SYNTHETIC GENERATION OF STREAMFLOW DATA USING COMPUTER SIMULATION MODEL

by

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THESIS

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1993

DECLARATION

I hereby declare that this thesis entitled ***"Synthetic Generation of Streamflow Data Using Computer Simulation Model"*** *is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, relationship or other similar title or any other University or Society.*

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SYMBOLS AND ABBREVIATIONS USED

cm	-	centimetre
dept	-	Department
engg	-	Engineering
ESO	-	Explicit Stochastic Optimisation
exp	-	exponential
Fig.	-	Figure
ISO	-	Implicit Stochastic Optimisation
Inst	-	Institute
Int	-	International
J.	-	Journal
km	-	kilometre
Mm^3	-	Million metre cube
%	-	percentage
Res.	-	Research
US	-	United States

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Introduction

INTRODUCTION

Occurrence of flood is a natural phenomenon all over the world. With the increase in population and human activity in the flood plains, flood damages represent an increasing hazard in many countries, in spite of increasing investments in flood control measures. Consequently it is of utmost importance to utilise the most efficient methods in streamflow determination, in assessment of reservoir operations schemes.

Also for planning, design and operation of water resources system, it is very much essential to have streamflow data that will be at least equal to the projected useful life of reservoir. But in most of the cases, the data for the required duration is not available. In such cases, streamflow data is usually generated for required number of years. This artificially generated data known as the 'synthetic' data will have the same statistical properties as that of the available historical data of streamflows. The synthetic data can be used for the design and operation of reservoirs.

The recent years progress within hydrology and river hydraulics has now made it feasible to peform streamflow generation by means of comprehensive mathematical models. The later years rapid development in size and speed of microcomputers has now also made it feasible to develop microcomputer versions of these mathematical models.

Hydrologic simulation is an effective technique in comprehensive watershed planning and equally important in subsequent implementation and refinement. The simulation approach is essentially a search method. First a reasonable initial operation rule is postulated. Then changes in decision rule that tend to move the operation in the direction of the desired objectives are tried. This approach resembles the trial and error approach used in traditional operation studies.

The practical problems of design ana operation of water resources systems are steadily becoming numerous and complex. Estimations of predictions of peak flow frequencies and run-off volumes are necessary in connection with the investigation and operation of all hydroelectric as well as irrigation projects. Hydrologist have little streamflow data and limited rainfall data to use as a basis for predicting flow behaviour at the project sites in the river basins of Western Ghats region.

The estimation of maximum expected flood in a natural drainage system has lately been given extra special attention due to unforeseen failure of civil structures. It has always been a difficult task for designer to choose the appropriate methodology while dealing with the hydrology of big structure such as dams and spillways. The failure of large dams and allied structures attributed to the unforeseen hydrometero-logical events has made the hydrologist rather cautious in selecting methodology for estimating maximum expected floods. Based on the statistical information a suitable stochastic model has been attempted in the present study to correlate peak flows with their recurrence interval for the flows of a river after collecting sufficiently large number of observations. The model thus generated is expected to give reliable forecast of flows. These results have been compared with the historic data available.

Kerala with all its forty four rivers and their tributories and with copious amount of rainfall has varying streamflows in its different reaches and regions. To determine the data, the rainfall-runoff relationship for atleast one river basin and its sub-basins have to be established taking into account as far as possible the hydro-meteorological, topographical, geographical and geomorpho-logical characteristics. The type of rainfall-run off relationships and the extent of sophistication and refinement required to be employed in developing the relationships would depend not only on the data available but also on the type of water resources development contemplated in the basin.

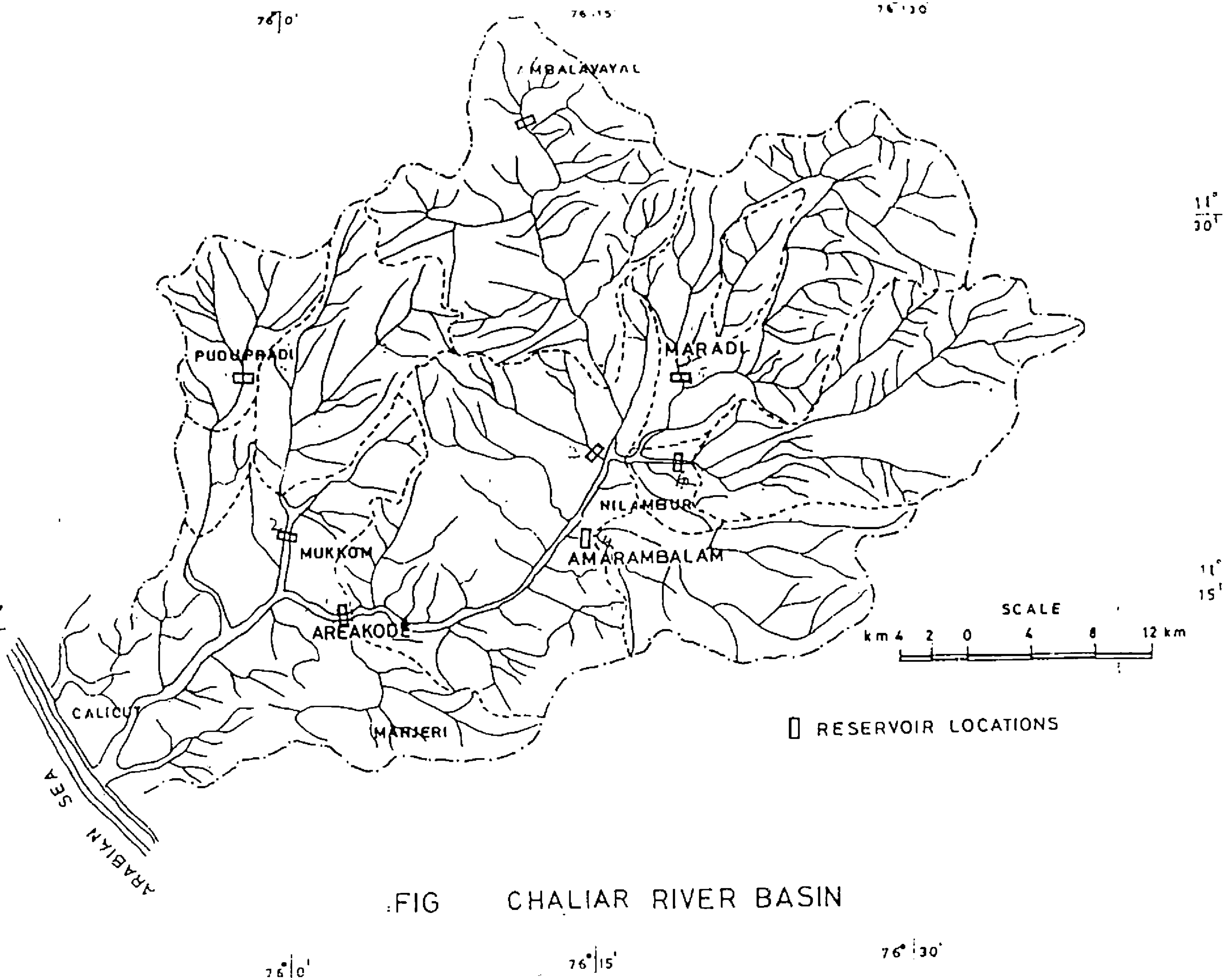


FIG CHALIAR RIVER BASIN

Considering these needs, an attempt has been made to establish a computer simulation model for the synthetic generation of streamflow data for one of the larger river basins of the region, namely Chaliyar.

The Chaliyar river basin selected for the present study is the third largest in Kerala with age area of two thousand nine hundred and twe are kilometre. The river has not been so far exploited for development of hydropower or major/medium irrigation schemes though all these have been contemplated. The streamflow data, especially the monthly flow data, are significant for future water resources development in the basin.

For hydrologic time series modelling of monthly flows based on non-stationarity of time series, the Thomas-Fiering model is well known. This model allows for non-stationarity that is observed in monthly streamflows. It preserves the statistical parameters like mean, standard deviation and serial correlation coefficient. This model considers periodic, correlation and random components of time series of streamflows. The detailed studies revealed that a univariate first order Thomas-Fiering model would be able to adequately represent monthly means for the Chaliyar basin.

The general purpose of the study is to develop a suitable mathematical model for the synthetic data generation, based on the available streamflow data which is useful for the design and operation of water resources system.

The specific objectives are:

1. Development of a computer simulation model for generation of synthetic data for river flows.

2. Test the model for Chaliyar river basin for statistical stability.

3. Comparison of the generated and historical data for different statistical parameters.

Review of Literature

REVIEW OF LITERATURE

In this chapter an attempt is made to give a brief review of literature relevant to the topic of study undertaken in the past.

2.1 Stochastic optimisation

Many papers (Takenchi, 1972) have been published these last years in the area of stochastic optimisation. Two facts may have caused this abundance of articles. Either the problem is difficult and requires to be solved by the joint efforts of many researchers, or no general method exists and each case asks for a special treatment. In reality, the truth lies in between. Hence only the methodologies relevant for the case under study will be reviewed here. Roefs (1968) prepared a good summary of the existing procedures which Croley (1972) took over and completed.

According to Roefs, two basic methods exist to solve stochastic optimisation problems. Implicit stochastic optimisation (ISO) and explicit stochastic optimisation (ESO). Croley himself has added a third one, which is in fact a combination of ISO and ESO, the alternative stochastic optimisation (ASO) technique.

Monte Carlo Dynamic Programming introduced by Young (1967) belongs to the first category. To optimise the operation of a reservoir under uncertainty, Young applies first a deterministic optimisation technique to each of the many available inflows sequences. The related optimal sets of releases are recorded. In a second step, the computed releases are related to some variables like storage or inflows, that have an influence on the release strategy and that describe the state of the system. Multiple linear regression analysis is most often used in the second step. Finally the established relations supply the information required to operate the reservoir.

In the second technique, one introduces the probability distribution of the inputs directly into the optimisation procedure. Stochastic linear programming developed by Manhe (1960) characterises well this approach. Manhe books for that set of probabilities which maximize the expected total benefit of reservoir operation. The solution of ESO consists of a table of optimal decisions indexed on the reservoir content and on the amount of previous inflow.

Finally Croley proposes a combination of both methods. First, as in ISO, the returns of the reservoir are optimized successively for various input samples, and then related release strategies are recorded. Second, this time in ESO, one evaluates the distribution of the decisions corresponding to the first stage of the operation period. Then an appropriate decision, corresponding either to the mean, mode or median of the obtained statistical distribution is selected, which applied to the system brings it to the beginning of the second stage. One repeats the same procedure for the second and all the following stages. Finally relations are established between decision and relevant state variables as in ISO. To reduce the burden of computations, the system is operated, in each case, only over a reduced period instead of the complete one.

As the ISO technique relies heavily on simulation, the problem does not have to be solvable by analytical techniques. So input time series with long persistence can be handled without problems. The application of ISO may require a lot of computations. However the real difficulties and drawbacks of this method appear in the last step, when relations are established between decision variables and relevant parameters describing the state of the system.

2.2 Hydrologic simulation

Hydrologic simulation is an effective technique in comprehensive watershed planning and equally important in subsequent implementation and refinement. Waliish (1972) has studied the practical considerations involved in the use of simulation in the preparation of three comprehensive watershed plans and has also used the results of that simulation study in implementing these plans.

Mejia et al. (1974) analysed a system that serves recreation and flow augmentation purposes. It uses flow forecasting and mathematical programming for optimisation. Historical data were used to simulate the operation of the system under different rules and an assessment of policies was made on the basis of multi-objective criteria.

Donald and Jose (1970) produced a set of simulation and optimization tools capable of analysing development and operation of a complex, multi-basin, interconnected water resource system. These models provide valuable information regarding the construction and operation of a proposed set of water projects. The simulation procedure developed by them employed a direct solution of a set of linear equations.

2.3 Different models in hydrology

A model is a simplified version of a complex system and a hydrological model can be either physical (Chow, 1967; Chery, 1963), analog (Diskin, 1967) or mathematical, in which behaviour of the system is represented by a set of equations, perhaps, together with logical statements expressing relationships between variables and parameters.

A continuous streamflow simulation model meant for large basin was generated in 1958 by Army Corps of Engineers (US). This model known as streamflow synthesis and reservoir regulation model (SSARR) is primarily intended for streamflow and flood forecasting and for reservoir design and operation studies. All components of run-off are routed separately and the sum of the routed values for any given time period is taken as the streamflow for the catchment.

The Boughton model (1966) originally developed in Australia was meant to simulate water yields from catchments in sub-humid to semi-arid regions. The model using daily rainfall and evaporation data, provides continuous simulation capability for general purpose use.

Quimpo and Yevjevich (1967) and Quimpo (1968) used a stochastic model for daily river flows. Roesner and Yevjevich (1966) studied the monthly run-off series. using, serial correlation analysis. An earlier study by Yevjevich (1964) on annual run-off sequences showed that the correlation coefficients were less than those for monthly flows. This increase in correlation with shorter time basis was also obtained by Corrigen and Huzen (1967) while analysing annual floods.

Sugawa (1967) applied TANK model for flood analysis and daily flow analysis to a number of basins in Japan and other countries. The application to some of the basins have been described in the publication of National Research Centre for Disaster Prevention (1974). The model has found its applications in the river basins of Malaysia, Thailand, Canada and some African countries. A few studies have been reported with regarded to river basins of India (Ekbote and Bhave, 1982).

The model structure is composed of several tanks laid vertically in series representing soil moisture and groundwater in different soil strata of the basin. The daily rainfall run-off model applicable to humid basins consists of four tanks laid vertically. The sum of outflows through side outflows of four tanks represents total run-off from the basin. Rainfall is the input to the top tank. The model is based on the hypothesis that the run-off at any instant from each tank depends on the storage in the tank at that instant and follows an exponential function. The model is non-linear in character and as much it is very difficult to find optimum parameter values using analytical techniques of optimisation. Only way of calibration is therefore, by trial and error or by using numerical techniques for optimisation.

The model is run after finalising the initial set of parameter values. The model simulates outflow hydrograph. The parameters are then calibrated leading to final model structure. Three main characteristics that are mainly looked into for comparison are (a) peak flow value, (b) time to peak and (c) recession slopes of the hydrograph.

A single deterministic black box model for monthly rainfall-run off simulation for the monsoon season has been evolved for the Chaliyar basin on tne Malabar Coast. The monthly rainfall-run off regression relationship reveals non-linear characteristics. The accuracy of the calibrated model has been verified using the data for the calibration period from the sub-basin. The validity of the model has been tested in another sub-basin of the Chaliyar. The regionalised model can be used for assessing the streamflow from similar sub-basins, which are not gauged. The model satisfactorily preserves the monthly historical means and the standard deviations of the flows.

The present rainfall-run off model has been selected with a view to fulfil the requirements, such as (l) assessing the monthly streamflow at the ungauged sites, (ii) computing flow at sites where the measuring operation has been terminated, (iii) estimation of monthly inflows into the envisaged reservoirs, (iv) calculating missing monthly flows. The simplicity of the model makes it suitable for application by field engineers. The limitation with regard to the quality and depth of data have been the major constraints in selecting other models suitable for the purposes described.

A monthly model similar to the one applied by Minikou and Rao (1983) for the Greek catchments can be used for both linear and non-linear rainfall-run off relationships. The model was calibrated and verified only for the monsoon months. Monthly streamflow data were available for 12 years (1960-80) from the Karimpuzha and the Punnapuzha sub-basins, monthly rainfall data were also available for the same period from the stations situated in the selected sub-basins and from the adjacent sub-basins. The model was verified by comparing the flows estimated using the model with the observed flows in the Punnapuzha sub-basin of the Chaliyar. The simple monthly rainfall-run off model evolved and validated for the sub-basin will be useful for computing streamflows in the ungauged sub-basins of Chaliyar for purposes of water resources development and management. This is especially significant since there are a number of raingauges in the basin and only a few stream gauging stations.

2.4 Stochastic models in hydrology

Stochastic techniques have been used for synthetic generation of hydrologic data by Thomas and Fiering (1962). They generated sequences of monthly and six-hourly flood flows by a stochastic model for the monthly run-off. Monthly flows were assumed to be normally distributed the correlation coefficients between successive pairs of monthly flows were same as those of historical records. The disaggregation problem namely that of generating a sequence of monthly streamflows which simultaneously preserves statistical properties of both the sequence of annual totals and the sequence of monthly flows has been solved by Valeneia and Schaake (1973). Singh and Lonnquist (1974) used an alternative mathod to generate monthly flows such that the annual totals retain desirable characteristics, the assumtion being monthly flows could be described by a mixture of two normal distributions. Thomas-Fiering technique was later extended by Harms and Campbell (1967) using a logarithmic transformation. Assuming normal distribution of historical flows, Brittan (1961) generated annual flows based on a Markov process. Chow and Ramaseshan (1965) used a non-stationary first order Markov chain process to describe hourly rainfall of maximum annual storms for sequential of annual floods. Using lognormally, transformed random numbers and a 'storm shifting' treatment to the rainfall data, annual storms were generated and routed through a system of linear reservoirs to arrive at the annual floods. Fiering (1964a) used a Markov model for sequential generation of daily flows which was used for lowflow analysis.

Thomas-Fiering model and autoregressive models based on the Gaussian distribution are likely to be less satisfactory than one which preserves the hydrograph characteristics of rapidly rising limb followed by more gradually decreasing recession. A generating model which preserves the characteristics hydrograph shape and which has been applied to the stochastic generation of daily flows, is the 'snotnoise' model. This was described by Parzen (1962) and applied to the daily streamflow generating problem by Weiss (1973).

A bivariate technique was used by Thomas and Fiering (1962) using the cross correlation of different pairs of gauging stations to generate discharges at several sites in a river basin from the recorded and generated flows at one of the stations and successive application to a chain of stations. Mstalas and Jacobs (1964) developed a procedure to generate and augment data by utilizing relationships between two given hydrologic phenomena such as rainfall and run-off.

Multivariate technique have been applied using spatial and temporal sequential correlation of hydrologic variables from stations having the same hydrologic and climatic conditions. Such a technique was first introduced by Fiering (1964b) and then developed further by Matalas (1967a, 1967b). Benson and Matalas (1967) adopted a regional analysis for hydrologic data generation for sites with short of inadequate records. Statistical techniques based on observations were combined with the knowledge of physical characteristics of the basin such as drainage area, channel slope, surface storage, precipitation and forested area, for constructing the model.

For approximating discrete fractional noise, two processes have been developed: (i) the broken-line process developed by Ditlevsen (1971) which is adapted to synthetic flow generation by Mejia (1971) and by Garcia et al. (1972) and (ii) the ARMA process (Box and Jenkins, 1970) which has been used to discuss streamflow sequences (Carlson et al., 1970) and adapted to synthetic flow generation by O'connel (1974).

Auto-regressive moving average (ARMA) time series models have been extensively used of late since it has a physically reasonable correlation structure which can reflect long term persistence resulting from long memory (Mandelbrot and Wallis, 1968), although this reasoning has been argued against by Klemes (1974). The long term persistence may also be due to shifts in the means of hydrologic processes, as demonstrated by Boes and Salas (1978). O'Connel (1971, 1974, 1977) has also pursued the long term persistence basis of the model. Multivariate ARMA (p, q) models have been proposed by Salas et al. (1980), Loucks et al. (1981), Jenkins and Alvi (1981), Box and Jenkins (1976), Stedinger et al. (1985).

Jain et al. (1985) developed a suitable stochastic model to give reliable forecast of flows for a river. Based on the statistical information, a suitable stochastic model has been attempted to correlate peak flows with their recurrence interval for the flows of a river after collecting sufficiently large number of observations. These results have been compared with those obtained from Gumpels method. This stochastic model establish a relation between expected peak flood and recurrence interval for a long services of recorded flows of a river scanning data from the year 1885 to 1984. The model uses Poissons Distribution applicable to investigate the encounter probability and accompanies magnitude for a remote possibility of occurrence of extreme event.

Jobi (1989) developed a computer simulation model for the operation of the multireservoir system with multiple objectives using historic and as well as generated streamflow. The objective of the study was to demonstrate the application of some of the systems analysis technique for optimal operation of water resources systems so as to later to the multi-objective needs of the population. It included the modelling for the selection of cropping pattern by conjective use of surface water and ground water, for getting maximum net, returns from the command area as well as for maximising the area of cultivation. Linear programming technique is adopted for this study.

The reservoir operation simulation model is designed for monthly operation with historic monthly mean streamflows. The monthly releases for various uses are obtained by running the model with the monthly streamflow data available for the reservoir sites from 1964 to 1983.

The linear programming model was developed by making use of the reservoir zoning concept introduced by Bend in 1967. In this study, the reservoir operation optimization model is designed for monthly operation with generated monthly streamflows. With the generated data optimal releases from the reservoirs for various uses with the application of linear programming technique are obtained.

Twenty years of data at the three sites for the period 1964-83 has been taken in the study for the generation of streamflows. The monthly streamflow data has been checked for its consistency with normal distribution.

For hydrologic time series modelling of monthly flows based on non-stationarity of time series, the Thomas-Fiering model is well known.

The studies conducted by Seth et al. (1985) revealed that a univariate first order Thomas-Fiering model would be able to adequately represent monthly means for the Chaliyar basin.

Ranga and Narasimhamurthy (1990) reported the generation of synthetic data of Cavery river flows. Thomas-Fiering model has been fitted to the observed monthly streamflows and after verification, data has been generated for a period of four hundred and ten years. For the study, data has been obtained from Chunchanakatto gauge station which is almost forty eight kms, upstream of Krishnaraja Sagara Dam. Data is available from Nineteen hundred and sixteen. The statistical parameters are found from the historical data. Trend component has not been consdered in this model because, it was observed from Kendal and Stuart's turning point test that there is no trend in the thirty years (1916 to 1945) data considered .

For the model verification, the total length of fifty years of data (1916 to 1965) was divided into two parts. First part having data of thirty years that was used to form the regression equations and then data was generated for twenty years, second part consists of twenty years of data that was used for comparing with the generated twenty years of data. The validation procedure includes (a) comparison of statistical prameters of historical and generated data (b) comparison of flow duration curves based on the generated data with the curves based on the historical data. Form the model verification tests, it was found that the Thômas-Fiering Model holds good for the site selected. Hence data was generated for a period of four hundred and ten years. First ten years of generated data was ignored to account for error caused due to initialisation of the generating sequence.

Materials and Methods

MATERIALS AND METHODS

The objective in general of this research work is to develop a suitable mathematical model for the synthetic data generation, based on the available streamflow data which is useful for the design and operation of water resources systems.

3.1 Objective

The specific objectives of this study are:

1. Development of a computer simulation model for generation of synthetic data for river flows.

2. Test the model for Chaliyar river basin for statistical stability.

3. Comparison of the generated and historical data for different statistical parameters.

3.2 Theoretical background

Few hydrologic populations can be represented by the normal distribution, and the degree of skewness depends upon the type of data. For example the distribution of daily flows is much more skewed than the distribution of annual flows. Since many of the statistical methods and techniques are primarily based the normal distribution, it has often been found advantageous to transform a skewed distribution into the normal one. Theoretically it is always possible to determine a function that would yield such a transformation (Hold, 1962), eventhough some transformations may be quite involved.

One of the most important and useful of such informations is the logarithmic transformation. It has been observed for the data having considerable skewness, their logarithms, are nearly normally distributed, and hence the original data are said to follow the log normal distribution.

Many hydrologic time series exhibit significant correlation. That is the value of the random variable under consideration at one time period is correlated with the values of the random variable at earlier time periods. The correlation of a random variable X at one time period with its value k time periods earlier is denoted by P_k (k) and is called the k th order serial correlation. If P_x (k) can be approximately by $P_x (k) = P_x^k (1)$, then the time series of the random variable X might be modelled by a first order Markov Process. A first order Markov process might also be used for a model if serial correlations for lags greater than one are not important.

A first order Markov process is defined by the equation

$$X_i + 1 = \mu_x + P_x (1) (X_i - \mu_x) + \varepsilon_{i+1}) \quad ----- (1)$$

$$\sigma_e^2 = \sigma_x^2 [1 - P_x^2 (1)] \quad ----- (2)$$

If the distribution of X is N (μ_x, σ_x^2) then the distribution of is N (O, σ_ϵ^2). If t is N(0,1), then $t\sigma_\epsilon$ or $t \sigma_x \sqrt{1-P_x^2 (1)}$ is N (O, σ_ϵ^2). Thus a model for generating X's that are N (μ_x, σ_x^2) and follow the 1st order Markov model is

$$X_{i+1} = \mu_x + P_x(1) (X_i - \mu_x) + t_{i+1}\sigma_x\sqrt{1-P_x^2(1)} \quad ---- (3)$$

3.3 Thomas-Fiering model

Thomas and Fiering (T1, 1962) have developed a recursive equation to model the monthly flows. This follows a lag-one Markov generation scheme, given by:

$$X_{i+1} = X_{j+1} + b_j(X_i - X_j) + t_i \sigma_{j+1} (1-r_j^2)^{\frac{1}{2}} \quad ---- (4)$$

where,

- X_i - discharge during the i^{th} month
- X_{i+1} - discharge during the (i+1)st month
- X_j, X_{j+1} - mean monthly discharge during j^{th} and (j+1)st month respectively, within a repetitive annual cycle of 12 months.

