DP-1

FLOOD FREQUENCY ANALYSIS USING POWER TRANSFORMATION

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CONTENTS

ABSTRACT

The purpose of the programme is (1) to transform the given independent and homogeneous annual maximum peak flood series to near normal distribution using Box-Cox transformation and (2) to perform frequency analysis on this near normally distributed series using method of moments for estimating 50,100,200,500,1000, and 10000 years return period floods using two approaches viz.,(a) based on the criteria of coefficient of skewness is nearly zero and (b) based on the criteria that coefficient of skewness is nearly zero and coefficient of kurtosis equal to 3.0. The documentation describes in brief the methodology adopted for transformation and necessity for correction of kurtosis of the transformed series. The programme is written in FORTRAN-IV. The input variable and input card description are detailed in the documentation. The documentation also lists the example input and the output generated by the programme.

1.0 INTRODUCTION

The objective of frequency analysis is to derive from the limited sample data, design events useful in practice. An assumption must be made of a theoretical frequency distribution which fits the population events and the statistical parameters of the distribution must be computed from the sample data. Instead of assuming a known distribution to fit the data, it is better to transform the data to a particular distribution of known characteristics and then analyse the transformed series. Since the properties of a normal distribution are completely defined, it is a common procedure to transform the given data to normal distribution. Power transformation or Box-Cox transformation (Box and Cox, 1964) is one of the procedures available for transforming the given data series to near normalization. The application of this procedure to flood frequency analysis has been found successful (Chander et.al.,1978). The computer program documented here performs flood frequency analysis using annual maximum series data after transforming it to near normalization by the power transformation method.

2.0 PURPOSE OF THF PROGRAMME

The purpose of the program is

(1) to transform the given independent and homogeneous annual maximum flood peak series to near normal distribution using power transformation and

(2) to perform frequency analysis on this near normally distributed series using method of moments for estimating 50,100,200,500, 1000 and 10000 years return period floods based on two approaches viz., (a) the coefficient of skewness is nearly zero and (b)the coefficient of skewness is nearly zero as well as coefficient of kurtosis equal to 3.00.

3.0 METHOD USED

The near normal distribution of the given annual peak flood series is obtained using power transformation, the form of which is given as:

$$Z_i = \frac{X_i^{\lambda} - 1}{\lambda} \quad \text{for } \lambda \neq 0 \qquad \dots (1)$$

$$Z_i = \ln X_i \quad \text{for } \lambda \to 0$$

where

X_i = the variate of the original series.

Z_i = the transformed series and

λ = an exponent which near normalizes the series.

The near normalization is considered to be achieved when the coefficient of skewness (CS) of the transformed series approaches zero. The unbiased coefficient of skewness of the sample data is computed as:

$$CS = \frac{N}{(N-1)(N-2)} \left[\frac{\sum_{i=1}^{N} (Z_i - \bar{Z}_i)^3}{S^3} \right] \qquad \dots (2)$$

in which,

S = Sample standard deviation

Z_i = the power transformed variate

$\bar{Z}_i$ = the mean of the power transformed variates.

N= the sample size

The mean of Z series is computed as:

$$\bar{Z}_i = \frac{1}{N} \sum_{i=1}^{N} Z_i \qquad \dots (3)$$

The standard deviation S is computed as:

$$S = \frac{1}{(N-1)} \left[\sum_{i=1}^{N} (Z_i - \bar{Z}_i)^2 \right]^{1/2} \qquad \dots (4)$$

In this program, when $|CS| \leqslant 0.001$, it is assumed that near normality is achieved. The exponent, λ which near normalizes the data series is obtained by grid search technique. The grid search technique is used to find out λ based on the criterion that there is a systematic variation of CS for variation in λ.

The transformed series is said to be near normally distributed as the coefficient of kurtosis (CK) of the transformed series may be near to, but not equal to 3.0 as required for normal distribution. The unbiased coefficient of kurtosis of the sample data is computed as:

$$CK = \frac{N^2}{(N-1)(N-2)(N-3)} \left[\frac{\sum_{i=1}^{N} (Z_i - \bar{Z}_i)^4}{S^4} \right] \quad \ldots (5)$$

Correction procedure is available(Box and Tiao,1973) for computing the standard normal deviates taking into consideration, the deviation of CK of the transformed series away from 3.0. The program invariably computes the estimates of different recurrence intervals based on this kurtosis correction procedure.

Statistical estimates of the near normalized series are computed for the required return period and it is transformed to the original domain using the following expression:

$$X_T = (Z_T \lambda + 1)^{1/\lambda} \quad \ldots \; (6)$$

where, X_T and Z_T are the flood peak magnitudes in the original and the transformed domain respectively.

Although log transformation is a particular case of power transformation, its identification through Box-Cox transformation may lead to computational difficulties due to the required division of the quantity$(X^{\lambda}-1)$ by λ ,which is nearly equal to zero. Therefore provision is made in the program to compute, invariably, the log transformation of the series for the purpose of computing flood peak estimates for 50,100,200,500,1000 and 10000 year return periods.

3.1 The Goodness of Fit Test:

The goodness of fit test is evaluated by the most commonly used Chi-square test procedure. There are two methods available to compute the Chi-square statistic viz.,(1) equal class interval method and (2) equal probability method. In this program the equal probability method is adopted. The observed data are grouped into NCLASS classes. The number of classes, NCLASS is supplied by the user. The Chi-square statistic is computed as:

$$\chi^2_\alpha = \sum_{i=1}^{NCLASS} \left[\frac{(f_{oi} - f_{ei})^2}{f_{ei}} \right] \quad \ldots(7)$$

in which,

f_{oi} = the observed frequency in the ith class interval.

f_{ei} = the expected frequency in the ith class interval.

α = the level of significance at which the distribution fitting the data is being tested.

The program only computes the χ^2 statistic. It is left to the user for verifying the goodness of fit.

4.0 COMPUTER PROGRAMME

The computer program developed at National Institute of Hydrology is given in this document. The program was tested at VAX 11/780 computer system available at NIH. The memory requirement of this program is 15600 bytes and the CPU time required for compilation is 19.65 secs. The CPU time required for running the program is 4.92 secs.

The program consists of a main program and six subroutines. Subroutine ARI computes the mean, the unbiased standard deviation, the unbiased coefficient of skewness and the unbiased coefficient of kurtosis. Subroutine SEQ arranges the data series in ascending order and assigns the corresponding years of occurrence against each arranged data. Subroutines SPLINE and AKIMA are used for interpolation. These subroutines are adapted from HEC-1 flood hydrograph package. Subroutine CHIST computes the Chi-square statistic based on equal probability criterion for each class interval. Subroutine NDTRI is adapted from IBM's Scientific Subroutine Package. This subroutine computes the standard normal deviate and the corresponding ordinate of the normal distribution for the given probability of non-exceedence.

The computer program is given in APPENDIX-I.

5.0 INPUT SPECIFICATION AND OUTPUT DESCRIPTION

The input variable description is given below:

Variable	Description
N	Number of annual maximum values to be analysed.
NCLASS	Number of classes used in the Chi-square test
RI	Recurrence interval for which flood estimate are made.
DL	Grid size used in the search method for determining the power transformation exponent which near normalizes the series.
IYEAR	Year corresponding to the annual maximum series.
X	The annual maximum series.

5.1 Input Cards:

Two input cards are required. They are read in the free format although they can be modified in the user required format. The form in which the data to be supplied is as follows:

Card 1

N, NCLASS, RI(1), RI(2), RI(3), RI(4), RI(5), RI(6), DL(1), DL(2),DL(3)

Card 2

IYEAR(1), IYEAR(2),........,IYEAR(N),

X(1), X(2),....... X(N)

5.2 Output Description

The output tabulates the original series in chronological order along with years and then it arranges them in ascending order of magnitude along with the corresponding year of occurrence. It assigns the rank to them according to the ascending order and computes the probability of non-exceedences of these events using Blom's plotting position. Plotting positions are written, in case the user wishes to display the original series and the corresponding power transformed series in a normal probability paper for the purpose of eye fit. Then the statistical parameters of the series are written. These tabulations are made for original, log transformed and power transformed series in their respective domains. Chi-square statistic values are written for log transformed as well as power transformed series. The recurrence intervals of 50,100,200,500,1000 and 10000 years, and the corresponding flood estimates using log transformed and the power transformed series are displayed. The tabular contents required for kurtosis correction are also written.

