can be drawn using the same pair of axes, and two separate frames and grids can be used. Control is again returned to the main program which adds an end of file mark to the tape and rewinds the reel. Thus, to control the plotting done by this subroutine, 27 control cards containing 98 parameters are required. Many of these parameters are relatively constant however, and the programmer need not change them from one job to another. Each variable used in the subroutine is described on comment cards in the computer listing of the subroutine.

XYAXIS

Calcomp provides a standard library program for the 663 called AXIS. AXIS will draw a solid line at any specified angle to represent a plot axis and will then mark this line at one-inch intervals, write the value of the variable which occurs at each interval and finally write an axis title. For the type of work being done by the Inland Waters Branch there were two shortcomings of AXIS:

(1) no control was offered on the form of the variable write-out, e.g., while it may be correct, it does not look very neat to label an axis measured in days as "1.00", "2.00" etc.

(2) no control was offered on the angle at which this output would be written; it was always written parallel to the axis. This is ideal for a horizontal axis, but for a vertical axis it necessitates some head twisting to read the printing.

Although these shortcomings may appear trivial they make it worthwhile to write a completely new subroutine, XYAXIS. This subroutine offers full control over the form of of the written output: any number of decimal places or an integer, and the angle of the writing; any angle, usually horizontal.

The meaning of each argument in the subroutine is described on comment cards in the XYAXIS listing.

XYGRID

XYGRID is a very simple subroutine which draws a linear grid to the specifications read in by XYREAD on plot control cards 26 and 27.

The use of each argument in the subroutine is described on comment cards in the computer listing of XYGRID.

```
C
      SUBROUTINE XYREAD
C     SUBROUTINE READING PLOT FORMAT INFORMATION
C
C
      COMMON ABS1(100),ORD1(100),ABS2(100),ORD2(100),TITLE2(100,5),      X
     1ABS3(100),ORD3(100)                                                  X
      COMMON NBNF,X1,Y1,H1,THETA1,X2,Y2,H2,THETA2,X3,Y3,H3,THETA3,X4,Y4,X
     1H4,THETA4,X5,Y5,H5,THETA5,X6,Y6,H6,THETA6,X7,Y7,H7,THETA7,NS1,      X
     2BCD1(16),NS2,BCD2(16),NS3,BCD3(16),NS4,BCD4(16),NN5,FPN5(16),NI1,  X
     3ID1(16),NI2,ID2(16),SW,SH,DIV,X0,Y0,THETA(4),XA,YA,NCO,             X
     4VORD(16),NCA,VABS(16),N1,J1,L1,K1,N2,J2,L2,K2,N3,J3,L3,K3,          X
     5NAME1,NAME2,NAME3,NAME4,NAME5,NAME6,NAME7,NAME8,NS6,THETA8,         X
     6XG1,XG2,YG1,YG2,DX1,DX2,DY1,DY2,MX1,MX2,MY1,MY2,IP1,IP2             X
      COMMON XMIN,YMIN,DX,DY                                                X
      DIMENSION BUFFER(4096)
      INTEGER BCD1,BCD2,BCD3,BCD4,FPN5,ID1,ID2,VORD,VABS,TITLE2
      INPUT=1
   10 READ(INPUT,1)NBNF
C*****************************************************************
C     NBNF       LENGTH OF BUFFER IN WORDS                            *
C*****************************************************************
   20 READ(INPUT,2)X1,Y1,H1,THETA1
   30 READ(INPUT,2)X2,Y2,H2,THETA2
   40 READ(INPUT,2)X3,Y3,H3,THETA3
   50 READ(INPUT,2)X4,Y4,H4,THETA4
   60 READ(INPUT,2)X5,Y5,H5,THETA5
   70 READ(INPUT,2)X6,Y6,H6,THETA6
   80 READ(INPUT,2)X7,Y7,H7,THETA7
C*****************************************************************
C    X,Y         COORDINATES OF LOWER LEFT CORNER OF 1ST CHARACTER     *
C    H           HEIGHT IN INCHES OF CHARACTERS TO BE DRAWN            *
C    THETA       ANGLE FROM HORIZONTAL IN DEGREES AT WHICH CHARACTERS  *
C                ARE TO BE DRAWN                                       *
C*****************************************************************
   90 READ(INPUT,3)NS1,(BCD1(I),I=1,16)
  100 READ(INPUT,3)NS2,(BCD2(I),I=1,16)
  110 READ(INPUT,3)NS3,(BCD3(I),I=1,16)
  120 READ(INPUT,3)NS4,(BCD4(I),I=1,16)
C*****************************************************************
C    NS          NUMBER OF CHARACTERS TO BE DRAWN FROM ARRAY           *
C    BCD         ADDRESS OF ALPHA ARRAY                                *
C*****************************************************************
  130 READ(INPUT,3)NN5,(FPN5(I),I=1,16)
C*****************************************************************
C    NN          NUMBER OF DIGITS TO RIGHT OF DECIMAL POINT            *
C    FPN         ADDRESS OF FLOATING POINT NUMBER                      *
C*****************************************************************
  140 READ(INPUT,3)NI1,(ID1(I),I=1,16)
  150 READ(INPUT,3)NI2,(ID2(I),I=1,16)
C*****************************************************************
C    NI          NUMBER OF CHARACTERS TO BE DRAWN FROM ARRAY           *
C    ID          IDENTIFICATION ARRAY                                  *
C*****************************************************************
  160 READ(INPUT,4)SW,XMIN,DX,SH,YMIN,DY,DIV
C*****************************************************************
C    SW         MAXIMUM WIDTH OF PLOT IN INCHES                        *
C    XMIN       INITIAL VALUE OF ABSCISSA SCALE                        *
C    DX         DIFFERENCE IN ABSCISSA IN 1 INCH                       *
C    SH         MAXIMUM HEIGHT OF PLOT IN INCHES                       *
C    YMIN       INITIAL VALUE OF ORDINATE SCALE                        *
C    DY         DIFFERENCE IN ORDINATE IN 1 INCH                       *
C    DIV        DIVISIONS TO THE INCH ( NORMALLY 10.0 )                *
C*****************************************************************
  170 READ(INPUT,5)X0,Y0,THETA(1),THETA(2),IP1
C*****************************************************************
```

```
C       XO,YO       COORDINATES OF STARTING POINT OF ORDINATE AXIS            *
C       THETA(1)    ANGLE IN DEGREES OF ORDINATE AXIS FROM HORIZONTAL         *
C       THETA(2)    ANGLE IN DEGREES OF VARIABLE VALUES                       *
C       IP1         SPECIFIES FIXED OR FLOATING POINT PRINTED OUTPUT          *
C                   IF +VE OUTPUT IS FLOATING POINT                           *
C                   IF -1  OUTPUT IS FIXED POINT                              *
C**************************************************************************
  180 READ(INPUT,5)XA,YA,THETA(3),THETA(4),IP2
C**************************************************************************
C       XA,YA       COORDINATES OF STARTING POINT OF ABSCISSA AXIS            *
C       THETA(3)    ANGLE IN DEGREES OF ABSCISSA AXIS FROM HORIZONTAL         *
C       THETA(4)    ANGLE IN DEGREES OF VARIABLE VALUES                       *
C**************************************************************************
  190 READ(INPUT,3)NCO,(VORD(I),I=1,16)
C**************************************************************************
C       NCO         NUMBER OF CHARACTERS IN ORDINATE AXIS TITLE               *
C       VORD        NAME OF ARRAY FOR ORDINATE AXIS TITLE                     *
C**************************************************************************
  200 READ(INPUT,3)NCA,(VABS(I),I=1,16)
C**************************************************************************
C       NCA         NUMBER OF CHARACTERS IN ABSCISSA AXIS TITLE               *
C       VABS        NAME OF ARRAY FOR ABSCISSA AXIS TITLE                     *
C**************************************************************************
  210 READ(INPUT,6)N1,J1,K1,L1
  220 READ(INPUT,6)N2,J2,K2,L2
  230 READ(INPUT,6)N3,J3,K3,L3
C**************************************************************************
C       N           NUMBER OF POINTS                                          *
C       K           REPEAT CYCLE                                              *
C       J           USED TO DETERMINE PLOT APPEARANCE                         *
C       L           INTEGER SPECIFYING SYMBOL TO BE PLOTTED                   *
C**************************************************************************
  240 READ(INPUT,7)NAME1,NAME2,NAME3,NAME4,NAME5,NAME6,NAME7,NAME8
C**************************************************************************
C       NAME1       PLOT TYPE     IF 1 THEN 4 TITLE LINES ARE DRAWN           *
C                                 IF 0 THEN 2 TITLE LINES ARE DRAWN           *
C       NAME2       PLOT TYPE     IF 1 THEN 1 NUMBER TITLE IS DRAWN           *
C                                 IF 0 THEN NO NUMBER TITLE IS DRAWN          *
C       NAME3       PLOT TYPE     IF 1 THEN POINT TITLES ARE DRAWN            *
C                                 IF 0 THEN NO POINT TITLES ARE DRAWN         *
C       NAME4       PLOT TYPE     IF 2 THEN 2 SMOOTH LINE PLOTS ARE DRAWN     *
C                                 IF 1 THEN 1 SMOOTH LINE PLOT IS DRAWN       *
C                                 IF 0 THEN NO SMOOTH LINE PLOT IS DRAWN      *
C       NAME5       PLOT TYPE     IF 1 THEN 3RD PLOT IS AVAILABLE             *
C                                 IF 0 THEN NO 3RD PLOT IS AVAILABLE          *
C       NAME6       PLOT TYPE     IF 3 THEN 11.0 * 35.0 INCH FRAME IS DRAWN   *
C                                 IF 2 THEN 11.0 * 16.0 INCH FRAME IS DRAWN   *
C                                 IF 1 THEN 8.5 * 11.00 INCH FRAME IS DRAWN   *
C                                 IF 0 THEN NO FRAME IS DRAWN                 *
C       NAME7       PLOT TYPE     IF 1 THEN A LINEAR GRID IS DRAWN            *
C       NAME8       PLOT TYPE     IF 1 THEN AXIS SCALING IS AUTOMATIC         *
C                                 IF 0 THEN THE MINIMUM AND INTERVAL VALUES   *
C                                 FOR EACH ARRAY MUST BE READ IN FROM CARD 16
C**************************************************************************
  250 READ(INPUT,8)NS6,THETA8
  260 READ(INPUT,9)XG1,YG1,DX1,DY1,MX1,MY1
  270 READ(INPUT,9)XG2,YG2,DX2,DY2,MX2,MY2
C**************************************************************************
C       XG,YG       GRID STARTING POINT COORDINATES ( INCHES )                *
C       DX,DY       GRID INTERVALS ( INCHES )                                 *
C       MX,MY       NO. OF DIVISIONS IN X AND Y DIRECTIONS                    *
C**************************************************************************
  280 CALL PLOTS(BUFFER,NBNF)
C**************************************************************************
C       BUFFER      LOW ORDER WORK AREA CORE LOCATION                         *
C**************************************************************************
```

```
  1 FORMAT(5X,I10)
  2 FORMAT(5X,4(4X,F6.3))
  3 FORMAT(5X,I5,16A4)
  4 FORMAT(5X,7F10.3)
  5 FORMAT(5X,4F5.2,I5)
  6 FORMAT(5X,4I5)
  7 FORMAT(5X,8I5)
  8 FORMAT(5X,I5,F5.1)
  9 FORMAT(5X,4F5.1,2I5)
290 RETURN
300 END


      SUBROUTINE XYPLOT
C
C
      COMMON ABS1(500),ABS2(500),ABS3(500),ORD1(500),ORD2(500),ORD3(500)X
      COMMON TITLE2(500,5)                                              X
      COMMON NBNF,X1,Y1,H1,THETA1,X2,Y2,H2,THETA2,X3,Y3,H3,THETA3,X4,Y4,X
     1H4,THETA4,X5,Y5,H5,THETA5,X6,Y6,H6,THETA6,X7,Y7,H7,THETA7,NS1,    X
     2BCD1(16),NS2,BCD2(16),NS3,BCD3(16),NS4,BCD4(16),NN5,FPN5(16),NI1, X
     3ID1(16),NI2,ID2(16),SW,SH,DIV,XO,YO,THETA(4),XA,YA,NCO,           X
     4VORD(16),NCA,VABS(16),N1,J1,L1,K1,N2,J2,L2,K2,N3,J3,L3,K3,        X
     5NAME1,NAME2,NAME3,NAME4,NAME5,NAME6,NAME7,NAME8,NS6,THETA8,       X
     6XG1,XG2,YG1,YG2,DX1,DX2,DY1,DY2,MX1,MX2,MY1,MY2,IP1,IP2           X
      COMMON XMIN,YMIN,DX,DY                                            X
      INTEGER BCD1,BCD2,BCD3,BCD4,FPN5,ID1,ID2,VORD,VABS,TITLE2,TITLE
      CALL PLOT(0.0,-30.0,-3)
      CALL PLOT(0.0,3.0,-3)
      CALL SYMBOL(X1,Y1,H1,BCD1,THETA1,NS1)
      CALL SYMBOL(X2,Y2,H2,BCD2,THETA2,NS2)
      IF(NAME1.NE.1)GO TO 20
   10 CALL SYMBOL(X3,Y3,H3,BCD3,THETA3,NS3)
      CALL SYMBOL(X4,Y4,H4,BCD4,THETA4,NS4)
   20 IF(NAME2.NE.1)GO TO 40
   30 CALL NUMBER(X5,Y5,H5,FPN5,THETA5,NN5)
   40 CALL SYMBOL(X6,Y6,H6,ID1,THETA6,NI1)
      CALL SYMBOL(X7,Y7,H7,ID2,THETA7,NI2)
      IF(NAME8.NE.1)GO TO 45
   41 CALL SCALE(ORD1,SH,N1,K1,DIV)
      CALL SCALE(ABS1,SW,N1,K1,DIV)
      GO TO 46
   45 ORD1(N1*K1+1)=YMIN
      ORD1(N1*K1+K1+1)=DY
      ABS1(N1*K1+1)=XMIN
      ABS1(N1*K1+K1+1)=DX
   46 ORD2(N2*K2+1)=ORD1(N1*K1+1)
      ORD3(N3*K3+1)=ORD1(N1*K1+1)
      ORD2(N2*K2+K2+1)=ORD1(N1*K1+K1+1)
      ORD3(N3*K3+K3+1)=ORD1(N1*K1+K1+1)
      ABS2(N2*K2+1)=ABS1(N1*K1+1)
      ABS3(N3*K3+1)=ABS1(N1*K1+1)
      ABS2(N2*K2+K2+1)=ABS1(N1*K1+K1+1)
      ABS3(N3*K3+K3+1)=ABS1(N1*K1+K1+1)
      CALL XYAXIS(XO,YO,VORD,NCO,SH,THETA(1),THETA(2),ORD1(N1*K1+1),
     1ORD1(N1*K1+K1+1),IP1)
      CALL XYAXIS(XA,YA,VABS,NCA,SW,THETA(3),THETA(4),ABS1(N1*K1+1),
     1ABS1(N1*K1+K1+1),IP2)
      IF(NAME4.EQ.2)GO TO 60
   50 CALL LINE(ABS1,ORD1,N1,K1,J1,L1)
      CALL PLOT(0.0,0.0,3)
      GO TO 70
   60 N1=-N1
      CALL XYCURV(ABS1,ORD1,N1,K1,J1,L1)
```

```
      CALL PLOT(0.0,0.0,3)
   70 IF(NAME3.NE.1)GO TO 120
   80 DO 110 KJ=1,N1
      J=KJ
      ZKJ=KJ
      ZKJ=ZKJ/2.0-KJ/2
      IF(ZKJ.GT.0.0)GO TO 82
   81 AKJ=((ABS1(J)-ABS1(N1*K1+1))/ABS1(N1*K1+K1+1))-0.1
      XKJ=AKJ-NS6*0.37
      CKJ=XKJ+NS6*0.34
      GO TO 83
   82 AKJ=((ABS1(J)-ABS1(N1*K1+1))/ABS1(N1*K1+K1+1))+0.10
      XKJ=AKJ+0.5
      CKJ=XKJ-0.05
   83 ADD=0.0
      IF(KJ.EQ.N1)GO TO 84
      IF(ORD1(J+1)-ORD1(J).LT.0.1*ORD1(N1*K1+K1+1))ADD=-0.05
   84 IF(KJ.LT.3)GO TO 85
      IF(ORD1(J)-ORD1(J-2).LT.0.1*ORD1(N1*K1+K1+1))ADD=+0.05
   85 BKJ=((ORD1(J)-ORD1(N1*K1+1))/ORD1(N1*K1+K1+1))
      YKJ=BKJ+ADD
      DKJ=YKJ+0.0375
      CALL PLOT(AKJ,BKJ,3)
      CALL PLOT(CKJ,DKJ,2)
      DO 110 KI=1,NS6
      TITLE=TITLE2(KJ,KI)
      IF(KI.GT.1)GO TO 100
   90 CALL SYMBOL(XKJ,YKJ,0.075,TITLE,THETA8,4)
      GO TO 110
  100 CALL SYMBOL(-0.,-0.,0.075,TITLE,THETA8,4)
  110 CONTINUE
  120 IF(NAME4.EQ.1)GO TO 140
  130 IF(NAME4.NE.2)GO TO 150
  140 N2=-N2
      CALL XYCURV(ABS2,ORD2,N2,K2,J2,L2)
      CALL PLOT(0.0,0.0,3)
  150 IF(NAME5.NE.1)GO TO 170
  160 CALL LINE(ABS3,ORD3,N3,K3,J3,L3)
      CALL PLOT(0.0,0.0,3)
  170 IF(NAME6.EQ.0)GO TO 220
  180 IF(NAME6.EQ.1)GO TO 210
  190 IF (NAME6.EQ.2) GO TO 200
  199 IF (NAME6.NE.3) GO TO 220
  205 CALL PLOT (-1.25,-1.25,3)
      CALL PLOT (-1.25,+9.25,2)
      CALL PLOT (+33.0,+9.25,2)
      CALL PLOT (+33.0,-1.25,2)
      CALL PLOT (-1.25,-1.25,2)
      GO TO 220
  200 CALL PLOT(-0.90,-0.90,3)
      CALL PLOT(-0.90,10.10,2)
      CALL PLOT(14.90,10.10,2)
      CALL PLOT(14.90,-0.90,2)
      CALL PLOT(-0.90,-0.90,2)
      CALL PLOT(-0.70,-0.70,3)
      CALL PLOT(-0.70,9.90,2)
      CALL PLOT(14.70,9.90,2)
      CALL PLOT(14.70,-0.70,2)
      CALL PLOT(-0.70,-0.70,2)
      GO TO 220
  210 CALL PLOT(-0.85,-0.80,3)
      CALL PLOT(-0.85,+7.70,2)
      CALL PLOT(10.15,+7.70,2)
      CALL PLOT(10.15,-0.80,2)
      CALL PLOT(-0.85,-0.80,2)
      CALL PLOT(-0.80,-0.75,3)
```

```
      CALL PLOT(-0.80,+6.90,2)
      CALL PLOT(10.10,+6.90,2)
      CALL PLOT(10.10,-0.75,2)
      CALL PLOT(-0.80,-0.75,2)
  220 CONTINUE
      IF(NAME7.NE.1)GO TO 240
  230 CALL XYGRID(XG1,YG1,DX1,DY1,MX1,MY1)
      CALL XYGRID(XG2.YG2,DX2,DY2,MX2,MY2)
  240 CALL PLOT(0.0,0.0,999)
      RETURN
      END
```

```
      SUBROUTINE XYGRID(X,Y,DX,DY,MX,MY)
C     SUBROUTINE FOR PLOTTING LINEAR GRID
C
C
C************************************************************************
C     X,Y         GRID STARTING POINT COORDINATES ( INCHES )              *
C     DX,DY       GRID SPACINGS ( INCHES )                                *
C     MX,MY       NO. OF DIVISIONS IN X AND Y DIRECTIONS                  *
C                 NO. OF LINES DRAWN IN EACH DIRECTION IS MX+1,MY+1       *
C************************************************************************
      XS1=X
      YS1=Y
      XS2=X+MX*DX
      YS2=Y+MY*DY
      MX=MX+1
      MY=MY+1
      CALL PLOT(X,Y,3)
      DO 10 I=1,MX
      CALL PLOT(XS1,Y,3)
      CALL PLOT(XS1,YS2,2)
   10 XS1=XS1+DX
      DO 20 I=1,MY
      CALL PLOT(X,YS1,3)
      CALL PLOT(XS2,YS1,2)
   20 YS1=YS1+DY
      RETURN
      END
```

```
      SUBROUTINE XYAXIS (X,Y,ARRAY,N,XLNG,THETA1,THETA2,XMIN,DX,IP)
      DIMENSION ARRAY(20)
      CALL PLOT (X,Y,3)
C***********************************************************************
C     X,Y     COORDINATES OF AXIS ORIGIN (INCHES)                      *
C     ARRAY   AXIS TITLE ARRAY.                                        *
C     N       NUMBER OF CHARACTERS IN AXIS TITLE.                      *
C             IF N IS &VE THEN TITLE IS DRAWN ON THE ANTICLOCKWISE SIDE*
C             OF THE AXIS.                                             *
C             IF N IS -VE THEN TITLE IS DRAWN ON THE CLOCKWISE SIDE OF *
C             THE AXIS.                                                *
C     XLNG    LENGTH OF THE AXIS (INCHES).                             *
C     THETA1  ANGLE OF THE AXIS ANTICLOCKWISE FROM HORIZONTAL (DEGREES)*
C     THETA2  ANGLE OF VARIABLE VALUE PLOT.                            *
C     XMIN    VALUE OF THE VARIABLE AT THE AXIS ORIGIN.                *
C     DX      INCREMENTAL VALUE OF THE VARIABLE FOR 1 INCH ALONG AXIS. *
C     IP      SPECIFIES THE VARIABLE PRINT OUT STYLE.                  *
C             IF IP IS &VE THEN THIS GIVES THE NUMBER OF DECIMAL       *
C             PLACES TO BE PRINTED                                     *
C             IF IP IS 0 THEN ONLY THE DECIMAL POINT WILL BE PRINTED   *
C             IF IP IS -1 THEN THE VARIABLE WILL BE PRINTED AS INTEGER *
C***********************************************************************
      ANGLE1=THETA1*0.0174532778
      ANGLE2=THETA2*0.0174532778
      SIN1=SIN(ANGLE1)
      SIN2=SIN(ANGLE2)
      COS1=COS(ANGLE1)
      COS2=COS(ANGLE2)
      IF (N.GT.0) GO TO 20
   10 IND=1
      THETA3=THETA1
      GO TO 30
   20 IND=-1
      THETA3=THETA1+180.0
   30 CONTINUE
      X1=X+XLNG*COS1
      Y1=Y+XLNG*SIN1
      CALL PLOT (X1,Y1,2)
      X2=X1+(0.1*SIN1*IND)
      Y2=Y1-(0.1*COS1*IND)
      LNG=XLNG+1.1
      CALL SYMBOL (X2,Y2,0.1,06,THETA3,-1)
      ING=LNG-1
      DO 40 J=1,ING
      X2=X2-COS1
      Y2=Y2-SIN1
   40 CALL SYMBOL (X2,Y2,0.1,06,THETA3,-1)
      IF (IP) 50,60,60
   50 XP=0.0
      GO TO 70
   60 XP=IP+1
   70 XOUT=ABS(XMIN+DX)
      IF (XOUT) 130,80,80
   80 XVAR=10.0
      DO 90 J=1,10
      IF (XOUT.LT.XVAR) GO TO 100
   90 XVAR=XVAR*10.0
  100 XDIV=ALOG10(XVAR)
      YOUT=ABS(XMIN+(DX*XLNG))
```

```
      YVAR-10.0
      DO 110 J=1,10
      IF (YOUT.LE.YVAR) GO TO 120
  110 YVAR=YVAR*10.0
  120 YDIV=ALOG10(YVAR)
      XN1=(XDIV+YDIV)/2.0+XP
      IF (XOUT.GE.0.0) GO TO 140
  130 XN1=XN1+1.0
  140 CONTINUE
      XH=XLNG*0.01
      XH1=XLNG*0.015
      IF(XH.LT.0.085) XH=0.085
  150 IF(XH1.LT.0.085) XH1=0.085
  151 IF(XH.GT.0.25) XH=0.25
  152 IF(XH1.GT.0.25) XH1=0.25
  155 Y3=Y-((XH+0.2)*COS1*COS2*IND)-((XH/2.0)*SIN1*COS2)-((XN1+3.0)*XH*
     1COS1*SIN2)-((XN1/2.0)*XH*SIN1*SIN2)
      X3=X-((XN1/2.0)*XH*COS1*COS2)+((XN1+3.0)*XH*SIN1*COS2*IND)+((XH/2.
     10)*COS1*SIN2)+((XH*2.0)*SIN1*SIN2*IND)
      X100=XMIN
      SHIFT=XN1*XH/2.0
      DO 160 J=1,LNG
      IF(THETA1.NE.0.0)GO TO 158
  156 IF(J.EQ.1)X3=X3+SHIFT
  157 IF(J.EQ.LNG)X3=X3-SHIFT
  158 CALL NUMBER (X3,Y3,XH,X100,THETA2,IP)
      IF(THETA1.NE.0.0)GO TO 159
  153 IF(J.EQ.1)X3=X3-SHIFT
  159 X3=X3+COS1
      Y3=Y3+SIN1
  160 X100=X100+DX
      NN=IABS(N)
      XN=NN
      X5=XH1
      X6=(X5*XN)/2.0
      X4=((X+X1)/2.0)-(X6*COS1)+((((XN1*COS2)+SIN2)*XH+0.25)*SIN1*IND)
      Y4=((Y+Y1)/2.0)-(X6*SIN1)-((((XN1*SIN2)+COS2)*XH+XH1+0.30)*COS1*IN
     1D)
      CALL SYMBOL (X4,Y4,X5,ARRAY,THETA1,NN)
      CALL PLOT (X,Y,3)
      RETURN
      END
```

Example 1a: Smooth Curve Plotting - Reservoir Flood Routing.