- b_j - the regression coefficient for estimating flow in the (j+1)st from the j^{th} month

t_i - a random normal variate with N (0, 1)

σ_{j+i} - is the standard deviation of flows in the (j+1)st month

r_j - the correlation coefficicent between the flows of the j^{th} and (j+1)th month

The flow chart of this model is given in Fig.2.

3.4 Two parameter model

The generation of sequence of monthly flows given by two-parameter Thomas-Fiering scheme is

$$Y_i = \mu_r + b_r \ (Y_{i-1} - \mu_r) + \sigma_r (1-P_r^2)^{\frac{1}{2}} \ \epsilon_i \qquad ----- \quad (5)$$

where, μ_r, σ_r, and P_r are the mean, standard deviation and lag 1 correlation coefficient of the transformed y distribution and ϵ_i is a random variate from N(0, 1). For example, if the monthly flows follow a log-normal distribution, then, μ_r, σ_r and P_r are obtained for the sequence of natural logarithms of the observed flows ($Y = \log_e X$) and $_i$ is drawn from a normal distribution having mean zero and unit variance. The transformed parameters are used in eg.5 to obtain a generated sequence. This sequence is to be inverse transformed (X = antilog Y) to obtain the generated flows. By this, the statistics of the historical flows may not be preserved well in the generated flows. To overcome this difficulty, Matalas (M1) suggested certain relationships between the statistics calculated from the historical data (μ_x, σ_x, P_x), and the statistics of the transformed sequence (μ_r, σ_r, P_r), which are given by

$$\mu_x = \exp\,[0.5\,\sigma_r^2 + \mu_r] \qquad \text{----- (6)}$$

$$\sigma_x^2 = \exp\,[2(\sigma_r^2+\mu_r)]-\exp\,[\sigma_r^2+2\,\mu_r] \qquad \text{----- (7)}$$

$$\rho_x = [\exp(\sigma_r^2\,P_r)-1]/[\exp\,(\sigma_r^2)-1] \qquad \text{----- (8)}$$

The generation scheme used in this study for the case of lognormal two parameter distribution is given in Fig. 3

3.5 Three parameter model

If the resemblance between the synthetic flows and historical flows is to be extended to the skewness also, it is preferable to go for the 3-parameter distribution of either lognormal or gamma. In case of gamma variates, the transformation of the same to normal variates could be done by the Wilson-Hilferty transformation if $|\gamma| < 3$ and by a modified transformation if $\gamma < 3$. However, this study is limited to using only the 3-parameter lognormal distribution and not the gamma distribution.

If the observed sequence (X) is assumed to follow the three-parameter, log normal distribution,

$$Y = \log (x-a) \qquad \text{----- (9)}$$

$$\mu_x = a + \exp [(\sigma_r^2/2) + \mu_r] \qquad \text{----- (10)}$$

in which the third parameter, 'a', provides the extra degree of freedom needed to fit the lognormal model to the first three moments of the historical record. The observed sequence is shifted by the amount a, and the resulting sequence is then treated by the two-parameter log normal algorithm for generating a synthetic sequence.

Further, an additional equation is added, which in reproduce the coefficient of skewness of the observed sequence, γ_x.

$$\gamma_x = \frac{[\exp (3\sigma_r^2)-3 \exp (\sigma_r^2) + 2]}{[\exp (\sigma_r^2)-1]^{3/2}} \qquad \text{----- (11)}$$

The procedure for generating synthetic events that will resemble the historic events in terms of μ_x, σ_x, γ_x and $r_x(1)$ is as follows. The values of μ_x, σ_x, γ_x and r_x (1) are set equal to the right handside of equation 6, 7, 8 and 12 where upon the solutions of these equations give the values of a, μ_r, σ_r, and γ_r (1).

A direct solution is proposed by Randal (R1) to solve the system of equations 6, 7, 8 and 11 by making the substitution

$$\phi = \exp(\sigma_r^2) \qquad \text{-----} \ (12)$$

Equation 11 becomes

$$\gamma_x = \frac{\phi^3-30+2}{(\phi-1)^{3/2}} = (\phi-1)^{1/2}\,(\phi+2) \qquad \text{-----} \ (13)$$

where $\phi \neq 1$.

From the equation 13, it is seen that ϕ is always greater than or equal to 1, and the right-hand side is always greater than zero. The last equation also shows that the 3-parameter log-normal transformation is applicable to distributions with positive coefficient of skewness. So for $\gamma_x > 0$. eg. 13 has one real root only.

$$\phi = [(1+\gamma_x^2/2)+(\gamma_x^2+\gamma_x^4/4)^{1/2}]^{1/3} + [(1+\gamma_x^2/2)-(\gamma_x^2+\gamma_x^4/4)^{1/2}]-1$$

$$\text{------} \ (14)$$

After finding out the value of ϕ from a given value of $_x$, then the three parameters σ_r, μ_r and a can be computed from equations 11, 7 and 10.

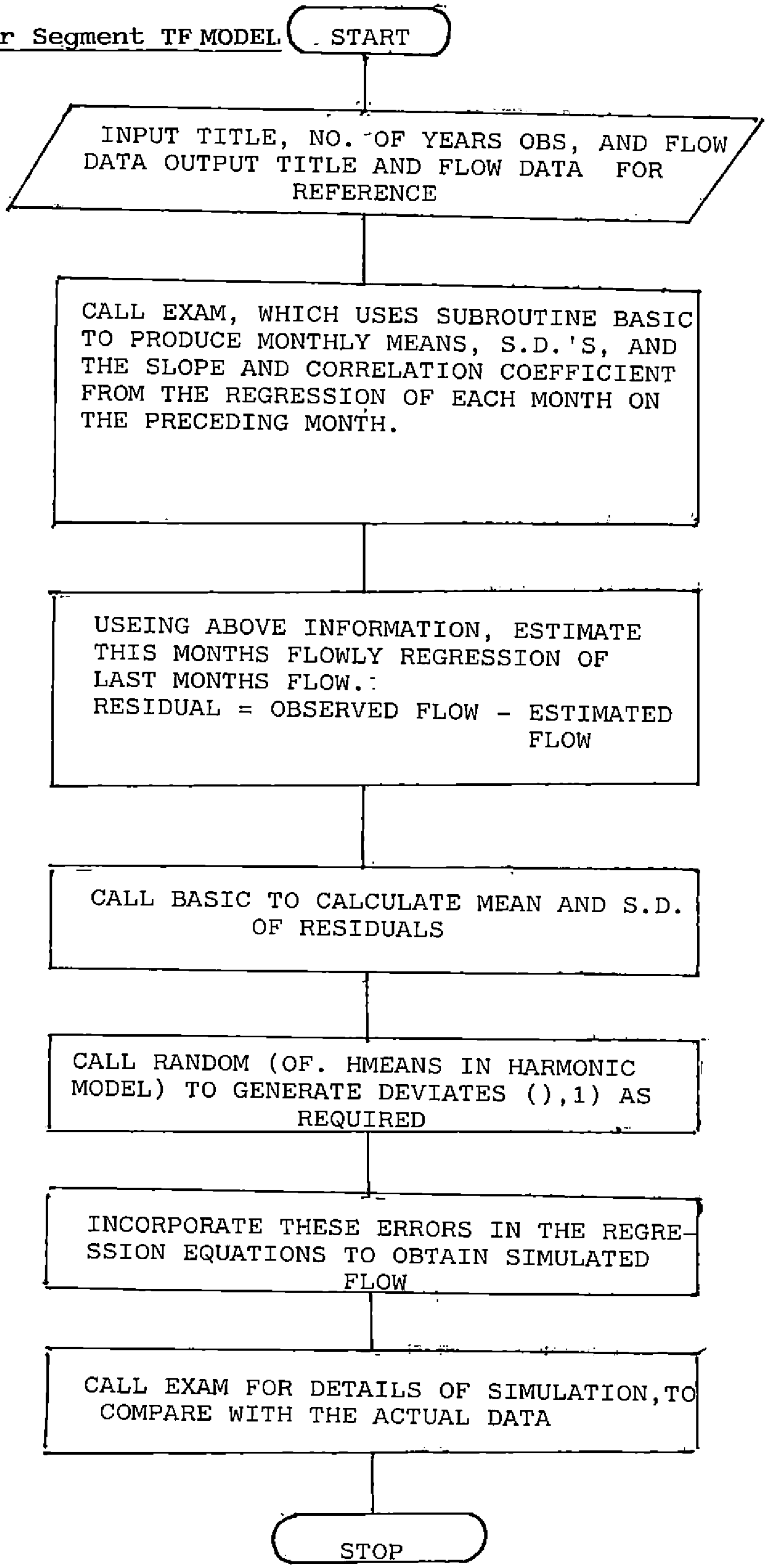
With the values for a, μ_r, γ_r, $\gamma_r(1)$, eq. 5 may be used to generate a sequence of y's. Finally to the antilog of each value of y, the value of a is added to obtain the synthetic sequence of flows that will resemble the historic sequences in terms of μ_x, σ_x, γ_x and $r_x(1)$.

It is observed that while the results using the 2-parameter log-normal distribution do not produce negative flows the 3-parameter distribution may produce negative flows if 'a' is negative (R2). In such a case, after generation, the negative flows are to be set to zero and then the properties are computed. The generation scheme used in this study for the case of log normal three parameter distribution is given in Fig.4.

3.6 Generation of monthly streamflows

Data generation procedure is used to provide equally likely flow sequences to historical one in capacity yield analysis. The Thomas Fiering model is a well known model for hydrologic time series modelling of monthly flows based on nonstationarity of time series. From the previous studies conducted for Chaliyar basin, it is seen that a univariate first order Thomas Fiering model would be able to adequately represent monthly means for this basin (Seth et al., 1985).

Master Segment TF MODEL



Subroutines

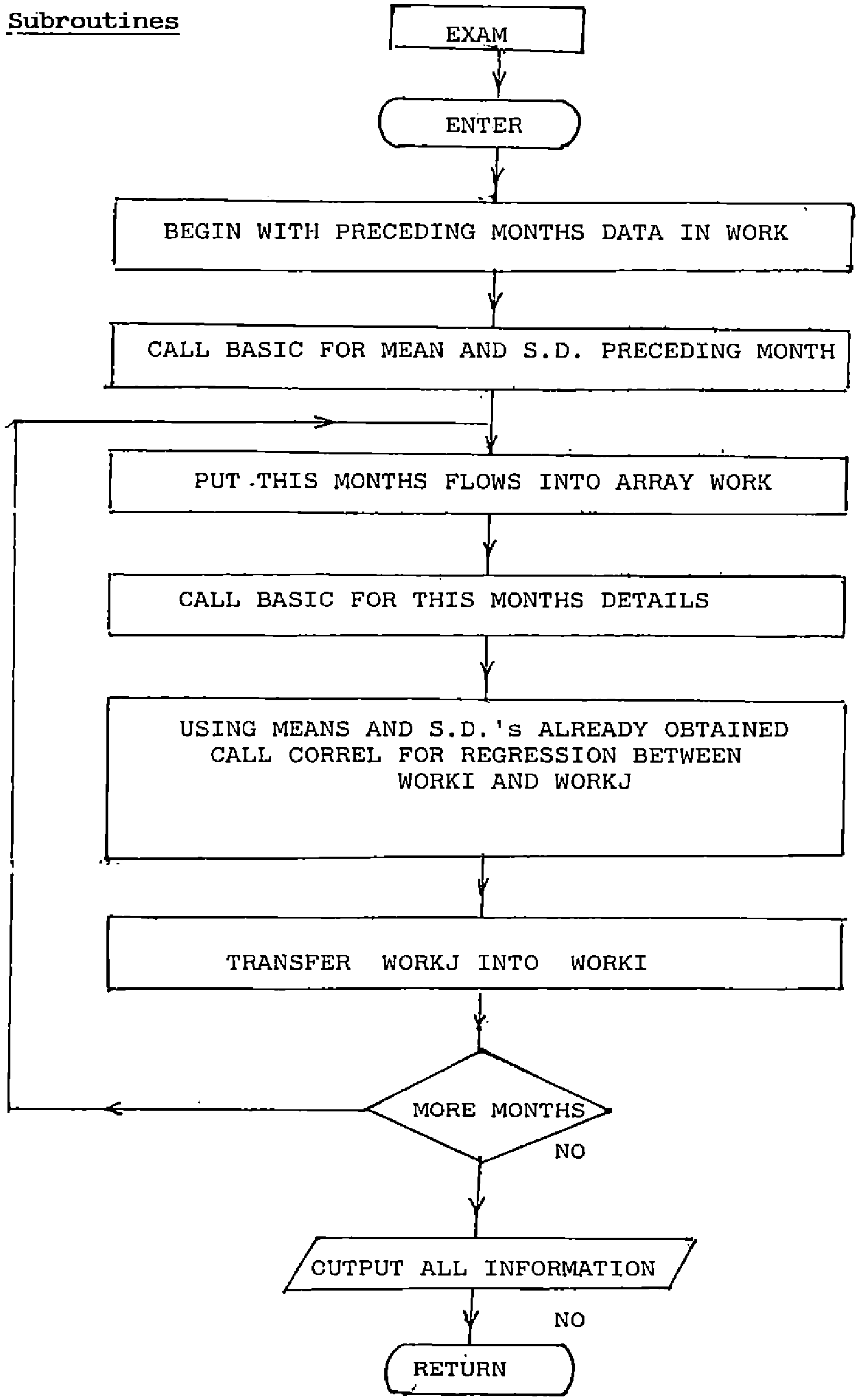
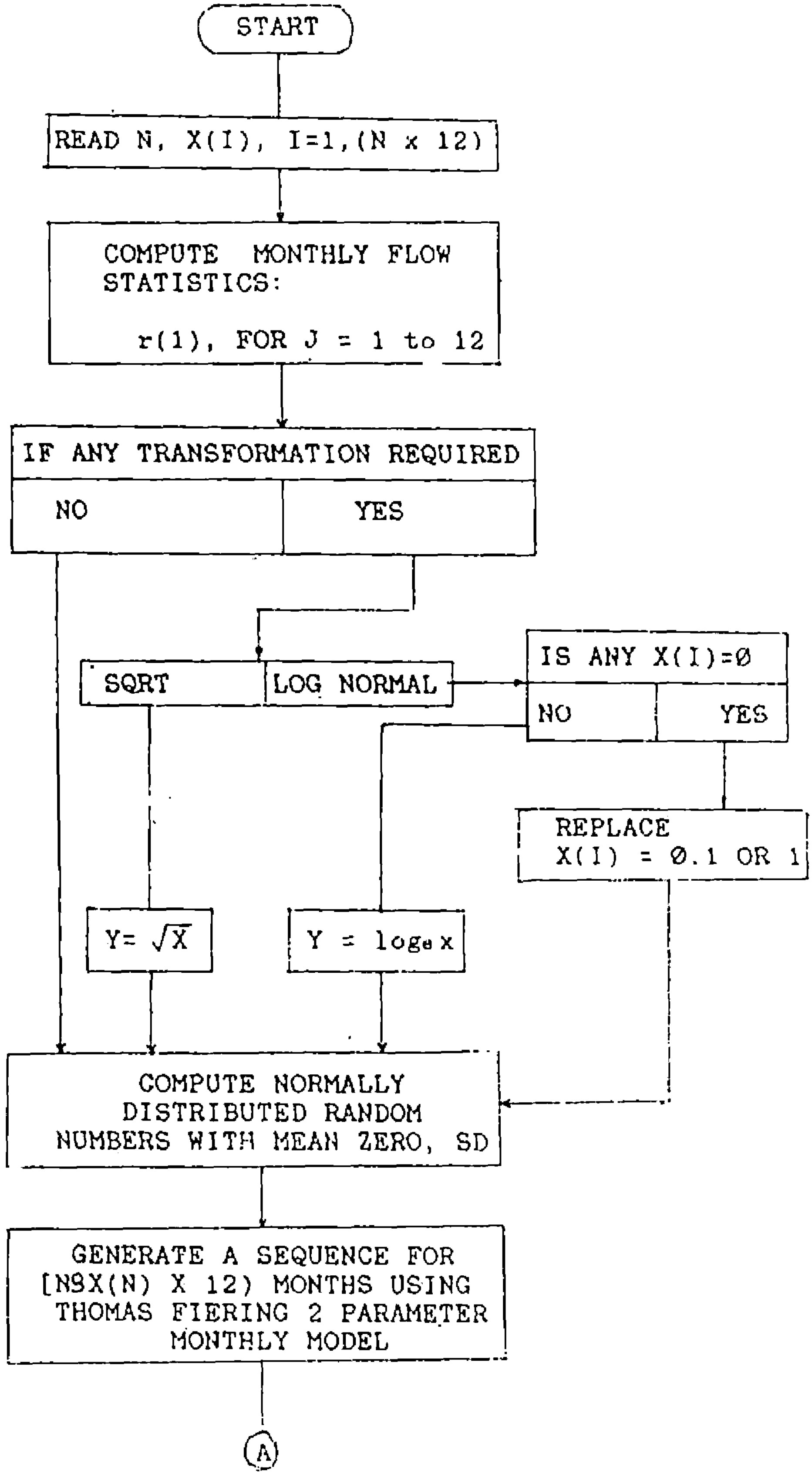


Fig.2 FLOW CHART OF THOMAS FIERING MODEL


START
READ N, X(I), I=1,(N x 12)
COMPUTE MONTHLY FLOW STATISTICS:
r(1), FOR J = 1 to 12
IF ANY TRANSFORMATION REQUIRED
NO
YES
SQRT
LOG NORMAL
IS ANY X(I)=Ø
NO
YES
REPLACE X(I) = Ø.1 OR 1
Y= √X
Y = loge x
COMPUTE NORMALLY DISTRIBUTED RANDOM NUMBERS WITH MEAN ZERO, SD
GENERATE A SEQUENCE FOR [NSX(N) X 12) MONTHS USING THOMAS FIERING 2 PARAMETER MONTHLY MODEL
A

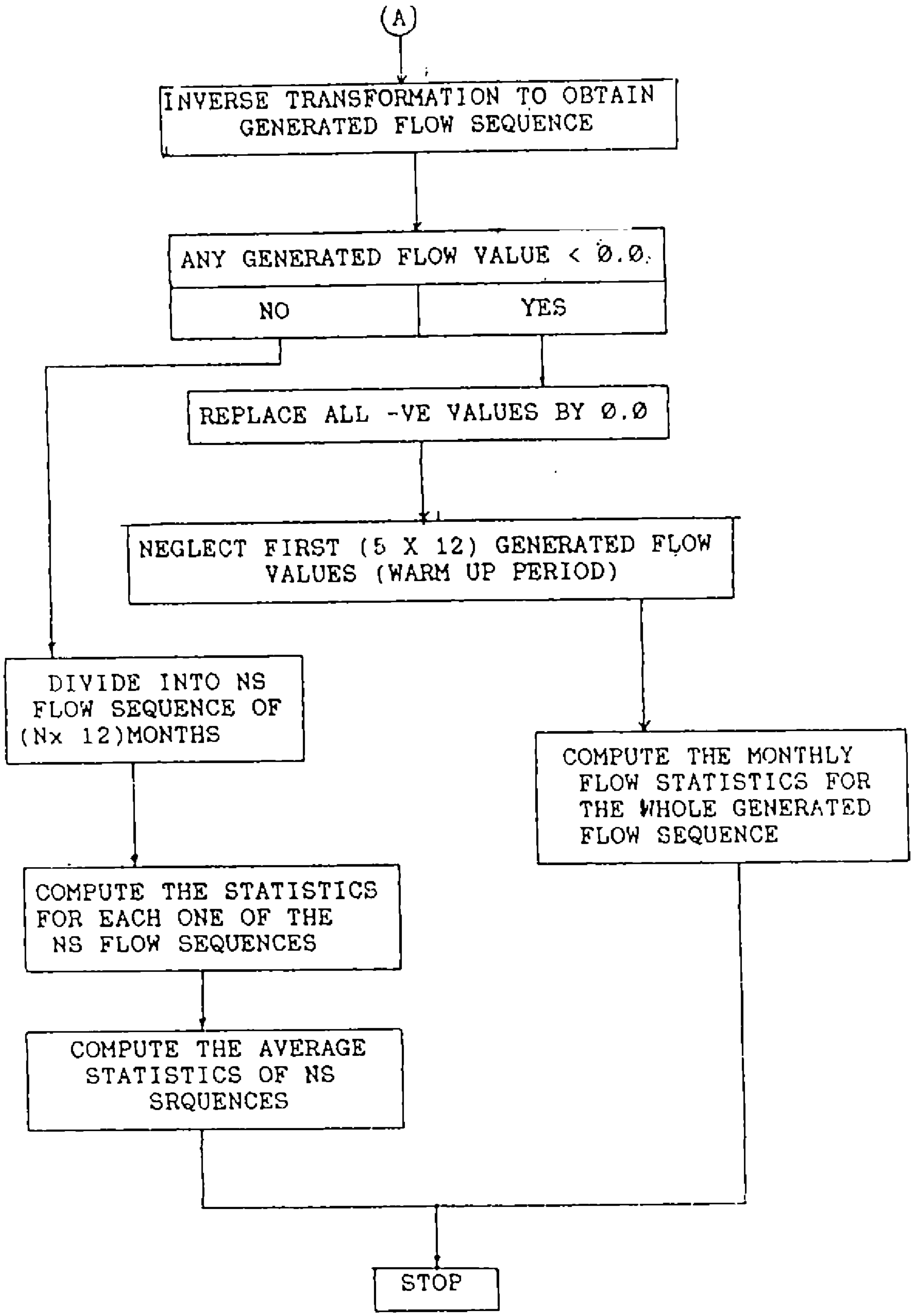
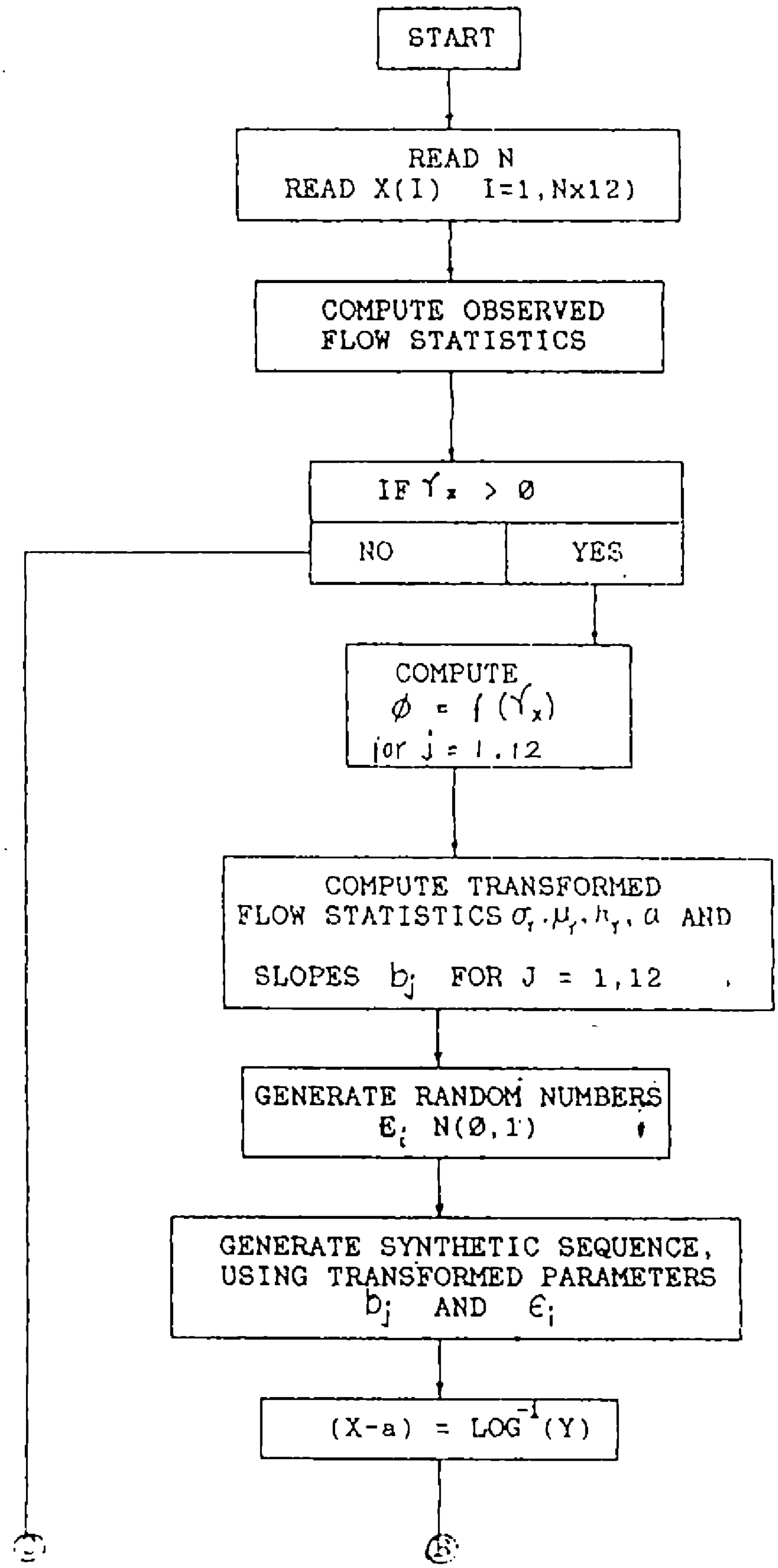


