UM - 24

TECHNIQUES FOR FLOOD FREQUENCY ANALYSIS

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CONTENTS

LIST OF APPENDICES

ABSTRACT

This user's manual gives the details of eight computer programmes to carry out flood frequency analysis. These programmes are for fitting of :

1. Lognormal two parameter,
2. Lognormal three parameter,
3. Extreme value type 1
4. Pearson type III
5. Log Pearson type III distributions, and for
6. Computation of standard errors,
7. Best fit distribution using normalization procedures and ch-square criterion and
8. Flood frequency analysis using power transformation method.

These programmes are written in FORTRAN language. The programmes listed 1 to 6 have been adopted from Kite (1977) and implemented and tested on VAX-11/780 Computer System of National Institute of Hydrology, Roorkee. While the programmes 7 to 8 have been developed and tested on the computer system of the Institute.

The programmes 1 to 5 compute the floods of 2,5,10,20, 50, and 100 years recurrence interval only. The parameters are estimated by method of moments and method of maximum likelihood.

The programme 6, computes standard errors of events computed from normal, 2 parameter log normal, 3 parameter log normal, EV-1, Pearson type III and log Pearson type III distributions compared to the observed event magnitudes.

Various normalization procedures used in the programme 7, include inverse Pearson type III transformation, lognormal transformation for which the parameters are estimated on the basis of theoretical relationships, log transformation, inverse log Pearson type III transformation and square root transformation.

Programme 8 estimates 50, 100, 200, 500, 1000 and 10,000 years return period floods using power transformation method to normalize the data.

All these programmes could be run on micro computers also with minor modifications on to suit particular system. This user's manual provides useful information for application by field engineers for hydrologic analysis and design. The results obtained by these programmes are subject to assumptions and limitation of flood frequency analysis approach.

1.0 INTRODUCTION

Flood frequency analysis is a tool used to estimate the frequencies of future floods. In this approach the sample data are used to fit frequency or probability distributions which in turn are used to extrapolate from recorded events to design events either graphically or analytically. The sample data can be either annual flood series or partial duration series. In annual flood series highest floods for each year are considered while in partial duration series all the floods above a particular threshold are considered. The only restriction about partial duration series is that the floods considered should be independent. Generally in field practice annual flood series is considered. The programmes given in this user's manual deal only with the annual flood series. Commonly used probability distributions for flood frequency analysis include log normal - two parameter distribution, log normal -3 parameter distribution, extreme value type 1 distribution, Pearson type III distribution and log Pearson type III distribution. Various methods for estimation of the parameters of these distributions are available in literature. Among these the method of moments and method of maximum likelihood are more popular. In frequency analysis goodness of fit of various distribution is examined based on some statistical criteria. The two most commonly used tests of goodness of fit are the Chi-square and Kolmogrov-Smirnov tests. An additional check on goodness of fit may be made by computing the sum of squares of differences between observed and computed event magnitudes. Once the distribution of sample data is decided the floods of various return periods can be estimated from the sample data. The standard errors of flood estimates increase as the return period increases.

Another method of carrying out flood frequency analysis is to first transform the data to normal distribution using power transformation, carry out the frequency analysis and again transform the results to original domain. This user's manual gives details of eight computer programmes which deal with the above aspects of flood frequency analysis.

2.0 PURPOSE

The main purpose of this user's manual is to provide, the computer programmes for carrying out the flood frequency analysis, to the field engineers. The user's manual gives the details of eight computer programmes. The first five programmes are for fitting of the :

1. log normal two parameter,
2. log normal three parameter,
3. extreme value type 1,
4. Pearson type III, and
5. log Pearson type III distributions.

The remaining three programmes are for

6. computation of standard error of various distributions in fitting the annual flood series,
7. best fit distribution using normalization procedures and Chi-square criterion, and
8. flood frequency analysis using power transformation method.

These programmes are written in FORTRAN language. The programmes listed 1 to 6 have been adopted from 'Frequency and Risk Analysis in Hydrology' by G.W. Kite. These programmes have been implemented and tested on VAX-11/780 Computer system of National Institute of Hydrology, Roorkee. While the programmes 7 to 8 have been developed and tested at NIH. The purpose of each programme is described as follows :

2.1 Programme 1 (LN2.FOR)

This programme computes method of moments and method of maximum likelihood estimates for T year events and standard errors for two parameter log normal distribution.

2.2 Programme 2 (LN3.FOR)

This programme computes method of moments and method of maximum likelihood estimates for T year events and standard errors for three parameter log normal distribution.

2.3 Programme 3 (T1E.FOR)

This programme computes method of moments and method of maximum likelihood estimates for T year events and standard error for extreme value type 1 distribution.

2.4 Programme 4 (PT3.FOR)

This programme computes method of moments and method of maximum likelihood estimates for T year events and standard errors for Pearson type 3 distribution.

2.5 Programme 5 (LP3.FOR)

This programme computes method of moments and method of maximum likelihood estimates for T year events and standard errors for Log Pearson type 3 distribution.

2.6 Programme 6 (SER.FOR)

This programme computes the standard errors of events computed from various probability distributions compared to the observed event magnitudes.

2.7 Programme 7 (CHI.FOR)

The purpose of this programme is to find out best fit distribution after testing various normalization procedures on the basis of Chi-square statistic for different seasons/ months of the year. The programme compares the following normalization procedures :

a. Normal distribution by method of moments

b. Inverse Pearson type III transformation

c. Log normal transformation (parameters are obtained on the basis of theoretical relationships)

d. Log transformation (parameters are estimated by method moments)

e. Inverse log Pearson type III transformation

f. Square root transformation.

The programme calculates the number of degrees of freedom and can be applied to data sets of weekly, monthly, seasonal and annual time series.

2.8 Programme 8 (POWTRA.FOR)

The purpose of the programme is

(1) to tranform 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 nearly normally distributed series using method of moments for estimating 50, 100, 200, 500, 1000 and 10,000 years return period floods based on two approaches viz.,

(a) The coefficient of skewness is nearly zero, and

(b) The coefficient of Kurtosis equal to 3.0.

3.0 METHODOLOGY

Some of the important terms which have appeared in the text very frequently are described first and later specific method used in each programme is explained.

Terminology :

(i) Population data: Population data encompasses all possible values, an event can take.

(ii) Sample data : Sample data are available data from the observation of an event.

(iii) Randam sample : A random sample is taken from the population in such a way that every possible sample, drawn in the specified manner, has an equal chance of being chosen.

(iv) Recurrence interval : T years recurrence interval or return period means an event which may occur, on an average, once in T years.

(v) Quantile estimate : Magnitude of an event which may occur once in T years.

(vi) Standard error : It is the measure of the variability of the resulting event magnitudes.

(vii) Mean : It is a measure of central tendency of the data and is given by

$$\bar{x} = \sum_{i=1}^{N} x_i \qquad \text{... (1)}$$

where x_i, $i = 1, 2, \quad ,N$ represents N years sample.

(viii) Standard deviation : Standard deviation is a measure of the variability of the data series. The unbiassed estimate of standard deviation is given by

$$\sigma_x = \left(\sum_{i=1}^{N} (x_i - \bar{x})^2 / (N-1) \right)^{\frac{1}{2}} \quad \ldots (2)$$

(ix) Variance : Variance is square of standard deviation.

(x) Coefficient of variation : Coefficient of variation is a dimensionless parameter, generally used as a regionalization parameter.

$$C_V = \frac{\sigma_x}{\bar{x}} \quad \ldots (3)$$

(xi) Coefficient of skewness : It is a measure of the symmetry of the empirial distribution of the sample data. The unbiassed estimate of the coefficient of skewness is given by

$$C_S = \frac{N \cdot \sum_{i=1}^{N} (x_i - \bar{x})^3}{(N-1)\,(N-2)\,\sigma_x^3} \quad \ldots (4)$$

(xii) Coefficient of kurtosis : It is a measure of the peakedness of the empirial distribution of the sample data. The unbiassed estimate of the coefficient of kurtosis is given by

$$C_k = \frac{N^2 \cdot \sum_{i=1}^{N} (x_i - \bar{x})^4}{(N-1)\,(N-2)\,(N-3)\sigma_x^4} \quad \ldots (5)$$

(xiii) Standard error of statistical parameters: The statistical parameters such as mean, standard deviation, coefficient of skewness calculated from the data are not the true representatives of population statistical parameters. The standard errors associated with these parameters are given by following equations

$$S_e(\bar{x}) = \frac{\sigma_x}{\sqrt{N}} \quad \ldots (6)$$

$$S_e(\sigma_x) = \frac{\sigma_x}{\sqrt{2N}} \quad \ldots (7)$$

$$S_e(C_S) = \frac{6N(N-1)}{(N-2)(N+1)(N+3)} \qquad \ldots (8)$$

where,

$S_e(\bar{x})$ = standard error of mean,

$S_e(\sigma_x)$ = standard error of standard deviation,

$S_e(C_S)$ = standard error of coeff. of skewness

N = sample size

σ_x = standard deviation of the programmes are explained as follows.

3.1 Programme 1 (Two Parameter Lognormal Distribution)

If the logarithms of a variable x are normally distributed, then the probability density function p(x) is given by the following equation :

$$p(x) = \frac{1}{x\sigma_y\sqrt{2\pi}} \; e^{\frac{-(\ln x-\mu_y)^2}{2\sigma_y^2}} \qquad \ldots (9)$$

where,

μ_y = mean of the natural logarithms of the variable x, and

σ_y = standard deviation of the natural logarithm of the variable x

3.1.1 Estimation of parameters

The parameters of the distribution are estimated using the following methods :

(i) Method of Moments

(ii) Method of Maximum likelihood

(i) Method of Moments :

The general equations for first moment of the p d f about the origin and second moment of the p d f about the centroid are given as :

$$\mu = e^{\mu_y + \sigma_y^2 / 2} \quad .. (10)$$

$$\sigma^2 = (e^{\sigma_y^2} - 1)\ \mu^2 \quad .. (11)$$

where μ and σ are the mean and standard deviation of the variable x.

If a sample of annual maximum flood peaks is given, then the mean and standard deviation estimated from that sample provide the estimates of μ and σ . Equation (10) and (11) are solved to estimate the two parameters, μ_y and σ_y , of the distribution.

(ii) Method of Maximum likelihood :

By this method, the parameters of the distribution, μ_y and σ_y are estimated by solving the following equations resulting from differenting the logarithms of the likelihood function with respect to μ_y and σ_y^2 respectively.

$$\mu_y = \sum_{i=1}^{n} \ln x_i / n \quad .. (12)$$

$$\sigma_y^2 = \sum_{i=1}^{n} (\ln x_i - \mu_y)^2 / n \quad .. (13)$$

3.1.2 Quantile estimates

T-year flood can be computed using the equation :

$$\ln x_T = \mu_y + t\sigma_y \quad \text{.. (14)}$$

where x_T is an estimate of T-year flood, and

t is standard normal deviate

An alternative way for calculating the T-year floods, involves the use of frequency factor, K in the frequency equation. The general frequency equation in terms of frequency factor, K is given by the equation :

$$x_T = \mu + \sigma K_T \quad \text{.. (15)}$$

where μ and σ are mean and standard deviation of the original flood peak series.

The frequency factor K_T for log normal two parameter distribution is given by the following equation (Kite 1977) :

$$K_T = \left[\frac{e^{[\ln(1+z^2)]^{1/2} t - [\ln(1+z^2)]/2} - 1}{z} \right] \quad \text{.. (16)}$$

where, z is the co-efficient of variation of recorded events.

3.1.3 Standard error of estimate

(i) Method of moments :

The standard error of estimates for T-year flood events are computed by method of moments using the following equations :

$$\Delta_T = [\,1 + (z^3 + 3z)\,K_T + (z^8 + 6z^6 + 15z^4 + 16z^2 + 2)\,K_T^2/4\,]^{1/2} \quad \text{.. (17)}$$

$$S_T = \Delta_T \sigma \;/\sqrt{n} \quad \text{.. (18)}$$

where

K_T is frequency factor given by equation (16)

z is co-efficient of variation of the recorded events

σ is standard deviation of ths recorded events

n is no. of recorded events, and

S_T is the standard error of estimate for T-year flood events.

(ii) Method of maximum likelihood :

The programme uses the following equations to compute the standard error of estimates for T-year flood events by method of maximum likelihood :

$$\delta_T = [\,(\ln(z^2 + 1)\;(1 + K_T z)^2\;(1 + t^2/2)\,)\,/z^2\,]^{1/2} \quad \text{.. (19)}$$

$$S_T = \delta_T \sigma\,/\sqrt{n} \quad \text{.. (20)}$$

The listing of thesource programme is given in Appendix IA.

3.2 Programme 2 (Three Parameter Lognormal Distribution)

The three parameter log normal distribution represents the normal distribution of the logarithms of the variable $(x-a)$, where a is a lower boundary. The probability density function of this distribution is given by :

$$p(x) = \left[\frac{1}{(x-a)\,\sigma_y \sqrt{2\pi}} \right] e^{\frac{-[\ln(x-a) - \mu_y]^2}{2\sigma_y^2}} \qquad .. (21)$$

where, μ_y and σ_y are the form and scale parameters for the distribution and considered to be the mean and standard deviation of the logarithms of $(x-a)$.

3.2.1 Estimation of parameters

The following methods of parameters estimation are used in the programme.

(i) Method of moments

(ii) Method of maximum likelihood

(i) Method of moments :

The three parameters, μ_y, σ_y and a of this distribution are computed as follows using method of moments in the programme.

$$w = \frac{-\gamma_1 + (\gamma_1^2 + 4)^{1/2}}{2} \qquad .. (22)$$

$$z_2 = (1 - w^{2/3}) / w^{1/3} \qquad .. (23)$$

$$\sigma_y = [\ln (z_2^2 + 1)]^{1/2} \quad .. (24)$$

$$\mu_y = \ln(\sigma/z_2) - \frac{1}{2}\ln(z_2^2 + 1) \quad .. (25)$$

$$a = \mu - a / z_2 \quad .. (26)$$

Therefore, the procedure involves the computation of the mean, μ standard deviation, σ and co-eficient of skew, γ_1 of the observed events, which are used in equatíon (22) to (26) to provide an estimate of parameters.

(ii) Method of maximum likelihood :

The parameters are obtained by method of maximum likelihood after solving the following non-linear equations using Newton's method :

$$\mu_y = \sum_{i=1}^{n} \ln(x_i - a) \quad .. (27)$$

$$\sigma_y^2 = \sum_{i=1}^{n} [\ln(x_i - a) - \mu_y]^2 / n \quad .. (28)$$

$$\sum_{i=1}^{n} (x_i - a)^{-1}(\mu_y - \sigma_y^2) = \sum_{i=1}^{n} (x_i - a)^{-1} \ln(x_i - a) \quad .. (29)$$

Equations (27) to (29) are solved by Newton's method of non-linear optimization in order to arrive at an optimum value of a which is substituted back in equations (27) and (28) to estimate μ_y and σ_y^2 respectively.

3.2.2 Quantile estimates

(i) Method of moments :

T-years flood events using the method of moments are estimated from the standard frequency equation :

$$x_T = \mu + K_T \sigma$$

where

$$K_T = \frac{\exp\left([\ln(1+z_2^2)]^{1/2} \; t - [\ln(1+z_2^2)]/2 \right) - 1.0}{z_2} \quad .. (30)$$

and μ and σ are the sample estimates of mean & standard deviation.

(ii) Method of Maximum Likelihood :

The following relationship is used to estimate T-years flood events by the maximum likelihood procedure :

$$x_T = a + e^{\mu_y + t\sigma_y} \quad .. (31)$$

3.2.3 Standard error of estimate

(i) Method of moments :

The standard error of estimate using method of moments is computed from the following expressions.

$$S_T^2 = \left(\frac{\partial x_T}{\partial \mu_1'}\right)^2 \text{var}\,\mu_1' + \left(\frac{\partial x_T}{\partial \mu_2}\right)^2 \text{var}\,\mu_2 + \left(\frac{\partial x_T}{\partial \mu_3}\right)^2 \text{var}\,\mu_3$$

$$+ 2\frac{\partial x_T}{\partial \mu_1'}\frac{\partial x_T}{\partial \mu_2}\text{cov}\,(\mu_1', \mu_2) + \frac{2\partial x_T}{\partial \mu_1'}\frac{\partial x_T}{\partial \mu_3}\text{cov}\,(\mu_1', \mu_3)$$

$$+ 2\frac{\partial x_T}{\partial \mu_2}\frac{\partial x_T}{\partial \mu_3}\text{cov}\,(\mu_2, \mu_3) \quad .. (32)$$

where

$$\frac{\partial x_T}{\partial \mu_1'} = 1 \qquad .. (33)$$

$$\frac{\partial x_T}{\partial \mu_2} = \frac{1}{2\sigma} [K - 3\gamma_1 \frac{\partial k}{\partial \gamma_1}] \qquad .. (34)$$

$$\frac{\partial x_T}{\partial \mu_3} = \frac{1}{\sigma^2} \frac{\partial k}{\partial \gamma_1} \qquad .. (35)$$

$$\text{var } \mu_1' = \mu_2 / n \qquad .. (36)$$

$$\text{var } \mu_2 = \frac{1}{n} (\mu_4 - \mu_2^2) \qquad .. (37)$$

$$\text{var } \mu_3 = \frac{1}{n} (\mu_6 - \mu_3^2 - 6\mu_4 \mu_2 + 9 \mu_2^3) \qquad .. (38)$$

$$\text{cov } (\mu_1', \mu_2) = \mu_3/n \qquad .. (39)$$

$$\text{cov } (\mu_1', \mu_3) = \frac{1}{n} (\mu_4 - 3\mu_2^2) \qquad .. (40)$$

$$\text{cov } (\mu_2, \mu_3) = \frac{1}{n} (\mu_5 - 4\mu_3 \mu_2) \qquad .. (41)$$

$$\mu_2 = e^{\sigma_y^2 + 2\sigma_y} (e^{\sigma_y^2} - 1) \qquad .. (42)$$

$$\mu_3 = e^{3\sigma_y^2/2 + 3\mu_y} (e^{\sigma_y^2} - 1)^2 (e^{\sigma_y^2} + 2) \qquad .. (43)$$

$$\mu_4 = e^{2\sigma_y^2 + 4\mu_y} (e^{\sigma_y^2} - 1)^2 (e^{4\sigma_y^2} + 2e^{3\sigma_y^2} + 3e^{2\sigma_y^2} - 3) \qquad .. (44)$$

$$\mu_5 = e^{5\sigma_y^2/2 + 5\mu_y} \left(e^{10\sigma_y^2} - 5e^{6\sigma_y^2} + 10e^{3\sigma_y^2} - 10e^{\sigma_y^2} + 4\right) \quad ..(45)$$

$$\mu_6 = e^{3\sigma_y^2 + 6\mu_y} \left(e^{15\sigma_y^2} - 6e^{10\sigma_y^2} + 15e^{6\sigma_y^2} - 20e^{3\sigma_y^2} + 15e^{\sigma_y^2} - 5\right) \quad ..(46)$$

Substitution of the estimates from eqns. (33) to (46) into equation (32) yields an expression for the standard error of estimate. The initial computations are to obtain the mean, variance and co-efficient of skew, μ_1', μ_2 and γ_1 respectively, from the observed events; calculate μ_y and σ_y and the moments μ_4 to μ_6.