The reservoir flood routing program uses a modified Goodrich technique to compute the reservoir outflow from the inflow, given a set of reservoir characteristics.

Six characteristics are initially called by the program; three describing the stage-discharge relationship of the reservoir's outflow mechanism and three describing the stage-storage relationship.

$$Q = C1\ (H - C2)^{C3}$$

$$S = C4\ (H - C5)^{C6}$$

where Q is the reservoir outflow

H is the reservoir stage

S is the reservoir storage

The program next requires that the period between inflow observations, in days, be read in, together with a figure signifying the accuracy, in cfs, to which the computer is required to calculate the outflow hydrograph co-ordinates.

Finally, the inflow hydrograph is read in in array form and the computer calculates for each inflow the corresponding outflow.

The results are tabulated and printed out and the program calls the necessary subroutines to produce a graph plot of the inflow and outflow hydrographs.

LIST OF GRAPH PLOT VARIABLES

PLOT TITLE: RESERVOIR FLOOD ROUTING PLOT NO: 1a

Card Number	Card Function	Card Format	Variable Name	Variable Value
1	Core location	5X,I10	NBNF	4096
2	First Title Position Data	5X,4(4X,F6.3)	X1 Y1 H1 THETA1	6.0 6.7 0.175
3	Second Title Position Data	5X,4(4X,F6.3)	X2 Y2 H2 THETA2	6.0 6.4 0.175 0.0
4	Third Title Position Data	5X,4(4X,F6.3)	X3 Y3 H3 THETA3	6.0 6.1 0.175 0.0
5	Fourth Title Position Data	5X,4(4X,F6.3)	X4 Y4 H4 THETA4	
6	Fifth Title Position Data (Numeric)	5X,4(4X,F6.3)	X5 Y5 H5 THETA5	
7	Sixth Title Position Data (Identification)	5X,4(4X,F6.3)	X6 Y6 H6 THETA6	0.25 -0.25 0.1 0.0

Card Number	Card Function	Card Format	Variable Name	Variable Value
8	Seventh Title Position Data (Identification)	5X,4(4X,F6.3)	X7 Y7 H7 THETA7	0.25 -0.4 0.1 0.0
9	First Title Content Data	5X,I5,16A4	NS1 BCD1	23 Reservoir Flood Routing
10	Second Title Content Data	5X,I5,16A4	NS2 BCD2	28 Hypothetical Example Showing
11	Third Title Content Data	5X,I5,16A4	NS3 BCD3	30 Inflow and Outlfow Hydrographs
12	Fourth Title Content Data	5X,I5,16A4	NS4 BCD4	
13	Fifth Title Content Data (Numeric)	5X,I5,16A4	NN5 FPN5	
14	Sixth Title Content Data (Identification)	5X,I5,16A4	NI1 ID1	15 G.W. Kite EMR40
15	Seventh Title Content Data (Identification)	5X,I5,16A4	NI2 ID2	20 Inland Waters Branch
16	Scaling Data	5X,7F10.3	SW XMIN DX SH XMIN DY DIV	10.0 0.0 1.0 7.0 1000.0 1000.0 10.0
17	Ordinate Position Data	5X,4F5.2,I5	XO YO THETA(1) THETA(2) IP1	0.0 0.0 90.0 0.0 -1

Card Number	Card Function	Card Format	Variable Name	Variable Value
18	Abscissa Position Data	5X,4F5.2,I5	XA	0.0
			YA	0.0
			THETA(3)	0.0
			THETA(4)	0.0
			IP2	-1
19	Ordinate Content Data	5X,I5,16A4	NCO	15
			VORD	Discharge - cfs
20	Abscissa Content Data	5X,I5,16A4	NCA	-11
			VABS	Time - Days
21	First Plot Data	5X,4I5	N1	21
			J1	1
			K1	1
			L1	4
22	Second Plot Data	5X,4I5	N2	21
			J2	1
			K2	1
			L2	4
23	Third Plot Data	5X,4I5	N3	
			J3	
			K3	
			L3	
24	Plot Type Data	5X,6I5	NAME1	1
			NAME2	0
			NAME3	0
			NAME4	2
			NAME5	0
			NAME6	1
			NAME7	1
			NAME8	0
25	Point Title	5X,I5,F5.1	NS6	
			THETA8	

Card Number	Card Function	Card Format	Variable Name	Variable Value
26	Grid Data (1)	5X,4F5.1,2I5	XG1 YG1 DX1 DY1 MX1 MY1	0.0 0.0 1.0 1.0 5 7
27	Grid Data (2)	5X,4F5.1,2I5	XG2 YG2 DX2 DY2 MX2 MY2	5.0 0.0 1.0 1.0 5 6

```
C      RESERVOIR FLOOD ROUTING
C
C
       COMMON ABS1(500),ABS2(500),ABS3(500),ORD1(500),ORD2(500),ORD3(5
       COMMON TITLE2(500,5)
       COMMON NBNF,X1,Y1,H1,THETA1,X2,Y2,H2,THETA2,X3,Y3,H3,THETA3,X4,
      1H4,THETA4,X5,Y5,H5,THETA5,X6,Y6,H6,THETA6,X7,Y7,H7,THETA7,NS1,
      2BCD1(16),NS2,BCD2(16),NS3,BCD3(16),NS4,BCD4(16),NN5,FPN5(16),NI
      3ID1(16),NI2,ID2(16),SW,SH,DIV,XO,YO,THETA(4),XA,YA,NCO,
      4VORD(16),NCA,VABS(16),N1,J1,L1,K1,N2,J2,L2,K2,N3,J3,L3,K3,
      5NAME1,NAME2,NAME3,NAME4,NAME5,NAME6,NAME7,NAME8,NS6,THETA8,
      6XG1,XG2,YG1,YG2,DX1,DX2,DY1,DY2,MX1,MX2,MY1,MY2,IP1,IP2
       COMMON XMIN,YMIN,DX,DY
       DIMENSION QI(50),QO(50),TITLE(10)
       INTEGER EXPUT,TITLE
       INPUT=1
       EXPUT=3
       REWIND 01
       READ(INPUT,1)N,(TITLE(I),I=1,10)
C*********************************************************************
C      N           NUMBER OF POINTS ON THE INFLOW HYDROGRAPH
C      TITLE       LOCATION NAME OR IDENTIFICATION
C*********************************************************************
       READ(INPUT,2)C1,C2,C3
       READ(INPUT,2)C4,C5,C6
       READ(INPUT,12)T,FF
C*********************************************************************
C      C1,C2,C3    CONSTANTS IN STAGE-DISCHARGE EQUATION
C      C4,C5,C6    CONSTANTS IN ELEVATION-STORAGE EQUATION
C      T           PERIOD,IN DAYS,BETWEEN INFLOW OBSERVATIONS
C      FF          ACCURACY,IN CFS,REQUIRED IN STORAGE COMPUTATIONS
C*********************************************************************
       READ(INPUT,3)(QI(I),I=1,N)
C*********************************************************************
C      QI          INFLOW MEASUREMENTS,CFS
C*********************************************************************
       WRITE(EXPUT,4)
       WRITE(EXPUT,5)
       WRITE(EXPUT,9)
       WRITE(EXPUT,6)(TITLE(I),I=1,10)
       WRITE(EXPUT,11)
       WRITE(EXPUT,8)
       WRITE(EXPUT,10)
       QO(1)=QI(1)
C*********************************************************************
C      QO          COMPUTED OUTFLOW,CFS
C*********************************************************************
       STOR1=((2.0*C4/T)*(C2-C5+(QO(1)/C1)**(1.0/C3))**C6)+QO(1)
       DO  40 I=2,N
       J=I-1
       STOR2=STOR1-2.0*QO(J)
       STOR1=QI(J)+QI(I)+STOR2
       QO(I)=QO(J)
    20 STOR3=((2*C4/T)*(C2-C5+(QO(I)/C1)**(1.0/C3))**C6)+QO(I)
       IF(ABS(STOR1-STOR3).GT.FF)GO TO 50
    40 CONTINUE
       GO TO 80
    50 IF(STOR1-STOR3)60,40,70
    60 QO(I)=QO(I)-1.0
       GO TO 20
    70 QO(I)=QO(I)+1.0
       GO TO 20
    80 CONTINUE
```

```
      DO   90 K=1,N
      AK=K
      ABS1(K)=(AK*T)-T
      ORD1(K)=QI(K)
      ABS2(K)=ABS1(K)
      ORD2(K)=QO(K)
      WRITE(EXPUT,7)ABS1(K),ORD1(K),ORD2(K)
   90 CONTINUE
      CALL XYREAD
      CALL XYPLOT
      WRITE(EXPUT,4)
      REWIND 01
    1 FORMAT(5X,I5,10A4)
    2 FORMAT(5X,3F10.2)
    3 FORMAT(5X,7F10.1)
    4 FORMAT(1H1)
    5 FORMAT(//,33X,23HRESERVOIR FLOOD ROUTING)
    6 FORMAT(25X,10A4)
    7 FORMAT(19X,F5.1,1X,2(15X,F10.1))
    8 FORMAT(21X,3HDAY,20X,6HINFLOW,19X,7HOUTFLOW,/,21X,3HNO.,22X,3HCFS'
     1,22X,3HCFS)
    9 FORMAT(33X,23H-----------------------,/)
   10 FORMAT(21X,3H---,20X,6H------,19X,7H-------,/)
   11 FORMAT(25X,40H----------------------------------------,/)
   12 FORMAT(5X,2F10.2)
      STOP
      END
```

RESERVOIR FLOOD ROUTING

SIMPLE HYPOTHETICAL EXAMPLE

DAY NO.	INFLOW CFS	OUTFLOW CFS
0.0	1100.0	1100.0
0.5	2150.0	1205.0
1.0	4200.0	1624.0
1.5	6700.0	2528.0
2.0	7670.0	3762.0
2.5	7700.0	4896.0
3.0	7100.0	5659.0
3.5	5490.0	5857.0
4.0	4200.0	5544.0
4.5	3450.0	5021.0
5.0	2850.0	4466.0
5.5	2450.0	3945.0
6.0	2170.0	3491.0
6.5	1950.0	3106.0
7.0	1800.0	2785.0
7.5	1660.0	2517.0
8.0	1550.0	2292.0
8.5	1440.0	2100.0
9.0	1330.0	1932.0
9.5	1220.0	1781.0
10.0	1200.0	1652.0

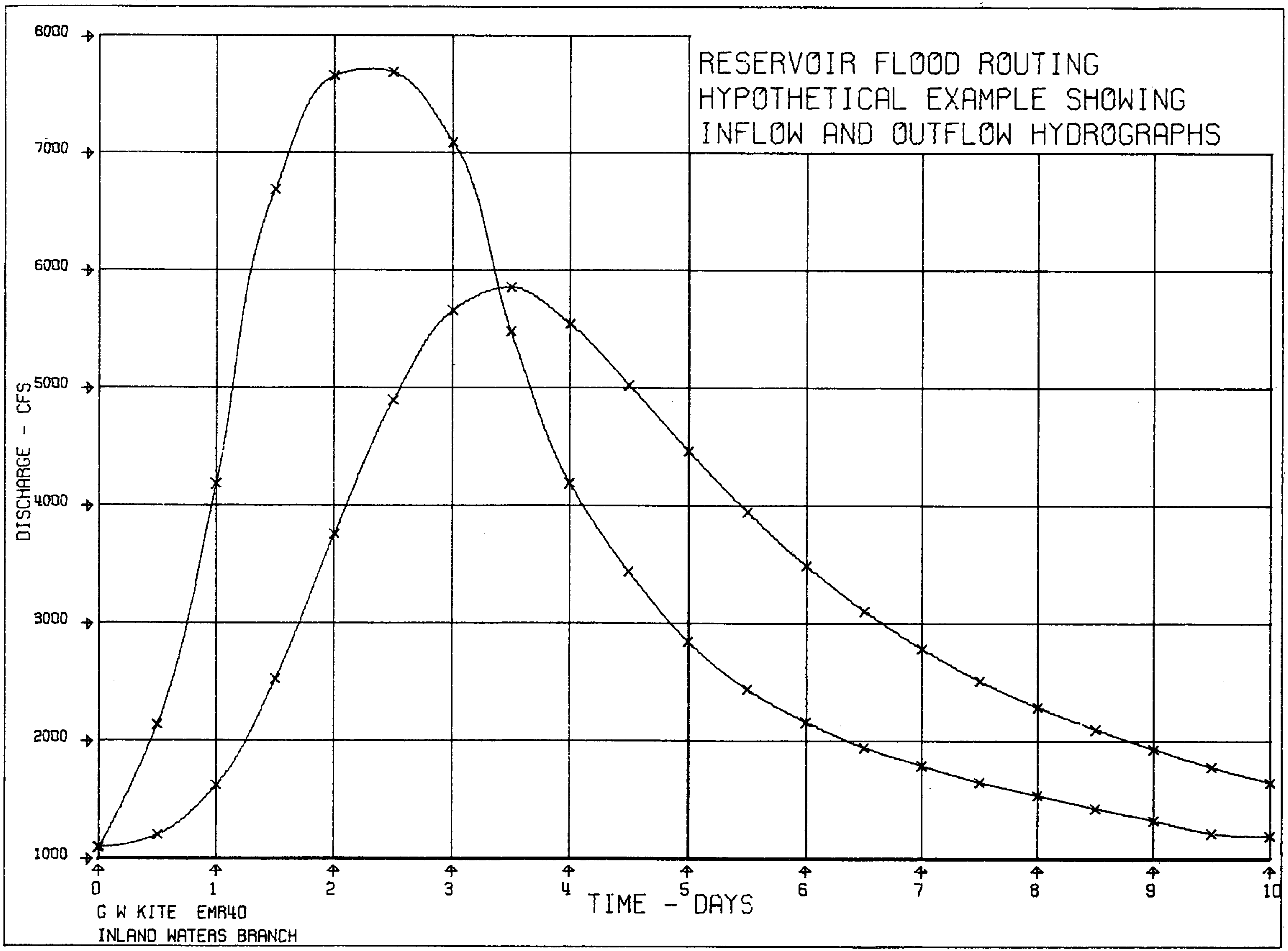


Figure 1. Smooth Curve Plotting: Resevoir Flood Routing

Example 1b: Smooth Curve Plotting - Stage Discharge Curve

This program is designed to take all the "guestimating" out of fitting a smooth curve to a series of stage and discharge measurements. The only data required by the program, apart from the standard plot format specifications, are the number of stage-discharge measurements and the actual measurements together with the dates on which they were obtained and any other short message such as "ice" or "backwater" etc.

The program arranges the series of measurements in order of increasing gauge elevation and, by assuming a relationship

$$Q = Q_o (H - H_o)^2$$

calculates a preliminary estimate of the gauge height at zero flow, H_o. A range of elevations either side of this H_o is then tested in the equation

$$Q = Q_o (H - H_o)^M$$

by means of a logarithmic correlation until a value of H_o is found which produces a minimum standard error in terms of the measured discharges.

Again, a range of elevation values around H_o is selected and the corresponding standard errors calculated until, after three iterations, the initial elevation, H_o, is accurate to 0.001 feet. The equation of the stage discharge curve can now be derived since H_o is known and Q_o and M are calculated in the correlation process.

Next, the program prints out the results and calls the plotter subroutines. These subroutines produce the plot in two stages:

(1) The stage-discharge measurements are plotted and the date of each measurement is printed alongside each point.

(2) From the equation of the stage-discharge curve, the computer calculates a series of co-ordinates and joins the corresponding points on the graph with a smooth curve.

Thus, a curve of mathematical best fit is calculated and plotted in a matter of minutes, eliminating entirely the process of fitting a curve by hand and then laboriously making a stage-discharge table to fit a curve of unknown equation.

The program has so far only been tested on rivers operating with a single control at all stages. It is not known how a river with multiple controls would be treated by the program but it would certainly not develop the best stage-discharge curve. The next step in the improvement of the program will be to adapt the program to accept any number of controls and still produce the curve of mathematical best fit. It is suggested that the optimum use of this program would be in a form of selective management, where it is realized that the program is not going to give perfect results for 100 per cent of the rivers but that 100 per cent of the rivers could be initially processed in this manner and then of the 100 per cent, the few examples where a stage-discharge measurement lay further than a certain desirable confidence limit from the calculated curve would be examined more closely.

As a practical point, the plot used here as an example appears very crowded and not very neat. This is simply because the plot was scaled to fit into an $8\frac{1}{2}$ x 11 inch report format; for practical purposes the scale may be altered to suit any specifications by changing the axis lengths on card 16 of the plot control data set.

LIST OF GRAPH PLOT VARIABLES

PLOT TITLE: STAGE-DISCHARGE PLOT NO: 1b

Card Number	Card Function	Card Format	Variable Name	Variable Value
1	Core location	5X,I10	NBNF	4096
2	First Title Position Data	5X,4(4X,F6.3)	X1 Y1 H1 THETA1	4.0 6.75 0.2 0.0
3	Second Title Position Data	5X,4(4X,F6.3)	X2 Y2 H2 THETA2	4.0 6.5 0.2 0.0
4	Third Title Position Data	5X,4(4X,F6.3)	X3 Y3 H3 THETA3	
5	Fourth Title Position Data	5X,4(4X,F6.3)	X4 Y4 H4 THETA4	
6	Fifth Title Position Data (Numeric)	5X,4(4X,F6.3)	X5 Y5 H5 THETA5	
7	Sixth Title Position Data (Identification)	5X,4(4X,F6.3)	X6 Y6 H6 THETA6	0.25 -0.25 0.1 0.0

Card Number	Card Function	Card Format	Variable Name	Variable Value
8	Seventh Title Position Data (Identification)	5X,4(4X,F6.3)	X7 Y7 H7 THETA7	0.25 -0.4 0.1 0.0
9	First Title Content Data	5X,I5,16A4	NS1 BCD1	23 Stage-Discharge Curve
10	Second Title Content Data	5X,I5,16A4	NS2 BCD2	40 Waterhen River below Waterhen Lake 5LH-5
11	Third Title Content Data	5X,I5,16A4	NS3 BCD3	
12	Fourth Title Content Data	5X,I5,16A4	NS4 BCD4	
13	Fifth Title Content Data (Numeric)	5X,I5,16A4	NN5 FPN5	
14	Sixth Title Content Data (Identification)	5X,I5,16A4	NI1 ID1	15 G.W. Kite EMR40
15	Seventh Title Content Data (Identification)	5X,I5,16A4	NI2 ID2	20 Inland Waters Branch
16	Scaling Data	5X,7F10.3	SW XMIN DX SH XMIN DY DIV	10.0 0.0 1000.0 7.0 2.0 1.0 10.0
17	Ordinate Position Data	5X,4F5.2,I5	XO YO THETA(1) THETA(2) IP1	0.0 0.0 90.0 0.0 -1

Card Number	Card Function	Card Format	Variable Name	Variable Value
18	Abscissa Position Data	5X,4F5.2,I5	XA YA THETA(3) THETA(4) IP2	0.0 0.0 0.0 0.0 2
19	Ordinate Content Data	5X,I5,16A4	NCO VORD	16 Elevation-Feet
20	Abscissa Content Data	5X,I5,16A4	NCA VABS	-15 Discharge - cfs
21	First Plot Data	5X,4I5	N1 J1 K1 L1	32 -1 1 3
22	Second Plot Data	5X,4I5	N2 J2 K2 L2	60 0 1 0
23	Third Plot Data	5X,4I5	N3 J3 K3 L3	
24	Plot Type Data	5X,6I5	NAME1 NAME2 NAME3 NAME4 NAME5 NAME6 NAME7 NAME8	0 0 1 1 0 1 1 0
25	Point Title	5X,I5,F5.1	NS6 THETA8	18 0.0