6.0 EXAMPLE

The preparation of an example input consisting of annual maximum peak flow series is given below as per the required format. The data was extracted from the following source:

Varshney, R.S." Engineering Hydrology", Nem Chand and Brothers, Roorkee(U.P.).

The input informations required for Card 1 is given below:

The number of years of annual peak flow series, N = 77

The number of class intervals used in Chi-square test, NCLASS=12

The recurrence intervals for which the flood magnitudes are to be estimated are RI(1) = 50; RI(2) = 100; RI(3) = 200; RI(4) = 500; RI(5)= 1000; RI(6) = 10000.

The grid sizes used in grid search technique for estimating the exponent are DL(1)=0.1; DL(2)=0.01; DL(3)= 0.001.

The card 1 input is typed as below

77, 8, 50, 100, 200, 500, 1000, 10000, 0.1, 0.01, 0.001.

The input information required for card 2 is given below:

The year of occurrence of the given magnitude of flood viz. IYEAR(1), IYEAR(2), ...IYEAR(77).

The peak flood series arranged in chronological order viz. X(1), X(2), ...X(77).

The card 2 input is typed as below:

1901, 1902,......., 1977, 11400, 9250,......,5710.

The test input and the corresponding test output of the program are given in APPENDIX II and III respectively.

7.0 RECOMMENDATIONS

The programme uses the grid search technique to estimate the power transformation exponent. As there is a systematic variation in the coefficient of skewness of the transformed series for different values of λ, this could be used to find λ in a somewhat more efficient manner by using the Newton-Raphson technique.

REFERENCES

1. Box,G.E.P., and D.R.Cox(1964)," An Analysis of Transformations", Journal of the Royal Statistical Society, Vol.B.26,pp.211-252.
2. Box,G.E.P., and G.C.Tiao(1973)," Bayesian Inference in Statistical Analysis", Addison Wiesley Publishing Co., New York, pp.156-160.
3. Chander,S., S.K.Spolia and Arun Kumar (1978),"Flood Frequency Analysis by Power Transformation", Journal of the Hydraulics Division, ASCE,Vol.104,No.HY 11, November, pp.1495-1504.