(ii) Method of maximum likelihood :

The equations used to compute the standard error of estimate by method of maximum likelihood are given as follows :

$$S_T^2 = \left(\frac{\partial x_T}{\partial a}\right)^2 \text{var } a + \left(\frac{\partial x_T}{\partial \sigma_y^2}\right)^2 \text{var } \sigma_y^2 + \left(\frac{\partial x_T}{\partial \mu_y}\right)^2 \text{var } \mu_y$$

$$+ 2\frac{\partial x_T}{\partial a}\frac{\partial x_T}{\partial \sigma_y^2} \text{cov}(a, \sigma_y^2) + 2\frac{\partial x_T}{\partial a}\frac{\partial x_T}{\partial \mu_y} \text{cov}(a, \mu_y)$$

$$+ 2\frac{\partial x_T}{\partial \sigma_y^2}\frac{\partial x_T}{\partial \mu_y} \text{cov}(\sigma_y^2, \mu_y) \quad ..(47)$$

$$x_T = a + e^{\mu_y + t\sigma_y} \quad ..(48)$$

$$\frac{\partial x_T}{\partial a} = 1 \quad ..(49)$$

$$\frac{\partial x_T}{\partial \sigma_y^2} = \frac{t\, e^{\mu_y + t\sigma_y}}{2\sigma_y} \quad ..(50)$$

$$\frac{\partial x_T}{\partial \mu_y} = e^{\mu_y + t\sigma_y} \qquad ..(51)$$

$$\text{var } a = \frac{1}{2\,n\,D} \qquad ..(52)$$

$$D = \frac{(\sigma_y^2+1)}{2\sigma_y^2}\, e^{2(\sigma_y^2 - \mu_y)} - \frac{(2\sigma_y^2+1)\, e^{\sigma_y^2 - 2\mu_y}}{2\sigma_y^2} \qquad ..(53)$$

$$\text{var } \mu_y = \frac{\sigma_y^2}{ND}\left[\frac{(\sigma_y^2+1)}{2\sigma_y^2}\, e^{2(\sigma_y^2 - \mu_y)} - e^{\sigma_y^2 - 2\mu_y} \right] \qquad ..(54)$$

$$\text{var } \sigma_y^2 = \frac{\sigma_y^2}{n\,D}\left[(\sigma_y^2+1)\, e^{2(\sigma_y^2 - \mu_y)} - e^{\sigma_y^2 - 2\mu_y} \right] \qquad ..(55)$$

$$\text{cov } (a, \mu_y) = - \frac{e^{\sigma_y^2/2 - \mu_y}}{2n\,D} \qquad ..(56)$$

$$\text{cov } (a, \sigma_y^2) = \frac{\sigma_y^2}{n\,D}\, e^{\sigma_y^2/2 - \mu_y} \qquad ..(57)$$

$$\text{cov } (\mu_y, \sigma_y^2) = - \frac{\sigma_y^2}{n\,D}\, e^{\sigma_y^2 - 2\mu_y} \qquad ..(58)$$

Substitution of the estimates using equations (48) to (58) in equation (47) yields the standard error of the T-year flood event. The listing of source programme is given in Appendix II A.

3.3 Programme 3 Extreme Value Type 1 Distribution

The type - I extremal distribution has the probability density function and cummulative probability density function respectively as ;

$$p(x) = \alpha\, e^{[-\alpha(x-\beta) - e^{-\alpha(x-\beta)}]} \qquad ..(59)$$

and

$$p(x) = e^{-e^{-\alpha(x-\beta)}} \qquad ..(60)$$

where

α is a concentration parameter, and

β is a measure of central tendency

3.3.1 Estimation of parameters

The programme uses the following two methods for estimating the parameters, α and β, of the distribution.

(i) Method of moments

(ii) Method of maximum likelihood

(i) Method of moments :

The two parameters α and β are computed in the programme EV1.BAS using the following equations :

$$\alpha = 1.2825/\sigma \quad ..(61)$$

$$\beta = \mu - 0.4500\,\sigma \quad ..(62)$$

where μ and σ are the mean and standard deviation of the sample.

The co-efficients of skew and Kurtosis for the EV1 distribution are approximately equal to 1.14 and 5.40 respectively.

(ii) Method of maximum likelihood :

The following non-linear equation is solved in the programme EV1.BAS using Newton's method of non-linear optimisation to compute the parameters α and β by method of maximum likelihood:

$$\frac{n}{\alpha} - n(\mu - \beta) + e^{\alpha\beta} \sum_{i=1}^{n} (x_i - \beta)\, e^{-\alpha x_i} \quad ..(63)$$

where $$e^{\alpha\beta} = n / \sum_{i=1}^{n} e^{-\alpha x_i}$$ ..(64 a)

or $$\beta = \frac{1}{\alpha} \ln [n / \sum_{i=1}^{n} e^{-\alpha x_i}]$$ ..(64 b)

3.3.2 Quantile estimates

(i) Method of moments :

The programme computes the T-year flood events using the following expressions by the method of moments.

$$x_T = \mu + K_T \sigma$$ ..(65)

where

$$K_T = - [0.45 + 0.7797 \ln (-\ln (1 - \frac{1}{T}))]$$ ..(66)

and μ and σ are sample estimates of mean and standard deviation, respectively.

(ii) Method of maximum likelihood :

T-year flood events are computed using the maximum likelihood estimates of parameters, α and β . in the following expressions :

$$x_T = \beta + \frac{1}{\alpha} y_T$$ ..(67)

$$y_T = -\ln (-\ln ((T - 1) / T))$$ ..(68)

3.3.3 Standard error

(i) Method of moments :

The standard error of T-year event is computed using the following equations by method of moments :

$$S_T = \frac{\sigma}{\sqrt{n}} (1 + 1.1396 K_T + 1.1000 K_T^2)^{1/2} \qquad ..(69)$$

(ii) Method of Maximum likelihood :

The standard error of estimates for T-year event is computed using the following equation in the programme :

$$S_T = \frac{1}{\sqrt{n}\alpha} (1.1086 + 0.514 y_T + 0.6079 y_T^2)^{1/2} \qquad .(70)$$

The listing of the source programme is given in Appendix-III.A

3.4 Programme 4 (Pearson type III Distribution)

The probability density distribution of the Pearson type III distribution is of the form

$$p(x) = \frac{1}{\alpha \Gamma \beta} \left(\frac{x-\gamma}{\alpha} \right)^{\beta-1} e^{-\left(\frac{x-\gamma}{\alpha}\right)} \qquad ..(71)$$

where α, β and γ are parameters to be defined for the distribution and $\Gamma\beta$ is the gamma function. of parameter β

3.4.1 Estimation of parameters

(i) Method of moments :

The programme computes the parameters of the pearson type III distribution, α, β and γ using the following equations by the method of moments :

$$\beta = (2/\gamma_1)^2 \qquad ..(72)$$

$$\alpha = \sigma/\sqrt{\beta} \qquad ..(73)$$

$$\gamma = \mu - \sigma\sqrt{\beta} \qquad ..(74)$$

where γ_1 is the unbiased estimate of skewness computed as

$$\gamma_1 = \hat{\gamma}_1 \sqrt{\frac{n(n-1)}{(n-2)}} \left(1 + \frac{8.5}{n}\right) \qquad ..(75)$$

$\hat{\gamma}_1$ = Biased estimate of skewness computedfrom the sample.

n = Size of the sample.

(ii) **Method ot maximum likelihood :**

The parameters, α, β and γ, of the distribution are estimated by method of maximum likelihood in the programme PT3.BAS using an iterative procedure of non-linear optimization, based on Newton's Method, to solve the following non-linear equation for γ :

$$-n\, \Gamma'(\beta) / \Gamma(\beta) + \sum_{i=1}^{n} \ln (x_i - \gamma) - n \ln \alpha = 0 \qquad ..(76)$$

where $\Psi(\beta) = \Gamma'(\beta) / \Gamma(\beta)$ ..(77)

$$= \ln(\beta + 2) - \frac{1}{2(\beta+2)} - \frac{1}{12(\beta+2)^2} + \frac{1}{120(\beta+2)^4}$$

$$- \frac{1}{252(\beta+2)^6} - \frac{1}{(\beta+1)} - \frac{1}{\beta} \qquad ..(78)$$

$$\beta = 1 / [\, 1 - \frac{n^2}{\sum_{i=1}^{n} (x_i - \gamma) \sum (1/(x_i - \gamma))}] \qquad ..(79)$$

$$\alpha = \frac{\sum_{i=1}^{n} (x_i - \gamma)}{n} - \frac{n}{\sum_{i=1}^{n} (1/(x_i - \gamma))} \qquad ..(80)$$

The optimum value of the parameter, γ is used in equation (79) and (80) for estimating the remaining two parameters, α and β .

3.4.2 Estimation of quantiles

(i) Method of moments :

The programme computes T-year flood events using the following equations by the method of moments :

$$x_T = \mu + \sigma . K_T \qquad ..(81)$$

where μ and σ are the mean and standard deviation estimated from the sample respectively,

$$K_T = t + (t^2 - 1)\frac{\gamma_1}{6} + \frac{1}{3}(t^3 - 6t)(\frac{\gamma_1}{6})^2 - (t^2 - 1)(\frac{\gamma_1}{6})^3 + t(\frac{\gamma_1}{6})^4 + \frac{1}{3}(\frac{\gamma_1}{6})^5 \qquad ..(82)$$

t= standard normal reduced variate corresponding to T-year return period

and γ_1 = co-efficient of skewkess

(ii) Method of maximum likelihood :

The parameters α, β and γ, estimated by the method of maximum likelihood, are used in the following equation to compute T-year flood events from the programme PT3.DAS.

$$x_T = \alpha\beta\left(1 - \frac{1}{9\beta} + t\sqrt{\frac{1}{9\beta}}\right)^3 + \gamma \qquad ..(83)$$

where t = standard normal reduced variate corresponding to T-year return period.

3.4.3 Standard error

(i) Method of moments :

The standard error of T-year flood event, S_T, is computed by Method of moments using the following equations, in the programme

$$S_T^2 = \frac{\sigma^2}{n}\left(1 + K\gamma_1 + \frac{K^2}{2}(3\gamma_1^2/4 + 1) + 3K\frac{\partial K}{\partial \gamma_1}(\gamma_1 + \gamma_1^3/4)\right.$$

$$\left. + 3\left(\frac{\partial K}{\partial \gamma_1}\right)^2 (2 + 3\gamma_1^2 + 5\gamma_1^4/8)\right) \quad ..(84)$$

$$\frac{\partial K}{\partial \gamma_1} = \frac{(t^2-1)}{6} + \frac{4(t^3-6t)}{6^3}\gamma_1 - \frac{3(t^2-1)}{6^3}\gamma_1^2$$

$$+ \frac{4t}{6^4}\cdot\gamma_1^3 - \frac{10}{6^6}\gamma_1^4 \quad ..(85)$$

where t = standard normal reduced variate

and γ_1 = co-efficient of skewness

(ii) Method of maximum likelihood :

The variance of the T-year event, S_T^2, is computed in the programme using the following equations by method of maximum likelihood :

$$S_T^2 = \left(\frac{\partial x_T}{\partial \alpha}\right)^2 \text{var}\,\alpha + \left(\frac{\partial x_T}{\partial \beta}\right)^2 \text{var}\,\beta + \left(\frac{\partial x_T}{\partial \gamma}\right)^2 \text{var}\,\gamma + 2\frac{\partial x_T}{\partial \alpha}\frac{\partial x_T}{\partial \beta}$$

$$\text{cov}(\alpha,\beta) + 2\frac{\partial x_T}{\partial \alpha}\frac{\partial x_T}{\partial \gamma}\text{cov}(\alpha,\gamma) + 2\frac{\partial x_T}{\partial \beta}\frac{\partial x_T}{\partial \gamma}\text{cov}(\beta,\gamma) \quad ..(86)$$

$$\frac{\partial x_T}{\partial \alpha} = \left(\beta^{1/3} - \frac{1}{9\beta^{2/3}} + \frac{t}{3\beta^{1/6}}\right)^3 \quad ..(87)$$

$$\frac{\partial x_T}{\partial \beta} = 3\alpha\left(\beta^{1/3} - \frac{1}{9\beta^{2/3}} + \frac{t}{3\beta^{1/6}}\right)^2$$

$$18\left(\frac{1}{3\beta^{2/3}} + \frac{2}{27\beta^{5/3}} - \frac{t}{18\,\beta^{7/6}}\right) \quad ..(88)$$

$$\frac{\partial x_T}{\partial \gamma} = 1 \quad ..(89)$$

$$\mathrm{var}\,\alpha = \frac{1}{n\alpha^2 D}\left(\frac{\Psi(\beta)}{(\beta-2)} - \frac{1}{(\beta-1)^2}\right) \quad ..(90)$$

$$\mathrm{var}\,\beta = \frac{2}{n\,n\alpha^4\,(\beta-2)} \quad ..(91)$$

$$\mathrm{var}\,\gamma = \frac{\beta\Psi'(\beta) - 1.0}{n\alpha^2 D} \quad ..(92)$$

$$\mathrm{cov}\,(\alpha,\beta) = \frac{-1}{n\alpha^3 D}\left(\frac{1}{(\beta-2)} - \frac{1}{(\beta-1)}\right) \quad ..(93)$$

$$\mathrm{cov}\,(\alpha,\gamma) = \frac{1}{n\alpha^2 D}\left(\frac{1}{(\beta-1)} - \Psi'(\beta)\right) \quad ..(94)$$

$$\mathrm{cov}\,(\beta,\gamma) = -\frac{1}{n\alpha^3 D}\left(\frac{\beta}{(\beta-1)} - 1\right) \quad ..(95)$$

$$D = \frac{1}{(\beta-2)\alpha^4}\left[2\Psi'(\beta) - \frac{(2\beta-3)}{(\beta-1)^2}\right] \quad ..(96)$$

$$\Psi'(\beta) = \frac{1}{(\beta+2)} + \frac{1}{2(\beta+2)^2} + \frac{1}{6(\beta+2)^3}$$

$$- \frac{1}{30(\beta+2)^5} + \frac{1}{42(\beta+2)^7} - \frac{1}{30(\beta+2)^9} + \frac{1}{(\beta+1)^2} + \frac{1}{\beta^2} \quad ..(97)$$

where D is the determinant of matrix of likelihood derivatives.

The listing of source programme is given in Appendix IV.A

3.5 Programme 5 (Log Pearson Type III Distribution)

If the logarithms, lnx of a variable x are distributed as a pearson type III variate, then the variable will be distributed as a log pearson type III with probability density function (pdf) :

$$p(x) = \frac{1}{\alpha\ x\Gamma\beta} \left(\frac{\ln x - \gamma}{\alpha}\right)^{\beta - 1} e^{-\left(\frac{\ln x - \gamma}{\alpha}\right)} \qquad ..(98)$$

where α , β and γ are the scale, shape and location parameters respectively.

3.5.1 Estimation of parameters

The parameters of the distribution are estimated by the following three methods.

(i) Method od moments (Direct)

(ii) Method of moments (Indirect)

(iii) Method of maximum likelihood

(i) Method of moments (Direct) :

The parameters, α , β and γ are estimated by the direct application of the moment generating function to the pdf of the log pearson type III distribution by this method. The following equations are used in the programme to compute the parameters of the distribution by this method :

$$B = \frac{\ln \mu_3' - 3\ln \mu_1'}{\ln \mu_2' - 2\ln\mu_1'} \qquad ..(99)$$

where μ_3', μ_2', μ_1' are the third, second and first moments of the pdf about the origin respectively and these moments can be estimated from the sample. Therefore, B can be estimated directly from the sample.

$$C = \frac{1}{(B-3)} \quad ..(100)$$

If $3.5 \leq B \leq 6.0$, then

$$A = -0.23019 + 1.65262\,C + 0.20911\,C^2 - 0.04557\,C^3 \quad ..(101)$$

If $3.0 < B \leq 3.5$, then

$$A = -0.47157 + 1.99955\,C \quad ..(102)$$

The values of C obtained from equation (100) is substituted either in regression equation (101) or equation (102) depending upon the value of B. If the value of B does not lie within the above stated ranges, then this method is considered to be inapplicable for that particular sample data and the programme prints out the instruction 'METHOD NOT APPLICABLE BECAUSE OF B VALUE OF 'X', where X is any value of B greater than 6.0. However, if the value of B lies within one of the above stated ranges then the parameters α, β and γ are estimated by substituting corresponding A, B and C values in the following equations :

$$\alpha = 1/(A+3) \quad ..(103)$$

$$\beta = (\ln \mu_2' - 2\ln \mu_1')/(\ln(1-\alpha)^2 - \ln(1-2\alpha)) \quad ..(104)$$

$$\gamma = \ln \mu_1' + \beta \ln(1-\alpha) \quad ..(105)$$

The parameters α , β and γ are then used to compute mean μ_y, standard deviation σ_y, and co-efficient of skew, γ_y of the logarithms of x as :

$$\mu_y = \gamma + \alpha\beta \qquad ..(106)$$

$$\sigma_y = \alpha\sqrt{\beta} \qquad ..(107)$$

$$\gamma_y = 2.0/\sqrt{\beta} \qquad ..(108)$$

(ii) Method of moments (Indirect) :

The programme computes the parameters, α , β and γ , by this method following the procedure stated in section 3.4.1. using the equations (72) to (75), from where the mean, μ , standard deviation, σ , and skewness, γ , are replaced by the calculated mean, μ_y, the standard deviation, σ_y, and the co-efficient of skewness, γ_y, of the logarithms of x respectively.

(iii) Method of maximum likelihood :

In the programme the parameters α , β and γ are estimated by this method by solving the following non linear equations iteratively using Newton's method of optimisation :

$$\sum_{i=1}^{n} (\ln x_i - \alpha) = n\alpha\beta \qquad ..(109)$$

$$n\Psi(\beta) = \sum_{i=1}^{n} \ln[(\ln x - \gamma)/\alpha] \qquad ..(110)$$

$$n = \alpha(\beta - 1) \sum_{i=1}^{n} 1/(\ln x_i - \gamma) \qquad ..(111)$$

3.5.2 Estimation of quantiles

(i) Method of moments (Direct) :

T-year events are computed using the following equation :

$$x_T = e^{\mu_y + K_T \sigma_y} \quad ..(112)$$

where μ_y and σ_y are the mean and standard deviation of the logarithms of x respectively and computed using the equations (106) to (108) and K_T is computed using the equation (82).

(ii) Method of moments (Indirect):

T-year events are computed by this method using the equation (112) where μ_y and σ_y are the sample estimates of mean and standard deviation respectively.

(iii) Method of Maximum likelihood :

By this method, T-year flood events are computed in the programme using the following equations :

$$x_T = \mathrm{ExP}\ (\alpha . E^3 + \gamma) \quad ..(113)$$

$$E = \beta \left(1 - \frac{1}{9\beta} + t\sqrt{\frac{1}{9\beta}} \right) \quad ..(114)$$

where α , β and γ are the maximum likelihood estimates of the parameters and t is the standard normal reduced variate.

3.5.3 Standard error

(i) Method of moments (Direct) :

The standard error of the T-year event for the log pearson type III distribution by this method is computed using equation (84) to obtain $S_{T,y}$ in log units from the standard normal deviate and the co-efficient of skew, computed from equation (85).

The standard error is then converted back to linear units as

$$S_{T,x} = \frac{x_T \,(e^{S_{T,y}} - e^{-S_{T,y}})}{2.0} \qquad \ldots(115)$$

where $S_{T,x}$ is the average of the positive and negative standard errors in linear units and x_T is the T-year event.

(ii) Method of moments (Indirect) :

The procedure for estimating the standard error of the T-year event by this method is same as for the method of moments (Direct) except the sample estimate of skewness in log domain is used to equation (84) and (85) along with standard normal reduced variate to obtain $S_{T,y}$ in log units. The equation (115) is used to obtain the standard error.

(iii) Method of maximum likelihood :

The standard error in log units is obtained from equation (86) to (97) using the maximum likelihood estimates of parameters α, β and γ. The logarithmic standard error is then converted to linear units using equation (115).

The listing of source programme is given in Appendix V.A

3.6 Program 6 (Standard Error of Frequency Distribution)

The programme is used to compute the standard error of each of the distribution including turncated normal distribution. The following equation is used for this computation :

$$SE_j = \left[\frac{\sum_{i=1}^{n} (x_i - y_i)^2}{(n - m_j)} \right]^{1/2} \qquad ..(116)$$

where x_i, $i = 1, 2....n$ are the recorded events

y_i, $i = 1, 2....n$ are the event magnitudes computed from the j^{th} probability distribution at probabilities computed from the sorted ranks of x_i, $i = 1....n$ and m_j is the number of parameters estimated from the j^{th} distribution.