Card Number	Card Function	Card Format	Variable Name	Variable Value
26	Grid Data (1)	5X,4F5.1,2I5	XG1 YG1 DX1 DY1 MX1 MY1	0.0 0.0 1.0 1.0 10 7
27	Grid Data (2)	5X,4F5.1,2I5	XG2 YG2 DX2 DY2 MX2 MY2	

```
C                       DEPARTMENT OF ENERGY, MINES AND RESOURCES
C                INLAND WATERS BRANCH                ENGINEERING DIVISION
C                                         OTTAWA
C                                      PROGRAM NO. 34
C
C                         STAGE - DISCHARGE CURVE FITTING
C
C
      COMMON ABS1(500),ABS2(500),ABS3(500),ORD1(500),ORD2(500),ORD3(500)X
      COMMON TITLE2(500,5)                                              X
      COMMON NBNF,X1,Y1,H1,THETA1,X2,Y2,H2,THETA2,X3,Y3,H3,THETA3,X4,Y4,X
     1H4,THETA4,X5,Y5,H5,THETA5,X6,Y6,H6,THETA6,X7,Y7,H7,THETA7,NS1,    X
     2BCD1(16),NS2,BCD2(16),NS3,BCD3(16),NS4,BCD4(16),NN5,FPN5(16),NI1, X
     3ID1(16),NI2,ID2(16),SW,SH,DIV,XO,YO,THETA(4),XA,YA,NCO,           X
     4VORD(16),NCA,VABS(16),N1,J1,L1,K1,N2,J2,L2,K2,N3,J3,L3,K3,        X
     5NAME1,NAME2,NAME3,NAME4,NAME5,NAME6,NAME7,NAME8,NS6,THETA8,       X
     6XG1,XG2,YG1,YG2,DX1,DX2,DY1,DY2,MX1,MX2,MY1,MY2,IP1,IP2           X
      COMMON XMIN,YMIN,DX,DY                                            X
      INTEGER EXPUT,TITLE1,TITLE2
      REAL LOWER
      DIMENSION H(100),Q(100),X(100),Y(100),TITLE1(100)
      INPUT=1
      EXPUT=3
      REWIND 01
      READ(INPUT,1)N
C*********************************************************************
C     N          NUMBER OF STAGE AND DISCHARGE MEASUREMENTS          *
C*********************************************************************
      READ(INPUT,3)(TITLE1(I),I=1,10)
C*********************************************************************
C     TITLE1     NAME AND NUMBER OF GAUGING STATION                  *
C*********************************************************************
      DO  10 K=1,N
      READ(INPUT,4)H(K),Q(K),(TITLE2(K,J),J=1,3)
C*********************************************************************
C     H          STAGE ( FEET )                                      *
C     Q          DISCHARGE (  CFS )                                  *
C     TITLE2     DATE OF STAGE - DISCHARGE MEASUREMENT               *
C*********************************************************************
   10 CONTINUE
      JEST=N/8
      IF(JEST.LT.1) JEST=1
   18 NN=N-(JEST-1)
      CALL SORTX(N,H)
      HSUM=0.0
      QSUM=0.0
      DO 19 K=1,JEST
      HSUM=HSUM+H(K)
   19 QSUM=QSUM+Q(K)
      H1BAR=HSUM/JEST
      Q1BAR=QSUM/JEST
      HSUM=0.0
      QSUM=0.0
      DO 20 K=NN,N
      HSUM=HSUM+H(K)
   20 QSUM=QSUM+Q(K)
      H2BAR=HSUM/JEST
      Q2BAR=QSUM/JEST
      HEST1=((H1BAR*Q2BAR**0.5)-(H2BAR*Q1BAR**0.5))/(Q2BAR**0.5
     1-Q1BAR**0.5)
      HEST2=H(1)
      HEST3=HEST1-(HEST2-HEST1)
      IH0=HEST3*10.0
      IH1=HEST2*10.0
      IH0=IH0*10
      IH1=IH1*10
```

```
      ISTEP1=5
      L=1
      DO  200 MMM=1,3
      SEMIN=1000.0
      HMIN=0.0
      QMIN=0.0
      WRITE(EXPUT,5)
      WRITE(EXPUT,11)
      WRITE(EXPUT,12)(TITLE1(I),I=1,10)
      WRITE(EXPUT,13)
      M=1
      DO 140 I=IH0,IH1,ISTEP1
      SUME=0.0
      NEG=0
      HII=I
      IF(MMM.EQ.3)GO TO 30
   25 HII=HII/100.0
      GO TO 40
   30 HII=HII/1000.0
   40 DO  70 K=1,N
      TEMP1=H(K)-HII
      IF(TEMP1)50,55,60
   50 NEG=NEG+1
      GO TO 60
   55 TEMP1=0.001
   60 X(K)=ALOG(ABS(TEMP1))
      Y(K)=ALOG(Q(K))
   70 CONTINUE
      CALL CORAN(N,X,Y,XBAR,YBAR,STDX,STDY,COVXY,CORCOF,SLOPE,YINT,
     1STERR)
      DO  80 K=1,N
      CALQ=EXP(YINT)*(H(K)-HII)**SLOPE
      ERROR=(CALQ-Q(K))**2
      SUME=SUME+ERROR
   80 CONTINUE
      ZZ=N
      SE=(SUME/(ZZ-1.0))**0.5
      QJJ=EXP(YINT)
      IF(SEMIN-SE)100,100,90
   90 SEMIN=SE
      LL=L
      MM=M
      HMIN=HII
      QMIN=QJJ
      SLOPE1=SLOPE
  100 IF(NEG)110,110,120
  110 WRITE(EXPUT,14)L,M,SE,HII,QJJ,SLOPE
      GO TO 130
  120 WRITE(EXPUT,17)L,M,SE,HII,QJJ,SLOPE
  130 M=M+1
  140 CONTINUE
      L=L+1
      WRITE(EXPUT,15)
      WRITE(EXPUT,14)LL,MM,SEMIN,HMIN,QMIN,SLOPE1
      IF(HMIN)230,230,150
  150 IF(MMM-1)190,170,160
  160 IF(MMM-2)150,180,200
  170 IH0=(HMIN-0.05)*100.0
      IH1=IH0+10
      ISTEP1=1
      GO TO 200
  180 IH0=(HMIN-0.005)*1000.0
      IH1=IH0+10
      ISTEP1=1
      GO TO 200
  190 MMM=MMM+1
```

```
200 CONTINUE
    LOWER=HMIN*10.0
    ILOWER=LOWER
    LOWER=ILOWER
    LOWER=LOWER/10.0
    UPPER=(H(N)+0.05)*10.0
    IUPPER=UPPER
    UPPER=IUPPER
    UPPER=UPPER/10.0
    NUMBER=(UPPER-LOWER)*100.0+1.0
    ORD2(1)=LOWER
    DO 210 K=1,NUMBER
    IF(ORD2(K).LE.HMIN)GO TO 202
201 ABS2(K)=QMIN*(ORD2(K)-HMIN)**SLOPE1
    GO TO 203
202 ABS2(K)=0.0
203 ORD2(K+1)=ORD2(K)+0.01
210 CONTINUE
    WRITE(EXPUT,5)
    WRITE(EXPUT,6)
    WRITE(EXPUT,12)(TITLE1(I),I=1,10)
    WRITE(EXPUT,7)
    N3=(NUMBER-1)/10
    N4=1
    N5=10
    DO 215 K=1,N3
    WRITE(EXPUT,8)ORD2(N4),(ABS2(J),J=N4,N5)
    N4=N4+10
215 N5=N5+10
    DO 220 K=1,N
    ORD1(K)=H(K)
    ABS1(K)=Q(K)
220 CONTINUE
    WRITE(EXPUT,5)
    CALL XYREAD
    N2=NUMBER
    CALL XYPLOT
    REWIND 01
  1 FORMAT(5X,I5)
  2 FORMAT(5X,3I10)
  3 FORMAT(5X,10A4)
  4 FORMAT(10X,2F10.2,10X,2A4,5X,A4)
  5 FORMAT(1H1)
  6 FORMAT(//,23X,30HSTAGE - DISCHARGE RATING TABLE,/)
  7 FORMAT(11X,1H0,6X,1H1,6X,1H2,6X,1H3,6X,1H4,6X,1H5,6X,1H6,6X,1H7,
   16X,1H8,6X,1H9,/)
  8 FORMAT(1X,F4.1,1X,10F7.1)
 11 FORMAT(//,22X,31HSTAGE - DISCHARGE CURVE FITTING)
 12 FORMAT(17X,10A4,/)
 13 FORMAT(4X,8HSEQUENCE,5X,8HSTANDARD,9X,7HINITIAL,8X,7HINITIAL,
   19X,5HSLOPE,/,6X,3HNOS,10X,5HERROR,11X,5HGAUGE,8X,9HDISCHARGE,/,
   235X,6HHEIGHT,//,36X,4HFEET,11X,3HCFS,/)
 14 FORMAT(5X,I2,2X,I2,4X,4(F10.3,5X))
 15 FORMAT(/,17X,40HCONDITIONS AT MINIMUM STANDARD ERROR ARE,/)
 16 FORMAT(2F10.2)
 17 FORMAT(5X,I2,2X,I2,4X,F10.3,2(5X,F10.2),5X,F10.3,1X,7HNEG LOG)
230 STOP
    END
```

```
C
      SUBROUTINE CORAN(N,X,Y,XBAR,YBAR,STDX,STDY,COVXY,CORCOF,SLOPE,
     1YINT,STERR)
C
C     CORRELATION ANALYSIS SUBROUTINE
C
      DIMENSION X(100),Y(100)
C*********************************************************************
C     N          NUMBER OF COORDINATE PAIRS OF POINTS               *
C     X,Y        ARRAYS OF COORDINATE POINTS                        *
C     XBAR       MEAN VALUE OF X ARRAY                              *
C     YBAR       MEAN VALUE OF Y ARRAY                              *
C     STDX       STANDARD DEVIATION OF X ARRAY                      *
C     STDY       STANDARD DEVIATION OF Y ARRAY                      *
C     COVXY      COVARIANCE OF X WITH Y                             *
C     CORCOF     COEFFICIENT OF CORRELATION OF X WITH Y             *
C     SLOPE      SLOPE OF LEAST SQUARES REGRESSION LINE             *
C     YINT       INTERCEPT OF LEAST SQUARES LINE ON Y AXIS          *
C     STERR      STANDARD ERROR OF Y AS CALCULATED FROM X           *
C*********************************************************************
      XN=N
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
      DO 100 J=1,N
      CP=X(J)*Y(J)
      XSQ=X(J)**2
      YSQ=Y(J)**2
      SUM1=SUM1+X(J)
      SUM2=SUM2+Y(J)
      SUM3=SUM3+CP
      SUM4=SUM4+XSQ
      SUM5=SUM5+YSQ
  100 CONTINUE
      XBAR=SUM1/XN
      YBAR=SUM2/XN
      STDX=((1.0/(XN-1.0))*(SUM4-((SUM1**2)/XN)))**0.5
      STDY=((1.0/(XN-1.0))*(SUM5-((SUM2**2)/XN)))**0.5
      COVXY=(1.0/(XN-1.0))*(SUM3-(SUM1*SUM2/XN))
      CORCOF=COVXY/(STDX*STDY)
      STERR=STDX*(1.0-(CORCOF**2))**0.5
      SLOPE=COVXY/STDX**2
      YINT=YBAR-(SLOPE*XBAR)
      RETURN
      END

C
      SUBROUTINE SORTX (N,XX)
      DIMENSION XX(100)
C**********************************************************************
C     SORT AN ARRAY OF FLOATING POINT VARIABLES IN  ASCENDING ORDER   *
C     N#NUMBER OF VARIABLES                                           *
C     XX#VARIABLE TO BE SORTED                                        *
C**********************************************************************
      K=(N-1)
      DO 2 L=1,K
      M=(N-L)
      DO 2 J=1,M
      IF (XX(J)-XX(J+1)) 2,1,1
    1 XTEMP=XX(J)
      XX(J)=XX(J+1)
      XX(J+1)=XTEMP
    2 CONTINUE
      RETURN
      END
```

STAGE - DISCHARGE CURVE FITTING
WATERHEN RIVER BELOW WATERHEN LAKE 5LH-5

SEQUENCE NOS		STANDARD ERROR	INITIAL GAUGE HEIGHT	INITIAL DISCHARGE	SLOPE
			FEET	CFS	
1	1	258.498	2.300	74.561	2.727
1	2	247.396	2.350	83.367	2.669
1	3	235.652	2.400	93.175	2.611
1	4	223.130	2.450	104.106	2.551
1	5	209.803	2.500	116.283	2.491
1	6	195.549	2.550	129.856	2.430
1	7	180.245	2.600	144.994	2.367
1	8	163.843	2.650	161.882	2.304
1	9	146.128	2.700	180.761	2.238
1	10	127.195	2.750	201.882	2.171
1	11	107.202	2.800	225.570	2.102
1	12	86.943	2.850	252.246	2.029
1	13	69.541	2.900	282.419	1.953
1	14	63.595	2.950	316.798	1.872
1	15	80.179	3.000	356.394	1.784
1	16	119.512	3.050	402.788	1.687
1	17	179.673	3.100	458.761	1.575
1	18	267.511	3.150	530.131	1.436
1	19	409.883	3.200	633.875	1.238

CONDITIONS AT MINIMUM STANDARD ERROR ARE

1	14	63.595	2.950	316.798	1.872

STAGE - DISCHARGE CURVE FITTING
WATERHEN RIVER BELOW WATERHEN LAKE 5LH-5

SEQUENCE NOS		STANDARD ERROR	INITIAL GAUGE HEIGHT	INITIAL DISCHARGE	SLOPE
			FEET	CFS	
2	1	72.498	2.890	276.072	1.969
2	2	69.541	2.900	282.419	1.953
2	3	67.035	2.910	288.929	1.937
2	4	65.062	2.920	295.619	1.921
2	5	63.761	2.930	302.484	1.905
2	6	63.237	2.940	309.541	1.889
2	7	63.595	2.950	316.798	1.872
2	8	64.909	2.960	324.255	1.855
2	9	67.237	2.970	331.938	1.838
2	10	70.571	2.980	339.846	1.820
2	11	74.898	2.990	347.992	1.803

CONDITIONS AT MINIMUM STANDARD ERROR ARE

2	6	63.237	2.940	309.541	1.889

STAGE – DISCHARGE CURVE FITTING
WATERHEN RIVER BELOW WATERHEN LAKE 5LH-5

SEQUENCE NOS		STANDARD ERROR	INITIAL GAUGE HEIGHT	INITIAL DISCHARGE	SLOPE
			FEET	CFS	
3	1	63.452	2.934	305.283	1.899
3	2	63.394	2.935	305.991	1.897
3	3	63.347	2.936	306.695	1.895
3	4	63.305	2.937	307.406	1.894
3	5	63.274	2.938	308.114	1.892
3	6	63.251	2.939	308.826	1.890
3	7	63.237	2.940	309.541	1.889
3	8	63.231	2.941	310.256	1.887
3	9	63.235	2.942	310.974	1.885
3	10	63.247	2.943	311.699	1.884
3	11	63.269	2.944	312.421	1.882

CONDITIONS AT MINIMUM STANDARD ERROR ARE

3	8	63.231	2.941	310.256	1.887

STAGE - DISCHARGE RATING TABLE

WATERHEN RIVER BELOW WATERHEN LAKE 5LH-5

	0	1	2	3	4	5	6	7	8	9
2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.7	1.0
3.0	1.5	2.0	2.6	3.2	3.9	4.7	5.6	6.5	7.5	8.5
3.1	9.7	10.8	12.1	13.4	14.7	16.2	17.7	19.2	20.8	22.5
3.2	24.2	26.0	27.9	29.8	31.8	33.8	35.9	38.1	40.3	42.6
3.3	44.9	47.3	49.7	52.2	54.8	57.4	60.1	62.8	65.6	68.5
3.4	71.4	74.3	77.3	80.4	83.6	86.7	90.0	93.3	96.6	100.0
3.5	103.5	107.0	110.6	114.2	117.9	121.7	125.5	129.3	133.2	137.2
3.6	141.2	145.3	149.4	153.6	157.8	162.1	166.5	170.9	175.3	179.8
3.7	184.4	189.0	193.6	198.4	203.1	207.9	212.8	217.8	222.7	227.8
3.8	232.9	238.0	243.2	248.4	253.7	259.1	264.5	270.0	275.5	281.0
3.9	286.6	292.3	298.0	303.8	309.6	315.5	321.4	327.4	333.4	339.5
4.0	345.7	351.8	358.1	364.4	370.7	377.1	383.5	390.0	396.6	403.2
4.1	409.8	416.5	423.3	430.1	436.9	443.8	450.8	457.8	464.8	471.9
4.2	479.1	486.3	493.5	500.9	508.2	515.6	523.1	530.6	538.1	545.8
4.3	553.4	561.1	568.9	576.7	584.6	592.5	600.4	608.4	616.5	624.6
4.4	632.8	641.0	649.2	657.5	665.9	674.3	682.8	691.3	699.8	708.4
4.5	717.1	725.8	734.5	743.3	752.2	761.1	770.0	779.0	788.1	797.2
4.6	806.3	815.5	824.8	834.1	843.4	852.8	862.3	871.7	881.3	890.9
4.7	900.5	910.2	919.9	929.7	939.5	949.4	959.3	969.3	979.4	989.4
4.8	999.5	1009.7	1019.9	1030.2	1040.5	1050.9	1061.3	1071.8	1082.3	1092.8
4.9	1103.4	1114.1	1124.8	1135.5	1146.3	1157.2	1168.1	1179.0	1190.0	1201.0
5.0	1212.1	1223.3	1234.4	1245.7	1256.9	1268.3	1279.6	1291.1	1302.5	1314.0
5.1	1325.6	1337.2	1348.9	1360.6	1372.3	1384.1	1396.0	1407.9	1419.8	1431.8
5.2	1443.8	1455.9	1468.1	1480.2	1492.5	1504.7	1517.1	1529.4	1541.8	1554.3
5.3	1566.8	1579.4	1592.0	1604.6	1617.3	1630.1	1642.9	1655.7	1668.6	1681.5
5.4	1694.5	1707.5	1720.6	1733.7	1746.9	1760.1	1773.4	1786.7	1800.0	1813.4
5.5	1826.9	1840.4	1853.9	1867.5	1881.1	1894.8	1908.5	1922.3	1936.1	1950.0
5.6	1963.9	1977.9	1991.9	2005.9	2020.0	2034.2	2048.4	2062.6	2076.9	2091.2
5.7	2105.6	2120.0	2134.5	2149.0	2163.6	2178.2	2192.9	2207.6	2222.3	2237.1
5.8	2252.0	2266.8	2281.8	2296.8	2311.8	2326.8	2342.0	2357.1	2372.3	2387.6
5.9	2402.9	2418.2	2433.6	2449.1	2464.6	2480.1	2495.7	2511.3	2527.0	2542.7
6.0	2558.4	2574.2	2590.1	2606.0	2621.9	2637.9	2653.9	2670.0	2686.1	2702.3
6.1	2718.5	2734.8	2751.1	2767.5	2783.9	2800.3	2816.8	2833.3	2849.9	2866.5
6.2	2883.2	2899.9	2916.7	2933.5	2950.3	2967.2	2984.2	3001.2	3018.2	3035.3
6.3	3052.4	3069.6	3086.8	3104.1	3121.4	3138.7	3156.1	3173.6	3191.1	3208.6
6.4	3226.2	3243.8	3261.5	3279.2	3296.9	3314.7	3332.6	3350.5	3368.4	3386.4
6.5	3404.4	3422.5	3440.6	3458.8	3477.0	3495.2	3513.5	3531.9	3550.3	3568.7
6.6	3587.2	3605.7	3624.3	3642.9	3661.5	3680.2	3699.0	3717.8	3736.6	3755.5
6.7	3774.4	3793.4	3812.4	3831.5	3850.6	3869.7	3888.9	3908.2	3927.4	3946.8
6.8	3966.1	3985.6	4005.0	4024.5	4044.1	4063.7	4083.3	4103.0	4122.7	4142.5
6.9	4162.3	4182.2	4202.1	4222.0	4242.0	4262.1	4282.1	4302.3	4322.4	4342.7
7.0	4362.9	4383.2	4403.6	4424.0	4444.4	4464.9	4485.4	4506.0	4526.6	4547.3
7.1	4568.0	4588.7	4609.5	4630.3	4651.2	4672.2	4693.1	4714.1	4735.2	4756.3

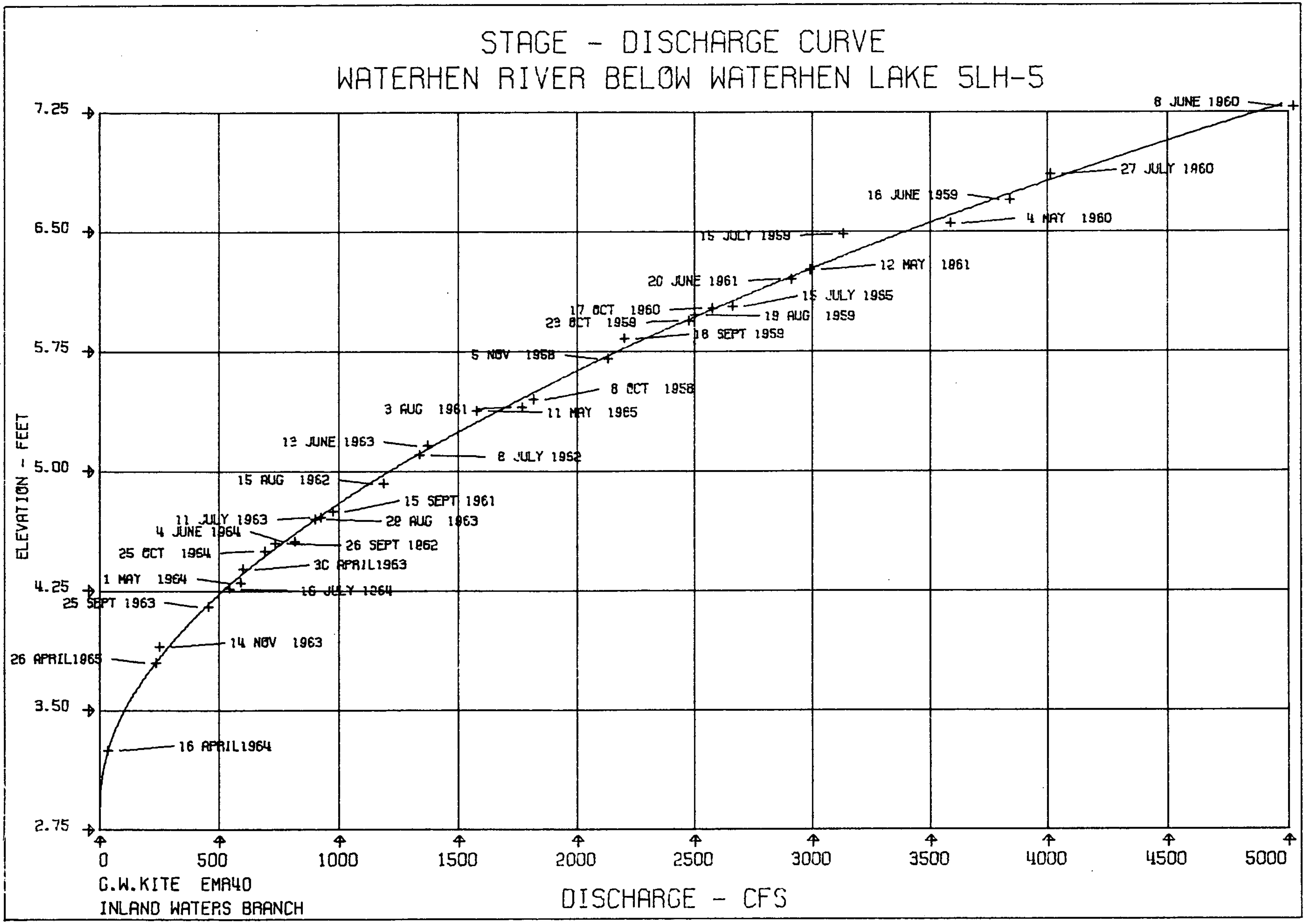


Figure 2. Smooth Curve Plotting: Stage Discharge Curve

Example 2a: Straight Line Plot - Lake Outflow

This is a very simple program. The computer reads in mean monthly Lake Ontario outflows, computes the annual means for fifty years, 1915 to 1964, and calls the plot subroutines. The subroutines produce a straight line plot.

