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PROCEDURES FOR SYSTEMATIC PROCESSING OF RAINFALL DATA

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PREFACE

Adequate hydrological data are essential for planning and management of engineering projects. In our country various organisations are involved in collection of hydrological and other related data. These are generally raw data and cannot be used directly in most hydrological analysis and design work. Therefore, processing of such data is essential to make them usable for various studies. Rainfall is the most important meteorological parameter among all types of hydrological data, which determines the quantity of runoff in a stream directly as overland flow and indirectly as subsurface and ground water flow. The data collected from field have to be processed to make it more accurate and suitable for further analysis.

Manual scrutiny for carrying out processing has obvious limitations. When the volume of the data is increased, it becomes impracticable to go in for manual methods. With the availability of modern computers, the processing can be done using various softwares available for this purpose.

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ABSTRACT

Hydrometeorological analysis forms an important and integral part of hydrological research. One of the important parameters needed for this purpose is the rainfall which itself forms a part of the hydrological cycle.

Rainfall data is collected by a number of organisations. It is a common experience that the rainfall data in its raw form contain many gaps and inconsistent values. As such preliminary processing of this data is essential before it is put to further use in analysis. Processing of the data has two major objectives. One is to evaluate the data for its accuracy and the other is to prepare the data in a most usable form to the users. In earlier times the processing was done manually. The need for use of faster methods of processing the data has been felt with the increase in the number of data records for processing and this led to the use of computers.

The present report is an attempt to compile out the procedures for systematic processing of rainfall data. The concepts of rainfall data processing etc. have been discussed. It provides computer programs which are meant for processing and analysis of rainfall data collected from various sources. Different well documented computer programs, their description with input specifications and test input are given in Appendices.

1.0 INTRODUCTION

Advances in hydrology are dependent on good, reliable and continuous recording, processing and analysis of hydrologic variables. This forms an important and integral part of hydrological research. One of the important parameters needed for this purpose is the rainfall which itself forms a part of the hydrological cycle.

The rainfall data are collected by a number of organisations as time series data. Once data is collected, the next important and necessary step is their proper storage. It is a common experience that the rainfall data in its raw form would contain many gaps and inconsistent values and as such preliminary processing of rainfall data is essential before it is put to further use. Processing of the data has two major objectives. One is to evaluate the data for its accuracy and the other is to prepare the data in a form appropriate for subsequent analysis. In earlier times the processing was done manually. The need for use of faster methods of processing the data has been felt with the increase in the number of data records for processing and this led to the use of computers. This results in manual processing techniques becoming totally obsolete, except for individual studies.

1.1 Use of Computers in Processing and Analysis of Rainfall Data

Rainfall data forms a primary input to many hydrological studies. With the use of computers it has become possible to increase the frequency of observations and number of gauges included in the analysis.

It is possible to have computers directly receiving the rainfall data on line and store them for further use. Even in case of well-maintained rainfall records often some data inconsistencies arise. Therefore, it is essential to process the data to detect the missing and erroneous data, locate errors and rectify them before the data could be put to further use.

Manual scrutiny has obvious limitations. Human errors are invariably associated with such procedures. However, when the volume of data is increased it becomes impracticable to go in for manual methods. Probably, it may take a month's time to analyse 20 stations having 50 years data, for which computer may take few seconds. Estimation of missing data, adjustment of data to obtain homogeneity and data conversion are some of the components in the processing of rainfall data. Statistical analysis of the data is carried out to understand the characteristics of the data. For example the mean and variance of the rainfall data at a station give an idea of the rainfall.

Higher order statistics such as the skewness and kurtosis may be needed in some cases. Often, frequency distribution is also determined in order to observe numerically how the data are arranged and to make frequency statements. The data is used to fit several frequency distributions to get a best fit distribution. Mean areal rainfall over a given catchment in an important input for several hydrological models. Computer programmes can be made and used to help in for this purpose.

A number of computer programmes have been developed and documented in many countries. HEC-4, FILLIN-1, MOSS-111 and MAP are some such programmes. The National Institute of Hydrology has also developed a number of computer programmes for processing and analysis of rainfall data.

2.0 CONCEPT OF DATA PROCESSING

Data processing may be defined as any systematic procedure through which basic information is transposed into more accessible for or directly usable form. It covers data preparation, data entry and transfer to the data base, data validation, data correction, filling of missing data, data compilation and analysis, data retrieval and data dissemination/publication of yearbooks. Basically, the aim of data processing is to manipulate the raw data and to put it in a proper form and extract the required information from it.

The processing activities are divided into primary and secondary processing. The primary processing consists of the data validation, i.e., removing the random and systematic errors, if any, from the raw data and putting it in a proper format. The secondary processing includes deriving some information from the data such as maximum, minimum, mean, daily, monthly, yearly values using rainfall data etc. Fig.1 shows a flow chart of general-purpose data processing framework.

2.1 Data Processing Operations

In data processing cycle, various activities are carried out in different situations. These activities are called data processing operations. They are as follows:

2.1.1 Recording

This step involves the recording of data in some form that allows it to be handled conveniently in any type of system being used. It refers to the transfer of data in some form or document.

2.1.2 Coding

As a means of further reducing the amount of data to be recorded or processed, abbreviated codes are often used to condense data. This results in saving time, effort and storage space.

2.1.3 Duplicating

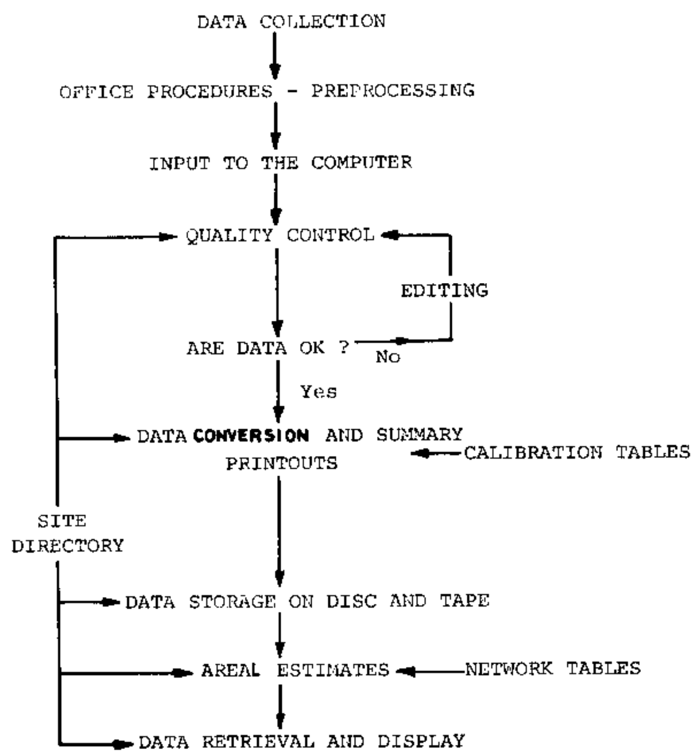

FIGURE 1 - FLOW CHART SHOWING THE GENERAL DATA PROCESSING FRAME WORK

This operation consists of reproducing the data in to many forms or documents. Duplicating may be done while the data are recorded manually, or it may be done afterwards, by some machine.

2.1.4 Verifying

Since recording is usually a manual operation, it is important that recorded data are carefully checked for any errors, using graphical and/or statistical techniques and inter station comparison.

2.1.5 Correction

In this step the erroneous data are corrected or replaced by missing value indication.

2.1.6 Filling in of Missing Data

The interpolation or regression techniques are applied to the data for filling in of the missing values.

2.1.7 Classifying

This operation separates data into various categories. It can be done in various ways.

2.1.8 Conversion

Conversion is a means of transforming data from one form to another. It facilitates easy processing of data.

2.1.9 Merging

This operation takes two or more sets of data, all sets having been sorted by the same key, and put them together to form a single sorted set of data.

2.1.10 Comparing and Analysis

In this step, factors such as nature, type, proportion, relationship, order or relative value of data are compared with existing one.

2.1.11 Calculating

It involves performing numerical calculations with the data.

2.1.12 Table Look up, Searching, Retrieving

It refers to finding specific data item in a sorted collection of data.

2.1.13 Summarizing

It is the process of condensing data so that the main points are emphasized.

Summarizing generally involves listing, tabulating and totaling of each list.

2.1.14 Report Preparation

The processed information that results from the data processing cycle is known as output. Report preparation is the processed information in any kind of output medium.

3.0 COLLECTION OF RAINFALL DATA

Advances in hydrology are dependent on good, reliable and continuous measurements of the data. These measurements are recorded by a wide range of methods, from the simple writing down of a number by an observer to the advanced electronic recording.

The data from conventional raingauge networks is most commonly in the form of daily read rainfall. This observation technique yields a simple regular time series. In remote areas, particularly where a reliable on-site observer cannot be found, monthly read raingauges are used, again producing a regular time series. For the same reasons, and usually in areas where rainfall is very sporadic, "accumulating" raingauges are used. These are visited infrequently, usually after the rainfall was expected, or was known to have occurred. Such data are processed as an irregular time series. An alternative approach is to apportion the accumulated total rainfall according to the totals recorded at adjacent daily stations, producing a regular time series. Data from these manually read totalizing raingauges comprises by far the greatest input into any rainfall processing system.

Now a days, automatic raingauges are widely used, normally recording data in chart form. There are two main considerations in abstracting digital data from this type of chart: whether the abstraction should be done manually or automatically and whether the abstraction should be made at regular or irregular time intervals. The manual versus automatic question is common to all types of chart for whatever data.

Regardless of the abstraction techniques, digitised rainfall charts are ultimately stored as irregular series because storing rainfall total for, say 15 minutes during extended periods without rainfall would be extremely wasteful of storage space.

3.1 Sources of Errors in Hydrological Data

The two basic error types are random and systematic. Either condition may be isolated or persistent in time. Isolated errors may occur at regular or irregular time intervals, while persistent errors may be constant and changing (normally increasing) with time. This latter case is relevant to many hydrological data errors, and fortunately is one of the easiest types of systematic error to detect. The errors may be associated with instrumentation, station condition, observation and recording, transmission, coding, transcription etc.

3.1.1 Systematic Errors

Systematic errors are essentially due to malfunctioning of the instrument, wrong exposure conditions and/or lack of knowledge of the observer. The adjustment needs to be made to get a near accurate estimate of rainfall from a measured rainfall report for the following errors:

(a) Error due to the systematic wind field deformation above the gauge orifice,
(b) Error due to the wetting loss on the internal walls of the collector,
(c) Error due to evaporation from the container (generally in hot climates),
(d) Error due to the wetting loss in the container when it is emptied,
(e) Error due to blowing and drifting snow,
(f) Error due to splashing in and out of water, and
(g) Random observational and instrumental errors

The net error due to blowing and drifting snow and due to splash in and out of water can be either negative or positive while net systematic errors due to the wind field and other factors are negative.

Since for the errors listed at (e) and (f) above are near zero, the general model for adjusting the data from most gauges takes the form

$$P_k = X\,P_c = K\,(P_g + \Delta P_1 + \Delta P_2 + \Delta P_3)$$

where P_k = Adjusted rainfall amount
K = Adjustment factor for the effects of wind field deformation
P_c = Amount of rainfall caught by the gauge collector
P_g = Measured amount of rainfall in the gauge
ΔP_1 = Adjustment for the wetting loss in the internal walls of the collector
ΔP_2 = Adjustment for wetting loss in the container after emptying
ΔP_3 = Adjustment for evaporation from the container

The data needed to make the adjustments include wind speed, rain drop size, rainfall intensity, air temperature, humidity and other characteristics of the gauge site. The design of data validation routines requires an appreciation of the possible sources of data error. By identification of these sources, routines may be developed in specific and hence, more effective manner.

All the above errors arise on translating the actual values of a parameter at a sampling point of the value, or some derived value, stored in the database. However, even if this process was completely error free, there is another factor that the validation system should be designed to monitor. This factor is the representativeness of the sampling point in terms of the spatial variation of the sampled parameter. Thus, while a raingauge may record with absolute accuracy the rainfall at a site, the site itself may be in a local area of rain shadow totally unrepresentative of the general nature of the area. Since the point data will undoubtedly be used to derive areal values, sets of unrepresentative areal values will be generated.

3.1.2 Random Errors

Some of the random errors could arise due to spilling of the water when transferring it to the measuring jar, leakage into or out of the receiver, observational error etc. The other errors that could be due to the observer are:

- Misreading and transposing digits
- Misrecording because of faulty memory
- Recording the data at a wrong place on the recording sheet
- Misplacing the decimal point
- Making readings at improper interval
- Incorrect dating of the report
- Making an estimate of the rainfall in some cases because of nonavailability or other problems with the gauge
- Incorrectly reading or communicating the data to a reporting centre etc.

It may, therefore, appear that automation may be the solution to reduce the error. However, even without human intervention chances of erroneous readings may be possible because of evaporation from gauge, overflowing gauge, mechanical or electrical malfunctions etc.

3.2 Storage of Rainfall Data

In India, rainfall data collected by state organisations is generally stored only in the form of printed records. The formats for storing the daily and hourly rainfall data by India Meteorological Department are as follows:

3.2.1 Format of Daily Rainfall Data

The daily rainfall data Were Punched in a 24 card format as shown in fig.2, until 1970 and was switched over to a 31 card format as shown in fig.3, since 1971.

In the 31 card format, the data of 12 months for each day are punched on each card together with station related information, year and date. In the 24 card format, each month's rainfall data are punched on 2 cards, 16 days data on the first card and

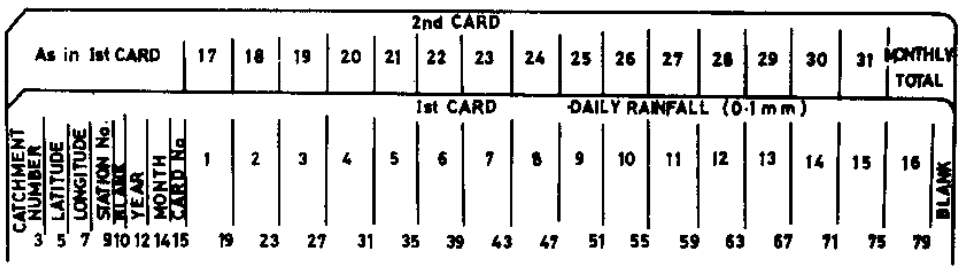

FIG. 2: 24 CARD DAILY RAINFALL DATA FORMAT

15 days data and monthly total on the second card.

3.2.2 Format of Hourly Rainfall Data

The format for storage of hourly rainfall data is shown in fig.4. The first card contains besides station code, year, month, date and card number, data of hourly rainfall corresponding to 1st to 16th hour. The second card contains besides station code and other details, data of hourly rainfall, time of maximum rainfall occurrence and total rainy duration in the day, given in hours and minutes.

4.0 PROCESSING OF RAINFALL DATA

Processing and analysis of rainfall data constitute an important component of hydrological analysis. The advent of computers, new techniques of hydrological analysis and special hydrological problems have placed new demands on analysis of rainfall data.

The main aim of processing rainfall data reflect the important data uses and, hence, different time bases of rainfall observation. Data from recording rain gauges are analysed to extract information relating to storm characteristics, whilst data from totalizing gauges serve primarily to quantify the availability and variation of water resources.

Before analysing the data from recording raingauges, it is necessary to produce regular interval time series from irregular series in which the data are usually input. If the data have been subjected to a previous stage of validation, this time series format conversion may already have taken place.

Whether derived from recording or totalizing gauges a first priority, if not performed as part of the data validation, is the apportionment of accumulated rainfall totals and, wherever possible, the filling of data gaps. Accumulated rainfall totals are common in daily raingauge networks when say, over a weekend, a raingauge was not read. However, they are also common with tipping bucket gauges reporting by telemetry. If reports of bucket tips are not received during a rainfall period, the first report received after the gap will contain the accumulated number of bucket tips. The difference between this accumulation and that provided by the last report received must be apportioned in a sensible manner.

The techniques for apportioning accumulated totals and for estimating completely missing values are essentially the same. Exactly the same techniques may be applied to shorter period data from recording raingauges, but estimates of lower quality will be obtained because of the fewer adjacent stations and the dynamic nature of short-term rainfall events.

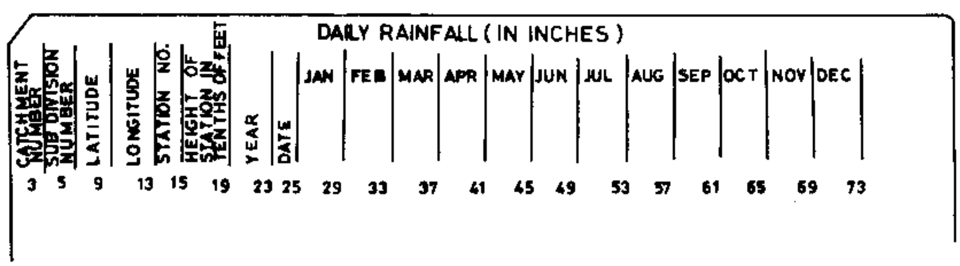

FIG.3. 31 CARD DAILY RAINFALL DATA FORMAT

4.1 Preliminary Scrutiny

Before the rainfall data is stored for processing, it becomes necessary to carry out preliminary checks, manual sorting, etc. Improper registering of data includes entering data against wrong time and date, alteration of figure etc. The official at receiving station could check reasonableness of the report by judging the report based on experience and statistics of the station and region to which the station belongs. Some of the parameters used for checking are values of normal rainfall, highest observed rainfall, corresponding to 25, 50 or 100 years return period.

The preliminary processing ensures the completeness of data for the period under consideration in respect of relevant details like station identification, date, time and other visible errors. The reasonableness of the report is checked by using appropriate verification and validation techniques.

4.1.1 Verification

It is very important to verify the reports received from manually observed stations. In case of data received by telemetering raingauges or automated weather stations, the parity check or some other checking process has to be devised and carried out.

4.1.2 Valid Status

Before using or storing rainfall records, the validity of the station should be checked. The worth of rainfall data depends primarily on the instruments, its installation, its site characteristics and its operation by a responsible observer. Therefore, the station should be equipped with standard instrument, with proper identification with respect to its location, latitude, longitude, elevation, district and state to which it belongs and it should be part of a recognised network. It is essential for a hydrologist using this data to have direct knowledge of raingauge station and it is recommended to keep the history of each raingauge station.

4.1.3 Reasonable Report

Copying or registering error of rainfall data includes entering against wrong date and time, misplaced decimal points and alteration of figures etc. Transmitting errors occur while sending the data either through telegram, wireless, telemetering or data transmission by automatic raingauges through VHF or other transmission modes. The reasonableness of the data received from automatic raingauges is checked by judging the report against data based on the history of raingauge and other rainfall studies for the region to which the reporting station belongs.

Before carrying out other tests, it is necessary to check the internal consistency of the records. By considering the possible physical, meteorological and climatological

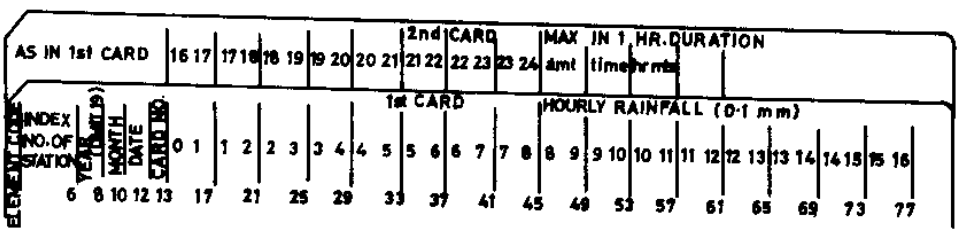

FIG. 4: HOURLY RAINFALL DATA FORMAT

constraints, limits of rainfall for the region of interest could be set and the values of rainfall checked against these limits. Any data falling outside these limits should be suspected and should be screened more carefully after flagging. Rainfall limits which could be used for checking are regional parameters like probable maximum rainfall or return period (25, 50 or 100 year) values and other locally recorded highest rainfall values

One kind of test which could be applied includes a test to see that the hourly report of rainfall is within the reported maximum and minimum values of daily record and a check for occurrence or nonoccurrence of rainfall based on the weather reports. The rainfall values could be checked by examining dew point, cloud amount, type of cloud etc.

In case of rainfall data reported for shorter duration, the total of such short period amounts could be compared with the equivalent long period total rainfall reported.

4.1.4 Checking Reasonableness of a Daily Reported Rainfall

For example, daily rainfall reported from a station is 360.5 mm and the rainfall statistics of the reporting station are:

a) Normal monthly rainfall of the corresponding month	: 350,0 mm
b) Mean ($\bar{x}$) of maximum 1 day rainfall	: 210.6 mm
c) Standard deviation (σ) of maximum 1 day rainfall	: 50.5 mm
d) Highest observed 1 day rainfall	: 285.3 mm
e) 100-year return period value of 1 day maximum rainfall	: 300.0 mm
f) Probable maximum rainfall value of 1 day rainfall	: 370.0 mm

The reported daily rainfall value of 360.5 mm is more than the normal monthly rainfall of the corresponding month and is, therefore, doubtful but reasonable. The reasonableness is checked with other statistics. The value is compared with the mean of 1 day maximum and the highest observed value. The reported value is more than the mean 1 day maximum and the highest ever observed value. It is also more than the 100 year return period value. The values corresponding to ($\bar{x} + \sigma$) and ($\bar{x} + 2\sigma$) are computed. They are 261.1 mm and 311.5 mm respectively. The reported value is higher than both the values.

The reported daily value is compared with the 1 day PMP value which is 370.0 mm. The value is less than the PMP and is, therefore, reasonable and is further checked by spatial consistency.

4.2 Identification of Missing Data

While retrieving data for climatological purpose or inputting data in real time, one often comes across missing data situations. Since blank in a data set is read as zero by computer, necessary software for identifying the blanks and marking them appropriately, need to be developed.

The computer program TAPE.FOR is given in Appendix-I. The programme reads the daily rainfall data from either the 24 card or 31 card format and identifies the missing data periods. The data is then written back on to an output file replacing the missing data by -999. For identifying the leap years the programme uses a subroutine LEAPYR.

4.3 Estimation of Missing Data

Data for the period of missing rainfall data could be filled using estimation technique. The length of period up to which the data could be filled is dependent on individual judgement. Rainfall for the missing period is estimated either by using the Normal Ratio method or the Distance Power method.

4.3.1 Normal Ratio Method

In this method, the rainfall at a station is estimated as a function of the normal monthly or annual rainfall of the station under question and those of the neighboring stations for the period of missing data at the station under question. The computer programme for this method GAPE.FOR is given in Appendix-II

4.3.2 Distance Power Method

In this method, the rainfall at a station is estimated as a weighted average of observed rainfall at the neighboring stations. The weights are taken as the reciprocal of the distance or some power of distance of the estimator stations. The computer programme for this method DISPOW.FOR is given in Appendix-III. The programme uses information on the latitude and longitude as provided by the user and computes the distance of each estimator station from the station whose data is estimated. The station whose data is to be estimated is to be treated as station 1 and its details provided first.

The programme makes use of the 'station characteristics' as provided by the user to adjust the data. The programme can also be used to test the consistency of the data at a particular station.

4.4 Internal Consistency Check

The internal consistency or self consistency checks are applied by using statistical information based on historical data of the station and current data in case of short duration rainfall.

4.5 Spatial Consistency Check

Spatial consistency checks for rainfall data are carried out by relating the observation from surrounding stations for the same duration with the rainfall observed at the station. This is achieved by interpolating rainfall at the station under question with rainfall data at neighboring stations.

4.6 Adjustment of Data

To obtain homogeneity among and within measurements of rainfall, adjustment of data becomes necessary. It has two principal objectives. First is to make the record homogeneous with a given environment and the second is to eliminate or reduce extraneous influences by correcting for change in gauge location or exposure. Adjustments for these errors are made by 'Double Mass Analysis' method which is a graphical method for identifying and adjusting inconsistencies in a station's data by comparing with the trend of reference station data.

In a double mass curve, the accumulated seasonal or annual rainfall values of reference station is taken as abscissa and those of the station under test as ordinate. A change in the regime of the raingauge such as change in exposure, change in location, etc. is revealed by a change in the slope of the straight line fit. The other records are adjusted by multiplying the rainfall values by the ratio of the slope of the later period to the slope of the earlier period.

A computer program DOUBLE.FOR is given in Appendix-IV which handles the computational aspects of Double Mass Analysis.

4.7 Data Conversion

For hydrological analysis, rainfall data of shorter duration is required. The network of recording raingauges in India being small in comparison to that of daily (non-recording) raingauges, it becomes necessary to convert the daily rainfall recorded at totaling gauge into shorter period (usually hourly) intervals either manually or by using appropriate computer program.