APPENDIX-I : POWER TRANSFORMATION PROGRAMME

```
C      THIS PROGRAM PERFORMS THE FLOOD FREQUENCY ANALYSIS OF
C      ANNUAL MAXIMUM SERIES USING LOG TRANSFORMATION AND
C      POWER TRANSFORMATION (BOX-COX TRANSFORMATION),ASSUMING
C      THE TRANSFORMED SERIES FOLLOWS THE NORMAL DISTRIBUTION
C
C      X        =ANNUAL MAXIMUM SERIES
C      Y        =POWER TRANSFORMED ANNUAL MAXIMUM SERIES
C      Z        =LOG TRANSFORMED ANNUAL MAXIMUM SERIES ARRANGED
C                IN DESCENDING ORDER
C      DL       =GRID SIZE USED IN THE SEARCH METHOD FOR DETER-
C                MINING THE EXPONENT ,LAMDA WHICH NEAR NORMALISES
C                THE SERIES
C      SK       =ARRAY FOR STORING KURTOSIS VALUES
C      X1       =ARRAY FOR STORING THE ANNUAL MAXIMUM SERIES IN
C                CHRONOLOGICAL ORDER
C      P        =PROBABILITY USING BLOM'S PLOTTING POSITION
C                FORMULA

C      IYEAR  =YEAR CORRESPONDING TO THE ANNUAL MAXIMUM VALUES
C      ALPHA  =TABLE OF STANDARD NORMAL DEVIATES CORRECTED FOR KURTOSIS
C      ALPHAS =TEMPORARY ARRAY FOR STORING ALPHA
C      ALINPI =ARRAY OF INTERPOLATED STANDARD NORMAL DEVIATES
C               CORRESPONDING TO THE DIFFERENT PROBABILITY OF
C               EXCEEDENCE LEVEL
C      IYEAR1 =ARRAY OF YEARS IN CHRONOLOGICAL ORDER
C      X2       =TABLE OF DEVIATION OF THE COEFFICIENT OF KURTOSIS
C                VALUES AWAY FROM 3.00
C      Y2       =TABLE OF CORRECTION FACTORS CORRESPONDING TO X2
C      Z1       =LOG TRANSFORMED FLOOD FLOW VALUES IN CHRONOLOGICAL
C                ORDER
C      Y1       =POWER TRANSFORMED FLOOD FLOW VALUES IN CHRONOLOGICAL
C                ORDER
C      RI       =RECURRENCE INTERVAL FOR WHICH FLOOD ESTIMATES ARE
C                MADE
C      TD       =STANDARD NORMAL DEVIATE OBTAINED FROM THE SUBROUTINE
C                NDTRI CORRESPONDING TO THE GIVEN PROBABILITY OF
C                EXCEEDENCE

C      ESTP     =ESTIMATED FLOOD PEAK USING POWER TRANSFORMATION
C      PEX      =TABLE OF EXCEEDENCE PROBABILITIES FOR WHICH KURTOSIS
C                CORRECTED STANDARD NORMAL DEVIATES ARE AVAILABLE
C      ALINPI1=TEMPORARY ARRAY FOR STORING ALINPI
C      PEX1     =TEMPORARY ARRAY FOR STORING PEX
C      IRI      =TEMPORARY ARRAY FOR STORING RI
C      NPTS     =NUMBER OF CK VALUES AVAILABLE FOR KURTOSIS CORRECTION
C      NALPHA =NUMBER OF EXCEEDENCE PROBABILITIES FOR WHICH KURTOSIS
C                CORRECTED STANDARD NORMAL DEVIATES ARE AVAILABLE
C      NCLASS =NUMBER OF CLASSES USED IN THE CHI-SQUARE TEST
C      N        =NUMBER OF ANNUAL MAXIMUM VALUES TO BE READ
C      *****************************************************************
       DIMENSION X(100),Y(100),Z(100),DL(3),SK(100),X1(100),P(100),
     1 IYEAR(100),ALPHA(9,7),ALPHAS(9),ALINPI(9),IYEAR1(100),
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```
     2  X2(9),Y2(9),Z1(100),Y1(100),RI(10),TD(10),ESTP(10),PEX(7),
     3  ALINPI1(9),PEX1(7),IRI(10)
        OPEN (UNIT=21,FILE='POWTRA.DAT',STATUS='OLD')
        OPEN (UNIT=22,FILE ='POWTRA.OUT',STATUS='NEW')
        OPEN (UNIT=23,FILE='NDTRI.OUT',STATUS='NEW')
        DATA X2/-1.20,-1.07,-0.81,-0.45,0.0,0.55,1.22,2.03,3.00/
        DATA Y2/-1.00,-0.75,-0.50,-0.25,0.0,0.25,0.50,0.75,1.00/
        DATA ((ALPHA(I,J),I=1,9),J=1,7)/0.87,0.84,0.80,0.73,0.67,0.62,
     1  0.58,0.53,0.49,1.39,1.36,1.35,1.31,1.28,1.25,1.22,1.18,1.14,
     2  1.56,1.57,1.61,1.63,1.64,1.65,1.65,1.64,1.63,1.65,1.71,1.81,
     3  1.89,1.96,2.02,2.06,2.09,2.12,1.70,1.84,2.03,2.18,2.33,2.46,
     4  2.58,2.68,2.77,1.71,1.91,2.16,2.37,2.58,2.77,2.94,3.10,3.28,
     5  1.73,2.05,2.41,2.75,3.09,3.43,3.75,4.08,4.39/
        DATA PEX/0.25,0.10,0.05,0.025,0.01,0.005,0.001/
C
C       READ INPUT INFORMATION
C
        READ (21,*) N,NCLASS,(RI(I),I=1,6),(DL(K),K=1,3)
        READ (21,*) (IYEAR(J),J=1,N),(X(J),J=1,N)
C
C
        WRITE(22,95)
95      FORMAT(40X,54(1H*))
        WRITE(22,96)
96      FORMAT(40X,1H*,11(1H ),'ANALYSIS OF THE ORIGINAL SERIES',
     1  10(1H ),1H*)
        WRITE (22,95)
        WRITE(22,100) N
100     FORMAT(//40X,'THE TOTAL NO. VALUES IN THE ORIGINAL SERIES
        1ARE=',I4//)
        WRITE (22,97)
97      FORMAT(//35X,'NOTE: BLOMS PLOTTING POSITION IS USED
     1  THROUGHOUT'//)
C       ARRANGING THE DATA IN ASCENDING ORDER)
        DO 5 I=1,N
        P(I)=(FLOAT(I)-0.375)/(FLOAT(N)+0.25)
        P2=P(I)
        CALL NDTRI(P2,T,D,IE)
        WRITE(23,7777) I,P2,T
7777    FORMAT(20X,'I=',I4,5X,'PNEX=',F8.4,5X,'SND=',F10.4)
        IYEAR1(I)=IYEAR(I)
5       X1(I)=X(I)
        CALL SEQ(N,IYEAR,X)
        WRITE (22,1016)
1016    FORMAT(14X,116(1H-))
        WRITE (22,1007)
1007    FORMAT (14X,'!',12X,'!',29X,'!',37X,'!',14X,'!',19X,'!')
        WRITE (22,106)
        WRITE(22,1007)
        WRITE (22,1018)
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```
1018    FORMAT(14X,'!',12X,'!',67(1H-),'!',14X,'!',3X,'PROBABILITY OF'
     1  ,2X,'!')
        WRITE (22,107)
        WRITE(22,1016)
107     FORMAT(14X,'!',5X,'SL.NO.',1X,'!',3X,'YEAR',4X,'!',6X,'DISCH
        1ARGE',2X,'!',9X,'YEAR',4X,'!',7X,'DISCHARGE',3X,'!',5X,'RANK'
        2,5X,'!',3X,'NON-EXCEEDENCE',2X,'!')
999     WRITE(22,200)(I,IYEAR1(I),X1(I),IYEAR(I),X(I),I,P(I),I=1,N)
        WRITE(22,1016)
200     FORMAT(14X,'!',2X,I5,5X,'!',2X,I5,4X,'!',5X,F8.1,4X,'!',8X,I5,
        14X,'!',6X,F8.1,5X,'!',2X,I5,7X,'!',4X,F8.3,7X,'!')
        WRITE (22,300)
        WRITE(22,3001)
3001    FORMAT(21X,59(1H-))
106     FORMAT(14X,'!',12X,'!',1X,'DATA IN CHRONOLOGICAL ORDER',1X,'!',7X,
        1'DATA IN  ASCENDING ORDER',6X,'!',14X,'!',19X,'!')
C       COMPUTE MEAN,STANDARD DEVIATION,COEFFECIENT OF SKEWNESS AND
C       KURTOSIS OF THE GIVEN ORIGINAL SERIES
300     FORMAT (///////21X,'STATISTICAL ESTIMATES OF THE ORIGINAL SERIES
        1 ARE AS FOLLOWS:')
        CALL ARI(X,N,SMEAN,SSD,SKEW,SKUR)
        AVEGE=SMEAN
        WRITE(22,400)SMEAN
400     FORMAT(/21X,'MEAN OF THE SERIES=',E16.8)
        WRITE(22,500)SSD
500     FORMAT(/21X,'STANDARD DEV OF THE SERIES=',E16.8)
        WRITE(22,600)SKEW
600     FORMAT(/21X,'COEFF. OF SKEWNESS OF THE SERIES=',E16.8)
        WRITE(22,700)SKUR
700     FORMAT(/21X,'COEFF. OF KURTOSIS OF THE SERIES=',E16.8////)
C
C       FREQUENCY ANALYSIS USING LOG TRANSFORMED SERIES
C
        WRITE (22,1003)
1003    FORMAT (1H1)
        WRITE (22,95)
        WRITE (22,98)
98      FORMAT (40X,'*          ANALYSIS OF THE LOG TRANSFORMED SERIES
        1  *')
        WRITE (22,95)
        WRITE(22,905)
905     FORMAT(/////////)
        WRITE(22,1016)
        WRITE(22,1007)
        WRITE(22,106)
        WRITE(22,1007)
        WRITE(22,1018)
        WRITE (22,107)
        WRITE(22,1016)
        DO 1 I=1,N
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```
C       XI(I)=X(I)+1
        Z(I)=ALOG10(X(I))
        Z1(I)=ALOG10(X1(I))
1       CONTINUE
        WRITE(22,250)(I,IYEAR1(I),Z1(I),IYEAR(I),Z(I),J,P(I),I=1,N)
250     FORMAT(14X,'!',2X,I5,5X,'!',2X,I5,4X,'!',5X,F8.3,4X,'!',8X,
        1I5,4X,'!',6X,F8.3,5X,'!',2X,I5,7X,'!',4X,F8.3,7X,'!')
        WRITE(22,1016)
        WRITE (22,301)
301     FORMAT(//////21X,'STATISTICAL ESTIMATES OF THE LOG TRANSFORMED
        1 SERIES ARE AS FOLLOWS:')
        WRITE(22,3002)
3002    FORMAT(21X,66(1H-))
C       COMPUTATION OF STATISTICAL PARAMETERS OF THE LOG TRANSFORMED
C       SERIES
        CALL ARI(Z,N,SMEAN,SSD,SKEW,SKUR)
        WRITE (22,400)SMEAN