LIST OF GRAPH PLOT VARIABLES

PLOT TITLE: LAKE ONTARIO OUTFLOW PLOT NO: 2a

Card Number	Card Function	Card Format	Variable Name	Variable Value
1	Core location	5X,I10	NBNF	4096
2	First Title Position Data	5X,4(4X,F6.3)	X1 Y1 H1 THETA1	2.75 6.75 0.2 0.0
3	Second Title Position Data	5X,4(4X,F6.3)	X2 Y2 H2 THETA2	2.75 6.50 0.2 0.0
4	Third Title Position Data	5X,4(4X,F6.3)	X3 Y3 H3 THETA3	2.75 6.25 0.2 0.0
5	Fourth Title Position Data	5X,4(4X,F6.3)	X4 Y4 H4 THETA4	
6	Fifth Title Position Data (Numeric)	5X,4(4X,F6.3)	X5 Y5 H5 THETA5	
7	Sixth Title Position Data (Identification)	5X,4(4X,F6.3)	X6 Y6 H6 THETA6	0.0 -0.5 0.1 0.0

Card Number	Card Function	Card Format	Variable Name	Variable Value
8	Seventh Title Position Data (Identification)	5X,4(4X,F6.3)	X7 Y7 H7 THETA7	0.0 -0.7 0.1 0.0
9	First Title Content Data	5X,I5,16A4	NS1 BCD1	32 Lake Ontario Annual Mean Outflow
10	Second Title Content Data	5X,I5,16A4	NS2 BCD2	22 Recorded Adjusted Data
11	Third Title Content Data	5X,I5,16A4	NS3 BCD3	12 1915 to 1965
12	Fourth Title Content Data	5X,I5,16A4	NS4 BCD4	
13	Fifth Title Content Data (Numeric)	5X,I5,16A4	NN5 FPN5	
14	Sixth Title Content Data (Identification)	5X,I5,16A4	NI1 ID1	15 G.W. Kite EMR40
15	Seventh Title Content Data (Identification)	5X,I5,16A4	NI2 ID2	20 Inland Waters Branch
16	Scaling Data	5X,7F10.3	SW XMIN DX SH XMIN DY DIV	10.0 1915.0 5.0 7.0 180.0 20.0 10.0
17	Ordinate Position Data	5X,4F5.2,I5	XO YO THETA(1) THETA(2) IP1	0.0 0.0 90.0 0.0 -1

Card Number	Card Function	Card Format	Variable Name	Variable Value
18	Abscissa Position Data	5X,4F5.2,I5	XA YA THETA(3) THETA(4) IP2	0.0 0.0 0.0 0.0 -1
19	Ordinate Content Data	5X,I5,16A4	NCO VORD	14 Outflow - Tcfs
20	Abscissa Content Data	5X,I5,16A4	NCA VABS	-12 Time - Years
21	First Plot Data	5X,4I5	N1 J1 K1 L1	51 1 1 0
22	Second Plot Data	5X,4I5	N2 J2 K2 L2	
23	Third Plot Data	5X,4I5	N3 J3 K3 L3	
24	Plot Type Data	5X,6I5	NAME1 NAME2 NAME3 NAME4 NAME5 NAME6 NAME7 NAME8	1 0 0 0 0 1 1 0
25	Point Title	5X,I5,F5.1	NS6 THETA8	

Card Number	Card Function	Card Format	Variable Name	Variable Value
26	Grid Data((1)	5X,4F5.1,2I5	XG1 YG1 DX1 DY1 MX1 MY1	0.0 0.0 1.0 1.0 10 6
27	Grid Data (2)	5X,4F5.1,2I5	XG2 YG2 DX2 DY2 MX2 MY2	

```
C       LAKE OUTFLOW PLOTTING
C
C
        COMMON ABS1(100),ORD1(100),ABS2(100),ORD2(100),TITLE2(100,5),          X
       1ABS3(100),ORD3(100)                                                    X
        COMMON NBNF,X1,Y1,H1,THETA1,X2,Y2,H2,THETA2,X3,Y3,H3,THETA3,X4,Y4,     X
       1H4,THETA4,X5,Y5,H5,THETA5,X6,Y6,H6,THETA6,X7,Y7,H7,THETA7,NS1,         X
       2BCD1(16),NS2,BCD2(16),NS3,BCD3(16),NS4,BCD4(16),NN5,FPN5(16),NI1,      X
       3ID1(16),NI2,ID2(16),SW,SH,DIV,X0,Y0,THETA(4),XA,YA,NCO,                X
       4VORD(16),NCA,VABS(16),N1,J1,L1,K1,N2,J2,L2,K2,N3,J3,L3,K3,             X
       5NAME1,NAME2,NAME3,NAME4,NAME5,NAME6,NAME7,NAME8,NS6,THETA8,            X
       6XG1,XG2,YG1,YG2,DX1,DX2,DY1,DY2,MX1,MX2,MY1,MY2,IP1,IP2                X
        COMMON XMIN,YMIN,DX,DY                                                 X
        DO 10 J=1,50
        READ(1,1)A,B,C,D,E,F,G,H,O,P,Q,R
      1 FORMAT(8X,12F6.0)
        XJ=J
        ORD1(J)=(A+B+C+D+E+F+G+H+O+P+Q+R)/12.0
        ABS1(J)=1914.0+XJ
     10 CONTINUE
        CALL XYREAD
        CALL XYPLOT
        STOP
        END
```

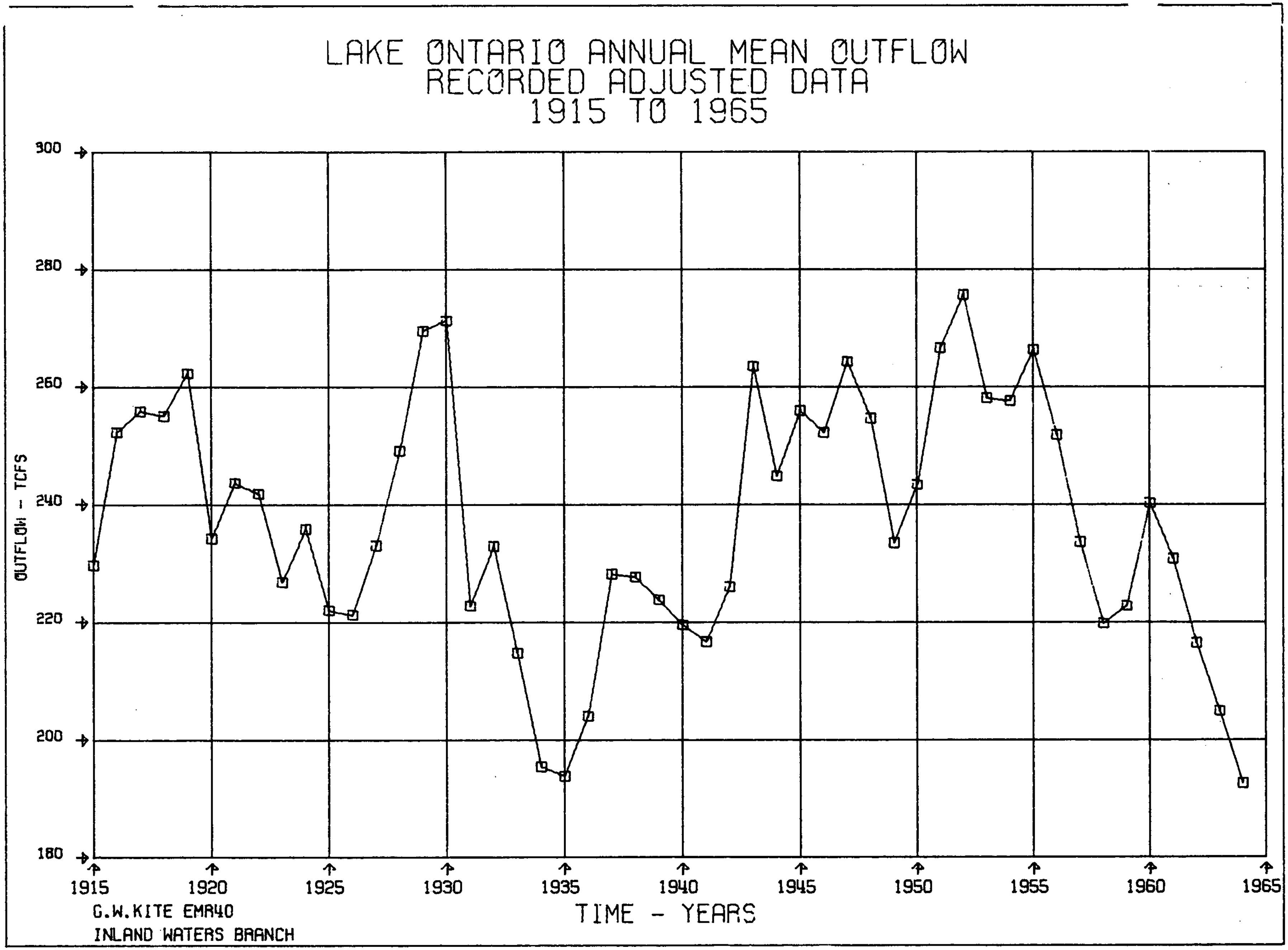


Figure 3. Straight Line Plot: Time Series - Lake Outflow

Example 2b: Straight Line Plot - Backwater Curve

This program develops a backwater curve using the standard step technique. It is a very versatile program in that any number of channel cross-sections at any intervals may be used. On any cross-section the program reads in the section's chainage from the origin, the flow at that section, and an array of figures giving the channel width at set intervals from the lowest elevation. Any cross-section may be divided into up to ten sub-areas; for each sub-area a different value of Manning's roughness coefficient, Coriolis's velocity distribution coefficient and the eddy loss may be used, thus permitting the common arrangement of a centre channel with a surrounding flood plain to be simulated. A subroutine calculates, for the first estimate of the backwater depth, the cross-sectional area and representative values of the coefficients. The procedure is then simply refining the estimate of the backwater depth by the standard step trial and error technique.

The program produces a table of results for the length of channel being examined and then calls the plotter subroutines which produce a graph showing a profile of channel bed elevation and water surface elevation above datum.

If required the program can be set to repeat this entire operation any number of times as, for example, if it were required to estimate the backwater elevations that would occur with floods of 50-year, 100-year, 500-year return periods.

An explanation of all the input data required to run the program is given in the program listing.

LIST OF GRAPH PLOT VARIABLES

PLOT TITLE: BACKWATER

PLOT NO: 4

Card Number	Card Function	Card Format	Variable Name	Variable Value
1	Core Location	5X,I10	NBNF	4096
2	First Title Position Data	5X,4(4X,F6.3)	X1 Y1 H1 THETA1	- 0.50 6.25 0.20 0.00
3	Second Title Position Data	5X,4(4X,F6.3)	X2 Y2 H2 THETA2	- 0.50 6.00 0.20 0.00
4	Third Title Position Data	5X,4(4X,F6.3)	X3 Y3 H3 THETA3	- 0.50 5.75 0.20 0.00
5	Fourth Title Position Data	5X,4(4X,F6.3)	X4 Y4 H4 THETA4	7.50 0.65 0.10 0.00
6	Fifth Title Position Data (Numeric)	5X,4(4X,F6.3)	X5 Y5 H5 THETA5	7.50 0.40 0.10 0.00
7	Sixth Title Position Data (Identification)	5X,4(4X,F6.3)	X6 Y6 H6 THETA6	0.0 - 0.5 0.1 0.0

Card Number	Card Function	Card Format	Variable Name	Variable Value
8	Seventh Title Position Data (Identification)	5X,4(4X,F6.3)	X7 Y7 H7 THETA7	0.0 -0.7 0.1 0.0
9	First Title Content Data	5X,I5,16A4	NS1 BCD1	65 Backwater, steady gradually varied flow computation
10	Second Title Content Data	5X,I5,16A4	NS2 BCD2	65 Squamish River study - Mamquam River
11	Third Title Content Data	5X,I5,16A4	NS3 BCD3	65 500 year design flood
12	Fourth Title Content Data	5X,I5,16A4	NS4 BCD4	34 0-Water surface elevation profile
13	Fifth Title Content Data (Numeric)	5X,I5,16A4	NN5 FPN5	22 X - Channel bed profile
14	Sixth Title Content Data (Identification)	5X,I5,16A4	NI1 ID1	14 G.W. Kite EMR40
15	Seventh Title Content Data (Identification)	5X,I5,16A4	NI2 ID2	20 Inland Waters Branch
16	Scaling Data	5X,7F10.3	SW XMIN DX SH XMIN DY DIV	10.0 -1500.0 1500.0 5.0 - 10.0 20.0 10.0
17	Ordinate Position Data	5X,4F5.2,I5	XO YO THETA(1) THETA(2) IP1	0.0 0.0 90.0 0.0 - 1

Card Number	Card Function	Card Format	Variable Name	Variable Value
18	Abscissa Position Data	5X,4F5.2,I5	XA YA THETA(3) THETA(4) IP2	0.0 0.0 0.0 0.0 -1
19	Ordinate Content Data	5X,I5,16A4	NCO VORD	16 Elevation - Feet
20	Abscissa Content Data	5X,I5,16A4	NCA VABS	15 Chainage - Feet
21	First Plot Data	5X,4I5	N1 J1 K1 L1	9 1 1 0
22	Second Plot Data	5X,4I5	N2 J2 K2 L2	9 1 1 5
23	Third Plot Data	5X,4I5	N3 J3 K3 L3	
24	Plot Type Data	5X,6I5	NAME1 NAME2 NAME3 NAME4 NAME5 NAME6 NAME7 NAME8	1 0 0 0 1 1 1 0
25	Point Title	5X,I5,F5.1	NS6 THETA8	

Card Number	Card Function	Card Format	Variable Name	Variable Value
26	Grid Data (1)	5X,4F5.1,2I5	XG1 YG1 DX1 DY1 MX1 MY1	0.0 0.0 1.0 1.0 7 5
27	Grid Data (2)	5X,4F5.1,2I5	XG2 YG2 DX2 DY2 MX2 MY2	7.0 1.0 1.0 1.0 3 4

BACKWATER, STEADY GRADUALLY VARIED FLOW COMPUTATION
STANDARD STEP METHOD

SQUAMISH RIVER STUDY - MAMQUAM RIVER

DISTANCE FEET	BED ELEVATION FEET	SURFACE ELEVATION FEET	CSA SQ.FEET	MANNINGS N	CORIOLIS CONSTANT	FLOW CFS
-317.	-2.11	33.09	43854.	0.1136	1.0000	88700.
2218.	9.00	34.18	5852.	0.0317	1.0000	88700.
3311.	14.30	38.07	8388.	0.0331	1.0000	88700.
4800.	21.50	41.91	4959.	0.0326	1.0000	88700.
7139.	33.00	53.59	8320.	0.0333	1.0000	88700.
8443.	39.50	58.43	6486.	0.0332	1.0000	88700.
10000.	47.20	66.44	4464.	0.0323	1.0000	88700.
11199.	53.10	80.56	15452.	0.0668	1.0000	88700.
12392.	59.00	88.49	19942.	0.0906	1.0000	88700.

```
C                       DEPARTMENT OF ENERGY, MINES AND RESOURCES
C              INLAND WATERS BRANCH                    ENGINEERING DIVISION
C                                         OTTAWA
C                                     PROGRAM NO. 22
C
C                                    BACKWATER PROGRAM
C                         STEADY GRADUALLY VARIED FLOW COMPUTATIONS
C
C
      COMMON ABS1(500),ABS2(500),ABS3(500),ORD1(500),ORD2(500),ORD3(500)X
C
      COMMON TITLE2(500,5)                                              X
      COMMON NBNF,X1,Y1,H1,THETA1,X2,Y2,H2,THETA2,X3,Y3,H3,THETA3,X4,Y4,X
     1H4,THETA4,X5,Y5,H5,THETA5,X6,Y6,H6,THETA6,X7,Y7,H7,THETA7,NS1,     X
     2BCD1(16),NS2,BCD2(16),NS3,BCD3(16),NS4,BCD4(16),NN5,FPN5(16),NI1,  X
     3ID1(16),NI2,ID2(16),SW,SH,DIV,X0,Y0,THETA(4),XA,YA,NCO,            X
     4VORD(16),NCA,VABS(16),N1,J1,L1,K1,N2,J2,L2,K2,N3,J3,L3,K3,         X
     5NAME1,NAME2,NAME3,NAME4,NAME5,NAME6,NAME7,NAME8,NS6,THETA8,        X
     6XG1,XG2,YG1,YG2,DX1,DX2,DY1,DY2,MX1,MX2,MY1,MY2,IP1,IP2            X
      COMMON XMIN,YMIN,DX,DY                                            X
      DIMENSION ITITLE(10),LNG(100),BED(100),DEPTH(100),WSE(100),
     1EDDY(100),DISCH(100),SLOPE(100),ELEV(100)
      INTEGER EXPUT
      REAL LNG,LENGTH,LOSS
      EXPUT=3
      INPUT=1
      READ(INPUT,12)NN1
C*********************************************************************
C     NN1       NUMBER OF PROFILES TO BE RUN                          *
C*********************************************************************
      DO 80 KKK=1,NN1
      READ(INPUT,1)(ITITLE(J),J=1,10)
C*********************************************************************
C     ITITLE    NAME OF LOCATION ETC                                  *
C*********************************************************************
      READ(INPUT,2)NN2,CHANGE
C*********************************************************************
C     NN2       NUMBER OF CROSS SECTIONS                              *
C     CHANGE    CHANGE IN ELEVATION AT ORIGIN, FEET                   *
C*********************************************************************
      WRITE(EXPUT,13)
      WRITE(EXPUT,4)
      WRITE(EXPUT,5)
      WRITE(EXPUT,6)(ITITLE(J),J=1,10)
      WRITE(EXPUT,8)
      WRITE(EXPUT,9)
      DO 60 J=1,NN2
      READ(INPUT,3)LNG(J),BED(J),DISCH(J),   EDDY(J)
C*********************************************************************
C     LNG       LOCATION OF CROSS SECTION, IN MILES, FROM THE ORIGIN  *
C     BED       ELEVATION OF THE CHANNEL BED AT THE CURRENT CROSS SECTION
C     DISCH     DISCHARGE, CFS ,BETWEEN THE CURRENT SECTION AND THE   *
C               PREVIOUS SECTION                                      *
C     EDDY      ESTIMATE OF THE LOSS IN HEAD DUE TO EDDIES BETWEEN THE *
C               CURRENT SECTION AND THE PREVIOUS SECTION, FEET        *
C*********************************************************************
      DATUM=BED(1)
      LNG(J)=LNG(J)*5280.0
      IF(J.EQ.1)GO TO 16
   15 DEPTH(J)=DEPTH(J-1)
      LENGTH=(LNG(J)-LNG(J-1))
      GO TO 17
   16 DEPTH(J)=CHANGE
   17 INDIC=0
      INDID=1
```

```
20 CALL XSECT(DEPTH(J),AREA,RADIUS,ROUGH,ALPHA,INDIC)
25 SPEED=DISCH(J)/AREA
   HEAD=((SPEED**2)/64.4)*ALPHA
   THEAD=BED(J)-DATUM+DEPTH(J)+HEAD
   RADIUS=RADIUS**1.333
   SLOPE(J)=((ROUGH    **2)*(SPEED**2))/(2.22*RADIUS)
   IF(J.NE.1) GO TO 27
26 ELEV(1)=THEAD
   GO TO 58
27 SLOPE(J)=(SLOPE(J)+SLOPE(J-1))/2.0
   LOSS=SLOPE(J)*LENGTH
   ELEV(J)=ELEV(J-1)+LOSS+EDDY(J)
28 IF(ABS(ELEV(J)-THEAD).LE.1.00)GO TO 40
29 IF(ELEV(J)-THEAD)30,58,31
30 DEPTH(J)=DEPTH(J)-1.00
   INDIC=10
   INDID=INDID+1
   IF(INDID.GT. 50)GO TO 32
   GO TO 20
31 DEPTH(J)=DEPTH(J)+1.00
   INDIC=10
   INDID=INDID+1
   IF(INDID.GT. 50)GO TO 33
   GO TO 20
32 DEPTH(J)=DEPTH(J)+1.0
   GO TO 40
33 DEPTH(J)=DEPTH(J)-1.0
40 IF(ABS(ELEV(J)-THEAD).LE.0.10)GO TO 50
41 IF(ELEV(J)-THEAD)42,58,43
42 DEPTH(J)=DEPTH(J)-0.10
   INDIC=10
   INDID=INDID+1
   IF(INDID.GT.100)GO TO 44
   GO TO 20
43 DEPTH(J)=DEPTH(J)+0.10
   INDIC=10
   INDID=INDID+1
   IF(INDID.GT.100)GO TO 45
   GO TO 20
44 DEPTH(J)=DEPTH(J)+0.1
   GO TO 50
45 DEPTH(J)=DEPTH(J)-0.1
50 IF(ABS(ELEV(J)-THEAD).LE.0.01)GO TO 58
51 IF(ELEV(J)-THEAD)52,58,53
52 DEPTH(J)=DEPTH(J)-0.01
   INDIC=10
   INDID=INDID+1
   IF(INDID.GT.150)GO TO 58
   GO TO 20
53 DEPTH(J)=DEPTH(J)+0.01
   INDIC=10
   INDID=INDID+1
   IF(INDID.GT.150)GO TO 58
   GO TO 20
58 WSE(J)=DEPTH(J)+BED(J)
   WRITE(EXPUT,11)LNG(J),BED(J),   WSE(J),AREA,ROUGH,ALPHA,DISCH(J)
60 CONTINUE
   DO 70 J=1,NN2
   ABS1(J)=LNG(J)
   ABS2(J)=ABS1(J)
   ORD1(J)=BED(J)
   ORD2(J)=WSE(J)
70 CONTINUE
   CALL XYREAD
   CALL XYPLOT
```

```
80 CONTINUE
 1 FORMAT(5X,10A4)
 2 FORMAT(5X,I5, F10.2)
 3 FORMAT(5X,F10.3,2F10.2,F10.4)
 4 FORMAT(20X,51HBACKWATER, STEADY GRADUALLY VARIED FLOW COMPUTATION)
 5 FORMAT(35X,20HSTANDARD STEP METHOD,/)
 6 FORMAT(25X,10A4,/)
 7 FORMAT(20X,12HDISCHARGE IS,F10.2,/)
 8 FORMAT(13X,8HDISTANCE,5X,3HBED,5X,7HSURFACE,4X,3HCSA,5X,8HMANNINGS
  1,2X,8HCORIOLIS,5X,4HFLOW)
 9 FORMAT(23X,9HELEVATION,1X,9HELEVATION,14X,1HN,6X,8HCONSTANT,/,
  1          15X,4HFEET,6X,4HFEET,7X,4HFEET,3X,7HSQ.FEET,26X,3HCFS,//)
11 FORMAT(10X,F10.0,2F10.2,F10.0,2F10.4,F11.0,/)
12 FORMAT(5X,I5)
13 FORMAT(1H1)
21 FORMAT(8F15.4)
90 STOP
   END


      SUBROUTINE    XSECT(DEPTH,AREA,RADIUS,ROUGH,ALPHA,INDIC)
C
C
C***********************************************************************
C      CALCULATES, FOR ANY CROSS SECTION, THE CSA, HYDRAULIC RADIUS,    *
C      VELOCITY DISTRIBUTION COEFFICIENT AND, USING PAVLOVSKIIS         *
C      ASSUMPTION, THE EQUIVALENT MANNING ROUGHNESS FACTOR              *
C      DEPTH    ESTIMATE OF CHANNEL DEPTH                               *
C      AREA     CALCULATED CROSS SECTIONAL AREA                         *
C      RADIUS   CALCULATED HYDRAULIC RADIUS                             *
C      ROUGH    CALCULATED COMPOSITE ROUGHNESS FACTOR                   *
C      ALPHA    CALCULATED VELOCITY DISTRIBUTION COEFFICIENT            *
C***********************************************************************
      DIMENSION WIDTH(100),PERIM(10),SROUGH(10),PAREA(10),SAREA(10),
     1SALPHA(10),CONV(10)
      INPUT=1
    5 IF(INDIC.EQ.10)GO TO 6
      READ(INPUT,4)NX1,DY
      READ(INPUT,2)    (WIDTH(K),K=1,NX1)
C***********************************************************************
C      DY       STAGE INTERVAL                                          *
C      NX1      NUMBER OF INTERVALS IN THE CHANNEL MAXIMUM DEPTH        *
C      WIDTH    CHANNEL WIDTH CORRESPONDING TO EACH INTERVAL IN         *
C               STAGE FROM ZERO TO MAXIMUM ELEVATION                    *
C***********************************************************************
    6 SUM1=0.0
      SUM2=0.0
      IELEV=DEPTH/DY
      DO 40 K=1,IELEV
      IF(K.EQ.1)GO TO 20
   10 DIFF=(WIDTH(K)-WIDTH(K-1))/2.0
      TPERIM=2.0*((DIFF**2+DY**2)**0.5)
      TAREA=((WIDTH(K)+WIDTH(K-1))/2.0)*DY
      SUM1=SUM1+TAREA
      GO TO 30
   20 TPERIM=WIDTH(1)
   30 SUM2=SUM2+TPERIM
   40 CONTINUE
      TAREA=(DEPTH-IELEV*DY )*WIDTH(IELEV)
      TPERIM=2.0*((DIFF**2)+(DEPTH-IELEV*DY )**2)**0.5
      SUM1=SUM1+TAREA
      SUM2=SUM2+TPERIM
      AREA=SUM1
      RADIUS=AREA/SUM2
```

```
      IF(INDIC.EQ.10)GO TO 45
      READ(INPUT,1)NX2
      DO 42 J=1,NX2
   42 READ(INPUT,3)PAREA(J),SROUGH(J),SALPHA(J)
C***********************************************************************
C     NX2       NUMBER OF CHANNEL AREA SUBDIVISIONS                     *
C     PAREA     PERCENTAGE OF TOTAL CSA WHICH IS OCCUPIED BY EACH SUBAREA
C               AT THE ESTIMATED BACKWATER ELEVATION                    *
C     SROUGH    ESTIMATE OF THE MANNING ROUGHNESS FACTOR CORRESPONDING  *
C               TO EACH SUBAREA FOR THE CHANNEL REACH BETWEEN THE CURRENT
C               SECTION AND THE PREVIOUS SECTION                        *
C     SALPHA    ESTIMATE OF THE VELOCITY DISTRIBUTION COEFFICIENT FOR   *
C               EACH SUBAREA                                            *
C***********************************************************************
   45 SUM3=0.0
      DO 50 J=1,NX2
      PERIM(J)=PAREA(J)*SUM2/100.0
      SAREA(J)=PAREA(J)*AREA/100.0
   50 SUM3=SUM3+PERIM(J)*SROUGH(J)**2
      ROUGH=(SUM3**0.5)/(SUM2**0.5)
      IF(SALPHA(1).LE.0.0)GO TO 70
      SUM4=0.0
      SUM5=0.0
      DO 60 J=1,NX2
      CONV(J)=(1.49*SAREA(J)*(SAREA(J)/PERIM(J))**0.666)/SROUGH(J)
      SUM4=SUM4+(SALPHA(J)*CONV(J)**3)/(SAREA(J)**2)
   60 SUM5=SUM5+(CONV(J)**3/SAREA(J)**2)
      ALPHA=SUM4/SUM5
      GO TO 80
   70 ALPHA=1.0
    1 FORMAT(5X,I5)
    2 FORMAT(10X,7F10.2)
    3 FORMAT(10X,F10.2,2F10.5)
    4 FORMAT(5X,I5,F10.2)
   80 RETURN
      END
```