A comparison of the mass curves of the recording raingauge stations with those of the non-recording stations would help in deciding which recording raingauges or group of gauges could be considered as representative of which of the non-recording hourly rainfall.

The process of distribution of daily rainfall at nonrecording raingauge stations into hourly rainfall (DAILY.FOR) is given in Appendix-V. This programme converts the daily rainfall data of ORG stations into hourly rainfall data in the ratio of the hourly rainfall values of an appropriate SRRG station for the day. The choice of the SRRG stations for each ORG station has to be made by the user. It also computes the average hourly rainfall values in the catchment during the storm using Theissen polygon method.

4.8 Data Computation

Analysis of rainfall data includes the determination of the following:

(i) For daily series : Daily maximum and minimum values total per month and year and date of occurrence of the extremes as well as the number of wet or dry days.
(ii) For monthly and annual series: 'basic' statistics extremes and fractiles.

For studies of short duration events the regular time series must be produced from recording raingauge data. It is obvious that the time interval selected for producing this time series should be compatible with the duration of interest.

Since the amount of rainfall varies from place to place, it is necessary to install measuring devices at various key points. It is assumed that the amount of rainfall collected in the gauge is representative of a certain area around the point where the measurement is made. The rainfall data of various stations is used to estimate areal rainfall.

4.9 Estimation of Mean Areal Rainfall

The average annual rainfall calculated from the rainfall measured at a raingauge station is a most important hydrological parameter and is used as input in number of hydrological models. It is, therefore, necessary that areal estimates of rainfall be available in a processed form for use directly as input in the hydrological models. Mean areal rainfall is estimated from the data (observed or converted) of rainfall at a number of locations by means of suitable methods.

Rainfall observations from gauges are point measurements and the rainfall process exhibits appreciable spatial variation over relatively short distance. An accurate assessment of mean areal rainfall is a prerequisite and basic input in the hydrological analysis.

It is also well recognised that the catchment rainfall derived from sparsely gauged areas can only be regarded as an index of rainfall and even with an ideal gauge coverage cannot be recognised as true due to wind influence and orographic characteristics.

The choice of the method is dependent on quality and nature of data, importance of use and required precision, availability of time, and availability of the computer. Various methods of computing areal rainfall from point raingauge measurements are as follows :

4.9.1 Arithmetic Average Method

The average depth of the rainfall is the net rain after the application of the areal reduction factors (weightage factor by either Thiessen Polygon method or Isohyetal method) to the rain incident at different stations in any catchment. It is obtained by simply averaging arithmetically the amounts of rainfall at the individual raingauge stations in that area for the time period of concern. It yields good estimates in flat regions if the gauges are uniformly distributed and the rainfall at various stations do not vary widely form the mean.

4.9.2 Thiessen Polygon Method

The Thiessen Polygon method is used with nonuniform stations spacing and gives weights to stations rainfall data according to the area which is closer to that station than to any other station. This area is found by drawing the perpendicular bisector of the lines joining the nearby station so that the polygons are formed around stations. The polygons thus formed around each station are the boundaries of the effective area assumed to be controlled by station. The area governed by each station is planimetered and expressed as a percentage of total area, weighted average rainfall for the basin is computed by multiplying each station rainfall amount by its assigned percentage of area and totaling.

The computation of mean areal rainfall using Thiessen Polygon weights (CATCH.FOR) is given in Appendix-VI.

The advantage of this method is stations outside the catchment may also be used for assigning weights of marginal stations within the catchment. The disadvantage, however, is it assumes that rainfall between two stations varies linearly and does not make allowance for variation due to orography. Also, whenever a set of stations is added to or removed from the network, new set of polygons have to be drawn. If a few observations are missing, it would be convenient to estimate the missing data than to construct new set of polygons.

4.9.3 Isohyetal Method

The isohyetal method employs the area encompassed between isohyetal lines. Rainfall values are plotted at their respective stations on a suitable base map and lines of equal rainfall, called isohyets are drawn. In regions of little or no physiographic influence, the drawing of isohyetal contours is a relatively simple matter of interpolation in which the degree of smoothness of contours and profiles which may be drawn or inferred from their spacing of stations and the quality and variability of the data.

In regions of pronounced orography, where the rainfall is influenced by topography, the analyst should take into consideration, the orographic effects, storm orientation etc. to adjust or interpolate between station values.

The modern computers equipped with plotters have the ability to draw isohyetal maps. Generally, it is preferred to carry out the analysis manually after getting the values plotted on the maps.

The average depth of rainfall is computed by measuring the area between successive isohyets and determining the total volume and dividing by total area. The computation of mean areal rainfall by Isohyetal method (ISO.FOR) is given in Appendix-VII.

4.9.4 Multiple Regression

In this method multiple regression of individual gauge storm total (independent variables) against an average based on isohyetal (dependent variables) is used. A combination of four strategically located gauges was found to give best results. Regression coefficient would provide a table of weighing coefficients for all combinations of gauges. This method would require areal estimate from isohyetal analysis of atleast 20 storms.

It is very well recognized that the areal rainfall estimates derived on the basis of point rainfall observations from a network of sparsely and unevenly distributed rainfall gauges could only be regarded as an index of rainfall. Even with an ideal gauge coverage, the catch from the gauges cannot be considered to be accurate because of wind influence and other exposure conditions.

Radar censed echo intensity reflected by rainfall could provide useful areal estimates of rainfall over areas with few or no raingauges. Rainfall observed by a dense network of rainfall gauges specially set up for the purpose on a temporary basis could be related to echo intensities as sensed by radar to develop reasonable relationships for the area of interest.

4.10 Determination of Maximum Rainfall for Different Duration

Rain storm analysis is the first step in the design storm estimation procedure. A list of all rain periods where the maximum rain amounts were received is made. The computer program MAX.FOR is given in Appendix-VIII, which estimates the maximum rainfall of different duration e.g. 1, 2, 3, 4 and 5 days from the daily rainfall data processed for missing rainfall amounts. It comprises of a main programme and three subroutines, SUM, MAXIM and LEAPYR.

4.11 Cumulated Rainfall Totals

In hydrological analysis the cumulated rainfall totals for different periods such as 10 daily, monthly and seasonal are required for use in the developing of rainfall-runoff relationships and determination of water availability.

A computer program TENDAY.FOR is given in Appendix-IX which computes the ten daily, monthly, seasonal and annual rainfall amounts. The programme uses the output file from the TAPE.FOR to compute the ten daily rainfall totals and the average rainfall during the ten-day period. If the data for any day or days is missing during the ten-day period, the total is computed for the available number of days and the average computed on the basis of the number of days for which data are available. Besides, the monthly, monsoon season and annual total rainfall are also computed.

4.12 Kriging

Kriging is an interpolation technique that provides an estimate and error of estimate for each interpolated points based on portraying the sampled rainfall data sets as a realization of an ergotic stochastic process. The theory rests on "differencing" of n-dimensional spatial processes.

A unique neighbourhood will indicate a kriging scheme which uses every rainfall data point in every interpolation calculation, whereas a moving neighbourhood scheme will use a subset of the rainfall data for each interpolation calculation.

Kriging can be used to make contour maps, but unlike conventional contouring algorithms, it has certain statistically optimal properties. Perhaps most importantly, the method provides measures of the error or uncertainty of the contoured surface. Kriging uses the information from the semivariogram to find an optimal set of weights that are used in the estimation of the surface at unsampled locations. Since the semivariogram is a function of distance, the weights change according to the geographic arrangement of the samples.

This analysis for rainfall data can be done through the modules " Variogram and Kriging" of the software "GEOSTATISTICAL ENVIRONMENTAL ASSESSMENT SOFTWARE" {developed for the U.S. EPA Environmental Monitoring Systems Laboratory in Las Vigas, Nv., by computer science corporation, with Applied Earth Sciences Department of Stanford University. (It is in the Public Domain and may be distributed.freely.)} and "KRIGING" developed by M.I.T., U.S.A.

4.12.1 Punctual Kriging

It is the simplest form of kriging, in which the observations consist of measurements taken at dimensionless points, and the estimates are made at other locations that are themselves dimensionless points.

To simplify the problem, it can be assumed that the variable being mapped is statistically stationary, or free from drift. The value at an unsampled location may be estimated as a weighted average of the known observations. That is, the value at a point p is based on a small set of nearby known control points:

$$Y_p = \Sigma(W_i Y_i)$$

It is expected that the estimate Y_p will differ somewhat from the true (but unknown) Y_p value by an amount we may call the estimation error.

$$\epsilon_p = (Y_p - Y_p)$$

If the weights used in the esitmation equation sum to one, the resulting estimates are unbiased provided there is no drift. This means that, over a great many estimations, the average error will be zero, as overestimates and underestimates will tend to cancel one another. However, even though the average estimation error may be zero, the estimates may scatter widely about the correct values.
This scatter can be expressed as the error variance.

$$S_e = \frac{\sum (Y_p - Y_p)^2}{n}$$

or as its square root, the standard error of the esitmate:

$$S_e = \sqrt{(S_e)}$$

It seems intuitively reasonable that nearby control points should be most influential in estimating the value at an unsampled location on a surface, and more distant control points should be less influential. It also seems resonable to expect that the weights used in the estimation process, and the error in the estimate, should be related in some way to the semivariogram of the surface.

4.12.2 Universal Kriging

A significant problem with punctual kriging is that it will not work unless the recognized variable being mapped is stationary. In the presence of a trend, or slow change in average value, a linear estimator is no longer unbiased. The computed estimates will be systematically shifted upwards or downwards from the true values depending upon the arrangement of the control points and the direction of dip of the surface.

In the parlance of geostatitics, a nonstationary regionalized variable can be regarded as having two components. The 'drift' consists of the average or expected value of the regionalized variable within a neighbourhood, and is a slowly varying, nonstationary part of the surface. The residual is the difference between the actual measurements and the drift. Obviously, if the drift is removed from a regionalized variable, the residuals must be stationary and kriging can be applied to them. Universal kriging can thus be regarded as consisting of three operations: First, the drift must be estimated and removed. Then, the stationary residuals are kriged to obtain the needed estimates. Finally, the estimated residuals are combined with the drift to obtain estimates of the actual surface.

With all the rainfall data , users can construct mean and covarience matrices and can obtain the optimal linear predictor through this analysis. Universal Kriging ia a black box statistical approach which proceeds with differencing until indices of residual stationarity are satisfactory.

4.13 Cluster Analysis

Cluster analysis is the name given to a bewildering assortment of that techniques designed to perform classification by assigning observations to groups so each group is more or less homogeneous and distinct from other groups. There is no analytical solution to this problem, which is common to all areas of classification, not just numerical taxonomy.

The basic data for cluster analysis is a set of N entities (for example, rainfall data) on which p measurements have been recorded. This initial choice of the perticular set of measurements used to describe each entity constitutes a frame of reference within which to establish the clusters, and the choice presumably reflects the investigator's judgement of relevance for the purpose of classification.

4.13.1 Partitioning Methods

They operate on the multivariate observations themselves, or on projections of these observations onto planes of lower dimension. Basically, these methods cluster by finding regions in the space defined by the m variables that are poorly populated with observations, and that separate densely populated regions. Mathematicaly "partitions" are placed in the sparse regions, subdividing the variable space into discrete classes. Although the analysis is done in the m-dimensional spaace defined by the variables rather than the n-dimensional spacae defined by the observations, it

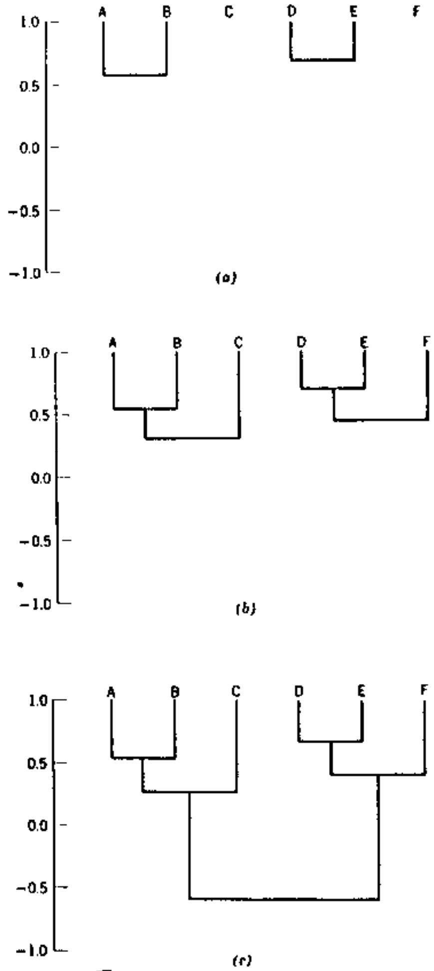

FIGURE 5. (*a*) Dendrogram with initial clusters. (*b*) Connection of remaining objects to clusters. (*c*) Final connection of two clusters, completing dendrogram.

proceeds iteratively and may be extremely time consuming.

4.13.2 Arbitrary Origin Methods

They operate on the similarity between the observations and a set of arbitrary starting points. If n observations are to be classified into k groups, it is necessary to compute an asymmetric n x k matrix of similarities between the n samples and the k arbitrary points that serve as initial group centroids. The observations closest or most similar to a starting point is combined with it to form a cluster. Observations are iteratively added to the nearest cluster, whose centroid is then recalculated for the expanded cluster.

4.13.3 Mutual Similarity Procedures

They group together observations that have a common similarity to other observations. First an n x n matrix of similarities between all pairs of observations is calcualted. Then the similarity between columns of this matrix is iteratively recomputed. Columns representing members of a single cluster will tend to have intercorrelations near +1, while having much lower correlations with nonmembers.

4.13.4 Hierarchical Clustering

It joins the most similar observations, then successively connects the next most simialr observations to these . First an n x n matrix of a similarities between all pairs of observations is calculated. Those pairs having the highest similarities are then merged, and the matrix recomputed. This is done by averaging the similarities that the combined observations have with other observations. The process iterates until the similarity matrix is reduced to 2 x 2 . The levels of similarity at which observations are merged is used to construct a dendrogram.

Clustering is an efficient way of displaying complex relationships among a series of rainfall data. However, the process of averaging together members of a cluster and treating them as a single new data introduces distortion into the dendrogram (Fig. 5). This distortion becomes increasingly apparent as successive levels of clusters are averaged together.

The hydrologist faced with a great bulk of rainfall data which is quite interactable unless classified into managable groups. Clustering techniques can be used to perform this data reduction, reducing the information on the whole set of say N individuals to information about K groups (where K is smaller than N). In this way it may be possible to give a more concise and understandable account of the observations under consideration i.e. simplification with minimal loss of information is sought.

4.14 Principal Component Analysis

Principal components are nothing more than the eigenvectors of a varience-covarience or a correlation matrix. Many analytic schemes employ principal components as starting points for the analysis.

In the processing of rainfall data, if m variables on a collection of data are having then m x m matrix of variences and co-variences, it can be computed. From where the user can extract m eigenvalues and m eigenvectors. Because a Varience-covarience matrix is symmetrical, the m eigenvectors will be mutually orthognal.

The elements of the eigenvectors that are used to compute the scores of observations are called 'Principal Component Loading'. They are simply coeficients of the linear equations which the eigenvectors define. The effects of Principal Component Analysis on a larger data, using randomly generated blocks can be examined. Sometimes this analysis is known as Factor Analysis.

5.0 STATISTICAL ANALYSIS

In any statistical analysis of hydrologic data certain calculations are made in order to determine some of the basic properties inherent in the data. The length of data, generally available being short, sample data is used to fit probability distributions which in turn are used to extrapolate recorded events to design events either graphically or analytically. Graphical approach requires concept of probability paper and plotting position while analytical approach requires estimation of parameters. The ultimate aim of rainfall frequency analysis is to arrive at T-year (t-hour) rainfall at a station.

5.1 Sample Statistics

Sample statistics provide the basic information about the variability of a given data set. The most useful sample statistics or sample moments, indicate the central tendency or value around which all other values are clustered, the dispersion or the spread of sample values around a central value, the asymetry or skewness of the frequency distribution and the flatness of the frequency distribution. These statistical properties are determined by sample statistics as described below:

5.1.1 Mean

The sample mean is a measure of the central tendency of a given data set. If x_1, x_2, x_3 ....x_N represents a sequence (series) of observations, where N is the number of observations, mean is calculated as

$$\bar{x}=\frac{1}{N}\sum_{i=1}^{N}x_i$$

where $\bar{x}$ represents the estimated or sample mean.

5.1.2 Standard Deviation, Variation and Coefficient of Variation

The standard deviation measures the dispersion of sample values around the mean. If x_1, x_2, x_3 ....x_N represents a sequence of observation, where N is the total number of observations, the unbiased estimate of standard deviation of this sequence may be determined by

$$S=\left[\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2\right]^{1/2}$$

Variance is square of standard deviation. The coefficient of variation is a dimensionless dispersion parameter equal to the ratio of the standard deviation and the mean, or,

$$\eta=\frac{S}{\bar{x}}$$

where S is the sample standard deviation and x is the sample mean.

5.1.3 Skewness Coefficient

The skewness coefficient measures the asymetry of the frequency distribution of the data. An estimate of this coefficient is given by,

$$C_s=\frac{N\sum_{i=1}^{N}(x_i-\bar{x})^3}{(N-1)(N-2)S^3}$$

The skewness coefficient has an important meaning since it gives indication of the symetry of the distribution of the data. Symetrical frequency distributions have very small or negligible sample skewness coefficient while asymetrical frequency distributions have either positive or negative coefficients. Often a small value of C_s will indicate that the frequency distribution of the sample may be approximated by the normal distribution function since $C_S = 0$ for this distribution.

5.1.4 Kurtosis Coefficient

The kurtosis coefficient measures the peakedness or the flatness of the frequency distribution near its center. An estimate of this coefficient is given by

$$C_k=\frac{N^2\sum_{i=1}^{N}(x_i-\bar{x})^4}{(N-1)(N-2)(N-3)S^4}$$

A related coefficient called the excess coefficient denoted by E is defined by $E = C_K - 3$

Positive values of E indicate that a frequency distribution is more peaked around its center than the normal while negatiave values may indicate that a given frequency distribution is more flat around its center than the normal. For the normal distribution the excess coefficient E = 0.

5.2 Regression and Correlation

5.2.1 Regression

The line of regression for variable 'y' versus variable 'x' is defined by a line (straight or curved) which gives the best estimate of 'y' for a given value of 'x'. Similarly, the best estimate of 'x' for a given 'y' is given by the regression line of 'x' versus 'y'. The shape of such line indicates the type of the functional relationship (parabolic, exponential etc.) to which the association of the variables approximates more or less roughly. The method of least squares is used for determining the parameters of this relationship, in other words the constants in the equation of the regression line. The fact that should be stressed here is that if a straight line, for instance, can be fitted to a number of observations, it does not mean that the data observed really follow a straight line. After all a non-linear relation may fit the same data better. The operation of fitting the best line must, therefore, be followed by a test of goodness of fit.

For straight line relationship, the equations of the two regression lines are

$$y = A_y + B_y \cdot x \quad \text{and}$$
$$x = A_x + B_x \cdot y$$

where,

B_y = regression coefficient of 'y' versus 'x'

B_x = regression coefficient of 'x' versus 'y'

Ay, A_x = respective intercepts for regression lines. The regression line of 'y' versus 'x' is not the same as that of 'x' versus 'y'.

If $\bar{x}$ and $\bar{y}$ are the means values of x and y for the sample size N. then B_y is given by

$$B_y = \frac{\sum_{i=1}^{N} x_i y_i - N\bar{x}\bar{y}}{\sum x_i^2 - N\bar{x}^2}$$

The intercept A_y is given by $A_y = \bar{y} - B_y \cdot \bar{x}$

5.2.2 Correlation

The relation between the random variables 'x' and 'y' is called the simple or bivariate correlative association. The correlation coefficient is the most commonly used statistical parameter for measuring the degree of association of two linearly dependent variables. It is defined as

$$r = \frac{\sum_{i=1}^{N} x_i y_i - N\bar{x}\bar{y}}{S_x S_y (N-1)}$$

where S_x and S_y are the standard deviation of x_i and y_i respectively. Correlation coefficient 'r' varies from +1 to -1. The correlation coefficient is unity only if all points fall on a straight line. A positive value of 'r' means that 'y' increases with an increase of 'x'. A negative value of 'r' means that 'y' decreases with an increase of 'x'. If the points (x_i , y_i) fall symmetrically around and all along a circle, 'r' is zero or linear dependence is zero. However, in this case there is a high correlation for the function which has circle as the regression line.

5.3 Frequency of Point Rainfall

In many hydrologic engineering application such as those concerned with floods, the probability of occurrence of a particular extreme rainfall, e.g. a 24 hour maximum rainfall will be of importance. Such information is obtained by the frequency analysis of the point rainfall data. The rainfall at a place is a random hydrologic proces and the rainfall data at a place when arranged in a chronological order constitute a time series. One of the commonly used data series is the annual series composed of annual values such as annual rainfall. If the extreme values of a specified event occurring in each year is listed, it also constitutes an annual series. Thus for example one may list the maximum x_1-hr rainfall occurring in a year at a station to prepare an annual series of 24-hr maximum rainfall values. The probability of occurrence of an event in this series is studied by frequency analysis of the annual data series.

The probability of occurrence of an event (e.g. rainfall) whose magnitude is equal to or in excess of a specified magnitude 'x' is denoted by 'P'. It's recurrence interval (also known as return period) is defined as T = 1/P.

This represents the average interval between the occurrence of a rainfall of magnitude equal to or greater than 'x'. Thus if it is stated that the return period of rainfall of 20 cm in 24 hour is 10 years at a certain station A, it implies that on an average rainfall magnitudes equal to or greater than 20 cm in 24 hours would occur once in 10-years, i.e. in a long period of say 100 years, 10 such events can be expected. However, it does not mean that every 10 years one such event is likely to occur. The probability of a rainfall of 20 cm in 24 hour occurring in any one year at station A is 1/T = 1/10 = 0.1.

The binomial or Poisson distributions can be used to find the probability of occurrence of the event 'r' times in 'n' successive years.

5.4 Continuous Distributions Used For Frequency Analysis of Rainfall Data

In order to carry out frequency analysis of rainfall data, the sample data of rainfall is used to fit frequency distributions which in turn is used to extrapolate from recorded events to desgin events either graphically or by estimating the parameters of frequency distribution. Graphical method is having the advantage of simplicity and visual presentation.

The following continuous distributions can be used to fit the annual series of T-hour maximum rainfall.

5.4.1 Normal Distribution

It is one of the most important distribution in statistical hydrology. This is used to fit empirical distributions with symmetrical histograms or with skewness coefficient close to zero. The normal distribution enjoys unique position in the field of statistics due to its role in the central limit theorem. This theorem validates use of an approxination to other distributions. It states that the distribution of sum of random variables from any distribution tends to a normal distribution as the number of terms in the sum imcreases.

5.4.2 Log Normal Distribution

Log normal distribution function can be applied to a wide variety of hydrologic events especially in the cases in which the corresponding variable has a lower bound, the empirical frequency distribution is not symetric and the factors causing those events are independent multiplicative. The causative factor for many hydrologic variables act multiplicatively rather than additively and so the logarithm of the peak flows which are the product of these causative factors follow the log normal distribution.

5.4.3 Gumbel or Extreme value type 1 Distribution.

It is used widely for frequency analysis of rainfall data in India. It is a member of the extreme value distribution family and is a two parameter distribution.

5.5 Parameter Estimation Techniques

The statistical parameters, by which a distribution is defined, have to be estimated from the observed records. Since sampling is subject to errors, it is desirable that the methods of parameter estimation keep the error in the estimated parameters to a minimum.

The commonly used parameter estimation techniques in current use are as follows :

5.5.1 Graphical Estimation

In this method, the variate under consideration is regarded as a function of a standardised or reduced variate with known distribution. The samle data is plotted as a series of 'N' discrete oints with abscissa being the reduced variate of the probability distribution under consideration and ordinate being the variate. The variates are plotted against the corresponding probability or reduced variate or return period determined using the appropriate plotting position formula. The plotted points represent the sample distribution and a line drawn through these is considered as an estimate of the population relation. Then this straight line is projected to arrive at the magnitude of desired return period. In this method the line is subjectively placed and could vary with analyst. This subjectivity is regarded as a mojor drwaback of this technique.