        WRITE (22,500)SSD
        WRITE (22,600)SKEW
        WRITE (22,700)SKUR
C       COMPUTATION OF CHI-SQUARE STATISTIC FOR LOG NORMAL FITTING
        CALL CHIST(N,NCLASS,Z,SMEAN,SSD)
C       COMPUTATION OF PEAKS FOR DIFFERENT RECURRENCE INTERVALS
        DO 701 I=1,6
        P1=1.-1./RI(I)
        IRI(I)=RI(I)
        CALL NDTRI(P1,T,D,IE)
        TD(I)=T
        ESTP(I)=SMEAN+SSD*T
701     ESTP(I)=10**ESTP(I)
        WRITE(22,711)
        WRITE(22,712)
        WRITE(22,713)
        WRITE(22,714)
        WRITE(22,712)
        WRITE(22,715)(I,IRI(I),ESTP(I),I=1,6)
        WRITE(22,712)
        WRITE (22,1003)
711     FORMAT(////////44X,'ESTIMATED FLOOD PEAKS')
712     FORMAT(35X,38(1H-))
713     FORMAT(35X,'!',1X,'SL.NO.','!',2X,'RECURRENCE',3X,'!',
        11X,'ESTIMATED',3X,'!')
714     FORMAT(35X,'!',7X,'!',2X,'INTERVAL',4X,'!',3X,'FLOOD',5X,
        1'!')
715     FORMAT(35X,'!',3X,I1,3X,'!',4X,I5,' YEARS','!',3X,F10.0,'!')
        WRITE (22,95)
        WRITE (22,99)
        WRITE (22,95)
        WRITE(22,905)
        WRITE(22,1016)
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      WRITE(22,1007)
      WRITE(22,106)
      WRITE(22,1007)
      WRITE(22,1018)
      WRITE (22,107)
      WRITE(22,1016)
C
C     FREQUENCY ANALYSIS USING POWER TRANSFORMED SERIES
C     COMPUTATION OF THE VALUE OF EXPONENT WHICH MAKES THE SERIES
C     SYMMETRICALLY DISTRIBUTED
      AL=1.5
      DO 2 K=1,3
      J=0
11    AL=AL-DL(K)
10    J=J+1
      IF (K.EQ.2.AND.J.EQ.10) GO TO 79
      IF (K.EQ.3.AND.J.EQ.10) GO TO 79
      DO 3 I=1,N
3     Y(I)=(X(I)**AL-1.)/AL
      CALL ARI(Y,N,SMEAN,SSD,SKEW,SKUR)
      SK(J)=SKEW
      IF(ABS(SK(J)).LT.0.001) GO TO 20
      IF(J.EQ.1) GO TO 11
      IF((SK(J)*SK(J-1)).LT.0.0) GO TO 4
      GO TO 11
4     AL=AL+DL(K)
2     CONTINUE
99    FORMAT (40X,'*       ANALYSIS OF THE POWER TRANSFORMED SERIES
     1      *')
C79   AL=AL+10.*DL(K)
79    DO 78 I=1,N
78    Y(I)=(X(I)**AL-1.)/AL
      CALL ARI (Y,N,SMEAN,SSD,SKEW,SKUR)
20    DO 77 I=1,N
77    Y1(I)=(X1(I)**AL-1.)/AL
      WRITE(22,250)(I,IYEAR1(I),Y1(I),IYEAR(I),Y(I),I,P(I),I=1,N)
      WRITE(22,1016)
      WRITE(22,1002)
      WRITE (22,3003)
3003  FORMAT(21X,69(1H-))
1002  FORMAT(///////21X,'STATISTICAL ESTIMATES OF THE POWER TRANSFORMED
      1SERIES ARE AS FOLLOWS :')
      WRITE(22,1000)AL,SMEAN,SSD,SKEW,SKUR
1000  FORMAT(/21X,'VALUE OF LANDA =',F15.8//21X,'MEAN OF THE
      1SERIES =',F15.8//21X,'STANDARD DEVIATION =',F15.8//21X,
      2'COEFF. OF SKEWNESS =',F15.8//21X,'COEFF. OF KURTOSIS =',
      3F15.8//)
C
C     COMPUTATION OF CHI-SQUARE STATISTIC FOR POWER TRANSFORMATION
C     FITTING
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C
      CALL CHIST(N,NCLASS,Y,SMEAN,SSD)
C
C     COMPUTATION OF PEAKS FOR DIFFERENT RECURRENCE INTERVALS
C     (WITHOUT KURTOSIS CORRECTION)
C
      DO 801 I=1,6
      ESTP(I)=SMEAN+SSD*TD(I)
801   ESTP(I)=(ESTP(I)*AL+1.)**(1./AL)
      WRITE(22,711)
      WRITE(22,712)
      WRITE(22,713)
      WRITE(22,714)
      WRITE(22,712)
      WRITE(22,715)(I,IRI(I),ESTP(I),I=1,6)
      WRITE(22,712)
      CK=SKUR-3.0
      XINP=CK
C
C     COMPUTATION OF THE STANDARD NORMAL DEVIATE CORRECTED FOR
C     KURTOSIS DEVIATION AWAY FROM 3.00
      NPTS=9
      NALPHA=7
      CALL SPLINE(NPTS,X2,Y2,XINP,YINP)
      DO 52 J=1,NALPHA
      DO 51 I=1,NPTS
51    ALPHAS(I)=ALPHA(I,J)
      CALL SPLINE (NPTS,Y2,ALPHAS,YINP,ALINP)
52    ALINPI(J)=ALINP
      WRITE (22,1003)
      WRITE(22,2004)
2004  FORMAT(63X,'TABLE-1',/63X,7(1H-))
      WRITE(22,1004)
      WRITE(22,1005)
      WRITE(22,1006)
      WRITE(22,1005)
      WRITE(22,1008)(Y2(I),I=1,NPTS)
      WRITE(22,1009)(X2(I),I=1,NPTS)
      WRITE(22,1005)
      WRITE(22,2006)
2006  FORMAT(/////////63X,'TABLE-2',/63X,7(1H-))
      WRITE(22,1010)
      WRITE(22,1005)
      WRITE(22,1011)
      WRITE(22,1012)
      WRITE(22,1005)
      DO 9999 I=1,9
9999        WRITE(22,1013)(Y2(I),(ALPHA(I,J),J=1,7))
      WRITE(22,1005)
      WRITE (22,1003)
```

```
1004     FORMAT(25X,'RELATIONSHIP BETWEEN BETA AND CK REQUIRED
        1FOR KURTOSIS CORRECTED STANDARD NORMAL DEVIATES')
1005     FORMAT(25X,89(1H-))
1006     FORMAT(25X,'!',1X,'DATA',1X,'!',35X,'VALUES',39X,'!')
1008     FORMAT(25X,'!',1X,'BETA',1X,'!',F5.2,8(4X,F5.2),3X,'!')
1009     FORMAT(25X,'!',2X,'CK',2X,'!',F5.2,8(4X,F5.2),3X,'!')
1010     FORMAT(30X,'ADJUSTED STANDARD DEVIATE K FOR SMALLER
        1PROBABILITIES ALPHA FOR VALUES OF BETA')
1011     FORMAT(25X,'!','BETA',5X,'!',6(3X,'ALPHA',2X,'!'),
        13X,'ALPHA',3X,'!')
1012     FORMAT(25X,'!',9X,'!',4X,'0.25',2X,'!',4X,'0.10',2X,'!',
        14X,'0.05',2X,'!',3X,'0.025',2X,'!',4X,'0.01',2X,'!',3X,
        2'0.005',2X,'!',3X,'0.001',3X,'!')
1013     FORMAT(25X,'!',F5.2,4X,'!',6(4X,F4.2,2X,'!'),4X,F4.2,3X,
        1'!')
         WRITE(22,280)
280      FORMAT(10X,'THE VALUE OF CK AND THE CORRESPONDING BETA REQUIRED
        1 FOR KURTOSIS CORRECTION IN THE STANDARD NORMAL DEVIATES ARE'/)
         WRITE(22,285)CK,YINP
285      FORMAT(40X,'CK=',F5.2,10X,'BETA=',F5.2/)
         WRITE(22,1023)
1023     FORMAT(35X,'KURTOSIS CORRECTED STANDARD DEVIATES
        1 CORRESPONDING TO THE COMPUTED CK')
         WRITE(22,1005)
         WRITE(22,1011)
         WRITE(22,1012)
         WRITE(22,1005)
         WRITE(22,1013)YINP,(ALINPI(J),J=1,NALPHA)
         WRITE(22,1005)
C
C        COMPUTATION OF PEAKS FOR DIFFERENT RECURRENCE INTERVALS
C        (WITH KURTOSIS CORRECTION)
C
         DO 1061 I=1,NALPHA
         PEX1(I)=PEX(I)
1061     ALINPI1(I)=ALINPI(I)
         DO 1071 I=1,NALPHA
         K=NALPHA-I+1
         PEX(I)=PEX1(K)
1071     ALINPI(I)=ALINPI1(K)
         DO 1081 I=1,6
         P1=1./RI(I)
         CALL SPLINE(NALPHA,PEX,ALINPI,P1,T1)
         ESTP(I)=SMEAN+SSD*T1
1081     ESTP(I)=(ESTP(I)*AL+1.)**(1./AL)
         WRITE(22,711)
         WRITE(22,712)
         WRITE(22,713)
         WRITE(22,714)
         WRITE(22,712)
```

```
      WRITE(22,715)(I,IRI(I),ESTP(I),I=1,5)
      WRITE(22,712)
1001  STOP
      END
C     SUBROUTINE ARI
C     SUBROUTINE FOR COMPUTING THE STATISTICAL PARAMETERS OF
C     THE DATA
C     COMUTES MEAN,STANDARD DEVIATION,COEFFICIENT OF SKEWNESS AND
C     COEFFICIENT OF KURTOSIS
C     INPUT DATA ARE AS FOLLOWS:
C             X=GIVEN SERIES FOR WHICH STATISTICAL PARAMETERS ARE REQUIRED
C             N=NUMBER OF X VALUES
C     OUTPUT DETAILS ARE AS FOLLOWS:
C             SMEAN=MEAN OF THE SERIES
C             SSD=UNBIASED STANDARD DEVIATION OF THE SERIES
C             SKEW=COEFFICIENT OF SKEWNESS OF THE SERIES
C             SKUR=COEFFICIENT OF KURTOSIS OF THE SERIES
      SUBROUTINE ARI(X,N,SMEAN,SSD,SKEW,SKUR)
      DIMENSION X(600)
      SUMG=0.0
      DO 4 I=1,N
4     SUMG=SUMG+X(I)
      SMEAN=SUMG/N
      SUM=0.0
      ASUM=0.0
      BSUM=0.0
      DO 5 J=1,N
      SUM=SUM+(X(J)-SMEAN)**2
      ASUM=ASUM+(X(J)-SMEAN)**3
      BSUM=BSUM+(X(J)-SMEAN)**4
5     CONTINUE
      SSD=SQRT(SUM/(N-1.))
      B=(N*N)/((N-1.)*(N-2.))
      C=(N*N*N)/((N-1.)*(N-2.)*(N-3.))
      SKEW=(ASUM/(SSD**3))*(1./N)
      SKEW=SKEW*B
      SKUR=(BSUM/(SSD**4))*(1./N)
      SKUR=SKUR*C
      RETURN
      END
C
C     SUBROUTINE FOR ARRANGING THE SERIES IN ASCENDING ORDER
C     INPUT DATA ARE AS FOLLOWS:
C             N=NUMBER OF VALUES TO BE ARRANGED
C             IYEAR=YEAR IN CHRONOLOGICAL ORDER
C             X=DATA SERIES IN CHRONOLOGICAL ORDER