FIG.3 LOGIC OF 2 PARAMETER MONTHLY MODEL


START
READ N
READ X(I) I=1,Nx12)
COMPUTE OBSERVED FLOW STATISTICS
IF γ_x > 0
NO
YES
COMPUTE
$\phi = f(\gamma_x)$
for j = 1,12
COMPUTE TRANSFORMED FLOW STATISTICS σ_y, μ_y, h_y, a AND
SLOPES b_j FOR J = 1,12
GENERATE RANDOM NUMBERS
ϵ_i N(0,1)
GENERATE SYNTHETIC SEQUENCE, USING TRANSFORMED PARAMETERS
b_j AND ϵ_i
(X-a) = LOG^{-1}(Y)
B

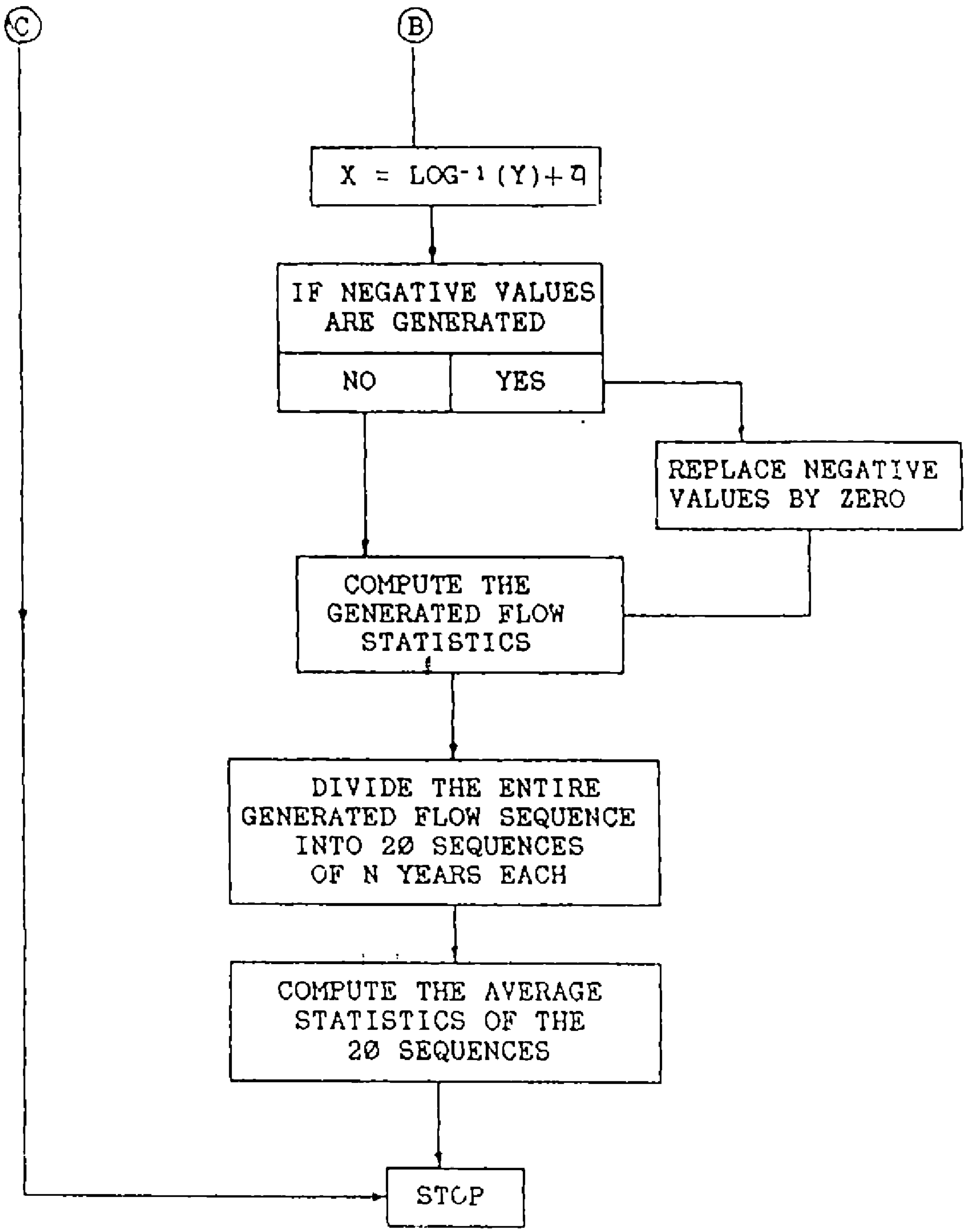


FIG. 4 LOGIC OF THOMAS FIERING MONTHLY MODEL: 3 PARAMETER LOG NORMAL DISTRIBUTION

The program listing for the Thomas-Fiering model is given in Appendix. To use the model to generate monthly flows at a site, thirty six parameters, i.e., monthly means, standard deviation and lag one serial correlations are required. These are obtained from the analysis of monthly historical flows. The statistical characteristics of monthly flows are computed for all the three sites. Though in some months, the monthly flows are non-normal, in general normality assumption could be reasonable as far as application of Thomas-Fiering model is concerned.

Monthly streamflows for the three locations and their statistical parameters are given in Tables 1,2&3. The mean, standard deviation and correlation with previous months have been calculated using the following equations.

$$X_j = \frac{\sum_{i=1}^{N} X_{i,j}}{N}$$

$$S_j = \left[\frac{\sum_{i=1}^{N} (X_{i,j} - X_j)^2}{N-1} \right]^{0.5}$$

$$\gamma_j = \frac{\sum_{i=1}^{N} (X_{i+1} - \bar{X}_{j+1})(X_i - \bar{X}_j)}{\left[\sum_{i=1}^{N} (X_{i,j} - X_j)^2\right]^{0.5} \left[\sum_{i=1}^{N} (X_{i+1} - X_{j+1})^2\right]^{0.5}}$$

The computation for generation of data has been performed in Siemens 7580 E Computer System of I.I.T., Madras.

3.7 Model verification

Before a data generation model is used in generation of data, it is necessary to check that it satisfactorily reproduces the main statistical characteristics defining the streamflow process. For this purpose, the historic data is used to form the regression equations and then data was generated for required number of years.

Twenty years of data at the three locations for the period 1964-83 has been taken in the present study for the generation of streamflows. Various graphs showing the mean monthly inflows, correlation of inflows to the previous months flow and standard deviation of historic and generated flows were drawn. The comparison of historic and generated data is effected from these plots.

3.8 Statistical analysis

The consistency of the monthly streamflow data has been checked with normal distribution. For all the three locations, the normal distribution test were performed and the agreement of historic and generated data was checked.

The frequency analysis of the monthly streamflow data at all the tree sites has been done by Weibull's method. Probability P = m/N+1 where m is the rank of streamflow values arranged in descending order, N is the length of the inflow record and return period T = 1/P. Using these values probability curves have been drawn for all the twelve months.

The statistical analysis of annual flows has been performed by comparing the mean, standard deviation and coefficient of correlation of both historic and generated data.

Results and Discussion

RESULTS AND DISCUSSION

The results of the simulation model verification and the statistical analysis of the generated data are discussed in this Chapter.

4.1 Model verification

Twenty years of data at the three locations for the period 1964-83 has been collected from the river gauge stations for the generation of streamflow. The data is presented in Tables 1, 2 and 3.

Figure 5 shows the mean monthly inflows to the three locations. Fig.6 ,7 &8 gives the correlation of inflows to the previous months flows at all three locations. The standard deviations of historic and generated flows were compared and they are shown in figures 22, 23 & 24. There is a good agreement between the standard deviation curves of both historic and generated data for almost all the months.

The data is generated for hundred years using the Thomas Fiering Model for the three locations. This generated data is presented in Tables 5, 6 & 7.

Table 1. Monthly streamflows at location one in Mm^3 from 1964-1983

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6.1	4.5	5.2	4.0	5.9	10.9	41.8	68.2	15.4	12.5	13.3	7.2
0.9	0.1	2.2	1.6	1.5	8.1	36.7	33.8	20.6	13.8	8.7	7.9
2.3	1.8	1.7	1.0	1.9	4.3	20.6	15.9	17.0	23.4	9.5	5.5
3.5	1.5	1.9	2.0	8.7	19.2	16.1	14.3	4.1	7.0	1.7	6.1
3.4	3.3	4.3	3.9	4.0	9.1	37.3	42.5	20.8	11.6	9.0	7.0
4.0	2.9	2.2	2.4	2.9	7.3	54.9	40.9	25.1	44.0	31.0	22.1
20.2	13.4	7.3	13.4	27.0	31.2	79.5	101.4	59.5	53.5	18.9	10.1
8.9	7.1	7.0	6.7	8.3	23.5	25.4	24.3	19.1	36.4	24.9	23.6
18.9	15.4	14.0	0.7	2.8	4.2	15.8	11.0	3.9	10.9	4.9	2.7
1.8	1.1	1.0	1.0	1.2	19.2	49.6	55.6	21.5	8.5	5.4	3.9
1.2	0.3	0.1	0.2	1.9	1.8	45.4	66.4	37.4	26.5	12.3	13.4
12.9	10.8	10.0	7.3	11.5	35.8	47.8	34.8	43.6	36.0	24.4	13.9
8.4	6.0	2.9	4.7	1.9	4.4	23.9	50.9	38.5	14.4	18.3	9.8

Contd.

Table 1 (Contd.)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8.2	8.8	9.1	6.8	10.6	15.8	53.5	43.3	33.7	34.7	25.2	11.6
12.1	8.3	6.0	4.8	8.0	22.4	66.2	103.6	44.0	23.9	74.4	16.1
8.9	5.1	4.0	2.7	3.4	21.1	60.8	130.6	25.9	21.7	22.0	10.0
2.5	1.4	0.7	1.1	2.8	50.0	108.6	60.8	33.5	35.0	27.4	5.7
1.3	0.4	0.8	0.4	1.5	20.1	28.0	80.7	32.8	18.3	7.8	4.3
5.5	3.1	1.2	1.0	5.3	11.9	23.8	48.9	20.0	13.0	24.0	6.7
2.6	1.7	0.8	0.3	1.3	6.4	27.4	49.3	65.3	35.0	19.6	1.7
Means											
8.1	5.8	4.6	3.6	6.3	19.1	46.8	66.6	34.2	26.3	22.1	10.3
Standard deviations											
6.3	4.9	4.3	3.8	6.9	13.5	25.9	32.8	16.2	12.7	16.8	5.8
Slopes											
-0.02	1.5	0.6	0.2	0.5	0.3	0.2	0.1	0.7	0.8	0.6	0.9
Correlations with previous month											
-0.01	0.8	0.5	0.4	0.6	0.2	0.5	0.1	0.9	0.9	0.5	0.9

Table 2. Monthly streamflows at location two in Mm^3 from 1964 to 1983

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.5	1.0	0.8	0.7	1.1	33.6	145.9	274.7	66.2	53.0	36.2	4.4
2.9	0.6	0.0	1.6	5.8	56.9	177.8	73.9	40.8	37.9	24.8	0.1
7.7	5.5	4.2	4.5	11.4	40.4	126.6	64.8	53.6	90.6	36.7	20.6
6.8	2.2	0.4	1.2	10.6	66.0	244.0	125.3	29.8	30.7	21.7	8.2
4.2	2.2	3.9	5.7	13.0	41.0	175.0	100.6	42.2	45.0	21.0	6.7
3.2	2.7	2.7	19.3	20.0	2.3	214.6	77.0	51.2	57.4	351.2	28.6
6.3	1.8	0.5	3.1	28.7	59.5	234.2	257.3	94.5	102.7	40.4	7.7
23.0	17.1	15.8	14.3	49.4	274.7	218.9	179.1	106.6	132.4	56.2	39.0
21.6	17.8	17.1	16.7	30.3	39.3	142.8	61.3	40.6	56.8	35.6	30.2
32.1	23.4	22.3	21.8	22.6	108.6	182.4	144.6	61.8	58.5	48.8	36.9
13.4	7.5	6.4	14.8	24.8	28.9	482.1	408. 4	148.7	106.0	33.9	20.1
16.8	14.1	15.4	11.8	19.0	194.9	144.7	322.6	133.8	102.1	81.3	19.7
13.7	10.4	9.1	9.5	9.6	15.7	145.4	174.2	90.4	36.0	53.6	20.3

Contd.

Table 2 (Contd.)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.8	1.3	1.1	1.1	14.2	122.2	262.8	97.2	99.9	91.9	67.0	18.6
8.0	2.7	2.0	2.1	6.7	121.4	253.7	255.9	62.4	36.4	124.0	14.7
6.9	2.6	1.9	1.0	6.3	66.5	191.0	336.1	40.1	27.5	27.8	12.3
5.0	3.4	1.6	2.3	6.4	217.5	381.5	132.0	50.1	54.6	26.4	13.1
8.8	4.4	2.5	2.7	5.8	229.7	247.4	416.9	191.2	86.8	42.3	16.8
2.9	1.4	0.0	0.0	2.6	62.2	233.1	221.8	19.1	12.0	15.8	2.9
5.3	2.1	1.9	1.5	1.7	130.9	244.1	247.7	145.3	61.4	34.8	17.1
Means											
11.89	7.90	7.35	9.07	19.06	84.37	215.65	186.03	75.39	69.58	71.37	20.28
Standard deviations											
3.36	7.36	7.32	7.32	11.71	75.18	88.67	112.15	37.20	33.87	85.03	10.31
Slopes											
0.35	0.84	0.99	0.76	0.88	3.20	-0.08	0.68	0.20	0.67	-0.18	0.03
Correlation with previous month											
0.41	0.98	0.99	0.76	0.55	0.50	-0.07	0.54	0.60	0.74	-0.07	0.27

Table 3. Monthly streamflows at location three in Mm^3 from 1964 to 1983

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24.9	12.8	9.6	3.1	26.5	99.9	688.6	368.6	327.7	534.6	211.2	73.3
46.9	18.2	7.4	5.4	38.2	285.4	1373.4	927.5	230.2	207.4	123.4	817.9
51.2	26.5	20.7	27.3	46.9	313.6	1770.8	1018.7	423.3	267.8	183.3	92.9
50.3	29.8	17.6	20.5	44.3	327.5	274.9	970.4	548.5	376.2	213.7	152.0
77.9	52.6	43.2	52.9	141.6	80.7	1559.1	1667.5	464.4	585.5	218.9	101.8
41.7	24.6	18.3	19.5	83.4	1069.2	813.1	636.8	386.1	427.9	148.5	91.5
44.2	27.3	17.3	15.4	85.5	163.4	969.0	404.9	164.9	304.5	171.4	107.3
46.5	22.2	14.4	13.0	19.6	447.4	887.9	711.2	230.7	155.7	122.8	61.1
33.0	16.5	9.2	13.9	28.8	83.0	1251.3	1130.5	537.9	367.0	109.9	59.9
25.2	18.0	19.3	13.9	21.0	757.8	646.0	1157.5	541.5	401.1	309.5	54.8
51.6	31.5	21.6	28.6	15.4	40.8	609.8	743.8	507.4	162.7	234.2	83.0
43.1	25.5	19.0	19.5	72.5	562.2	1131.8	565.1	525.3	546.9	346.6	141.7
33.4	11.5	5.9	4.2	11.5	572.5	1147.6	1316.1	368.6	149.1	465.5	62.1

Contd.

Table 3 (Contd.)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
33.4	13.3	6.8	5.5	35.7	363.5	1052.3	1526.9	243.1	150.5	170.8	63.5
75.9	44.0	32.3	39.7	69.5	487.0	584.1	962.9	502.7	648.9	279.6	89.8
28.4	17.4	10.2	6.7	24.8	60.8	196.4	604.3	216.1	171.5	315.8	118.1
52.3	30.7	23.6	28.6	26.0	153.2	1062.6	934.0	461.9	498.9	227.8	273.7
31.3	21.5	16.2	16.4	49.5	94.0	1498.0	1415.8	457.7	222.3	271.5	27.8
38.6	20.4	13.0	15.8	17.0	189.5	704.7	678.1	210.6	266.9	219.5	196.4
26.2	14.5	11.7	7.2	29.1	212.4	732.5	863.8	351.3	206.1	315.8	36.7
Means											
43.1	23.6	16.5	17.3	47.9	366.5	1012.5	938.9	392.8	331.2	216.5	140.1
Standard deviations											
13.5	10.6	9.5	13.0	36.2	292.6	401.7	396.4	134.8	155.7	98.9	197.4
Slopes											
0.02	0.72	0.85	1.32	1.96	-0.13	-0.256	0.382	0.074	0.510	0.046	-0.52
Correlation with previous month											
0.23	0.92	0.95	0.96	0.71	-0.02	-0.187	0.387	0.217	0.441	0.073	-0.26

Table 4 Normal distribution test for inflows at location two

Months	Mean inflow $\bar{X}$	Standard deviation	Percentage values in the range $\bar{X} \pm$	Percentage values in the ranges $\bar{X} \pm 25$	Percentage values in the range $\bar{X} \pm 30$
January	11.96	8.63	71.43	92.86	100.00
February	7.90	7.36	78.57	92.86	100.00
March	7.35	7.32	71.43	92.86	100.00
April	9.07	7.33	57.14	100.00	100.00
May	19.06	11.71	78.57	92.86	100.00
June	84.37	75.18	78.57	92.86	100.00
July	215.65	88.67	92.86	92.86	100.00
August	186.03	112.15	64.29	100.00	100.00
September	75.39	37.20	78.57	100.00	100.00
October	69.52	33.87	71.43	100.00	100.00
November	71.37	85.03	82.86	100.00	100.00
December	20.28	10.31	64.29	100.00	100.00

Table 5 Generated flows of location one for 100 years (No transformation)

Jan	Feb	Mar	Apr	May	Jun
10.059	6.437	6.112	6.451	14.876	31.279
2.221	0.000	0.000	0.000	0.000	19.744
3.035	2.188	2.081	3.862	8.890	20.736
0.000	1.233	0.763	0.000	0.000	0.000
13.483	10.083	12.623	10.888	16.083	32.419
4.309	2.082	0.801	3.013	5.260	30.255
12.101	8.939	6.402	3.171	5.972	14.171
5.201	4.292	1.787	2.640	3.729	15.523
1.377	0.975	0.000	0.000	0.000	0.000
12.371	9.491	7.650	7.350	15.218	7.898
10.795	9.160	5.740	1.220	0.000	27.542
9.218	6.548	1.365	3.704	5.265	11.966
3.924	3.770	4.450	4.068	4.359	23.109
10.147	7.568	4.745	2.124	1.729	1.793
6.212	2.633	1.951	2.892	3.658	23.888
7.722	7.586	5.434	5.310	6.931	15.809
9.077	7.619	7.350	6.316	18.431	25.133
8.413	5.256	2.289	1.724	2.403	0.000
5.834	3.708	2.554	0.000	0.000	12.412
4.468	3.599	1.786	0.144	0.432	2.257
10.870	8.382	5.956	0.000	0.000	7.846
11.288	7.114	8.723	5.768	7.435	20.558

Contd.

Jul	Aug	Sep	Oct	Nov	Dec
66.838	129.289	43.470	29.000	25.132	9.795
53.326	30.581	37.666	25.356	9.206	7.204
68.849	85.926	40.422	34.071	30.244	5.208
8.109	59.083	10.751	7 200	28.559	19.228
38.760	28.635	58.201	28.843	18.497	5.772
91.477	101.425	21.548	20.365	32.468	15.119
50.432	70.236	43.094	17.478	26.403	7.551
56.310	84.570	47.514	21.023	0.986	5.093
20.681	19.423	20.435	16.547	38.687	14.689
38.408	50.138	24.349	22.598	38.912	15.742
34.092	19.926	14.247	22.027	16.893	12.458
1.380	61.591	19.325	9.368	52.732	9.239
38.170	32.737	45.447	38.178	26.144	12.220
33.421	46.694	0.000	19.636	15.136	13.051
10.616	16.363	22.182	28.892	56.973	14.622
44.213	78.862	24.341	19.100	10.297	11.968
43.211	17.135	0.481	7.247	35.455	11.693
13.320	53.698	17.743	29.283	17.942	11.445
49.236	46.904	27.850	21.556	31.466	6.388
9.849	38.681	16.510	20.010	24.023	13.531
57.188	51.810	51.439	36.659	50.236	16.469
40.417	53.178	6.918	1.896	0.000	0.985

Contd.

Table 5 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
0.000	0.000	0.000	0.000	0.000	7.609
6.298	5.391	5.058	1.891	4.195	4.055
4.851	5.125	2.978	2.920	3.392	3.972
0.000	0.000	0.000	2.418	3.684	0.977
4.112	3.703	4.268	1.344	1.485	17.977
14.995	10.696	8.471	5.793	8.954	28.473
1.322	2.132	2.357	0.058	2.587	10.888
11.386	10.154	8.068	7.566	8.048	23.944
0.000	0.912	3.877	0.942	1.658	6.109
14.686	11.845	8.101	2.856	0.000	10.496
3.521	2.335	2.753	8.260	15.170	38.617
17.078	13.639	9.639	0.000	0.000	5.050
16.169	11.636	7.880	5.436	7.377	0.000
9.305	6.187	5.332	3.318	3.714	27.197
7.876	5.477	5.994	4.507	4.928	9.973
14.413	12.095	11.202	4.512	7.648	21.196
3.646	1.341	1.391	3.464	3.701	24.135
7.309	5.766	4.479	4.853	8.927	25.127
0.000	0.000	0.000	0.000	0.000	13.051
0.000	0.000	0.000	0.000	0.000	11.360
0.000	0.767	1.816	4.438	7.199	10.224
2. 637	1.271	3.170	2.564	12.898	29.880

Contd.

Table 5 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
44.221	67.142	54.448	36.662	48.175	7.380
15.635	16.912	20.714	29.750	22.072	10.530
15.360	72.442	48.362	30.731	21.098	0.000
23.833	63.632	44.406	34.740	20.256	2.548
80.409	50.711	17.477	23.454	19.983	15.738
45.459	38.147	35.147	21.865	27.832	5.156
70.411	104.897	31.816	15.496	8.400	13.239
86.449	87.980	38.927	13.760	25.007	5.139
32.133	66.533	38.240	21.274	41.575	15.527
35.939	64.849	14.606	16.335	13.331	7.765
94.061	164.618	67.828	40.536	39.822	22.828
24.373	31.984	29.400	13.838	27.849	20.528
24.054	41.694	20.733	22.952	30.385	15.213
48.004	26.509	31.914	36.538	9.208	7.965
11.097	24.811	8.344	11.187	23.557	16.183
59.784	77.949	24.957	24.314	1.851	7.666
22.094	64.159	6.850	5.495	0.000	9.652
50.334	13.213	17.335	19.717	23.163	4.706
0.000	14.004	10.790	15.934	18.383	2.804
55.925	80.380	23.813	8.800	0.000	1.912
49.181	85.632	18.827	24.926	29.064	9.604
51.383	68.465	43.831	29.109	17.347	0.000

Contd.

Table 5 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
0.000	0.000	0.000	0.000	0.000	7.140
13.023	9.840	9.380	7.824	15.630	37.433
11.036	7.895	9.618	7.007	11.631	8.743
2.758	1.948	2.142	7.441	17.900	15.406
3.370	3.351	2.221	0.211	0.000	21.428
10.470	7.080	4.227	0.551	0.253	15.141
13.916	10.509	8.888	2.115	0.690	0.000
10.223	8.164	6.526	5.330	10.997	29.519
0.636	2.475	3.727	2.077	5.914	2.636
16.645	13.183	10.900	8.863	13.952	17.614
10.704	8.671	7.342	0.189	0.338	8.214
13.952	11.850	7.861	9.624	14.808	31.940
3.272	1.079	2.840	3.989	5.805	11.229
13.057	8.271	7.545	6.961	18.105	14.123
7.076	4.130	2.723	4.178	6.235	5.723
5.728	3.060	3.280	6.250	15.100	14.379
7.145	6.630	4.558	6.733	13.183	11.167
0.286	1.392	0.389	4.573	1.467	21.091
12.471	9.683	8.394	0.000	0.000	9.855
0.000	0.000	1.229	3.192	2.920	0.000
7.447	6.704	4.091	0.907	6.027	8.958
11.123	6.972	6.876	5.554	17.850	26.937

Contd.