5.5.2 Least Squares Estimation

In this method a simple linear regression equation is fitted between the variate under consideration and the corresponding frequency factor 'K'. The form of Chow's general equation is used as the linear regression equation and it is written as :

$$X_i = a + b K_i + \epsilon_i$$

where,

a and b are intercept and slope of linear regression equation,

X_i is the i th variate

K_i is the frequency factor corresponding to the i th variate and

ϵ_i is the error term with mean = 0 and standard deviation = $\sigma\epsilon$

It is not correct to interpret 'a' and 'b' as mean and standard deviation of the X_i series as these parameters are estimated in the least square sense and they can never become equal to mean and standard deviation of the sample data.

This method has not been accepted as a standard method in practice as it involves the use of plotting position to determine the frequency factor K_i and the assumption that the error variance $\sigma\epsilon^2$ remain same for all the observations. The defect due to former assumption could be eliminated by using the appropriate plotting position. However, the later assumption make the method more defective as the higher events recordrd will have more error variance than the recorded lower events. All these assumptions affect the correct parameter estimation of 'a' and 'b'.

5.5.3 Method of Moments

This method makes use of the fact that if all the moments of a distribution are known then every thing about the distribution is known. In all the distributions in common usage four moments or fewer are sufficient to specify all the moments. For instance, two moments, the first together with any moment of even order are sufficient to specify all the moments of the normal distribution. Similarly, in the EV-1 distribution, the first two moments are sufficient to specify all the moments.

This method of parameter estimation is dependent on the assumption that the distribution of variate values in the sample is representative of the population distribution. Therefore, a representative of the former provides an estimate of the later.

5.5.4 Method of Maximum likelihood

The principle of maximum likelyhood states that for a distribution with probability density function p (X, α, β) where α and β are the parameters to be estimated, the probability of obtaining a given value of X_i is proportional to u (X_i, α, β) and the joint probability L, of obtaining a sample of 'n' values X_1, X_2.......X_n is proportional to the product

$$L=\prod_{i=1}^{n}(x_i,\alpha,\beta)$$

This L, is called the likelihood function. The method of maximum likelihood is to estimate α and β such as that L is maximised. This is obtained by partially differentiating L with respect to each of the parameters and equating to zero. Frequently Log_e L is used instead of L to simplify the computations.

Maximum likelihood estimators are sufficient and consistent. An estimator θ' is said to be a sufficient estimator of θ if θ' uses all the information relevant to θ that is contained in the sample. An estimator θ' of a parameter θ is said to be consistent if the probability that θ' differs from θ by more than an arbitrary constant approaches zero as the sample size approaches infinity. In view of the properties of the maximum likelyhood estimators, the method is generally preferred over the method of moments.

5.6 Probability Analyses

The selection of suitable probability analysis method for routine evaluation is largely determined by the duration of the rainfall events of interest. The reason is that different durations are best described by different frequency distributions.

For studies of short duration events daily totals are inadequate and the regular time series produced from recording raingauge data must be used. It is obvious that the time interval selected for producing this time series should be compatible with the duration of interest, i.e. the duration are equal to, or are some multiple of, the time interval used. It is illogical to produce a 15-minute regular time series if 10-minutes duration rainfall is required for many storm analyses. The duration selected relate to the response time of each hydrological system. For urban areas it may be necessary to produce regular time series for duration as low as 2.5 to 10 minutes, whereas for larger natural catchments, 6-36 hours may be more appropriate. If the original recorded record has been digitized with sufficient resolution, any duration may be analysed.

Although it would be feasible for the computer to evaluate all possible occurrences of any specified rainfall duration, it is in practice to define fixed starting times. Thus, when preparing data of 15-minute duration, the analysis should be made for the periods 0-15, 15-30, 30-45 and 45-60 minutes past each hour.

Duration of 25 hour, 72 hour, 1 month etc., may be analysed using data from totalizing gauges, but it should be noted that 24-hour (and multiples) data from recording gauges will not be compatible, except in the special case that the same starting time is used. The advantage of including the daily raingauge values is that a much larger data set is made available.

Most analyses relate the probability of occurrence of rainfall depths intencities to specified duration. The probability of occurrence is usually expressed as the inverse factor "return period" and the method of its computation depends upon the underlying frequency distribution assumed. Whilst analyses are performed on the basis of single stations, areal comparison of rainfall frequencies allow the determination of adjustment factors to convert computed depths the equivalent area estimates

Computer processing allows the routine management and updating of a wide variety of intensity/depth/area/duration relationships. Whilst extremely laborious when manually evaluated, the rapidity of computerised techniques allows detailed investigations of rainfall frequency distribution and the subsequent use of those best suited to different rainfall events, regions and times.

The software to perform the above analysis should be sufficiently general to handle any specific duration but will need separate subroutines to computer return periods depending upon the particular frequency distribution used. The same software should be capable of analysing both flood and drought periods and again, different distribution functions may be utilised to describe these different rainfall population.

A relationship between the average rainfall value of a region and rainfall values at different stations located within/outside the region is needed in some of the hydrological analysis. Generally rainfall values for a region may be available and it is required to disaggregate this information to all the stations of the concern.

Some programs for time series anaysis and statistical analysis are given in Appendix - XI and XII respectively.

6.0 DEVELOPMENT OF DISAGGREGATION TECHNIQUES

Sometimes the rainfall data for a basin are available but they are not available for all the stations of that basin. Or, in hydrological analysis it is desired to have a relationship between average rainfall value of a basin and rainfall values at stations of concern. The disaggregation techniques can be very useful in these situations. They can be used to disaggregate the average rainfall data of a basin to the rainfall data of a station of concern. Disaggregation models being very versatile, have recently become very imortant for modelling of hydrological time series in temporal as well as in spatial domain. The basic goal of any of these model is to maintain relavant statistical properties at all levels of aggregation owing to the fact that the general model preserves all linear relationships between variables at successive levels of aggregation.

The disaggregation of arealy averaged monthly rainfall values of a basin or a region into point rainfall values can be done using some statistical methods based on frequency analysis approach, correlation approach and disaggregation approach. The relative performences of these methods can be evaluated based on some error criteria evaluated from observed and disaggregated point rainfall and mean areal rainfall values and their statistics.

6.1 Disaggregation Approach

The basic goal of any disaggregation model is to allow the preservation of statistical properties at more than one level. Disaggregation models being very versatile, have recently become a major technique for modelling of hydrologic time series in temporal as well as in spatial domain. General form of is:

$$Y = AX + B\varepsilon$$

Here, 'X' is the basin average value and 'Y' is column matrix (NS x 1) containing corresponding 'NS' values at different stations located within/outside the basin, all reduced to zero mean values by substracting the series mean value from each value. 'ε' is the stochastic term and A(NS x 1) and B(NS x NS) are the parameters matrices. 'ε' is a (NS x 1) matrix of independent identically distributed normal deviates. Parameter estimation of above equation is done by using the method of moments as

$$A = S_{YY} \, S_{YY}^{-1}$$

$$BB^T = S_{YY} - S_{YX} S_{XX}^{-1} S_{XY}$$

Here, S_{YY} is the matrix of co-variances among the station values. S_{YX} is the matrix of co-variances between the station values and the average basin value and S_{XX} is the matrix of co-variances among the average basin values. Matrix B can be obtained from BB^T.

From the above parameter estimation, it is clear that this approach considers rainfall series at all the stations and average basin value series simultaneously and thus preserves the correlation among all the station values and also between each station value and average basin value. In order to preserve these correlation parameters required to be preserved are also large in numbers, which make the matrix notation necessary. However these matrices can be solved easily with the help of computer.

In this approach also, similar to frequency analysis method, first parameter estimation of the above equation is performed using the monthly rainfall values at different stations average values of basin or region. Once the parameters of matrices A and B are known, average value can be disagregated using the above equation to calculate corresponding values at various stations. Here it may be worth to note that as parameters so calculated try to preserve the correlation between each station value and also between the station value and basin average value, this approach has added advantage over the frequency analysis method and correlation method.

6.2 Performance Evaluation Criteria

Different methods are listed and described in Table 1. Four are considering frequency analysis approach, four considering disaggregation techniqye and two are using correlation concept. The programme DIS.FOR for this purpose is given in Appendix-X. The performance of all the methods was evaluated on the basis of reproduction of the statistics at the stations and for mean areal values. Owing to the large number of stations and methods involved in the analysis, it would be difficult to arrive at a conclusion by comparing all the statistical parameters or rainfall values for all the stations. For a method to be consistent, it should perform well simultaneously at all the stations and also for mean areal values. To account for this, two criteria were used: total absolute error (TAE) (which accounted for the performances at all the stations and also for mean areal rainfall for statistics) and average absolute error

(AAE) (which take into consideration the deviation of mean rainfall values, computed from disaggregated station values from observed mean values).

Table 1 : Description of Disaggregation Methods

Method No.	Description
1.	Disaggregation approach, considering one matrix A and different relationships for all twelve months.
2.	Disaggregation approach, considering one matrix A and one relationship equally good for all the twelve months
3.	Disaggregation approach, considering both matrices A and B and different relationships for all twelve months.
4.	Disaggregation approach, considering both matrices A and B and one relationship equally good for all the twelve months.
5.	Normal distribution frequency analysis approach.
6.	Power Transformation frequency analysis approach.
7.	PT3 distribution frequency analysis approach.
8.	EV1 distribution frequency analysis approach.
9.	Normal distribution regression analysis approach.
10.	Power Transformation regression analysis approach.

7.0 RAINFALL DATA PROCESSING USING 'HYMOS'

HYMOS software has been developed by the Delft Hydraulics, The Nethelands for storage, processing and retrieval of hydro-meteorological data. It arranges a convenient structuring of data in a database and provides an extensive set of tools for data entry, validation, completion, analysis, retrieval and reporting of the data. It is comprehensive, well tuned and easy to use via full screen menus with on-line help to guide the user. The package includes many tabular and graphical options facilitating efficient reporting.

HYMOS is developed to streamline the storage and processing of (geo-) hydrological and meteorological data. It includes various options like data processing system, including validation, series completion by interpolation, simulation and regression techniques, data compilation, statistical analysis and time series analysis.

The validation, completion and analysis of hydrometeorological data under HYMOS is logically structured in the following data processing modules:

- Data validation : tabular, graphical and computational procedures are available for proper screening of various types of data.
- Data completion and regression : a number of time and spatial interpolation techniques, as well as powerful regression and rainfall-runoff simulation (Sacramento model) are included for series completion.
- Data compilation : including aggregation and dis-aggregation of series, series transformation, computation of average and extreme values, catchment rainfall and evapotranspiration computation.
- Statistical analysis : computation of basic statistics, fitting of distribution functions, statistical tables, random data generation, computation of IDF-curves and frequency and duration curves.
- Time series analysis: covering correlogram and spectral analysis, range and run analysis and computation of storage requirements.
- Interpolation : To fill - in missing data HYMOS offers linear interpolation, use of relation equations, spatial interpolation methods.
- Regression Analysis : The regression analysis option in HYMOS includes computation of correlation matrix, and fitting of the functions like polynomial, simple linear, exponential, power, logarithmic, hyperbolic and multiple linear.

8.0 RAINFALL DATA PROCESSING USING 'GEAS'

Geostatistical Environmental Assessment Software (GEAS) has been developed by USEPA Environmental Monitoring System Laboratory. This software consists of the following data processing modules :

- Data preparation utilities : It provides the data reparation and file maniulation functions such as merge, append, compress, row extract, column extract, sort, report etc.
- Transformation of variables : It covers several arithmatic transformations. The transformations are restricted to unary or binary operations.
- Basic univariate statistics : It procuces univariate statistics and graphs including histogram and probability plots.
- Scatter plots : It produces scatter plots including log and semi-log and also

gives regression line and coefficient.

- Variogram analysis : It computes variograms.
- Cross validation of kriging parameters : Apart from the facilities of cross-validating a set of parameters for kriging, it has the capability for log-kriging.
- 2-D estimation using kriging : It is used to estimate a 2-D grid of values. A grid of upto 100 X 100 blocks or points may be kriged and upto 10 variables may be kriged for each point or block in the grid.
- Contour plots for gridded data : It produces contour maps of variables with gridded values. It also allows missing values.
- 2-D scatter and line graphs
- Graphs of 2-D sample locations and values

9.0 CONCLUSIONS

Automated collection and processing techniques can lead to significant improvements in hydrological data collection, quality control, storage, accessibility, preparation of publications and the use of data for analytical studies. However, the realisation of these improvements requires specialised training of the personnel involved in all phases of the work.

Great care is needed in the design of data processing systems, not only to achieve the technical goals but also to reduce the complexity and costs of associated non-computer tasks.

It is important that the use of automated techniques does not necessarily imply the use of highly sophisticated computer installations. The role of personal computers as an economical, powerful and readily available way to introduce computer based technologies and to develop the necessary human skills is very much important now-a-days. It is also been shown that distributed data processing systems tend to be more flexible in meeting changing needs, but that a centralised approach may be necessary where expertise and / or funds are limited. Distributed systems may also present some problems of compatibility, particularly if several different types of computer systems are linked to the system.

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APPENDIX-I

Listing of Computer Programme TAPE.FOR

```
C  PROGRAMME TO READ DATA FROM IND TAPES AND OTHER SOURCE
C  IT WILL CHECK MISSING DATA AND SUBSTITUTE THEM BY -999
C  CONDITIONS! IT WILL NOT TAKE CARE OF CONTINUOUS YEAR DATA
C  THEREFOR, FOR WATERYEAR CALCULATIONS NOT APPLICABLE
C  NDAY    = Number of days in different calendar months.
C  NOSTAT  = Code Number of State
C  NODIST  = Code Number of District
C  AMSTAT  = Name of the State in India
C  AMDIST  = Name of the District in the State
C  ANSTB   = Name of the Station in District
C  IR      = Two dimensional array containing daily rainfall data
C            of different raingauge stations.
C  IYEAR   = Calendar year for which data is provided.

      DIMENSION IR(12,31),NDAY(12),SUMMON(100,13)
      CHARACTER*10 AMSTAT
      CHARACTER*16 AMDIST,AMSTN
      DATA NDAY/31,28,31,30,31,30,31,31,30,31,30,31/
      OPEN(UNIT=1,FILE='WORK.DAT',STATUS='OLD')
      OPEN(UNIT=2,FILE='WORK9.DAT',STATUS='NEW')
      GOTO 777
888   BACKSPACE UNIT=1
777   READ(1,109)NOSTAT,NODIST,AMSTAT,AMDIST,AMSTN
      WRITE(2,110)NOSTAT,NODIST,AMSTAT,AMDIST,AMSTN
109   FORMAT(2I2,A,2A)
110   FORMAT(1X,2I2,A,2A)
      READ(1,199)CT
      WRITE(2,189)CT
189   FORMAT(1X,A2)
199   FORMAT(A2)
      NYR=1000
      DO 40,II=1,NYR
      IF(CT.EQ.'31') GOTO 111
      DO 10,I=1,12
      READ(1,101,END=999,ERR=111)ICATNO,LAT,LONG,IST,IY,IM
      READ(1,192,END=999,ERR=111)ICD,(IR(I,J),J=1,15)
      DO 600 J=1,15
      IF(IR(I,J).EQ.'    ') THEN
      IR(I,J)='-999'
      ENDIF
600   CONTINUE
      WRITE(2,201)ICATNO,LAT,LONG,IST,IY,IM,ICD,(IR(I,J),J=1,15)
      IY=IY+1900
      IF(I.EQ.2) THEN
```

```
      CALL LEAPYR(IY,NDAY)
      ENDIF
      READ(1,101,END=999,ERR=111)ICATNO,LAT,LONG,IST,IY,IM
      READ(1,192,END=999,ERR=111)ICD,(IR(I,J),J=16,NDAY(I))
      DO 601 J=16,NDAY(I)
      IF(IR(I,J).EQ.'    ') THEN
      IR(I,J)='-999'
      ENDIF
601   CONTINUE
      WRITE(2,201)ICATNO,LAT,LONG,IST,IY,IM,ICD00,(IR(I,J),J=16,
     1NDAY(I))
10    CONTINUE
      GOTO 40
111   DO 50 K=1,31
      READ(1,105,END=999,ERR=888)ICATNO,STR,LAT,LONG,IST,IY
      READ(1,155,END=999,ERR=888)IDATE,(IR(J,K),J=1,12)
      DO 603 J=1,12
      IF(K.GT.NDAY(J)) THEN
      GOTO 603
      ENDIF
      IF(IR(J,K).EQ.'  ') IR(J,K)='-999'
603   CONTINUE
      WRITE(2,205)ICATNO,LAT,LONG,IST,IY,IDATE,(IR(J,K),J=1,12)
50    CONTINUE
40    CONTINUE
101   FORMAT(I3,A2,2I2,2X,2I2\)
192   FORMAT(I1,16A4)
201   FORMAT(1X,I3,A2,2I2,2X,2I2,I1,16A4)
105   FORMAT(I3,A2,2I4,I2,4X,I4\)
155   FORMAT(I2,12A4)
205   FORMAT(1X,I3,2X,2I4,I2,4X,I4,I2,12A4)
999   END
C
      SUBROUTINE LEAPYR (IY,NDAY)
C     YEAR SOULD BE DEFINED IN FULL DIGITS IN MAIN PROGRAMME
      DIMENSION NDAY(2)
      LPYR=MOD(IY,4)
      IF(LPYR.EQ.0) NDAY(2)=29
      RETURN
      END
```

Listing of Sample Input Data File WORK.DAT

```
1704ORISSA      CUTTACK          JAGATSINGPUR            320201686101400091871
24
3202016861060011000000000000000000000000000000000000000000000000000000000000
32020168610600120000000000000000000000000000000000000000000000000005400700055
3202016861060021000000000000000000000000000000000000000000000000000000000000
32020168610600220000000000000000000000000000000000000007000000000000
3202016861060031000000000000000000000000000000000000000000000000000000000000
32020168610600320000000000000000000000000000000000000000000000000000000000000000
3202016861060041000000000000000000000000000000000000000000000000000000000000
3202016861060042000000000000000000000000000000000000000000000000000000000032
3202016861060051000000950000000000000000000000000000006500000000000000000000
32020168610600520000000000000000000300000000007400000000000400000000000000000000
3202016861060061008300000043001300000015000000000000003502630000000000500011
3202016861060062
3202016861060071000200000000000000780077014700220349067801920001000000000002
32020168610600720000013500000006000600110009000000000000000000570100007000020063
3202016861060081001400060008000000120000000000510121003900250000000000620128
32020168610600820000005400150000000000000000900000044000200000000000000000000000
3202016861060091000000000073000200000053014600980018000400000000000900000000
3202016861060092000000000000000000230000002300450000000000000000005200720008
3202016861060101003001340000000000180000018402350465000500640000000000000000
32020168610601020014000002210000000000000000000000000000000000000000000000000000
3202016861060111000000000000000000000000000000000000000000000000000000000000
3202016861060112000000100217025100100000000000000000000000000000000000000000
3202016861060121000000000000000000000000000000000000000000000000000000000000
32020168610601220000000000000000000000000000000000000000000000000000000000000000
```

APPENDIX-II

Listing of Computer Programme GAPE.FOR

```
C      PROGRAMME FOR ESTIMATING MISSING DATA USING NORMAL RATIO
C      METHOD
C NS       = No. of raingauge stations
C NEV      = No. of events
C NRAIN    = No. of rainfall values
C RN       = Two dimensional array containing the normal rainfall
C            values at each raingauge stations
C RAIN     = Two dimensional array containing the observed
C          rainfall values and each raingauge stations for C
C          different events.
C ARAIN    = Two dimensional array containing observed rainfall
C          values and estimated values of missing rainfall at each
C          raingauge stations for different events.
       DIMENSION RN(10,50),RAIN(10,50),ARAIN(10,50)
       OPEN (UNIT=1,FILE='GAPE.DAT',STATUS='OLD')
       OPEN (UNIT=2,FILE='GAPE.OUT',STATUS='NEW')
       READ (1,*) NEV
       WRITE(2,51)
51     FORMAT(20X,'RAINFALL AT DIFFEREN STATIONS AFTER FILLING
     1THE      1MISSING RECORDS')
       WRITE(2,52)
52     FORMAT(10X,120('-'))
       DO 1 I=1,NEV
       READ(1,*) NS
       READ(1,*) NRAIN
       READ(1,*)((RN(J,K),K=1,NRAIN),J=1,NS)
       READ(1,*)((RAIN(J,K),K=1,NRAIN),J=1,NS)
       DO 2 J=1,NS
       DO 3 K=1,NRAIN
       IF(RAIN(J,K).NE.-1) THEN
         GOTO 100
       ENDIF
       RAT=0.
       L=0
       DO 4 K1=1,NS
       IF(J.EQ.K1) THEN
         GOTO 4
       ENDIF
       IF(RAIN(K1,K).EQ.-1) THEN
         GOTO 4
       ENDIF
       L=L+1
       RAT=RAT+RAIN(K1,K)/RN(K1,K)
       CONTINUE
```

```
      IF(L.EQ.0)ARAIN(J,K)=RN(J,K)
      IF(L.NE.0)ARAIN(J,K)=RAT*RN(J,K)/L
      GOTO 101
100   ARAIN(J,K)=RAIN(J,K)
101   CONTINUE
3     CONTINUE
2     CONTINUE
      WRITE(2,30)I
30    FORMAT(4X,'EVENT NO:-',I5)
      WRITE(2,45) ((ARAIN(J,K),K=1,NRAIN),J=1,NS)
45    FORMAT(4X,F10.3)
1     CONTINUE
50    END
```

Listing of Sample Input Data File GAPE.DAT

```
1
4
1
331.3    290.8    325.9    360.5
 -1        98.9   120.5    110.0
```

APPENDIX-III

Listing of Computer Programme DISPOW.FOR

```
C PROGRAMME FOR INTERPOLATION OF RAINFALL BY DISTANCE POWER
C  METHOD
C NST       = Number of stations including the station whose data
C            is estimated. Normally four stations from around the
C            estimated station are used.
C NVAL      =Number of values to be estimated. Programme provides
C            for upto 20 values.
C NPOW      = Number of powers to be tried. Upto 10 can be used.
C POW       = Value of power to be used with the distance
C ST1,ST2, = Name of station (upto 16 letters)
C ST3,ST4
C LAT,LONG = Latitude and longitude of the raingauge station
C  STNCH(I,J)= Two dimensional array containing the station
C             characteristics for adjusting different values and
C             for the different stations.
C RF(I,J)   = Two dimensional array containing the rainfall data
C             (hourly, daily, monthly or seasonal) of different
C             stations for the different periods.
C WT(I)     = Weight of each estimator station obtained by the
C             distance power weighting.
C ERF       = Estimated rainfall
C DRF       = Difference between observed and estimated rainfall
C             squared.
      DIMENSION LAT(10),LONG(10),T1(10),STNCH(10,20),RF(10,20)
      DIMENSION DREC(10),WT(10),POW(10), DT(10),ERF(20),DRF(20)
      INTEGER*2 Z
      CHARACTER*16 T1
      OPEN (UNIT = 1,FILE = 'DIS.DAT',STATUS = 'OLD')
      OPEN (UNIT = 2,FILE = 'DIS.OUT',STATUS = 'NEW')
      READ (1,*) NST,NVAL,NPOW
      READ (1,*) (POW(I),I = 1,NPOW)
      DO 100 I =1,NST
      READ (1,10) T1(I),LAT(I),LONG(I)
      READ (1,*) (STNCH(I,J), J=1,NVAL)
100   READ (1,*) (RF(I,J), J=1,NVAL)
      WRITE (2,1000) (T1(I),I = 1,NST)
      NS = NST - 1
      DO 200 I = 1,NS
      DIS = (LAT(I+1)-LAT(1))**2+(LONG(I+1)-LONG(1))**2
      DT(I)=1.10 * (DIS**0.5)
      Z=I+1
200  WRITE(2,2000)T1(Z),T1(1),DT(I)
      DO 300 J = 1,NPOW
      TWT = 0.0
```

```
      DO 400 I = 1,NS
      DREC(I) = 1.0/DT(I)**POW(J)
400   TWT = TWT + DREC(I)
      DO 500 I = 1,NS
500   WT(I) = DREC(I) / TWT
      DO 600 K = 1,NVAL
      ERF(K) = 0.0
      DO 600 I = 1,NS
      ERF(K) = ERF(K) + RF(I+1,K)*WT(I)*STNCH(1,K)/STNCH(I+1,K)
600   DRF(K) = (RF(1,K) - ERF(K)) ** 2.0
      WRITE(2,4000) POW(J)
      WRITE(2,4000)(WT(I),I = 1,NS)
      WRITE(2,3000)(RF(1,K),K = 1,NVAL)
      WRITE(2,3000) (ERF(I),I = 1,NVAL)
      WRITE(2,5000) (DRF(I),I = 1,NVAL)
300   CONTINUE
10    FORMAT(A16,2I4)
1000  FORMAT(2X,'INTERPOLATED RAINFALL FOR'A16'FROM'4(A16))
2000  FORMAT(2X,'DISTANCE OF 'A16'FROM'A16'IS'F10.1'KMS')
3000  FORMAT(2X,20F6.1)
4000  FORMAT(2X,20F6.3)
5000  FORMAT(2X,20F6.0)
      END
```