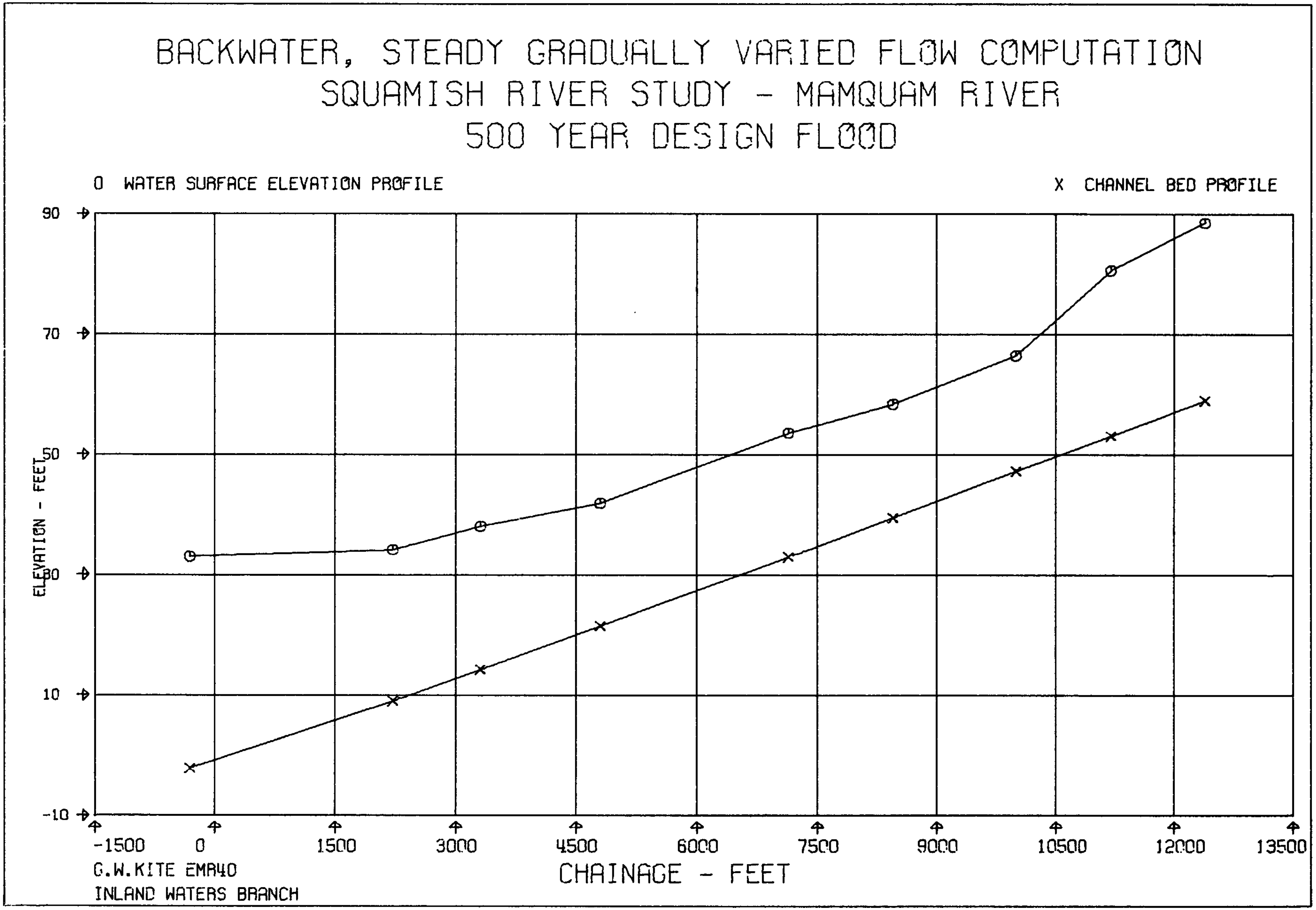


Figure 4: Straight Line Plot: Backwater Curve

Job Set-up CDC 3100

```
Column 1          Column 10

7
9JOB,J           (Job number and programmer's initials)
7
9EQUIP, 01        = MTC0E0U01
7
9EQUIP, 56        = MTC1E0U01
7
9EQUIP, 21        = 56
7
9EQUIP, 55        = MTC1E0U00
7
9EQUIP, 20        = 55
7
9FORTRAN, L, X

Source Deck

                  FINIS

7
9LOAD, 56

Object Deck

7
9RUN

Input Data for Main.
Plot Control Cards.

77
88
```

Submission Form

DEPT. MINES & TECHNICAL SURVEYS

COMPUTING REQUEST

NAME DIVISION	G.W. Kite, Engineering, Inland Waters
Estimated run time	30 Minutes
FOR C.S.D. USE	SEQ
Agency. Code	
Tel. No.	
JOB NO.	J55000
Date, time needed	
PROGRAM	
Reserved time	[ ]
STD. JOB	[ ]
PLOT	[x]
Language	Fortran IV
Source	[x]
Obj.	[ ]
Production 0 / Test 1 / Rerun 2	0
IN	Date / Time
OUT	Date / Time

DISPOSAL INSTRUCTIONS

Will collect [x] See overleaf [ ]

Suitable for running at Northern Electric: Yes [ ] No [x]

QUANTITIES

Cards		Print		Plot	
In	500	Est. No. Pages	10		12 plots + dummy
Est. Out		Act. No. Pages		Inches	150
Act. Out					

Complete [ ] Aborted [ ]

Actual run time

Initials of opr. ______

Fold back along this line

COMPLETE THE LOWER HALF OF THE FORM FOR ALL NON-STANDARD JOBS.

NON-STANDARD JOB REQUIREMENTS

OPERATING INSTRUCTIONS

Standard [ ] Standing Order [ ] Attached [ ]

Programmer attendance is requested [ ]

The only non-standard feature is the estimated run time [ ]

Operator Comment

OUTPUT SPECS.

Card
Electro ______
Colour ______
Cut ______

Print
Form ______
Parts ______
Loop ______
Burst [ ]
Decollate [ ]

Tape Tpt.	Work	Input	File identification or reel number	Cycle	Output	Release
01						
02						
20						
21						
00			S Y S T E M S			

Plot Pen 0.3 mm Stock No. ______ Ink black

Example 1a: Time Series fitted with a Least Squares Straight Line -Crustal Movement.

The essential data read in for this program are arrays of mean monthly lake elevations as observed at different stations around a lake's perimeter. The computer calculates for each year of observation at each station, the four-monthly mean elevation from June to September.

Using the first station read in as a base, the annual differences in this mean elevation are computed for the base station minus each "slave" station. This results in several time series of differences in mean elevations.

For each series of differences a least squares line of best fit is computed; this being the average rate of crustal movement between the two stations.

The program then plots each annual difference and joins the points with straight lines, finally superimposing the least squares line. Printed output is also given; and for each pair of stations a list of statistical parameters is given together with the calculated rate of crustal movement in feet per century.

```
C                                      PROGRAM NO. 29
C
C                        DEPARTMENT OF ENERGY, MINES AND RESOURCES
C                                INLAND WATERS BRANCH
C                                      OTTAWA
C
C
C                                  CRUSTAL MOVEMENT
C
C                                  GREAT LAKES BASIN
C
C
      PROGRAM CRUST
      COMMON K(10),L(10),T1(10),T2(10),T3(10),DIFF(100),SLOPE(10),
     1CONST(10),KARAY(25),T4(10)
      DIMENSION E(10,100)
      INTEGER T1,T2,T3,T4
      JI=60
      JO=61
      WRITE(JO,205)
      WRITE(JO,220)
      WRITE(JO,221)
      READ(JI,201) N
C*****************************************************************
C     N           NUMBER OF STATIONS TO BE COMPUTED
C*****************************************************************
      DO 10 I=1,N
      READ(JI,203) T1(I),T2(I),T3(I),T4(I)
C*****************************************************************
C     T1,T2 ETC ALPHAMERIC GAUGE TITLE
C*****************************************************************
      READ(JI,202) K(I),L(I)
C*****************************************************************
C     K,L         LOWER AND UPPER YEARS OF DATA RANGE
C*****************************************************************
      KK=1
      LL=L(I)-K(I)+1
      DO 10 J=KK,LL
      READ(JI,204)A,B,C,D
C*****************************************************************
C     A B C D     MEAN MONTHLY ELEVATIONS, JUNE TO SEPTEMBER
C*****************************************************************
      IA=A
      IB=B
      IC=C
      ID=D
      IF(IA)112,112,113
  113 IF(IB)112,112,114
  114 IF(IC)112,112,115
  115 IF(ID)112,112,116
  116 E(I,J)=(A+B+C+D)/4.0
C*****************************************************************
C     E           MEAN JUNE TO SEPT. ELEVATION
C*****************************************************************
      GO TO 10
  112 E(I,J)=0.0
   10 CONTINUE
      DO 40 I=2,N
      IF(I-7)110,111,110
  111 WRITE(JO,205)
  110 SDIFF=0.0
      SYRS=0.0
      SDDS=0.0
      SDYS=0.0
      SCP=0.0
      IF((L(I)-K(I))-(L(1)-K(1)))101,102,102
```

```
  101 IJK=1
C*********************************************************************
C       IJK         AN INDICATOR
C*********************************************************************
        KK=1
        LL=L(I)-K(I)+1
        SUMZ=0.0
        DO 60 J=KK,LL
        NO=(K(I)-K(1))+J
        IF(E(1,NO))117,117,118
  118   IF(E(I,J))117,117,119
  117   DIFF(J)=100.0
        SUMZ=SUMZ+1.0
        GO TO 60
  119   DIFF(J)=E(1,NO)-E(I,J)
C*********************************************************************
C       DIFF        DIFFERENCE IN ELEVATION BETWEEN TWO STATIONS
C*********************************************************************
        SDIFF=SDIFF+DIFF(J)
C*********************************************************************
C       SDIFF       SUM OF DIFFERENCES OVER L-K YEARS
C*********************************************************************
        SYRS=SYRS+J
C*********************************************************************
C       SYRS        SUM OF YEARS
C*********************************************************************
   60   CONTINUE
        GO TO 301
  102   IJK=0
        K1=1
        L1=L(1)-K(1)+1
        SUMZ=0.0
        DO 55 J=K1,L1
        NO=(K(1)-K(I))+J
        IF(E(1,J))120,120,121
  121   IF(E(I,NO))120,120,122
  120   DIFF(J)=100.0
        SUMZ=SUMZ+1.0
        GO TO 55
  122   DIFF(J)=E(1,J)-E(I,NO)
        SDIFF=SDIFF+DIFF(J)
        SYRS=SYRS+J
   55   CONTINUE
  301   IF(IJK-1)103,104,105
  103   RANGE=L(1)-K(1)+1-SUMZ
C*********************************************************************
C       RANGE       NUMBER OF YEARS OF DATA AVAILABLE
C*********************************************************************
        XK=K(1)-1
        GO TO 32
  104   RANGE=L(I)-K(I)+1-SUMZ
        XK=K(I)-1
   32   DBAR=SDIFF/RANGE
C*********************************************************************
C       DBAR        MEAN ANNUAL DIFFERENCE IN ELEVATION
C*********************************************************************
        YBAR=SYRS/RANGE
C*********************************************************************
C       YBAR        MEAN YEAR
C*********************************************************************
        YBAR=YBAR+XK
        WRITE(JO,206) T1(1),T2(1),T3(1),T4(1),T1(I),T2(I),T3(I),T4(I)
        WRITE(JO,229)
        WRITE(JO,228)RANGE
        WRITE(JO,224)DBAR,YBAR
        YBAR=YBAR-XK
        IF(IJK-1)106,107,105
```

```
  106 K1=1
      L1=L(1)-K(1)+1
      DO 50 J=K1,L1
      IF(DIFF(J)-100.0)124,50,126
  124 XJ=J
      DDS=DIFF(J)-DBAR
C*****************************************************************
C     DDS         (DIFFERENCE - MEAN DIFFERENCE)
C*****************************************************************
      DYS=XJ-YBAR
C*****************************************************************
C     DYS         (YEAR - MEAN YEAR)
C*****************************************************************
      CP=DDS*DYS
C*****************************************************************
C     CP          PRODUCT OF DDS AND DYS
C*****************************************************************
      DDS=DDS**2
      DYS=DYS**2
      SDDS=SDDS+DDS
C*****************************************************************
C     SDDS        SUM OF DDS SQUARED OVER L-K YEARS
C*****************************************************************
      SDYS=SDYS+DYS
C*****************************************************************
C     SDYS        SUM OF DYS SQUARED OVER L-K YEARS
C*****************************************************************
      SCP=SCP+CP
C*****************************************************************
C     SCP         SUM OF CP OVER L-K YEARS
C*****************************************************************
   50 CONTINUE
      GO TO 302
  107 KK=1
      LL=L(I)-K(I)+1
      DO 56 J=KK,LL
      IF(DIFF(J)-100.0)125,56,126
  125 XJ=J
      DDS=DIFF(J)-DBAR
      DYS=XJ-YBAR
      CP=DDS*DYS
      DDS=DDS**2
      DYS=DYS**2
      SDDS=SDDS+DDS
      SDYS=SDYS+DYS
      SCP=SCP+CP
   56 CONTINUE
  302 STDD=(SDDS/RANGE)**0.5
C*****************************************************************
C     STDD        STANDARD DEVIATION OF THE DIFFERENCES IN ELEVATION
C*****************************************************************
      STDY=(SDYS/RANGE)**0.5
C*****************************************************************
C     STDY        STANDARD DEVIATION OF THE YEARS
C*****************************************************************
      CC=(SCP/RANGE)/(STDD*STDY)
C*****************************************************************
C     CC          CORRELATION COEFFICIENT
C*****************************************************************
      SLOPE(I)=CC*STDD/STDY
C*****************************************************************
C     SLOPE       PRINCIPAL COMPONENTS SLOPE FOR ELEVATION DIFFERENCES
C     CONST       ≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠INTERCEPT≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠
C*****************************************************************
      YBAR=YBAR+XK
      IF(IJK-1)400,410,400
  410 CONST(I)=DBAR-SLOPE(I)*(YBAR-K(I))
```

```
      GO TO 420
  400 CONST(I)=DBAR-SLOPE(I)*(YBAR-K(1))
  420 CONTINUE
      RATE=SLOPE(I)*100.0
C*********************************************************************
C     RATE       RATE OF CHANGE IN THE DIFFERENCE IN ELEVATION PER 100 YE
C*********************************************************************
      WRITE(JO,208)STDD,STDY
      WRITE(JO,222)CC
      WRITE(JO,218) SLOPE(I),CONST(I)
      WRITE(JO,207) RATE
      CALL AXISXY(01,14.0,10.5,10.0,140.0,105.0,1850.0,-52.5,1860.0,0.0,
     12.5)
      CALL PLOTXY(1840.0,-55.0,0,10)
      CALL PLOTXY(1840.0,+55.0,1,10)
      CALL PLOTXY(1995.0,+55.0,1,10)
      CALL PLOTXY(1995.0,-55.0,1,10)
      CALL PLOTXY(1840.0,-55.0,1,0)
      CALL PLOTXY(1848.0,-54.0,0,0)
      CALL PLOTXY(1848.0,+54.0,1,0)
      CALL PLOTXY(1994.0,+54.0,1,0)
      CALL PLOTXY(1994.0,-54.0,1,0)
      CALL PLOTXY(1848.0,-54.0,1,0)
      CALL PLOTXY(1850.0,-50.0,0,0)
      CALL PLOTXY(1990.0,-50.0,1,0)
      VAR=1990.0
      DO 100 IYZ=1,13
      CALL PLOTXY(VAR,-50.0,0,29)
      CALL PLOTXY(VAR,+30.0,1,0)
      VAR=VAR-10.0
  100 CONTINUE
      VAR=-40.0
      DO 200 IYZ=1,8
      IF(IYZ-5)199,200,199
  199 CALL PLOTXY(1860.0,VAR,0,0)
      CALL PLOTXY(1990.0,VAR,1,0)
  200 VAR=VAR+10.0
      CALL PLOTXY(1987.5,-52.5,0,0)
      ENCODE(4,209,KARAY(1))
      CALL LABEL(4,2,0,KARAY(1))
      CALL PLOTXY(1956.5,-52.5,0,0)
      ENCODE(4,227,KARAY(1))
      CALL LABEL(4,2,0,KARAY(1))
      CALL PLOTXY(1926.0,-52.5,0,0)
      ENCODE(5,213,KARAY(1))
      CALL LABEL(5,2,0,KARAY(1))
      CALL PLOTXY(1896.5,-52.5,0,0)
      ENCODE(4,226,KARAY(1))
      CALL LABEL(4,2,0,KARAY(1))
      CALL PLOTXY(1866.5,-52.5,0,0)
      ENCODE(4,210,KARAY(1))
      CALL LABEL(4,2,0,KARAY(1))
      CALL PLOTXY(1851.0,-49.5,0,0)
      ENCODE(5,225,KARAY(1))
      CALL LABEL(5,2,0,KARAY(1))
      CALL PLOTXY(1880.0,-46.0,0,0)
      ENCODE(21,230,KARAY(1))
      CALL LABEL(21,1,0,KARAY(1))
      CALL PLOTXY(1880.0,-48.0,0,0)
      ENCODE(9,231,KARAY(1))
      CALL LABEL(9,1,0,KARAY(1))
      CALL PLOTXY(1852.5,0.5,0,0)
      ENCODE(4,211,KARAY(1))
      CALL LABEL(4,2,0,KARAY(1))
      CALL PLOTXY(1852.5,49.5,0,0)
      ENCODE(4,212,KARAY(1))
      CALL LABEL(4,2,0,KARAY(1))
```

```
      CALL PLOTXY(1880.0,48.0,0,0)
      ENCODE(36,214,KARAY(1))
      CALL LABEL(36,3,0,KARAY(1))
      CALL PLOTXY(1880.0,45.0,0,0)
      ENCODE(43,215,KARAY(1))
      CALL LABEL(43,2,0,KARAY(1))
      CALL PLOTXY(1880.0,42.5,0,0)
      ENCODE( 39,216,KARAY(1))T1(1),T2(1),T3(1),T4(1),T1(I),T2(I),T3(I),
     1T4(I)
      CALL LABEL(39,2,0,KARAY(1))
      CALL PLOTXY(1880.0,40.0,0,0)
      ENCODE(44,217,KARAY(1))RATE
      CALL LABEL(44,2,0,KARAY(1))
      CALL PLOTXY(1855.0,-35.0,0,0)
      ENCODE(18,223,KARAY(1))
      CALL LABEL(18,2,3,KARAY(1))
      CALL PLOTXY(1855.0,+08.0,0,0)
      ENCODE(17,232,KARAY(1))
      CALL LABEL(17,2,3,KARAY(1))
      CALL PLOTXY(1860.0,0.0,0,0)
      IRANGE=RANGE+SUMZ
      ICHANGE=0
      DO 58 J=1,IRANGE
      DIFF(J)=DIFF(J)*100.0
      IF(DIFF(J)-10000.0)135,58,126
  135 IF(DIFF(J)-37.5)58,136,136
  136 ICHANGE=1
   58 CONTINUE
      IF(ICHANGE-1)137,138,137
  138 DO 59 J=1,IRANGE
   59 DIFF(J)=DIFF(J)-15.0
      CALL PLOTXY(1880.0,37.5,0,0)
      ENCODE(35,234,KARAY(1))
      CALL LABEL(35,2,0,KARAY(1))
      CONST(I)=CONST(I)-0.15
  137 CONTINUE
      IF(IJK-1)108,109,105
  108 P1=K(1)
      J=1
      K1=2
      L1=L(1)-K(1)+1
      IF(DIFF(J)-10000.0)151,152,152
  151 CALL PLOTXY(P1,DIFF(J),0,15)
      GO TO 153
  152 CALL PLOTXY(P1,0.0,0,0)
  153 DO 53 J=K1,L1
      P2=J+K(1)-1
      J1=J-1
      IF(DIFF(J1)-10000.0)127,129,126
  127 IF(DIFF(J)-10000.0)130,128,126
  130 CALL PLOTXY(P2,DIFF(J),1,0)
      GO TO 53
  128 CALL PLOTXY(P2,0.0,0,0)
      GO TO 53
  129 CALL PLOTXY(P2,DIFF(J),0,15)
   53 CONTINUE
      CONST(I)=CONST(I)*100.0
      SLOPE(I)=SLOPE(I)*100.0
      GO TO 303
  109 P1=K(I)
      J=1
      KK=2
      LL=L(I)-K(I)+1
      IF(DIFF(J)-10000.0)251,252,252
  251 CALL PLOTXY(P1,DIFF(J),0,15)
      GO TO 253
  252 CALL PLOTXY(P1,0.0,0,0)
```

```
253 DO 57 J=KK,LL
    P2=J+K(I)-1
    J1=J-1
    IF(DIFF(J1)-10000.0)131,132,126
131 IF(DIFF(J)-10000.0)133,134,126
133 CALL PLOTXY(P2,DIFF(J),1,0)
    GO TO 57
134 CALL PLOTXY(P2,0.0,0,0)
    GO TO 57
132 CALL PLOTXY(P2,DIFF(J),0,15)
 57 CONTINUE
    CONST(I)=CONST(I)*100.0
    SLOPE(I)=SLOPE(I)*100.0
303 CALL PLOTXY(P1,CONST(I),0,0)
    Y=CONST(I)
    DO 70 M=1,IRANGE
    Y=Y+SLOPE(I)
    PP2=P1+M
    CALL PLOTXY(PP2,Y,1,0)
 70 CONTINUE
201 FORMAT(I10)
202 FORMAT(27X,I4,4X,I4,/////)
203 FORMAT(28X,4A4,/)
204 FORMAT(14X,4(6X,F7.2))
205 FORMAT(1H1)
206 FORMAT(1X,4A4,7H MINUS ,4A4)
207 FORMAT(20H RATE OF MOVEMENT IS,F6.3,19H FEET PER 100 YEARS,///)
208 FORMAT(8H STDD IS,11X,F6.2,10X,7HSTDY IS,7X,F6.2)
209 FORMAT(4H1990)
210 FORMAT(4H1870)
211 FORMAT(4H0.00)
212 FORMAT(4H0.50)
213 FORMAT(5HYEARS)
214 FORMAT(36HCRUSTAL MOVEMENT - GREAT LAKES BASIN)
215 FORMAT(43HDIFFERENCES IN FOUR-MONTHLY MEAN ELEVATIONS)
216 FORMAT( 4A4,7H MINUS , 4A4)
217 FORMAT(19HRATE OF MOVEMENT IS,F6.2,19H FEET PER 100 YEARS)
218 FORMAT(9H SLOPE IS,11X,F6.3, 9X,12HINTERCEPT IS,F8.2)
219 FORMAT(9H FAULTY Z)
220 FORMAT(37H CRUSTAL MOVEMENT - GREAT LAKES BASIN)
221 FORMAT(38H -------------------------------------,///)
222 FORMAT(27H CORRELATION COEFFICIENT IS,21X,F7.2)
223 FORMAT(18HDIFFERENCE IN MEAN)
224 FORMAT(19H MEAN DIFFERENCE IS,F6.2,10X,12HMEAN YEAR IS,F8.2)
225 FORMAT(5H-0.50)
226 FORMAT(4H1900)
227 FORMAT(4H1960)
228 FORMAT(15H DATA LENGTH IS,5X,F5.2,6H YEARS)
229 FORMAT(33H --------------------------------)
230 FORMAT(21H INLAND WATERS BRANCH)
231 FORMAT(9H G W KITE)
232 FORMAT(17HELEVATIONS - FEET)
233 FORMAT(20H ERROR IN DIFFERENCE)
234 FORMAT(35HMEAN DIFFERENCES REDUCED BY 0.15 FT)
    CALL PLOTXY(1990.0,0.50,0,9)
    CALL ENDPLOT(01)
    GO TO 40
105 WRITE(J0,219)
    GO TO 40
126 WRITE(J0,233)
 40 CALL ENDPLOT(01)
    CALL AXISXY(01,14.0,10.5,10.0,140.0,105.0,1850.0,-52.5,1860.0,0.0,
   15.0)
    CALL ENDPLOT(01)
    WRITE(J0,205)
    REWIND 01
    STOP
    END
```