Table 5 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
42.314	78.633	54.043	47.838	41.838	21.216
85.128	54.754	7.885	31.608	26.102	14.094
50.696	49.589	34.808	34.129	40.997	8.842
40.014	40.539	23.958	22.333	36.837	10.044
15.536	31.849	13.939	25.002	21.917	21.059
58.193	46.595	8.579	34.303	48.532	17.667
0.000	0.000	0.000	24.215	20.933	11.658
37.925	0.000	5.161	0.000	2.110	6.247
4.059	27.375	32.740	47.700	51.068	18.784
47.309	97.005	42.186	19.996	12.423	13.839
25.445	15.950	15.268	35.154	49.541	17.995
48.006	38.410	28.709	36.023	23.752	5.727
46.541	54.759	29.881	27.494	40.174	16.813
51.618	62.171	23.220	26.924	26.268	12.988
41.644	73.951	33.795	34.725	19.143	12.360
49.829	47.487	47.448	32.207	21.756	8.091
52.247	55.409	25.052	9.098	29.096	6.659
67.279	79.071	61.764	58.591	40.0687	16.357
53.450	58.572	20.862	22.521	21.531	6.377
0.000	8.356	38.976	19.976	16.273	14.863
4.046	27.392	23.909	29.726	11.595	12.552
69.455	62.638	16.753	4.175	14.033	8.011

Contd.

Table 5 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
6.184	2.730	3.211	1.866	5.593	21.577
8.122	6.145	2.742	2.156	5.374	4.651
2.238	0.000	0.456	1.211	0.000	0.000
1.966	1.130	0.000	0.000	0.000	0.000
0.000	0.000	0.0000	0.000	0.000	0.000
15.866	11.605	7.275	6.896	9.140	45.760
4.765	3.010	4.606	2.867	1.671	22.671
2.042	0.654	2.372	6.163	6.603	0.000
5.737	4.631	2.705	6.914	6.432	22.668
1.636	0.000	0.000	0.000	2.216	13.612
13.387	10.071	5.351	4.616	4.547	26.307
0.000	0.000	0.000	0.000	0.000	27.872
18.069	12.228	9.051	7.028	10.755	23.037
12.529	11.123	11.286	12.418	21.105	23.475
10.985	6.691	6.760	6.805	14.753	23.202
15.417	10.534	6.967	2.327	5.959	23.742
5.232	2.818	4.930	2.952	6.360	26.269
10.849	7.178	7.908	5.930	9.327	28.192
8.528	5.827	6.807	6.911	13.822	34.119
9.948	7.363	4.802	0.000	0.000	20.472
4.099	3.141	0.000	0.000	0.000	17.131
11.649	9.051	8.660	5.042	5.659	13.327
11.755	10.292	6.882	4.021	9.109	15.716

Contd.

Table 5 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
51.507	51.074	58.752	46.874	26.698	9.982
39.686	83.481	21.542	3.486	0.000	6.827
19.103	0.000	4.182	32.095	12.024	4.029
8.779	37.595	26.605	21.572	6.513	2.438
37.416	12.478	17.822	3.049	24.201	18.378
103.368	113.950	60.138	21.825	42.129	7.983
56.088	91.982	38.187	39.312	18.046	4.062
0.000	50.621	10.856	22.400	29.036	8.636
82.193	111.656	58.067	30.652	9.198	4.460
33.572	72.590	56.048	46.477	19.108	15.368
38.485	13.440	23.574	10.977	4.165	0.053
37.699	61.686	63.880	31.607	41.491	25.068
42.064	69.036	46.437	43.029	21.916	16.133
41.744	4.770	26.616	41.335	36.931	11.678
72.531	84.003	53.080	20.794	37.101	17.218
50.986	74.591	38.538	34.588	15.244	10.331
28.706	33.322	53.857	52.598	31.116	16.148
88.444	97.265	38.159	26.296	24.734	7.795
44.349	47.115	13.351	12.836	13.086	12.717
39.998	76.416	21.886	22.541	52.742	6.416
28.933	57.093	29.358	6.633	20.258	17.221
12.603	57.189	52.461	25.075	13.302	16.823
52.026	66.754	7.126	26.168	0.000	6.952

Contd.

Table 5 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
4.165	4.004	4.533	1.791	4.157	16.782
12.154	7.631	7.330	6.901	16.397	36.030
0.511	1.006	0.000	1.405	2.678	20.791
9.555	7.917	6.625	4.761	7.461	12.047
0.000	0.035	0.000	4.511	13.018	39.553
0.000	0.000	0.000	0.000	0.000	0.043
15.201	10.473	9.685	7.736	12.075	11.228
0.042	0.000	0.000	1.462	2.573	22.115
9.053	7.799	6.642	5.820	7.135	22.747
4.432	5.579	3.045	2.985	1.644	14.348
4.466	3.613	1.989	1.642	5.962	7.718
Means					
7.1664	5.3633	4.4477	3.6149	6.1955	16.2151
Standard deviations					
5.1702	3.9439	3.3096	2.9244	5.6444	10.9549
Skewness co-efficient					
0.1595	0.1967	0.2920	0.4885	0.7309	0.2594
Slopes					
0.8531	0.7399	0.7581	0.5360	1.7190	0.9513
Correlations with previous month					
0.9147	0.9699	0.9034	0.6066	0.8891	0.4910

Table 5 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
76.464	82.172	23.767	24.972	1.556	12.024
54.514	109.198	41.471	55.519	46.304	5.012
59.714	110.531	47.393	40.143	9.953	9.477
12.910	39.078	28.893	22.510	10.807	5.741
71.257	60.237	28.480	37.240	9.050	3.358
18.055	56.411	35.365	35.055	44.535	19.830
35.292	15.884	0.000	2.549	0.000	6.410
65.315	56.094	37.429	14.023	19.424	14.048
42.383	35.733	20.328	7.377	1.091	9.386
1.618	0.000	13.890	20.742	25.262	9.542
60.278	87.495	27.540	43.058	19.619	13.252
Means					
42.0324	55.3094	29.5272	25.2358	23.5798	10.7857
Standard deviations					
23.6905	31.1307	16.5585	12.5033	14.4223	5.5404
Skewness co-efficient					
0.1629	0.4588	0.2817	0.2059	0.2693	0.1707
Slopes					
1.3402	0.8368	0.2725	0.4263	0.4433	0.1733
Correlations with previous month					
0.6198	0.6368	0.5123	0.5645	0.3843	0.4511

Table 6 Generated flows of location two for 100 years (no transformation)

Jan	Feb	Mar	Apr	May	Jun
15.025	9.234	9.000	13.054	35.804	170.516
0.000	0.000	0.000	0.000	0.000	150.429
4.949	2.466	1.177	5.883	21.451	115.164
0.000	0.000	0.000	0.000	3.893	0.000
12.297	8.304	10.551	16.404	16.015	146.810
10.536	5.647	4.132	7.525	15.744	196.192
15.158	10.536	9.187	8.158	18.036	83.391
9.747	6.952	4.941	6.974	11.966	98.436
4.788	2.414	0.852	0.000	0.929	0.000
16.472	11.960	11.192	15.177	34.432	4.275
9.718	7.657	5.762	2.819	0.488	192.611
12.698	8.302	4.824	8.743	13.324	65.909
1.512	0.808	0.791	3.787	2.378	133.359
14.615	10.260	8.513	7.189	8.283	10.754
3.141	0.000	0.000	0.853	3.127	144.289
1.480	1.930	0.678	4.759	5.344	70.555
13.763	10.680	10.656	13.400	49.036	124.183
11.126	6.155	3.982	4.455	9.608	0.000
4.486	1.281	0.118	0.000	5.994	95.604
9.299	6.421	4.773	3.139	10.185	24.956
15.115	11.001	9.639	3.457	2.456	74.334
8.525	3.578	4.776	6.632	6.698	102.200

Contd.

Jul	Aug	Sep	Oct	Nov	Dec
236.404	451.954	135.899	83.673	77.753	15.047
262.189	89.033	85.542	59.419	2.276	12.674
326.303	299.098	114.284	89.972	93.228	3.733
179.420	308.399	58.885	38.181	139.599	36.939
102.324	48.135	127.411	60.453	42.185	7.530
393.115	324.214	63.948	58.311	138.206	26.012
271.136	265.628	121.790	49.960	106.851	11.162
294.797	317.641	137.905	60.153	0.000	10.124
250.466	140.687	62.990	50.106	171.760	24.361
236.240	203.818	7.635	63.132	160.646	25.951
121.415	36.540	19.271	51.359	48.271	22.899
35.075	268.677	68.247	36.629	258.325	10.886
159.440	95.090	105.374	89.338	63.123	19.051
253.735	214.087	4.483	62.260	45.499	24.808
17.579	44.882	43.655	68.796	239.598	19.594
226.010	298.468	78.094	58.109	21.580	23.401
169.239	19.844	0.000	16.462	172.917	19.424
180.271	270.192	69.579	87.271	40.657	19.870
279.571	177.667	74.447	57.848	124.408	7.322
134.761	196.955	56.217	60.421	89.975	24.179
346.033	205.509	138.120	92.880	190.017	23.999
181.442	182.877	19.347	12.317	0.000	5.388

Contd.

Table 6 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
7.738	2.720	0.797	0.000	12.660	84.955
11.099	8.384	7.991	6.183	16.819	22.864
3.034	2.875	1.251	3.420	15.313	6.127
0.000	0.000	0.000	0.925	5.955	0.000
15.648	12.092	12.030	9.360	14.362	133.176
23.071	6.409	15.504	15.969	22.740	170.169
2.704	2.244	1.766	0.057	14.403	77.053
18.347	5.403	14.515	18.033	12.106	129.467
0.000	0.000	0.000	0.000	4.453	35.679
21.248	16.692	14.938	11.401	0.000	77.148
5.405	2.550	2.231	12.311	25.808	205.282
14.019	10.726	9.101	0.000	2.584	66.956
17.425	11.842	10.073	11.234	13.760	0.000
6.951	3.055	2.459	3.397	3.920	168.007
17.113	11.859	12.034	12.841	12.489	0.000
20.795	16.910	17.110	13.538	22.566	127.865
6.396	1.966	1.254	5.332	5.328	148.874
14.325	10.507	9.519	12.268	23.530	148.330
0.000	0.000	0.000	0.000	0.000	94.784
0.000	0.000	0.000	0.000	0.000	81.532
7.315	5.659	5.511	10.099	17.409	47.317
0.000	0.000	0.000	6.223	14.805	143.531

Contd.

Table 6 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
284.508	279.171	155.864	97.096	179.829	4.889
151.335	97.350	53.659	77.314	59.901	17.063
146.983	324.336	149.359	87.680	53.632	0.000
206.387	290.658	135.883	96.295	41.396	0.000
407.024	157.643	40.662	60.387	61.693	29.255
167.687	98.337	77.002	50.358	104.498	5.269
392.706	404.955	109.191	53.967	19.488	26.860
396.360	286.462	105.871	99.111	107.008	6.612
223.320	284.686	116.989	63.173	177.197	25.159
221.599	264.869	53.348	52.709	42.747	14.124
351.540	555.259	202.796	110.588	129.689	39.162
191.103	151.345	80.566	40.039	121.450	39.112
286.785	239.511	76.341	71.241	116.937	26.352
188.693	52.820	63.932	83.929	0.000	13.144
142.502	139.815	29.028	37.285	105.123	30.853
280.171	272.199	73.183	67.646	0.000	15.147
74.733	233.274	25.836	24.037	0.000	22.226
210.279	1.458	21.815	42.974	84.737	5.359
25.003	73.620	24.182	43.365	68.680	2.573
317.434	312.821	79.662	34.682	0.000	5.712
283.902	339.181	70.924	75.986	106.220	14.354
182.426	211.500	110.262	71.788	36.679	0.000

Contd.

Table 6 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
0.000	0.000	0.000	0.000	0.000	76.081
4.880	2.382	2.605	7.370	24.015	191.583
13.960	9.270	10.633	12.824	21.349	14.381
0.000	0.000	0.000	6.932	33.394	37.741
0.000	0.000	0.000	0.000	0.000	150.076
0.000	0.000	0.000	0.000	0.000	96.346
14.102	9.898	9.404	5.048	2.275	0.000
16.748	12.692	11.819	13.505	29.369	173.892
1.214	2.140	2.404	2.633	17.475	2.997
19.253	14.848	14.287	17.785	24.704	65.863
14.862	11.296	10.741	4.391	11.080	68.131
13.496	14.086	9.194	16.696	22.082	155.991
7.021	2.508	2.903	6.505	10.943	53.962
14.004	7.799	7.580	11.602	42.264	40.172
4.743	0.810	0.000	4.007	8.420	9.455
2.194	0.000	0.000	5.678	29.035	42.273
14.112	11.601	10.210	15.582	31.418	35.624
0.000	0.000	0.000	3.652	0.000	119.510
11.956	8.508	8.120	0.109	2.483	83.437
0.000	0.000	0.000	0.000	0.000	0.000
3.247	2.517	0.810	0.000	20.496	50.409
18.106	11.392	11.382	13.221	51.168	143.320

Contd.

Table 6 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
276.194	328.333	60.860	126.831	125.238	34.583
311.623	112.184	1.888	74.742	76.186	23.759
294.611	191.513	93.965	88.082	147.943	9.572
200.647	141.688	58.996	57.694	150.109	14.108
60.229	114.046	31.824	64.648	68.525	40.164
306.433	161.323	21.843	89.419	186.215	27.131
46.433	0.000	0.000	60.410	64.868	20.244
123.431	0.000	0.000	0.000	17.619	14.551
98.381	150.826	91.684	122.414	172.383	27.694
228.424	364.440	129.314	60.626	30.687	26.939
182.217	77.610	35.292	88.983	189.457	27.553
154.109	84.644	56.999	83.658	55.169	5.771
265.200	211.386	83.691	73.755	157.179	27.513
268.327	227.330	66.614	73.179	87.261	21.882
268.348	307.333	107.272	96.886	35.590	21.040
258.025	167.538	120.621	79.318	53.024	11.619
290.525	208.510	70.384	29.576	137.415	9.622
316.906	271.245	164.717	144.561	97.094	23.225
315.528	230.065	63.655	64.256	72.001	9.014
77.809	98.331	105.123	53.688	49.833	28.413
65.582	134.731	65.178	78.390	6.455	23.302
293.383	185.183	38.801	14.007	59.927	15.735

Contd.

Table 6 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
13.038	6.677	6.439	6.111	21.648	135.372
12.554	8.746	6.401	6.837	20.122	24.179
6.598	0.823	0.583	2.081	0.000	0.000
7.317	4.101	2.034	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	8.444
21.182	15.171	12.994	16.300	17.548	281.504
6.484	3.072	3.645	4.244	0.467	144.745
6.823	3.012	3.312	10.393	6.063	0.000
8.943	6.201	4.634	12.398	3.630	118.857
5.814	1.356	0.000	0.714	14.289	98.143
18.314	13.301	10.640	12.264	9.907	165.049
6.015	1.329	1.282	0.000	13.352	214.654
12.932	7.058	5.791	9.131	13.906	108.480
14.354	12.253	13.040	21.715	33.820	73.854
17.214	10.440	10.503	14.404	34.988	114.138
20.519	13.701	11.883	8.809	23.479	157.594
4.774	0.970	1.871	2.636	14.100	159.200
8.495	4.068	4.682	7.359	13.102	152.176
18.693	12.958	13.491	17.070	34.346	164.853
14.926	10.448	8.846	3.519	5.90	161.076
6.777	4.134	0.870	1.520	0.000	134.362
11.263	7.939	8.063	8.497	6.774	63.510

Contd.

Table 6 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
244.214	170.150	147.521	112.351	48.695	13.263
268.828	352.940	82.762	26.213	0.000	20.834
256.840	0.000	0.311	79.950	3.543	4.678
202.113	223.158	90.873	67.957	0.000	0.396
308.155	87.682	46.559	13.452	124.379	36.264
366.244	324.792	153.294	52.839	177.931	8.765
255.131	329.208	112.959	104.879	20.517	2.951
79.497	255.862	50.351	70.790	111.218	12.547
381.287	389.808	166.905	82.983	0.000	6.290
193.033	290.065	159.412	120.311	11.422	26.270
146.095	8.171	39.145	21.773	5.070	0.000
142.008	206.966	163.639	76.309	155.043	44.530
174.312	239.328	123.900	108.196	32.380	27.742
162.437	0.000	42.045	92.341	111.579	15.593
327.982	280.369	142.274	54.664	154.425	29.601
224.878	258.916	105.840	89.796	15.341	17.376
95.816	96.006	126.387	122.836	59.530	25.091
382.489	311.464	104.863	69.854	80.520	11.047
129.138	119.663	22.367	31.774	47.450	25.099
192.324	285.105	69.869	65.819	231.741	3.439
153.494	221.506	83.633	24.126	97.194	34.136
81.947	238.223	246.099	67.281	24.522	32.637

Contd.

Table 6 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
12.072	10.086	8.356	8.374	24.233	82.928
9.394	7.313	7.296	5.810	16.810	11.334
22.906	15.145	15.078	18.043	44.326	205.889
0.000	0.000	0.000	0.000	6.254	133.528
19.005	14.878	14.189	14.611	21.788	64.518
0.000	0.000	0.000	3.666	29.300	230.470
0.214	0.000	0.000	0.000	4.022	16.027
14.049	8.546	8.613	12.139	17.975	23.979
0.000	0.000	0.000	0.088	6.531	143.779
9.413	7.379	6.800	9.881	9.197	122.846
6.148	6.541	4.654	6.365	2.205	89.687
3.872	2.004	0.507	1.586	18.844	39.871
Means					
9.2104	6.1587	5.5289	6.7900	14.0978	93.5924
Standard deviations					
6.7285	5.1584	4.9975	5.7464	12.0855	65.9466
Skewness co-efficient					
0.1422	0.3374	0.4356	0.4865	0.9051	0.2395
Slopes					
0.3258	0.7432	0.9507	0.9362	1.4022	1.1359
Correlations with previous month					
0.5169	0.9694	0.9813	0.8142	0.6667	0.2082

Table 6 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
268.626	245.027	28.061	74.518	0.000	14.088
390.605	291.343	72.689	70.540	0.000	24.490
169.785	362.791	119.504	142.690	132.454	0.000
283.749	408.126	145.682	109.934	0.000	15.959
92.357	167.948	79.328	63.029	16.896	9.574
235.564	141.041	57.951	88.767	0.000	3.162
189.212	270.775	112.330	97.967	164.837	32.445
202.180	56.038	0.000	10.337	0.000	16.606
305.185	177.222	92.690	35.668	77.575	26.691
180.913	104.682	42.962	19.016	0.000	20.683
25.191	5.332	23.085	50.460	93.845	15.271
355.214	330.515	91.827	117.991	21.400	22.015
Means					
219.5857	205.5499	81.2822	67.4815	79.0723	18.0357
Standard deviations					
95.7561	114.5880	46.8976	29.9427	64.9309	10.6412
Skewness co-efficient					
-0.1112	0.0838	0.1831	0.1551	0.5844	0.1613
Slopes					
0.1471	0.6181	0.2678	0.3559	0.1348	0.0360
Correlations with previous month					
0.1013	0.5165	0.6544	0.5574	0.0622	0.2198

Table 7 Generated flows of location three for 100 years (No transformation)

Jan	Feb	Mar	Apr	May	Jun
53.183	27.210	20.259	24.992	95.262	521.574
16.058	0.000	0.000	0.000	0.000	572.476
35.985	20.099	13.780	15.368	62.966	369.741
23.303	19.454	12.258	3.709	47.079	0.000
34.109	18.084	20.416	26.864	40.215	437.878
50.846	25.804	15.702	17.677	45.317	669.430
47.497	27.519	17.460	17.060	48.657	262.150
46.125	29.664	17.156	18.634	38.095	336.484
37.657	21.624	12.513	8.260	18.135	0.000
50.983	31.395	21.860	27.374	88.303	0.000
35.729	24.766	13.945	10.311	6.051	699.051
45.172	24.971	9.792	10.175	22.321	200.768
27.356	18.087	14.419	15.134	16.010	488.802
51.652	31.204	19.030	18.866	27.440	35.649
23.680	1.458	0.000	0.000	0.000	504.984
21.705	18.251	10.918	11.329	14.936	250.880
47.361	32.249	24.484	29.853	139.127	329.718
42.903	20.066	9.779	7.236	21.235	0.000
29.862	12.568	7.051	0.092	24.159	344.281
47.550	30.090	18.444	17.362	43.656	91.546
49.039	30.527	19.603	15.808	18.412	281.839
34.214	31.991	13.095	12.962	15.227	356.198

Contd.

Table 7 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
914.118	1650.962	455.722	300.842	253.479	78.260
1054.435	607.662	531.325	312.641	164.852	152.688
1436.978	1287.873	495.106	417.010	271.919	0.000
903.907	1308.546	246.430	176.560	332.441	336.958
285.352	402.906	735.535	249.601	212.734	9.070
1637.443	1347.200	254.754	295.319	321.844	172.019
1214.220	1178.028	553.143	148.677	291.577	0.000
1304.091	1333.178	581.607	174.965	125.166	160.755
1294.727	874.896	406.069	285.245	370.430	84.897
1173.101	1030.489	384.927	341.934	355.858	128.160
298.392	346.639	272.870	387.848	221.494	248.112
78.652	1061.650	303.075	153.768	475.926	0.000
578.449	578.394	606.788	469.458	235.802	165.308
1237.546	1061.763	89.754	453.904	217.250	283.750
0.000	343.536	368.620	454.959	451.024	0.000
1006.915	1254.344	334.708	273.363	188.170	297.284
659.875	377.163	134.009	233.535	375.115	1.291
939.308	1209.898	325.161	486.819	208.938	212.453
1230.869	914.853	417.734	304.863	312.506	0.000
628.591	933.320	318.485	349.296	270.802	206.298
1589.618	1047.799	677.920	414.195	388.518	53.635
738.877	869.826	167.092	103.922	103.591	114.277

Contd.

Table 7 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
47.246	20.755	10.908	6.015	47.795	293.856
52.444	35.535	25.822	27.618	68.919	71.967
25.454	21.985	12.611	12.131	48.599	2.500
28.472	16.151	8.322	9.505	26.300	0.000
66.837	46.070	34.376	39.007	70.103	475.395
62.813	36.530	25.254	29.625	56.576	552.101
35.127	25.531	18.283	16.714	64.573	271.896
54.805	41.378	28.785	36.791	31.628	439.801
23.445	18.255	17.550	15.923	40.525	154.563
60.529	41.517	26.544	28.032	0.330	297.118
35.589	18.722	13.807	20.344	62.121	6665.676
36.407	23.587	13.874	3.967	13.389	254.203
43.716	22.683	12.844	12.701	19.453	0.000
30.031	11.788	8.054	5.092	5.282	594.104
61.683	36.906	28.403	33.752	44.846	0.000
56.492	40.765	31.326	34.754	72.433	417.359
37.756	15.075	10.092	10.277	11.296	524.657
49.723	31.604	21.393	25.525	64.305	477.709
14.847	9.821	2.166	0.000	0.000	390.165
16.810	8.168	5.622	1.207	0.000	335.032
46.001	32.185	24.034	30.122	61.761	149.151
19.310	4.913	6.118	8.835	32.589	476.778

Contd

Table 7 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
1273.734	1222.839	690.748	392.346	375.703	0.000
715.164	653.003	388.843	486.280	233.205	137.249
721.422	1327.156	622.806	331.884	224.038	0.000
1036.237	1271.938	596.690	421.325	208.437	0.000
1800.207	905.817	293.262	388.628	236.780	331.303
571.450	573.086	479.255	264.832	289.091	0.000
1818.176	1658.794	395.331	169.953	185.716	356.473
1756.816	1280.967	472.425	103.460	290.729	0.000
1044.182	1233.179	516.910	239.613	375.496	90.443
971.473	1147.674	253.327	289.889	214.349	114.546
1423.766	1996.671	668.236	334.675	313.555	391.909
838.653	804.340	461.370	181.944	310.346	399.763
1624.049	1248.251	394.790	380.608	302.362	201.250
670.932	450.186	460.373	518.174	135.711	195.593
721.921	793.035	249.731	260.545	291.177	290.339
1189.477	1174.021	334.101	350.188	122.324	245.590
139.754	925.588	143.552	154.873	142.014	338.259
814.978	327.650	322.318	338.752	266.236	0.000
0.000	460.224	264.980	318.834	246.733	0.000
1433.368	1339.454	335.223	115.674	118.657	99.084
1331.323	1423.294	276.924	396.054	288.981	23.298
682.899	929.261	535.633	321.015	205.161	0.000

Contd.