The probabilities of non-exceedence, F_i, for each distribution are computed as :

$$F_i = \frac{i}{(n+1)} \qquad ..(117)$$

where i is the rank no. in ascending order.

The listing of the source programme is given in Appendix-VI. A

3.7 Program 7 . (Best Fit Distribution Using Chi-Square Criterion)

The following steps are involved.

i. The programme first sorts out the data for a particular season. In the case of time series of monthly data the programme sorts out the data for each month while in the case of weekly data, the data for each week is separated.

ii. The programme arranges the seasonal data in descending order.

iii. Various transformations are tested on this arranged data, which are as follows:

a. Normal distribution by method of moments:

The data as such is compared with the normal distribution.

b. Inverse Pearson type III transformation:

The following equation is used to normalize the data:

$$Y = \{(\frac{C_s}{2}(\frac{X-\mu}{\sigma})+1)^{1/3}-1\}\frac{6}{C_s} + \frac{C_s}{6} \qquad \ldots(118)$$

where,

X : Original series

μ : Mean of the original series

σ : Standard deviation of original series

C_s : Coefficient of skewness of original series

Y : Pearson type III transformed series

c. Log normal distribution (parameters estimation on the basis of theoretical (parameters estimation on the basis of theoretical relationships):

Parameters of the log transformed series are calculated on the basis of following theoretical relationships:

$$\mu_y = \log(\mu_x) - 0.5 \log\{(\sigma_x/\mu_x)^2 + 1\} \quad \ldots (119)$$

$$\sigma_y = \{\log((\sigma_x/\mu_x)^2 + 1)\}^{1/2} \quad \ldots (120)$$

where,

μ_x : Mean of the original series

σ_x : Standard deviation of the original series

μ_y : Mean of log transformed series

σ_y : Standard deviation of the log transformed series

The parameters so obtained are used for the calculation of chi-square statistic.

d. Log transformation:

$$Y = \log X \quad \ldots (121)$$

where,

Y : Log transformed series

X : Original series

e. **Inverse log Pearson type III transformation:**

In inverse log Pearson type III transformation log transformed series is used instead of original series. Rest of the procedure for transformation is similar to that for inverse Pearson type III transformation.

f. Square root transformation:

In this procedure square root of the original series is used as transformed series.

iv. After computing the statistical parameters of the transformed series, the programme calculates the chi-square statistic for the transformation.

There are two methods available to compute the Chi-square statistic viz., (i) equal class interval method (2) equal probability method. In this programme the equal probability method is adopted. The chi-square statistic is computed as

$$\chi^2 = \sum_{i=1}^{NCLAS} \frac{((f_{oi} - f_{ei})^2)}{f_{ei}} \quad \ldots(122)$$

where,

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 programme only computes χ^2 statistic and it is left to user for verifying the goodness of fit.

Number of degress of freedom is also calculated. Number of degress of freedom is given N-p-1 where p is the parameter of the distribution and N is the number of classes.

v. The chi-square value so obtained can be compared with critical chi-square value for desired significance level and calculated number of degrees of freedom. The transformation giving the least chi-square value is considered to be the best for that season/month/week data set. The critical value of X^2 can be seen from Appendix IX. For example χ^2 value for 95% significance level and 3 degrees of freedom is 7.81.

vi. Steps i to v are repeated for other seasons. The computer programme for best fit distribution consists of one main routine and ten subroutines. The subroutine NDTRI calculates standared normal variate corresponding to a given probability. The subroutine MSS calculates mean, standard deviation and coefficient of skewness of the given series. The subroutine CSS calculates chi-square and degrees of freedom for a transformation. Subroutine NORMAL, analyses normal distribution. Subroutine PT3, LP3 and SQRTT analyse inverse pearson Type III, log inverse Pearson Type III and square root transformations respectively. Subroutine LNC analyses log normal distribution for which parameters are calculated on the basis of theoretical relationships. The subroutine LN analyses log transformation. The subroutine SORTX arranges the data in descending order.

The listing of the source programme is given in Appendix - VII A.

3.8 Programme 8 (Flood Frequency Analysis using Power Transformation)

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

$$Z_i = \frac{X_i^{\lambda} - 1}{\lambda} \quad \text{for } \lambda \neq 0 \qquad \dots (123)$$

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

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:

$$CS = \frac{N}{(N-1)(N-2)} \left[\frac{\sum_{i=1}^{N} (z_i - \bar{z}_i)^3}{S^3} \right] \qquad \ldots(124)$$

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:

$$\bar{z}_1 = \frac{1}{N} \sum_{i=1}^{N} z_i \qquad \ldots(125)$$

The standard deviation S is computed as:

$$S = \frac{1}{(N-1)} \left[\sum_{i=1}^{N} (z_i - \bar{z})^2 \right]^{1/2} \qquad \ldots(126)$$

In this program, when $|C_s| \leq 0.001$, it is assumed that near normality is achieved. The exponent, λ which near normalizes the data series is obtained by Newton Raphson technique.

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:

$$CK = \frac{N^2}{(N-1)(N-2)(N-3)} \left[\frac{\sum_{i=1}^{N} (Z_i - \bar{Z}_1)^4}{S^4} \right] \qquad ...(127)$$

Correction procedure is available 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:

$$X_T = (Z_T\lambda + 1)^{1/\lambda} \qquad ...(128)$$

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 10,000 year return periods.

The goodness of fit test is evaluated by the most commonly used Chi-square test procedure. The program only computes X^2 statistic. It is left to the user for verifying the goodness of fit.

The programme consists of a main programme 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. Subroutine SPLINE and AKIMA are used for interpolation. These subroutines are adopted from HEC 1 flood hydrograph package. Subroutine CHIST computes the Chi-square statistic based on equal probability criteria for each class interval. Subroutine NDTRI is adopted 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 nonexecedance.

The list of the source programme is given in Appendix VIII.A.

4.0 INPUT SPECIFICATIONS AND OUTPUT DESCRIPTION

4.1 Input Specifications

Input card/lines have been devided in two parts

(a) Job cards

(b) Data cards

4.1.1 Programme 1-6

The input specifications from programme 1 to 6 are same.

Job Cards

Card	Variable	Description	Format
FIRST	TITLE	Title of the problem	A
SECOND	N	Number of annual maximum events	Free

Data Cards

X (1), X (2),....X (N), series of annual maximum events is punched till end, in free format.

4.1.2 Programme 7 (Best Fit Distribution using Chi-square criterion)

Job Cards

Card	Variable	Description	Format
FIRST	TITLE	Title of the problem	A
SECOND	N	Total number of observations	Free
	NS	Number of seasons in a year	
	NCLAS	Number of classes for the calculation of Chi-square	
THIRD	N1	Option code for normal distribution	Free
	N2	Option code for inverse Pearson type III transformation	

N3	Option code for log normal distribution (parameters on the basis of theoretical relationships)
N4	Option code for log transformation
N5	Option code for inverse log Pearson type III transformation
N6	Option code for square root transformation

If any of the transformation is not required 0 is given corresponding to its option code, otherwise 1 is given.

Data Cards

Observations KX(1), KX(2)...., KX(N) are punched till end in free format.

The number of classes should be chosen in such a way that at least 5 observations are there in each class and the observations for a season should be independent.

The listing of data file is given in Appendix - VII B.

4.1.3 Programme 8 (Flood Frequency Analysis using Power Transformation)

Job Cards

Card	Variable	Description	Format
FIRST	TITLE	Title of the problem	A
SECOND	N	Number of annual maximum values to be analysed	Free
	NCLASS	Number of classes used in the Chi-square test	
	RI	Recurrence interval for which flood estimate is made	

Data Cards

IYEAR (1),... IYEAR (N), series of years of flood observations are punched in free form at till end.

X (1), X(2),--, X (N), series of annual maximum peaks are punched till end in free format.

The listing of data file is given in Appendix VIII-B.

4.2 Output Description

4.2.1 Programme 1 (Two parameter Log normal Distribution)

The main variables used in the output list are described below

Variable	Description	Format
TITLE	Title of the problem	A
M1	Mean of X	E12.5
M2	Variance of X	E12.5
G	Skew of X	E12.5
XT(J)	Array of flood estimates for different return periods by method of moments	6E12.5
SX(J)	Array of standard error of flood magnitudes of different return periods by method of moments	6E12.5
M1	Mean of ln (X)	E12.5
M2	Variance of ln (X)	E12.5
G	Skew of ln (X)	E12.5
XT(I)	Array of flood estimates for different return periods by method of maximum likelihood	E12.5
SX (I)	Array of standard error of flood magnitudes of different return periods by method of mamximum likelihood	6E12.5

The listing of output file is given in Appendix -I C.

4.2.2 Programme 2 (Three parameter Log normal Distribution)

The main variables used in the output list are described below

Variable	Description	Format
TITLE	Title of the problem	A
M1	Mean of X	E12.5
M2	Variance of X	E12.5
G	Skew of X	E12.5
AMO	Location parameter, A	E12.5
XT(J)	Array of flood estimates for different return periods by method of moments	6E12.5
SX(J)	Array of standard error of flood magnitudes of different return periods by method of moments	6E12.5
ICOUNT	Serial number	I2
AS	Location parameter	E12.5
FCN	Objective function	E12.5
AML	Location parameter A, using method of maximum likelihood	E12.5
MU	Mean of ln (X- A)	E12.5
VAR	Variance of ln (X-A)	E12.5
SKEW	Skewnessof ln (X-A)	E12.5
XT(J)	Array of flood estimates for different return periods by method of maximum likelihood	6E12.5
ST(J)	Array of standard errors of flood estimates for different return periods by method of maximum likelihood	6E12.5

The listing of the output file is given in Appendix-II B.

4.2.3 Programme 3 (Extreme Value Type 1 Distribution)

The main variables used in the output list are described below:

Variable	Description	Format
TITLE	Title of the problem	A
ALPHA	Location parameter of EV-1 distribution by method of moments	E12.5
M1	Mean of the sample	E12.5
BETA	Scale parameter of EV1 distribution by method of moments	E12.5
M2	Variance of the sample	E12.5
SKEW	Skewness of the sample	E12.5
XT(J)	Array of flood estimates for different return periods by method of moments.	6E12.5
SX(J)	Array of standard errors of flood estimates for different return periods by method of moments	6E12.5
ICOUNT	Serial number	I2
AS	Location parameter	E12.5
FCN	Objective function	E12.5
ALPHA	Location parameter by method of maximum likelihood	E12.5
M1	Mean of the sample estimated indirectly assuming ALPHA and BETA estimated by method of maximum likelihood as correct	E12.5
BETA	Scale parameter by method of maximum likelihood	E12.5
M2	Variance of the sample estimated indirectly assuming ALPHA-and BETA estimated by method of maximum likelihood as correct	E12.5

XT(J)	Array of flood estimates for different return periods by method of maximum likelihood	6E12.5
ST(J)	Array of standard errors of flood magnitudes for different return periods by method of maximum likelihood	6E12.5

The listing of output file is given in Appendix - III D.

4.2.4 Programme 4 (Pearson type III Distribution)

The main variables used in the output list are described below:

Variable	Description	Format
TITLE	Title of the problem	A
ALPHA	Scale parameter estimated by method of moments	E12.5
M1	Mean of the sample	E12.5
BETA	Shape parameter estimated by method of moments	E12.5
M2	Variance of the sample	E12.5
GAMMA	Location parameter estimated by method of moments	E12.5
SKEW	Skewness of the sample	E12.5
XT(J)	Array of flood estimates for different return periods by method of moments	6E12.5
SX(J)	Array of standard error of flood magnitudes for different return periods by method of moments	6E12.5
ICOUNT	Serial number	I2
AS	Location parameter	E12.5
FCN	Objective function	E12.5

ALPHA	Scale parameter estimated by method of maximum likelihood	E12.5
M1	Mean of the sample estimated indirectly assuming parameters estimated by method of maximum likelihood as correct	E12.5
BETA	Shape parameter estimated by method of maximum likelihood	E12.5
M2	Variance of the sample assuming parameters estimated by method of maximum likelihood as correct	E12.5
GAMMA	Location parameter	E12.5
SKEW	Skewness of the sample assuming parameters estimated by method of maximum likelihood as correct	E12.5
XT(J)	Array of flood estimates for different return periods by method of maximum likelihood	6E12.5
XS(J)	Array of standard error of flood estimates for different return periods by method of maximum likelihood	6E12.5

The listing of the output file is given in Appendix - IV B.

4.2.5 Programme 5 (Log Pearson Type III Distribution)

The main variables used in the output list are described below:

Variable	Description	Format
TITLE	Title of the problem	A
L1	First moment about origin of original series	E12.5
L2	Second moment about origin of original series	E12.5
L3	Third moment about origin of original series	E12.5
M1	Mean of the sample	E12.5
M2	Variance of the logarithms	E12.5

SKEW	Skewness of the logarithms	E12.5
XT(J)	Array of flood estimates by method of moments direct	6E12.5
ST(J)	Array of standard errors by method of moments-direct	6E12.5
ALPHA	Scale parameter (method of moments-indirect)	6E12.5
BETA	Shape parameter (method of moments-indirect)	E12.5
GAMMA	Location parameter (method of moment-indirect)	E12.5
M1	Mean of logarithms of sample	E12.5
M2	Variance of logarithms of sample	E12.5
SKEW	Skewness of logarithms of sample.	E12.5
XT(J)	Array of flood estimates by method of moments-indirect	6E12.5
ST(J)	Array of flood estimates by method of moments-indirect	6E12.5
ICOUNT	Serial number	I2
AS	Location parameter	E12.5
FCN	Objective function	E12.5
ALPHA	Scale parameter by method of maximum likelihood	E12.5
M1	Mean of logarithms assuming parameter estimated by method of maximum likelihood as correct	E12.5
BETA	Shape parameter by method of maximum likelihood	E12.5
M2	Variance of the logarithms assuming parameters estimated by method of maximum likelihood as correct	E12.5
GAMMA	Location parameter by method of maximum likelihood	E12.5
SKEW	Skewness of the logarithms assuming parameters estimated by method of maximum likelihood as correct	E12.5

XT(J)	Array of flood estimates by method of maximum likelihood	6E12.5
ST(J)	Array of standard errors by method of maximum likelihood	6E12.5

The listing of output file is given in appendix - V B.

4.2.6 Programme 6 (Standard Error of Different Distributions)

The main variables used in the output list are described below:

Variable	Description	Format
TITLE	Title of the problem	A
M1	Mean of the sample	E12.5
M2	Variance of the sample	E12.5
SKEW	Skewness of the sample	E12.5
X(I)	Array of sorted recorded events	6E12.5
L1	Mean of logarithms	E12.5
L2	Variance of logarithms	E12.5
LG	Skewness of logarithms	E12.5
Z(I)	Array of truncated normal events	6E12.5
Z(I)	Array of 2 parameter lognormal events	6E12.5
Z(I)	Array of 3 parameter log normal events	6E12.5
Z(I)	Array of type 1 extremal events	6E12.5
Z(I)	Array of Pearson type III events	6E12.5
Z(I)	Array of log Pearson type III events	6E12.5
SUM	Standard error	E12.5

The listing of output file is given in Appendix - VI B.

4.2.7 Programme 7(Best fit Distribution using Chi-square criterion)

The following statistics are printed for desired transformations) for all the seasons

Statistics	Format
Mean of the transformed series	F8.3
Standard deviation of the transformed series	F8.3
Coeff. of skewness of the transformed series	F8.3
Chi-square	F8.3
Number of degrees of freedom	I5

The listing of output file is given in Appendix VII-C.

4.2.8 Programme 8 (Flood Frequency Analysis using Power Transformation)

The output tabulates the riginal series in Chronological order alongwith years and then it arranges then,in ascending order of magnitude alongwith the corresponding year of occurrence. It assigns the rank to them according to the ascending order and computes the probability of non exceedances using Blom's plotting position. 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 logtransformed 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 displayed.

The listing of output file is given in Appendix - VIII C.

5.0 RECOMMENDATIONS

The eight computer programmes given in this user's manual are written in FORTRAN language. FORTRAN compiler and simple FORTRAN instructions are required to run the programmes. The memory requirement depends upon the length of the data which will modify the dimension statements of the programmes.

The programmes LN2.FOR, LN3.FOR, TIE.FOR, PT3.FOR and LP3.FOR, Compute the floods of 2, 5, 10, 20, 50 and 100 years recurrence interval only. If the user wants to estimate the floods of the recurrence intervals mentioned above, then one more statement should be added in the programmes to supply the normal reduced variate corresponding to the desired recurrence interval through the single subscripted variable SND.

The programme CHI.FOR for best fit distribution using normalization procedures and Chi-square criterion, can be used for any type of seasonal hydrologic data e.g. daily, pented, ten daily, monthly or annual. It can also be applied to other data sets. The data should be continuous without any gap and the observations across the year should be independent.

The programme POWTRA.FOR uses Newton-Raphson technique to estimate the power transformation exponent, λ . The same can be done by grid search technique also. Since there is a systematic variation in the coefficient of skewness of the transformed series for different values of λ , the Newton-Raphson technique is somewhat more efficient.

The results obtained by these computer programmes are subject to various assumption regarding adequacy, relevency and accuracy of data and limitations of flood frequency analysis approach.

REFERENCES

1. Kite, G.W. (1977), 'Frequency and Risk Analysis in Hydrology', Water Resources Publication, Fort Collins, Colorado 80522, U.S.A.

2. Seth, S.M. and Goel, N.K. (1982), 'Best Fit Distribution using Normalization Procedures and Chi-square criterion', National Institute of Hydrology, Roorkee, Technical Report, DP-3.

3. Seth, S.M. and Perumal, M. (1982), 'Flood Frequency Analysis using Power Transfo rmation', National Institute of Hydrology, Roorkee, Technical Report DP-1.

4. Seth, S.M., Singh, R.D. and Jain, Vibha, (1986), 'Flood Frequency Analysis on a Microcomputer with Basic Language', National Institute of Hydrology, Roorkee, Technical Report, UM-19.