Listing of Sample Input Data File DIS.DAT

```
05,09,01
2.0
  BAUDHGARH      20838432
1.01,1.01,1.01,1.06,1.06,1.06,1.05,1.05,1.05
33.2,125.2,199.0,307.0,28.0,86.6,62.6,7.8,89.0
  PHULBANI       20488423
1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00
23.8,105.6,115.0,330.2,13.9,106.8,46.0,36.6,134.4
  KRISHNANAGAR  20978447
0.92,0.92,0.92,1.23,1.23,1.23,1.14,1.14,1.14
42.8,84.1,266.6,187.0,7.0,195.4,66.6,40.8,83.4
  ATHMALIK       20728453
1.17,1.17,1.17,1.10,1.10,1.10,1.01,1.01,1.01
127.5,48.1,229.1,271.1,17.5,101.6,153.2,18.6,57.6
  KHEJURIPARA   20438442
0.95,0.95,0.95,0.88,0.88,0.88,0.99,0.99,0.99
110.0,40.0,28.4,278.4,22.1,125.1,59.9,233.3,76.9
```

APPENDIX-IV

Listing of Computer Programme DOUBLE.FOR

```
C      THIS PROGRAMME CHECKS THE CONSISTENCY OF A PARTICULAR
C      RECORD USING DOUBLE MASS CURVE ANALYSIS HERE:
C NS = No. of raingauge stations
C N  = No. of observations at each stations
C NT = Station no. at which consistency check of the record is C
C    required
C R  = Two dimensional array containing the observed rainfall C
C    values at different stations.
C B  = Cumulative rainfall at the selected raingauge station for C
C   the consistency check
C X  = Average of cumulative falls at other raingauge stations C
C    excluding the one selected for consistency check.
       DIMENSION R(20,100)
       OPEN(UNIT=1,FILE='DOUBLE.DAT',STATUS='OLD')
       OPEN(UNIT=2,FILE='DOUBLE.OUT',STATUS='NEW')
       READ(1,*) NS,N,NT
       READ(1,*) ((R(J,I),I=1,N),J=1,NS)
       WRITE(2,7)
7      FORMAT(20X,'DOUBLE MASS CURVE ANALYSIS')
       WRITE(2,8)
8      FORMAT(20X,27('_')///)
       WRITE(2,6)NT
6      FORMAT(5X,'STATION NO.',I3,28X,'SUM OF OTHER STATIONS')
       A=0.0
       B=0.0
       DO 1 I=1,N
       DO 2 J=1,NS
       IF(J.EQ.NT) THEN
         GOTO 3
       ENDIF
       A=A+R(J,I)
       X=A/(NS-1)
       GOTO 2
3      B=B+R(J,I)
2      CONTINUE
       WRITE(2,5) B,X
5      FORMAT(5X,F10.2,31X,F12.2)
1      CONTINUE
       END
```

Listing of Sample Input Data File DOUBLE.DAT

```
5 8 1
43.54  48.80  47.57  43.15  45.03  45.99  40.41  63.77
40.10  47.54  46.77  43.26  44.91  47.06  40.16  61.75
44.21  48.41  47.50  43.86  50.96  43.10  38.94  60.57
39.17  43.34  42.28  35.02  37.86  37.36  35.71  52.23
39.91  45.15  42.74  33.12  48.91  37.15  40.77  54.07
```

APPENDIX-V

Listing of Computer Programme DAILY.FOR

```
C  THIS PROGRAMME DISTRIBUTES THE DAILY RAINFALL INTO HOURLY
C  RAINFALL AS PER THE CHOICE OF THE SRRG AND COMPUTES
C  THE AVERAGE HOURLY RAINFALL
C NDAY     = No. of days
C NSRRG    = No. of operational SRRG for the day
C NORG     = No. of operational ORG for the day
C WTONS    = Vector containing the Theissen Weights for all the
C            operational raingauge stations (ORG+SRRG)
C CHO      = Vector containing the SRRG No. of chosen for
C            different ORG station for the distribution of daily
C            rainfall
C RORG     = Vector containing the ORG stations rainfall for the
C            day
C RSRRG    = Two dimensional array containing 24 values of hourly
C            rainfall at each SRRG stations for the day
C SUMI     = Vector containing 24 values of average hourly
C            rainfall for the day.
      DIMENSION RORG(50),RSRRG(24,50),WTONS(50),SUM1(24),CHO(50)
      DIMENSION S(50),RAIN(24,50),ORG(10),SSRG(10)
      CHARACTER*16 ORG,SSRG
      OPEN(UNIT=1,FILE='DAILY.DAT',STATUS='OLD')
      OPEN(UNIT=2,FILE='DAILY.OUT',STATUS='NEW')
C     NDAY=NO. OF DAYS
C     NORG=NO. OF O.R.G. STATIONS
C     NSRRG=NO. OF S.R.R.G STATIONS
C     WTONS=VECTOR CONTAINING WEIGHTS OF SRRG AND ORG STATIONS
C     CHO=VECTOR CONTAINING CHOICE OF S.R.R.G FOR EACH O.R.G.
      READ(1,*)NDAY
      WRITE(2,20)
20    FORMAT(30X,'DAILY TO HOURLY CONVERSION OF RAINFALL AND '\)
      WRITE(2,40)
40    FORMAT ('COMPUTATION 1 OF AVERAGE HOURLY RAINFALL')
      WRITE(2,21)
21    FORMAT(10X,120('-'))
      DO 1 I=1,NDAY
      READ(1,*)NSRRG
      READ(1,*)NORG
      NTONS=NORG+NSRRG
      READ(1,60)(ORG(J),J=1,NORG)
      READ(1,60)(SSRG(J),J=1,NSRRG)
60    FORMAT(10A16)
      READ(1,*)(WTONS(J),J=1,NTONS)
      READ(1,*)(CHO(J),J=1,NORG)
C     RORG=VECTOR CONTAINING ORG STATIONS RAINFALL FOR THE DAY
```

```
      READ(1,*)(RORG(J),J=1,NORG)
C     RSRRG=VECTOR CONTAINING RAINFALL AT EACH S.R.R.G. STATIONS
      READ(1,*)((RSRRG(J,K),J=1,24),K=1,NSRRG)
      DO 2 J=1,NSRRG
      S(J)=0.0
      DO 3 K=1,24
      S(J)=S(J)+RSRRG(K,J)
3     CONTINUE
2     CONTINUE
      DO 4 J=1,24
      DO 5 K=1,NORG
      K1=CHO(K)
      RAIN(J,K)=RORG(K)*RSRRG(J,K1)/S(K1)
5     CONTINUE
4     CONTINUE
      DO 6 J=1,24
      L1=0
      L2=NORG+1
      DO 7 K=L2,NTONS
      L1=L1+1
      RAIN(J,K)=RSRRG(J,L1)
7     CONTINUE
6     CONTINUE
      DO 8 J=1,24
      SUM1(J)=0.0
      DO 9 K=1,NTONS
      SUM1(J)=SUM1(J)+RAIN(J,K)*WTONS(K)
9     CONTINUE
8     CONTINUE
      WRITE(2,12)I
12    FORMAT(4X,'ORG ST.NO.',10X,'RAINFALL OBS. FOR THE
     1DAY(MM)1:-',I5)
      WRITE(2,14)(J,RORG(J),J=1,NORG)
14    FORMAT(10X,I4,10X,F15.2)
      DO 15 K=1,NSRRG
      WRITE(2,16)SSRG(K)
16    FORMAT(30X,'RAINFALL OBSERVED AT S.R.R.G STATION(MM)- ',A16)
      WRITE(2,11)(RSRRG(J,K),J=1,24)
15    CONTINUE
      DO 30 K=1,NORG
      WRITE(2,17)ORG(K)
17    FORMAT(30X,'HOURLY DISTRIBUTED RAINFALL AT ORG
     1STATION(MM)-',  1A16)
      WRITE(2,11)(RAIN(J,K),J=1,24)
30    CONTINUE
      WRITE(2,23)
23 FORMAT(10X,'THIESSEN WEIGHTS OF ALL THE
1STATIONS(O.R.G+S.R.R.G)')
```

```
      WRITE(2,24)(WTONS(J),J=1,NTONS)
24    FORMAT(4X,10F12.4)
      WRITE(2,10) I
10    FORMAT(30X,'AVERAGE RAINFALL FOR THE DAY(MM):---',I5)
      WRITE(2,11)(SUM1(J),J=1,24)
11    FORMAT(4X,10F12.4)
1     CONTINUE
      END
```

Listing of Sample Input Data File DAILY.DAT

```
1
2
3
MAKRAI          HARDA           SEONI
BETUL           HOSHANGABAD
0.1  0.3  0.20  0.25  0.15
1  1  2
235.0 96.5 52.3
12.5 0.0 0.0 0.0 0.3 0.0 0.1 0.8 4.8 14.0 12.3 0.5 1.8 5.0
10.6 6.3 2.3
0.9 6.5 0.5 0.5 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 5.0 3.5 2.0 0.0 0.0 0.7 0.1
0.0 0.0 1.6
1.5 0.0 0.0 0.0 0.0 0.0
```

APPENDIX-VI

Listing of Computer Programme CATCH.FOR

```
C       PROGRAMME FOR COMPUTING CATCHMENT RAINFALL
C NSTN     = Number of Raingauge Stations(Max.20 stations)
C IYR      = Number of years (Upto 100 years)
C NVAL     = Number of values in an year upto 40 values are taken
C            (Say 10 daily or monthly values)
C WT       = Thiessen weights or any other user desired weights
C NYR      = Calendar year in four digits
C RAIN(I,J,K)= Three dimensional array consisting of rainfall C
C          data of all stations for all the years for given
C          number of values.
C AVRF (J,K) = Two dimensional array consisting of the average
C               rainfall for each of the values for the years
C               under consideration
        DIMENSION RAIN(10,25,20), AVRF(25,20), WT(10), NYR(25)
        OPEN (UNIT = 1,FILE='CAT.DAT',STATUS ='OLD')
        OPEN (UNIT = 2,FILE='CAT.OUT',STATUS ='NEW')
C NSTN=NO.OF STATIONS,IYR=NO.OF YEARS,NVAL=NO.OF VALUES IN A YEAR
        READ (1,5) NSTN,IYR, NVAL
5       FORMAT (3I2)
C       READ THIESSEN HEIGHTS OF STATIONS
        READ (1,10) (WT(I), I = 1,NSTN)
10      FORMAT (20F3.2)
C       READ RAINFALL DATA FOR ALL YEARS STATION WISE
        DO 100 I = 1,NSTN
        DO 100 J = 1,IYR
        READ (1,*) NYR(J), (RAIN(I,J,K), K = 1, NVAL)
100     CONTINUE
C       COMPUTE CATCHMENT AVERAGE RAINFALL
        DO 300 J = 1,IYR
        DO 300 K = 1,NVAL
        AVRF (J,K) = 0.0
        DO 200 I = 1,NSTN
200     AVRF (J,K) =AVRF(J,K)+RAIN(I,J,K) * WT(I)
300     CONTINUE
        WRITE (2,2000)
        DO 400 J = 1,IYR
400     WRITE (2,1000)NYR(J), (AVRF(J,K), K = 1,NVAL)
1000    FORMAT (I8,15F8.1)
2000    FORMAT (10X,'MEAN AVERAGE CATCHMENT RAINFALL IN MM'//)
        END
```

Listing of Sample Input Data File CAT.DAT

```
041413
.41.35.10.14
1971 00.00 00.00 00.00 55.80 98.60 401.6 253.6 214.6 125.8 67.40 00.00 00.00 1217.4
1972 00.00 01.20 09.60 69.50 111.6 155.8 422.8 112.8 152.4 82.00 26.40 00.00 1144.1
1973 00.00 00.00 00.00 00.00 06.40 314.8 365.2 171.6 00.00 00.00 00.00 00.00 858.0
1974  0.00  0.00  3.6   38.4  195.1 137.0 360.0 216.3 126.4 143.4  0.00  0.00 1220.5
1975 00.00 00.00 00.00 02.60 123.8 695.1 467.4 201.9 262.2 143.6 77.60 00.00 1974.2
1976 00.00 00.00 00.00 108.8 00.00 193.5 449.2 192.7 142.7 00.20 116.6 00.00 1203.7
1977 00.00 00.00 00.00 64.00 71.20 297.3 489.6 137.2 126.1 103.8 105.0 00.00 1394.2
1978 00.00 00.00 00.00 28.40 72.30 256.4 314.7 356.3 189.2 34.20 25.30 01.20 1278.0
1979 00.00 10.00 00.00 11.20 76.00 268.8 186.2 442.4 192.2 93.20 88.30 00.00 1368.3
1980 00.00 00.00 00.00 121.4 26.80 290.8 547.9 343.1 87.40 175.8 104.0 07.00 1704.2
1981  0.00  0.00  1.1    90.0 112.9 212.5 324.3 212.8 281.8  26.8 20.30  0.00 1282.5
1982  0.00  0.00  1.2    24.0 153.2  80.6 250.1 150.1  80.4 183.2  31.5  0.00  954.3
1983  0.00  0.00  0.00  0.00   38.0 493.7 164.2 232.6  83.4  31.3  28.2  12.9 1084.3
1984  0.00  40.0  28.6 111.2  14.6 123.5 351.3  77.0 174.3 128.8   1.9   1.2 1052.5
1971 0.00 0.00 0.00 0.00 73.00 633.5 403.6 267.6 147.5 60.00 14.00 0.00 1599.2
1972 0.00 0.00 0.00 17.70 51.30 464.3 842.0 204.2 182.3 66.80 16.00 0.00 1844.6
1973 0.00 0.00  0.00 02.50 99.80 570.6 826.1 255.8 38.5 157.4 14.00 0.00 1964.7
1974 0.00 0.00 02.50 35.50 151.7 198.2 921.2 527.8 181.4 146.9 0.00 0.00 2165.2
1975 0.00 0.00 0.00 05.10 30.70 858.8 50.9 528.8 236.3 123.7 61.40 0.00 2345.7
1976 0.00 0.00 27.70 53.90 0.00 410.8 766.6 322.1 149.2 70.60 92.80 0.00 1893.7
1977 0.00 08.90 03.10 40.70 72.00 328.7 735.5 235.6 207.0 135.1 110.4 0.00 1877.0
1978 0.00 05.00 0.00 22.00 74.80 528.8 435.6 436.4 109.9 129.0 32.30 0.00 1771.8
1979  25.5  2.2   0.00  1.00 80.40 405.8 294.6 704.9 193.0  46.3 193.7 0.00 1947.4
1980  0.0  0.00  0.00  66.0  27.1  680.6 725.4 601.6  65.2  4.1  39.3 20.8  2257.1
1981  0.00  0.00  0.00  26.6  88.8 323.1 830.4 507.5 139.1  32.7 40.1   0.00 1988.3
1982  0.00  0.00   0.5   8.3 137.4 276.5 843.6 290.2  57.8  71.6 12.2   0.00 1698.1
1983  0.00  0.00  0.00  0.00  43.8 730.6 617.3 457.9 170.0  33.9 23.4   9.1  2086.0
1984  16.8  1.9   13.9  24.3   7.7 519.2 685.3 263.9 127.3  57.4 0.00   0.2  1717.9
1971   0.0   0.0   0.0  11.4  50.8 130.2  45.8  99.6  94.0 128.0   0.0   0.0 559.8
1972   0.0   0.0  12.2  55.1  83.7  93.5 113.5  46.2  84.3 158.9  23.4   0.0 670.8
1973   0.0   0.0   0.0   1.5  82.9 207.2 107.3  67.2  86.2 103.5   3.8   0.0 659.6
1974   0.0   0.0   2.8  29.0  99.8  21.4 111.5  52.6 208.2 168.8   0.0   0.0 694.1
1975   0.0   0.0   0.0  53.3 151.2  71.9 174.3  34.3 209.0 238.4  22.5   0.0 954.9
1976   0.0   0.0  20.8  28.8  40.3 117.3  98.4  42.9  43.2  54.6  66.2   0.0 512.5
1977   0.0   0.0  14.0  35.5 188.1  90.0  99.5  70.1  48.1  93.7  49.6   0.0 688.6
1978   0.0   7.1   0.0  77.5  87.0  50.9  97.4 118.3 157.5 129.0  43.9   6.1 774.7
1979  0.0   2.0   0.0  30.5  79.1   172.0 56.5  304.3 235.6  82.9  39.9  0.0 1002.8
1980  0.0   0.0   0.0  99.1   6.0    95.0 177.0  96.5 181.6  69.6  51.0  8.2   784.8
1981  0.0   0.0   0.0  13.8  41.0   137.6 295.8 106.1 222.5  36.2  61.4  0.0   914.4
1982  0.0   0.0   0.0  13.1 148.2   71.2 161.1  55.7  63.5   30.7  19.4  0.0   562.9
1983  0.0   0.0   0.0   0.0  19.2 304.3  91.9 138.7  67.7   19.6   2.1  17.8 661.3
1984  0.0   0.7   8.4  47.2   0.0  52.2 141.4  29.3 153.6   88.8  0.0   0.0   521.6
1971 00.00 00.00 00.00 73.30 107.0 49.40 20.20 111.7 88.70 72.90 00.00 00.00 523.2
1972 00.00 00.00 01.30 19.40 29.70 34.40 37.40 14.90 108.1 103.4 03.50 00.00 352.1
1973 00.00 00.00 00.00 12.50 17.60 68.20 52.50 63.80 46.70 172.8 06.60 00.00 440.7
1974 00.00 00.00 14.70 16.90 30.50 29.00 44.80 28.30 266.5 116.1 00.00 00.00 546.8
1975 00.00 04.10 05.10 02.00 76.80 59.80 97.00 13.10 281.6 121.0 06.10 00.00 666.6
1976 00.00 00.00 19.40 20.60 00.00 73.70 36.60 11.30 49.10 16.70 36.10 00.00 263.5
1977 00.00 00.00 34.20 49.00 166.0 81.10 52.30 13.30 12.40 81.60 85.10 00.00 575.0
1978 00.00 00.50 00.00 47.40 65.20 18.30 46.20 33.50 257.3 92.30 31.10 15.20 607.0
1979 16.8   0.00  0.00  0.00 78.10 141.8 148.6 197.1 200.0 61.10 57.90  0.00 901.4
1980 0.00   0.00  0.00 50.70 42.20 56.10 70.20 70.20 123.4 13.00 24.80  4.00 454.6
1981 12.0   0.00  0.00 11.30 43.30 134.5 87.10 40.20 212.3 26.20 87.10  0.00 654.0
1982 0.00   0.00  0.00  0.00 63.30 102.1 65.20 26.60 53.50 107.0 62.50  0.00 480.1
1983 0.00   0.00  0.00  0.00 77.00 224.5 18.40 67.90 28.80 18.20 17.50  9.40 461.7
1984 0.00   64.0  9.20  27.0 15.60 14.80 70.00 27.30 70.70 29.70  0.00  0.00 327.6
```

APPENDIX-VII

Listing of Computer Programme ISO.FOR

```
C      THIS PROGRAMME COMPUTES THE AREAL AVERAGE
C      RAINFALL USING ISOHYETAL METHOD
C N    = No. of Isohyetal areas
C HISO = Vector containing the rainfall values associated with
C           each isohyets
C AEN  = Vector containing the comulative area enclosed C
        between the two isohyets.
C R        = Vector containing the average rainfall between the
C            two consecutive isohyets except the first one to be
C            supplied by the user based on the observations at
C            rainfall stations of the neighbouring basin
C E        = Vector containing the net area enclosed between the
C            two consecutive isohyets
C P        = Vector containing the rainfall volume between the two
C            consecutive isohyets
C Q        = Vector containing the cumulative values of rainfall
C            volume
C D        = Vector containing the total areal average rainfall
C            over the area enclosed by consecutive isohyets.
       DIMENSION HISO(100), AEN(100),R(100),E(100)
       DIMENSION P(100),Q(100),D(100)
       OPEN(UNIT=1,FILE='ISO.DAT',STATUS='OLD')
       OPEN(UNIT=2,FILE='ISO.OUT',STATUS='NEW')
       READ(1,*)N
       READ(1,*)(HISO(I),I=1,N)
       READ(1,*)(AEN(I),I=1,N)
       READ(1,*)(R(I),I=1,N)
       WRITE(2,1)
1      FORMAT(30X,'ISOHYETAL METHOD')
       WRITE(2,2)
2      FORMAT(30X,16('_')///)
       A=0.0
       B=0.0
       AEN(0)=0.0
       DO 3 I=1,N
       E(I)=AEN(I)-AEN(I-1)
       P(I)=E(I)*R(I)
       B=B+P(I)
       Q(I)=B
       D(I)=Q(I)/AEN(I)
3      CONTINUE
       WRITE(2,4)
4      FORMAT(1X,'ISOHYET',2X,'AREA',2X,'NET AREA',2X,'AVG.
     1 PREC.',2X\)
```

```
      WRITE(2,9)
9     FORMAT('PREC. VOL.',2X,'TOTAL PREC.VOL.',2X,'AVG. DEPTH')
      WRITE(2,5)
5     FORMAT(10X,'(SQ KM)',2X,'(SQ KM)',4X,'(MM)',8X,'(CU M)',9X\)
      WRITE(2,10)
10    FORMAT('CU M',9X,'(MM)')
      WRITE(2,6)
6     FORMAT(1X,7('_')2X,4('_'), 2X,8('_'),2X,10('_'),2X,10('_')\)
      WRITE(2,11)
11    FORMAT(2X,15('_'),2X,10('_')/)
      WRITE(2,7)(HISO(I),AEN(I),E(I),R(I),P(I),Q(I),D(I),I=1,N)
7     FORMAT(1X,F7.0,2X,F5.0,2X,F7.2,F10.1,2X,F10.1,F15.1,2X,
     1F10.4)
      END
```

Listing of Sample Input Data File ISO.DAT

```
5
100     75      50      25      15
 32    224     500    1005    1517
110      87.50  62.50  37.50  20.00
```