Table 7 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
230.031	9.089	8.572	2.348	14.337	333.004
20.122	8.338	7.789	7.879	53.078	618.316
47.007	26.082	23.793	28.460	61.134	12.317
23.394	10.723	7.465	11.100	86.056	56.180
20.880	13.363	7.522	2.382	0.000	569.408
6.480	0.000	0.000	0.000	0.000	351.196
43.992	25.790	18.534	15.822	12.692	0.000
55.352	36.507	25.272	30.198	84.204	556.190
26.649	23.487	18.831	19.120	68.622	0.000
54.683	36.423	26.093	33.095	61.750	177.985
47.181	31.163	22.191	19.333	45.250	240.087
42.396	30.936	18.461	25.397	45.464	495.513
44.439	20.102	16.746	19.112	37.552	183.913
43.814	18.074	13.684	15.875	103.320	35.297
28.608	9.087	4.250	2.460	11.610	16.441
24.282	5.748	4.379	4.824	67.754	78.055
55.611	40.696	26.869	35.183	91.221	63.188
20.518	15.070	8.181	9.598	0.000	465.323
42.933	26.382	19.228	13.617	25.943	320.510
18.543	5.391	5.903	4.359	0.000	0.000
21.472	14.857	7.262	1.806	59.897	142.903
56.787	28.502	21.829	25.600	138.776	386.339

Contd.

Table 7 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
1236.183	1363.519	672.505	566.949	307.301	324.945
1248.397	683.722	150.708	559.527	253.393	220.795
1438.594	1019.116	499.064	466.253	338.371	0.000
944.966	806.080	379.192	339.514	343.732	0.000
60.416	564.506	263.929	434.923	244.752	497.901
1361.394	881.749	204.393	610.585	384.954	109.554
252.443	72.723	156.335	571.619	241.238	180.124
348.977	0.000	217.144	90.627	189.938	156.167
485.907	792.108	508.730	700.095	365.155	141.384
1034.501	1455.555	504.918	183.023	198.602	341.157
795.317	583.397	323.571	599.728	388.877	111.482
527.693	534.615	403.658	521.792	226.958	0.000
1227.135	1032.959	433.099	385.452	350.725	159.243
1278.928	1096.470	348.226	409.728	266.417	173.804
1313.728	1345.239	462.109	474.227	201.785	239.683
1219.652	911.759	629.481	364.628	224.278	59.785
1388.855	1054.388	381.303	122.331	330.503	0.000
1371.981	1193.108	734.743	688.109	271.896	184.294
1424.158	1095.875	332.139	355.879	248.720	0.000
472.180	662.395	612.174	238.588	222.631	335.525
253.615	696.867	400.782	462.213	168.458	319.405
1243.115	921.918	255.183	80.711	250.448	97.642

Contd.

Table 7 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
50.417	21.675	16.216	15.612	63.164	440.369
51.273	31.564	17.644	18.167	60.655	52.716
35.463	8.472	6.604	3.352	0.000	0.000
46.297	26.542	14.712	11.221	0.000	0.000
13.740	4.019	2.878	0.000	0.000	104.061
53.529	30.861	17.682	21.373	27.506	946.306
40.099	20.683	17.658	17.984	13.784	536.727
46.238	23.925	19.254	25.410	21.316	0.000
43.463	27.359	16.692	22.656	3.414	420.150
42.157	17.804	9.881	7.193	46.601	331.226
55.226	33.892	18.525	20.852	18.522	565.146
46.803	20.497	15.812	12.632	59.279	759.032
30.281	8.639	4.013	1.982	9.347	336.935
45.645	35.081	28.759	40.793	86.897	182.455
58.974	29.275	22.571	28.186	93.726	325.009
56.261	29.380	17.571	15.867	59.836	506.788
32.377	12.362	12.518	10.932	45.830	547.372
34.722	14.297	13.176	13.731	32.041	515.433
65.407	38.917	30.846	39.510	101.573	620.515
48.438	28.589	17.539	13.611	23.423	577.144
43.723	26.436	11.375	9.165	0.000	517.557
34.190	19.951	15.973	16.022	14.607	218.479

Contd.

Table 7 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
1001.141	849.515	735.595	528.998	216.208	94.598
1295.419	1470.679	318.097	46.467	0.000	498.995
1388.370	323.341	296.904	637.711	165.380	21.760
1055.271	1105.707	452.500	324.948	158.364	9.967
1497.852	719.562	377.362	86.845	316.297	347.800
1375.374	1279.990	633.606	95.288	376.953	0.000
1030.876	1312.120	457.365	508.255	182.873	0.000
454.373	1114.332	246.714	415.246	295.619	0.000
1696.502	1580.878	653.868	257.260	150.473	65.456
803.[illegible]97	1193.948	689.980	533.337	170.384	362.293
468.471	297.720	386.091	165.668	171.602	0.000
368.034	844.969	762.252	252.520	347.428	438.667
700.095	1029.651	574.747	528.930	196.931	353.703
700.496	258.500	437.849	632.305	294.577	35.748
1452.953	1237.122	632.122	139.658	348.524	196.628
872.958	1084.945	480.380	437.055	177.930	210.636
229.512	529.663	690.975	648.497	228.625	270.237
1653.678	1331.898	445.237	300.138	258.242	8.888
345.772	598.572	220.520	236.499	222.002	284.164
698.535	1137.091	300.237	339.004	441.444	0.000
543.847	943.281	410.174	55.000	282.253	355.171
309.399	999.441	668.680	220.579	190.598	443.148

Contd.

Table 7 (Contd.)

Jan	Feb	Mar	Apr	May	Jun
37.629	28.059	16.806	16.929	65.108	243.641
45.029	31.303	23.776	25.021	65.899	382.146
66.581	35.055	26.455	33.245	116.161	622.115
29.969	19.326	9.505	8.275	30.572	482.690
63.856	44.035	31.237	37.543	71.261	196.275
22.576	12.627	6.534	7.853	80.045	752.912
32.520	14.612	5.700	0.549	22.726	71.599
40.572	18.361	14.681	16.947	35.200	40.430
22.933	9.794	4.170	1.187	17.141	505.698
35.402	24.419	17.279	19.885	22.801	423.275
33.255	29.722	17.533	18.842	13:076	332.688
31.074	18.061	10.116	7.764	57.431	111.792
Means					
39.6479	22.6839	15.4268	16.0435	41.2701	314.0305
Standard deviations					
13.7037	10.5161	7.8194	10.8064	32.3678	227.2364
Skewness co-efficient					
-0.1134	-0.0705	0.1540	0.3955	0.7435	0.1782
Slopes					
0.0119	0.6791	0.6946	1.3183	1.7962	0.0292
Correlations with previous month					
·0.1245	0.8849	0.9342	0.9539	0.5997	0.0042

Table 7 (Contd.)

Jul	Aug	Sep	Oct	Nov	Dec
1205.067	1117.516	162.951	483.493	95.540	261.840
1755.859	1303.211	325.478	368.254	118.803	401.249
534.296	1329.849	448.943	733.691	314.954	0.000
1191.519	1568.066	538.949	465.768	130.507	245.770
362.928	800.420	436.251	316.098	182.357	80.401
813.372	699.472	362.417	541.261	131.334	39.033
908.896	1186.144	507.108	478.325	357.800	228.802
969.148	562.778	127.080	183.072	113.671	283.763
1283.059	897.927	495.351	126.392	257.611	264.777
704.871	627.420	330.794	121.406	162.073	288.382
0.000	265.874	315.802	382.159	276.615	55.439
1695.88	1444.601	380.287	636.197	183.026	277.889
Means					
950.8210	959.8047	419.9355	350.0090	250.6422	159.9830
Standard deviations					
470.8245	384.0735	162.1550	165.4883	88.0898	142.6572
Skewness co-efficient					
-0.1992	-0.2267	0.2002	0.1673	0.1021	0.4554
Slopes					
-0.2855	0.5034	0.1178	0.1136	0.0350	-0.5241
Correlations with previous month					
-0.1378	0.6171	0.2789	0.1113	0.0657	-0.3237

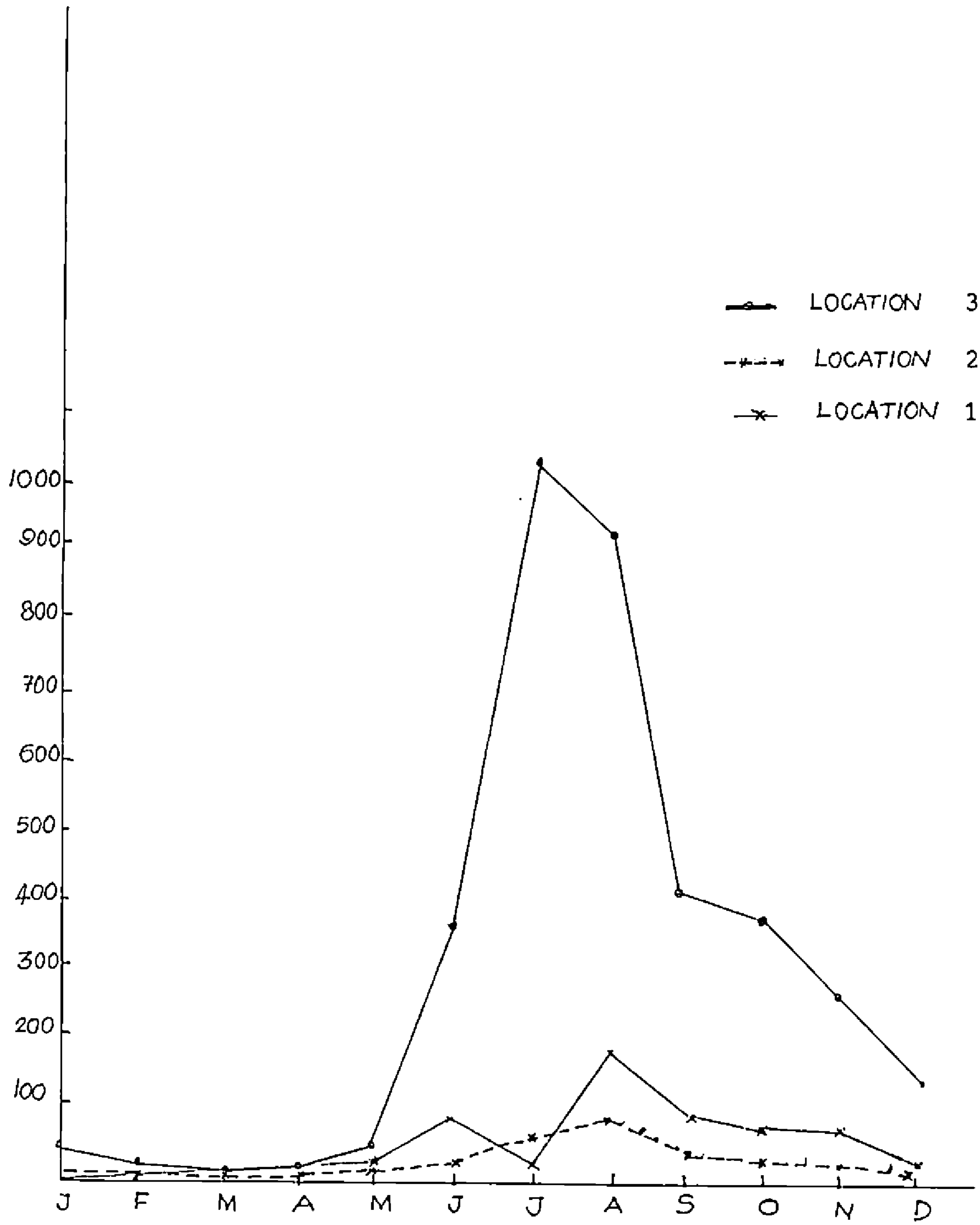


FIG.5 MEAN MONTHLY INFLOWS OF THREE LOCATIONS

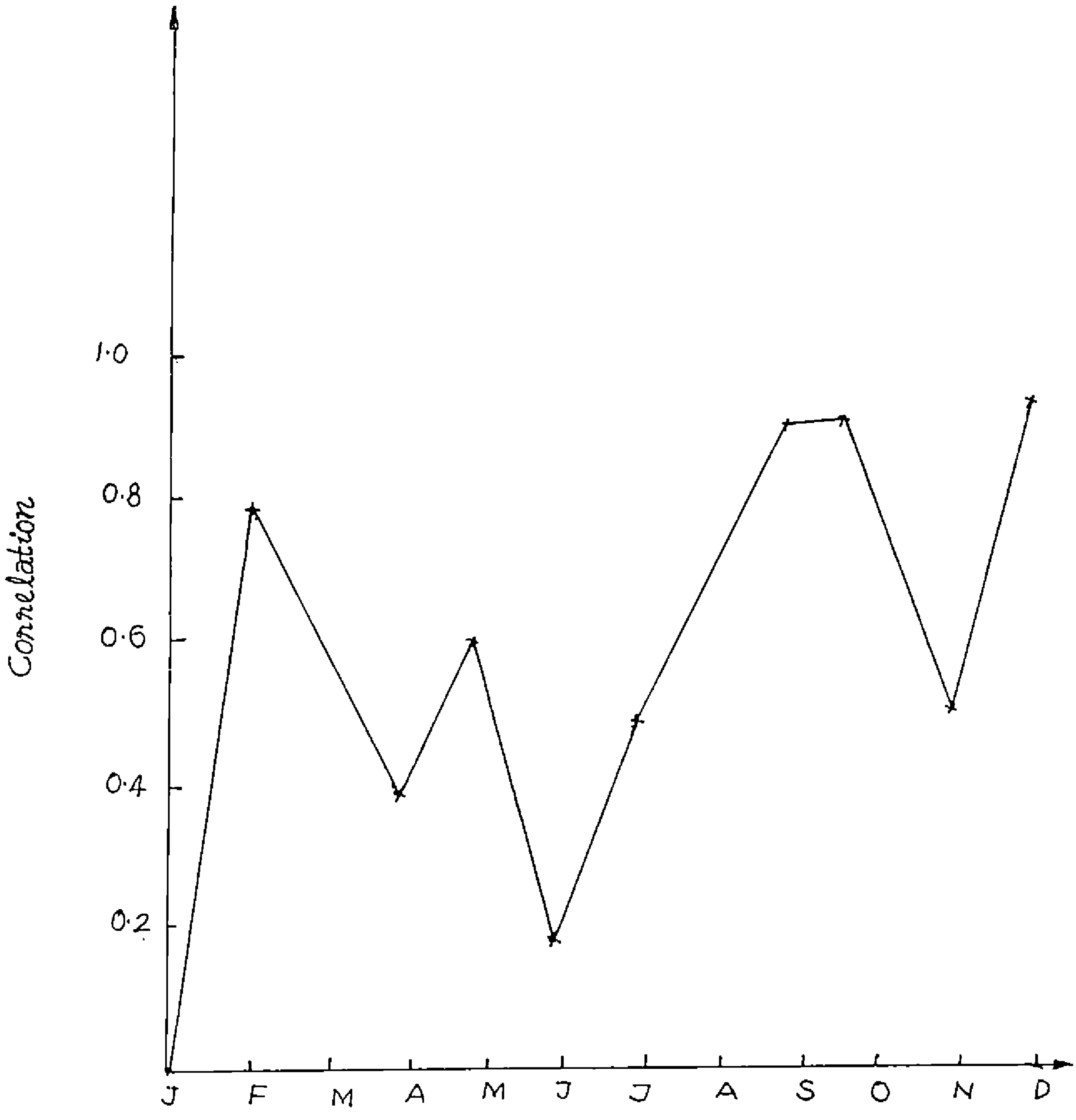


FIG.6 CORRELATION WITH PREVIOUS MONTH LOCATION ONE

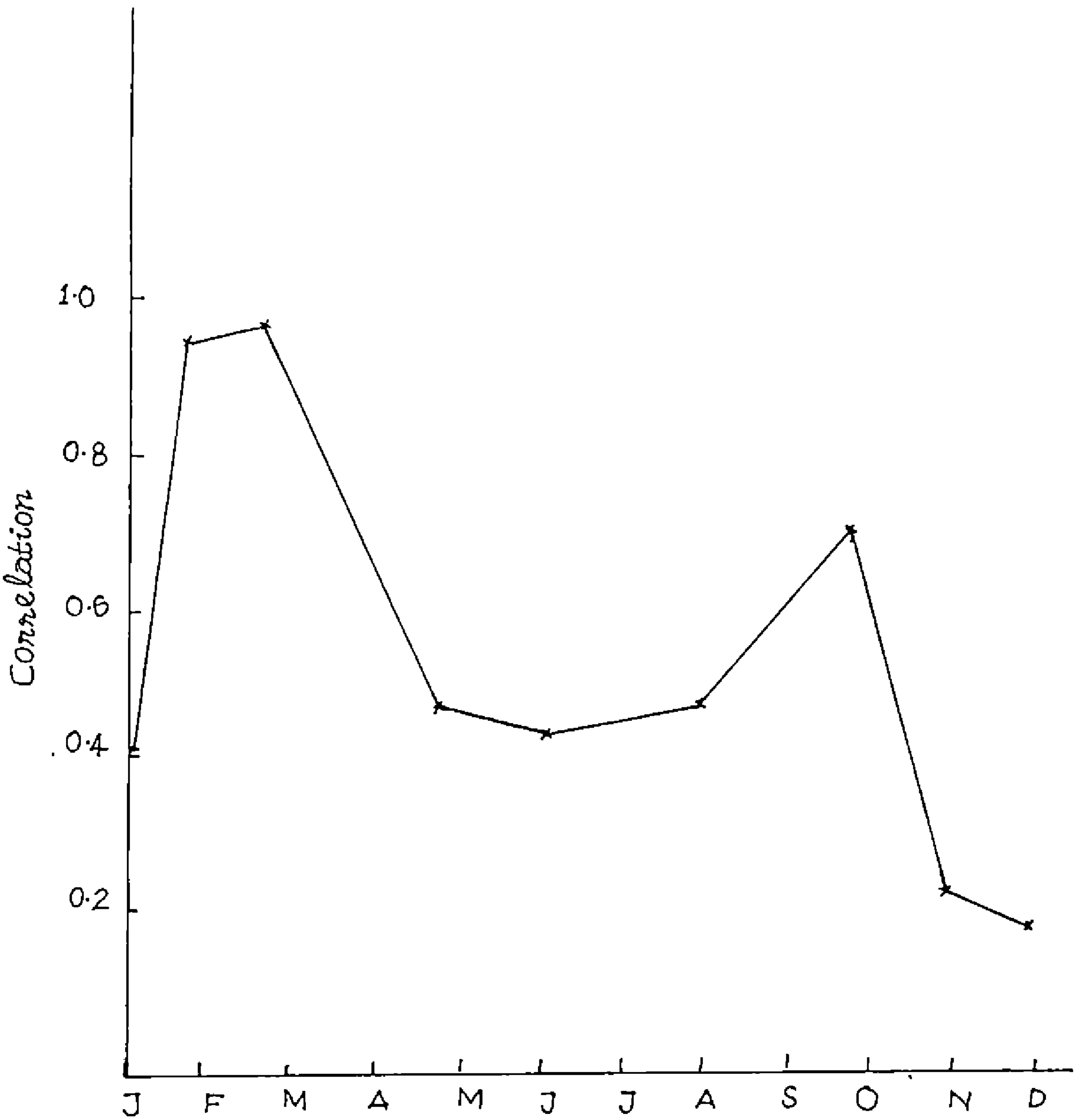


FIG.7 CORRELATION WITH PREVIOUS MONTH - (LOCATION TWO)

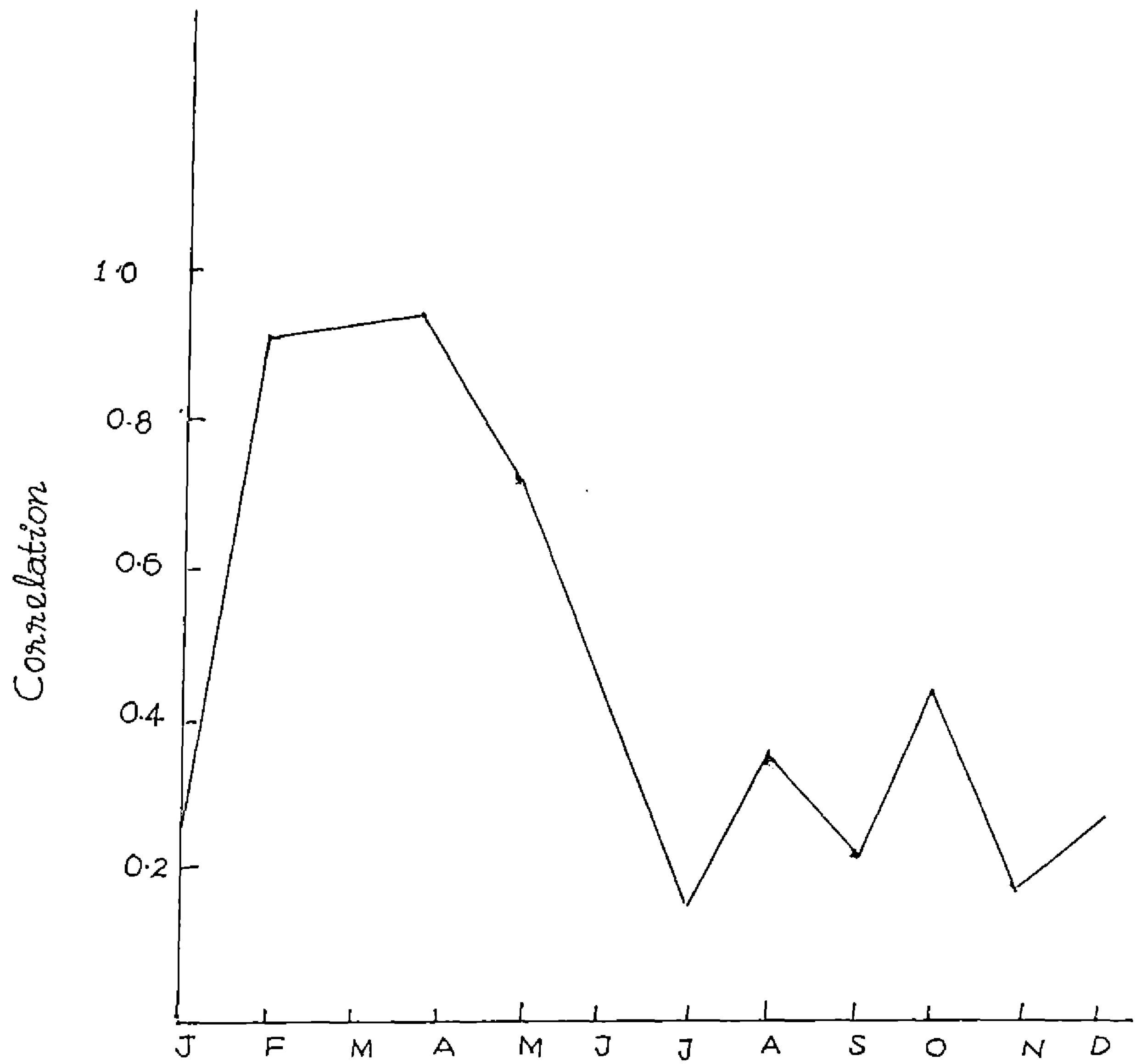


FIG.8 CORRELATION WITH PREVIOUS MONTH - LOCATION THREE

Table 8. Comparison of measure and generated statistics - Thomas Fiering Model - Generated sample size 100 years

Location 1

Months	Measured Flow Statistics			Generated Flow Statistics		
	μ	σ	r	μ	σ	r
January	8.1	6.3	-0.01	7.1664	5.1702	0.9147
February	5.8	4.9	0.8	5.3633	3.9439	0.9699
March	4.6	4.3	0.5	4.4477	3.3696	0.9034
April	3.6	3.8	0.4	3.6149	2.9244	0.8066
May	6.3	6.9	0.6	6.1955	5.6544	0.8891
June	19.1	13.5	0.2	16.2151	10.9549	0.4198
July	46.8	25.9	0.5	42.032	23.6905	0.6178
August	66.8	32.8	0.1	55.309	31.1307	0.6368
September	34.2	16.2	0.9	29.567	16.5585	0.5123
October	26.3	12.7	0.9	25.235	12.503	0.5640
November	22.1	16.8	0.5	23.579	14.422	0.3843
December	10.3	5.6	0.9	10.785	5.54	0.4511

Table 9. Comparison of measured and generated statistics - Thomas Fiering Model
Generated sample size - 100 years

Location 2

Months	Measured Flow Statistics			Generated Flow Statistics		
	μ	σ	ν	μ	σ	ν
January	11.96	3.63	0.41	9.21	6.728	0.5169
February	7.90	7.36	0.98	6.1587	5.158	0.0694
March	7.35	7.32	0.99	5.289	4.997	0.9873
April	9.07	7.32	0.76	6.79	5.745	0.8142
May	19.06	11.71	0.55	14.0978	12.085	0.6667
June	84.37	75.18	0.50	93.592	65.946	0.2082
July	215.65	88.67	-0.07	219.585	95.7561	0.1013
August	186.03	112.15	0.54	205.549	144.588	0.5165
September	75.39	37.20	0.60	81.282	46.897	0.6544
October	69.38	33.87	0.74	67.481	29.942	0.5574
November	71.37	85.03	-0.07	79.072	64.931	0.0622
December	20.28	10.31	0.27	18.0357	15.64	0.2198

Table 10. Comparison of measured and generated statistics – Thomas Fiering model – Generated sample size : 100 years