APPENDIX - IA

SOURCE PROGRAMME (LN2.FOR)

```
C       MASTER LOG NORMAL DISTRIBUTION WITH TWO PARAMETERS
C       ESTIMATES FOR T YEAR EVENTS AND STANDARD ERRORS FOR 2 PARA
C       METERS LOGNORMAL DISTRIBUTION
        DIMENSION SND(6),X(100),XT(6),SX(6),TITLE(80)
        REAL K,M1,M2,M3
        OPEN(UNIT=5,FILE='DATA.DAT',STATUS='OLD')
        OPEN(UNIT=6,FILE='LN2.OUT',STATUS='NEW')
        SND(1)=0.0
        SND(2)=0.8416
        SND(3)=1.2816
        SND(4)=1.6449
        SND(5)=2.0538
        SND(6)=2.3264
        READ(5,8) TITLE
        READ(5,*) N
        XN=N
        READ(5,*) (X(I),I=1,N)
        WRITE(6,11) TITLE
        WRITE(6,12)
        A=0.0
        B=0.0
        C=0.0
        DO 1 I=1,N
        A=A+X(I)
        B=B+X(I)**2
        C=C+X(I)**3
1       CONTINUE
        M1=A/XN
        M2=(B/XN)-(A/XN)**2
        M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
        M2=M2*XN/(XN-1.0)
        G=M3/(M2**1.5)
        WRITE(6,5) M1
        WRITE(6,6) M2
        WRITE(6,7) G
        Z=(SQRT(M2))/M1
        A=ALOG(1.0+Z**2)
        DO 2 J=1,6
        T=SND(J)
        K=(EXP(SQRT(A)*T-A/2.0)-1.0)/Z
        XT(J)=M1+K*SQRT(M2)
        DELTA=SQRT(1.0+((Z**3+3.0*Z)*K)+((Z**8+6.0*Z**6+15.0*Z**4
        1+16.0*Z**2+2.0)*K**2)/4.0)
2       SX(J)=DELTA*SQRT(M2/XN)
        WRITE(6,13)
        WRITE(6,14) (XT(J),J=1,6)
        WRITE(6,15) (SX(J),J=1,6)
        DO 3 J=1,6
        T=SND(J)
        K=(EXP(SQRT(A)*T-A/2.0)-1.0)/Z
```

```
      DELTA=SQRT((A*((1.0+K*Z)**2)*(1.0+(T**2)/2.0))/Z**2)
 3    SX(J)=DELTA*SQRT(M2/XN)
      WRITE(6,20)
      A=0.0
      B=0.0
      C=0.0
      DO 4 I=1,N
      X(I)=ALOG(X(I))
      A=A+X(I)
      B=B+X(I)**2
      C=C+X(I)**3
 4    CONTINUE
      M1=A/XN
      M2=(B/XN)-(A/XN)**2
      M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
      M2=M2*XN/(XN-1.0)
      G=M3/(M2**1.5)
      WRITE(6,17) M1
      WRITE(6,18) M2
      WRITE(6,19) G
      WRITE(6,16)
      WRITE(6,13)
      WRITE(6,14) (XT(J),J=1,6)
      WRITE(6,15) (SX(J),J=1,6)
      STOP
5     FORMAT(20X,'MEAN OF X',16X,E12.5)
6     FORMAT(20X,'VARIANCE OF X',12X,E12.5)
7     FORMAT(20X,'SKEW OF X',16X,E12.5,/)
8     FORMAT(80A1)
9     FORMAT(I5)
10    FORMAT(8F10.0)
11    FORMAT(/,80A1,//,21X,'  TWO PARAMETER LOGNORMAL DISTRIB
     1UTION',/)
12    FORMAT(31X,'METHOD OF MOMENTS',//)
13    FORMAT(3X,7HT,YEARS,4X,1H2,11X,1H5,10X,2H10,10X,2H20,10X,
     12H50,10X,3H100,/)
14    FORMAT(3X,1HX,3X,6E12.5,/,4X,1HT)
15    FORMAT(3X,1HS,3X,6E12.5,/,4X,1HT,//)
16    FORMAT(3X,'NOTE-FOR GOOD USE OF THIS DISTRIBUTION SKEW OF
     1LOGS SHOULD BE CLOSE TO ZERO',/)
17    FORMAT(20X,'MEAN OF LN(X)  ',6X,E12.5)
18    FORMAT(20X,'VARIANCE OF LN(X)  ',6X,E12.5)
19    FORMAT(20X,'SKEW OF LN(X)  ',10X,E12.5,/)
20    FORMAT(25X,'METHOD OF MAX. LIKELIHOOD')
      END
```

APPENDIX - IB

DATA FILE FOR PROGRAMMES 1-6 (DATA. DAT)

```
ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS
32
23890 26810 45630 10380 13290 17100 28650 29150 12810 26700 19700 38800
21250 43360 38880 15250 19560 15250 13000 22670 58100 31170 69400 19980
47980 61350 27300 33750 19500 22700 34260 38200
```

APPENDIX - IC

OUTPUT FILE FOR PROGRAMME 1 (LN2.OUT)

ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS

TWO PARAMETER LOGNORMAL DISTRIBUTION

METHOD OF MOMENTS

MEAN OF X	0.29557E+05
VARIANCE OF X	0.22095E+09
SKEW OF X	0.95539E+00

T,YEARS	2	5	10	20	50	100
X_T	0.26406E+05	0.39378E+05	0.48528E+05	0.57665E+05	0.70022E+05	0.79698E+05
S_T	0.22498E+04	0.44411E+04	0.64268E+04	0.84931E+04	0.11339E+05	0.13587E+05

METHOD OF MAX. LIKELIHOOD

MEAN OF LN(X)	0.10179E+02
VARIANCE OF LN(X)	0.23820E+00
SKEW OF LN(X)	0.94500E-01

NOTE-FOR GOOD USE OF THIS DISTRIBUTION SKEW OF LOGS SHOULD BE CLOSE TO Z

T,YEARS	2	5	10	20	50	100
X_T	0.26406E+05	0.39378E+05	0.48528E+05	0.57665E+05	0.70022E+05	0.79698E+05
S_T	0.22165E+04	0.38464E+04	0.54973E+04	0.74247E+04	0.10364E+05	0.12879E+05

APPENDIX - IIA

SOURCE PROGRAMME 2 (LN3.FOR)

```
C       MASTER PROGRAM FOR LOG NORMAL 3 PARAMETER DISTRIBUTION
C      ESTIMATES FOR T YEAR EVENTS AND STANDARD ERROR
C      FOR 3 PARAMETER LOGNORMAL DISTRIBUTION BY METHOD OF MOMENTS
C      AND METHOD OF MAXIMUM LIKLIHOOD
       REAL M1,M2,M3,M4,M5,M6,MY,K,MU
       DIMENSION SND(6),X(100)
       DIMENSION XT(6),SX(6),TITLE(80)
       REAL* 8 SND,X,XT,SX
       OPEN (UNIT=5,FILE='DATA.DAT',STATUS='OLD')
       OPEN (UNIT=6,FILE='LN3.OUT',STATUS='NEW')
       SND(1)=0.0
       SND(2)=0.8416
       SND(3)=1.2816
       SND(4)=1.6449
       SND(5)=2.0538
       SND(6)=2.3264
       READ(5,16) TITLE
       READ(5,*) N
       XN=N
       READ(5,*) (X(I),I=1,N)
       WRITE(6,19) TITLE
       WRITE(6,20)
       A=0.0
       B=0.0
       C=0.
       DO 1 I=1,N
       A=A+X(I)
       B=B+X(I)**2
       C=C+X(I)**3
1      CONTINUE
       M1=A/XN
       M2=(B/XN)-(A/XN)**2
       M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
       G=M3/(M2**1.5)
       M2=M2*XN/(XN-1.0)
       WRITE(6,11) M1
       WRITE(6,12) M2
       WRITE(6,13) G
       IF(G.LT.0.0) GO TO 3
       W=(-G+((G**2)+4.0)**0.5)/2.
       Z2=(1.-W**(2./3.))/(W**(1./3.))
       AMO=M1-(M2**.5)/Z2
       WRITE(6,21) AMO
       SY=(ALOG(Z2**2+1.0))**0.5
       SY2=SY**2
       MY=ALOG((M2**.5)/Z2)-.5*ALOG(Z2**2+1.0)
       E=EXP(SY2)
       EA=EXP(2.*SY2)
       EB=EXP(2.5*SY2)
       EC=EXP(3.0*SY2)
```

```
      ED=EXP(4.0*SY2)
      EF=EXP(6.0*SY2)
      EG=EXP(10.*SY2)
      EH=EXP(15.*SY2)
      EI=EXP(4.*MY)
      EJ=EXP(5.0*MY)
      EK=EXP(6.0*MY)
      EL=(EXP(SY2)-1.0)**2
      M4=EA*EI*EL*(ED+2.*EC+3.*EA-3.)
      M5=EB*EJ*(EG-5.*EF+10.*EC-10.*E+4.)
      M6=EC*EK*(EH-6.0*EG+15.*EF-20.*EC+15.*E-5.)
      VM1=M2/XN
      VM2=(M4-M2**2)/XN
      VM3=(M6-M3**2-6.*M4*M2+9.*M2**3)/XN
      CM1M2=M3/XN
      CM1M3=(M4-3.*M2**2)/XN
      CM2M3=(M5-4.*M3*M2)/XN
      DO 2 J=1,6
      T=SND(J)
      DXDM1=1.0
      DWDG=-.5+G/(2.*(G**2+4.)**.5)
      DZ2DW=(-1./3.)*(W**(-4./3.)+W**(-2./3.))
      D1=ALOG(Z2**2+1.0)
      D2=EXP((SQRT(D1))*T-D1/2)
      D3=(2.*Z2)/(1.0+Z2**2)
      D4=T/(2.0*Z2*SQRT(D1))
      D5=1.0/Z2
      D6=1.0/(2.0*Z2**3)
      DKDZ2=D3*(D2*(D4-D5-D6)+D6+D5/2.)
      K=(D2-1.0)/Z2
      DKDG=DKDZ2*DZ2DW*DWDG
      DXDM2=(1.0/(2.*SQRT(M2)))*(K-3.0*G*DKDG)
      DXDM3=DKDG/M2
      SX(J)=SQRT((DXDM1**2)*VM1+(DXDM2**2)*VM2+(DXDM3**2)
     1 *VM3+2.0*DXDM1*DXDM2*CM1M2+2.0*DXDM1*DXDM3*CM1M3+2.0
     2 *DXDM2*DXDM3*CM2M3)
2     XT(J)=M1+K*M2**.5
      WRITE(6,24)
      WRITE(6,25) (XT(J),J=1,6)
      WRITE(6,26) (SX(J),J=1,6)
      GO TO 4
3     WRITE(6,14)
4     WRITE(6,27)
      WRITE(6,28)
      XMIN=10000000.
      DO 5 I=1,N
5     IF(X(I).LT.XMIN) XMIN=X(I)
      AML=XMIN*.8
      ICOUNT=0
6     ICOUNT=ICOUNT+1
```

```
      A=0.0
      B=0.0
      C=0.0
      D=0.0
      E=0.0
      F=0.0
      P=0.0
      DO 7 I=1,N
      A=A+DLOG(X(I)-AML)
      B=B+(DLOG(X(I)-AML))**2
      P=P+(DLOG(X(I)-AML))**3
      C=C+1.0/((X(I)-AML))
      D=D+1.0/((X(I)-AML)**2)
      E=E+(1.0/((X(I)-AML)))*DLOG(X(I)-AML)
7     F=F+(1.0/((X(I)-AML)**2))*DLOG(X(I)-AML)
      G=(B/XN)-(A/XN)**2-(A/XN)
      H=(-2.*E/XN)+(2.*A/XN)*(C/XN)+(C/XN)
      FCN=C*G+E
      FPN=C*H+D*G+F-D
      AS=AML-(FCN/FPN)
      WRITE(6,29) ICOUNT,AS,FCN
      DELTA=ABS(0.00001*AS)
      IF(ABS(AS-AML).LT.DELTA) GO TO 8
      IF (ICOUNT.GT.50) GO TO 10
      AML=AS
      GO TO 6
8     CONTINUE
      AML=AS
      MU=A/XN
      VAR=(B/XN)-(A/XN)**2
      VAR=VAR*XN/(XN-1)
      SKEW=(P/XN)+2.0*MU**3-3.0*MU*(B/XN)
      SD=SQRT(VAR)
      A=EXP(VAR-2.*MU)
      B=EXP(2.0*VAR-2.*MU)
      C=EXP(VAR/2.-MU)
      D1=(VAR+1.0)/(2.0*VAR)
      D2=1.0/(2.*VAR)
      D=D1*B-D2*A-A
      E=1.0/(N*D)
      VA=E*.5
      VMU=(VAR*E)*(D1*B-A)
      VVAR=VAR*E*((VAR+1.0)*B-A)
      CAMU=C*E/2.
      CAVAR=VAR*E*C
      CMUVAR=VAR*E*A
      CAMU=-CAMU
      CMUVAR=-CMUVAR
      DO 9 J=1,6
      T=SND(J)
```

```
      Z=EXP(MU+T*SD)
      VX=VA+(VMU*Z**2)+(T*Z*CAVAR/SD)+(2.*Z*CAMU)
     1 +(T*Z**2*CMUVAR/SD)+(T**2*Z**2*VVAR/(4.0*VAR))
      XT(J)=AML+Z
      SX(J)=SQRT(VX)
9     CONTINUE
      WRITE(6,30)
      WRITE(6,32) AML
      WRITE(6,22) MU
      WRITE(6,23) VAR
      WRITE(6,15) SKEW
      WRITE(6,33)
      WRITE(6,24)
      WRITE(6,25) (XT(J),J=1,6)
      WRITE(6,26) (SX(J),J=1,6)
      WRITE(6,31)
10    CONTINUE
      STOP
11    FORMAT(20X,9HMEAN OF X,16X,E12.5)
12    FORMAT(20X,13HVARIANCE OF X,12X,E12.5)
13    FORMAT(20X,9HSKEW OF X,16X,E12.5)
14    FORMAT(/,3X,'NO MOMENTS SOLUTION IS POSSIBLE',
     1 ' OF -VE SKEW',/)
15    FORMAT(20X,15HSKEW OF LN(X-A),10X,E12.5)
16    FORMAT(80A1)
17    FORMAT(I5)
18    FORMAT(8F10.0)
19    FORMAT(/,80A1,//,21X,
     1 38HTHREE PARAMETER LOGNORMAL DISTRIBUTION,/)
20    FORMAT(31X,17HMETHOD OF MOMENTS,//)
21    FORMAT(20X,1HA,24X,E12.5,/)
22    FORMAT(20X,15HMEAN OF LN(X-A),10X,E12.5)
23    FORMAT(20X,19HVARIANCE OF LN(X-A),6X,E12.5)
24    FORMAT(3X,7HT,YEARS,4X,1H2,11X,1H5,10X,2H10,10X,2H20
     1 ,10X,2H50,9X,3H100,/)
25    FORMAT(3X,1HX,3X,6E12.5,/,4X,1HT,//)
26     FORMAT(3X,1HS,3X,6E12.5,/,4X,1HT,//)
27    FORMAT(25X,28HMAXIMUM LIKELIHOOD PROCEDURE,//)
28    FORMAT(21X,5HTRIAL,11X,1HA,11X,4HF(A),/)
29    FORMAT(22X,I2,8X,E12.5,1X,E12.5)
30    FORMAT(//)
31    FORMAT(/1H1)
32    FORMAT(20X,1HA,24X,E12.5)
33    FORMAT(/,3X,33HFOR GOOD USE OF THIS DISTRIBUTION,
     1 39HSKEW OF LN(X-A) SHOULD BE CLOSE TO ZERO,/)
      END
```

APPENDIX — IIB

OUTPUT FILE FOR PROGRAMME 2 (LN3.OUT)

ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS

THREE PARAMETER LOGNORMAL DISTRIBUTION

METHOD OF MOMENTS

MEAN OF X	0.29557E+05
VARIANCE OF X	0.22095E+09
SKEW OF X	0.10020E+01
A	-0.16493E+05

T,YEARS	2	5	10	20	50	100
X_T	0.27330E+05	0.40625E+05	0.49112E+05	0.57061E+05	0.67166E+05	0.74663E+05
S_T	0.29353E+04	0.37490E+04	0.50350E+04	0.72629E+04	0.11370E+05	0.15173E+05

MAXIMUM LIKELIHOOD PROCEDURE

TRIAL	A	F(A)
1	0.73863E+04	-0.28105E-03
2	0.63678E+04	-0.11043E-03
3	0.54662E+04	-0.39067E-04
4	0.49400E+04	-0.11189E-04
5	0.48042E+04	-0.19483E-05
6	0.47884E+04	-0.20489E-06
7	0.47865E+04	-0.24214E-07
8	0.47869E+04	0.55879E-08
9	0.47888E+04	0.24214E-07
10	0.47892E+04	0.55879E-08
11	0.47853E+04	-0.50291E-07
12	0.47888E+04	0.44703E-07
13	0.47891E+04	0.37253E-08
14	0.47932E+04	0.52154E-07
15	0.47917E+04	-0.18626E-07
16	0.47916E+04	-0.18626E-08
17	0.47913E+04	-0.37253E-08
18	0.47920E+04	0.93132E-08
19	0.47898E+04	-0.27940E-07
20	0.47866E+04	-0.40978E-07
21	0.47903E+04	0.46566E-07
22	0.47961E+04	0.74506E-07
23	0.47867E+04	-0.12107E-06

24	0.47927E+04	0.76368E-07
25	0.47830E+04	-0.12480E-06
26	0.47862E+04	0.40978E-07
27	0.47878E+04	0.20489E-07
28	0.47875E+04	-0.37253E-08
29	0.47955E+04	0.10245E-06
30	0.47907E+04	-0.61467E-07
31	0.47900E+04	-0.93132E-08
32	0.47862E+04	-0.48429E-07
33	0.47859E+04	-0.37253E-08
34	0.47942E+04	0.10617E-06
35	0.47895E+04	-0.61467E-07
36	0.47902E+04	0.93132E-08
37	0.47934E+04	0.40978E-07
38	0.47913E+04	-0.26077E-07
39	0.47916E+04	0.37253E-08
40	0.47899E+04	-0.22352E-07
41	0.47867E+04	-0.40978E-07
42	0.47922E+04	0.70781E-07
43	0.47898E+04	-0.31665E-07
44	0.47857E+04	-0.52154E-07
45	0.47850E+04	-0.93132E-08
46	0.47921E+04	0.91270E-07
47	0.47983E+04	0.80094E-07
48	0.47969E+04	-0.18626E-07
49	0.47884E+04	-0.10990E-06
50	0.47897E+04	0.16764E-07
51	0.47917E+04	0.26077E-07

APPENDIX - III A

SOURCE PROGRAMME 3(T1E.FOR)

```
C       MASTER PROGRAM FOR GUMBEL EV1 DISTRIBUTION
C
C       COMPUTES METHODE OF MOMENTS AND MAXIMUM LIKELIHOOD ESTIMATES
C       FOR T YEAR EVENTS AND STANDARD ERRORS FOR EV1 DISTRIBUTION
        REAL M1,M2,M3,K
        DIMENSION T(6),X(100)
        DIMENSION XT(6),SX(6),TITLE(80)
        REAL *8 T,X,XT,SX
        OPEN (UNIT=5,FILE='DATA.DAT',STATUS='OLD')
        OPEN (UNIT=6,FILE='T1E.OUT',STATUS='NEW')
        T(1)=2.
        T(2)=5.
        T(3)=10.
        T(4)=20.
        T(5)=50.
        T(6)=100.
        READ (5,9) TITLE
        READ (5,*) N
        XN=N
        READ (5,*) (X(I),I=1,N)
        A=0.0
        B=0.0
        C=0.0
        DO 1 I=1,N
        A=A+X(I)
        B=B+X(I)**2
        C=C+X(I)**3
1       CONTINUE
        M1=A/XN
        M2=(B/XN)-(A/XN)**2
        M2=M2*XN/(XN-1.)
        M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
        SKEW=M3/(M2**1.5)
        ALPHA=1.2825/(SQRT(M2))
        BETA=M1-0.45*SQRT(M2)
        A=0.0
        B=0.0
        DO 2 I=1,N
        XI=I
        XN=N
        Y=-ALOG(-ALOG((XN+1.0-XI)/(XN+1.0)))
        A=A+Y
        B=B+Y**2
2       CONTINUE
        YBAR=A/XN
        YSTD=SQRT((B/XN)-YBAR**2)
        DO 3 J=1,6
        YM=-DLOG(-DLOG((T(J)-1.0)/T(J)))
        K=(YM-YBAR)/YSTD
        XT(J)=M1+K*SQRT(M2)
```

```
      DELTA=1.0+1.139547093*K+1.100000027*K**2
      SX(J)=SQRT(M2*DELTA/XN)
3     CONTINUE
      WRITE(6,12) TITLE
      WRITE(6,13)
      WRITE(6,20) ALPHA,M1
      WRITE(6,21) BETA,M2
      WRITE(6,22) SKEW
      WRITE(6,25)
      WRITE(6,14)
      WRITE(6,15) (XT(J),J=1,6)
      WRITE(6,16) (SX(J),J=1,6)
      WRITE(6,17)
      WRITE(6,18)
      ICOUNT=0
      AML=ALPHA
4     ICOUNT=ICOUNT+1
      A=1.0/(AML**2)
      B=M1-1.0/AML
      C=0.0
      D=0.0
      E=0.0
      DO 5 I=1,N
      TEMP=EXP(-AML*X(I))
      C=C+TEMP
      D=D+TEMP*X(I)
      E=E+TEMP*X(I)**2
5     CONTINUE
      FCN=D-B*C
      FPN=B*D-E-A*C
      AS=AML-(FCN/FPN)
      WRITE(6,19) ICOUNT,AS,FCN
      DELTA=ABS(0.0000001*AS)
      IF(ABS(AS-AML).LT.DELTA) GO TO 6
      IF(ICOUNT.GE.50) GO TO 8
      AML=AS
      GO TO 4
6     CONTINUE
      ALPHA=AS
      BETA=(1.0/ALPHA)*ALOG(XN/C)
      M2=1.2825/ALPHA
      M1=BETA+0.45*M2
      M2=M2**2
      DO 7 J=1,6
      YM=-DLOG(-DLOG(1.0-1.0/T(J)))
      XT(J)=BETA+YM/ALPHA
      SX(J)=SQRT((1.1086+.5140*YM+0.6079*YM**2)/(XN*ALPHA**2))
7     CONTINUE
      WRITE(6,23)
      WRITE(6,20) ALPHA,M1
```

```
      WRITE(6,24) BETA,M2
      WRITE(6,14)
      WRITE(6,15) (XT(J),J=1,6)
      WRITE(6,16) (SX(J),J=1,6)
8     CONTINUE
      STOP
9     FORMAT(80A1)
10    FORMAT(I5)
11    FORMAT(8F10.0)
12    FORMAT(/,80A1,//,26X'GUMBEL EV1 DISTRIBUTION'/)
13    FORMAT(31X,17HMETHOD OF MOMENTS,//)
14    FORMAT(3X,7HT,YEARS,4X,1H2,11X,1H5,10X,2H10,10X,
     1 2H20,10X,2H50,9X,3H100,/)
15    FORMAT(3X,1HX,3X,6E12.5,/,4X,1HT)
16    FORMAT(3X,1HS,3X,6E12.5,/,4X,1HT,//)
17    FORMAT(25X'MAXIMUM LIKELIHOOD PROCEDURE'//)
18    FORMAT(21X,5HTRIAL,11X,1HA,11X,4HF(A),/)
19    FORMAT(22X,I2,8X,E12.5,1X,E12.5)
20    FORMAT(9X,5HALPHA,5X,E12.5,14X,4HM1  ,6X,E12.5)
21    FORMAT(9X,5HBETA ,5X,E12.5,14X,4HM2  ,6X,E12.5)
22    FORMAT(45X,4HSKEW,6X,E12.5,/)
23    FORMAT(//)
24    FORMAT(9X,5HBETA,5X,E12.5,14X,4HM2  ,6X,E12.5,/)
25    FORMAT(3X,'NOTE - FOR GOOD USE OF THIS DISTRIBUTION SKEW
     1  ' SHOULD BE AROUND 1.13',/)
      END
```