C     OUTPUT RESULTS ARE AS FOLLOWS:
C             X=DATA SERIES IN ASCENDING ORDER
C             IYEAR=YEAR CORRESPONDING TO X
      SUBROUTINE SER(N,IYEAR,X)
```

```
      DIMENSION X(100),IYEAR(100)
      J=0
20    J=J+1
      DO 10 I=J,N
      IF (X(I).GT.X(J)) GO TO 10
      XT=X(J)
      XTY=IYEAR(J)
      X(J)=X(I)
      IYEAR(J)=IYEAR(I)
      X(I)=XT
      IYEAR(I)=XTY
10    CONTINUE
      IF(J.NE.(N-1)) GO TO 20
      RETURN
      END
C     PROGRAM FOR SPLINE INTERPOLATION
C
      SUBROUTINE SPLINE(NPTS,X,Y,XINP,YINP)
C     NPTS-NO. OF POINTS
C
C       DIMENSIONS SET FOR DAMAGE CLACULATION IN HEC-1
C
C       ARRAY NAME   DIMENSION
C       ----------   ---------
C       EM, T        KPTS=(10*(KRTIO-1)+1)
C
C......  COMMON FOR INPUT AND OUTPUT UNITS
C
C
       DIMENSION X(20),Y(20),XINP1(20)
      DIMENSION EM(81),T(81)
       DATA KPTS/81/
C
C     *** COMPUTES SPLINE COEFFICIENTS BY AKIMA METHOD -- A NEW METHOD
C     OF INTERPOLATION AND SMOOTH CURVE FITTING BASED ON LOCAL PROCEDURE
C     H. AKIMA, J.A.C.M., 17, 589-602, 1970.
C     PROGRAM BY H. KUBIK, HYDROLOGIC ENGINEERING CENTER -- AUGUST 1976
C           N   - NUMBER OF POINTS IN ARRAY.
C           X   - X ARRAY, VALUES MUST BE UNIQUE AND INCREASE.
C           Y   - Y ARRAY.
C           T   - COEFFICIENT ARRAY
C
C     * * * *  IF ONLY TWO POINTS, USE LINEAR INTERPOLATION
      N=NPTS
      IF(N.LE.2) GO TO 555
      IF (N.GT.KPTS) GO TO 1080
      DO 1000 I=2,N
      J=I
      TMP=X(I)-X(I-1)
      IF(TMP.LE.0.) GO TO 1100
```

```
 1000 EM(I-1)=(Y(I)-Y(I-1))/TMP
      DO 1070 I=1,N
      IF(I.EQ.1) GO TO 1010
      IF(I.EQ.2) GO TO 1020
      IF(I.EQ.(N-1)) GO TO 1030
      IF(I.EQ.N) GO TO 1040
      TEMP1=ABS(EM(I+1)-EM(I))
      TEMP2=ABS(EM(I-1)-EM(I-2))
      TEMP3=EM(I-1)
      TEMP4=EM(I)
      GO TO 1050
 1010 TEMP1=ABS(EM(2)-EM(1))
      TEMP2=TEMP1
      TEMP3=2.*EM(1)-EM(2)
      TEMP4=EM(1)
      GO TO 1050
 1020 TEMP1=ABS(EM(3)-EM(2))
      TEMP2=ABS(EM(2)-EM(1))
      TEMP3=EM(1)
      TEMP4=EM(2)
        GO TO 1050
1030    TEMP1=ABS(EM(N-1)-EM(N-2))
        TEMP2=ABS(EM(N-2)-EM(N-3))
        TEMP3=EM(N-2)
        TEMP4=EM(N-1)
        GO TO 1050
1040    TEMP1=ABS(EM(N-1)-EM(N-2))
        TEMP2=TEMP1
        TEMP3=EM(N-1)
        TEMP4=2.*EM(N-1)-EM(N-2)
1050    IF(TEMP1.LE.0..AND.TEMP2.LE.0.) GO TO 1060
        T(I)=(TEMP3*TEMP1+TEMP4*TEMP2)/(TEMP1+TEMP2)
        GO TO 1070
1060    T(I)=(TEMP4+TEMP3)/2.
1070    CONTINUE
        CALL AKIMA(NPTS,X,Y,XINP,YINP,T)
555     CALL AKIMA(NPTS,X,Y,XINP,YINP,T)
1080    WRITE(2,1090) KPTS,N
 1090 FORMAT (/44H *** ERROR *** ARRAY SIZE EXCEEDED IN AKIMA.,
    1          13H  DIMENSION =,I4,12H, BUT NPTS =,I4)
 1100 WRITE (2,1110) J,X(J-1),X(J)
 1110 FORMAT (/47H *** HEC-1 ERROR 30 *** X VALUES ARE NOT UNIQUE,
    1         49H AND/OR INCREASING FOR CUBIC SPLINE INTERPOLATION/
    2         22X,3H J=,I3,5X,8H X(J-1)=,F10.2,5X,6H X(J)=,F10.2)
      RETURN
     END
     SUBROUTINE AKIMA (NPTS,X,Y,XINP,FUNCT,T)
     DIMENSION X(NPTS), Y(NPTS) ,T(81)
C
C
```

```
C     *** INTEROLATION BY AKIMA METHOD. SEE SUBROUTINE AKIMA FOR REF.
C     PROGRAM BY H. KUBIK, HYDROLOGIC ENGINEERING CENTER -- AUGUST 1976
C
      N=NPTS
      XIN=XINP
      IF(N.LT.2) GO TO 1060
 1020 IF (N.GT.2) GO TO 1030
C               USE LINEAR INTERPOLATION IF ONLY TWO POINTS
      FUNCT=Y(1)+(XIN-X(1))/(X(2)-X(1))*(Y(2)-Y(1))
        GO TO 666
 1030 DO 1040 II=2,N
      I=II-1
      IF(XIN.LT. X(II)) GO TO 1050
 1040 CONTINUE
 1050 TP1=XIN-X(I)
      TP2=Y(I+1)-Y(I)
      TP3=X(I+1)-X(I)
        FUNCT=Y(I)+T(I)*TP1+((3.*TP2)/TP3-2.*T(I)-T(I+1))/TP3*TP1**2
        1+(T(I)+T(I+1)-2.*TP2/TP3)*TP1**3/TP3**2
666      RETURN
 1060 WRITE (IP,1070)
 1070 FORMAT (/47H *** HEC-1 ERROR 29 *** ONLY ONE DATA POINT FOR,
     1         14H INTERPOLATION)
        RETURN
      END
C       SUBROUTINE CHIST FINDS CHI-SQUARE STATISTIC
C
C       EQUAL PROBABILITY METHOD IS ADOPTED
C       INPUT INFORMATION ARE AS FOLLOWS:
C             X=THE PEAK FLOOD SERIES
C             N=NUMBER OF X
C             NCLASS=NUMBER OF CLASSES USED IN COMPUTING THE CHI-
C                    SQUARE STATISTIC
C             SMEAN=MEAN OF THE X SERIES
C             SSD=STANDARD DEVIATION OF THE X SERIES
C             NDF=NUMBER OF DEGREES OF FREEDOM (NCLASS-NUMBER
C                 OF PARAMETERS -1)
        SUBROUTINE CHIST(N,NCLASS,X,SMEAN,SSD)
        REAL MINP
        DIMENSION FL(20),EXPF(20),THFL(20),SND(20),MINP(20),OBSF(20),X(600)
        DO 10 I=1,NCLASS
        FL(I)=1./FLOAT(NCLASS)
10      EXPF(I)=FL(I)*FLOAT(N)
        NCLAS=NCLASS-1
        DO 11 I=1,NCLAS
        K=I
        THFL(I)=FLOAT(K)*FL(I)
        P=THFL(I)
        CALL NDTRI(P,Y,D,IE)
        SND(I)=Y
```

```
      MINP(I)=SMEAN+SSD*SND(I)
11    OBSF(I)=0.
      TNUM=0.
      J=1
      DO 14 I=1,N
13    IF(X(I)-MINP(J))70,70,60
70    OBSF(J)=OBSF(J)+1.
      TNUM=TNUM+1.
      GO TO 14
60    IF(J.LT.NCLAS) GO TO 15
      GO TO 16
15    J=J+1
      GO TO 13
14    CONTINUE
16    OBSF(NCLASS)=FLOAT(N)-TNUM
C     CALCULATION OF CHI-SQUARE STATISTIC
      CHISQ=0.
      DO 17 I=1,NCLASS
      CHIS=(OBSF(I)-EXPF(I))**2/EXPF(I)
      CHISQ=CHISQ+CHIS
17    WRITE (20,111)I,OBSF(I),EXPF(I),CHIS,CHISQ
111   FORMAT (10X,'I=',I5,4X,'OBSF(I)=',F8.3,'EXPF(I)='
      1,F8.3,'CHIS=',F8.3,'CHISQ=',F8.3)
      NDF=NCLASS-3
      WRITE(22,51)NCLASS,NDF,CHISQ
51    FORMAT(//40X,'NCLASS=',I5,10X,'NDF=',I5,
      110X,'CHISQ=',F7.3)
      RETURN
      END
C
C.......................................................................
C
C     SUBROUTINE NDTRI
C
C     PURPOSE
C       COMPUTES X=P**(-1)(Y), THE ARGUMENT X SUCH THAT Y=P(X)
C       =THE PROBABILITY THAT THE RANDOM VARIABLE U,DISTRIBUTED
C       NORMALLY(0,1), IS LESS THAN OR EQUAL TO X. F(X), THE
C       ORDINATE OF THE NORMAL DENSITY, AT X, IS ALSO COMPUTED.
C
C     USAGE
C       CALL NDTRI(P,X,C,IER)
C
C     DESCRIPTION OF PARAMETERS
C       P    -INPUT PROBABILITY
C       X    -OUTPUT ARGUMENT SUCH THAT P=Y=THE PROBABILITY THAT
C             THE RANDOM VARIABLE IS LESS THAN OR EQUAL TO X
C       C    -OUTPUT DENSITY,F(X)
C       IER  -OUTPUT ERROR CODE
C             =-1  IF P IS NOT IN THE INTERVAL (0,1),INCLUSIVE
```

```
C            X=C=.99999E+37 IN THIS CASE
C             =C  IF THERE IS NO ERROR
C                   SEE REMARKS BELOW
C        REMARKS
C          MAXIMUM ERROR IS 0.00045
C          IF P=0,X IS SET TO -(10)**74.D IS SET TO C
C          IF P=1,X IS SET TO  (10)**74.D IS SET TO C
C        SUBROUTINES AND SUBPROGRAMS REQUIRED
C          NONE
C        METHOD
C           BASED ON APPROXIMATIONS IN C.HASTINGS,''APPROXIMATIONS
C           FOR DIGITAL COMPUTERS'',PRICETON UNIV.PRESS,PRINCETON,
C           N.J.,1955.SEE EQUATION 26.2.23,HAND BOOK OF MATHEMAICAL
C           FUNCTIONS,ABRAMOWITZ AND STEGUN,DOVER PUBLICATIONS,INC.,
C           NEW YORK.
        SUBROUTINE NDTRI(P,X,D,IE)
        IE=C
        X=.99999E+37
        D=X
        IF(P)1,4,2
1       IE=-1
        GO TO 12
2       IF(P-1.0)7,5,1
4       X=-0.999999E+37
5       D=0.0
        GO TO 12
7       D=P
        IF(D-0.5)9,9,8
8       D=1.0-D
9       T2=ALOG(1.0/(D*D))
        T=SQRT(T2)
        X=T-(2.515517+0.802853*T+0.010328*T2)/(1.0+1.432788*T+
        10.189269*T2+0.001308*T*T2)
        IF(P-0.5)10,10,11
10      X=-X
11      D=0.3989423*EXP(-X*X/2.0)
12      RETURN
        END
```