Location 3

Months	Measured Flow Statistics			Generated Flow Statistics		
	μ	σ	γ	μ	σ	γ
January	43.1	13.5	0.23	39.647	13.703	0.1245
February	23.6	10.6	0.92	22.683	16.514	0.8849
March	16.5	9.5	0.95	15.426	7.810	0.9342
April	17.3	13.0	0.96	15.048	10.306	0.9539
May	47.9	36.2	0.71	41.270	32.367	0.5997
June	366.5	292.6	-0.02	314.034	227.236	0.0042
July	1012.5	401.7	-0.187	950.821	470.824	0.1378
August	938.9	396.4	0.387	959.804	384.735	0.1710
September	392.8	134.8	0.217	419.935	162.155	0.2799
October	331.2	153.7	0.441	350.009	165.488	0.1113
November	216.5	98.9	0.073	250.642	88.089	0.0657
December	140.1	197.4	-0.26	159.983	142.657	0.3837

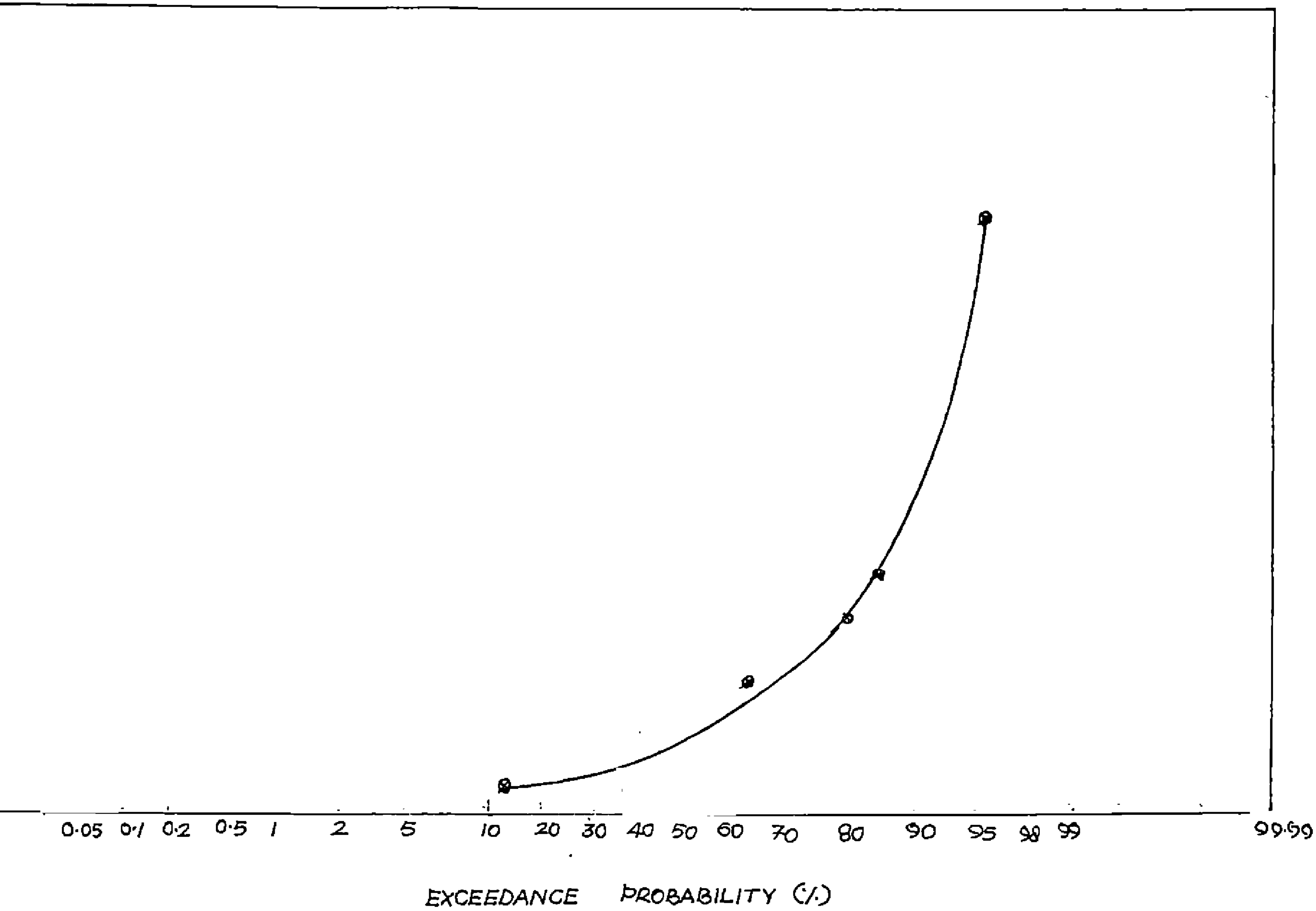


Fig. 9 PROBABILITY CHART FOR THE MONTH OF MAY AT LOCATION ONE

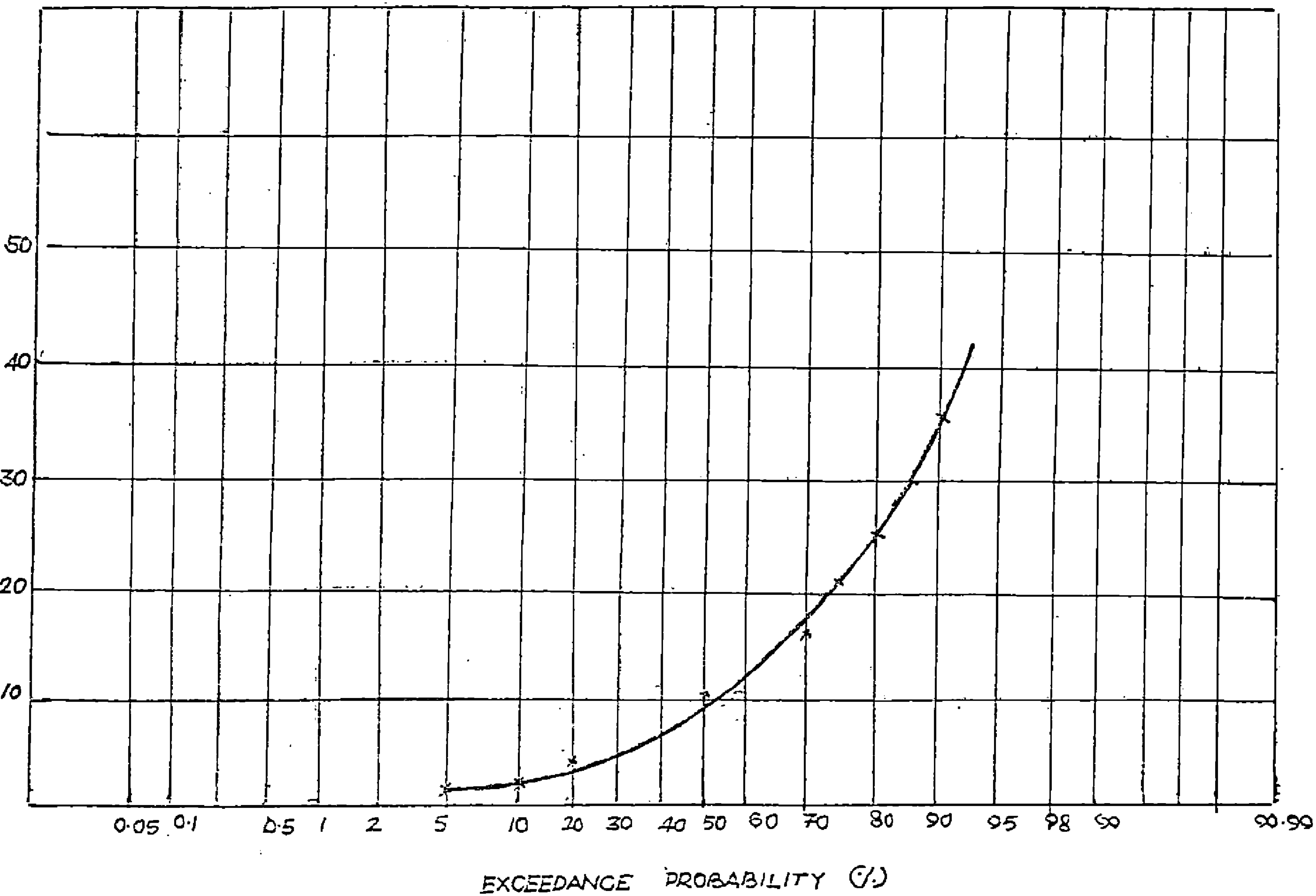


Fig. 10 PROBABILITY CHART FOR THE MONTH OF JUNE AT LOCATION ONE.

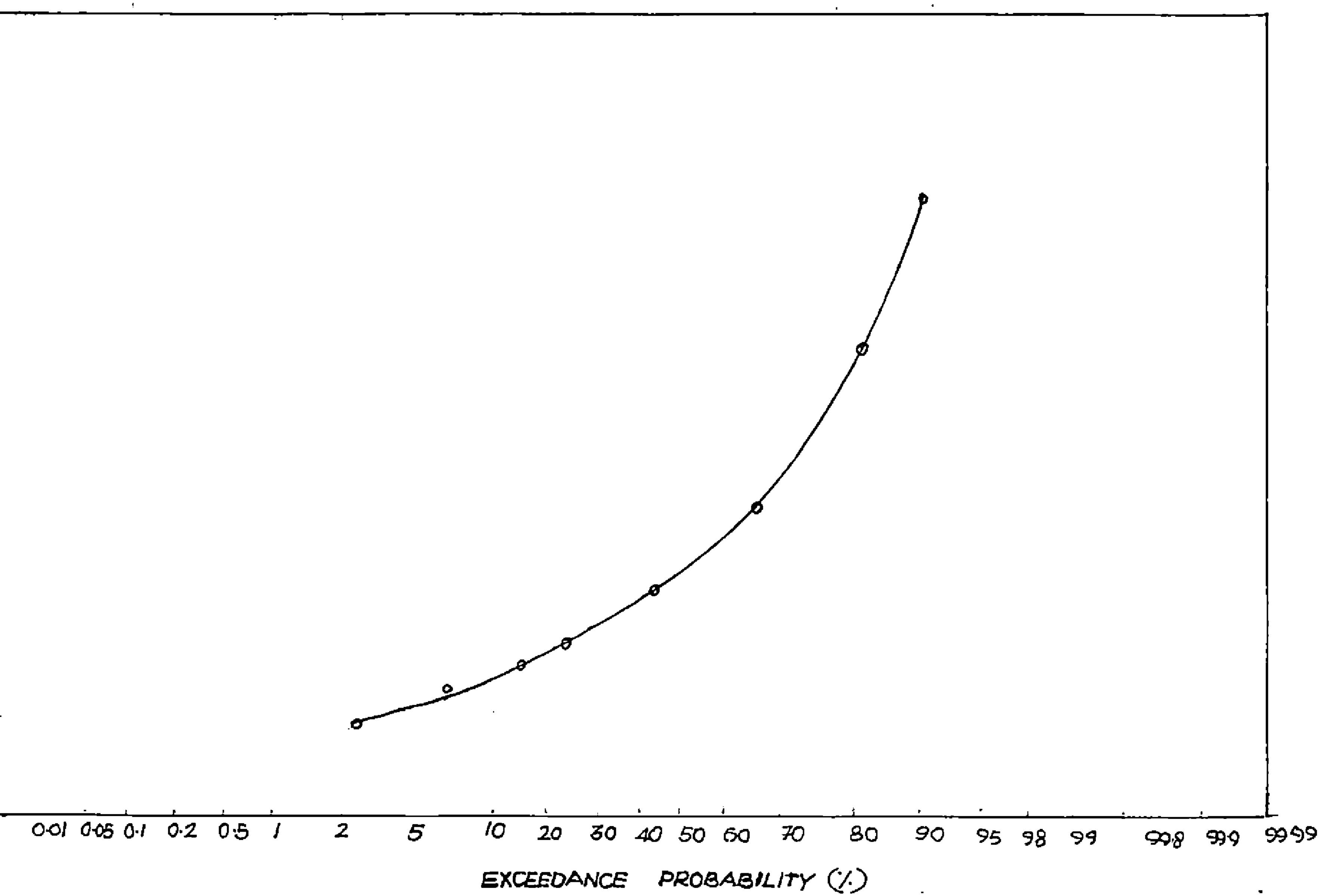


Fig. 11 PROBABILITY CHART FOR THE MONTH OF JULY AT LOCATION ONE.