APPENDIX - III B

OUTPUT FILE FOR PROGRAMME 3 (T1E.OUT)

ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS

GUMBEL EV1 DISTRIBUTION

METHOD OF MOMENTS

ALPHA	0.86280E-04	M1	0.29557E+05
BETA	0.22868E+05	M2	0.22095E+09
		SKEW	0.95539E+00

NOTE - FOR GOOD USE OF THIS DISTRIBUTION SKEW SHOULD BE AROUND 1.13

T,YEARS	2	5	10	20	50	100
X_T	0.27280E+05	0.42332E+05	0.52298E+05	0.61857E+05	0.74231E+05	0.83503E+05
S_T	0.24244E+04	0.43905E+04	0.60596E+04	0.77373E+04	0.99577E+04	0.11640E+05

MAXIMUM LIKELIHOOD PROCEDURE

TRIAL	A	F(A)
1	0.92424E-04	0.57902E+04
2	0.93714E-04	0.86889E+03
3	0.93762E-04	0.30406E+02
4	0.93762E-04	0.31250E-01
5	0.93762E-04	0.00000E+00

ALPHA	0.93762E-04	M1	0.29177E+05
BETA,	0.23022E+05	M2	0.18709E+09

T,YEARS	2	5	10	20	50	100
X_T	0.26931E+05	0.39019E+05	0.47023E+05	0.54700E+05	0.64637E+05	0.72084E+05
S_T	0.22137E+04	0.33975E+04	0.43583E+04	0.53320E+04	0.66309E+04	0.76205E+04

APPENDIX - IV A

COURSE PROGRAMME 4 (PT3.FOR)

```
C       MASTER COMPUTER PROGRAM FOR PEARSON TYPE 3 DISTRIBUTION
C       ESTIMATES FOR T YEAR EVENTS AND STANDARD ERRORS
C       FOR PEARSON TYPE 3 DISTRIBUTION BY METHOD OF MOMENTS AND
C       METHOD OF MAXIMUM LIKELIHOOD
        REAL M1,M2,M3,K
        DIMENSION SND(6),X(100)
        DIMENSION XT(6),SX(6),TITLE(80)
        REAL *8 SND,XT,SX,P,P1,P2
        OPEN (UNIT=5,FILE='DATA.DAT',STATUS='OLD')
        OPEN (UNIT=6,FILE='PT3.OUT',STATUS='NEW')
        SND(1)=0.0
        SND(2)=0.84162
        SND(3)=1.28155
        SND(4)=1.64485
        SND(5)=2.05375
        SND(6)=2.32635
        READ(5,9) TITLE
        READ(5,*) N
        READ (5,*) (X(I),I=1,N)
        XN=N
        A=0.0
        B=0.0
        C=0.
        DO 1 I=1,N
        A=A+X(I)
        B=B+X(I)**2
        C=C+X(I)**3
1       CONTINUE
        M1=A/XN
        M2=(B/XN)-(A/XN)**2
        M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
        SKEW=M3/(M2**1.5)
        C1=(SQRT(XN*(XN-1.0)))/(XN-2.0)
        C2=1.0+8.5/XN
        C3=XN/(XN-1.0)
        SKEW=SKEW*C1*C2
        M2=M2*C3
        BETA=(2.0/SKEW)**2
        ALPHA=(M2**0.5)/(BETA**0.5)
        GAMMA=M1-(M2**0.5)*(BETA**0.5)
        WRITE(6,12) TITLE
        WRITE(6,13)
        WRITE(6,22) ALPHA,M1
        WRITE(6,23) BETA,M2
        WRITE(6,24) GAMMA,SKEW
        DO 2 J=1,6
        T=SND(J)
        T1=T
        T2=(T**2-1.0)/6.
        T3=2.*(T**3-6.*T)/6.**3
```

```
      T4=(T**2-1.0)/6.**3
      T5=T/6.**4
      T6=2./6.**6
      K=T1+T2*SKEW+T3*SKEW**2-T4*SKEW**3+T5*SKEW**4-T6*SKEW**5
      SLOPE=T2+T3*2.*SKEW-T4*3.*SKEW**2+T5*4.*SKEW**3-T6*5.*SKEW**4
      T7=(1.0+0.75*SKEW**2)*(0.5*K**2)
      T8=K*SKEW
      T9=6.*(1.+0.25*SKEW**2)*SLOPE
      T10=SLOPE*(1.0+1.25*SKEW**2)+(SKEW*K/2.)
      DELTA=T7+T8+T9*T10
      XT(J)=M1+K*SQRT(M2)
2     SX(J)=SQRT(M2*DELTA/XN)
      WRITE(6,14)
      WRITE(6,15)(XT(J),J=1,6)
      WRITE(6,16) (SX(J),J=1,6)
      WRITE(6,17)
      WRITE(6,18)
      ICOUNT=0
      XMIN=10000000.
      DO 3 I=1,N
3     IF (X(I).LT.XMIN) XMIN=X(I)
      GML=XMIN*.99
4     ICOUNT=ICOUNT+1
      A=0.
      B=0.
      C=0.
      R=0.
      DO 5 I=1,N
      A=A+1./(X(I)-GML)
      B=B+(X(I)-GML)
      C=C+ALOG(X(I)-GML)
      R=R+1.0/((X(I)-GML)**2)
5     CONTINUE
      BETA=A/(A-(XN**2)/B)
      ALPHA=B/(XN*BETA)
      D=BETA+2.
      PSI=ALOG(D)-(1./(2.*D))-(1./(12.*D**2))+(1./(120.*D**4))
      1-(1./(252.0*D**6))-(1./(BETA+1.0))-(1.0/BETA)
      FCN=-XN*PSI+C-XN*ALOG(ALPHA)
      TRI=(1./D)+(1./(2.*D**2))+(1.0/(6.*D**3))-(1.0/(30.*D**5))
     1 +(1./(42.*D**7))-(1.0/(30.*D**9))+(1./((BETA+1.)**2))
     2 +(1.0/(BETA**2))
      V=A-(XN**2)/B
      U=A
      W=(B/XN)-(XN/A)
      DU=R
      DV=R-(XN**3)/(B**2)
      DW=-1.0+(XN*R)/(A**2)
      FPN=-XN*TRI*((V*DU-U*DV)/(V**2))-A-XN*DW/W
      AS=GML-(FCN/FPN)
```

```
      WRITE(6,19) ICOUNT,AS,FCN
      DELTA=ABS(.00000001*AS)
      IF (ABS(AS-GML).LT.DELTA) GO TO 6
      IF(ICOUNT.GE.50) GO TO 8
      GML=AS
      GO TO 4
 6    CONTINUE
      GAMMA=AS
      M1=GAMMA+ALPHA*BETA
      M2=BETA*ALPHA**2
      SKEW=2./SQRT(BETA)
      WRITE(6,20)
      WRITE(6,22)ALPHA,M1
      WRITE(6,23) BETA,M2
      WRITE(6,24) GAMMA,SKEW
      JRITE(6,20)
      D=BETA+2.0
      TRI=(1.0/D)+(1.0/(2.0*D**2))+(1.0/(6.0*D**3))
     1 -(1.0/(30.*D**5))+(1.0/(42.0*D**7))-(1.0/(30.*
     2 D**9))+(1.0/((BETA+1.0)**2))+(1.0/(BETA**2))
      H=(BETA-2.0)*ALPHA**4
      P1=2.0*TRI
      P2=(2.0*BETA-3.0)/((BETA-1.0)**2.)
      P=P1-P2
      DET=P/H
      VARA=(1.0/(XN*(ALPHA**2)*DET))*((TRI/(BETA-2.0))
     1 -1.0/((BETA-1.0)**2))
      VARB=2.0/(XN*DET*(BETA-2.0)*ALPHA**4)
      VARG=(BETA*TRI-1.0)/(XN*DET*ALPHA**2)
      COVAB=(-1.0/(XN*DET*ALPHA**3))*((1.0/(BETA-2.0))
     1 -(1.0/(BETA-1.0)))
      COVAG=(1.0/(XN*DET*ALPHA**2))*((1.0/(BETA-1.0))-TRI)
      COVBG=(-1.0/(XN*DET*ALPHA**3))*((BETA/(BETA-1.0))-1.0)
      DO 7 J=1,6
      T=SND(J)
      E=BETA**(1./3.)-1.0/(9.0*BETA**(2./3.))+T/(3.0*BETA
     1 **(1./6.))
      F=1.0/(3.0*BETA**(2./3.))+2.0/(27.0*BETA**(5./3.)
     1 )-T/(18.0*BETA**(7./6.))
      XT(J)=GAMMA+ALPHA*E**3
      DXDA=E**3
      DXDB=3.0*ALPHA*E**2*F
      DXDG=1.0
      SX(J)=SQRT(VARA*DXDA**2+VARB*DXDB**2+VARG*DXDG**2
     1 +2.0*DXDA*DXDB*COVAB+2.0*DXDA*DXDG*COVAG+2.0*DXDB
     2 *DXDG*COVBG)
 7    CONTINUE
      WRITE(6,14)
      WRITE(6,15) (XT(J),J=1,6)
      WRITE(6,16) (SX(J),J=1,6)
```

```
      WRITE(6,21)
8     CONTINUE
      STOP
9     FORMAT(80A1)
10    FORMAT(I5)
11    FORMAT(8F10.0)
12    FORMAT(/,80A1,//,26X,
     1 'PEARSON TYPE 3 DISTRIBUTION'/)
13    FORMAT(31X,17HMETHOD OF MOMENTS,//)
14    FORMAT(3X,7HT,YEARS,4X,1H2,11X,1H5,10X,2H10,10X,2H20,10X,
     1  2H50,9X,3H100,/)
15    FORMAT(3X,1HX,3X,6E12.5,/,4X,1HT)
16    FORMAT(3X,1HS,3X,6E12.5,/,4X,1HT,//)
17    FORMAT(25X,'MAXIMUM LIKELIHOOD PROCEDURE',//)
18    FORMAT(21X,5HTRIAL,11X,1HG,11X,4HF(G),/)
19    FORMAT(22X,I2,8X,E12.5,1X,E12.5)
20    FORMAT(//)
21    FORMAT(/1H1)
22    FORMAT(9X,5HALPHA,5X,E12.5,14X,4HM1  ,6X,E12.5)
23    FORMAT(9X,5HBETA ,5X,E12.5,14X,4HM2  ,6X,E12.5)
24    FORMAT(9X,5HGAMMA,5X,E12.5,14X,4HSKEW,6X,E12.5,/)
      END
```

APPENDIX - IV B

OUTPUT FILE FOR PROGRAMME 4 (PT3.OUT)

ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS

PEARSON TYPE 3 DISTRIBUTION

METHOD OF MOMENTS

ALPHA	0.98951E+04	M1	0.29557E+05
BETA	0.22566E+01	M2	0.22095E+09
GAMMA	0.72278E+04	SKEW	0.13314E+01

T,YEARS	2	5	10	20	50	100
X_T	0.26418E+05	0.40093E+05	0.49302E+05	0.58090E+05	0.69354E+05	0.77720E+05
S_T	0.18796E+04	0.32450E+04	0.49677E+04	0.76948E+04	0.12280E+05	0.16252E+05

MAXIMUM LIKELIHOOD PROCEDURE

TRIAL	G	F(G)
1	0.99971E+04	0.22898E+01
2	0.98023E+04	0.68268E+00
3	0.97169E+04	0.16794E+00
4	0.97055E+04	0.17914E-01
5	0.97053E+04	0.27466E-03
6	0.97053E+04	0.00000E+00

ALPHA	0.12316E+05	M1	0.29557E+05
BETA	0.16119E+01	M2	0.24448E+09
GAMMA	0.97053E+04	SKEW	0.15753E+01

T,YEARS	2	5	10	20	50	100
X_T	0.25728E+05	0.40058E+05	0.50133E+05	0.59963E+05	0.72800E+05	0.82470E+05
S_T	0.23279E+04	0.42895E+04	0.59747E+04	0.77544E+04	0.10211E+05	0.12134E+05