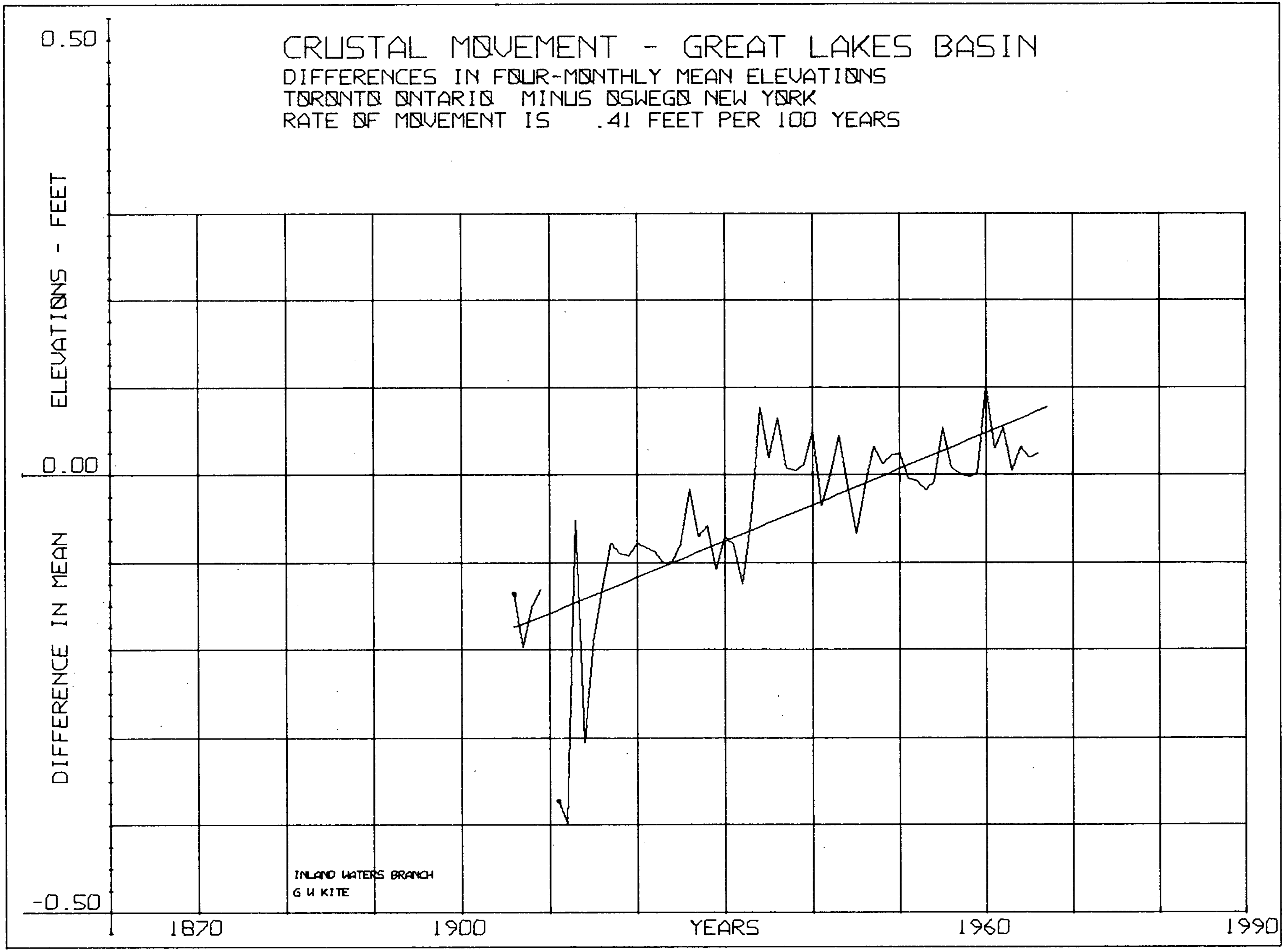


Figure 5: Time Series fitted with a Least Squares Straight Line: Crustal Movement

CRUSTAL MOVEMENT - GREAT LAKES BASIN

TORONTO ONTARIO MINUS KINGSTON ONTARIO

```
DATA LENGTH IS       57.00 YEARS
MEAN DIFFERENCE IS -0.08            MEAN YEAR IS 1937.98
STDD IS               .13           STDY IS        16.48
CORRELATION COEFFICIENT IS                           .87
SLOPE IS             .007           INTERCEPT IS   -0.28
RATE OF MOVEMENT IS  .662 FEET PER 100 YEARS
```

TORONTO ONTARIO MINUS OSWEGO NEW YORK

```
DATA LENGTH IS       60.00 YEARS
MEAN DIFFERENCE IS -0.05            MEAN YEAR IS 1936.43
STDD IS               .10           STDY IS        17.43
CORRELATION COEFFICIENT IS                           .74
SLOPE IS             .004           INTERCEPT IS   -0.17
RATE OF MOVEMENT IS  .413 FEET PER 100 YEARS
```

TORONTO ONTARIO MINUS PORT WELLER ONT.

```
DATA LENGTH IS       11.00 YEARS
MEAN DIFFERENCE IS    .06           MEAN YEAR IS 1961.00
STDD IS               .03           STDY IS         3.16
CORRELATION COEFFICIENT IS                           .11
SLOPE IS             .001           INTERCEPT IS     .06
RATE OF MOVEMENT IS  .091 FEET PER 100 YEARS
```

TORONTO ONTARIO MINUS COBOURG ONTARIO

```
DATA LENGTH IS       10.00 YEARS
MEAN DIFFERENCE IS -0.02            MEAN YEAR IS 1961.50
STDD IS               .02           STDY IS         2.87
CORRELATION COEFFICIENT IS                           .04
SLOPE IS             .000           INTERCEPT IS   -0.02
RATE OF MOVEMENT IS  .030 FEET PER 100 YEARS
```

TORONTO ONTARIO MINUS FORT NIAGARA ONT

```
DATA LENGTH IS       16.00 YEARS
MEAN DIFFERENCE IS -0.02            MEAN YEAR IS 1954.50
STDD IS               .03           STDY IS         4.61
CORRELATION COEFFICIENT IS                           .63
SLOPE IS             .004           INTERCEPT IS   -0.05
RATE OF MOVEMENT IS  .404 FEET PER 100 YEARS
```

```
TORONTO ONTARIO  MINUS ROCHESTER NY
--------------------------------
DATA LENGTH IS      17.00 YEARS
MEAN DIFFERENCE IS -0.00            MEAN YEAR IS 1951.82
STDD IS               .07           STDY IS         17.90
CORRELATION COEFFICIENT IS                            .32
SLOPE IS              .001          INTERCEPT IS    -0.06
RATE OF MOVEMENT IS  .129 FEET PER 100 YEARS


TORONTO ONTARIO  MINUS PT DALHOUSIE NY
--------------------------------
DATA LENGTH IS      52.00 YEARS
MEAN DIFFERENCE IS   .04            MEAN YEAR IS 1940.50
STDD IS               .03           STDY IS         15.01
CORRELATION COEFFICIENT IS                            .25
SLOPE IS              .000          INTERCEPT IS      .03
RATE OF MOVEMENT IS  .048 FEET PER 100 YEARS


TORONTO ONTARIO  MINUS CAPE VINCENT NY
--------------------------------
DATA LENGTH IS      51.00 YEARS
MEAN DIFFERENCE IS -0.03            MEAN YEAR IS 1941.00
STDD IS               .07           STDY IS         14.72
CORRELATION COEFFICIENT IS                            .70
SLOPE IS              .004          INTERCEPT IS    -0.12
RATE OF MOVEMENT IS  .358 FEET PER 100 YEARS


TORONTO ONTARIO  MINUS HAMILTON ONT.
--------------------------------
DATA LENGTH IS       6.00 YEARS
MEAN DIFFERENCE IS   .16            MEAN YEAR IS 1963.50
STDD IS               .01           STDY IS          1.71
CORRELATION COEFFICIENT IS                          -0.44
SLOPE IS            -0.003          INTERCEPT IS      .17
RATE OF MOVEMENT IS-0.264 FEET PER 100 YEARS
```

DURATION ANALYSIS

LAKE ONTARIO OUTFLOW -

FLOW - TCFS

PERCENT	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1.54	264	264	281	293	300	303	298	291	281	272	267	269
3.08	261	264	275	290	298	300	295	290	278	267	263	256
4.62	259	251	266	288	296	299	295	289	278	266	262	256
6.15	257	251	262	284	294	297	294	285	274	266	261	255
7.69	255	245	260	284	293	296	294	284	272	263	257	253
9.23	250	245	257	282	292	294	292	282	268	263	257	252
10.77	249	243	255	275	289	291	291	279	268	263	253	252
12.31	247	242	254	272	283	289	289	277	268	256	253	250
13.85	243	239	254	269	282	288	286	277	267	256	251	250
15.38	243	239	252	269	281	287	286	276	266	255	251	250
16.92	241	237	250	268	281	286	284	275	263	255	251	249
18.46	241	237	249	268	277	285	279	274	262	253	251	247
20.00	240	237	248	267	277	284	278	271	261	253	250	245
21.54	239	235	247	267	277	281	276	270	261	253	250	244
23.08	238	234	247	264	273	281	275	267	260	253	249	244
24.62	237	234	242	263	271	280	274	265	260	253	248	243
26.15	236	233	241	262	271	277	273	265	258	250	245	240
27.69	233	232	240	261	271	274	271	265	256	249	244	240
29.23	230	232	239	260	270	273	270	265	256	249	244	238
30.77	230	230	236	259	268	272	270	264	255	248	241	238
32.31	229	230	235	259	268	270	269	262	254	246	241	235
33.85	228	229	234	257	268	269	269	261	254	246	240	235
35.38	227	227	233	257	267	268	268	261	254	245	240	235
36.92	227	227	233	255	263	268	267	260	254	244	239	235
38.46	225	225	233	254	262	268	267	259	252	243	237	235
40.00	225	225	233	254	262	264	265	259	250	242	237	234
41.54	224	225	232	253	261	264	265	258	250	241	237	234
43.08	224	225	232	252	261	264	263	257	249	240	237	234
44.62	224	222	232	252	260	263	262	256	247	239	235	233
46.15	222	221	232	249	257	262	259	255	244	239	234	232
47.69	222	219	232	248	256	258	259	253	242	238	231	231
49.23	222	218	231	247	255	258	258	251	242	237	231	228
50.77	222	217	231	247	253	257	258	250	242	236	231	228
52.31	220	216	228	247	253	255	258	250	241	235	229	227
53.85	220	216	228	246	252	255	257	250	241	234	228	226
55.38	220	215	226	244	252	254	254	248	239	232	227	226
56.92	219	215	225	243	251	254	252	246	238	231	226	226
58.46	219	214	223	243	250	253	251	244	238	231	226	224
60.00	219	214	222	243	250	250	249	242	237	230	223	221
61.54	218	214	221	242	250	250	248	241	237	229	223	221
63.08	217	211	221	242	249	250	248	241	235	227	222	220
64.62	216	210	220	241	248	249	246	241	234	226	222	220
66.15	216	210	220	241	248	249	246	241	232	225	222	219
67.69	216	210	219	240	247	249	244	240	232	225	221	219
69.23	215	209	218	240	245	249	244	239	231	224	220	219
70.77	215	209	218	238	244	246	244	239	230	224	219	219
72.31	213	208	217	236	242	245	243	238	229	223	217	218
73.85	210	208	212	235	242	243	242	238	228	221	217	217

PERCENT	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
75.38	209	206	212	234	241	243	241	237	228	220	217	217
76.92	208	206	212	233	241	242	241	235	227	220	216	216
78.46	207	199	211	232	238	241	239	232	223	220	216	216
80.00	207	198	210	232	238	238	236	230	222	216	216	215
81.54	205	197	209	231	236	237	234	228	220	216	211	214
83.08	205	197	209	230	234	237	233	227	220	214	211	208
84.62	201	196	209	229	234	235	231	226	220	214	210	207
86.15	199	195	209	227	234	233	230	225	219	214	210	207
87.69	199	194	206	227	233	233	229	224	219	214	208	206
89.23	196	193	204	226	232	230	228	221	214	210	206	206
90.77	194	192	196	224	232	230	226	219	213	206	205	200
92.31	192	190	194	223	232	228	223	217	212	204	202	195
93.85	191	184	193	219	231	228	222	217	206	202	195	190
95.38	180	182	190	218	229	227	220	209	204	195	190	189
96.92	179	178	189	214	217	214	211	206	197	192	185	184
98.46	178	173	187	202	213	213	211	203	195	186	181	181
100.00	176	163	183	197	204	209	206	198	191	185	179	174

Example 2a: Point Plot -Duration Analysis.

Program DAPLOT is written in very general terms to read in a series of data, perform a duration analysis on the data and plot the results. In order to specify the output of the program several control cards are necessary.

The first data to be read in from a control card are the number of variables which are to be analysed and plotted and the number of values in each variable array. Next the plot format specifications are read in, and, on the final control card, the type of plot to be drawn is given. This last specification card controls the choice of scale for both axes of the plot. The abscissa, on which the variable probabilities are scaled, can have either a linear scale or a normal probability scale. The ordinate, on which the variable is scaled, can have either a linear or a logarithmic scale. This permits four combinations of scale:

1. Variable on a linear scale v. probability on a linear scale.

2. Variable on a linear scale v. probability on a normal scale.

3. Variable on a logarithmic scale v. probability on a linear scale.

4. Variable on a logarithmic scale v. probability on a normal scale.

The program then directs the computer to read in the required volume of data, perform the duration analysis, print out a table of results and then produce the required number of plots to the specified scales. Through the plot control cards it can be specified that all four scale combinations should be plotted for each variable.