APPENDIX-VIII

Listing of Computer Programme MAX.FOR

```
C     THIS PROGRAM COMPUTES THE 1,2,3,4,&5 DAY RAINFALL TOTALS
C     THIS PROGRAM USES THE OUTPUT FROM THE PROGRAM TAPE.FOR
C AMSTAT  = Name of state
C AMDIST  = Name of district
C AMSTN   = Name of station
C NDAY    = Number of days in different months in a year.
C IR      = Daily rainfall data in the integer mode i.e.
C           rainfall data written together with tenths of mm
C           or cents of inches in four digits.
C R,R2,R3,= Rainfall totals corresponding to 1day, 2days,
C R4 & R5   3days, 4days and 5 days written as floating point
C variable with units in mm (inches are converted to mm)
C AMAX    = Maximum value of rainfall for the corresponding
C           duration in each calendar month.
C AMMAX   = Annual maximum value of rainfall for the
C           corresponding duration for each year
C IPT     = Day or dates of maximum rainfall in the year for
C           the corresponding duration
C IPB & IPE=Day or dates of maximum rainfall in the year for
C           the corresponding duration
C ITTB, ITTE =      Beginning and ending dates of the
C IT1B, IT1E
C IT2B, IT2E        Period corresponding to the maximum
C IT3B, IT3E
C IT4B, IT4E        rainfall for the respective durations.
C IT5B, IT5E
C IMNB, IMNE =      Beginning and ending months for
C IMB1, IME1
C IMB2, IME2        periods starting in one months and
C IMB3, IME3
C IMB4, IME4        ending in another month.
C YMAX1,YMAX2 = Maximum rainfall corresponding to 1day, 2day,
C YMAX3, YMAX4  3day, 4day and
C YMAX5         5 days
      DIMENSION R2(12,31),R3(12,31),R4(12,31),R5(12,31)
      DIMENSION IR(12,31),R(12,31),NDAY(12),AMAX(12),IT(12)
      CHARACTER*10 AMSTAT
      CHARACTER*16 AMDIST,AMSTN
      DATA NDAY/31,28,31,30,31,30,31,31,30,31,30,31/
      OPEN(UNIT=1,FILE= 'MAX.DAT',STATUS='OLD')
      OPEN(UNIT=2,FILE= 'MAX.OUT',STATUS='NEW')
      GOTO 777
 888  BACKSPACE UNIT=1
 777  READ(1,109)NOSTAT,NODIST,AMSTAT,AMDIST,AMSTN
```

```
109    FORMAT(1X,2I2,A,2A/)
       WRITE(2,600)
       WRITE(2,500)AMSTAT,AMDIST,AMSTN
500    FORMAT(/2X,'STATE-  ',A10,15X,'DIST- ',A16,15X,
     1'STATION-',A16)
600    FORMAT(32X,'MAXIMUM 1 DAY,2 DAY,3 DAY,4 DAY AND 5 DAY',
     1RAINFALL')
       WRITE(2,700)
700    FORMAT(2X,40('-+-'))
       DO 10 I=1,12
       READ(1,101,END=999,ERR=111)ICT,LAT,LONG,IST,IY,IMONTH,
     1ICRDNO,IR(I,J),J=1,15)
       IY=IY+1900
       IF(LAT.EQ.'  ') THEN
          GOTO 111
       ENDIF
       IF(I.EQ.2) CALL LEAPYR(IY,NDAY)
       READ(1,101,END=999)ICT,LAT,LONG,IST,IY,IMONTH,
     1ICRDNO,(IR(I,J),J=16,NDAY(I))
10     CONTINUE
       GOTO 222
111    BACKSPACE UNIT=1
       BACKSPACE UNIT=1
       DO 50 K=1,31
       READ(1,105,END=222)ICT,STR,LAT,LONG,IST,IY,IDATE,
     1(IR(J,K),J=1,12)
       WRITE(*,105)ICT,STR,LAT,LONG,IST,IY,IDATE,
     1(IR(J,K),J=1,12)
50     CONTINUE
222    CALL SUM(IY,NDAY,IR,R,R2,R3,R4,R5)
       CALL MAXIM(IY,NDAY,R,YMAX1,IT1B,IT1E,IMB1,IME1,1)
       CALL MAXIM(IY,NDAY,R2,YMAX2,IT2B,IT2E,IMB2,IME2,2)
       CALL MAXIM(IY,NDAY,R3,YMAX3,IT3B,IT3E,IMB3,IME3,3)
       CALL MAXIM(IY,NDAY,R4,YMAX4,IT4B,IT4E,IMB4,IME4,4)
       CALL MAXIM(IY,NDAY,R5,YMAX5,IT5B,IT5E,IMB5,IME5,5)
       WRITE(2,800)
       WRITE(2,701)
701   FORMAT(' MAX  3 DAYS' 9X,' MAX  4  DAYS' 9X,' MAX  5
     1DAYS'/)
       WRITE(2,900) IY,YMAX1,YMAX2,YMAX3,YMAX4,YMAX5
       WRITE(2,1001)
       WRITE(2,1000)IT1B,IMB1,IT1E,IME1
       WRITE(2,1000)IT2B,IMB2,IT2E,IME2
       WRITE(2,1000)IT3B,IMB3,IT3E,IME3
       WRITE(2,1000)IT4B,IMB4,IT4E,IME4
       WRITE(2,1000)IT5B,IMB5,IT5E,IME5
       WRITE(2,*)'/'
       WRITE(2,700)
```

```
800     FORMAT(2X,'  YEAR  ' 8X' MAX  1  DAY' 9X' MAX  2  DAYS'
     19X\)
900     FORMAT(2X,I6,5(15X,F6.1)/)
1000    FORMAT(8X,I2'/'I2' TO 'I2'/'I2\)
1001    FORMAT(8X\)
101     FORMAT(1X,I3,A2,2I2,2X,2I2,I1,16I4)
105     FORMAT(1X,I3,A2,2I4,I2,4X,I4,I2,12I4)
999     STOP
        END
C
        SUBROUTINE SUM(IY,NDAY,IR,R,R2,R3,R4,R5)
C SUBROUTINE FOR SUMMING ONE DAY,TWO DAY,THREE DAY,FOUR DAY
C AND FIVE DAY TOTALS OF RAINFALL
        DIMENSION R2(12,31),R3(12,31),R4(12,31),R5(12,31)
        DIMENSION IR(12,31),R(12,31),NDAY(12)
        IF (IY.LT.1600) IY = IY +1900
        DO 10 I = 1,12
        IF (I.EQ.2) CALL LEAPYR (IY,NDAY)
        ND = NDAY(I)
        DO 15 J = 1,ND
        R(I,J) = IR(I,J)
        IF (R(I,J).EQ.-999) THEN
           GOTO 999
        ENDIF
        IF (IY.LE.1957) THEN
           GOTO 888
        ENDIF
        R(I,J) = R(I,J) / 10.0
        GOTO 15
888     R(I,J) = R(I,J) * 0.254
        GOTO 15
999     R(I,J) = R(I,J) / 10.0
15      CONTINUE
        DO 20 J = 1,ND
        IF (R(I,J).EQ.-99.9) THEN
           GOTO 20
        ENDIF
        IF (J.EQ.ND) THEN
           GOTO 11
        ENDIF
        IF (R(I,J+1).EQ.-99.9) THEN
           GOTO 20
        ENDIF
        R2(I,J) = R(I,J) + R(I,J+1)
        GOTO 12
11      IF (R(I+1,1).EQ.-99.9) THEN
           GOTO 20
        ENDIF
```

```
      R2 (I,J) = R(I,J) + R(I+1,1)
      IF (R(I+1,2).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R3 (I,J) = R2(I,J) + R(I+1,2)
      IF (R(I+1,3).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R4 (I,J) = R3(I,J) + R(I+1,3)
      IF (R(I+1,4).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R5 (I,J) = R4(I,J) + R(I+1,4)
      GOTO 20
12    IF (J.EQ.ND-1) THEN
         GOTO 13
      ENDIF
      IF (R(I,J+2).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R3 (I,J) = R2(I,J) + R(I,J+2)
      GOTO 14
13    IF (R(I+1,1).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R3 (I,J) = R2(I,J) + R(I+1,1)
      IF (R(I+1,2).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R4 (I,J) = R3(I,J) + R(I+1,2)
      IF (R(I+1,3).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R5 (I,J) = R4(I,J) + R(I+1,3)
      GOTO 20
14    IF (J.EQ.ND-2) THEN
         GOTO 16
      ENDIF
      IF (R(I,J+3).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R4 (I,J) = R3(I,J) + R(I,J+3)
      GOTO 17
16    IF (R(I+1,1).EQ.-99.9) THEN
         GOTO 20
      ENDIF
      R4 (I,J) = R3(I,J) + R(I+1,1)
      IF (R(I+1,2).EQ.-99.9) THEN
```

```
            GOTO 20
         ENDIF
         R5 (I,J) = R4(I,J) + R(I+1,2)
         GOTO 20
17       IF (J.EQ.ND-3) THEN
            GOTO 18
         ENDIF
         IF (R(I,J+4).EQ.-99.9) THEN
            GOTO 20
         ENDIF
         R5 (I,J) = R4(I,J) + R(I,J+4)
         GOTO 20
18       IF (R(I+1,1).EQ.-99.9) THEN
            GOTO 20
         ENDIF
         R5 (I,J) = R4(I,J) + R(I+1,1)
20       CONTINUE
10       CONTINUE
         RETURN
         END
C        ***********************************
         SUBROUTINE MAXIM(IY,NDAY,R,AMMAX,ITTB,ITTE,IMNB,IMNE,N)
C        SUBROUTINE FOR COMPUTING MAXIMUM RAINFALL TOTALS
         DIMENSION R(12,31),NDAY(12),AMAX(12),IT(12)
         DO 10 I= 1,12
         IF(I.EQ.2)CALL LEAPYR(IY, NDAY)
         ND=NDAY(I)
         AMAXM= R(I,1)
         IPT = 1
         DO 20 J=2,ND
         IF(AMAXM.GE.R(I,J)) THEN
           GOTO 20
         ENDIF
         AMAXM= R(I,J)
         IPT=J
20       CONTINUE
         AMAX(I)=AMAXM
         IT(I)=IPT
10       CONTINUE
         AMMAX=AMAX(1)
         IPB=IT(1)
         IMK = 1
         DO 15 I= 2,12
         IF(AMMAX.GE.AMAX(I)) THEN
            GOTO 15
         ENDIF
         AMMAX=AMAX(I)
         IPB = IT(I)
```

```
      IMK=I
15    CONTINUE
      ITTB = IPB
      IMNB = IMK
      IPE = IPB + (N-1)
      IF (NDAY(IMK).GE.IPE) THEN
         GOTO 25
      ENDIF
      ITTE = IPE - NDAY(IMK)
      IMNE = IMK + 1
      GOTO 30
25    ITTE = IPE
      IMNE = IMK
30    RETURN
      END
C     *********************************
      SUBROUTINE LEAPYR (IY,NDAY)
      DIMENSION NDAY(2)
      LPYR = MOD(IY,4)
      IF (LPYR.EQ.0) NDAY(2)=29
      RETURN
      END
```

Listing of Sample Input Data File MAX.DAT

```
1129M P        RAIPUR          MAINPUR
31
320  2017821414     1960 1000000000000000000000043000003120000000000000000
320  2017821414     1960 2000000000000000000000037056201910000000000000000
320  2017821414     1960 3000000280000000000000035021901600077000000000000
320  2017821414     1960 4000000000000000000000000062003001060000000000000
320  2017821414     1960 5000000000000000000000000093001000700000000000000
320  2017821414     1960 6000000000000000000000000011004000720020000000000
320  2017821414     1960 7000000000000000000000000063002000000000000000000
320  2017821414     1960 8000000000000000000000085008900350102000000000000
320  2017821414     1960 9000000000000000000000082000100030001000000000000
320  2017821414     19601000000000000000000000000061000000600580000000000
320  2017821414     19601100000000000000000000000057000000000000000000000
320  2017821414     19601200000000000000000047000000280021000000000000000
320  2017821414     19601300000000000000000020000000201150000003000000000
320  2017821414     19601400000000000000000000000000001800000002300000000
320  2017821414     1960150000-99900000000000000000037012000000000000000000
320  2017821414     19601600000000000000000000830078001500000000000000000
320  2017821414     19601700000000000000000000960039008600000000000000000
320  2017821414     19601800000000000000000000001000000000000000000000000
320  2017821414     196019000000000000-9990000004500000044016100000000000
320  2017821414     19602000000000000000000000000010001300000000000000000
320  2017821414     19602100000000000000000040030001180073008000000000000
320  2017821414     19602200000000000000000043000500370010015000000000000
320  2017821414     19602300000000000000000030004700610003014000000000000
320  2017821414     19602400000000000000000000000590000008500000000000000
320  2017821414     19602500000000000000000000011000000001910000000000000
320  2017821414     19602600000000000000000000021009700000220067000000000
320  2017821414     19602700000000000000000350018700580000000000000000000
320  2017821414     19602800000000000000000153000200080000000000000000000
320  2017821414     19602900000000000000000085002000800000005000000000000
320  2017821414     1960300000     000000000001000000100086000000000000000
320  2017821414     1960310055     0000      0000      01100000     0000      0000
```

APPENDIX-IX

Listing of Computer Programme TENDAY.FOR

```
C    PROGRAMME TO READ DATA FROM IMD TAPES AND OTHER SOURCE
C    CONDITIONS! IT WILL NOT TAKE CARE OF CONTINIOUS YEAR DATA
C    THEREFORE, FOR WATERYEAR CALCULATIONS NOT APPLICABLE
C
C NDAY      = Number of days in different calendar months
C NOSTAT = Code number of district
C NODIST = Code number of district
C AMSTAT = Name of the state in the country
C AMDIST = Name of the district in the state
C AMSTN  = Name of the station in the district
C IYEAR  = Calendar year for which data is provided
C IR(I,J) & R(I,J) = Two dimensional array containing daily
C                    rainfall data (together with -999 for the
C                    missing period) of raingauge stations.
C DAYS10  = Ten daily rainfall totals of first ten days
C DAYS20  = Ten daily rainfall totals of second ten days
C DAYSRES = Ten daily rainfall totals of the remaining days
C K1,K2,K3= Actual number of days for which data are available
C           in each of the periods above.
AV10      = Average daily rainfall during the first ten days
AV20      = Average daily rainfall during the second ten days
AVERS     = Average daily rainfall during the remaining days.
SUMMON    = Monthly rainfall totals
AMON      = Monsoon season total rainfall
SUMYR     = Annual rainfall total
       DIMENSION IR(12,31),NDAY(12),SM(100,13),DY(50,12,3)
   1,AMON(50),K(50,12,3),SUMYR(50),NNDAY(50,12),AVER(50,12,3)
       DIMENSION AVMON(250,12),KK1(50,12),NY(50),NNY(50)
       CHARACTER*10 AMSTAT
       CHARACTER*16 AMDIST,AMSTN
       DATA NDAY/31,28,31,30,31,30,31,31,30,31,30,31/
       OPEN(UNIT=1, FILE= 'WORK9.DAT', STATUS ='OLD')
       OPEN(UNIT=2, FILE= 'WORK.OUT', STATUS ='NEW')
       GOTO 777
888    BACKSPACE UNIT=1
777    READ(1,109)NOSTAT,NODIST,AMSTAT,AMDIST,AMSTN
109    FORMAT(2I2,A,2A)
       READ(1,199)CT
199    FORMAT(A2)
       WRITE(2,104)
       WRITE(2,5000)AMSTAT,AMDIST,AMSTN
5000   FORMAT(2X,'STATE-',A10,15X,'DIST-',A16,15X,'STATION-',
     1A16)
       NYR=1000
```

```
      DO 40 II=1,NYR
      IF(CT.EQ.'31') THEN
        GOTO 111
      ENDIF
      DO 10 I=1,12
      READ(1,101,END=999,ERR=111)ICATNO,LAT,LONG,ISTANO,
     1IYEAR,IMONTH,IC,RDNO, (IR(I,J),J=1,15)
      IYEAR=IYEAR+1900
      IF(I.EQ.2) CALL LEAPYR(IYEAR,NDAY)
      READ(1,101,END=999)ICATNO,LAT,LONG,ISTANO,IYEAR,IMONTH,
     1ICRDNO,(IR(I,J),J=16,NDAY(I))
10    CONTINUE
      GO TO 222
111   DO 50 K9=1,31
      READ(1,105,END=999,ERR=888)ICATNO,STR,LAT,LONG,ISTANO,
     1IYEAR,IDAT,E, (IR(J,K9),J=1,12)
50    CONTINUE
222   CALL TENDAY(II,IR,NDAY,IYEAR,DY,K,NNDAY,AVER)
      CALL SUM(II,DY,SM,SUMYR,AVMON,K,NDAY,KK1,AMON)
      NY(II)=IYEAR
      CALL OUT(II,NY,NNY,DY,K,NDAY,KK1,SM,SUMYR,AVMON,
     1AVER,AMON)
40    CONTINUE
104   FORMAT(4X,128('*'))
101   FORMAT(1X,I3,A2,2I2,2X,2I2,I1,16I4)
105   FORMAT(1X,I3,A2,2I4,I2,4X,I4,I2,12I4)
999   END
C
      SUBROUTINE LEAPYR (IYEAR,NDAY)
C     YEAR SHOULD BE DEFINED IN FULL DIGITS IN MAIN PROGRAMME
      DIMENSION NDAY(2)
      LPYR=MOD(IYEAR,4)
      IF(LPYR.EQ.0) NDAY(2)=29
      RETURN
      END
C     ***************************
      SUBROUTINE TENDAY(II,IR,NDAY,IYEAR,DY,K,NNDAY,AVER)
      DIMENSION DAYS10(12),DAYS20(12),DAYRES(12),R(12,31),
     1IR(12,31),NDAY(12),K1(12),K2(12),K3(12),DY(50,12,3),
     2K(50,12,3), AVER(50,12,3),AV10(12),AV20(12),AVRES(12),
     3NNDAY(50,12),AK1(12),AK2(12),AK3(12)
      IF(IYEAR.LT.1600)IYEAR=IYEAR+1900
      DO 1 I=1,12
      NDAY(2)=28
      IF(I.EQ.2) CALL LEAPYR(IYEAR,NDAY)
      NDAYS=NDAY(I)
      DO 2 J=1,NDAYS
      R(I,J)=IR(I,J)
```

```
      IF(R(I,J).EQ.-999) THEN
        GOTO 9875
      ENDIF
C     TYPE *,IYEAR
      IF(IYEAR.LE.1957) THEN
        GOTO 9869
      ENDIF
      R(I,J)=R(I,J)/10.0
      GOTO 2
9869  R(I,J)=R(I,J)*0.254
      GOTO 2
9875  R(I,J)=R(I,J)/10.0
2     CONTINUE
      DAYS10(I)=0.0
      DAYS20(I)=0.0
      DAYRES(I)=0.0
      K1(I)=0
      K2(I)=0
      K3(I)=0
      DO 3 J=1,NDAYS
      IF(J.GT.10.AND.J.LE.20) THEN
        GOTO 41
      ENDIF
      IF(J.GT.20) THEN
        GOTO 42
      ENDIF
      IF(R(I,J).NE.-99.9) K1(I)=K1(I)+1
      IF(R(I,J).EQ.-99.9) THEN
        GOTO 3
      ENDIF
      DAYS10(I)=DAYS10(I)+R(I,J)
      GOTO 3
41    IF(R(I,J).NE.-99.9) K2(I)=K2(I)+1
      IF(R(I,J).EQ.-99.9) THEN
        GOTO 3
      ENDIF
      DAYS20(I)=DAYS20(I)+R(I,J)
      GOTO 3
42    IF(R(I,J).NE.-99.9) K3(I)=K3(I)+1
      IF(R(I,J).EQ.-99.9) THEN
        GOTO 3
      ENDIF
      DAYRES(I)=DAYRES(I)+R(I,J)
3     CONTINUE
      IF(K1(I).EQ.0) THEN
        GOTO 43
      ENDIF
      AK1(I)=K1(I)
```

```
      AV10(I)=DAYS10(I)/AK1(I)
      GOTO 44
43    DAYS10(I)=-99
      AV10(I)=-99
44    IF(K2(I).EQ.0) THEN
        GOTO 45
      ENDIF
      AK2(I)=K2(I)
      AV20(I)=DAYS20(I)/AK2(I)
      GOTO 46
45    DAYS20(I)=-99
      AV20(I)=-99
46    IF(K3(I).EQ.0) THEN
        GOTO 47
      ENDIF
      AK3(I)=K3(I)
      AVRES(I)=DAYRES(I)/AK3(I)
      GOTO 48
47    DAYRES(I)=-99
      AVRES(I)=-99
48    DY(II,I,1)=DAYS10(I)
      DY(II,I,2)=DAYS20(I)
      DY(II,I,3)=DAYRES(I)
      K(II,I,1)=K1(I)
      K(II,I,2)=K2(I)
      K(II,I,3)=K3(I)
      AVER(II,I,1)=AV10(I)
      AVER(II,I,2)=AV20(I)
      AVER(II,I,3)=AVRES(I)
      NNDAY(II,I)=NDAY(I)
1     CONTINUE
      RETURN
      END
C     ********************************
      SUBROUTINE SUM(II,DY,SM,SUMYR,AVMON,K,NDAY,KK1,AMON)
      DIMENSION DY(50,12,3),SM(50,12),SUMYR(50),AVMON(50,12),
     1K(50,12,3),NDAY(12),KK1(50,12),AKK1(50,12),AMON(50)
      SUMYR(II)=0.0
      DO 20 I=1,12
      SM(II,I)=0.0
      KK1(II,I)=0.0
      DO 30 J=1,3
      IF(DY(II,I,J).EQ.-99) THEN
        GOTO 30
      ENDIF
      SM(II,I)=SM(II,I)+DY(II,I,J)
      KK1(II,I)=KK1(II,I)+K(II,I,J)
30    CONTINUE
```

```
      SUMYR(II)=SUMYR(II)+SM(II,I)
      IF(KK1(II,I).EQ.0) THEN
        GOTO 32
      ENDIF
      AKK1(II,I)=KK1(II,I)
      AVMON(II,I)=SM(II,I)/AKK1(II,I)
      GOTO 20
32    AVMON(II,I)=-99
      SM(II,I)=-99
20    CONTINUE
      AMON(II)=0.0
      DO 300 I=6,10
      IF(SM(II,I).EQ.-99) THEN
        GOTO 300
      ENDIF
      AMON(II)=AMON(II)+SM(II,I)
      IF(AMON(II).EQ.0.0) AMON(II)=-99
300   CONTINUE
      RETURN
      END
      SUBROUTINE OUT(II,NY,NNY,DY,K,NDAY,KK1,SM,SUMYR,
 1AVMON,AVER,AMON)
      DIMENSION NY(50),NNY(50),DY(50,12,3),K(50,12,3),
     1NDAY(12),KK1(50,12),SM(50,12),SUMYR(50),AVMON(50,12)
      DIMENSION AVER(50,12,3),AMON(50)
      WRITE(2,199)
199   FORMAT(14X,'TEN DAILY RAINFALL (MM)')
      IF (NY(II).LT.1900) NY(II)=NY(II)+1900
      WRITE(2,201) NY(II)
201   FORMAT(4X,'YEAR-',I4)
      WRITE(2,104)
104   FORMAT(4X,129('*'))
      WRITE(2,202)
202   FORMAT(4X,'NO',4X,'JAN',7X,'FEB',7X,'MAR',7X,'APR',7X,
     1'MAY',7X,'JUN',7X,'JUL',7X,'AUG',7X,'SEP',7X,'OCT',7X,
     2'NOV',7X,'DEC')
      WRITE(2,104)
      WRITE(2,203)
203   FORMAT(8X,'TR1',2X,'NV1',2X,'TR2',2X,'NV2',2X,'TR3',2X,
     1'NV3',2X\)
      WRITE(2,300)
300   FORMAT('TR4',2X,'NV4',2X,'TR5',2X,'NV5',2X,'TR6',2X,
     1'NV6',2X\)
      WRITE(2,301)
301   FORMAT('TR7',2X,'NV7',2X,'TR8',2X,'NV8',2X,'TR9',2X,
     1'NV9',1X\)
      WRITE(2,302)
302   FORMAT('TR10',1X,'NV10',1X,'TR11',1X,'NV11',1X,'TR12',
```

```
     11X,'NV12')
      WRITE(2,104)
      DO 204 J=1,3
      K9=J
      WRITE(2,205) K9,(DY(II,I,J),K(II,I,J),I=1,12)
204   CONTINUE
205   FORMAT(4X,I2,12(1X,F5.0,2X,I2))
      WRITE(2,104)
      WRITE(2,206) (SM(II,I),KK1(II,I),I=1,12)
206   FORMAT(1X,'SUM=',12(2X,F5.0,1X,I2))
      WRITE(2,104)
      WRITE(2,212) SUMYR(II)
212   FORMAT(4X,'ANNUAL RAINFALL(MM)=',F10.2)
      WRITE(2,641) AMON(II)
641   FORMAT(4X,'TOTAL RAINFALL IN MONSOON ',
   1SEASON(MM)=',F10.2)
      WRITE(2,104)
      WRITE(2,341)
341   FORMAT(2X,'WHERE1-'/4X,'TR   =TOTAL RAINFALL (MM)'/4X,
     1'NV  = NO.OF VALUES AVAILABLE')
      WRITE(2,207)
207   FORMAT(14X,'TEN DAILY AVERAGE RAINFALL(MM)')
      WRITE(2,201) NY(II)
      WRITE(2,104)
      WRITE(2,202)
      WRITE(2,104)
      WRITE(2,303)
303   FORMAT(8X,'AR1',2X,'NV1',2X,'AR2',2X,'NV2',2X,'AR3',2X,
     1'NV3',2X\)
      WRITE(2,304)
304   FORMAT('AR4',2X,'NV4',2X,'AR5',2X,'NV5',2X,'AR6',2X,
     1'NV6',2X\)
      WRITE(2,305)
305   FORMAT('AR7',2X,'NV7',2X,'AR8',2X,'NV8',2X,'AR9',2X,
     1'NV9',1X\)
      WRITE(2,306)
306   FORMAT('AR10',1X,'NV10',1X,'AR11',1X,'NV11',1X,'AR12',
     11X,'NV12')
      WRITE(2,104)
      DO 209 J=1,3
      WRITE (2,205)J,(AVER(II,I,J),K(II,I,J),I=1,12)
209   CONTINUE
      WRITE(2,104)
      WRITE(2,210) (AVMON(II,I),I=1,12)
210   FORMAT(1X,'MON AV=',F4.0,11(4X,F6.2))
      WRITE(2,104)
      WRITE(2,530)
530   FORMAT(2X,'WHERE1-'/4X,'AR =AVERAGE RAINFALL    (MM)'
```

```
     1/4X,'NV.= NO.OF VALUES')
      WRITE(2,531)
531   FORMAT('1')
      RETURN
      END
```