APPENDIX - V A

SOURCE PROGRAMMES 5 (LP3.FOR)

```
C       MASTER PROGRAM FOR LOG PEARSON TYPE 3 DISTRIBUTION
C  COMPUTES METHOD OF MOMENTS AND MAXIMUM LIKLIHOOD ESTIMATES FOR
C T YEAR EVENTS AND STANDRAD ERROR FOR LOG-PEARSON TYPE 3
C DISTRIBUTION
        REAL M1,M2,M3,K,NSX,L1,L2,L3
        DIMENSION SND(6),X(100)
        DIMENSION XT(6), TITLE(80),ST(6)
        OPEN(UNIT=5,FILE='DATA.DAT',STATUS='OLD')
        OPEN(UNIT=6,FILE='LP3.OUT',STATUS='NEW')
        SND(1)=0.0
        SND(2)=0.84162
        SND(3)=1.28155
        SND(4)=1.64485
        SND(5)=2.05375
        SND(6)=2.32635
        READ(5,16) TITLE
        READ(5,*) N
        XN=N
        READ(5,*) (X(I),I=1,N)
        C1=(SQRT(XN*(XN-1.0)))/(XN-2.0)
        C2=1.0+8.5/XN
        C3=XN/(XN-1.0)
        WRITE(6,19) TITLE
        WRITE(6,20)
        A=0.0
        B=0.0
        C=0.0
        DO 1 I=1,N
        A=A+X(I)
        B=B+X(I)**2
        C=C+X(I)**3
 1      CONTINUE
        L1=A/XN
        L2=B/XN
        L3=C/XN
        M1=A/XN
        M2=(B/XN)-(A/XN)**2
        M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
        SKEW=M3/(M2**1.5)
        B=(ALOG(L3)-3.0*ALOG(L1))/(ALOG(L2)-2.0*ALOG(L1))
        WRITE(6,34) L1,M1
        WRITE(6,35) L2,M2
        WRITE(6,36) L3,SKEW
        C=1.0/(B-3.0)
        IF(B.GT.6.0) GOTO 3
        IF(B.LE.3.0) GOTO 3
        IF(B.LE.3.5) GOTO 2
        A=-0.23019+1.65262*C+0.20911*C**2-0.04557*C**3
        GOTO 4
 2      A=-0.47157+1.99955*C
```

```
      GOTO 4
3     WRITE(6,21) B
      GOTO 6
4     ALPHA=1.0/(A+3.0)
      A1=ALOG(1.0-ALPHA)
      A2=ALOG(1.0-2.0*ALPHA)
      BETA=(ALOG(L2)-2.0*ALOG(L1))/(2.0*A1-A2)
      GAMMA=ALOG(L1)+BETA*A1
      M1=GAMMA+ALPHA*BETA
      M2=BETA*ALPHA**2
      SKEW=2.0/SQRT(BETA)
      WRITE(6,23) ALPHA,M1
      WRITE(6,24) BETA,M2
      WRITE(6,25) GAMMA,SKEW
      IF(SKEW.LT.0.0) WRITE(6,33)
      DO 5 J=1,6
      T=SND(J)
      T1=T
      T2=(T**2-1.0)/6.0
      T3=2.0*(T**3-6.0*T)/6.0**3
      T4=(T**2-1.0)/6.0**3
      T5=T/6.0**4
      T6=2.0/6.0**6
      K=T1+T2*SKEW+T3*SKEW**2-T4*SKEW**3+T5*SKEW**4-T6*SKEW**5
      SLOPE=T2+T3*2.0*SKEW-T4*3.0*SKEW**2+T5*4.0*SKEW**3-T6*5.0*SKEW**
      14
      T7=1.0
      T8=SKEW*K
      T9=(1.0+.75*SKEW**2)*((K**2)/2.0)
      T10=3.0*SLOPE*K*(SKEW+0.25*SKEW**3)
      T11=3.0*(SLOPE**2)*(2.0+3.0*SKEW**2+(5.0/8.0)*SKEW**4)
      DELTA=T7+T8+T9+T10+T11
      XT(J)=EXP(M1+K*SQRT(M2))
      SX=SQRT(M2*DELTA/XN)
      PSX=XT(J)*(EXP(SX)-1.0)
      NSX=-XT(J)*(EXP(-SX)-1.0)
      ST(J)=(PSX+NSX)/2.0
5     CONTINUE
      WRITE(6,26)
      WRITE(6,27) (XT(J),J=1,6)
      WRITE(6,28) (ST(J),J=1,6)
6     DO 7 I=1,N
7     X(I)=ALOG(X(I))
      A=0.0
      B=0.0
      C=0.0
      DO 8 I=1,N
      A=A+X(I)
      B=B+X(I)**2
      C=C+X(I)**3
```

```
8       CONTINUE
        M1=A/XN
        M2=(B/XN)-(A/XN)**2
        M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
        SKEW=M3/(M2**1.5)
        SKEW=SKEW*C1*C2
        M2=M2*C3
        BETA=(2.0/SKEW)**2
        ALPHA=(M2**0.5)/(BETA**0.5)
        GAMMA=M1-(M2**0.5)*(BETA**0.5)
        WRITE(6,22)
        WRITE(6,23) ALPHA,M1
        WRITE(6,24) BETA,M2
        WRITE(6,25) GAMMA,SKEW
        IF(SKEW.LT.0.0) WRITE(6,33)
        DO 9 J=1,6
        T=SND(J)
        T1=T
        T2=(T**2-1.0)/6.0
        T3=2.0*(T**3-6.0*T)/6.0**3
        T4=(T**2-1.0)/6.0**3
        T5=T/6.0**4
        T6=2.0/6.0**6
        K=T1+T2*SKEW+T3*SKEW**2-T4*SKEW**3+T5*SKEW**4-T6*SKEW**5
        SLOPE=T2+T3*2.0*SKEW-T4*3.0*SKEW**2+T5*4.0*SKEW**3-T6*5.0*SKEW**
        14
        T7=1.0
        T8=SKEW*K
        T9=(1.0+0.75*SKEW**2)*((K**2)/2.0)
        T10=3.0*SLOPE*K*(SKEW+0.25*SKEW**3)
        T11=3.0*(SLOPE**2)*(2.0+3.0*SKEW**2+(5.0/8.0)*SKEW**4)
        DELTA=T7+T8+T9+T10+T11
        XT(J)=EXP(M1+K*SQRT(M2))
        SX=SQRT(M2*DELTA/XN)
        PSX=XT(J)*(EXP(SX)-1.0)
        NSX=-XT(J)*(EXP(-SX)-1.0)
        ST(J)=(PSX+NSX)/2.0
9       CONTINUE
        WRITE(6,26)
        WRITE(6,27) (XT(J),J=1,6)
        WRITE(6,28) (ST(J),J=1,6)
        WRITE(6,29)
        WRITE(6,30)
        ICOUNT=0
        XMIN=10000000.
        DO 10 I=1,N
10      IF(X(I).LT.XMIN) XMIN=X(I)
        GML=XMIN*.99
11      ICOUNT=ICOUNT+1
        A=0.0
```

```
      B=0.0
      C=0.0
      R=0.0
      DO 12 I=1,N
      A=A+1.0/(X(I)-GML)
      B=B+(X(I)-GML)
      C=C+ALOG(X(I)-GML)
      R=R+1.0/((X(I)-GML)**2)
12    CONTINUE
      BETA=1.0/(1.0-(XN**2)/(B*A))
      ALPHA=(B/XN)-(XN/A)
      D=BETA+2.0
      PSI=ALOG(D)-(1.0/(2.0*D))-(1.0/(12.0*D**2))+(1./(120.*D**4))-1.
     10/(252.0*D**6)-(1./(BETA+1.))-(1./BETA)
      FCN=-XN*PSI+C-XN*ALOG(ALPHA)
      TRI1=(1.0/D)+(1./(2.*D**2))+(1./(6.0*D**3))-(1.0/(30.*D**5))
      TRI2=(1.0/(42.*D**7))-(1./(30.*D**9))
      TRI3=(1./((BETA+1.0)**2))
      TRI4=(1.0/(BETA**2))
      TRI=TRI1+TRI2+TRI3+TRI4
      V=A-(XN**2)/B
      U=A
      W=(B/XN)-(XN/A)
      DU=R
      DV=R-(XN**3)/(B**2)
      DW=-1.0+(XN*R)/(A**2)
      FPN=-XN*TRI*((V*DU-U*DV)/(V**2))-A-XN*DW/W
      AS=GML-(FCN/FPN)
      WRITE(6,31) ICOUNT,AS,FCN
      DELTA=ABS(0.000001*AS)
      IF(ABS(AS-GML).LT.DELTA) GOTO 13
      IF(ICOUNT.GE.50) GOTO 13
      GML=AS
      GOTO11
13    CONTINUE
      GAMMA=AS
      M1=GAMMA+ALPHA*BETA
      M2=BETA*ALPHA**2
      SKEW=2.0/SQRT(BETA)
      WRITE(6,32)
      WRITE(6,23) ALPHA,M1
      WRITE(6,24) BETA,M2
      WRITE(6,25) GAMMA,SKEW
      IF(SKEW.LT.0.0) WRITE (6,33)
      D=BETA+2.0
      TRI=(1.0/D)+(1.0/(2.0*D**2))+(1.0/(6.0*D**3))-(1.0/(30.0*D**5))+
     1(1.0/(42.*D**7))-(1./(30*D**9))+(1./((BETA+1.)**2))+(1./(BETA**
     22))
      H=(BETA-2.0)*ALPHA**4
      P=2.0*TRI-(2.0*BETA-3.)/((BETA-1.)**2)
```

```
      DET=P/H
      VARA=(1./(XN*(ALPHA**2)*DET))*((TRI/(BETA-2.0))-1.0/((BETA-1.0)*
     4*2))
      VARB=2.0/(XN*DET*(BETA-2.0)*ALPHA**4)
      VARG=(BETA*TRI-1.0)/(XN*DET*ALPHA**2)
      COVAB=(-1.0/(XN*DET*ALPHA**3))*((1.0/(BETA-2.0))-(1.0/(BETA-1.0)
     1))
      COVAG=(1.0/(XN*DET*ALPHA**2))*((1.0/(BETA-1.0))-TRI)
      COVBG=(-1.0/(XN*DET*ALPHA**3))*((BETA/(BETA-1.0))-1.0)
      DO 14 J=1,6
      T=SND(J)
      E=BETA**(1./3.)-1.0/(9.0*BETA**(2./3.))+T/(3.0*BETA**(1./6.))
      TYPE *,E
      F=1.0/(3.*BETA**(2./3.))+2.0/(27.*BETA**(5./3.))-T/(18.0*BETA**(
     57./6.))
      XT(J)=EXP(ALPHA*E**3+GAMMA)
      DXDA=E**3
      DXDB=3.0*ALPHA*E**2*F
      DXDG=1.0
      SX=SQRT(VARA*DXDA**2+VARB*DXDB**2+VARG*DXDG**2+2.*DXDA*DXDB*COVA
     5B+2.0*DXDA*DXDG*COVAG+2.0*DXDB*DXDG*COVBG)
      PSX=XT(J)*(EXP(SX)-1.0)
      NSX=-XT(J)*(EXP(-SX)-1.0)
      ST(J)=(PSX+NSX)/2.0
14    CONTINUE
      WRITE(6,26)
      WRITE(6,27) (XT(J),J=1,6)
      WRITE(6,28) (ST(J),J=1,6)
15    CONTINUE
      STOP
16    FORMAT(80A1)
17    FORMAT(I5)
18    FORMAT(8F10.0)
19    FORMAT(/80A1,/,24X,31HLOG-PEARSON TYPE 3 DISTRIBUTION,/)
20    FORMAT(28X,26HMETHOD OF MOMENTS (DIRECT),/)
21    FORMAT(/3X'METHOD NOT APPLICABLE BECAUSE OF B VALUE '9X,E12.5/)
22    FORMAT(27X,28HMETHOD OF MOMENTS (INDIRECT),/)
23    FORMAT(9X,5HALPHA,5X,E12.5,14X,4HM1  ,6X,E12.5)
24    FORMAT(9X,'BETA',5X,E12.5,14X,'M2  ',6X,E12.5)
25    FORMAT(9X,'GAMMA',5X,E12.5,14X,'SKEW',6X,E12.5,/)
26    FORMAT(3X,'T,YEARS',4X,1H2,11X,1H5,10X,2H10,10X,2H20,10X,2H50,9X
     33H100,/)
27    FORMAT(3X,1HX,3X,6E12.5,/,4X,1HT)
28    FORMAT(3X,1HS,3X,6E12.5,/,4X,1HT,/)
29    FORMAT(27X,'MAXIMUM LIKLIHOOD PROCEDURE',/)
30    FORMAT(21X,'TRIAL',11X,1HG,11X,4HF(G),/)
31    FORMAT(22X,I2,8X,E12.5,1X,E12.5)
32    FORMAT(/)
33    FORMAT(/,3X,'SKEW IS NEGATIVE- DISTIBUTION HAS AN UPPER BOUND'/)
34    FORMAT(9X,'L1  ',5X,E12.5,14X,'M1  ',6X,E12.5)
```

```
35      FORMAT(9X,'L2  ',5X,E12.5,14X,'M2  ',6X,E12.5)
36      FORMAT(9X,'L3  ',5X,E12.5,14X,'SKEW',6X,E12.5,/)
        END
```

APPENDIX - V B

OUTPUT FILE FOR PROGRAMME 5 (LP3.OUT)

```
ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS
                  LOG-PEARSON TYPE 3 DISTRIBUTION

                      METHOD OF MOMENTS (DIRECT)

      L1          0.29557E+05                M1          0.29557E+05
      L2          0.10877E+10                M2          0.21404E+09
      L3          0.47938E+14                SKEW        0.10020E+01
 METHOD NOT APPLICABLE BECAUSE OF B VALUE               0.28233E+01

                      METHOD OF MOMENTS (INDIRECT)
      ALPHA        0.32136E-01                M1          0.10179E+02
      BETA        0.23065E+03                M2          0.23820E+00
      GAMMA        0.27663E+01                SKEW        0.13169E+00
 T,YEARS    2            5            10           20           50           100

 X     0.26051E+05 0.39569E+05 0.49535E+05 0.59823E+05 0.74239E+05 0.85909E+05
  T
 S     0.24340E+04 0.41392E+04 0.62407E+04 0.93927E+04 0.15422E+05 0.21554E+05
  T
                      MAXIMUM LIKLIHOOD PROCEDURE
                  TRIAL            G            F(G)
                    1          0.90767E+01  0.10644E+01
                    2          0.89577E+01  0.47768E+00
                    3          0.87890E+01  0.20828E+00
                    4          0.85638E+01  0.88318E-01
                    5          0.82776E+01  0.36594E-01
                    6          0.79281E+01  0.14870E-01
                    7          0.75220E+01  0.58670E-02
                    8          0.70641E+01  0.23346E-02
                    9          0.65962E+01  0.84686E-03
                   10          0.63792E+01  0.17548E-03
                   11          0.61311E+01  0.16022E-03
                   12          0.61311E+01  0.00000E+00
      ALPHA        0.57369E-01                M1          0.10179E+02
      BETA        0.70551E+02                M2          0.23220E+00
      GAMMA        0.61311E+01                SKEW        0.23811E+00
 T,YEARS    2            5            10           20           50           100

 X     0.25834E+05 0.39237E+05 0.49361E+05 0.60014E+05 0.75259E+05 0.87853E+05
  T
 S     0.23548E+04 0.41431E+04 0.63953E+04 0.97679E+04 0.16220E+05 0.22872E+05
  T
```

APPENDIX - VI A

SOURCE PROGRAMME 6 (SER.FOR)

```
C  PROGRAM TO COMPUTE THE STANDARD ERRORS OF EVENTS COMPUTED
C  FROM VARIOUS PROBABILITY DISTRIBUTIONS COMPARED TO THE
C  OBSERVED EVENT MAGNITUDES
      DIMENSION X(100),Y(100),Z(100),P(100),RP(100),T(100),TITLE(80)
      REAL L1,L2,L3,LG
      REAL K,M1,M2,M3
      REAL *8 X,Y,Z,P,RP,T
      E=2.515517
      C1=0.802853
      C2=0.010328
      D1=1.432788
      D2=0.189269
      D3=0.001308
      OPEN(UNIT=5, FILE='DATA.DAT',STATUS='OLD')
      OPEN(UNIT=6, FILE='SER.OUT',STATUS='NEW')
      READ (5,6) TITLE
      READ (5,*) N
      XN=N
      READ (5,*) (X(I),I=1,N)
      WRITE (6,9) TITLE
      A=0.0
      B=0.0
      C=0.0
      DO 1 I=1,N
      A=A+X(I)
      B=B+X(I)**2
      C=C+X(I)**3
1     CONTINUE
      M1=A/XN
      M2=(B/XN)-(A/XN)**2
      M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
      M2=M2*XN/(XN-1.0)
      G=M3/(M2**1.5)
      WRITE (6,11) M1
      WRITE (6,12) M2
      WRITE (6,13) G
      CALL SORTX(N,X)
      WRITE (6,10)
      WRITE (6,19) (X(I),I=1,N)
      WRITE (6,17)
      A=0.0
      B=0.0
      C=0.0
      DO 2 I=1,N
      Y(I)=DLOG(X(I))
      A=A+Y(I)
      B=B+Y(I)**2
      C=C+Y(I)**3
2     CONTINUE
      L1=A/XN
```

```
      L2=(B/XN)-(A/XN)**2
      L3=(C/XN)+2.0*L1**3-3.0*L1*(B/XN)
      L2=L2*XN/(XN-1.0)
      LG=L3/(L2**1.5)
      WRITE (6,14) L1
      WRITE (6,15) L2
      WRITE(6,16) LG
      DO 3 I=1,N
      XI=I
      P(I)=1.0-XI/(XN+1.0)
      RP(I)=1.0/(1.0-P(I))
      D=P(I)
      IF (D.GT.0.5) D=1.0-D
      W=SQRT(ALOG(1.0/(D**2)))
      T(I)=W-(E+C1*W+C2*W**2)/(1.0+D1*W+D2*W**2+D3*W**3)
      IF (P(I).LT.0.5) T(I)=-T(I)
3     CONTINUE
      WRITE (6,18)
      CALL TN (N,M1,M2,T,Z)
      WRITE (6,19) (Z(I),I=1,N)
      CALL SSQ (N,X,Z)
      WRITE (6,20)
      CALL TN (N,L1,L2,T,Z)
      DO 4 I=1,N
4     Z(I)=EXP(Z(I))
      WRITE (6,19) (Z(I),I=1,N)
      CALL SSQ (N,X,Z)
      WRITE (6,21)
      CALL LN3 (N,X,T,Z)
      WRITE (6,19) (Z(I),I=1,N)
      CALL SSQ (N,X,Z)
      WRITE (6,22)
      CALL TIE (N,X,M1,M2,RP,Z)
      WRITE (6,19) (Z(I),I=1,N)
      CALL SSQ (N,X,Z)
      WRITE (6,23)
      CALL PI3 (N,X,T,Z)
      WRITE (6,19) (Z(I),I=1,N)
      CALL SSQ (N,X,Z)
      WRITE (6,24)
      CALL PI3 (N,Y,T,Z)
      DO 5 I=1,N
5     Z(I)=EXP(Z(I))
      WRITE (6,19) (Z(I),I=1,N)
      CALL SSQ (N,X,Z)
      STOP
6     FORMAT (80A1)
7     FORMAT (I5)
8     FORMAT (8F10.0)
9     FORMAT (/,80A1,/)
```

```
10      FORMAT (3X,22HSORTED RECORDED EVENTS)
11      FORMAT (20X,9HMEAN OF X,16X,E12.5)
12      FORMAT (20X,13HVARIANCE OF X,12X,E12.5)
13      FORMAT (20X,9HSKEW OF X,16X,E12.5,/)
14      FORMAT (20X,15HMEAN OF LN(X)   ,10X,E12.5)
15      FORMAT (20X,19HVARIANCE OF LN(X)   ,6X,E12.5)
16      FORMAT (20X,15HSKEW OF LN(X)   ,10X,E12.5,/)
17      FORMAT (///)
18      FORMAT (3X,23HTRUNCATED NORMAL EVENTS)
19      FORMAT (3X,6E12.5)
20      FORMAT (3X,28H2 PARAMETER LOGNORMAL EVENTS)
21      FORMAT (3X,28H3 PARAMETER LOGNORMAL EVENTS)
22      FORMAT (3X,22HTYPE 1 EXTREMAL EVENTS)
23      FORMAT (3X,21HPEARSON TYPE 3 EVENTS)
24      FORMAT (3X,25HLOG-PEARSON TYPE 3 EVENTS)
        END
        SUBROUTINE SSQ (N,X,Z)
        DIMENSION X(100),Z(100)
        REAL *8 X,Z
        SUM=0.0
        DO 1 I=1,N
1       SUM=SUM+(Z(I)-X(I))**2
        XN=N
        SUM=SQRT(SUM/XN)
        WRITE (6,2) SUM
        RETURN
2       FORMAT (3X,17HSTANDARD ERROR IS,E12.5,//)
        END
        SUBROUTINE TN (N,XBAR,XVAR,T,X)
        DIMENSION X(100),T(100)
        REAL *8 X,T
        XSTD=SQRT(XVAR)
        DO 1 I=1,N
1       X(I)=XBAR+T(I)*XSTD
        RETURN
        END
        SUBROUTINE SORTX (N,X)
C   SORTS IN DECREASING ORDER, X(I)=LARGEST
        DIMENSION X(100)
        REAL *8 X
        K=N-1
        DO 2 L=1,K
        M=N-L
        DO 2 J=1,M
        IF (X(J)-X(J+1)) 1,1,2
1       XT=X(J)
        X(J)=X(J+1)
        X(J+1)=XT
2       CONTINUE
        RETURN
```

```
END
SUBROUTINE PI3 (N,X,SND,XT)
DIMENSION X(100),SND(100),XT(100)
REAL *8 X,SND,XT
XN=N
ICOUNT=0
XMIN=10000000.
DO 1 I=1,N
IF (X(I).LT.XMIN) XMIN=X(I)
CONTINUE
GML=XMIN*0.99
ICOUNT=ICOUNT+1
A=0.0
B=0.0
C=0.0
R=0.0
DO 3 I=1,N
A=A+1.0/(X(I)-GML)
B=B+(X(I)-GML)
C=C+DLOG(X(I)-GML)
R=R+1.0/((X(I)-GML)**2)
CONTINUE
BETA=A/(A-(XN**2)/B)
ALPHA=B/(XN*BETA)
D=BETA+2.
PSI=ALOG(D)-(1.0/(2.0*D))-(1.0/(12.*D**2))+(1./(120.*D**4))-(1.
10/(252.*D**6))-(1./(BETA+1.))-(1./BETA)
FCN=-XN*PSI+C-XN*ALOG(ALPHA)
TRI=(1./D)+(1./(2.*D**2))+(1./(6.*D**3))-(1.0/(30.0*D**5))+(1.0/
2(42.*D**7))-(1./(30.*D**9))+(1.0/((BETA+1.0)**2))+(1.0/(BETA**2))
V=A-(XN**2)/B
U=A
W=(B/XN)-(XN/A)
DU=R
DV=R-(XN**3)/(B**2)
DW=-1.+(XN*R)/(A**2)
FPN=-XN*TRI*((V*DU-U*DV)/(V**2))-A-XN*DW/W
AS=GML-(FCN/FPN)
DELTA=ABS(0.00000001*AS)
IF (ABS(AS-GML).LT.DELTA) GOTO 4
IF(ABS(FCN).LT. .001)GOTO 4
IF (ICOUNT.GT.25) GOTO 6
GML=AS
GOTO 2
CONTINUE
GAMMA=AS
DO 5 J=1,N
T=SND(J)
E=BETA**(1./3.)-1.0/(9.0*BETA**(2./3.))+T/(3.0*BETA**(1./6.))
XT(J)=GAMMA+ALPHA*E**3
```

```
5       CONTINUE
6       CONTINUE
        RETURN
        END
        SUBROUTINE TIE (N,X,M1,M2,T,XT)
        DIMENSION X(100),T(100),XT(100)
        REAL M1,M2
        REAL *8 X,T,XT
        XN=N
        ICOUNT=0
        ALPHA=1.2825/(SQRT(M2))
        AML=ALPHA
1       ICOUNT=ICOUNT+1
        A=1.0/(AML**2)
        B=M1-1.0/AML
        C=0.0
        D=0.0
        E=0.0
        DO 2 I=1,N
        TEMP=EXP(-AML*X(I))
        C=C+TEMP
        D=D+TEMP*X(I)
        E=E+TEMP*X(I)**2
2       CONTINUE
        FCN=D-B*C
        FPN=B*D-E-A*C
        AS=AML-(FCN/FPN)
        DELTA=ABS(0.0000001*AS)
        IF (ABS(AS-AML).LT.DELTA) GO TO 3
        IF (ICOUNT.GT.25)  GO TO 5
        AML=AS
        GO TO 1
3       CONTINUE
        ALPHA=AS
        BETA=(1.0/ALPHA)*ALOG(XN/C)
        DO 4 J=1,N
        YM=-DLOG(-DLOG(1.0-1.0/T(J)))
        XT(J)=BETA+YM/ALPHA
4       CONTINUE
5       CONTINUE
        RETURN
        END
        SUBROUTINE LN3 (N,X,SND,XT)
        DIMENSION X(100),SND(100),XT(100)
        REAL MU
        REAL *8 X,SND,XT
        XN=N
        XMIN=10000000.
        DO 1 I=1,N
1       IF (X(I).LT.XMIN) XMIN=X(I)
```

```
      AML=XMIN*0.80
      ICOUNT=0
2     ICOUNT=ICOUNT+1
      A=0.0
      B=0.0
      C=0.0
      D=0.0
      E=0.0
      F=0.0
      P=0.0
      DO 3 I=1,N
      A=A+DLOG(X(I)-AML)
      B=B+(DLOG(X(I)-AML))**2
      P=P+(DLOG(X(I)-AML))**3
      C=C+1.0/((X(I)-AML))
      D=D+1./((X(I)-AML)**2)
      E=E+(1./((X(I)-AML)))*DLOG(X(I)-AML)
      F=F+(1./((X(I)-AML)**2))*DLOG(X(I)-AML)
3     CONTINUE
      G=(B/XN)-(A/XN)**2-(A/XN)
      H=(-2.0*E/XN)+(2.0*A/XN)*(C/XN)+(C/XN)
      FCN=C*G+E
      FPN=C*H+D*G+F-D
      AS=AML-(FCN/FPN)
      DELTA=ABS(0.0000001*AS)
      IF(ABS(AS-AML).LT.DELTA) GOTO 4
      IF (ICOUNT.GT.100) GOTO 4
      AML=AS
      GOTO 2
4     CONTINUE
      AML=AS
      MU=A/XN
      VAR=(B/XN)-(A/XN)**2
      VAR=VAR*XN/(XN-1)
      SKEW=(P/XN)+2.*MU**3-3.0*MU*(B/XN)
      SD=SQRT(VAR)
      DO 5 J=1,N
      T=SND(J)
      Z=EXP(MU+T*SD)
      XT(J)=AML+Z
5     CONTINUE
6     CONTINUE
      RETURN
      END
```