At present the program is designed to read in mean monthly values of any variable, twelve months to a card; carry out the duration analysis on each month's data and then plot four graphs for each month in the order given above. The graphs with a linear probability scale are fitted with a least squares cubic curve while those with a normal probability scale are fitted with the theoretical straight line. This enables the engineer to see from the graphs and the accompanying statistical output whether the variable is normally distributed, log normally distributed or neither.

```
C                                  PROGRAM NO. 27
C
C                   DEPARTMENT OF ENERGY, MINES AND RESOURCES
C                             INLAND WATERS BRANCH
C                                    OTTAWA
C
C                            DURATION ANALYSIS PLOT
C
C
      PROGRAM DAPLOT
      DIMENSION KARAY(25),DATA(100,12),PCENT(100),T7(12),T8(12),T9(12),
     1TEMP(100),F(6),PCAL(100),TEMP2(100)
      INTEGER EXPUT,TYPE,T1,T2,T3,T4,T5,T6,T7,T8,T9,UNIT1,UNIT2
      COMMON DATA
      INPUT=60
      EXPUT=61
      READ(INPUT,99)UNIT1,UNIT2,LMT,IPLOT,NOPLOT
   99 FORMAT(5X,2A4,12X,3I5)
C*********************************************************************
C     UNIT        VARIABLE NAME AND UNITS                            *
C     LMT         MAXIMUM NUMBER OF VALUES OF THE VARIABLE           *
C     IPLOT       MONTH IN WHICH PLOTTING IS TO START                *
C     NOPLOT      NUMBER OF PLOTS REQUIRED                           *
C*********************************************************************
      READ(INPUT,100)LUN,XL,YL,XTIC,XLNG,YLNG,XMIN,YMIN,XORG,YORG,YTIC,N
  100 FORMAT(5X,I5,10F5.0,I5)
C*********************************************************************
C     LUN         LOGICAL UNIT NUMBER                                *
C     XL          LENGTH OF THE X AXIS IN INCHES                     *
C     YL          LENGTH OF THE Y AXIS IN INCHES                     *
C     XTIC        INTERVAL BETWEEN TICK MARKS ON THE X AXIS          *
C                 ( LOGICAL UNITS PER INCH )                         *
C     XLNG        LENGTH OF THE X AXIS IN LOGICAL UNITS              *
C     YLNG        LENGTH OF THE Y AXIS IN LOGICAL UNITS              *
C     XMIN        INITIAL POINT OF THE X AXIS IN LOGICAL UNITS       *
C     YMIN        INITIAL POINT OF THE Y AXIS IN LOGICAL UNITS       *
C     XORG        X AXIS ORIGIN IN LOGICAL UNITS                     *
C     YORG        Y AXIS ORIGIN IN LOGICAL UNITS                     *
C     YTIC        INTERVAL BETWEEN TICK MARKS ON THE Y AXIS          *
C                 ( LOGICAL UNITS PER INCH )                         *
C     N           NUMBER OF TICKS BETWEEN GRID LINES                 *
C*********************************************************************
      IXTIC=XTIC
      IYTIC=YTIC
      IYMIN=YMIN
      KK=(YLNG/YTIC)+1.0
      LL=(XLNG/XTIC)+1.0
      READ(INPUT,101)ISIZ,IDIR,IDIRY,IDIRX
  101 FORMAT(5X,4I5)
C*********************************************************************
C     ISIZ        INTEGER SIZE OF THE CHARACTERS TO BE PLOTTED       *
C                 ( IN 1/12 INCHES )                                 *
C     IDIR        DIRECTION OF THE CHARACTER LINE (1)                *
C     IDIRY       DIRECTION OF THE CHARACTER LINE (2)                *
C     IDIRX       DIRECTION OF THE CHARACTER LINE (3)                *
C*********************************************************************
      READ(INPUT,102)TYPE,ITYPE,JTYPE
  102 FORMAT(5X,3I5)
C*********************************************************************
C     TYPES OF PLOT                                                  *
C     TYPE=100    LINEAR ORDINATE SCALE                              *
C     TYPE=250    LOGERITHMIC ORDINATE SCALE                         *
C     ITYPE=350 NORMAL PROBABILITY ABSCISSA SCALE                    *
C     ITYPE=400 LINEAR ABSCISSA SCALE                                *
C     JTYPE=500 FIT A CUBIC CURVE                                    *
C     JTYPE=600 FIT A STRAIGHT LINE (N. PROB. ONLY)                  *
C*********************************************************************
```

```
      READ(INPUT,115)IT1,IT2,IT3,IT4,IT5,IT6
      READ(INPUT,115)T1,T2,T3,T4,T5,T6
  115 FORMAT(5X,6A4)
C**********************************************************************
C     IT1....   DATA SOURCE                                          *
C     T1.....   PLOT TITLE                                           *
C**********************************************************************
      DO 130 M=1,12
      READ(INPUT,116)T7(M),T8(M),T9(M)
  116 FORMAT(5X,3A4)
  130 CONTINUE
C**********************************************************************
C     T7...     MONTH TITLE                                          *
C**********************************************************************
      DO  40 L=1,LMT
      READ(INPUT,103)(DATA(L,M),M=IPLOT,NOPLOT)
  103 FORMAT(8X,12F6.0)
   40 CONTINUE
C**********************************************************************
C     THE ABOVE READ AND FORMAT STATEMENTS MUST BE ARRANGED          *
C     TO SUIT THE DATA USED                                          *
C**********************************************************************
      DO 5000 JZ=1,4
      DO 1000 JK=IPLOT,NOPLOT
      X1=XORG+3.200*XTIC
      X1A=XORG+5.100*XTIC
      Y1=YORG+5.834*YTIC
      Y1A=Y1-0.250*YTIC
      X2=X1
      Y2=Y1A-0.250*YTIC
      X3=X1
      Y3=Y2-0.250*YTIC
      X4=XORG+9.700*XTIC
      Y4=YORG-0.300*YTIC
      X5=XORG+9.400*XTIC
      Y5=Y4
      X6=XORG+1.500*XTIC
      Y6=YORG-0.600*YTIC
      X7=XORG-0.100*XTIC
      Y7=YORG+2.100*YTIC
      X8=XORG-0.500*XTIC
      Y8=YORG
      X9=X8
      Y9=YORG
      X10=XORG-0.650*XTIC
      Y10=YORG-0.900*YTIC
      X11=XORG+10.35*XTIC
      Y11=YORG+7.600*YTIC
      X12=XORG+0.200*XTIC
      Y12=YORG+0.795*YTIC
      X13=X12
      Y13=Y12-0.250*YTIC
      X14=X12
      Y14=Y13-0.250*YTIC
      X15=X12
      Y15=Y14-0.250*YTIC
C**********************************************************************
C     X,Y       CHARACTER PLOTTING POSITIONS                         *
C     1         PLOT TITLE(1)                                        *
C     2         PLOT TITLE(2)                                        *
C     3         PLOT TITLE(3)                                        *
C     4         ABSCISSA VALUE TITLES - LINEAR SCALE                 *
C     5         ABSCISSA VALUE TITLES - PROBABILITY SCALE            *
C     6         ABSCISSA TITLE                                       *
C     7         ORDINATE TITLE                                       *
C     8         ORDINATE VALUE TITLES - LOGFRITHMIC SCALE            *
C     9         ORDINATE VALUE TITLES - ARITHMETIC SCALE             *
```

```
C     10           FRAME COORDINATES(1)                                        *
C     11           FRAME COORDINATES(2)                                        *
C     12           STATISTICAL OUTPUT TITLE(1)                                 *
C     13           STATISTICAL OUTPUT TITLE(2)                                 *
C     14           STATISTICAL OUTPUT TITLE(3)                                 *
C     15           STATISTICAL OUTPUT TITLE(4)                                 *
C***********************************************************************
      IF(ITYPE-400)201,202,201
  202 XX3=30.0
      LINE=8
      GO TO 203
  201 XX3=31.8
      X1=X1+0.2*XTIC
      X2=X1
      X3=X1
      X1A=X1A+0.2*XTIC
      LINE=9
  203 IF(TYPE-250)204,205,204
  205 YY2=281.171
      Y1=Y1+0.250*YTIC
      Y1A=Y1-0.250*YTIC
      Y2=Y1A-0.250*YTIC
      Y3=Y2-0.250*YTIC
      Y12=Y12+0.15*YTIC
      Y13=Y12-0.250*YTIC
      Y14=Y13-0.250*YTIC
      Y15=Y14-0.250*YTIC
      GO TO 206
  204 YY2=275.0
  206 CONTINUE
      CALL AXISXY(LUN,XL,YL,XLNG, XLNG,YLNG,XMIN,YMIN,XORG,YORG,YLNG, N)
      CALL PLOTXY(X1,Y1,0,0)
      ENCODE(22,110,KARAY(1))
      CALL LABEL(22,ISIZ,IDIR,KARAY(1))
  110 FORMAT(22HDURATION ANALYSIS PLOT)
      CALL PLOTXY(X1,Y1A,0,0)
      ENCODE(11,449,KARAY(1))
      CALL LABEL(11,ISIZ,IDIR,KARAY(1))
  449 FORMAT(11HPLOT TYPE -)
      CALL PLOTXY(X1A,Y1A,0,0)
      IF(TYPE+ITYPE-450)401,401,402
  401 ENCODE(18,450,KARAY(1))
      CALL LABEL(18,ISIZ,IDIR,KARAY(1))
  450 FORMAT(18HNORMAL PROBABILITY)
      GO TO 407
  402 IF(TYPE+ITYPE-500)403,403,404
  403 ENCODE( 6,451,KARAY(1))
      CALL LABEL( 6,ISIZ,IDIR,KARAY(1))
  451 FORMAT( 6HLINEAR)
      GO TO 407
  404 IF(TYPE+ITYPE-600)405,405,406
  405 ENCODE(10,452,KARAY(1))
      CALL LABEL(10,ISIZ,IDIR,KARAY(1))
  452 FORMAT(10HLOG NORMAL)
      GO TO 407
  406 ENCODE(08,453,KARAY(1))
      CALL LABEL(08,ISIZ,IDIR,KARAY(1))
  453 FORMAT(08HSEMI LOG)
  407 CONTINUE
      CALL PLOTXY(X2,Y2,0,0)
      ENCODE(24,124,KARAY(1))IT1,IT2,IT3,IT4,IT5,IT6
      CALL LABEL(24,ISIZ,IDIR,KARAY(1))
  124 FORMAT(6A4)
      CALL PLOTXY(X3,Y3,0,0)
      ENCODE(36,113,KARAY(1))T1,T2,T3,T4,T5,T6,T7(JK),T8(JK),T9(JK)
      CALL LABEL(36,ISIZ,IDIR,KARAY(1))
```

```
 113 FORMAT(9A4)
     CALL PLOTXY(X7,Y7,0,0)
     ENCODE(11,123,KARAY(1))UNIT1,UNIT2
     CALL LABEL(11,ISIZ,IDIRY,KARAY(1))
 123 FORMAT(A4,3H - ,A4)
     CALL PLOTXY(X6,Y6,0,0)
     ENCODE(43,122,KARAY(1))
     CALL LABEL(43,ISIZ,IDIR,KARAY(1))
 122 FORMAT(43HPROBABILITY OF EQUALITY OR EXCEEDENCE - PCT)
     XX6=XORG+100.50
     YY6=YORG+50.0
     CALL PLOTXY(XX6,YY6,0,0)
     ENCODE(12,139,KARAY(1))JZ,JK
 139 FORMAT(7HFIGURE ,I2,1H-,I2)
     CALL LABEL(12,ISIZ,IDIRX,KARAY(1))
     DO 1003 K=1,LMT
1003 TEMP(K)=DATA(K,JK)
     CALL SORTX(LMT,TEMP)
     DO 3030 K=1,LMT
3030 DATA(K,JK)=TEMP(K)
     XLMT=LMT
     DO 1521 K=1,LMT
     XK=K
1521 PCENT(K)=(XK/XLMT)*100.0
     CALL MULREG(LMT,PCENT,TEMP,C,B2,B3,B4,YBAR,SIGY,COVAR,COSKEW)
     CALL PLOTXY(X12,Y12,0,0)
     ENCODE(36,454,KARAY(1))YBAR
     CALL LABEL(36,ISIZ,IDIR,KARAY(1))
 454 FORMAT(13HMEAN VALUE IS,17X,F6.1)
     CALL PLOTXY(X13,Y13,0,0)
     ENCODE(36,455,KARAY(1))SIGY
     CALL LABEL(36,ISIZ,IDIR,KARAY(1))
 455 FORMAT(21HSTANDARD DEVIATION IS,9X,F6.1)
     CALL PLOTXY(X14,Y14,0,0)
     ENCODE(36,456,KARAY(1))COVAR
     CALL LABEL(36,ISIZ,IDIR,KARAY(1))
 456 FORMAT(27HCOEFFICIENT OF VARIATION IS,   F9.3)
     CALL PLOTXY(X15,Y15,0,0)
     ENCODE(36,457,KARAY(1))COSKEW
     CALL LABEL(36,ISIZ,IDIR,KARAY(1))
 457 FORMAT(22HCOEFFICIENT OF SKEW IS,5X,F9.3)
     IF(TYPE-250)500,501,500
 501 ISCALE=IYMIN
     XX5=XORG+100.0
     YY1=Y8
     TEMP1=YMIN/ (ALOG10(YLNG+YMIN)-ALOG10( YMIN))
     DO 20 I=1,KK
     IF(I-3)151,152,153
 153 IF(I-4)151,152,151
 151 CALL PLOTXY(X8,YY1,0,0)
     ENCODE(3,125,KARAY(1))ISCALE
     CALL LABEL(3,ISIZ,IDIR,KARAY(1))
 125 FORMAT(I3)
 152 IF(I-7)135,136,136
 136 XX5=XX3
 135 CALL PLOTXY(XORG,YY1,0,0)
     CALL PLOTXY(XX5,YY1,1,0)
     ISCALE=ISCALE+IYTIC
     SCALE=ISCALE
     YY1=((ALOG10( SCALE)-ALOG10( YMIN))*TEMP1)+YMIN
     IF(I-1)20,472,20
 472 FCOUNT=YY1
  20 CONTINUE
     GO TO 460
 500 IY=IYMIN
     YY1=Y9
```

```
      XX2=XORG+100.0
      DO 30 I=1,KK
      IF(I-3)128,129,128
  129 YY1=YY1-5.0
  128 IF(I-4)163,164,163
  163 CALL PLOTXY(X9,YY1,0,0)
      ENCODE(3,127,KARAY(1))IY
      CALL LABEL(3,ISIZ,IDIR,KARAY(1))
  127 FORMAT(I3)
  164 IF(I-3)131,132,131
  132 YY1=YY1+5.0
  131 IF(I-1)177,178,177
  177 CALL PLOTXY(XORG,YY1,0,0)
      IF(I-7)179,181,181
  179 CALL PLOTXY(XX2,YY1,1,0)
      GO TO 178
  181 CALL PLOTXY(XX3,YY1,1,0)
  178 IY=IY+IYTIC
      YY1=YY1+YTIC
   30 CONTINUE
  460 IF(ITYPE-350)143,144,143
  144 SLOPE=4.66*SIGY
      DIFF3=SLOPE/2.0
      F(1)=YBAR+DIFF3
      F(2)=YBAR-DIFF3
      IVAR=100
      C0=2.515517
      C1=0.802853
      C2=0.010328
      D1=1.432788
      D2=0.189269
      D3=0.001308
      DO 1007 K=1,11
      YY4=YORG
      XIVAR=IVAR
      P=XIVAR/100.0
      YLIN=F(1)-SLOPE*P
      IF(IVAR-50)801,802,802
  802 P=1.0-P
  801 IF(IVAR-100)806,807,806
  806 IF(IVAR)808,807,808
  807 T=0.0
         GO TO 809
      808 T=(ALOG(1.0/(P**2)))**0.5
      809 YNOR=T-(C0+C1*T+C2*T**2)/(1.0+D1*T+D2*T**2+D3*T**3)
          IF(IVAR-50)803,804,804
      804 YNOR=YBAR-(YNOR*SIGY)
          P=1.0-P
          GO TO 805
      803 YNOR=YBAR+(YNOR*SIGY)
      805 PCOL=1.0-((1.0-P)*(YNOR-F(2))/(YLIN-F(2)))
          PCOL=ABS(PCOL*100.0)
          IF(K-2)831,832,831
      832 F(6)=PCOL
      831 IF(K-10)833,834,833
      834 F(5)=PCOL
      833 PCOL=PCOL-3.0
          IF(K-11)720,721,720
      721 PCOL=-3.0
      720 IF(K-1)722,723,722
      723 PCOL=PCOL-1.5
      722 CONTINUE
          CALL PLOTXY(PCOL,Y4,0,0)
          ENCODE(3,112,KARAY(1))IVAR
          CALL LABEL(3,ISIZ,IDIR,KARAY(1))
          IF(K-5)724,725,725
      725 IF(TYPE-250)731,732,731
```

```
 732 YY4=FCOUNT
     GO TO 724
 731 YY4=YORG+YTIC
 724 IF(K-1)1014,1015,1014
1015 PCOL=PCOL+1.5
1014 PCOL=PCOL+3.0
     CALL PLOTXY(PCOL, YY4,0,0)
     IF(K-LINE)1008,1009,1009
1008 YY3=YY2
     GO TO 1010
1009 YY3=YORG+150.0
1010 CALL PLOTXY(PCOL,YY3,1,0)
     IVAR=IVAR-10
1007 CONTINUE
     GO TO 700
 143 XX1=X4
     YY1=YORG+150.0
     IVAR=100
     IVAR=100
     DO 10 I=1,LL
     YY5=YORG
     IF(I-1)137,138,137
 138 XX1=XX1-1.5
 137 CALL PLOTXY(XX1,Y4,0,0)
     ENCODE(3,112,KARAY(1))IVAR
 112 FORMAT(I3)
     CALL LABEL(3,ISIZ,IDIR,KARAY(1))
     IVAR=IVAR-IXTIC
     IF(I-1)142,141,142
 141 XX1=XX1+1.5
 142 XX1=XX1+3.0
     IF(I-6)726,727,727
 727 IF(ITYPE-250)728,729,728
 729 YY5=FCOUNT
     GO TO 726
 728 YY5=YORG+YTIC
 726 CALL PLOTXY(XX1,YY5,0,0)
     GO TO 147
 146 CALL PLOTXY(XX1,YY1,1,0)
 147 XX1=XX1-XTIC-3.0
  10 CONTINUE
 700 DO 140 KL=1,2
     CALL PLOTXY(X10,Y10,0,0)
     CALL PLOTXY(X10,Y11,1,0)
     CALL PLOTXY(X11,Y11,1,0)
     CALL PLOTXY(X11,Y10,1,0)
     CALL PLOTXY(X10,Y10,1,0)
     X10=X10+1.0
     Y10=Y10+3.0
     X11=X11-0.75
     Y11=Y11-25.0
 140 CONTINUE
     X10=X10-2.0
     Y10=Y10-6.0
     X11=X11+1.5
     Y11=Y11+50.0
     DF=XLMT/(XLMT+1.0)
     DO 70 K=1,LMT
     IND1=0
     IF(TYPE-250)600,200,600
 200 TEMP2(K)=((ALOG10(TEMP(K))-ALOG10( YMIN))*TEMP1)+YMIN
     GO TO 1030
 600 TEMP2(K)=TEMP(K)
1030 IF(ITYPE-350)1020,1021,1020
1021 PCENT(K)=(PCENT(K)/100.0)*DF
     YLIN=F(1)-SLOPE*PCENT(K)
     IF(PCENT(K)-0.50)901,902,902
```

```
 902 PCENT(K)=1.0-PCENT(K)
     IND1=10
 901 IF(PCENT(K))906,907,906
 906 T=(ALOG(1.0/(PCENT(K)**2)))**0.5
     GO TO 908
 907 T=0.0
 908 YNOR=T-(C0+C1*T+C2*T**2)/(1.0+D1*T+D2*T**2+D3*T**3)
     IF(IND1-10)903,904,903
 904 YNOR=YBAR-(YNOR*SIGY)
     PCENT(K)=1.0-PCENT(K)
     GO TO 905
 903 YNOR=YBAR+(YNOR*SIGY)
 905 PCLL=1.0-((1.0-PCENT(K))*(YNOR-F(2))/(YLIN-F(2)))
     PCAL(K)=PCLL*100.0
     GO TO 1022
1020 PCAL(K)=PCENT(K)
1022 IF(K-LMT)80,90,80
  80 IF(TEMP(K)-TEMP(K+1))90,70,90
  90 CALL PLOTXY(PCAL(K),TEMP2(K),0,15)
  70 CONTINUE
     IF(JTYPE-500)1750,1001,810
1001 E=4.0
     CALL MULREG(LMT,PCAL,TEMP2,C,B2,B3,B4,YBAR,SIGY,COVAR,COSKEW)
     DO 1002 KLM=1,47
     D=C+B2*E+B3*E**2+B4*E**3
     IF(KLM-1)1004,1005,1004
1005 CALL PLOTXY(E,D,0,0)
     GO TO 1002
1004 CALL PLOTXY(E,D,1,0)
1002 E=E+2.0
 810 IF(JTYPE-600)1750,1200,1750
1200 F(3)=YBAR+1.28174*SIGY
     F(4)=YBAR-1.28174*SIGY
     IF(TYPE-250)811,812,811
 812 F(3)=((ALOG10(F(3))-ALOG10(YMIN))*TEMP1)+YMIN
     F(4)=((ALOG10(F(4))-ALOG10(YMIN))*TEMP1)+YMIN
 811 CALL PLOTXY (F(5),F(3),0,0)
     CALL PLOTXY (F(6),F(4),1,0)
1750 CALL PLOTXY(XLNG,YORG,0,0)
1000 CALL ENDPLOT(LUN)
     IF(JZ-1)1500,1510,1500
1510 TYPE=250
     GO TO 5000
1500 IF(JZ-2)5000,1520,1530
1520 TYPE=100
     ITYPE=350
     JTYPE=600
     GO TO 5000
1530 TYPE=250
5000 CONTINUE
     WRITE(EXPUT,104)
 104 FORMAT(1H1)
     WRITE(EXPUT,105)
 105 FORMAT(36X,17HDURATION ANALYSIS,/)
     WRITE(EXPUT,106)T1,T2,T3,T4,T5,T6
 106 FORMAT(33X,6A4,/)
     WRITE(EXPUT,107)UNIT1,UNIT2
 107 FORMAT(40X,A4,3H - ,A4,/)
     WRITE(EXPUT,108)
 108 FORMAT(1X,7HPERCENT,2X,3HJAN,3X,3HFEB,2X,5HMARCH,2X,5HAPRIL,2X,
    13HMAY,3X,4HJUNE,2X,4HJULY,2X,3HAUG,3X,4HSEPT,2X,3HOCT,3X,3HNOV,
    23X,3HDEC,/)
     DO 300 K=1,LMT
     XK=K
     XLMT=LMT
     PCENT(K)=(XK/XLMT)*100.0
```

```
      WRITE(EXPUT,114)PCENT(K),(DATA(K,L),L=1,12)
  114 FORMAT(1X,F7.2,12(1X,F5.0))
      IF(K-48)300,305,300
  305 WRITE(EXPUT,104)
      WRITE(EXPUT,108)
  300 CONTINUE
      WRITE(EXPUT,104)
      CALL AXISXY(LUN,XL,YL,XTIC,XLNG,YLNG,XMIN,YMIN,XORG,YORG,YTIC,N)
      CALL ENDPLOT(LUN)
      REWIND 01
      STOP
      END
```

3200 FORTRAN DIAGNOSTIC RESULTS - FOR DAPLOT

NO ERRORS

```
      SUBROUTINE MULREG(N,X,Y,C,B2,B3,B4,YBAR,STGY,COVAR,COSKEW)
C     MULTIPLE REGRESSION  SUBROUTINE
C
C
      DIMENSION X(100),Y(100),X2(100),X3(100),XX1(100),YY1(100),XX2(100)
     1,XX3(100)
C*****************************************************************************
C     N                NUMBER OF COORDINATE PAIRS OF POINTS                  *
C     X,Y          VARIABLE NAMES                                           *
C     C,B2,B3,B4       CONSTANTS IN THE DERIVED REGRESSION EQUATION          *
C                      Y = C + B2*X + B3*X**2 + B4*X**3                      *
C*****************************************************************************
      SUMY=0.0
      SUMX1=0.0
      SUMX2=0.0
      SUMX3=0.0
      SUMYY1=0.0
      SUMXX1=0.0
      SUMXX2=0.0
      SUMXX3=0.0
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
      SUM6=0.0
      SUM7=0.0
      DO 100 K=1,N
      SUMY=SUMY+Y(K)
      X2(K)=X(K)**2
      X3(K)=X(K)**3
      SUMX1=SUMX1+X(K)
      SUMX2=SUMX2+X2(K)
      SUMX3=SUMX3+X3(K)
  100 CONTINUE
      XN=N
      YBAR=SUMY/XN
      X1BAR=SUMX1/XN
      X2BAR=SUMX2/XN
      X3BAR=SUMX3/XN
      DO 200 K=1,N
      YY1(K)=Y(K)-YBAR
      SUMYY1=SUMYY1+YY1(K)**2
      XX1(K)=X(K)-X1BAR
      SUMXX1=SUMXX1+XX1(K)**2
      XX2(K)=X2(K)-X2BAR
```

```
      SUMXX2=SUMXX2+XX2(K)**2
      XX3(K)=X3(K)-X3BAR
      SUMXX3=SUMXX3+XX3(K)**2
      SUM1=SUM1+(YY1(K)*XX1(K))
      SUM2=SUM2+(XX1(K)*XX2(K))
      SUM3=SUM3+(XX1(K)*XX3(K))
      SUM4=SUM4+(YY1(K)*XX2(K))
      SUM5=SUM5+(XX2(K)*XX3(K))
      SUM6=SUM6+(YY1(K)*XX3(K))
      SUM7=SUM7+((Y(K)/YBAR)-1.0)**3
  200 CONTINUE
      SIGY=(SUMYY1/N)**0.5
      COVAR=SIGY/YBAR
C
      COSKEW=SUM7/((N-1)*COVAR**3)
      B=SUM2*SUM3-SUM5*SUMXX1
      A=SUM2**2-SUMXX1*SUMXX2
      E=SUM2*SUM1-SUM4*SUMXX1
      F=SUM3**2-SUMXX1*SUMXX3
      G=SUM3*SUM1-SUM6*SUMXX1
      B4=(B*E-A*G)/(B**2-A*F)
      B3=(E-B4*B)/A
      B2=(SUM1-B3*SUM2-B4*SUM3)/SUMXX1
      C=YBAR-B2*X1BAR-B3*X2BAR-B4*X3BAR
      RETURN
      END
```

3200 FORTRAN DIAGNOSTIC RESULTS - FOR   MULREG

NO ERRORS

```
      SUBROUTINE SORTX (N,XX)
      DIMENSION XX(100)
C*********************************************************************
C     SORT AN ARRAY OF FLOATING POINT VARIABLES IN DESCENDING ORDER
C     N=NUMBER OF VARIABLES
C     XX=VARIABLE TO BE SORTED
C*********************************************************************
      K=(N-1)
      DO 2 L=1,K
      M=(N-L)
      DO 2 J=1,M
      IF (XX(J)-XX(J+1)) 1,2,2
    1 XTEMP=XX(J)
      XX(J)=XX(J+1)
      XX(J+1)=XTEMP
    2 CONTINUE
      RETURN
      END
```