Listing of Sample Input Data File WORK9.DAT

```
17 4ORISSA    CUTTACK        JAGATSINGPUR
24
320201686   60 11000000000000000000000000000000000000000000000000000000000000
320201686   60 120000000000000000000000000000000000000000000000000000005400700055
320201686   60 21000000000000000000000000000000000000000000000000000000000000
320201686   60 2200000000000000000000000000000000000000070000000000000-999
320201686   60 31000000000000000000000000000000000000000000000000000000000000
320201686   60 320000000000000000000000000000000000000000000000000000000000000000
320201686   60 41000000000000000000000000000000000000000000000000000000000000
320201686   60 42000000000000000000000000000000000000000000000000000000000032
320201686   60 51000000950000000000000000000000000000006500000000000000000000
320201686   60 520000000000000000000300000000000740000000000040000000000000000000
320201686   60 61008300000043001300000015000000000000000350263000000000500011
320201686   60 62-999-999-999-999-999-999-999-999-999-999-999-999-999-999-999
320201686   60 71000200000000000000780077014700220349067801920001000000000002
320201686   60 720000013500000006000600110009000000000000000000570100007000020063
320201686   60 81001400060008000000120000000000510121003900250000000000620128
320201686   60 820000005400150000000000000009000000440002000000000000000000000000
320201686   60 91000000000007300020000005301460098001800040000000000900000000
320201686   60 92000000000000000000230000002300450000000000000000005200720008
320201686   60101003001340000000000180000018402350465000500640000000000000000
320201686   601020014000002210000000000000000000000000000000000000000000000000000
320201686   60111000000000000000000000000000000000000000000000000000000000000
320201686   60112000000100217025100100000000000000000000000000000000000000000
320201686   60121000000000000000000000000000000000000000000000000000000000000
320201686   601220000000000000000000000000000000000000000000000000000000000000000
```

APPENDIX-X

Listing of Computer Programme DIS.FOR

```
C THIS PROGRAME IS FOR disaggregating the average values
C of stations including and excluding zero values also using
C normal distribution, power transformation, pt3 and ev1
c distributions regression analysis, frequency analysis and
c disaggregation technique USING LEAST SQUARE METHOD
C       X = VECTOR CONTAINING station VALUES

      COMMON Y(40,12,12),X(40,12),NY,ND,NS,NG,WT(14),KCV,
      1  Z(40,12,12),gx(100,12),AX(480),T(480),TB(14),
      2 TC(14),ERR(16),OERR(16),ix
      DIMENSION AVA(14),SDA(14),SKA(14),CVA(14),MK(20),
      1 AVR(20,14), SD(20,14),CV(20,14),SK(20,14),
      2 AVH(14),SDH(14)  ,CVH(14),SKH(14),avr1(20,14,11),
      3 sd1(20,14,11),sk1(20,14,11),cv1(20,14,11),err1(16),
      4 oerr1(16),covm(20,14),covsd(20,14) ,covcv(20,14),
      5 covsk(20,14)
      CHARACTER*30 FYLE1,FYLEN,TITLE*80,HEAD*120,TIT*80,
      1 STN(14)*10,FYLE2,HD
      IX=1972
      WRITE(*,101)
101   FORMAT(5x,'SUPPLY INPUT FILE (1) NAME
     1(for calibration) :'\)
      READ(*,34)FYLE1
      WRITE(*,102)
102   FORMAT(//5x,'SUPPLY OUTPUT FILE NAME :'\)
      READ(*,34)FYLEN
106   WRITE(*,104)
104   FORMAT(//5X,'For Calibration mode enter 1
      1  /5X,'For Validation mode enter 2'
      2  /5x,'For Disaggregation from file data enter 0 '
      3  /5x,'For disaggregation from gen data enter 3 :'\)
      READ(*,*)KCV
      IF(KCV.EQ.1)HD='CALIBRATION PERIOD'
      IF(KCV.EQ.2)HD='VALIDATION PERIOD'
      IF(KCV.EQ.0.OR.KCV.EQ.3)HD='DISAGGREGATED DETAILS'
      IF(KCV.GT.3.OR.KCV.LT.0)GO TO 106
      IF(KCV.NE.1)THEN
      IF(KCV.EQ.3) THEN
      FYLE2='TEMP.DAT'
      OPEN(7,FILE=FYLE2, STATUS='UNKNOWN')
      GO TO 968
      endif
      WRITE(*,103)
103   FORMAT(//5x,'Enter File Name (2)(For Disaggregation'
```

```
     1  ' / Validation) :'\)
      READ(*,34)FYLE2
      OPEN(UNIT=7,FILE=FYLE2,STATUS='OLD')
      ENDIF
34    FORMAT(A)
968   OPEN(UNIT=2,FILE=FYLEN,STATUS='UNKNOWN')
      OPEN(UNIT=1,FILE=FYLE1,STATUS='OLD')
      READ(1,34)TIT
      READ(1,34)TITLE
      READ(1,*)NY,NS
      ND = 12
      NG = NY
      READ(1,134)(stn(i),i=1,ns)
      READ(1,*)(WT(I),I=1,NS)
      READ(1,34)TITLE
      DO 201 I=1,NY
      DO 201 J=1,ND
201   READ(1,*)I1,I2,(Y(I,J,L),L=1,NS),X(I,J)
      REWIND (UNIT=1)
      N=0
      DO 209 I=1,NY
      DO 209 J=1,ND
      N=N+1
209   AX(N)=X(I,J)
      CALL STAT(AX,N,AVA(NS+1),SDA(NS+1),SKA(NS+1),CVA(NS+1))
      CALL STAT(AX,N,AVH(NS+1),SDH(NS+1),SKH(NS+1),CVH(NS+1))
      DO 202 L=1,NS
      MK(L)=L
      N=0
      DO 204 I=1,NY
      DO 204 J=1,ND
      N=N+1
204   AX(N)=Y(I,J,L)
      CALL STAT(AX,N,AVA(L),SDA(L),SKA(L),CVA(L))
      CALL STAT(AX,N,AVH(L),SDH(L),SKH(L),CVH(L))
202   CONTINUE
      IF(KCV.EQ.3)THEN
      write(*,*)'     Enter no of years for'
      1    ,' which data is to be generated: '
      Read(*,*)ng
      write(*,*)'     Enter no of samples to be generated:
      Read(*,*)nsmp
1001  WRITE(7,*)'GENERATED DATA'
      WRITE(7,*)'NO OF YEARS OF GENERATED DATA'
      WRITE(7,*)NG
      WRITE(7,*)'YEAR MONTH VALUES'
      CALL GEN
      DO I=1,NG
```

```
DO J=1,ND
WRITE(7,*)I,J,GX(I,J)
ENDDO
enddo
REWIND (UNIT=7)
kcv=0
if(nsmp.eq.0)go to 301
mtd=18
write(*,*)'   Step =', nsm+1
CALL NFR(AVR,SD,SK,CV,MTD,MM)
do i=1,mm
err1(i)=err1(i)+err(i)
oerr1(i)=oerr1(i)+oerr(i)
do j=1,ns+1
avr1(i,j,nsm+1)=avr(i,j)
sd1(i,j,nsm+1)=sd(i,j)
sk1(i,j,nsm+1)=sk(i,j)
cv1(i,j,nsm+1)=cv(i,j)
avr1(i,j,nsmp+1)=avr1(i,j,nsmp+1)+avr(i,j)
sd1(i,j,nsmp+1)=sd1(i,j,nsmp+1)+sd(i,j)
sk1(i,j,nsmp+1)=sk1(i,j,nsmp+1)+sk(i,j)
cv1(i,j,nsmp+1)=cv1(i,j,nsmp+1)+cv(i,j)
enddo
enddo
nsm=nsm+1
if(nsm.ge.nsmp)then
do i=1,mm
err(i)=err1(i)/nsmp
oerr(i)=oerr1(i)/nsmp
do j=1,ns+1
avr(i,j)=avr1(i,j,nsmp+1)/nsmp
sd(i,j)=sd1(i,j,nsmp+1)/nsmp
sk(i,j)=sk1(i,j,nsmp+1)/nsmp
cv(i,j)=cv1(i,j,nsmp+1)/nsmp
enddo
enddo
do i=1,mm
do j=1,ns+1
a=0.
b=0.
c=0.
d=0.
do k=1,nsmp
a=a+(abs(avr1(i,j,k)-avr(i,j)))**2
b=b+(abs(sd1(i,j,k)-sd(i,j)))**2
c=c+(abs(sk1(i,j,k)-sk(i,j)))**2
d=d+(abs(cv1(i,j,k)-cv(i,j)))**2
enddo
```

```
      a=(a/nsmp)**0.5
      b=(b/nsmp)**0.5
      c=(c/nsmp)**0.5
      d=(d/nsmp)**0.5
      covm(i,j)=a/avh(j)
      covsd(i,j)=b/sdh(j)
      covsk(i,j)=c/skh(j)
      covcv(i,j)=d/cvh(j)
      enddo
      enddo
      write(2,641)
 641  Format(////////)
      do j=1,ns+1
      write(2,*)(covm(i,j),i=1,mm)
      write(2,*)(covsd(i,j),i=1,mm)
      write(2,*)(covcv(i,j),i=1,mm)
      write(2,*)(covsk(i,j),i=1,mm)
      enddo
      go to 1002
      endif
      close(unit=7)
      open(7,file='temp.dat',status='unknown')
      go to 1001
      ENDIF
 301  WRITE(*,491)
      WRITE(*,492)
      WRITE(*,493)
 134  FORMAT(10X,14A10)
 491  FORMAT(///'  1)      DISAGGREGATION SINGLE MATRIX
     1 METHOD',
     1  ' SEPERATE EQN FOR EACH PERIOD'/
     1  '   2) DISAGGREGATION SINGLE MATRIX METHOD'
     1  ' ONE EQN FOR ALL PERIOD'/
     1  '   3) DISAGGREGATION DOUBLE MATRIX METHOD'
     1  ' SEPERATE EQN FOR EACH PERIOD'/
     1  '   4) DISAGGREGATION DOUBLE MATRIX METHOD'
     1  ' ONE EQN FOR ALL PERIOD'//
     1  '   5) FREQUENCY ANALYSIS METHOD EXCLUDING ZEROS'
     1  ' NORMAL DISTRIBUTION'/
     1  '   6) FREQUENCY ANALYSIS METHOD EXCLUDING ZEROS'
     1  ' POWER TRANSFORMATION')
 492   FORMAT('  7) FREQUENCY ANALYSIS METHOD EXCLUDING ZEROS'
     1  ' PT3 DISTRIBUTION'/
     1  '   8) FREQUENCY ANALYSIS METHOD EXCLUDING ZEROS'
     1  ' EV1 DISTRIBUTION'/
     1  '   9) FREQUENCY ANALYSIS METHOD INCLUDING ZEROS'
     1  ' NORMAL DISTRIBUTION'/
     1 ' 10) FREQUENCY ANALYSIS METHOD INCLUDING ZEROS'
```

```
     1 ' POWER TRANSFORMATION'/
     1 ' 11) FREQUENCY ANALYSIS METHOD INCLUDING ZEROS'
     1 ' PT3 DISTRIBUTION')
493   FORMAT(' 12) FREQUENCY ANALYSIS METHOD INCLUDING ZEROS'
     1 ' EV1 DISTRIBUTION'//
     1 ' 13) REGRESSION METHOD INCLUDING ZEROS'/
     1 ' 14) REGRESSION METHOD INCLUDING ZEROS'
     1 ' POWER TRANSFORMATION'/
     1 ' 15) REGRESSION METHOD EXCLUDING ZEROS'/
     1 ' 16) REGRESSION METHOD EXCLUDING ZEROS'
     1 ' POWER TRANSFORMATION'/
     1 ' 17) ALL THE ABOVE TECHNIQUES'/
     1 ' 18) ALL THE ABOVE TECHNIQUES INCLUDING ZEROS ONLY'//
     1 '  0) TO END THE PROGRAMME'//
     1 '     CHOOSE  METHOD NO :'\)
     READ(*,*)MTD
     IF(MTD.EQ.0)STOP
     IF(MTD.GT.0.AND.MTD.LT.5) CALL NORDD(MTD)
     IF(MTD.GT.4.AND.MTD.LT.13) CALL FRE(MTD)
     IF(MTD.GT.12.AND.MTD.LT.17) CALL REGR(MTD)
1002 IF(MTD.EQ.17.OR.MTD.EQ.18) THEN
     if(nsmp.eq.0)CALL NFR(AVR,SD,SK,CV,MTD,MM)
     IF(KCV.EQ.0.OR.KCV.EQ.2) THEN
     READ(7,'(A)')TITLE
     READ(7,'(A)')TITLE
     READ(7,*)NG
     READ(7,'(A)')TITLE
     N=0
     DO 309 I =1,NG
     DO 309 J =1,ND
     N=N+1
     IF(KCV.EQ.0)READ (7,*)I1,I2,X(I,J)
     IF(KCV.EQ.2)READ (7,*)I1,I2,(Y(I,J,L),L=1,NS),X(I,J)
309  AX(N)=X(I,J)
     REWIND(UNIT=7)
     CALL STAT(AX,N,AVA(NS+1),SDA(NS+1),SKA(NS+1),CVA(NS+1))
     DO 302 L=1,NS
     IF(KCV.EQ.0)THEN
     AVA(L)=0.0
     SDA(L)=0.0
     SKA(L)=0.0
     CVA(L)=0.0
     go to 302
     ENDIF
     N=0
     DO 304 I=1,NG
     DO 304 J=1,ND
     N=N+1
```

```
304  AX(N)=Y(I,J,L)
     CALL STAT(AX,N,AVA(L),SDA(L),SKA(L),CVA(L))
302  CONTINUE
     ENDIF
     DO L=1,MM
     MK(L)=L
     ENDDO
     WRITE(2,34)TIT
     WRITE(2,34)HD
     WRITE(2,990)
     IF(MTD.EQ.17)WRITE(2,896)(mk(l),l=1,16)
     IF(MTD.EQ.18)WRITE(2,796)(mk(l),l=1,10)
990  FORMAT(/2x,'STATIONWISE HISTORICAL, TO BE DISAGGREGATED'
     1  ,' AND DISAGGREGATED STATISTICS DETAILS')
896    FORMAT(2X,160('=')/2X,'STATION     STAT   HIST   TO BE
     1DIS'
     1  ,16(1X,'MTD =',I2)/2X,160('='))
796    FORMAT(2X,114('=')/2X,'STATION     STAT   HIST    TO BE
     1DIS'
     1  ,10(1X,'MTD =',I2)/2X,114('='))
     STN(NS+1)='AVR VALUE'
     DO 978 L=1,NS+1
     IF(MTD.EQ.17)WRITE(2,648) STN(L),AVH(L),AVA(L),(AVR(K,L)
     1  ,K=1,MM),SDH(L),SDA(L),(SD(K,L),K=1,MM),CVH(L),CVA(L)
     1  ,(CV(K,L),K=1,MM),SKH(L),SKA(L),(SK(K,L),K=1,MM)
     IF(MTD.EQ.18)WRITE(2,748) STN(L),AVH(L),AVA(L),(AVR(K,L)
     1  ,K=1,MM),SDH(L),SDA(L),(SD(K,L),K=1,MM),CVH(L),CVA(L)
     1  ,(CV(K,L),K=1,MM),SKH(L),SKA(L),(SK(K,L),K=1,MM)
978  CONTINUE
     IF(KCV.EQ.0) GO TO 791
     IF(MTD.EQ.17)WRITE(2,456)
     IF(MTD.EQ.18)WRITE(2,556)
     IF(MTD.EQ.17)WRITE(2,896)(mk(l),l=1,16)
     IF(MTD.EQ.18)WRITE(2,796)(mk(l),l=1,10)
     DO L=1,NS+1
     DO K=1,MM
     AVR(K,L)=(AVR(K,L)-AVA(L))*100./AVA(L)
     SD(K,L)=(SD(K,L)-SDA(L))*100./SDA(L)
     CV(K,L)=(CV(K,L)-CVA(L))*100./CVA(L)
     SK(K,L)=(SK(K,L)-SKA(L))*100./SKA(L)
     ENDDO
     IF(MTD.EQ.17)WRITE(2,658)STN(L),(AVR(K,L),K=1,MM)
     1  ,(SD(K,L),K=1,MM),(CV(K,L),K=1,MM),(SK(K,L),K=1,MM)
     IF(MTD.EQ.18)WRITE(2,758)STN(L),(AVR(K,L),K=1,MM)
     1  ,(SD(K,L),K=1,MM),(CV(K,L),K=1,MM),(SK(K,L),K=1,MM)
     ENDDO
791  if(MTD.EQ.17)WRITE(2,987)
     if(MTD.EQ.18)WRITE(2,787)
```

```
      IF(MTD.EQ.17)WRITE(2,879)(OERR(L),L=1,MM)
      IF(MTD.EQ.18)WRITE(2,479)(OERR(L),L=1,MM)
779   FORMAT(/2X,'AVR ABS ERR',21X,16(2X,F6.1)/)
579   FORMAT(/2X,'AVR ABS ERR',21X,10(2X,F6.1)/)
      IF(MTD.EQ.17)WRITE(2,987)
      IF(MTD.EQ.18)WRITE(2,787)
      IF(MTD.EQ.17)WRITE(2,779)(ERR(L),L=1,MM)
      IF(MTD.EQ.18)WRITE(2,579)(ERR(L),L=1,MM)
879   FORMAT(/2X,'OVERALL ABS ERR',17X,16(2X,F6.1)/)
479   FORMAT(/2X,'OVERALL ABS ERR',17X,10(2X,F6.1)/)
      if(MTD.EQ.17)WRITE(2,987)
      if(MTD.EQ.18)WRITE(2,787)
987   FORMAT(2X,160('='))
456   FORMAT(2X,160('=')///2x'STATIONWISE PERCENTAGE ERROR'
      1  ' IN STATISTICAL PARAMETERS')
787   FORMAT(2X,114('='))
556   FORMAT(2X,114('=')///2x'STATIONWISE PERCENTAGE ERROR'
      1  ' IN STATISTICAL PARAMETERS')
648   FORMAT(2X,A10,' MEAN ',18(2X,F6.1)/2X,10X,'  SD  '
      1  ,18(2X,F6.1)/2X,10X,'  CV  ',18(2X,F6.1)
      2  /2x,10X,' SKEW ',18(2X,F6.1)/)
748     FORMAT(2X,A10,' MEAN ',12(2X,F6.1)/2X,10X,'  SD  '
      1  ,12(2X,F6.1)/2X,10X,'  CV  ',12(2X,F6.1)
      2  /2X,10X,' SKEW ',12(2X,F6.1)/)
658     FORMAT(2X,A10,' MEAN ',16X,16(2X,F6.1)/2X,10X,'  SD
      1 ',16X
      1  ,16(2X,F6.1)/2X,10X,'  CV  ',16X,16(2X,F6.1)/2X,10X,'
      1SKEW ',16X,16(2X,F6.1)/)
758   FORMAT(2X,A10,' MEAN ',16X,10(2X,F6.1)/2X,10X,'  SD
      1 ',16X
      1  ,10(2X,F6.1)/2X,10X,'  CV  ',16X,10(2X,F6.1)/2X,10X,'
      1SKEW ',16X,10(2X,F6.1)/)
      ENDIF
      IF(MTD.GT.18.OR.MTD.LT.0)GO TO 301
401   N=0
      WRITE(2,97)(STN(K),K=1,NS)
      IF(KCV.EQ.0.OR.KCV.EQ.2) THEN
      READ(7,'(A)')TITLE
      READ(7,'(A)')TITLE
      READ(7,*)NG
      READ(7,'(A)')TITLE
      N=0
      DO 403 I =1,NG
      DO 403 J =1,ND
      N=N+1
      IF(KCV.EQ.0)READ (7,*)I1,I2,X(I,J)
      IF(KCV.EQ.2)READ (7,*)I1,I2,(Y(I,J,L),L=1,NS),X(I,J)
403   AX(N)=X(I,J)
```

```
      REWIND(UNIT=7)
      CALL STAT(AX,N,AVA(NS+1),SDA(NS+1),SKA(NS+1),CVA(NS+1))
      IF(KCV.EQ.0)THEN
      DO L=1,NS
      AVA(L)=0.0
      SDA(L)=0.0
      SKA(L)=0.0
      CVA(L)=0.0
      ENDDO
      ENDIF
      IF(KCV.EQ.2)THEN
      DO 402 L=1,NS
      N=0
      DO 404 I=1,NG
      DO 404 J=1,ND
      N=N+1
404   AX(N)=Y(I,J,L)
      CALL STAT(AX,N,AVA(L),SDA(L),SKA(L),CVA(L))
402   CONTINUE
      ENDIF
      ENDIF
      N=0
      DO 205 I=1,NG
      DO 205 J=1,ND
      WRITE(2,129)I,J,(Z(I,J,K),K=1,NS)
      N=N+1
205   AX(N)=GX(I,J)
      CALL STAT(AX,N,AVR(1,NS+1),SD(1,NS+1),
     1SK(1,NS+1),CV(1,NS+1))
      DO 207 L=1,NS
      N=0
      DO 206 I=1,NG
      DO 206 J=1,ND
      N=N+1
206   AX(N)=Z(I,J,L)
      CALL STAT(AX,N,AVR(1,L),SD(1,L),SK(1,L),CV(1,L))
207    CONTINUE
      IF(MTD.EQ.1)HEAD='DISAGGREGATION SINGLE MATRIX METHOD
      1 SEPERATE EQN FOR EACH PERIOD'
      IF(MTD.EQ.2)HEAD='DISAGGREGATION SINGLE MATRIX METHOD
      1 ONE EQN FOR ALL PERIOD'
      IF(MTD.EQ.3)HEAD='DISAGGREGATION DOUBLE MATRIX METHOD
      1 SEPERATE EQN FOR EACH PERIOD'
      IF(MTD.EQ.4)HEAD='DISAGGREGATION DOUBLE MATRIX METHOD
      1 ONE EQN FOR ALL PERIOD'
      IF(MTD.EQ.5) HEAD='FREQUENCY ANALYSIS METHOD EXCLUDING
      1ZEROS NORMAL DISTRIBUTION'
      IF(MTD.EQ.6) HEAD='FREQUENCY ANALYSIS METHOD EXCLUDING
```

```
      1ZEROS POWER TRANSFORMATION'
      IF(MTD.EQ.7) HEAD='FREQUENCY ANALYSIS METHOD EXCLUDING
      1 ZEROS  PT3 DISTRIUTION'
      IF(MTD.EQ.8) HEAD='FREQUENCY ANALYSIS METHOD EXCLUDING
      1ZEROS EV DISTRIBUTION'
      IF(MTD.EQ.9) HEAD='FREQUENCY ANALYSIS METHOD INCLUDING
      1ZEROS  NORMAL DISTRIBUTION'
      IF(MTD.EQ.10) HEAD='FREQUENCY ANALYSIS METHOD INCLUDING
      1ZEROS POWER TRANSFORMATION'
      IF(MTD.EQ.11) HEAD='FREQUENCY ANALYSIS METHOD INCLUDING
      1ZEROS PT3 DISTRIBUTION'
      IF(MTD.EQ.12) HEAD='FREQUENCY ANALYSIS METHOD INCLUDING
      1ZEROS EV DISTRIBUTION'
      IF(MTD.EQ.13) HEAD='REGRESSION METHOD INCLUDING ZEROS'
      IF(MTD.EQ.14) HEAD='REGRESSION METHOD INCLUDING ZEROS
      1 POWER TRANSFORMATION'
      IF(MTD.EQ.15) HEAD='REGRESSION METHOD EXCLUDING ZEROS'
      IF(MTD.EQ.16) HEAD='REGRESSION METHOD EXCLUDING ZEROS
      1 POWER TRANSFORMATION'
97    FORMAT(2x,'year month',5X,12A10/)
      WRITE(2,138)
138   FORMAT(//2X,51('=')/2X,'year month   avr basin value',3X,
      1  'wt av of disag value'/2X,51('='))
      DO 789 I=1,NG
      DO 789 J=1,ND
789   WRITE(2,139)I,J,X(I,J),GX(I,J)
      WRITE(2,856)
856   FORMAT(2X,51('=')/)
139   FORMAT(2X,I4,2X,I4,9X,F7.2,15X,F7.2)
129   format(2X,I4,2X,I3,2X,12F9.2)
      WRITE(2,234)HEAD
234   FORMAT(2X,A110)
      WRITE(2,604)
604   FORMAT(//8X,'STATISTICS OF HISTORICAL,'
      1  ,' TO BE DISAGGREGATED AND DISAGGREGATED VALUES')
      WRITE(2,188)ERR(MTD)
      WRITE(2,288)OERR(MTD)
      WRITE(2,578)
      DO K=1,NS+1
      IF(K.NE.NS+1.AND.MTD.GT.4)WRITE(2,576)TB(K),TC(K)
      IF(K.EQ.NS+1.AND.MTD.GT.4)WRITE(2,577)TB(K),TC(K)
      IF(K.NE.NS+1)WRITE(2,178)STN(K),AVH(K),AVA(K),
      1AVR(1,K),SDH(K),SDA(K),SD(1,K),CVH(K),
      1CVA(K),CV(1,K),SKH(K),SKA(K),SK(1,K)
      IF(K.EQ.NS+1)WRITE(2,179)AVH(K),AVA(K),AVR(1,K),
      1SDH(K),SDA(K),
      1SD(1,K),CVH(K),CVA(K),CV(1,K),SKH(K),SKA(K),SK(1,K)
179   FORMAT(2X,'AVERAGE  MEAN  ',3(F10.2,5X)
```

```
     1   /4X,'VALUE',2X,'STDEV ',3(F10.2,5X)/
     2  11X,'CV    ',3(F10.2,5X)/11X,'SKEW  ',3(F10.2,5X)/2x
     3  ,62('='))
188    FORMAT(/10X,'AVERAGE ABSOLTE ERROR =',F10.4/62('='))
288    FORMAT(/10X,'OVERALL ABSOLTE ERROR =',F10.4/62('='))
     ENDDO
578    FORMAT(2X,'STATION',2X,' STAT   OBSERVRD',6X,'TO BE
   DISAGGR',6X,'DISAGGREGATED')
178  FORMAT(A10,1X,'MEAN  ',3(F10.2,5X)
     1   /11X,'STDEV ',3(F10.2,5X)/
     2  11X,'CV    ',3(F10.2,5X)/11X,'SKEW  ',3(F10.2,5X)/2X
     3  ,62('='))
576  FORMAT(/5X,'B = ',F7.2,2X,'C = ',F7.2/2X,62('='))
577  FORMAT(2X,'AVERAGE OF STATIONS',1X,'B = ',F7.2,2X
     1  ,'C = ',F7.2/2X,62('='))
     GO TO 301
     END
C      ******************************************************
     SUBROUTINE REGR(MTD)
C LINEAR EQN DEVELOPMENT BETWEEN WT AV AND SINGLE STN VALUE
C EXCLUDING ZEROS USING LEAST SQUARE METHOD PROBABILITIES ARE
C ASSIGNED USING BLOM'S PLOTTING POSITION FORMULA
C       X = VECTOR CONTAINING PPTN VALUES
C       F = VECTOR CONTAINING EXCEDENCE PROBABILITY
c       iop=1 zeros considered
c       iop=2 zeros excluded
     common y(40,12,12),x(40,12),NY,ND,NS,NG,WT(14),KCV,
     1  z(40,12,12),gx(100,12),ax(480),t(480),tb(14),
     2 tc(14),ERR(16),OERR(16),ix
     DIMENSION XX(14),al(14)
     iop=1
     if(mtd.gt.14)iop=2
     IF(MTD.EQ.13.OR.MTD.EQ.15)THEN
     K1=1
     K2=1
     ENDIF
     IF(MTD.EQ.14.OR.MTD.EQ.16)THEN
     K1=2
     K2=2
     ENDIF
     DO 99 KK=K1,K2
     DO 1 KKK = 1,ns
     n=0
     DO 100 I=1,NY
     DO 100 J=1,ND
     if(iop.eq.2)then
     IF(X(i,j).EQ.0.0)GO TO 100
     endif
```

```
      n=n+1
      AX(n)=y(i,j,kkk)
      t(n)=x(i,j)
      IF(X(I,J).NE.0.0.AND.AX(N).EQ.0.0)AX(N)=0.5
100   CONTINUE
      IF(KK.EQ.2)THEN
      CALL POWTFM(N,aX,AL(KKK))
      CALL POWTFM(N,T,AL(NS+1))
      IF(AL(KKK).EQ.999) GO TO 117
      IF(AL(NS+1).EQ.999) GO TO 117
      DO 12 I=1,N
      IF(aX(I).LE.0.0) GO TO 14
      IF(AL(KKK).NE.0.0)aX(I)=(aX(I)**AL(KKK)-1.)/AL(KKK)
      IF(AL(KKK).EQ.0.0)aX(I)=ALOG(aX(I))
14    IF(T(I).LE.0.0) GO TO 12
      IF(AL(NS+1).NE.0.0)T(I)=(T(I)**AL(NS+1)-1.)/AL(NS+1)
      IF(AL(NS+1).EQ.0.0)T(I)=ALOG(T(I))
12    CONTINUE
      ENDIF
117   CALL REG(AX,T,N,C,B)
      TC(KKK)=C
      TB(KKK)=B
1     CONTINUE
      IF(KCV.EQ.0.OR.KCV.EQ.2)THEN
      READ(7,'(A)')TITLE
      READ(7,'(A)')TITLE
      READ(7,*)NG
      READ(7,'(A)')TITLE
      K=0
      DO 34 I =1,NG
      DO 34 J =1,ND
      K=K+1
      IF(KCV.EQ.0)READ (7,*)I1,I2,X(I,J)
      IF(KCV.EQ.2)READ (7,*)I1,I2,(Y(I,J,L),L=1,NS),X(I,J)
34    AX(K)=X(I,J)
      REWIND(UNIT=7)
      ELSE
      K=0
      DO L=1,NY
      DO J=1,ND
      K=K+1
      AX(K)=X(L,J)
      ENDDO
      ENDDO
      ENDIF
      II=1
      kki=1
      ERR(MTD)=0.0
```

```
      OERR(MTD)=0.0
      DO 3 I=1,K
      A=0.0
      IF(KK.EQ.2) THEN
      IF(AL(NS+1).EQ.999)GO TO 13
      IF(AX(I).EQ.0.0) GO TO 13
      IF(AL(NS+1).NE.0.0)AX(I)=(AX(I)**AL(NS+1)-1.)/AL(NS+1)
      IF(AL(NS+1).EQ.0.0)AX(I)=ALOG(AX(I))
      ENDIF
13    IF(AX(I).EQ.0.) THEN
      DO KKK=1,NS
      XX(KKK)=0.0
      ENDDO
      GO TO 4
      ENDIF
      RV=AX(I)
      IF(KK.EQ.2)THEN
      IF(AL(NS+1).EQ.999) GO TO 6
      IF(AL(NS+1).NE.0.0)AX(I)=(1.+AL(NS+1)*AX(I))**(1./AL
     1(NS+1))
      IF(AL(NS+1).EQ.0.0)AX(I)=EXP(AX(I))
      ENDIF
6     DO 2 KKK=1,NS
      XX(KKK)=TC(KKK)+TB(KKK)*RV
      IF(AL(KKK).EQ.999) GO TO 2
      IF(KK.NE.2) THEN
      IF(XX(KKK).LT.0.0)XX(KKK)=0.00
      ENDIF
      IF(KK.EQ.2)THEN
      pp=(1.+AL(KKK)*XX(KKK))
      if(pp.lt.0.0)pp=0.01
      IF(AL(KKK).NE.0.)XX(KKK)=pp**(1./AL(KKK))
      IF(AL(KKK).EQ.0.0)XX(KKK)=EXP(XX(KKK))
      ENDIF
      A=A+XX(KKK)*WT(KKK)
2     CONTINUE
4     do kkk=1,ns
      z(kki,ii,kkk)=xx(kkk)
      OERR(MTD)=OERR(MTD)+WT(KKK)*(ABS(XX(KKK)-Y(KKI,II,KKK)))
      enddo
      gx(kki,ii)=a
      II=II+1
      IF(II.GT.12)then
      II=1
      kki=kki+1
      endif
      ERR(MTD)=ERR(MTD)+ABS(A-AX(I))
3     CONTINUE
```

```
      ERR(MTD)=ERR(MTD)/FLOAT(K)
      OERR(MTD)=OERR(MTD)/FLOAT(K)
99    CONTINUE
      return
      END
C********************************************************
   subroutine fre(MTD)
C  THIS PROGRAME IS FOR disaggregating the average values of
C  stations excluding zero values also using NORMAL
c  DISTRIBUTION power transformation pt3 and ev1 distributions
c  USING LEAST SQUARE METHOD
C  iop=1 zeros considered
c  iop=2 zeros excluded
c  X = VECTOR CONTAINING AVERAGE station VALUES
      common y(40,12,12),x(40,12),NY,ND,NS,NG,WT(14),KCV,
      1  z(40,12,12),gx(100,12),ax(480),t(480),tb(14),
      2  tc(14),ERR(16),OERR(16),ix
      DIMENSION XX(14),al(14)
      IOP=1
      IF(MTD.GT.4.OR.MTD.LT.9)IOP=2
      IF(MTD.EQ.5.OR.MTD.EQ.9)THEN
      K1=1
      K2=1
      ENDIF
      IF(MTD.EQ.6.OR.MTD.EQ.10)THEN
      K1=2
      K2=2
      ENDIF
      IF(MTD.EQ.7.OR.MTD.EQ.11)THEN
      K1=3
      K2=3
      ENDIF
      IF(MTD.EQ.8.OR.MTD.EQ.12)THEN
      K1=4
      K2=4
      ENDIF
      DO 99 KK=K1,K2
      do 1 kkk=1,ns+1
      n=0
      DO 11 ii=1,Ny
      do 11 j=1,ND
      if(iop.eq.2) then
      IF(X(ii,j).EQ.0.0) GO TO 11
      endif
      n=n+1
      if(kkk.ne.ns+1)ax(n)=y(ii,j,kkk)
      if(kkk.eq.ns+1)ax(n)=x(ii,j)
      if(x(ii,j).ne.0.0.and.ax(n).eq.0.0)ax(n)=0.05
```

```
11    continue
      IF(KK.EQ.2)THEN
      go to 117
      CALL POWTFM(N,aX,AL(KKK))
      do 201 i=1,n
      IF(AL(KKK).EQ.999) GO TO 117
      IF(AL(KKK).NE.0.0)aX(I)=(aX(I)**AL(KKK)-1.)/AL(KKK)
      IF(AL(KKK).EQ.0.0)aX(I)=ALOG(aX(I))
201   CONTINUE
      ENDIF
117   CALL RANK (aX,N)
      AN=N
      DO 10 I=1,N
      AI=I
      IF(KK.EQ.3)THEN
      P=(AI-0.44)/(AN+0.12)
      T1=SQRT(6)*7./22.
      T(I)=-T1*(0.5772+ALOG(-ALOG(P)))
      GO TO 10
      ENDIF
      IF(KK.EQ.4)THEN
      P=(AI-0.40)/(AN+0.2)
      CALL NDTRI(P,XY,D,IE)
      CALL STAT(AX,N,QM,SDQ,G,CV)
      T(I)=2./g*(1.+(xy*g/6.0)-(g**2/36.0))**3-2./g
      GO TO 10
      ENDIF
      P=(AI-0.375)/(AN+0.25)
      CALL NDTRI(P,XY,D,IE)
      T(I)=XY
10    CONTINUE
      CALL REG(AX,T,N,C,B)
      TC(KKK)=C
      TB(KKK)=B
1     CONTINUE
      IF(KCV.EQ.1) THEN
      I=0
      DO L=1,NY
      DO J=1,ND
      I=I+1
      AX(I) = X(L,J)
      ENDDO
      ENDDO
      K=NY*ND
      GO TO 768
      ENDIF
      READ(7,'(A)')TITLE
      READ(7,'(A)')TITLE
```

```
      READ(7,*)NG
      READ(7,'(A)')TITLE
      K=0
      DO 34 I =1,NG
      DO 34 J=1,ND
      K=K+1
      IF(KCV.EQ.0)READ (7,*)I1,I2,X(I,J)
      IF(KCV.EQ.2)READ (7,*)I1,I2,(Y(I,J,L),L=1,NS),X(I,J)
34    AX(K)=X(I,J)
      REWIND(UNIT=7)
768   II=1
      kki=1
      ERR(MTD)=0.0
      OERR(MTD)=0.0
      DO 3 I=1,K
      A=0.0
      IF(KK.EQ.2) THEN
      go to 13
      IF(AL(NS+1).EQ.999)GO TO 13
      IF(AX(I).lt.1.0) GO TO 13
      IF(AL(NS+1).NE.0.0)AX(I)=(AX(I)**AL(NS+1)-1.)/AL(NS+1)
      IF(AL(NS+1).EQ.0.0)AX(I)=ALOG(AX(I))
      ENDIF
13    IF(AX(I).lt.1.0) THEN
      DO KKK=1,NS
      XX(KKK)=ax(i)/ns
      ENDDO
      GO TO 4
      ENDIF
      RV=(AX(I)-TC(NS+1))/TB(NS+1)
      IF(KK.EQ.2)THEN
      go to 6
      IF(AL(NS+1).EQ.999) GO TO 6
      IF(AL(NS+1).NE.0.0)AX(I)=(1.+AL(NS+1)*AX(I))**(1./AL
     1(NS+1))
      IF(AL(NS+1).EQ.0.0)AX(I)=EXP(AX(I))
      ENDIF
6     DO 2 KKK=1,NS
      XX(KKK)=TC(KKK)+TB(KKK)*RV
      IF(AL(KKK).EQ.999) GO TO 2
      IF(KK.NE.2)THEN
      IF(XX(KKK).LT.0.0)XX(KKK)=0.00
      ENDIF
      IF(KK.EQ.2)THEN
      go to 90
      IF(AL(KKK).NE.0.)XX(KKK)=(1.+AL(KKK)*XX(KKK))**(1./AL
     1(KKK))
      IF(AL(KKK).EQ.0.0)XX(KKK)=EXP(XX(KKK))
```

```
      ENDIF
90    A=A+XX(KKK)*WT(KKK)
2     CONTINUE
4     do kkk =1,ns
      z(kki,ii,kkk)=xx(kkk)
      OERR(MTD)=OERR(MTD)+WT(KKK)*(ABS(XX(KKK)-Y(KKI,II,KKK)))
      enddo
      gx(kki,ii)=a
      II=II+1
      IF(II.GT.12)then
      II=1
      kki=kki+1
      endif
      ERR(MTD)=ERR(MTD)+ABS(A-AX(I))
3     CONTINUE
      ERR(MTD)=ERR(MTD)/FLOAT(K)
      OERR(MTD)=OERR(MTD)/FLOAT(K)
99    CONTINUE
      RETURN
      END
C ***********************************************************
      SUBROUTINE NFR(AVR,SD,SK,CV,MTD,MM)
      common y(40,12,12),x(40,12),NY,ND,NS,NG,WT(14),KCV,
      1  z(40,12,12),gx(100,12),ax(480),t(480),tb(14),
      2  tc(14),ERR(16),OERR(16),ix
      DIMENSION AVR(20,14),SD(20,14),CV(20,14),SK(20,14)
      CHARACTER*100 TITLE,TIT,STN(16)*10
      MM=0
      if(ino.eq.0)then
      write(*,*)'Enter number of station excluded'
      read(*,*)ino
      endif
      DO 999 M=1,16
      IF(M.EQ.1)GO TO 101
      READ(1,34)TIT
      READ(1,34)TITLE
      READ(1,*)NY,NS
      READ(1,134)(stn(i),i=1,ns)
      READ(1,*)(WT(I),I=1,NS)
      READ(1,34)TITLE
      DO 401 I=1,NY
      DO 401 J=1,ND
401   READ(1,*)I1,I2,(Y(I,J,L),L=1,NS),X(I,J)
      REWIND (UNIT=1)
12    format(///5x,'Method = ',i3)
101   IF(MTD.EQ.17) THEN
      MM=M
      IF(M.GT.0.AND.M.LT.5) CALL NORDD(M)
```

```
      IF(M.GT.4.AND.M.LT.13) CALL FRE(M)
      IF(M.GT.12.AND.M.LT.17) CALL REGR(M)
      ENDIF
      IF(MTD.EQ.18) THEN
      IF(M.GE.5.AND.M.LE.8) GO TO 999
      IF(M.GE.15) GO TO 999
      MM=MM+1
      WRITE(*,12)MM
      IF(M.GT.0.OR.M.LT.5) CALL NORDD(M)
      IF(M.GT.8.AND.M.LT.13) CALL FRE(M)
      IF(M.GT.12.AND.M.LT.15) CALL REGR(M)
      ERR(MM)=ERR(M)
      OERR(MM)=OERR(M)
      ENDIF
      N=0
      DO 791 I=1,NG
      DO 791 J=1,ND
      N=N+1
791   AX(N)=GX(I,J)
      call stat(AX,N,AVR(MM,NS+1),SD(MM,NS+1),SK(MM,NS+1)
      1  ,CV(MM,NS+1))
      DO 707 L=1,NS
      N=0
      DO 706 I=1,NG
      DO 706 J=1,ND
      N=N+1
706   AX(N)=Z(I,J,L)
      if(l.eq.ino)write(3,214)m,l,stn(l)
      if(l.eq.ino)write(3,216)(ax(i),i=1,n)
214   format(2x,'Method No= ',i6,' Station excluded ',i3,a12)
216   format(12f10.2)
      call stat(AX,N,AVR(MM,L),SD(MM,L),SK(MM,L),CV(MM,L))
707   CONTINUE
999   continue
134   format(10X,14A10)
34    format(a)
      RETURN
      END
C**********************************************************
      SUBROUTINE GEN
      COMMON Y(40,12,12),X(40,12),NY,ND,NS,NG,WT(14),KCV,
      1 Z(40,12,12),gx(100,12),AX(480),T(480),TB(14),
      2 TC(14),ERR(16),OERR(16),ix
      DIMENSION atb(12),atc(12)
      do 11 j=1,ND
      DO 1 ii=1,Ny
      ax(ii)=x(ii,j)
      continue
```

```
      CALL RANK (aX,Ny)
      AN=Ny
      DO 10 I=1,Ny
      AI=I
      P=(AI-0.375)/(AN+0.25)
      CALL NDTRI(P,XY,D,IE)
      T(I)=XY
10    CONTINUE
      CALL REG(AX,T,Ny,C,B)
      ATC(j)=C
      ATB(j)=B
11    CONTINUE
      do i=1,ng
      do j=1,nd
      gx(i,j)=0.0
      enddo
      enddo
      DO 34 I =1,NG
      DO 34 J=1,ND
      p=randu(0.0,1.0,ix)
      call ndtri(p,v,d,ie)
      gx(i,j)=ATC(j)+ATB(j)*V
      IF(GX(I,J).LT.0.0)GX(I,J)=0.0
34    CONTINUE
      RETURN
      END
C************************************************************
```