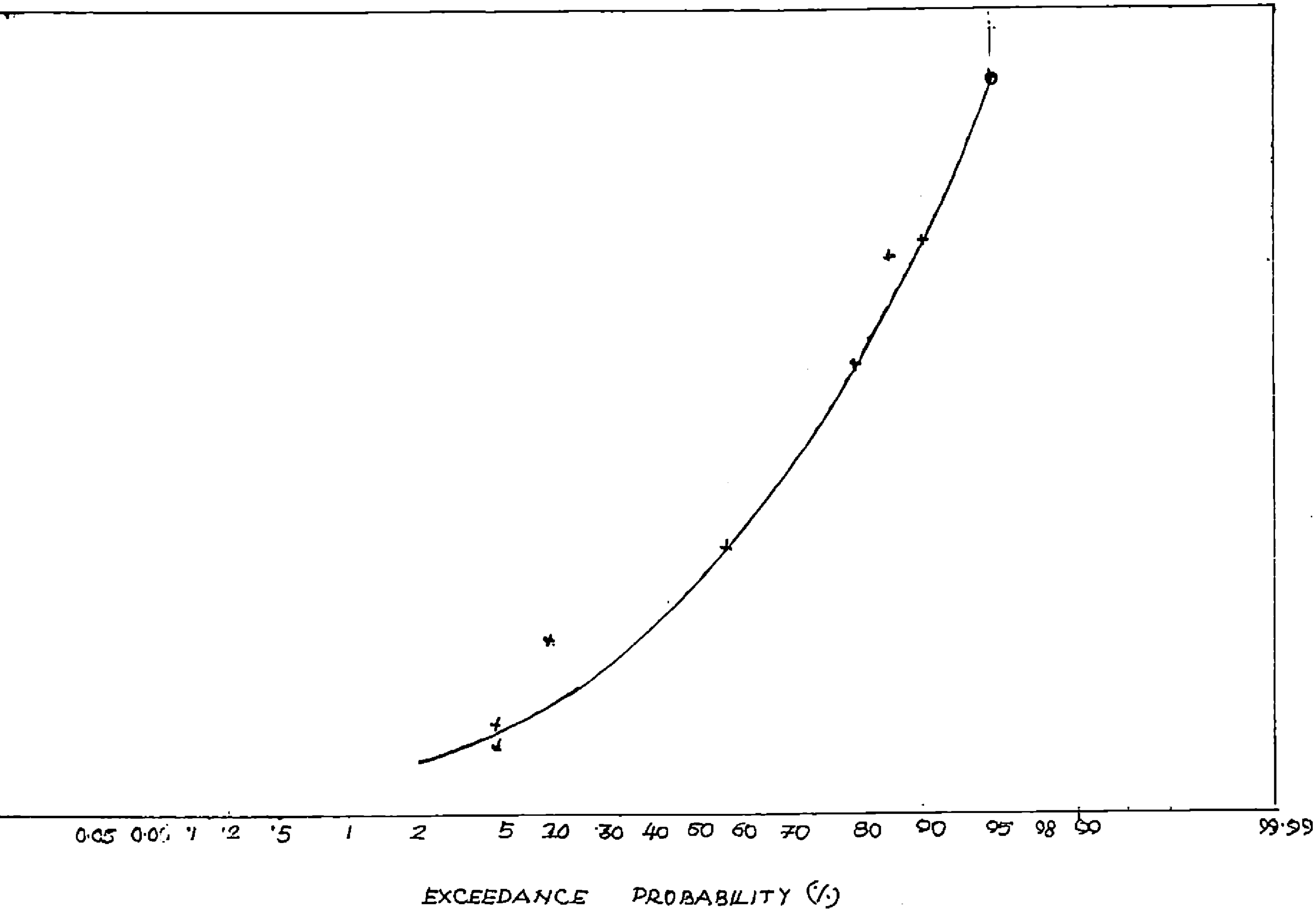


Fig. 12 PROBABILITY CHART FOR THE MONTH OF AUGUST AT LOCATION ONE

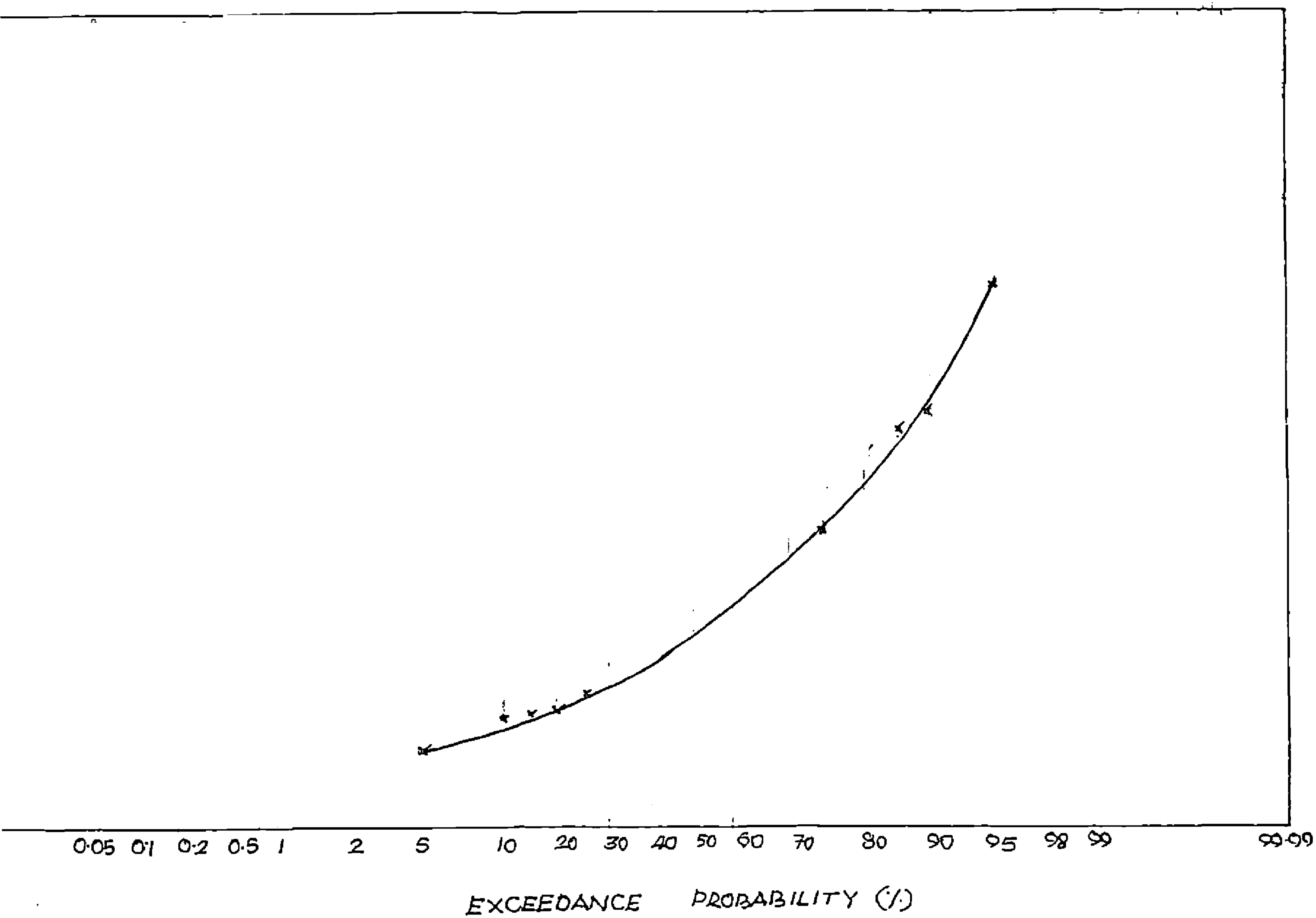


Fig.13 PROBABILITY CHART FOR THE MONTH OF SEPTEMBER AT LOCATION TWO

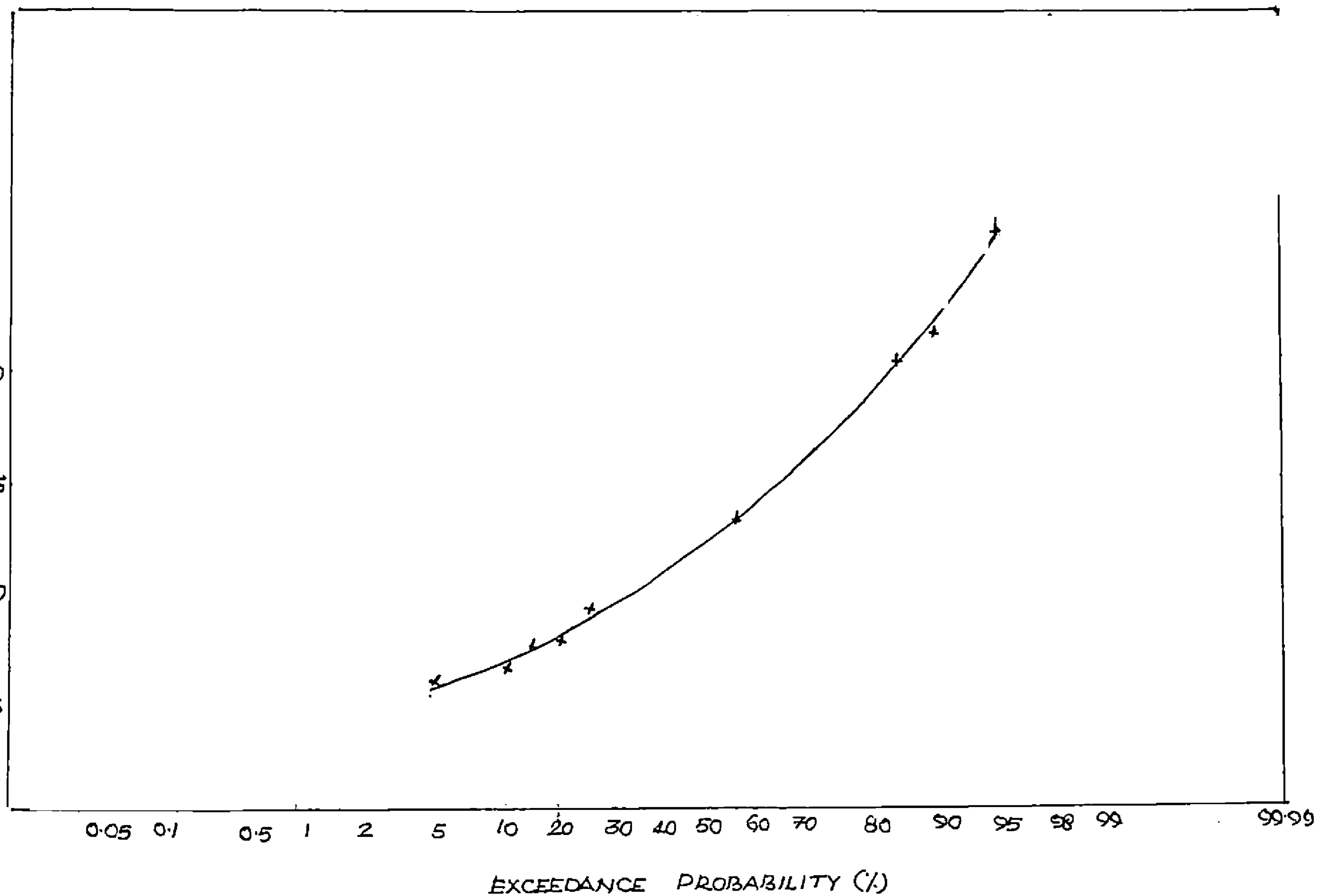


Fig. 14 PROBABILITY CHART FOR THE MONTH OF OCTOBER AT LOCATON TWO

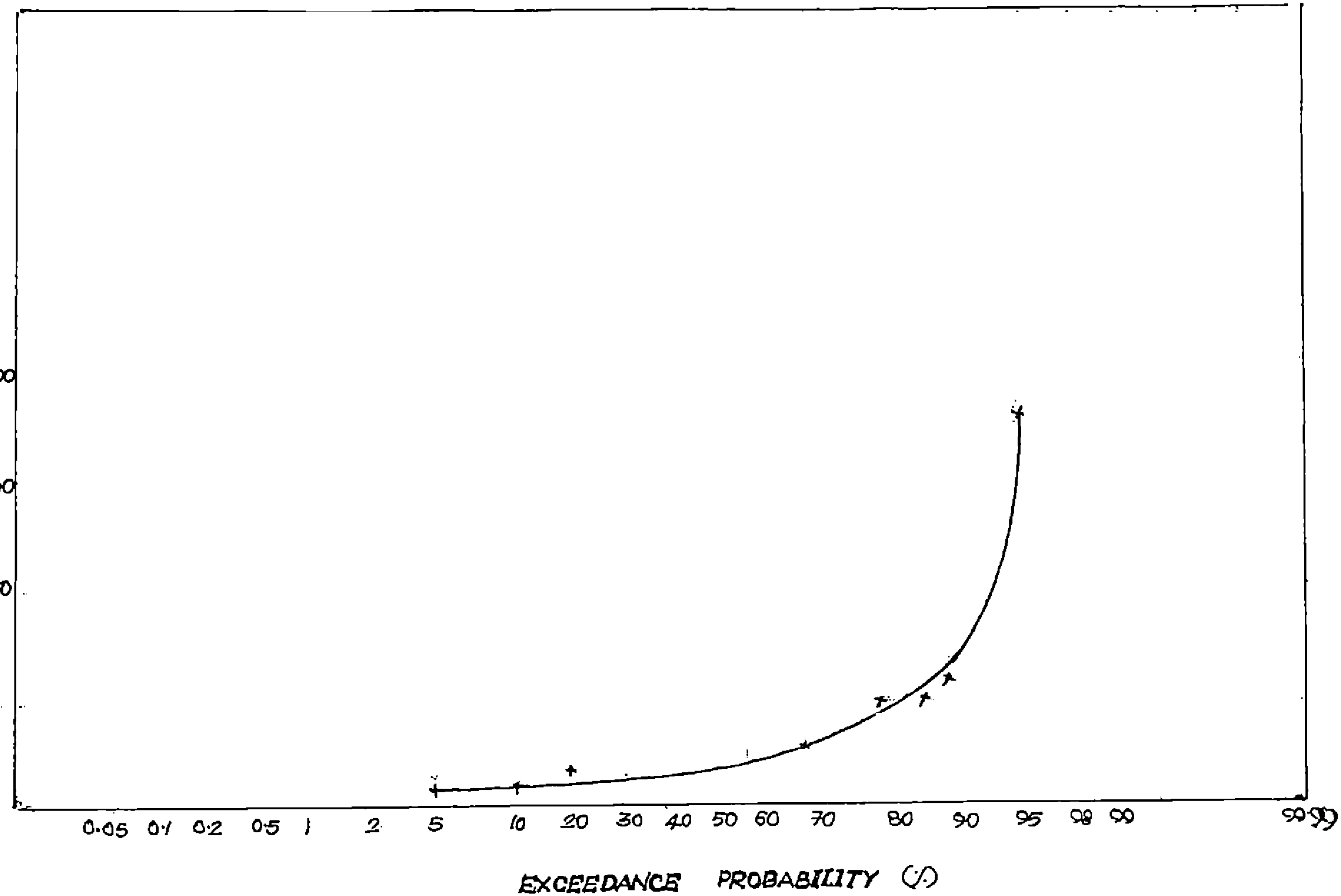


Fig.15 PROBABILITY CHART FOR THE MONTH OF NOVEMBER AT LOCATION TWO

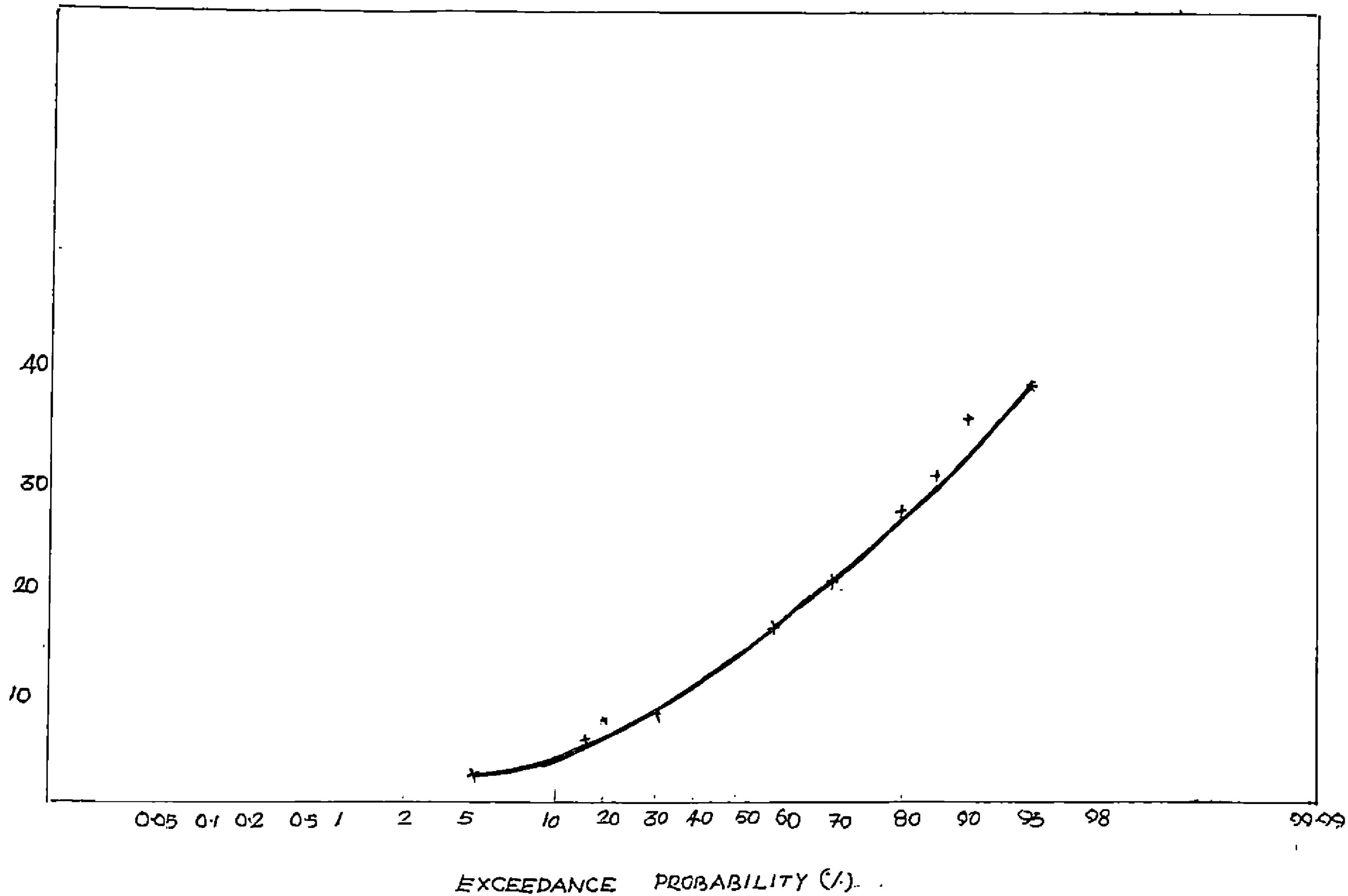


Fig. 16 PROBABILITY CHART FOR THE MONTH OF DECEMBER AT LOCATION TWO

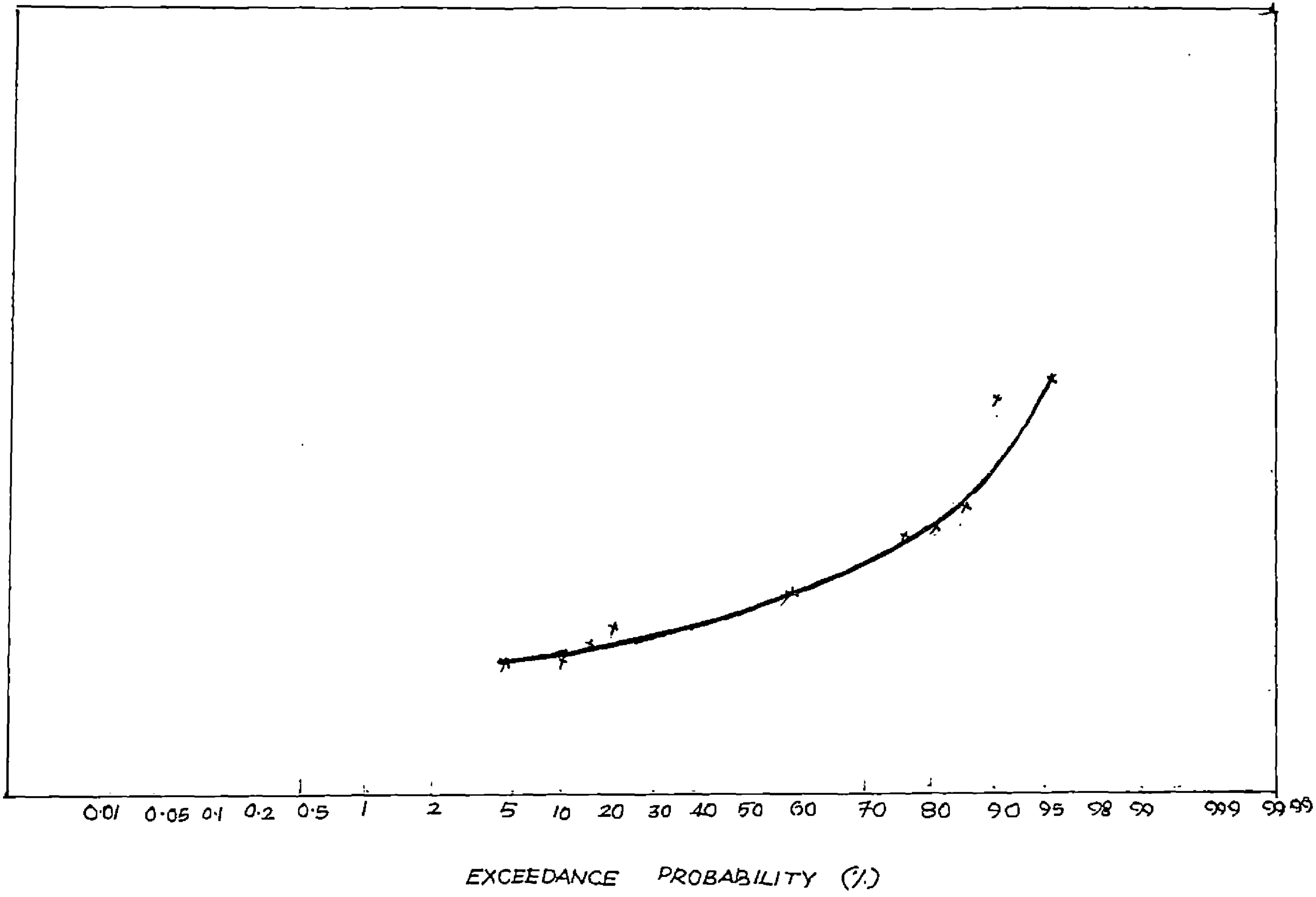


Fig.17 PROBABILITY CHART FOR THE MONTH OF JANUARY AT LOCATION THREE

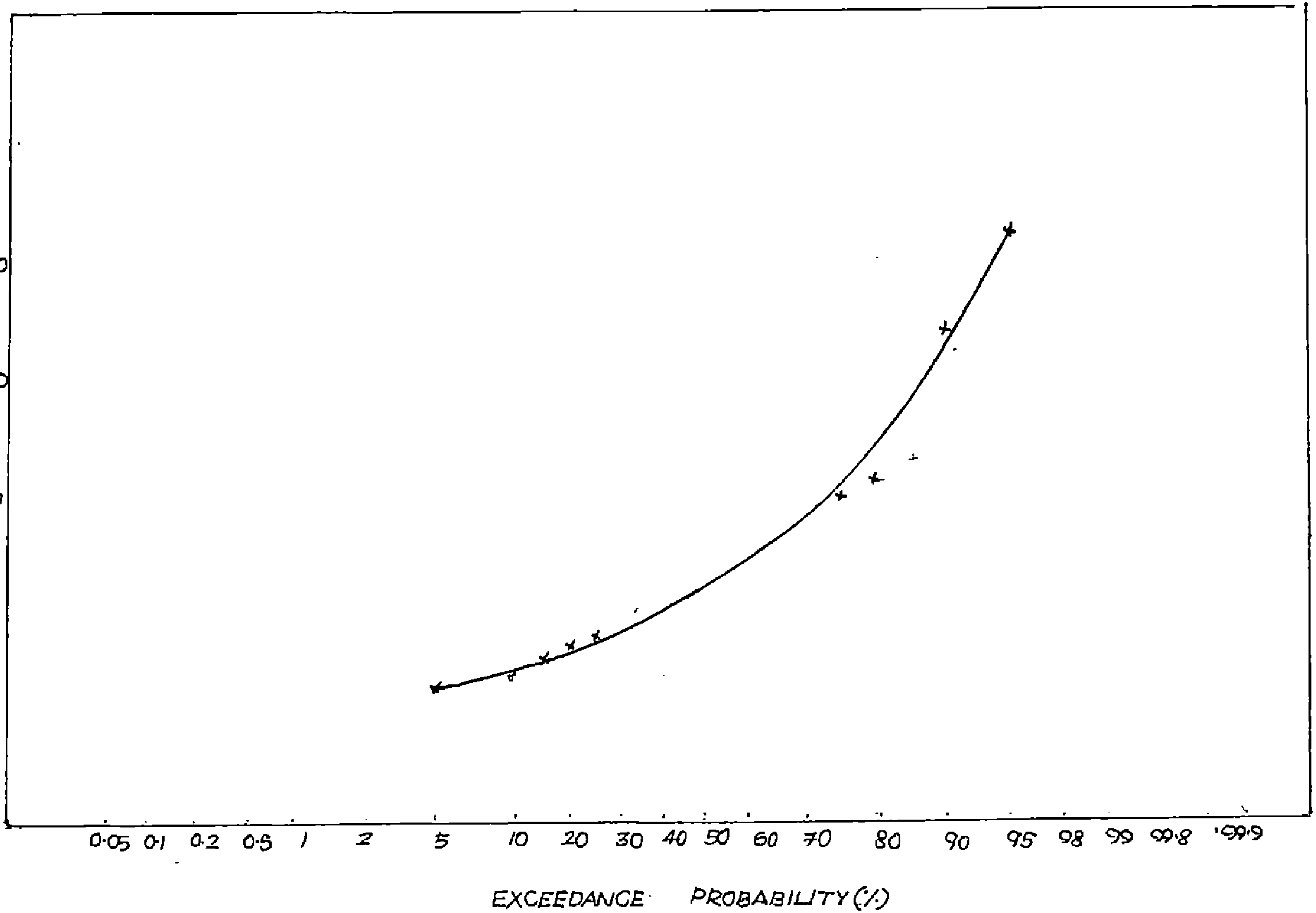


Fig. 18 PROBABILITY CHART FOR THE MONTH OF FEBRUARY AT LOCATION THREE

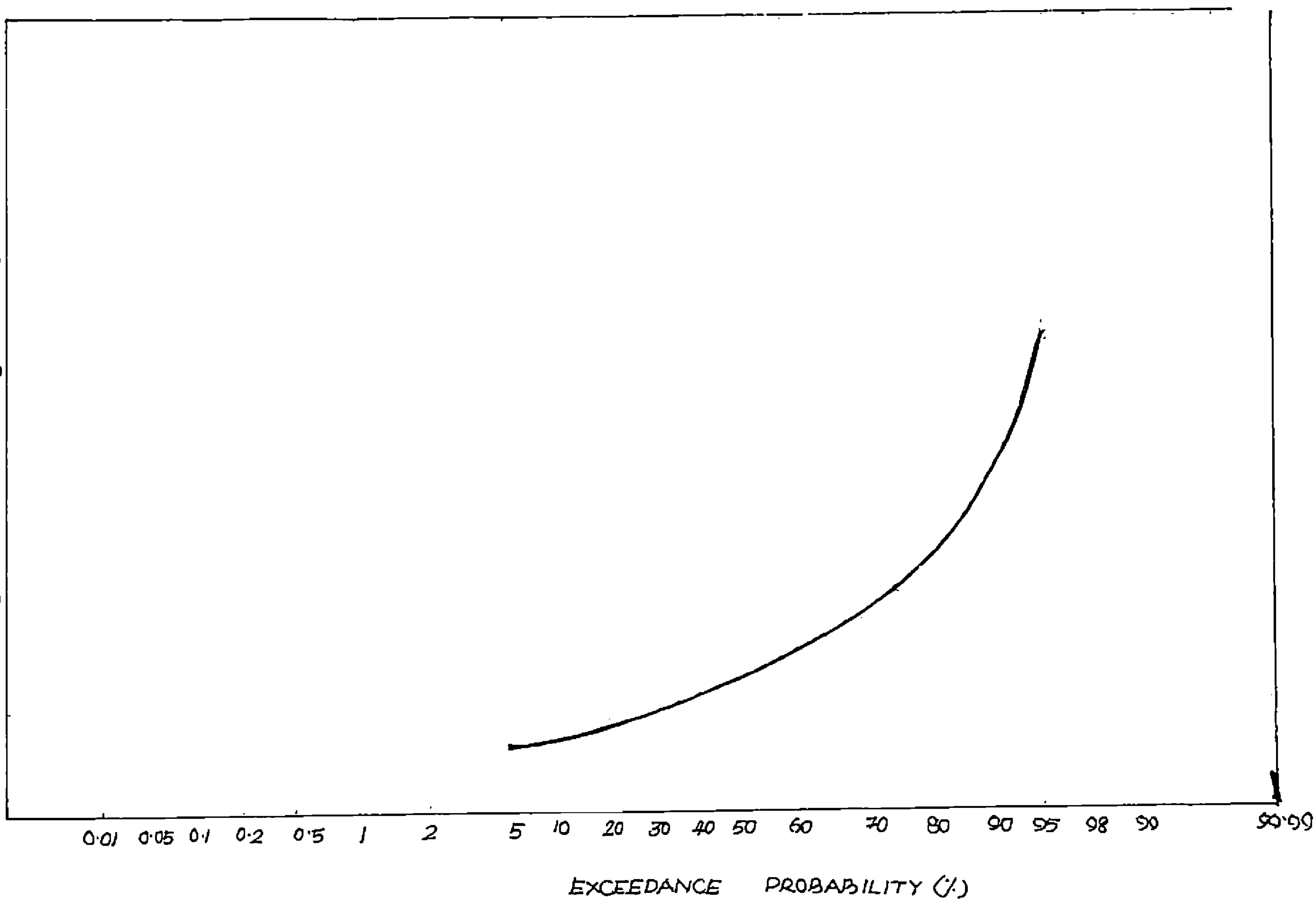


Fig. 19. PROBABILITY CHART FOR THE MONTH OF MARCH AT LOCATION THREE

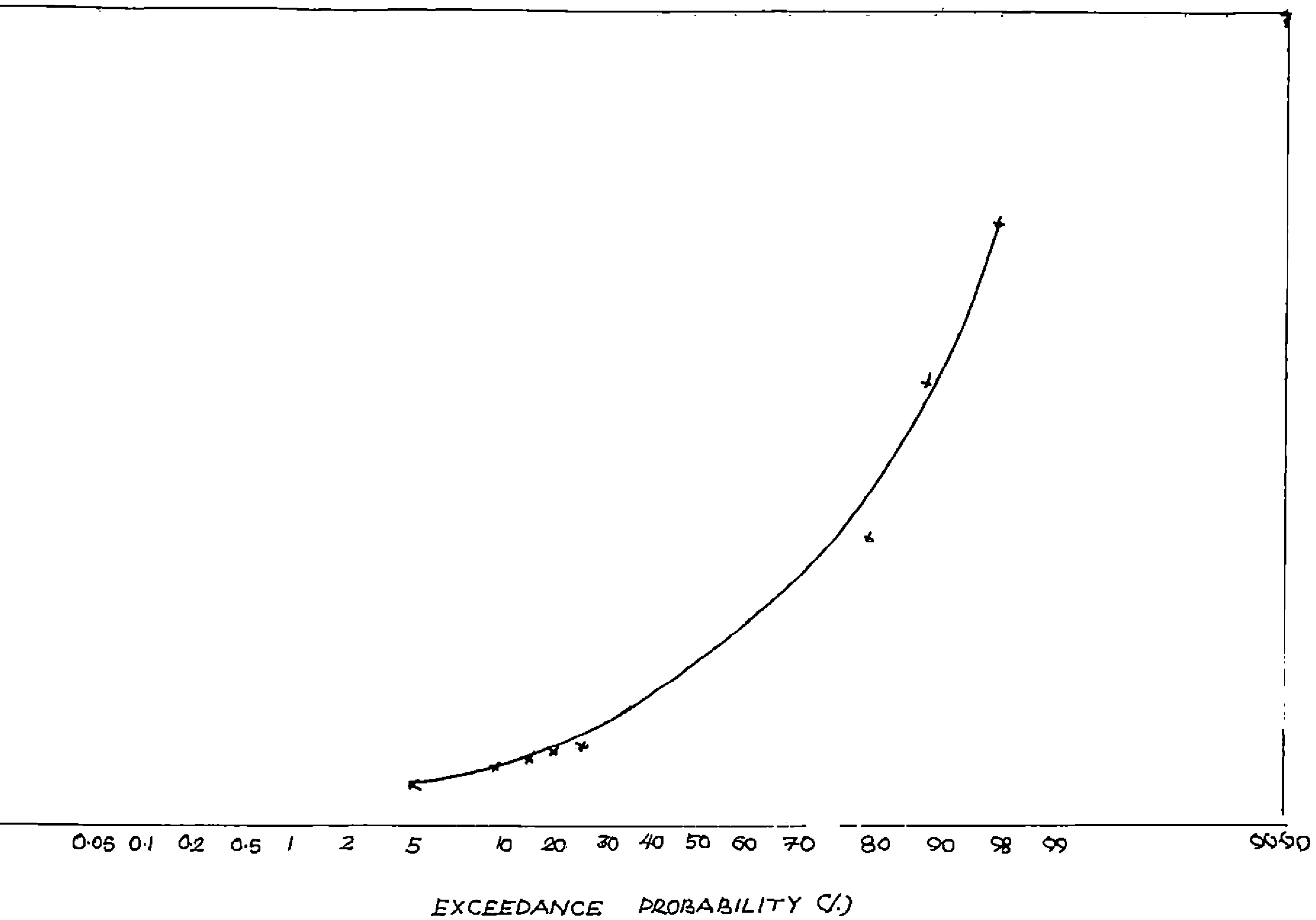


Fig. 20 PROBABILITY CHART FOR THE MONTH OF APRIL AT LOCATION THREE

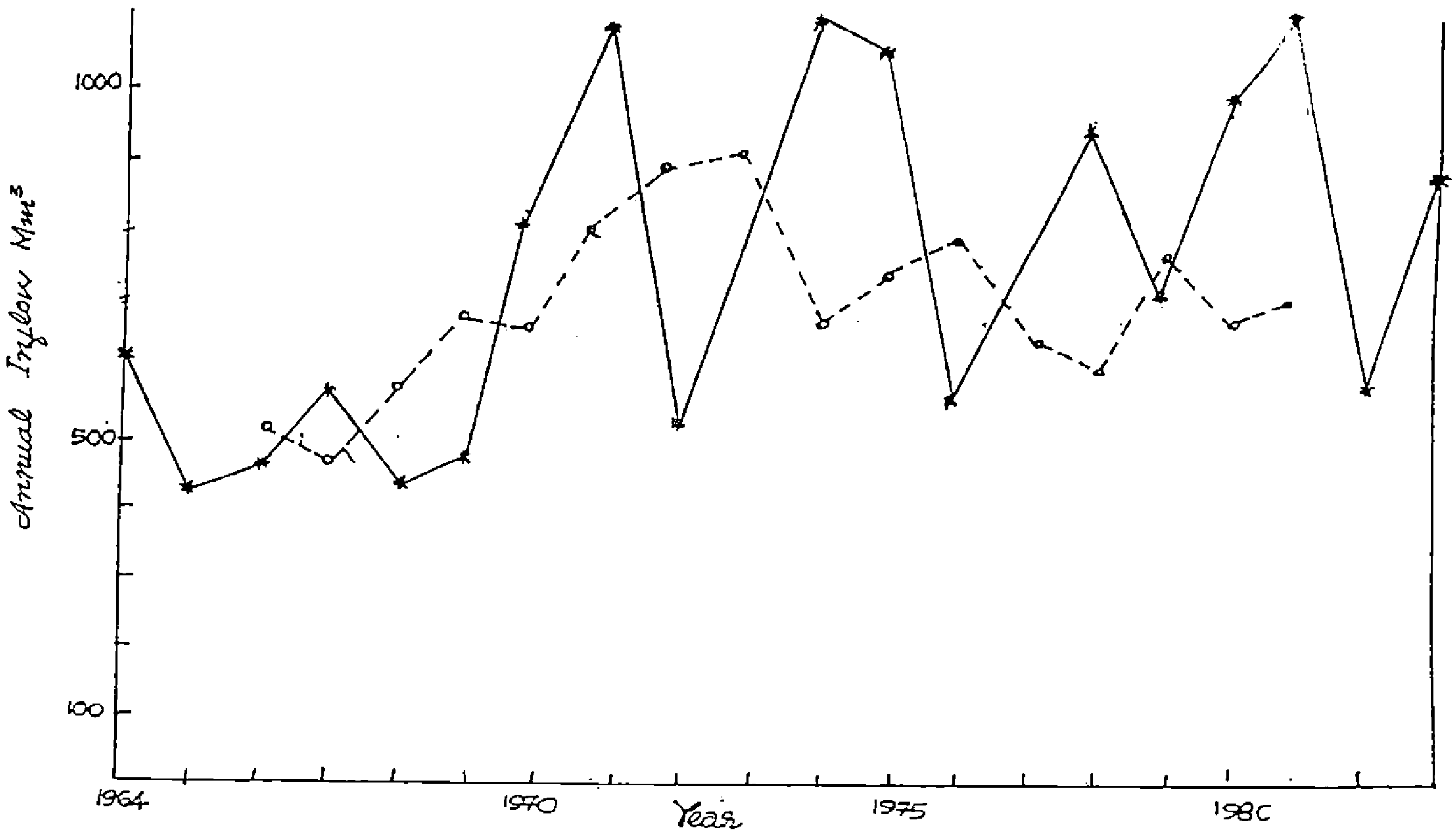


FIG. 21 TIME SERIES PLOT - LOCATION ONE

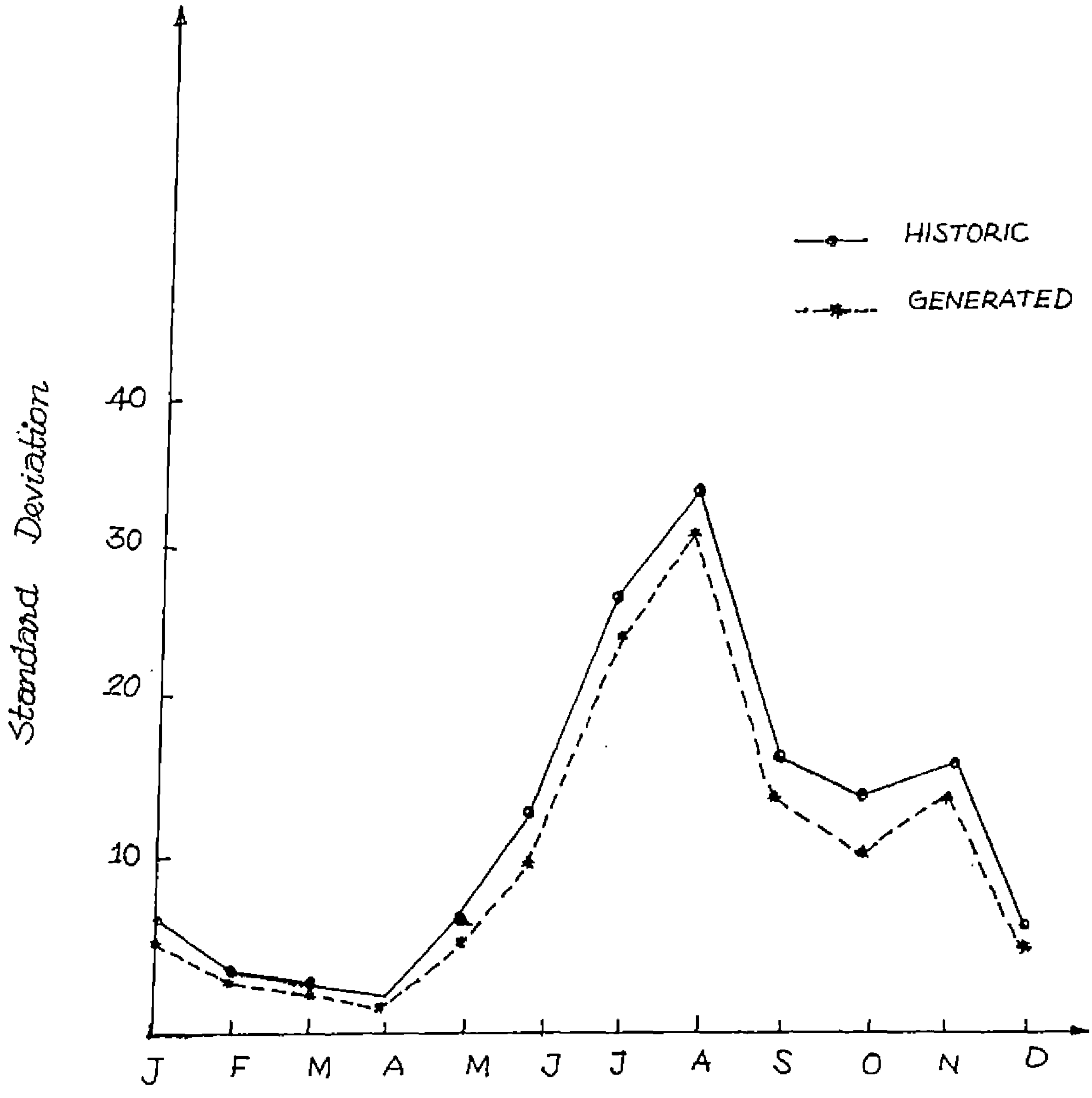


FIG.22. STANDARD DEVIATIONS OF HISTORIC AND GENERATED FLOW AT LOCATION ONE

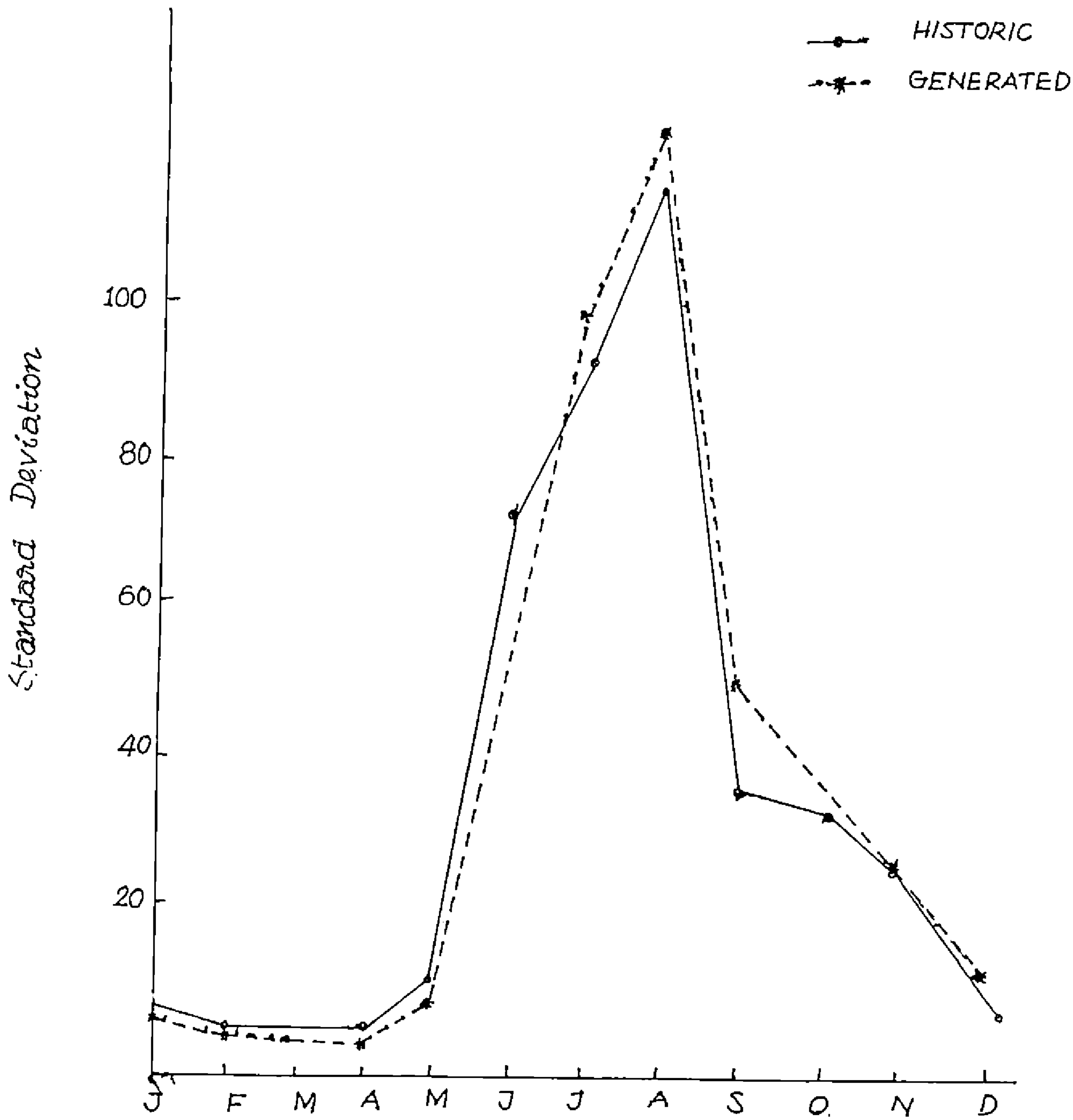


FIG. 23. STANDARD DEVIATIONS OF HISTORIC AND GENERATED FLOW AT LOCATION TWO

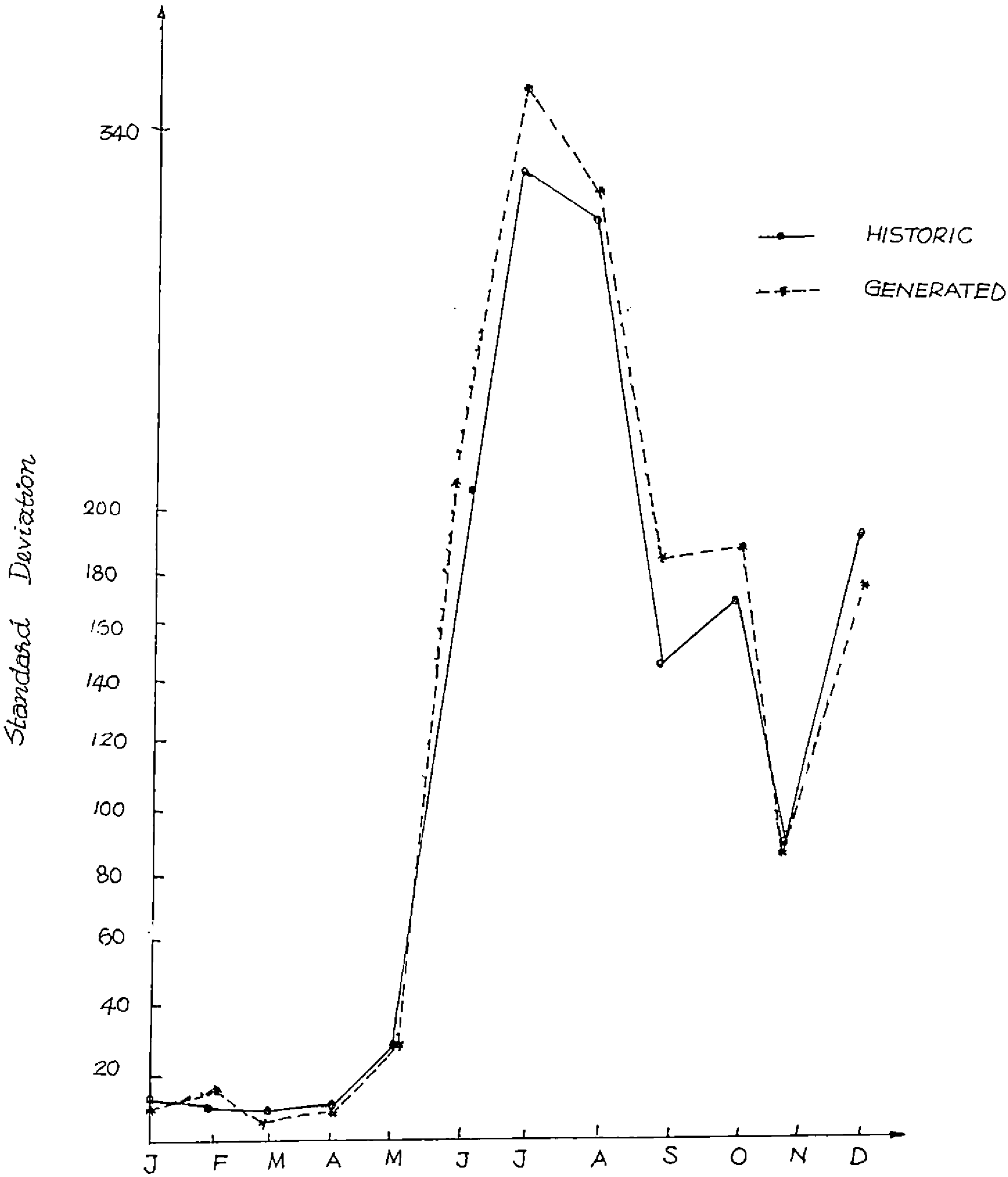


FIG. 24 STANDARD DEVIATIONS OF HISTORIC AND GENERATED FLOW AT LOCATION THREE

4.2 Statistical analysis

The monthly streamflow data has been checked for its consistency with normal distribution. The ranges of values for location two are shown in Table 4. It is seen that the streamflows are mostly consistent with normal distribution. The mean monthly inflows to the three locations are plotted in Fig. 5. The statistical analysis shows that flows generated by the model agree with the trend of historic flows.

Weibull's method is used for the frequency analysis of the monthly streamflow data. Using the tabulated values of the probability, probability curves have been drawn for all the months. Probability curves for various months for locations one, two and three are shown in fig. 9 to 20.

The statistical analysis of annual flows has been done and the values of annual mean, standard deviation and coefficient of correlation are shown in Table 8,9 & 10.The 75 per cent probable annual flows are 133.2, 508.4 and 4210 Mm^3 for location one, two, three respectively. An annual time series plot of the inflows has been made and compared with five year moving average. Figure.21. shows the total annual flows and five years moving average for location two. From the data it is seen that June to October the rivers carry the maximum inflows due to the two monsoons.

The model verification tests reveals that Thomas Fiering model holds good for the site selected. The statistical analysis also ensures the suitability of the model for the site. So the model preserve the statistical parameters like mean, standard deviation and coefficient of correlation. This points out that the simulation model is very effective in the management of water resources systems.

Summary and Conclusion

SUMMARY AND CONCLUSION

The scarcity of water and conflicts among purposes causes the problem of reservoir operation. There is virtually no serious management problem, if plenty of water is available. So an optimisation approach is needed for the optimal utilisation of available resources.

Here a suitable computer simulation model is developed using the available streamflow data. From the model verification tests it was observed that the Thomas Fiering model holds good for the site selected. Hence data is generated for a period of hundred years. The statistical comparison of the synthetic data and the historical data assures that the generated data can be treated as equal to the historical data.

The comparison of statistical parameters of historical and generated data includes the comparison of mean, standard deviation and coefficient of correlation computed from generated data with the actual value of those statistics computed from the historical data. From the Table 8-10 which compares the various statistical parameters of both historical and generated flows, it can be seen that the model chosen very much holds good. The mean monthly flow of 21.15 Mm^3 obtained from observed data of location 1 compares favourably with the monthly mean of 18.01 Mm^3 obtained from generated streamflow data. The values of standard deviation of historic data shows good agreement with the corresponding parameter per synthetic data.

There is good agreement between the flow duration curves of both observed and synthesised data for all the months. As far as the preservation of the historical statistics is concerned, the coefficient of skewness was also well preserved.

The simulation model could preserve the mean, the standard deviation and the correlation coefficient. However, the performance of the stochastic model is to be evaluated by applying the different generated sequences obtained using the model in the water resources system under consideration.

The study on computer simulation shows that the model developed is an effective tool for the reservoir systems proper management.

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Appendices

APPENDIX I

PROGRAM LISTING FOR UNIVARIATE THOMAS FIERING MODEL FOR STREAMFLOW GENERATION

```
C
C     UNIVARIATE THOMAS FIERING MODEL FOR GENERATION OF STREAMFLOW
C
      COMMON B(12), R(12)
      DIMENSION Q(480), WQ(480), RES(480), TITLE(80),SYNQ(1200),E(1200),
     1MONS(12), AVEMON(12), SDMON(12),GAVEMON(12),GSDMON(12),DAVEMON(12)
     1,DSVMON(12)
C     Q IS THE INPUT  SERIES  OF FLOWS, WQ IS THE WORKING TRANSFORMATION
C     OF  Q, MONS HOLDS THE MONTH BY TITLE
C     RFS IS THE RESIDUAL FROM THE FIT
C     B AND R ARE THE SLOPES  OF REGRESSION AND CORRESLATION COEFFICIENT
C     AVEMON, SDMON ARE MONTHLY MEANS AND STANDARD DEVIATIONS.
C     SYNQ AND E ARE GENERATED SERIES AND GENERATED RESIDUALS FOR 100 YR
C     INPUT SECTION
      WRITE(16,444)
C444  FORMAT(5X,'GENERATED FLOWS USING THOMAS FIERING MODEL WITH LOG NOR