APPENDIX -II

TEST INPUT

77,8,50,100,200,500,1000,10000,0.1,0.01,0.001

1901,1902,1903,1904,1905,1906,1907,1908,1909,1910,

1911,1912,1913,1914,1915,1916,1917,1918,1919,1920,

1921,1922,1923,1924,1925,1926,1927,1928,1929,1930,

1931,1932,1933,1934,1935,1936,1937,1938,1939,1940,

1941,1942,1943,1944,1945,1946,1947,1948,1949,1950,

1951,1952,1953,1954,1955,1956,1957,1958,1959,1960,

1961,1962,1963,1964,1965,1966,1967,1968,1969,1970

1971,1972,1973,1974,1975,1976,1977,

11400,9250,7400,8550,9070,7070,7530,11500,8320,11880,

6940,8320,3510,9230,7400,4700,8410,4640,6280,8150,

9070,7400,5480,19130,9650,3680,7240,3680,4540,6160,

3460,6150,5270,9000,5280,3310,3220,3520,2340,2430,

3130,6620,4400,4220,5100,4620,4340,4880,3610,6190,

4760,3810,5470,6375,4610,6365,4520,4050,5020,3880,

4850,5750,6350,4010,2430,4750,5920,3320,5360,6310,

5700,4920,7400,5160,3810,6790,5710

APPENDIX-III: TEST OUTPUT

```
*********************************************************
*           ANALYSIS OF THE ORIGINAL SERIES             *
*********************************************************
```

THE TOTAL NO. VALUES IN THE ORIGINAL SERIESARE= 77

NOTE: BLOMS PLOTTING POSITION IS USED THROUGHOUT

SL.NO.	DATA IN CHRONOLOGICAL ORDER: YEAR	DISCHARGE	DATA IN ASCENDING ORDER: YEAR	DISCHARGE	RANK	PROBABILITY OF NON-EXCEEDENCE
1	1901	11400.0	1939	2340.0	1	0.008
2	1902	9250.0	1965	2430.0	2	0.021
3	1903	7400.0	1940	2430.0	3	0.034
4	1904	8550.0	1941	3130.0	4	0.047
5	1905	9070.0	1937	3220.0	5	0.060
6	1906	7070.0	1936	3310.0	6	0.073
7	1907	7330.0	1968	3320.0	7	0.086
8	1908	11500.0	1931	3460.0	8	0.099
9	1909	8320.0	1913	3510.0	9	0.112
10	1910	11880.0	1938	3520.0	10	0.125
11	1911	6940.0	1949	3610.0	11	0.138
12	1912	8320.0	1928	3680.0	12	0.150
13	1913	3510.0	1926	3680.0	13	0.163
14	1914	9230.0	1975	3810.0	14	0.176
15	1915	7400.0	1952	3810.0	15	0.189
16	1916	4700.0	1960	3880.0	16	0.202
17	1917	8410.0	1964	4010.0	17	0.215
18	1918	4640.0	1958	4050.0	18	0.228
19	1919	6280.0	1944	4220.0	19	0.241
20	1920	8150.0	1947	4340.0	20	0.254
21	1921	9070.0	1943	4400.0	21	0.267
22	1922	7400.0	1957	4520.0	22	0.280
23	1923	5480.0	1929	4540.0	23	0.293
24	1924	19130.0	1955	4610.0	24	0.306
25	1925	9650.0	1946	4620.0	25	0.319
26	1926	3680.0	1918	4640.0	26	0.332
27	1927	7240.0	1916	4700.0	27	0.345
28	1928	3680.0	1966	4750.0	28	0.358
29	1929	4540.0	1951	4760.0	29	0.371
30	1930	6160.0	1961	4850.0	30	0.383