Listing of Sample Input Data File (DIS1.DAT) for DIS.FOR

MONTHLY RAINFALL DATA OF A BASIN (1978-81)

Length of Data	No of Years	No of Stations
	4	3

Stn wt	Station-1	Station-2	Station-3
	.350	.250	.400

Year	Month	Station 1	Station 2	Station 3	Weighted Average
1978	1	21.44	22.16	23.12	22.29
1978	2	36.64	36.88	37.36	36.99
1978	3	37.68	37.68	37.68	37.68
1978	4	.96	.96	.96	.96
1978	5	.00	.00	.00	.00
1978	6	164.09	166.49	170.13	167.11
1978	7	326.46	328.77	332.18	329.33
1978	8	297.73	297.73	297.71	297.72
1978	9	54.04	54.01	53.90	53.98
1978	10	.00	.00	.00	.00
1978	11	5.28	5.28	5.28	5.28
1978	12	59.28	59.04	59.04	59.12
1979	1	56.16	56.16	56.16	56.16
1979	2	63.12	63.12	63.12	63.12
1979	3	.00	.00	.00	.00
1979	4	.00	.00	.00	.00
1979	5	.00	.00	.00	.00
1979	6	134.13	134.13	134.13	134.13
1979	7	328.03	328.03	328.03	328.03
1979	8	302.10	302.10	302.10	302.10
1979	9	93.05	93.05	93.05	93.05
1979	10	2.00	2.00	2.00	2.00
1979	11	36.01	36.01	36.01	36.01
1979	12	.00	.00	.00	.00
1980	1	10.92	6.61	.08	5.51
1980	2	8.32	5.04	.05	4.19
1980	3	.00	.00	.00	.00
1980	4	.00	.00	.00	.00
1980	5	1.28	.80	.08	.68
1980	6	236.01	213.37	179.11	207.59
1980	7	219.28	200.53	171.41	195.44
1980	8	399.57	388.80	372.42	386.02
1980	9	79.32	97.17	124.17	101.72
1980	10	.00	.00	.00	.00
1980	11	.00	.00	.00	.00
1980	12	42.34	25.64	.10	21.27
1981	1	12.00	7.20	.20	6.08
1981	2	.00	.00	.00	.00
1981	3	22.56	13.68	.05	11.34
1981	4	19.22	11.65	.05	9.66
1981	5	26.64	15.84	.05	13.30
1981	6	254.72	278.56	313.92	284.36
1981	7	287.44	325.52	382.56	335.01
1981	8	245.92	250.72	257.90	251.91
1981	9	198.82	182.95	157.93	178.50
1981	10	1.20	.72	.10	.64
1981	11	.00	.00	.00	.00
1981	12	17.23	10.66	.05	8.72

Listing of Sample Input Data File (DIS2.DAT) for DIS.FOR

```
NORMAL MONTHLY RAINFALL AV VALUE FOR A BASIN
No of Years
    1
Year Month  Value
1     1      51.760
1     2      55.750
1     3     122.900
1     4     159.220
1     5     220.710
1     6     450.740
1     7     546.960
1     8     530.560
1     9     220.650
1     10     48.820
1     11     17.350
1     12     23.250
```

Listing of Sample Input Data File (DIS3.DAT) for DIS.FOR

```
MONTHLY RAINFALL DATA OF A BASIN  ( 1982-84)
No of Years
    2
     Year Month Station 1 Station 2 Station 3 Weighted Average

     1983    1        .00       .00       .00        .00
     1983    2      14.24      8.45       .30       7.22
     1983    3        .24       .00       .02        .09
     1983    4        .00       .00       .00        .00
     1983    5        .00       .00       .00        .00
     1983    6     217.73    189.17    145.59     181.73
     1983    7     381.77    347.36    295.57     338.69
     1983    8     182.95    268.24    398.32     290.42
     1983    9     412.36    375.20    318.87     365.67
     1983   10      48.16     44.00     38.00      43.06
     1983   11        .00       .00       .00        .00
     1983   12       8.64      5.28       .30       4.46
     1984    1        .00       .00       .00        .00
     1984    2        .00       .00       .00        .00
     1984    3        .00       .00       .00        .00
     1984    4        .00       .00       .00        .00
     1984    5        .00       .00       .00        .00
     1984    6     123.84    106.59     81.02     102.40
     1984    7     249.28    222.24    180.24     214.90
     1984    8     702.72    662.56    600.80     651.91
     1984    9      62.24     49.76     29.92      46.19
     1984   10        .96      2.16      3.84       2.41
     1984   11        .00       .00       .00        .00
     1984   12      37.04     42.08     49.92      43.45
```