C    1MAL TRANSFORMATION'//)
444   FORMAT(5X,'GENERATED FLOWS  USING THOMAS FIERING MODEL WITH SQUARE
     1ROOT TRANSFORMATION'//)
      NYEARS=14
C     READ (12,2)NYEARS
2     FORMAT(I4)
      WRITE(16,1000)NYEARS
1000  FORMAT(15X,'NO. OF YEARS DATA='.I3/)
      WRITE(16,300)
300   FORMAT(1X,119('*')/6X,'JUN',5X,'JUL'/6X,'AUG',7X,'SEP',6X,'OCT',6X
     1,'NOV',5X,'DEC',5X,'JAN',6X,'FEB',7X,'MAR',7X,'APR',6X,'MAY',1X,11
     29('*'))
      N=NYEARS*12
      NA=N-1
      READ(12,103)(Q(I),I=1,N)
103   FORMAT(7X10.3/5F10.3)
      WRITE(16,105)(Q(I),I=1,N)
105   FORMAT(5X,' ******* FLOWS *****'/(12F9.1)
      CALL EXAM(Q,NYEARS,DAVEMON,DSDMON)
      DO 999 I=1
C     Q(I)=ALOG(Q(I))
      Q(I)=SQRT(Q(I))
999   CONTINUE
      WRITE(16.300)
      WRITE(16,666) (Q(I),I=1,N)
666   FORMAT(5X,'SQUARE ROOT VALUES OF ACTUAL FLOWS'////(12F
      CALL EXAM(Q,NYEARS,DAVEMON,DSDMON)
      DO 303 I=1,12
      AVEMON(I)=DAVEMON(I)
303   SDMON(I)=DSDMON(I)
```

```
      DO 7  I=1,N
      J=MOD(I,12)
      IF(J.EQ.0) J=12
 7    WQ(I)=Q(I)-AVEMON(J)
      DO 8 I=2,N
      J=I-1
      K=MOD(I,12)
      A=B(K)*WQ(J)
      RES(J)=WQ(I)-A
 8    CONTINUE
      WRITE(16,109)(RES(I),I=1,NA)
 109  FORMAT('RESIDUALS OF FIT'/9X,11F9.1/(12F9.1))
C     EXAMINE RESIDUALS
      CALL BASIC(RES,AVER,SD,NA)
     .WRITE(16,110)AVER,SD
 110  FORMAT(//'MEAN OF RESIDUALS IS =',2X,F9.3,5X,'AND VARIANCE= IS',3X
     1,F9.3)
      CALL RANDOM(E,1200)
      DO 10 I=1,12
      COR=R(I)
  10  TITLE(I)=SDMON(I)*SQRT(1.0-COR*COR)
      SYNQ(1)=B(1)WQ(N)+E(1)*TITLE(1)
      DO N9 I=2,1200
      J=I-1
      K=MOD(I,12)
      IF(K.EQ.0)K=12
  9   SYNQ(I)=B(K)*SYNQ(J)+E(I)*TITLE(K)
C     MONTHLY MEANS
      DO 31 I=1,1200
      J=MOD(I,12)
      IF(J.EQ.0)J=12
  031 SYNQ(I)=EXP(SYNQ(I)+AVEMON(J))
  31  SYNQ(I)=(SYNQ(I)+AVEMON(J))**2
C     EXAMINE GENERATED DATA
      WRITE(16,300)
      WRITE(16,106)(SYNQ(I),I=1,1200)
      CALL EXAM(SYNQ,100,GAVEMON,GSDMON)
 106  FORMAT('*********GENERATED FLOWS FOR 100 YEARS *******'/////
     1(12F9.2))
      STOP
      END
      SUBROUTINE RANDOM(E,N)
      DIMENSION E(N)
      IX=1073741823
      DO 20 I=1,N
      CALL GAUSS (IX,1.0,0.,V)
 20   E(I)=V
      RETURN
      END
      SUBROUTINE EXAM(Q,NYEARS,AVEMON,SDMON)
C     A SUBROUTINE TO CALCULATE MONTHLY MEANS, SD.SLOPES & CORRELATIONS
      COMMON B(12),R(12)
      DIMENSION Q(1),WORKI(100),WORKJ(100),AVEMON(12),SDMON(12)
      N=NYEARS*12
      DO 20 I=12,N,12
```

```
      J=1,12
 20   WORKI(J)=O(I)
      CALL BASIC(WORKI,AVEMON(12),SDMON(12),NYEARS)
      DO 21 I=1,12
      M=I-1
      IF(M.EQ.0)M=12
      DO 22 J=I,N,12
      K=(J+11)/12
 22   WORKJ(K)=B(J)
      CALL BASIC(WORKJ,AVEMON(I),SDMON(I),NYEARS)
      IF(I-1) 24,25,24
 25   NYEARS=NYEARS-1
      A=WORKJ(1)
      DO 26 IJ=1,NYEARS
 26   WORKJ(IJ)=WORKJ(IJ+1)
 24   CALL BORREL(WORKI,WORKJ,AVEMON(M),AVEMON(I),SDMON(M),SDMON(I),B(I)
     1,R(I),NYEARS)
      IF(I-1)27,28,27
 28   NYEARS=NYEARS+1
      NN=NYEARS-1
      DO 20 IJ=1,NN
      IK=NYEARS-IJ
 29   WORKJ(IK)=WORKJ(IK-1)
      WORKJ(1)=A
 27   DO 23 K=1,NYEARS
 23   WORKI(K)=WORKJ(K)
 21   CONTINUE
C     OUTPUT INFORMATION FOR CHECKING
      WRITE(16,106)AVEMON
      WRITE(16,114)SDMON
      WRITE(16,107)B
      WRITE(16,115)R
 106  FORMAT(4X,'MEANS'/12F9.2)
 114  FORMAT(4X,'STANDARD DEVIATIONS'///12F9.2)
 107  FORMAT(//'SLOPES'///12F12.4)
 115  FORMAT(//'CORRELATIONS WITH PREVIOUS MONTH'//12F9.3)
      RETURN
      END
      SUBROUTINE BASIC(X,AVER,SD,N)
      DIMENSION X(1)
      SX=0.0
      SSX=0.0
      RN=1.0/FLOAT(N)
      DO 1 I=1,N,1
      A=X(I)
      SX=SX+A
      AVER=SX*RN
      DO 2 I=1,N
      A=X(I)
 2    SSX=SSX+(A-AVER)*(A-AVER)
      SD=SQRT(SSX/FLOAT(N-1))
      RETURN
      END
      SUBROUTINE BORREL(X,Y,XMEAN,YMEAN,SDX,SDY,SLOPE,R,N)
      DIMENSION X(1),Y(1),WX(100),WY(100)
```

```
      DO 1 I=1,N
      WX(I)=X(I)-XMEAN
      WY(I)=Y(I)-YMEAN
      SSX=0.0
      SSY=0.0
      DO 2 I=1,N
      A=WX(I)
      B=WY(I)
      SXY=SXY+A*B
      SSX=SSX+A*B
2     SSY=SSY+B*B
      SSX=SQRT(SSX)
      R=SXY/(SSX*SSY)
      SLOPE=R*SSY/SSX
      RETURN
```

SYNTHETIC GENERATION OF STREAMFLOW DATA USING COMPUTER SIMULATION MODEL

by

Levan K. V.

ABSTRACT OF A THESIS

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ABSTRACT

A greater emphasis has to be laid in the planned optimum utilisation of the available water resources due to the increasing demand for agricultural, domestic and industrial purposes. Though the country has been favoured with plentiful rainfall, the spatial and temporal distribution is quite uneven and erratic resulting in droughts and floods in several parts of the country. Kerala experiences severe shortage of water for domestic, irrigation and hydropower generation during the summer months. The need for an assured supply of water for the summer months has become highly essential for the state. Therefore the present need of the state is the scientific approach in water resources planning to achieve optimum use and conservation of available water resources. Considering this an effort has been made to develop a computer simulation model for the synthetic generation of streamflow data for Chaliyar, one of the larger basins of region the state

The streamflow data is are needed for various purposes as far as the water resources system is concerned. However, the available data for the required duration is inadequate. So we have to generate synthetic data.

The data was collected from different river gauging stations for different durations. A suitable mathematical model namely Thomas Fiering Model was developed for the generation of synthetic data. The model was fitted for the observed monthly streamflows. The validity of the model was checked by comparing the statistical parameters of historical and generated data and by comparing the flow duration curves.

It is seen that the model preserves various statistical parameters like mean, standard deviation and correlation coefficient. The study reveals that the computer simulation model developed is a very effective tool in the proper management of water resources system.