APPENDIX - VI B

OUTPUT FILE FOR PROGRAMME 6 (SER.OUT)

ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS

```
              MEAN OF X                   0.29557E+05
              VARIANCE OF X               0.22095E+09
              SKEW OF X                   0.95539E+00

 SORTED RECORDED EVENTS
  0.69400E+05 0.61350E+05 0.58100E+05 0.47980E+05 0.45630E+05 0.43360E+05
  0.38880E+05 0.38800E+05 0.38200E+05 0.34260E+05 0.33750E+05 0.31170E+05
  0.29150E+05 0.28650E+05 0.27300E+05 0.26810E+05 0.26700E+05 0.23890E+05
  0.22700E+05 0.22670E+05 0.21250E+05 0.19980E+05 0.19700E+05 0.19560E+05
  0.19500E+05 0.17100E+05 0.15250E+05 0.15250E+05 0.13290E+05 0.13000E+05
  0.12810E+05 0.10380E+05


              MEAN OF LN(X)               0.10179E+02
              VARIANCE OF LN(X)           0.23823E+00
              SKEW OF LN(X)               0.90287E-01

 TRUNCATED NORMAL EVENTS
  0.57454E+05 0.52597E+05 0.49407E+05 0.46934E+05 0.44866E+05 0.43059E+05
  0.41432E+05 0.39936E+05 0.38538E+05 0.37217E+05 0.35953E+05 0.34734E+05
  0.33550E+05 0.32391E+05 0.31250E+05 0.30120E+05 0.28994E+05 0.27863E+05
  0.26722E+05 0.25564E+05 0.24379E+05 0.23161E+05 0.21897E+05 0.20575E+05
  0.19178E+05 0.17682E+05 0.16055E+05 0.14247E+05 0.12180E+05 0.97072E+04
  0.65167E+04 0.16598E+04
 STANDARD ERROR IS 0.43011E+04


 2 PARAMETER LOGNORMAL EVENTS
  0.65811E+05 0.56110E+05 0.50529E+05 0.46589E+05 0.43531E+05 0.41022E+05
  0.38888E+05 0.37024E+05 0.35363E+05 0.33861E+05 0.32485E+05 0.31211E+05
  0.30021E+05 0.28900E+05 0.27837E+05 0.26823E+05 0.25849E+05 0.24907E+05
  0.23991E+05 0.23096E+05 0.22215E+05 0.21343E+05 0.20476E+05 0.19606E+05
  0.18727E+05 0.17829E+05 0.16902E+05 0.15928E+05 0.14882E+05 0.13722E+05
  0.12357E+05 0.10535E+05
 STANDARD ERROR IS 0.20778E+04


 3 PARAMETER LOGNORMAL EVENTS
  0.70601E+05 0.58646E+05 0.52001E+05 0.47421E+05 0.43934E+05 0.41120E+05
  0.38760E+05 0.36726E+05 0.34936E+05 0.33335E+05 0.31885E+05 0.30556E+05
  0.29326E+05 0.28181E+05 0.27105E+05 0.26087E+05 0.25120E+05 0.24193E+05
  0.23301E+05 0.22436E+05 0.21595E+05 0.20770E+05 0.19958E+05 0.19153E+05
  0.18348E+05 0.17536E+05 0.16708E+05 0.15851E+05 0.14947E+05 0.13961E+05
  0.12830E+05 0.11369E+05
 STANDARD ERROR IS 0.16516E+04
```

TYPE 1 EXTREMAL EVENTS

0.60149E+05	0.52589E+05	0.48092E+05	0.44846E+05	0.42284E+05	0.40151E+05
0.38313E+05	0.36689E+05	0.35226E+05	0.33888E+05	0.32650E+05	0.31491E+05
0.30398E+05	0.29358E+05	0.28361E+05	0.27400E+05	0.26468E+05	0.25557E+05
0.24662E+05	0.23778E+05	0.22899E+05	0.22019E+05	0.21131E+05	0.20230E+05
0.19304E+05	0.18344E+05	0.17333E+05	0.16249E+05	0.15057E+05	0.13694E+05
0.12028E+05	0.96714E+04				

STANDARD ERROR IS 0.32660E+04

PEARSON TYPE 3 EVENTS

0.67006E+05	0.57260E+05	0.51501E+05	0.47372E+05	0.44136E+05	0.41464E+05
0.39179E+05	0.37178E+05	0.35393E+05	0.33777E+05	0.32297E+05	0.30928E+05
0.29652E+05	0.28454E+05	0.27322E+05	0.26247E+05	0.25220E+05	0.24233E+05
0.23280E+05	0.22355E+05	0.21455E+05	0.20574E+05	0.19709E+05	0.18854E+05
0.18004E+05	0.17155E+05	0.16300E+05	0.15429E+05	0.14531E+05	0.13588E+05
0.12563E+05	0.11377E+05				

STANDARD ERROR IS 0.17300E+04

LOG-PEARSON TYPE 3 EVENTS

0.42720E+05	0.35446E+05	0.31455E+05	0.28723E+05	0.26651E+05	0.24984E+05
0.23588E+05	0.22386E+05	0.21328E+05	0.20382E+05	0.19525E+05	0.18739E+05
0.18012E+05	0.17332E+05	0.16694E+05	0.16089E+05	0.15512E+05	0.14959E+05
0.14425E+05	0.13906E+05	0.13399E+05	0.12900E+05	0.12408E+05	0.11917E+05
0.11424E+05	0.10924E+05	0.10410E+05	0.98751E+04	0.93044E+04	0.86754E+04
0.79413E+04	0.69695E+04				

STANDARD ERROR IS 0.13437E+05

APPENDIX - VII A

SOURCE PROGRAMME 7 (CHI. FOR)

```
C       PROGRAM TO TEST VARIOUS NORMALIZATION PROCEDURES ON THE
C       BASIS OF CHI SQUARE
C       N1 STANDS FOR NORMAL DISTRIBUTION
C       N2 STANDS FOR PEARSON TYPE 3 DISTRIBUTION
C       N3 STANDS FOR LOGNORMAL DISTRIBUTION PARAMETERS ARE ESTIMATED
C       ON THE BASIS OF THEORETICAL RELATIONS
C       N4 STANDS FOR LOGNORMAL DISTRIBUTION
C       N5 STANDS FOR LOG PEARSON DISTRIBUTION
C       N6 STANDS FOR SQUARE ROOT DISTRIBUTION
C       IF ANY OF THE TRANSFORMATION IS NOT REQUIRED GIVE 0 CORRES
C       PONDING TO THAT TRANSFORMATION
        DIMENSION TITLE(80),KX(500),THF(100),FL(100),T(100),CX(500)
        1,CX1(500),CX2(500)
        COMMON/BL1/L
        COMMON/BK1/N1,N2,N3,N4,N5,N6
        COMMON/BL2/NCLAS
        REAL KX
         OPEN(UNIT=1,FILE='GOEL.DAT',STATUS='OLD')
        OPEN(UNIT=2,FILE='GOEL.OUT',STATUS='NEW')
 80     FORMAT(80A1)
 81     FORMAT(1X,80A1)
 14     FORMAT(1X,10F8.0)
 1001    FORMAT(' TOTAL NO. OF VALUES=',I6/' NO.OF SEASONS PER YEAR=',I6
        1/' NCLAS=',I6)
 1002    FORMAT(11H INPUT DATA/12(1H*)/)
        READ(1,80) TITLE
        WRITE(2,81) TITLE
 118    READ(1,*) N,NS,NCLAS
C       N IS THE TOTAL NO. OF OBSERVATIONS
C       NS IS THE NO. OF SEASONS PER YEAR
C       NCLAS IS THE NO. OF CLASSES REQUIRED FOR CHI
C       SQUARE CALCULATION;  THIS DEPENDS UPON THE NO.
C       OF VALUES PER YEAR
        READ(1,*)N1,N2,N3,N4,N5,N6
        WRITE(2,1001) N,NS,NCLAS
        READ(1,*) (KX(I),I=1,N)
        WRITE(2,1002)
        WRITE(2,14) (KX(I),I=1,N)
        NPT=NCLAS+1
        L=N/NS
        FL(1)=0.0
        FL(NPT)=0.9999
        DO 5 I=2,NCLAS
 5      FL(I)=FLOAT(I-1)/FLOAT(NCLAS)
C        CALCULATE STANDARISED VARIATES CORRESPONDING TO LIMITS OF
C       SELECTED CLASS INTERVALS
        DO 555 I=1,NPT
        FFL=FL(I)
        CALL NDTRI(FFL,AX,C,IER)
 555    T(I)=AX
```

```
C       CALCULATE THEORETICAL FREQUENCY FOR EACH CLASS
        DO 68 I=1,NCLAS
68      THF(I)=FLOAT(L)/FLOAT(NCLAS)
       J=1
 100   DO 15 I=1,L
       II=(I-1)*NS+J
       CX(I)=KX(II)
       CX2(I)=CX(I)
 15    CX1(I)=CX(I)
       WRITE(2,40)J
40     FORMAT(20X,'ANALYSIS FOR SEASON',4X,I5/20X,19(1H*)/)
       WRITE(2,10)(CX(I),I=1,L)
 10    FORMAT(3X,10F8.0)
       CALL SORTX(L,CX)
       WRITE(2,20)
20     FORMAT(3X,'SORTED RECORDED EVENTS')
       WRITE(2,10)(CX(I),I=1,L)
       CALL NORMAL(CX,L,THF,T,AMEAN,STDEV,SKEW)
       CALL PT3(CX,L,THF,T,AMEAN,STDEV,SKEW)
       CALL LNC(CX1,L,THF,T,AMEAN,STDEV,SKEW)
       CALL LN(CX1,L,THF,T,AMEAN,STDEV,SKEW)
       CALL LP3(CX1,L,THF,T,AMEAN,STDEV,SKEW)
       CALL SQRTT(CX2,L,THF,T,AMEAN,STDEV,SKEW)
       J=J+1
       IF(J.GT.NS)GO TO 200
       GO TO100
 200   STOP
       END
C      NORMAL DISTRIBUTION
       SUBROUTINE NORMAL(CX,L,THF,T,AMEAN,STDEV,SKEW)
       DIMENSION CX(500),THF(100),T(100)
       COMMON/BK1/N1,N2,N3,N4,N5,N6
       IF(N1)500,100,500
500    WRITE(2,1003)
1003    FORMAT(33H ANALYSIS FOR NORMAL DISTRIBUTION)
       CALL MSS(CX,AMEAN,STDEV,SKEW)
       CALL CSS(CX,AMEAN,STDEV,SKEW,THF,T)
100    RETURN
       END
C      PEARSON TYPE 3 DISTRIBUTION BY BEARD NORMALIZATION
       SUBROUTINE PT3(CX,L,THF,T,AMEAN,STDEV,SKEW)
       COMMON/BK1/N1,N2,N3,N4,N5,N6
       DIMENSION CX(500),THF(100),T(100)
       IF(N2.EQ.0)GOTO 100
        IF(N1.EQ.0)GO TO 200
       GO TO 300
200    CALL MSS(CX,AMEAN,STDEV,SKEW)
300    WRITE(2,25)
25     FORMAT(1X,'PEARSON TYPE 3 DISTRIBUTIN')
        DO 725 J=1,L
```

```
          CX(J)=(CX(J)-AMEAN)/STDEV
         CX(J)=(SKEW*CX(J))/2.0+1.0
         IF(CX(J))507,507,508
507       CX(J)=(-1.)*(ABS(CX(J)))**(1./3.)
          GO TO 509
508       CX(J)=CX(J)**(1./3.)
509       CX(J)=(6./SKEW)*(CX(J)-1.)+(SKEW)/6.
725       CONTINUE
         CALL MSS(CX,AMEAN,STDEV,SKEW)
         CALL CSS(CX,AMEAN,STDEV,SKEW,THF,T)
100      RETURN
         END
C        LOGNORMAL DISTRIBUTION PARAMETERS ESTIMATED BY CHOW'S METHOD
         SUBROUTINE LNC(CX,L,THF,T,AMEAN,STDEV,SKEW)
         COMMON/BK1/N1,N2,N3,N4,N5,N6
         DIMENSION CX(500),THF(100),T(100)
         IF(N3.EQ.0)GO TO 100
         IF(N1.EQ.0)GO TO 300
         IF(N2.EQ.1)GO TO 300
         GOTO 500
300      CALL MSS(CX,AMEAN,STDEV,SKEW)
500      WRITE(2,25)
25       FORMAT(1X,'CHOW METHOD FOR LOGNORMAL DISTRIBUTION')
         VAR=(STDEV/AMEAN)**2+1.0
         AMEAN=ALOG(AMEAN)-0.5*ALOG(VAR)
         STDEV=ALOG(VAR)
         STDEV=SQRT(STDEV)
         DO 60 I=1,L
         IF(CX(I).EQ.0.0)CX(I)=1.
60       CX(I)=ALOG(CX(I))
         CALL MSS(CX,AMEAN1,STDEV1,SKEW1)
         CALL CSS(CX,AMEAN,STDEV,SKEW1,THF,T)
100      RETURN
         END
C        LOG TRANSFORMATION
         SUBROUTINE LN(CX,L,THF,T,AMEAN,STDEV,SKEW)
         COMMON/BK1/N1,N2,N3,N4,N5,N6
         DIMENSION CX(500),THF(100),T(100)
         IF(N4.EQ.0)GO TO 100
         IF(N3.EQ.0)GO TO 200
         GO TO 500
200      DO 20 I=1,L
         IF(CX(I).EQ.0.)CX(I)=1.
20       CX(I)=ALOG(CX(I))
500      WRITE(2,1012)
1012      FORMAT(1X,19H LOG TRANSFORMATION)
         CALL MSS(CX,AMEAN,STDEV,SKEW)
         CALL CSS(CX,AMEAN,STDEV,SKEW,THF,T)
100      RETURN
         END
```

```
C       LOG PEARSON TYPE 3 DISTRIBUTION
        SUBROUTINE LP3(CX,L,THF,T,AMEAN,STDEV,SKEW)
        COMMON/BK1/N1,N2,N3,N4,N5,N6
        DIMENSION CX(500),THF(100),T(100)
        IF(N5.EQ.0)GO TO 100
        IF(N3.EQ.0.AND.N4.EQ.0)GOTO 200
        GO TO 500
200     DO 20 I=1,L
        IF(CX(I).EQ.0.)CX(I)=1.0
20      CX(I)=ALOG(CX(I))
        CALL MSS(CX,AMEAN,STDEV,SKEW)
500     DO 728 J=1,L
         CX(J)=(CX(J)-AMEAN)/STDEV
        CX(J)=(SKEW*CX(J))/2.0+1.0
        IF(CX(J))607,607,608
607      CX(J)=(-1.)*(ABS(CX(J)))**(1./3.)
         GO TO 609
608      CX(J)=CX(J)**(1./3.)
609      CX(J)=(6./SKEW)*(CX(J)-1.)+(SKEW)/6.
728      CONTINUE
        WRITE(2,1023)
 1023   FORMAT(1X,'LOG PEARSON TYPE 3 DISTRIBUTION')
        CALL MSS(CX,AMEAN,STDEV,SKEW)
        CALL CSS(CX,AMEAN,STDEV,SKEW,THF,T)
 100    RETURN
        END
C       SQUARE ROOT TRANSFORMATION
        SUBROUTINE SQRTT(CX,L,THF,T,AMEAN,STDEV,SKEW)
        COMMON/BK1/N1,N2,N3,N4,N5,N6
        DIMENSION CX(500),THF(100),T(100)
        IF(N6)500,100,500
500     DO 123 I=1,L
        IF(CX(I).LE.0.)CX(I)=0.1
123     CX(I)=SQRT(CX(I))
        WRITE(2,1020)
1020     FORMAT(' SQUARE ROOT TRANSFORMATION')
        CALL MSS(CX,AMEAN,STDEV,SKEW)
        CALL CSS(CX,AMEAN,STDEV,SKEW,THF,T)
100     RETURN
        END
C        CALCULATE AND TYPE SEASONAL STATISTICAL PARAMETERS
        SUBROUTINE MSS(X,AMEAN,STDEV,SKEW)
        DIMENSION X(500)
        COMMON/BL1/L
        SUM=0.
         DO 2 I=1,L
 2       SUM=SUM+X(I)
        AMEAN=SUM/L
         SUM1=0.
         SUM2=0.
```

```
         DO 4 I=1,L
        SUM1=SUM1+(X(I)-AMEAN)**2
4       SUM2=SUM2+(X(I)-AMEAN)**3
        STDEV=SQRT(SUM1/(L-1))
        SKEW=(L*SUM2)/((L-1)*(L-2)*STDEV*STDEV*STDEV)
        RETURN
        END
C       CALCULATE CHI SQUARE AND NO. OF DEGREE OF FREEDOM
        SUBROUTINE CSS(X,AMEAN,STDEV,SKEW,THF,T)
        COMMON/BL2/NCLAS
        COMMON/BL1/L
        DIMENSION X(500),THF(100),T(100),FREQ(100)
         DO 78 I=1,NCLAS
78       FREQ(I)=0,
         DO 59 I=1,L
        AMINP=AMEAN+STDEV*T(2)
         M=1
61       IF(X(I)-AMINP)62,62,63
62       FREQ(M)=FREQ(M)+1.0
        GO TO 59
63       IF(M-NCLAS)501,62,501
501      M=M+1
        AMINP=AMEAN+STDEV*T(M+1)
         GO TO 61
59       CONTINUE
C        CALCULATE CHI-SQUARE STATISTIC AND NO. OF DEGREES OF FREEDOM
         CHIS=0.
         DO 69 I=1,NCLAS
69       CHIS=CHIS+((ABS(FREQ(I)-THF(I))))**2/THF(I)
         NDF=NCLAS-3
        WRITE(2,1004)AMEAN,STDEV,SKEW,CHIS,NDF
 1004   FORMAT(7X,'MEAN',2X,'STD. DEVIATION',2X,'COEF.OF SKEW',2X
        1,'CHI SQUARE',2X,'DEGREE OF FREEDOM'/5X,F9.3,2X,F9.3
        2,6X,F8.3,5X,F8.4,4X,I5)
        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'',PRINCETON 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)
      1 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
        SUBROUTINE SORTX (N,X)
C   SORTS IN DECREASING ORDER, X(I)=LARGEST
        DIMENSION X(100)
        K=N-1
        DO 2 L=1,K
```

```
      M=N-L
      DO 2 J=1,M
      IF (X(J)-X(J+1)) 1,1,2
1     XT=X(J)
      X(J)=X(J+1)
      X(J+1)=XT
2     CONTINUE
      RETURN
      END
```