31	1931	3460.0	1948	4880.0	31	0.396
32	1932	6150.0	1972	4920.0	32	0.409
33	1933	5270.0	1959	5020.0	33	0.422
34	1934	9000.0	1945	5100.0	34	0.435
35	1935	5280.0	1974	5160.0	35	0.448
36	1936	3310.0	1933	5270.0	36	0.461
37	1937	3220.0	1935	5280.0	37	0.474
38	1938	3520.0	1969	5360.0	38	0.487
39	1939	2340.0	1953	5470.0	39	0.500
40	1940	2430.0	1923	5480.0	40	0.513
41	1941	3130.0	1971	5700.0	41	0.526
42	1942	6620.0	1977	5710.0	42	0.539
43	1943	4400.0	1962	5750.0	43	0.552
44	1944	4220.0	1967	5920.0	44	0.565
45	1945	5100.0	1932	6150.0	45	0.578
46	1946	4620.0	1930	6160.0	46	0.591
47	1947	4340.0	1950	6190.0	47	0.604
48	1948	4880.0	1919	6280.0	48	0.617
49	1949	3610.0	1970	6310.0	49	0.629
50	1950	6190.0	1963	6350.0	50	0.642
51	1951	4760.0	1956	6365.0	51	0.655
52	1952	3810.0	1954	6375.0	52	0.668
53	1953	5470.0	1942	6620.0	53	0.681
54	1954	6375.0	1976	6790.0	54	0.694
55	1955	4610.0	1911	6940.0	55	0.707
56	1956	6365.0	1906	7070.0	56	0.720
57	1957	4520.0	1927	7240.0	57	0.733
58	1958	4050.0	1973	7400.0	58	0.746
59	1959	5020.0	1922	7400.0	59	0.759
60	1960	3880.0	1915	7400.0	60	0.772
61	1961	4850.0	1903	7400.0	61	0.785
62	1962	5750.0	1907	7530.0	62	0.798
63	1963	6350.0	1920	8150.0	63	0.811
64	1964	4010.0	1912	8320.0	64	0.824
65	1965	2430.0	1909	8320.0	65	0.837
66	1966	4750.0	1917	8410.0	66	0.850
67	1967	5920.0	1904	8550.0	67	0.862
68	1968	3320.0	1934	9000.0	68	0.875
69	1969	5360.0	1921	9070.0	69	0.888
70	1970	6310.0	1905	9070.0	70	0.901
71	1971	5700.0	1914	9230.0	71	0.914
72	1972	4920.0	1902	9250.0	72	0.927
73	1973	7400.0	1925	9630.0	73	0.940
74	1974	5160.0	1901	11400.0	74	0.953
75	1975	3810.0	1908	11500.0	75	0.966
76	1976	6790.0	1910	11880.0	76	0.979
77	1977	5710.0	1924	19130.0	77	0.992

STATISTICAL ESTIMATES OF THE ORIGINAL SERIES ARE AS FOLLOWS:

MEAN OF THE SERIES= 0.60268833E+04

STANDARD DEV OF THE SERIES= 0.26401655E+04

COEFF. OF SKEWNESS OF THE SERIES= 0.19354383E+01

COEFF. OF KURTOSIS OF THE SERIES= 0.99327736E+01

****
*   ANALYSIS OF THE LOG TRANSFORMED SERIES   *
****

SL.NO.	DATA IN CHRONOLOGICAL ORDER		DATA IN ASCENDING ORDER		RANK	PROBABILITY OF NON-EXCEEDENCE
	YEAR	DISCHARGE	YEAR	DISCHARGE		
1	1901	4.0569	1939	3.3692	1	0.008
2	1902	3.9661	1965	3.3856	2	0.021
3	1903	3.8692	1940	3.3856	3	0.034
4	1904	3.9320	1941	3.4955	4	0.047
5	1905	3.9576	1937	3.5079	5	0.060
6	1906	3.8494	1936	3.5198	6	0.073
7	1907	3.8768	1968	3.5211	7	0.086
8	1908	4.0607	1931	3.5391	8	0.099
9	1909	3.9201	1913	3.5453	9	0.112
10	1910	4.0748	1938	3.5465	10	0.125
11	1911	3.8414	1949	3.5575	11	0.138

12	1912	3.9201	1928	3.5638	12	0.150
13	1913	3.5453	1926	3.5658	13	0.163
14	1914	3.9632	1975	3.5809	14	0.176
15	1915	3.8692	1952	3.5809	15	0.189
16	1916	3.6721	1960	3.5888	16	0.202
17	1917	3.9248	1964	3.6031	17	0.215
18	1918	3.6665	1958	3.6075	18	0.228
19	1919	3.7980	1944	3.6253	19	0.241
20	1920	3.9112	1947	3.6375	20	0.254
21	1921	3.9576	1943	3.6435	21	0.267
22	1922	3.8692	1957	3.6551	22	0.280
23	1923	3.7388	1929	3.6571	23	0.293
24	1924	4.2817	1955	3.6637	24	0.306
25	1925	3.9845	1946	3.6646	25	0.319
26	1926	3.5658	1918	3.6665	26	0.332
27	1927	3.8597	1916	3.6721	27	0.345
28	1928	3.5638	1966	3.6767	28	0.358
29	1929	3.6571	1951	3.6776	29	0.371
30	1930	3.7896	1961	3.6857	30	0.383
31	1931	3.5391	1948	3.6884	31	0.396
32	1932	3.7889	1972	3.6920	32	0.409
33	1933	3.7218	1959	3.7007	33	0.422
34	1934	3.9542	1945	3.7076	34	0.435
35	1935	3.7226	1974	3.7126	35	0.448
36	1936	3.5198	1933	3.7218	36	0.461
37	1937	3.5079	1935	3.7226	37	0.474
38	1938	3.5465	1969	3.7292	38	0.487
39	1939	3.3692	1953	3.7380	39	0.500
40	1940	3.3856	1923	3.7388	40	0.513
41	1941	3.4955	1971	3.7559	41	0.526
42	1942	3.8209	1977	3.7566	42	0.539
43	1943	3.6435	1962	3.7597	43	0.552
44	1944	3.6253	1967	3.7723	44	0.565
45	1945	3.7076	1932	3.7889	45	0.578
46	1946	3.6646	1930	3.7896	46	0.591
47	1947	3.6375	1950	3.7917	47	0.604
48	1948	3.6884	1919	3.7980	48	0.617
49	1949	3.5575	1970	3.8000	49	0.629
50	1950	3.7917	1963	3.8028	50	0.642
51	1951	3.6776	1956	3.8038	51	0.655
52	1952	3.5809	1954	3.8045	52	0.668
53	1953	3.7380	1942	3.8209	53	0.681
54	1954	3.8045	1976	3.8319	54	0.694
55	1955	3.6637	1911	3.8414	55	0.707
56	1956	3.8038	1906	3.8494	56	0.720
57	1957	3.6551	1927	3.8597	57	0.733
58	1958	3.6075	1973	3.8692	58	0.746
59	1959	3.7007	1922	3.8692	59	0.759
60	1960	3.5888	1915	3.8692	60	0.772
61	1961	3.6857	1903	3.8692	61	0.785

62	1962	3.7597	1907	3.8768	62	0.798
63	1963	3.8028	1920	3.9112	63	0.811
64	1964	3.6031	1912	3.9201	64	0.824
65	1965	3.3856	1909	3.9201	65	0.837
66	1966	3.6767	1917	3.9248	66	0.850
67	1967	3.7723	1904	3.9320	67	0.862
68	1968	3.5211	1934	3.9542	68	0.875
69	1969	3.7292	1921	3.9576	69	0.888
70	1970	3.8000	1905	3.9576	70	0.901
71	1971	3.7559	1914	3.9652	71	0.914
72	1972	3.6920	1902	3.9661	72	0.927
73	1973	3.8692	1925	3.9845	73	0.940
74	1974	3.7126	1901	4.0369	74	0.953
75	1975	3.5809	1908	4.0607	75	0.966
76	1976	3.8319	1910	4.0748	76	0.979
77	1977	3.7566	1924	4.2817	77	0.992

STATISTICAL ESTIMATES OF THE LOG TRANSFORMED SERIES ARE AS FOLLOWS:

MEAN OF THE SERIES= 0.37453470E+01

STANDARD DEV OF THE SERIES= 0.17192274E+00

COEFF. OF SKEWNESS OF THE SERIES= 0.23994009E+00

COEFF. OF KURTOSIS OF THE SERIES= 0.34124138E+01

NCLASS= 8 NDF= 5 CHISQ= 1.026

ESTIMATED FLOOD PEAKS

SL.NO.	RECURRENCE INTERVAL	ESTIMATED FLOOD
1	50 YEARS	12546.
2	100 YEARS	13976.
3	200 YEARS	15426.
4	500 YEARS	17387.
5	1000 YEARS	18909.
6	10000 YEARS	24252.