3200 FORTRAN DIAGNOSTIC RESULTS - FOR   SORTX

NO ERRORS
LOAD,56
RUN

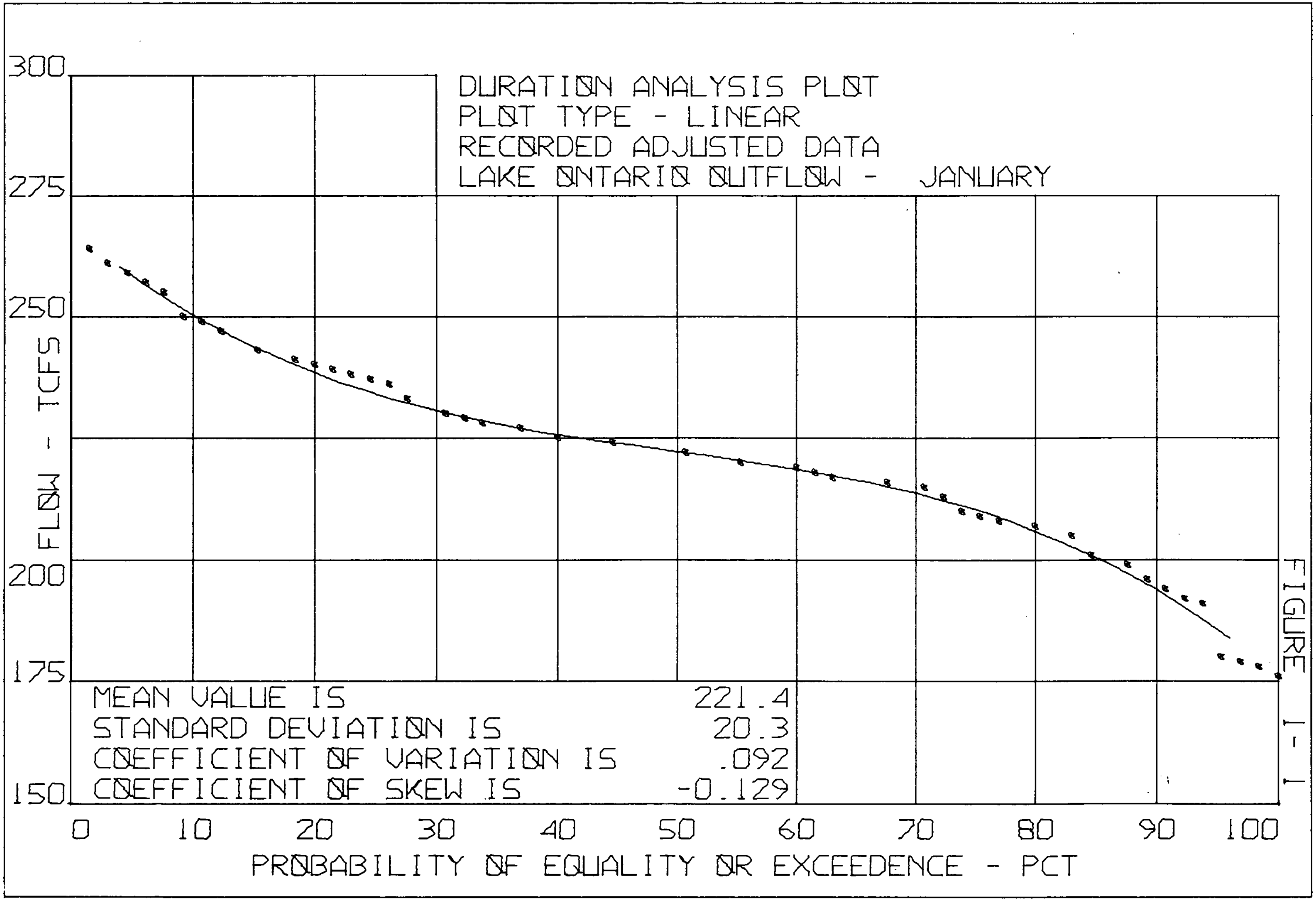


Figure 6: Plotting on various axis scales - Duration Analysis

(a) Smooth Curve Plotting: linear scale

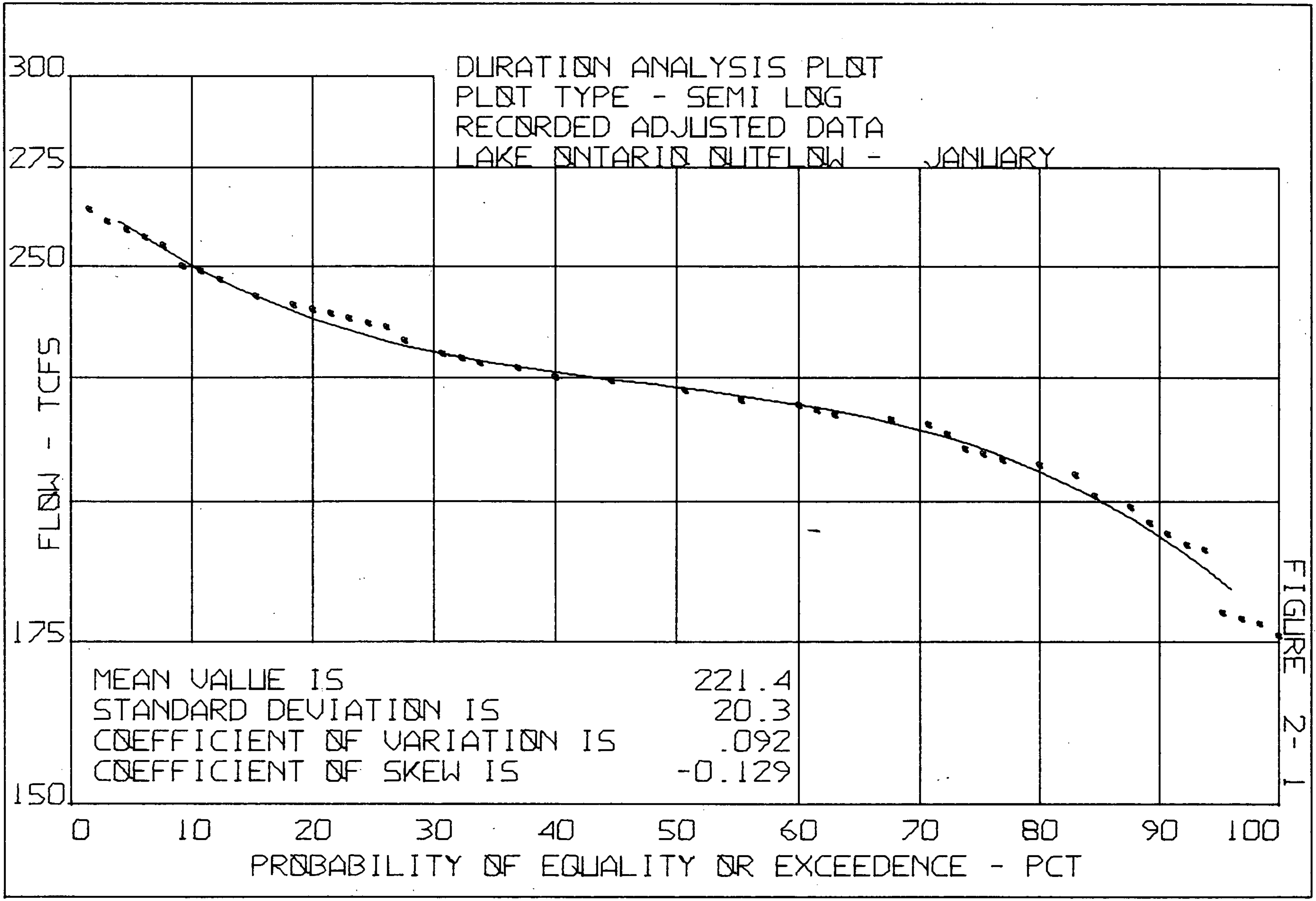


Figure 6: Plotting on various axis scales - Duration Analysis

(b) Smooth Curve Plotting: semi-log scale

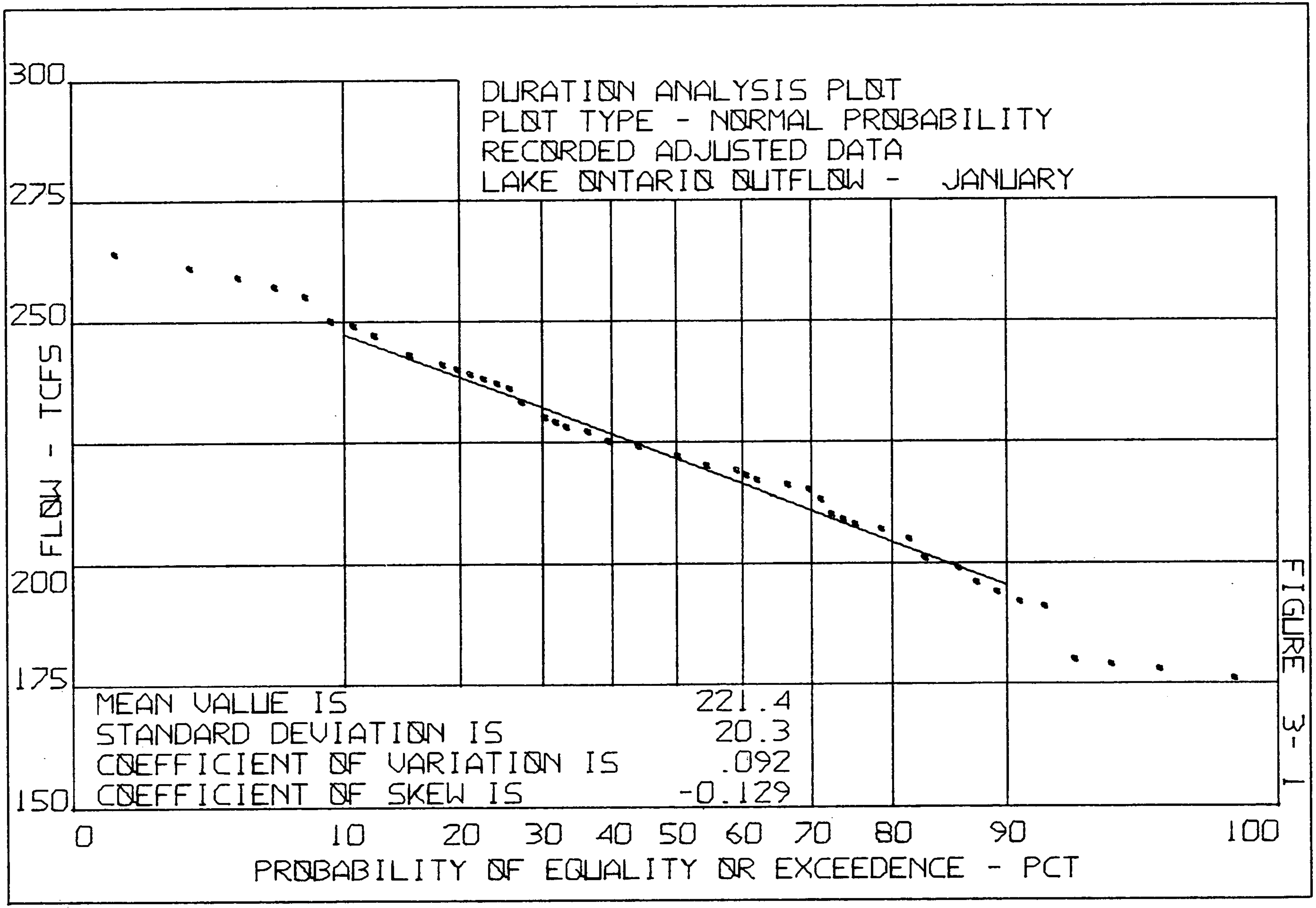


Figure 6: Plotting on various axis scales - Duration Analysis

(c) Straight Line Plotting: normal probability scale

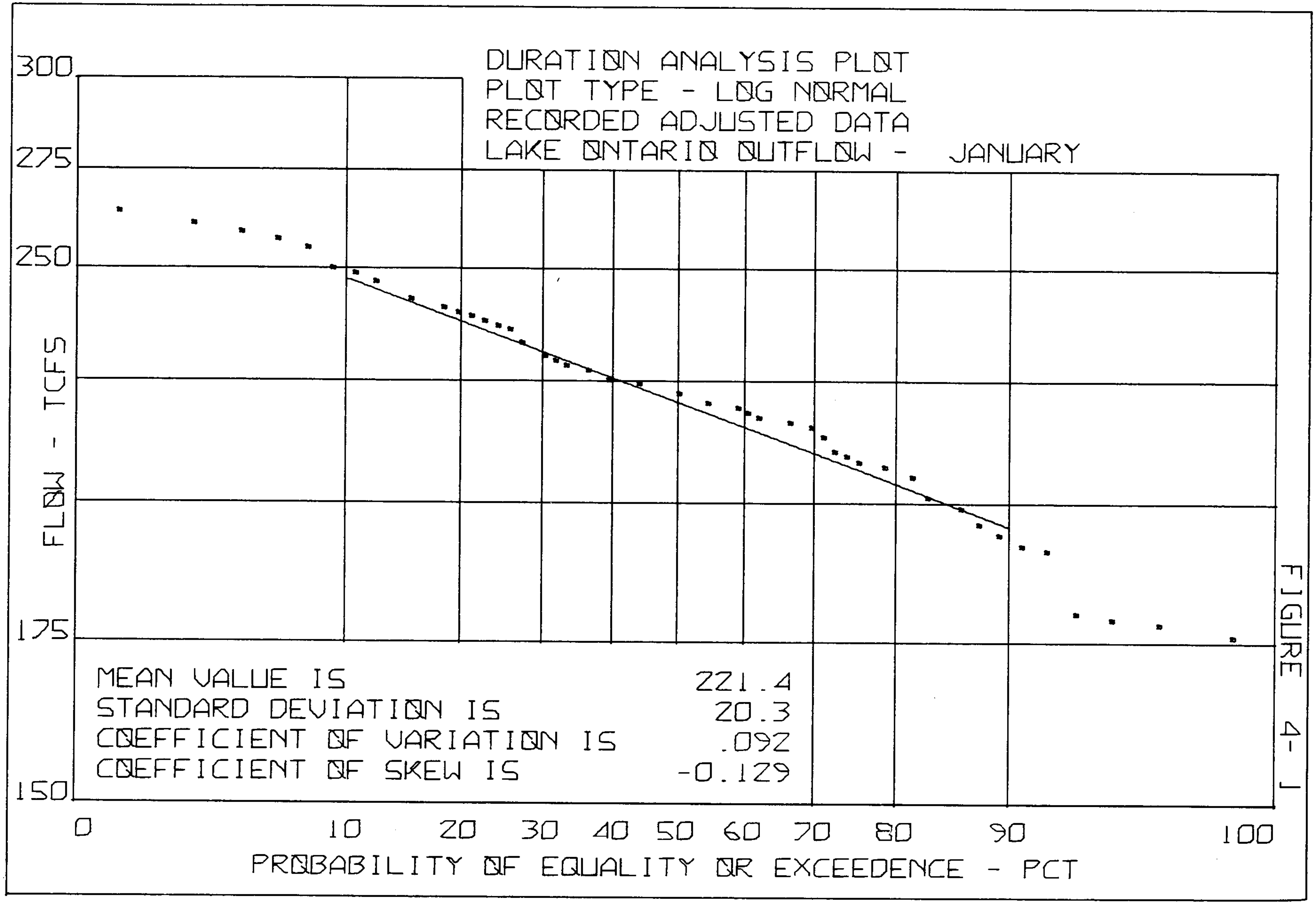


Figure 6: Plotting on various axis scales - Duration Analysis

(d) Straight Line Plotting: log-normal scale

FUTURE DEVELOPMENTS

This bulletin outlines the present development of plotter programs in the Engineering Division of the Inland Waters Branch. The possibilities of the plotter are enormous however, and further development of programs is planned. The following programs are now written but not tested:-

(a) Three dimensional plot; this program is written to draw, on the one graph, hydrographs of all the Great Lakes for inflows, outflows or elevations. The "third dimension" comes in in spacing each lake hydrograph and slightly to the right of the previous lake's hydrograph as in a draftsman's oblique projection drawing. On looking at the graph this will appear as a series of spaced "waves" and an insight into the complex relationships between elevations and flows in adjacent lakes may be obtained.

(b) River flood routing; using the Muskingum method, this program will route floods through rivers taking account of wedge storage and local inflow.

(c) Hydrograph with confidence limits; this program will plot, for any variable, a hydrograph in the form of a histogram of long term mean values together with confidence limits placed at one standard deviation either side of the mean. This will enable such concepts as deviation, variation and skew to be demonstrated visually.

In addition, the following programs are in the planning stage and will shortly be written and key-punched for use on the 360-663 computer-plotter combination:-

(d) Flood Frequency; this program will be written to plot extreme value distributions using both Gumbel's method and the method of maximum likelihood.

(e) Dam burst; in the problem of a dam burst or the sudden opening of a sluice gate, a negative surge wave of progressively varying shape is produced. This program will trace the successive shape of the wave through a time period.

Development of programs for the plotter can be continued as long as hydrologic problems remain to be solved. In the future it is likely that the form of the plotter itself may change. At present the plotting is entirely mechanical, program statements being translated into mechanical lengthwise movement of the paper and crosswise movement of the pen across the paper.

An immediate difficulty to be overcome with all plotters is the development of a suitable pen. Standard equipment now is the Rapidograph, an ordinary drafting pen. Even at the speed of manual drafting this pen is far from perfect; sometimes it floods, sometimes it dries up. At the very much faster speeds of mechanical plotting it is very difficult to obtain an even flow of ink and so the pen often skips small sections of the plot. Ball point pens are often used on the plotters but these also skip and do not produce as dark a plot as liquid ink, which in practice means that they do not reproduce as well. Both types of pen are usually discarded as worn out after between one and two hours plotting.

Another difficulty which occasionally arises is paper slippage. On the drum type plotter the paper is moved forward by projections on the drums engaging in holes in the paper. Since these projections are of polished metal it is possible for the paper to slip off a projection, particularly if the paper is warped or stretched. If the slippage is only one or two projections, perhaps half an inch, it will not be noticed until the programmer carefully checks each plot and perhaps not even then. To guard against this, it is advisable to order the plotter to mark the paper before any serious plotting is attempted and then when the plot is finished, order the plotter to print a second mark coincident with the first. If the paper has moved during the plot the two marks will be separated by a distance equal to the paper shift. If the paper has not moved then the marks will be exactly coincident.

In the less immediate future there would seem to be the possibility of replacing the mechanical plotter with some form of electronic plotter combined with a means of transferring the image from a cathode-ray tube onto paper, maybe by some electrostatic technique. This would result in more rapid plotting with none of the uncertainties of mechanical linkages and liquid pens.

Control Data Corporation of California does in fact produce an electronic plotter. This forms the graph on a cathode-ray tube which is then photographed using a rapid sequence camera. About 200 plots per minute can be photographed and a waiting period of only twenty minutes is required before the finished photographic prints are available. The machine is, however, very costly and its capacity far exceeds the requirements of most users. It is being used to speed up written output from computers whose output is in the hundreds of pages or more. A conventional line printer will type up to 600 lines per minute, say 10 pages per minute. Putting sixty lines of output at a time onto a cathode-ray tube in the CDC machine, up to 200 pages per minute can be cleared from storage.

A more basic electrical plotter is also available which uses a carbon electrode instead of a pen and uses a two part paper made up of a normal thin sheet of paper backed by some conducting material such as aluminum foil. A current is passed through the carbon electrode which burns through the paper forming the required graph.

It is not envisaged, however, that the plotter will ever reach the stage where a person will whisper a few magic words into the plotter and have the plotter automatically produce an art piece; as has been implied in advertisements by some of the plotter manufacturers.

In conclusion, a few economic facts should be mentioned;

(a) key-punching of data costs approximately $5 per 100 cards

(b) use of input/output devices on the IBM 360-65 costs about $55 per hour

(c) use of the main computer at 50,000 units of storage averages around $200 per hour

(d) the plotter use costs between $20 and $30 per hour depending on the speed of the plotter

Converting a program to plotter output will add approximately 30 cards to the program, about one and one-half minutes extra computer time and usually about ten minutes on the digital plotter per plot, adding up to an approximate cost of $12.00 for the first plot. Additional plots add on to this figure only the actual plotting time at 50 cents a minute so the more plots that are to be produced the more economical the use of the plotter becomes.

Further copies of this bulletin may be obtained by writing to:

Director,
Inland Water Branch,
Department of Energy,
Mines and Resources,
588 Booth Street,
Ottawa, Ont.

TECHNICAL BULLETIN SERIES

No. 1 Natural flow of North Saskatchewan River at Alberta - Saskatchewan boundary by the rim station method. E. P. Collier and A. Coulson, October 1965.*

Discusses methods of estimating the natural flow of the North Saskatchewan River at the provincial boundary by simple regression with the flow at Rocky Mountain House and also by multiple regression techniques involving precipitation.

No. 2 LACOR - Program for streamflow correlation. R. O'N. Lyons, November 1965.*

A program for the IBM 1620 computer to correlate streamflow records in terms of deviations in log units from the geometric mean of each calendar month's discharges.

No. 3 Tables for computing and plotting flood frequency curves. A. Coulson, 1966.

A compilation of tables for the computation and plotting of flood frequency curves according to the first asymptotic distribution of extreme values (the Gumbel method). A worked example of the use of the tables is included.

No. 4 Flood frequencies of Nova Scotia streams. A. Coulson, 1967.*

Recorded flood flows have been analysed on a regional basis and a method for estimating the flood frequency curve for any stream in Nova Scotia is outlined.

No. 5 Measurement of the physical characteristics of drainage basins. A. Coulson and P. N. Gross, 1967.

Methods of obtaining quantitative descriptions of certain physical characteristics of drainage basins are outlined using as examples Marmot Creek and Streeter Creek two of the experimental basins of the East Slopes (Alberta) Watershed Research Program.

No. 6 Hydrologic zones in the headwaters of the Saskatchewan River. D. A. Davis and A. Coulson, 1967.

The Saskatchewan River headwaters area of Alberta has been divided into seven by hydrologically similar zones, based on correlations of mean monthly recorded stream discharge.

No. 7 Estimating runoff in Southern Ontario. A. Coulson, 1967.

Methods of estimating the runoff and its distribution in ungauged streams or in streams with short periods of record in the area of Southern Ontario south of the Canadian shield.

No. 8 Tables for computing and plotting drought frequency curves. W. Q. Chin, 1967.

A compilation of tables for the computation and plotting of low flow frequency curves by both the third asymptotic distribution and the Pearson Type III distribution. Worked examples are included.

No. 9 Flood Frequency analysis for the New Brunswick - Gaspé region. E. P. Collier and G. A. Nix.

Presents a method of estimating the flood frequency curve from basin characteristics for any stream in a large part of New Brunswick and the Gaspé area of Quebec.

No. 10 Diefenbaker Lake - Effects of bank erosion on storage capacity. R. O. Van Everdingen.

Discussion of the factors causing bank erosion on Diefenbaker Lake and their effect on the storage capacity of the lake.

* Out of print. Photo copies will be provided, if requested.