APPENDIX - VII B

DATA FILE FOR PROGRAMME 7 (GOEL.DAT)

```
ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS
32,1,6
1,1,1,1,1,1
23890 26810 45630 10380 13290 17100 28650 29150 12810 26700 19700 38800
21250 43360 38880 15250 19560 15250 13000 22670 58100 31170 69400 19980
47980 61350 27300 33750 19500 22700 34260 38200
```

APPENDIX - VII C

OUTPUT FILE FOR PROGRAMME 7 (GOEL.OUT)

```
 ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS
 TOTAL NO. OF VALUES=    32
 NO.OF SEASONS PER YEAR=     1
 NCLAS=     6
 INPUT DATA
************
23890.  26810.  45630.  10380.  13290.  17100.  28650.  29150.  12810.  26700
 19700.  38800.  21250.  43360.  38880.  15250.  19560.  15250.  13000.  22670
58100.  31170.  69400.  19980.  47980.  61350.  27300.  33750.  19500.  22700
34260.  38200.
                   ANALYSIS FOR SEASON        1
                   *******************

23890.  26810.  45630.  10380.  13290.  17100.  28650.  29150.  12810.  26700
 19700.  38800.  21250.  43360.  38880.  15250.  19560.  15250.  13000.  22670
58100.  31170.  69400.  19980.  47980.  61350.  27300.  33750.  19500.  22700
34260.  38200.
  SORTED RECORDED EVENTS
69400.  61350.  58100.  47980.  45630.  43360.  38880.  38800.  38200.  34260
33750.  31170.  29150.  28650.  27300.  26810.  26700.  23890.  22700.  22670
21250.  19980.  19700.  19560.  19500.  17100.  15250.  15250.  13290.  13000
 12810.  10380.
 ANALYSIS FOR NORMAL DISTRIBUTION
      MEAN  STD. DEVIATION  COEF.OF SKEW  CHI SQUARE  DEGREE OF FREEDOM
    29556.875  14864.373        1.052        5.8750        3
 PEARSON TYPE 3 DISTRIBUTIN
      MEAN  STD. DEVIATION  COEF.OF SKEW  CHI SQUARE  DEGREE OF FREEDOM
       0.016      0.958         0.391        0.6250        3
 CHOW METHOD FOR LOGNORMAL DISTRIBUTION
      MEAN  STD. DEVIATION  COEF.OF SKEW  CHI SQUARE  DEGREE OF FREEDOM
      10.181      0.475         0.104        1.3750        3
  LOG TRANSFORMATION
      MEAN  STD. DEVIATION  COEF.OF SKEW  CHI SQUARE  DEGREE OF FREEDOM
      10.179      0.488         0.104        1.3750        3
 LOG PEARSON TYPE 3 DISTRIBUTION
      MEAN  STD. DEVIATION  COEF.OF SKEW  CHI SQUARE  DEGREE OF FREEDOM
       0.001      1.000         0.036        0.6250        3
 SQUARE ROOT TRANSFORMATION
      MEAN  STD. DEVIATION  COEF.OF SKEW  CHI SQUARE  DEGREE OF FREEDOM
      167.040     41.328        0.583        1.0000        3
```

APPENDIX - VIII A

SOURCE PROGRAMME 8 (POWTRA.FOR)

```
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),X1(100),P(100),
     1  IYEAR(100),ALPHA(9,7),ALPHAS(9),ALINPI(9),IYEAR1(100),
```

```
     2  X2(9),Y2(9),Z1(100),Y1(100),RI(10),TD(10),ESTP(10),PEX(7),
     3  ALINPI1(9),PEX1(7),IRI(10),TITLE(80)
        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(21,333)TITLE
333     FORMAT(80A1)
        WRITE(22,333)TITLE
        READ (21,*) N,NCLASS,(RI(I),I=1,6)
        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)
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
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),I,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,'!',3X,'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)
      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
99    FORMAT (40X,'*      ANALYSIS OF THE POWER TRANSFORMED SERIES
     1      *')
      AL1=1.0
      DO 2 I=1,N
2     Y(I)=(X(I)**AL1-1.)/AL1
      CALL ARI(Y,N,SMEAN,SSD,SKEW,SKUR)
      SK1=SKEW
      AL2=AL1+0.2
1201  DO 3 I=1,N
3     Y(I)=(X(I)**AL2-1.)/AL2
      CALL ARI(Y,N,SMEAN,SSD,SKEW,SKUR)
      SK2=SKEW
      DL=-SK2*(AL2-AL1)/(SK2-SK1)
      IF(ABS(DL).LE.0.001)GO TO 79
      SK1=SK2
      AL1=AL2
      AL2=AL2+DL
      GO TO 1201
79    AL=AL2
      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 LAMDA =',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
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)
        DO 666 I=1,N
        P2=P(I)
        CALL NDTRI(P2,T,D,IE)
        ZCOM=SMEAN+SSD*T
        XCOM=(ZCOM*AL+1.)**(1./AL)
C       WRITE(22,*) X(I),XCOM
666     CONTINUE
        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 REQUIRE
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 SEQ(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 YQRK.
        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 - VIII B

DATA FILE FOR PROGRAMME 8 (POWTRA.DAT)

```
 ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS
32 5 50 100 200 500 1000 10000
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 1978 1979
 23890 26810 45630 10380 13290 17100 28650 29150 12810 26700 19700 38800
 21250 43360 38880 15250 19560 15250 13000 22670 58100 31170 69400 19980
 47980 61350 27300 33750 19500 22700 34260 38200
```

APPENDIX - VIII C

OUTPUT FILE FOR PROGRAMME 8 (POWTRA.OUT)

ANNUAL PEAK FLOOD DATA FOR NARMADA AT GARUDESHWAR (1948-79) IN CUMECS

****

*   ANALYSIS OF THE ORIGINAL SERIES   *

****

THE TOTAL NO. VALUES IN THE ORIGINAL SERIESARE= 32

NOTE: BLOMS PLOTTING POSITION IS USED THROUGHOUT

SL.NO.	DATA IN CHRONOLOGICAL ORDER		DATA IN ASCENDING ORDER		RANK	PROBABILITY OF NON-EXCEEDENCE
	YEAR	DISCHARGE	YEAR	DISCHARGE		
1	1948	23890.0	1951	10380.0	1	0.019
2	1949	26810.0	1956	12810.0	2	0.050
3	1950	45630.0	1966	13000.0	3	0.081
4	1951	10380.0	1952	13290.0	4	0.112
5	1952	13290.0	1965	15250.0	5	0.143
6	1953	17100.0	1963	15250.0	6	0.174
7	1954	28650.0	1953	17100.0	7	0.205
8	1955	29150.0	1976	19500.0	8	0.236
9	1956	12810.0	1964	19560.0	9	0.267
10	1957	26700.0	1958	19700.0	10	0.298
11	1958	19700.0	1971	19980.0	11	0.329
12	1959	38800.0	1960	21250.0	12	0.360
13	1960	21250.0	1967	22670.0	13	0.391
14	1961	43360.0	1977	22700.0	14	0.422
15	1962	38880.0	1948	23890.0	15	0.453
16	1963	15250.0	1957	26700.0	16	0.484
17	1964	19560.0	1949	26810.0	17	0.516
18	1965	15250.0	1974	27300.0	18	0.547
19	1966	13000.0	1954	28650.0	19	0.578
20	1967	22670.0	1955	29150.0	20	0.609
21	1968	58100.0	1969	31170.0	21	0.640
22	1969	31170.0	1975	33750.0	22	0.671
23	1970	69400.0	1978	34260.0	23	0.702
24	1971	19980.0	1979	38200.0	24	0.733
25	1972	47980.0	1959	38800.0	25	0.764
26	1973	61350.0	1962	38880.0	26	0.795
27	1974	27300.0	1961	43360.0	27	0.826
28	1975	33750.0	1950	45630.0	28	0.857
29	1976	19500.0	1972	47980.0	29	0.888

30	1977	22700.0	1968	58100.0	30	0.919
31	1978	34260.0	1973	61350.0	31	0.950
32	1979	38200.0	1970	69400.0	32	0.981

STATISTICAL ESTIMATES OF THE ORIGINAL SERIES ARE AS FOLLOWS:

MEAN OF THE SERIES= 0.29556875E+05

STANDARD DEV OF THE SERIES= 0.14864373E+05

COEFF. OF SKEWNESS OF THE SERIES= 0.10519611E+01

COEFF. OF KURTOSIS OF THE SERIES= 0.38579183E+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	1948	4.378	1951	4.016	1	0.019
2	1949	4.428	1956	4.108	2	0.050
3	1950	4.659	1966	4.114	3	0.081
4	1951	4.016	1952	4.124	4	0.112
5	1952	4.124	1965	4.183	5	0.143
6	1953	4.233	1963	4.183	6	0.174
7	1954	4.457	1953	4.233	7	0.205
8	1955	4.465	1976	4.290	8	0.236
9	1956	4.108	1964	4.291	9	0.267
10	1957	4.427	1958	4.294	10	0.298
11	1958	4.294	1971	4.301	11	0.329
12	1959	4.589	1960	4.327	12	0.360
13	1960	4.327	1967	4.355	13	0.391
14	1961	4.637	1977	4.356	14	0.422
15	1962	4.590	1948	4.378	15	0.453
16	1963	4.183	1957	4.427	16	0.484
17	1964	4.291	1949	4.428	17	0.516
18	1965	4.183	1974	4.436	18	0.547
19	1966	4.114	1954	4.457	19	0.578
20	1967	4.355	1955	4.465	20	0.609
21	1968	4.764	1969	4.494	21	0.640
22	1969	4.494	1975	4.528	22	0.671
23	1970	4.841	1978	4.535	23	0.702
24	1971	4.301	1979	4.582	24	0.733
25	1972	4.681	1959	4.589	25	0.764
26	1973	4.788	1962	4.590	26	0.795
27	1974	4.436	1961	4.637	27	0.826
28	1975	4.528	1950	4.659	28	0.857
29	1976	4.290	1972	4.681	29	0.888
30	1977	4.356	1968	4.764	30	0.919

! 31	! 1978	! 4.535	! 1973	! 4.788	! 31	! 0.950	!
! 32	! 1979	! 4.582	! 1970	! 4.841	! 32	! 0.981	!

STATISTICAL ESTIMATES OF THE LOG TRANSFORMED SERIES ARE AS FOLLOWS:

MEAN OF THE SERIES= 0.44204741E+01

STANDARD DEV OF THE SERIES= 0.21196480E+00

COEFF. OF SKEWNESS OF THE SERIES= 0.10410827E+00

COEFF. OF KURTOSIS OF THE SERIES= 0.25930965E+01

NCLASS= 5 NDF= 2 CHISQ= 0.187

ESTIMATED FLOOD PEAKS

SL.NO.	RECURRENCE INTERVAL	ESTIMATED FLOOD
1	50 YEARS	71761.
2	100 YEARS	81973.
3	200 YEARS	92586.
4	500 YEARS	107304.
5	1000 YEARS	119003.
6	10000 YEARS	161729.

ANALYSIS OF THE POWER TRANSFORMED SERIES

SL.NO.	DATA IN CHRONOLOGICAL ORDER: YEAR	DISCHARGE	DATA IN ASCENDING ORDER: YEAR	DISCHARGE	RANK	PROBABILITY OF NON-EXCEEDENCE
1	1948	6.131	1951	5.839	1	0.019
2	1949	6.169	1956	5.915	2	0.050
3	1950	6.340	1966	5.920	3	0.081
4	1951	5.839	1952	5.928	4	0.112
5	1952	5.928	1965	5.977	5	0.143
6	1953	6.017	1963	5.977	6	0.174
7	1954	6.191	1953	6.017	7	0.205
8	1955	6.197	1976	6.062	8	0.236
9	1956	5.915	1964	6.063	9	0.267
10	1957	6.168	1958	6.066	10	0.298
11	1958	6.066	1971	6.070	11	0.329
12	1959	6.289	1960	6.091	12	0.360
13	1960	6.091	1967	6.113	13	0.391
14	1961	6.324	1977	6.114	14	0.422
15	1962	6.290	1948	6.131	15	0.453
16	1963	5.977	1957	6.168	16	0.484
17	1964	6.063	1949	6.169	17	0.516
18	1965	5.977	1974	6.175	18	0.547
19	1966	5.920	1954	6.191	19	0.578
20	1967	6.113	1955	6.197	20	0.609
21	1968	6.415	1969	6.219	21	0.640
22	1969	6.219	1975	6.245	22	0.671
23	1970	6.468	1978	6.249	23	0.702
24	1971	6.070	1979	6.284	24	0.733
25	1972	6.356	1959	6.289	25	0.764
26	1973	6.431	1962	6.290	26	0.795
27	1974	6.175	1961	6.324	27	0.826
28	1975	6.245	1950	6.340	28	0.857
29	1976	6.062	1972	6.356	29	0.888
30	1977	6.114	1968	6.415	30	0.919
31	1978	6.249	1973	6.431	31	0.950
32	1979	6.284	1970	6.468	32	0.981

STATISTICAL ESTIMATES OF THE POWER TRANSFORMED SERIES ARE AS FOLLOWS :

VALUE OF LAMDA = -0.10844612

MEAN OF THE SERIES = 6.15926981

STANDARD DEVIATION = 0.16166110

COEFF. OF SKEWNESS = 0.00050505

COEFF. OF KURTOSIS = 2.57971287

NCLASS= 5 NDF= 2 CHISQ= 0.187

ESTIMATED FLOOD PEAKS

SL.NO.	RECURRENCE INTERVAL	ESTIMATED FLOOD
1	50 YEARS	74954.
2	100 YEARS	87090.
3	200 YEARS	100128.
4	500 YEARS	118911.
5	1000 YEARS	134412.
6	10000 YEARS	195204.

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

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

CK=-0.42 BETA=-0.23

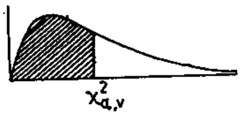
KURTOSIS CORRECTED STANDARD DEVIATES CORRESPONDING TO THE COMPUTED CK

BETA	ALPHA 0.25	ALPHA 0.10	ALPHA 0.05	ALPHA 0.025	ALPHA 0.01	ALPHA 0.005	ALPHA 0.001
-0.23	0.73	1.31	1.63	1.90	2.19	2.38	2.77

ESTIMATED FLOOD PEAKS

SL.NO.	RECURRENCE INTERVAL	ESTIMATED FLOOD
1	50 YEARS	71753.
2	100 YEARS	80773.
3	200 YEARS	89945.
4	500 YEARS	104504.
5	1000 YEARS	112005.

Percentile Values ($\chi^2_{\alpha,\nu}$) for the Chi-Square Distribution with ν Degrees of Freedom (shaded area = α).



ν	$\chi^2_{.995}$	$\chi^2_{.99}$	$\chi^2_{.975}$	$\chi^2_{.95}$	$\chi^2_{.90}$	$\chi^2_{.75}$	$\chi^2_{.50}$
1	7.88	6.63	5.02	3.84	2.71	1.32	.455
2	10.6	9.21	7.38	5.99	4.61	2.77	1.39
3	12.8	11.3	9.35	7.81	6.25	4.11	2.37
4	14.9	13.3	11.1	9.49	7.78	5.39	3.36
5	16.7	15.1	12.8	11.1	9.24	6.63	4.35
6	18.5	16.8	14.4	12.6	10.6	7.84	5.35
7	20.3	18.5	16.0	14.1	12.0	9.04	6.35
8	22.0	20.1	17.5	15.5	13.4	10.2	7.34
9	23.6	21.7	19.0	16.9	14.7	11.4	8.34
10	25.2	23.2	20.5	18.3	16.0	12.5	9.34
11	26.8	24.7	21.9	19.7	17.3	13.7	10.3
12	28.3	19.8	23.3	21.0	18.5	14.8	11.3
13	29.8	27.7	24.7	22.4	29.6	16.0	12.3
14	31.3	29.1	26.1	23.7	21.1	17.1	13.3
15	32.8	30.6	27.5	25.0	22.3	18.2	14.3
16	34.3	32.0	28.8	26.3	23.5	19.4	15.3
17	35.7	33.4	30.2	27.6	24.8	20.5	16.3
18	37.2	34.8	31.5	28.9	26.0	21.6	17.3
19	38.6	36.2	32.9	30.1	27.2	22.7	18.3
20	40.0	37.6	34.2	31.4	28.4	23.8	19.3
21	41.4	38.9	35.5	32.7	29.	24.9	20.3
22	42.8	40.3	36.8	33.9	30.8	26.0	21.3
23	44.2	41.6	38.1	35.2	32.0	27.1	22.3
24	45.6	43.0	39.4	36.4	33.2	28.2	23.3
25	46.9	44.3	40.6	37.7	34.4	29.3	24.3
26	48.3	45.6	41.9	38.9	35.6	30.4	25.3
27	49.6	47.0	43.2	40.1	36.7	31.5	26.3
28	51.0	48.3	44.5	41.3	37.9	32.6	27.3
29	52.3	49.6	45.7	42.6	39.1	33.7	28.3
30	53.7	50.9	47.0	43.8	40.3	34.8	29.3
40	66.8	63.7	59.3	55.8	51.8	45.6	39.3
50	79.5	76.2	71.4	67.5	63.2	56.3	49.3
60	92.0	88.4	83.3	79.1	74.4	67.0	59.3
70	104.2	100.4	95.0	90.5	85.5	77.6	69.3
80	116.3	112.3	106.6	101.9	96.6	88.1	79.3
90	128.3	124.1	118.1	113.1	107.6	98.6	89.3
100	140.2	135.8	129.6	124.3	118.5	109.1	99.3

ν	$\chi^2_{.25}$	$\chi^2_{.1}$	$\chi^2_{.05}$	$\chi^2_{.025}$	$\chi^2_{.01}$	$\chi^2_{.005}$
1	.102	.0158	.0039	.001	.0002	.0000
2	.575	.211	.103	.050	.0201	.0100
3	1.21	.584	.352	.216	.115	.072
4	1.92	1.06	.711	.484	.297	.207
5	2.67	1.61	1.15	.831	.554	.412
6	3.45	2.20	1.64	1.24	.872	.676
7	4.25	2.83	2.17	1.69	1.24	.989
8	5.07	3.49	2.73	2.18	1.65	1.34
9	5.90	4.17	3.33	2.70	2.09	1.73
10	6.74	4.87	3.94	3.25	2.56	2.16
11	7.58	5.58	4.57	3.82	3.05	2.60
12	8.44	6.30	5.23	4.40	3.57	3.07
13	9.30	7.04	5.89	5.01	4.11	3.57
14	10.2	7.79	6.57	5.63	4.66	4.07
15	11.0	8.55	7.26	6.26	5.23	4.60
16	11.9	9.31	7.96	6.91	5.81	5.14
17	12.8	10.1	8.67	7.56	6.41	5.70
18	13.7	10.9	9.39	8.23	7.01	6.26
19	14.6	11.7	10.1	8.91	7.63	6.84
20	15.5	12.4	10.9	9.59	8.26	7.43
21	16.3	13.2	11.6	10.3	8.90	8.03
22	17.2	14.0	12.3	11.0	9.54	8.64
23	18.1	14.8	13.1	11.7	10.2	9.26
24	19.0	15.7	13.8	12.4	10.9	9.89
25	19.9	16.5	14.6	13.1	11.5	10.5
26	20.8	17.3	15.4	13.8	12.2	11.2
27	21.7	18.1	16.2	14.6	12.9	11.8
28	22.7	18.9	16.9	15.3	13.6	12.5
29	23.6	19.8	17.7	16.0	14.3	13.1
30	24.5	20.6	18.5	16.8	15.0	13.8
40	33.7	29.1	26.5	24.4	22.2	20.7
50	42.9	37.7	34.8	32.4	29.7	28.0
60	52.3	46.5	43.2	40.5	37.5	35.5
70	61.7	55.3	51.7	48.8	45.4	43.3
80	71.1	64.3	60.4	57.2	53.5	51.2
90	80.6	73.3	69.1	65.6	61.8	59.2
100	90.1	82.4	77.9	74.2	70.1	67.3