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* ANALYSIS OF THE POWER TRANSFORMED SERIES *

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	DATA IN CHRONOLOGICAL ORDER		DATA IN ASCENDING ORDER			
SL.NO.	YEAR	DISCHARGE	YEAR	DISCHARGE	RANK	PROBABILITY OF NON-EXCEEDENCE
1	1901	4.3857	1939	4.0699	1	0.008
2	1902	4.3492	1965	4.0786	2	0.021
3	1903	4.3087	1940	4.0786	3	0.034
4	1904	4.3351	1941	4.1352	4	0.047
5	1905	4.3457	1937	4.1414	5	0.060
6	1906	4.3002	1936	4.1474	6	0.073
7	1907	4.3119	1968	4.1480	7	0.086
8	1908	4.3872	1931	4.1569	8	0.099
9	1909	4.3302	1913	4.1600	9	0.112
10	1910	4.3928	1938	4.1606	10	0.125
11	1911	4.2967	1949	4.1660	11	0.138
12	1912	4.3302	1928	4.1700	12	0.150
13	1913	4.1600	1926	4.1700	13	0.163
14	1914	4.3489	1975	4.1774	14	0.176
15	1915	4.3087	1952	4.1774	15	0.189
16	1916	4.2207	1960	4.1812	16	0.202
17	1917	4.3321	1964	4.1881	17	0.215
18	1918	4.2181	1958	4.1901	18	0.228
19	1919	4.2777	1944	4.1987	19	0.241

20	1920	4.3264	1947	4.2044	20	0.254
21	1921	4.3457	1943	4.2073	21	0.267
22	1922	4.3087	1957	4.2128	22	0.280
23	1923	4.2513	1929	4.2137	23	0.293
24	1924	4.4701	1955	4.2168	24	0.306
25	1925	4.3568	1946	4.2172	25	0.319
26	1926	4.1700	1918	4.2181	26	0.332
27	1927	4.3046	1916	4.2207	27	0.345
28	1928	4.1700	1966	4.2228	28	0.358
29	1929	4.2137	1951	4.2232	29	0.371
30	1930	4.2740	1961	4.2270	30	0.383
31	1931	4.1569	1948	4.2283	31	0.396
32	1932	4.2737	1972	4.2299	32	0.409
33	1933	4.2436	1959	4.2339	33	0.422
34	1934	4.3444	1945	4.2371	34	0.435
35	1935	4.2440	1974	4.2394	35	0.448
36	1936	4.1474	1933	4.2436	36	0.461
37	1937	4.1414	1935	4.2440	37	0.474
38	1938	4.1606	1969	4.2469	38	0.487
39	1939	4.0699	1953	4.2509	39	0.500
40	1940	4.0786	1923	4.2513	40	0.513
41	1941	4.1352	1971	4.2590	41	0.526
42	1942	4.2878	1977	4.2593	42	0.539
43	1943	4.2073	1962	4.2607	43	0.552
44	1944	4.1987	1967	4.2664	44	0.565
45	1945	4.2371	1932	4.2737	45	0.578
46	1946	4.2172	1930	4.2740	46	0.591
47	1947	4.2044	1950	4.2750	47	0.604
48	1948	4.2283	1919	4.2777	48	0.617
49	1949	4.1660	1970	4.2786	49	0.629
50	1950	4.2750	1963	4.2799	50	0.642
51	1951	4.2232	1956	4.2803	51	0.655
52	1952	4.1774	1954	4.2806	52	0.668
53	1953	4.2509	1942	4.2878	53	0.681
54	1954	4.2806	1976	4.2926	54	0.694
55	1955	4.2168	1911	4.2967	55	0.707
56	1956	4.2803	1906	4.3002	56	0.720
57	1957	4.2128	1927	4.3046	57	0.733
58	1958	4.1901	1973	4.3087	58	0.746
59	1959	4.2339	1922	4.3087	59	0.759
60	1960	4.1812	1915	4.3087	60	0.772
61	1961	4.2270	1903	4.3087	61	0.785
62	1962	4.2607	1907	4.3119	62	0.798
63	1963	4.2799	1920	4.3264	63	0.811
64	1964	4.1881	1912	4.3302	64	0.824
65	1965	4.0786	1909	4.3302	65	0.837
66	1966	4.2228	1917	4.3321	66	0.850
67	1967	4.2664	1904	4.3351	67	0.862
68	1968	4.1480	1934	4.3444	68	0.875
69	1969	4.2469	1921	4.3457	69	0.888

70	1970	4.2786	1905	4.3457	70	0.901
71	1971	4.2590	1914	4.3489	71	0.914
72	1972	4.2299	1902	4.3492	72	0.927
73	1973	4.3087	1925	4.3568	73	0.940
74	1974	4.2394	1901	4.3857	74	0.953
75	1975	4.1774	1908	4.3872	75	0.966
76	1976	4.2926	1910	4.3928	76	0.979
77	1977	4.2593	1924	4.4701	77	0.992

STATISTICAL ESTIMATES OF THE POWER TRANSFORMED SERIES ARE AS FOLLOWS :

VALUE OF LAMDA = -0.18900023

MEAN OF THE SERIES = 4.25141573

STANDARD DEVIATION = 0.07722939

COEFF. OF SKEWNESS = -0.00007506

COEFF. OF KURTOSIS = 3.20270395

NCLASS= 8 NDF= 5 CHISQ= 1.234

ESTIMATED FLOOD PEAKS

SL.NO.	RECURRENCE INTERVAL	ESTIMATED FLOOD
1	50 YEARS	13168.
2	100 YEARS	14966.
3	200 YEARS	16872.
4	500 YEARS	19583.

5	1000 YEARS	21797.
6	10000 YEARS	30344.

TABLE-1

RELATIONSHIP BETWEEN BETA AND CK REQUIRED FOR KURTOSIS CORRECTED STANDARD NORMAL DEVIATES

DATA	VALUES								
BETA	-1.00	-0.75	-0.50	-0.25	0.00	0.25	0.50	0.75	1.00
CK	-1.20	-1.07	-0.81	-0.45	0.00	0.55	1.22	2.03	3.00

TABLE-2

ADJUSTED STANDARD DEVIATE K FOR SMALLER PROBABILITIES ALPHA FOR VALUES OF BETA

BETA	ALPHA 0.25	ALPHA 0.10	ALPHA 0.05	ALPHA 0.025	ALPHA 0.01	ALPHA 0.005	ALPHA 0.001
-1.00	0.87	1.39	1.56	1.65	1.70	1.71	1.73
-0.75	0.84	1.36	1.57	1.71	1.84	1.91	2.05
-0.50	0.80	1.35	1.61	1.81	2.03	2.16	2.41
-0.25	0.73	1.31	1.63	1.89	2.18	2.37	2.75
0.00	0.67	1.28	1.64	1.96	2.33	2.58	3.09
0.25	0.62	1.25	1.65	2.02	2.46	2.77	3.43
0.50	0.58	1.22	1.65	2.06	2.58	2.94	3.75
0.75	0.53	1.18	1.64	2.09	2.68	3.10	4.08
1.00	0.49	1.14	1.63	2.12	2.77	3.28	4.39

CK AND THE CORRESPONDING BETA REQUIRED FOR KURTOSIS CORRECTION IN THE STANDARD NORMAL DEVIATES ARE

CK= 0.20 BETA= 0.10

KURTOSIS CORRECTED STANDARD DEVIATES CORRESPONDING TO THE COMPUTED CK

BETA	ALPHA 0.25	ALPHA 0.10	ALPHA 0.05	ALPHA 0.025	ALPHA 0.01	ALPHA 0.005	ALPHA 0.001

0.10	0.65	1.27	1.64	1.99	2.38	2.66	3.22

ESTIMATED FLOOD PEAKS

SL.NO.	RECURRENCE INTERVAL	ESTIMATED FLOOD
1	50 YEARS	13392.
2	100 YEARS	15380.
3	200 YEARS	17561.
4	500 YEARS	21298.
5	1000 YEARS	23326.