APPENDIX-XI

Listing of Computer Programs For Time Series Analysis

```
C     THIS PROGRAMME CALCULATES MOVING MEAN OF DESIRED DURATION
      CHARACTER *6 FYLE,FYLEN
      DIMENSION IYEAR(100),RAIN(100,100),ISAVE(2),K(100),R(100)
      1,T(100),L2(100)
      WRITE(5,100)
100   FORMAT(4X,'INPUT FILE NAME?'$)
      READ(5,101)FYLE
101   FORMAT(A)
      WRITE(5,102)
102   FORMAT(4X,'OUTPUT FILE NAME?'$)
      READ(5,101)FYLEN
      OPEN(UNIT=1,FILE=FYLE,STATUS='OLD')
      OPEN(UNIT=2,FILE=FYLEN,STATUS='NEW')
      K(1)=1
      DO 1 I=1,100
      READ(1,*,END=2) IYEAR(I),(RAIN(I,J),J=1,13)
      K(I+1)=K(I)+1
      N=K(I)
1     CONTINUE
2     DO 3 I=1,N
      DO 3 J=1,13
      IF(IYEAR(I).GT.1957)RAIN(I,J)=RAIN(I,J)*25.4
3     CONTINUE
      WRITE(5,202)
202   FORMAT(4X,'MONTH FOR WHICH ANALYSIS REQUIRED?'$)
      READ(5,*)M
      WRITE(5,203)
203   FORMAT(4X,'ENTER NO. OF YEARS FOR MEAN?'$)
      READ(5,*)NM
      ANM=NM
      DO 5 J=1,13
      IF(J.NE.M)GO TO 5
      DO 6 I=1,N
6     R(I)=RAIN(I,J)
5     CONTINUE
      A=0
      L=1
```

```
      L1=N-(NM-1)
      DO 8 I=1,L1
      DO 9 J=1,NM
      A=A+R(J+(I-1))
9     CONTINUE
      T(L)=A/ANM
      L=L+1
      A=0.0
8     CONTINUE
      L2(1)=1
      DO 11 I=1,L1
      L2(I+1)=L2(I)+1
11    CONTINUE
      WRITE(5,12)L1
12    FORMAT(4X,'NO. OF OBSERVATIONS=',I3)
      WRITE(2,*)(L2(I),I=1,L1)
      WRITE(2,*)(T(I),I=1,L1)
      N1=2
      ISAVE(1)=1
      ISAVE(2)=2
      WRITE(2,*)N1
      WRITE(2,*)(ISAVE(I),I=1,2)
      END
```

```
C  THIS PROGRAMME COMPUTES THE COEFFICIENTS A  AND B USED
C  IN THE EQUATION XT(t)=A+B*(t-TMU) TO IDENTIFY THE TREND
C        ,IF PRESENT,IN THE TIME SERIES WHERE:-
C  XMU=MEAN OF THE OBSERVED TIME SERIES
C  TMU=MEAN OF THE TIME VARIABLE
C  N=NO. OF OBSERVATIONS
C  X=VECTOR CONTAINING OBSERVED TIME SERIES
   DIMENSION X(100)
   READ(1,*)N,TMU,XMU
   READ(1,*)(X(I),I=1,N)
   A=XMU
   SUMP=0.0
   SUMS=0.0
   DO 1 I=1,N
   SUMPI=I*X(I)
   SUMP=SUMP+SUMPI
   SUMSI=I*I
   SUMS=SUMS+SUMSI
1  CONTINUE
   TERM1=SUMP-N*TMU*XMU
   TERM2=SUMS-N*TMU*TMU
   B=TERM1/TERM2
   WRITE(2,2)A,B
2  FORMAT(4X,'COEFFICIENT A=',F8.2/4X,'COEFFICIENT B=',F8.2)
   END
```

```
C THIS PROGRAMME COMPUTES THE FOURIER COEFFICIENTS AK AND BK
C WHERE:--
C N=NO. OF OBSERVATIONS
C K=INEGER INDEX TO IDENTIFY HARMONIC
C OMEGA=ANGULAR FREQUENCY IN RADIANS PER UNIT TIME
C X=VECTOR CONTAINING OBSERVED TIME SERIES
  DIMENSION X(100)
  READ(1,*)N,K,OMEGA
  READ(1,*)(X(I),I=1,N)
  SUMA=0.0
  SUMB=0.0
  DO 1 I=1,N
  ARG=K*OMEGA*I
  SUMAI=X(I)*SIN(ARG)
  SUMA=SUMA+SUMAI
  SUMBI=X(I)*COS(ARG)
  SUMB=SUMB+SUMBI
1 CONTINUE
  AK=SUMA*2/N
  BK=SUMB*2/N
  WRITE(2,2)AK,BK
2 FORMAT(4X,'FOURIER COEFFICIENT AK=',F8.2/4X,'FOURIER
  1 'COEFFICIENT BK=',F8.2)
  END
```

```
C  THIS PROGRAMME COMPUTES AUTOCOVARIANCE AS A FUNCTION OF TAU
C  WHERE:--
C  N=NO. OF OBSERVATIONS
C  M=MAXIMUM TIME LAGS
C  XMU=MEAN OF THE OBSEREVED TIME SERIES
C  X=VECTOR CONTAINING OBSERVED TIME SERIES
   DIMENSION X(100)
   READ(1,*)N,M,XMU
   READ(1,*)(X(I0,I=1,N)
   DO1 J=1,M
   K=N+1-J
   SUM=0.0
   DO 2 I=1,K
   TERM1=X(I)-XMU
   L=I-1+J
   TERM2=X(L)-XMU
   TERM3=TERM1*TERM2/K
   SUM=SUM+TERM3
2  CONTINUE
   JJ=J-1
   WRITE(2,3)JJ,SUM
3  FORMAT(1X,I3,4X,F10.2)
1  CONTINUE
   END
```

```
C  THIS PROGRAMME COMPUTES THE SMOOTHED ESTIMATE OF THE
C  VARIANCE SPECTRUM AS A FUNCTION OF PERIODICITY  WHERE:--
C  M=NO. OF HARMONICS
C  R=VECTOR CONTAINING AUTO COVARINCE AT DIFFERENT TIME LAGS
C  DELT=TIME INTERVAL BETWEEN TWO CONSECUTIVE VALUES IN THE
C     TIME SERIES
C  PRD=VECTOR CONTAINING PERIOD CORRESPONDING TO EACH LAG
      DIMENSION R(100),PRD(100),U(100),VARS(100)
      READ(1,*)M
      READ(1,*)(R(I),I=1,M)
      READ(1,*)DELT
      DO 1 J=1,M
      JJ=J-1
      SUM=0.0
      MM=M-2
      DO 2 L=2,MM
      ARG1=L*JJ*3.1416/(M-1)
      SUM1=R(L)*COS(ARG1)
      SUM=SUM+SUM1
2     ARG2=3.1416*JJ
      TERM1=R(M)*COS(ARG2)
      TERM2=R(1)+TERM1+2*SUM
      IF(0-JJ)3,4,4
3     IF(MM-JJ)4,4,5
4     AK=0.5
      GO TO 6
5     AK=1.0
6     VARS(J)=AK*TERM2/(M-1)
1     DO 7 J=1,M
      JJ=J-1
      IF(1-J)8,9,9
8     IF(M-J)10,10,11
9     U(J)=0.5*(VARS(1)+VARS(2))
      GO TO 12
10    U(J)=0.5*(VARS(M-1)+VARS(M))
      GO TO 12
11    U(J)=0.25*VARS(J-1)+0.5*VARS(J)+0.25*VARS(J+1)
12    PRD(J)=2.*(M-1)*DELT/JJ
7     WRITE(2,14)(PRD(J),U(J),J=1,M)
14    FORMAT(4X,2F10.2)
      END
```

APPENDIX-XII

Listing of Computer Programs For Statistical Analysis

```
C  THIS PROGRAMME EXTRACTS THE RANDOM COMPONENT OF A GIVEN
C  TIME SERIES WHERE:--
C  N=NO. OF OBSERVATIONS
C  M=TOTAL NO. OF HARMONICS CONSIDERED NONNEGLIGIBLE
C  A=INTERCEPT USED IN STRAIGHT LINE EQUATION TO ESTIMATETREND
C  B=SLOPE OF THE STRAIGHT LINE EQ. USED TO ESTIMATE TREND
C  TMU=MEAN OF TIME VARIABLE
C  X=VECTOR CONTAINING TIME SERIES
C  AK, BK & K = VECTOR CONTAINING THE FOURIER COEFFICIENT AK &
C  BK & INTEGER INDEX FOR DIFFERENT HARMONICS
C  OMEGA=ANGULAR FREQUENCY IN RADIANS PER TIME UNIT
C  XRI=VECTOR CONTAINING RANDOM COMPONENT OF THE TIME SERIES
   DIMENSION X(100),AK(100),BK(100),K(100),XRI(100)
   READ(1,*)N,M,A,B,TMU
   READ(1,*)(X(I),I=1,N)
   READ(1,*)(AK(I),I=1,M)
   READ(1,*)(BK(I),I=1,M)
   READ(1,*)(K(I),I=1,M)
   READ(1,*)OMEGA
   DO 1 I=1,N
   SUM=0.0
   DO 2 J=1,M
   TERM1=AK(J)**2+BK(J)**2
   CJ=SQRT(TERM1)
   ARG1=AK(J)/BK(J)
   THETAJ=ATAN(ARG1)
   ARG2=K(J)*OMEGA*I-THETAJ
   SUMJ=CJ*COS(ARG2)
   SUM=SUM+SUMJ
1  CONTINUE
   XRI(I)=X(I)-(A+B*(I-TMU))-SUM
2  CONTINUE
   WRITE(2,3)
3  FORMAT(10X,'RANDOM COMPONENT OF TIME SERIES'/)
   WRITE(2,4)(XRI(I),I=1,N)
4  FORMAT(4X,10F10.3)
   END
```

```
C THIS PROGRAMME COMPUTES THE VARIANCE AND STANDARD DEVIATION
C WHERE:--
C N=NO. OF OBSERVATIONS
C X=VECTOR CONTAINING OBSERVED TIME SERIES
C XMU=MEAN OF OBSERVED TIME SERIES
C VAR=VARIANCE OF THE TIME SERIES
C SIGMA=STANDARD DEVIATION OF THE TIME SERIES
  DIMENSION X(100)
  READ(1,*)N,XMU
  READ(1,*)(X(I),I=1,N)
  SUM=0.0
  DO 1 I=1,N
  DIFFS=(X(I)-XMU)**2
  SUM=SUM+DIFFS
1 CONTINUE
  VAR=SUM/(N-1)
  SIGMA=SQRT(VAR)
  WRITE(2,2)VAR,SIGMA
2 FORMAT(4X,'VARIANCE=',F8.2/4X,'STAND. DEVIATION=',F8.2)
  END
```

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

```
      YSTD=SQRT((B/XN)-YBAR**2)
      DO 3 J=1,6
      YM=-DLOG(-DLOG((T(J)-1.0)/T(J)))
      K=(YM-YBAR)/YSTD
      XT(J)=M1+K*SQRT(M2)
      DELTA=1.0+1.139547093*K+1.100000027*K**2
      SX(J)=SQRT(M2*DELTA/XN)
    3 CONTINUE
      WRITE(6,12) TITLE
      WRITE(6,13)
      WRITE(6,20) ALPHA,M1
      WRITE(6,21) BETA,M2
      WRITE(6,22) SKEW
      WRITE(6,25)
      WRITE(6,14)
      WRITE(6,15) (XT(J),J=1,6)
      WRITE(6,16) (SX(J),J=1,6)
      WRITE(6,17)
      WRITE(6,18)
      ICOUNT=0
      AML=ALPHA
    4 ICOUNT=ICOUNT+1
      A=1.0/(AML**2)
      B=M1-1.0/AML
      C=0.0
      D=0.0
      E=0.0
      DO 5 I=1,N
      TEMP=EXP(-AML*X(I))
      C=C+TEMP
      D=D+TEMP*X(I)
      E=E+TEMP*X(I)**2
    5 CONTINUE
      FCN=D-B*C
      FPN=B*D-E-A*C
      AS=AML-(FCN/FPN)
      WRITE(6,19) ICOUNT,AS,FCN
      DELTA=ABS(0.0000001*AS)
      IF(ABS(AS-AML).LT.DELTA) GO TO 6
      IF(ABS(FCN).LT. .001)GOTO 6
      IF(ICOUNT.GT.25) GO TO 8
      AML=AS
```

```
      GO TO 4
    6 CONTINUE
      ALPHA=AS
      BETA=(1.0/ALPHA)*ALOG(XN/C)
      M2=1.2825/ALPHA
      M1=BETA+0.45*M2
      M2=M2**2
      DO 7 J=1,6
      YM=-DLOG(-DLOG(1.0-1.0/T(J)))
      XT(J)=BETA+YM/ALPHA
      SX(J)=SQRT((1.1086+.5140*YM+0.6079*YM**2)/(XN*ALPHA**2))
    7 CONTINUE
      WRITE(6,23)
      WRITE(6,20) ALPHA,M1
      WRITE(6,24) BETA,M2
      WRITE(6,14)
      WRITE(6,15) (XT(J),J=1,6)
      WRITE(6,16) (SX(J),J=1,6)
    8 CONTINUE
      STOP
    9 FORMAT(80A1)
   10   FORMAT(I5)
   11   FORMAT(8F10.0)
   12   FORMAT(1H1,/,80A1,//,26X,28HTYPE 1 EXTERNAL ',
        1'DISTRIBUTION'/)
   13   FORMAT(31X,17HMETHOD OF MOMENTS,//)
   14   FORMAT(3X,7HT,YEARS,4X,1H2,11X,1H5,10X,2H10,10X,
        1  2H20,10X,2H50,9X,3H100,/)
   15   FORMAT(3X,1HX,3X,6E12.5,/,4X,1HT)
   16   FORMAT(3X,1HS,3X,6E12.5,/,4X,1HT,//)
   17   FORMAT(25X,27HMAXIMUM LIKELIHOODPROCEDURE,//)
   18   FORMAT(21X,5HTRIAL,11X,1HA,11X,4HF(A),/)
   19   FORMAT(22X,I2,8X,E12.5,1X,E12.5)
   20   FORMAT(9X,5HALPHA,5X,E12.5,14X,4HM1  ,6X,E12.5)
   21   FORMAT(9X,5HBETA ,5X,E12.5,14X,4HM2  ,6X,E12.5)
   22   FORMAT(45X,4HSKEW,6X,E12.5,/)
   23   FORMAT(//)
   24   FORMAT(9X,5HBETA,5X,E12.5,14X,4HM2  ,6X,E12.5,/)
   25   FORMAT(3X,'NOTE - FOR GOOD USE OF THIS DISTRIBUTION SKEW'
        1' SHOULD BE AROUND 1.13',/)
        END
```

Data File DATA.DAT

```
TEST DATA AT SRIPALPUR GAUGING SITE AT PUNPUN RIVER IN BIHAR
       21
  121.8000       213.3400       217.7500       223.6600       250.7100
  341.0900       381.1200       424.7400       457.0800       465.0000
  496.0000       526.4300       568.5000       576.4700       611.9500
  621.5500       621.9000       628.0000       630.3900       641.1700
  697.6500
```

```
C  THIS PROGRAMME CALCULATES PARAMETERS FOR EV1 DISTRIBUTION
C  ON THE BASIS OF MAXIMUM ENTROPY
      CHARACTER *6 FYLE,FYLEN
      DIMENSION X(200),Z(200),ZE(200),Y(200),EST(10),T(10),
     1 F(200),XEST(200),YY(200)
      WRITE(5,1)
1     FORMAT(4X,'INPUT FILE NAME?'$)
      READ(5,2)FYLE
2     FORMAT(A)
      WRITE(5,3)
3     FORMAT(4X,'OUPUT FILE NAME?'$)
      READ(5,2)FYLEN
      OPEN(UNIT=1,FILE=FYLE,STATUS='OLD')
      OPEN(UNIT=2,FILE=FYLEN,STATUS='NEW')
      READ(1,*)N
      READ(1,*) (X(I),I=1,N)
      READ(1,*) NRET
      READ(1,*) (T(I),I=1,NRET)
      CALL RANK(X,N)
      CALL MNSD(X,N,XBAR,SDX,SKX)
      WRITE(2,4567)XBAR,SDX,SKX
4567  FORMAT(4X,'MEAN=',E15.7/4X,'STAND DEV=', E15.7/4X,
     1'SKEW=',F6.2)
      PI=3.1415926
      ALPH0=(SQRT(6.0)/PI)*SDX
      U0=XBAR-0.5772*ALPH0
      WRITE(2,134)
134   FORMAT(10X,'METHOD OF MOMENTS ESTIMATES')
      WRITE(2,135) U0,ALPH0
135   FORMAT(4X,'VALUE OF U=',E15.7/4X,'VALUE OF ALPHA=',E15.7)
      DO 136 I=1,NRET
      FF=1.0-(1.0/T(I))
      A=-ALOG(FF)
      B=-ALOG(A)
      EST(I)=U0+ALPH0*B
136   CONTINUE
      WRITE(2,137)
137   FORMAT(4X,'NO',10X,'RETURN PERIOD',10X,'ESTIMATED FLOOD')
      WRITE(2,138) (I,T(I),EST(I),I=1,NRET)
138   FORMAT(4X,I2,10X,F10.1,10X,E14.8)
      SUM3=0.0
      SUM4=0.0
```

```
      AN=N
      DO 100 I=1,N
      AI=I
      F(I)=(AI-0.12)/(AN+0.44)
      YY(I)=-ALOG(-ALOG(F(I)))
      XEST(I)=U0+ALPH0*YY(I)
      SUM3=SUM3+(X(I)-XBAR)**2
      SUM4=SUM4+(XEST(I)-X(I))**2
100   CONTINUE
      RMSE=SQRT(SUM4/AN)
      EFF=(SUM3-SUM4)/SUM3
      EFF=EFF*100.0
      WRITE(2,784) RMSE,EFF
784   FORMAT(4X,'ROOT MEAN SQUARE ERROR=',E15.6/4X,
      1'EFFICIENCY=',F8.4)
      CALL MAXM(X,U0,ALPH0,N)
      WRITE(2,139)
139   FORMAT(10X,'METHOD OF MAXIMUM LIKELY HOOD')
      WRITE(2,135) U0,ALPH0
      DO 140 I=1,NRET
      FF=1.0-(1.0/T(I))
      A=-ALOG(FF)
      B=-ALOG(A)
      EST(I)=U0+ALPH0*B
140   CONTINUE
      WRITE(2,137)
      WRITE(2,138) (I,T(I),EST(I),I=1,NRET)
      SUM3=0.0
      SUM4=0.0
      DO 792 I=1,N
      XEST(I)=U0+ALPH0*YY(I)
      SUM3=SUM3+(X(I)-XBAR)**2
      SUM4=SUM4+(XEST(I)-X(I))**2
792   CONTINUE
      RMSE=SQRT(SUM4/AN)
      EFF=(SUM3-SUM4)/SUM3
      EFF=EFF*100.0
      WRITE(2,784) RMSE,EFF
      CALL PROB(X,N,ALPH0,U0,ALPHA1,U1,XBAR)
      WRITE(2,146)
146   FORMAT(10X,'METHOD OF PROBABILITY WEIGHTED MOMENTS')
      WRITE(2,135) U1,ALPHA1
```

```
      DO 147 I=1,NRET
      FF=1.0-(1.0/T(I))
      A=-ALOG(FF)
      B=-ALOG(A)
      EST(I)=U1+ALPHA1*B
147   CONTINUE
      WRITE(2,137)
      WRITE(2,138) (I,T(I),EST(I),I=1,NRET)
      SUM3=0.0
      SUM4=0.0
      DO 786 I=1,N
      XEST(I)=U1+ALPHA1*YY(I)
      SUM3=SUM3+(X(I)-XBAR)**2
      SUM4=SUM4+(XEST(I)-X(I))**2
786   CONTINUE
      RMSE=SQRT(SUM4/AN)
      EFF=(SUM3-SUM4)/SUM3
      EFF=EFF*100.0
      WRITE(2,784) RMSE,EFF
12    DO 10 I=1,N
      Z(I)=(X(I)-U0)/ALPH0
10    ZE(I)=EXP(-Z(I))
      CALL MNSD(Z,N,ZBAR,SDZ,SKZ)
      CALL MNSD(ZE,N,ZEBAR,SDZE,SKZE)
      BETA=ZBAR+ALOG(ZEBAR)+0.4228
      V=ZBAR-0.5772*BETA
      ALPHA=ALPH0*BETA
      U=U0+ALPH0*V
      A=ABS((ALPH0-ALPHA)/ALPH0)
      B=ABS((U0-U)/U0)
      IF(A.LE.0.00001.AND.B.LE.0.00001) GO TO 11
      ALPH0=ALPHA
      U0=U
      GO TO 12
11    SUM1=0.0
      SUM2=0.0
      DO 14 I=1,N
      Y(I)=(X(I)-U)/ALPHA
      SUM1=SUM1+Y(I)
      SUM2=SUM2+EXP(-Y(I))
14    CONTINUE
      AV1=SUM1/N
```

```
      AV2=SUM2/N
      WRITE(2,142)
142   FORMAT(10X,'MAXIMUM ENTROPY PRINCIPLE ESTIMATES')
      WRITE(2,15)AV1,AV2,U,ALPHA
15    FORMAT(4X,'AV1=',E12.6/4X,'AV2=',E12.6/4X,'U=',E12.6
      1/4X,'ALPHA=',E12.6)
      DO 143 I=1,NRET
      FF=1.0-(1.0/T(I))
      A=-ALOG(FF)
      B=-ALOG(A)
      EST(I)=U+ALPHA*B
143   CONTINUE
      WRITE(2,137)
      WRITE(2,138) (I,T(I),EST(I),I=1,NRET)
      SUM3=0.0
      SUM4=0.0
      DO 789 I=1,N
      XEST(I)=U+ALPHA*YY(I)
      SUM3=SUM3+(X(I)-XBAR)**2
      SUM4=SUM4+(XEST(I)-X(I))**2
789   CONTINUE
      RMSE=SQRT(SUM4/AN)
      EFF=(SUM3-SUM4)/SUM3
      EFF=EFF*100.0
      WRITE(2,784) RMSE,EFF
      STOP
      END
C     ***********************************************************
      SUBROUTINE MNSD(Q,N,QM,SDQ,SKEW)
      DIMENSION Q(100)
      AN=N
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 20 I=1,N
      SUM1=SUM1+Q(I)
20    SUM2=SUM2+Q(I)**2
      QM=SUM1/AN
      VARQ=(1./(AN-1.0))*(SUM2-AN*(QM**2))
      SDQ=SQRT(VARQ)
      DO 30 I=1,N
30    SUM3=SUM3+(Q(I)-QM)**3
```

```
      SK=((AN)/((AN-1.0)*(AN-2.0)))*SUM3
      SKEW=SK/(SDQ**3)
      RETURN
      END
C   **********************************************************
CTHIS SUBROUTINE GIVES RANK TO ANY VECTOR COLUMN IN DESCENDIND
      SUBROUTINE RANK(Y,N)
      DIMENSION Y(100)
      N1=N-1
      DO 3 I=1,N1
      K=N-I
      DO 3 J=1,K
      IF(Y(J)-Y(J+1))3,3,2
2     SAVE=Y(J)
      Y(J)=Y(J+1)
      Y(J+1)=SAVE
3     CONTINUE
      RETURN
      END
C   **********************************************************
      SUBROUTINE MAXM(X,XO,ALPHA,N)
      DIMENSION X(100),BB(2),DEL(2),Y(100)
      NTRIAL=0
      AN=N
43    S1=0.0
      S2=0.0
      S3=0.0
      DO 15 I=1,N
      Y(I)=((X(I)-XO))/(ALPHA)
      S1=S1+EXP(-Y(I))
      S2=S2+Y(I)
      S3=S3+EXP(-Y(I))*Y(I)
15    CONTINUE
      AP=AN-S1
      AR=AN-S2+S3
      BB(1)=-AP/ALPHA
      BB(2)=AR/ALPHA
      DEL(1)=(1.11*AP-0.26*AR)*(ALPHA/AN)
      DEL(2)=(0.26*AP-0.61*AR)*(ALPHA/AN)
      XO1=XO+DEL(1)
      ALPHA1=ALPHA+DEL(2)
      ARAT1=(ALPHA-ALPHA1)/ALPHA
```

```
      ARAT2=(XO-XO1)/XO
      IF(ABS(ARAT1).LE.0.000001.AND.ABS(ARAT2).LE.0.000001)
      1 GO TO 42
      IF(ABS(BB(1)).LE.0.0001.AND.ABS(BB(2)).LE.0.0001)
      1GO TO 42
      NTRIAL=NTRIAL+1
      IF(NTRIAL.GT.100) GO TO 42
      ALPHA=ALPHA1
      XO=XO1
      GO TO 43
42    ALPHA=ALPHA1
      XO=XO1
      RETURN
      END
C
*****************************************************************
      SUBROUTINE PROB(X,N,A1,AAM1,A2,AAM2,XMEAN)
      DIMENSION X(100),AM(5),F(100)
      AM(1)=0.0
      AM(2)=0.0
      AN=N
      DO 10 I=1,N
      Y1=(X(I)-AAM1)/A1
      Y2=EXP(-Y1)
      Y3=EXP(-Y2)
      F(I)=Y3
      AM(1)=AM(1)+X(I)
      AM(2)=AM(2)+X(I)*(1.0-F(I))
10    CONTINUE
      AM(1)=AM(1)/(XMEAN*AN)
      AM(2)=AM(2)/(XMEAN*AN)
      A2=(AM(1)-2.*AM(2))/(ALOG(2.0))
      AAM2=(AM(1)-0.57721*A2)
      A2=A2*XMEAN
      AAM2=AAM2*XMEAN
      RETURN
      END
```

```
C  MASTER PROGRAM FOR LOG PEARSON TYPE 3 DISTRIBUTION COMPUTES C
METHOD OF MOMENTS AND MAXIMUM LIKLYHOOD ESTIMATES FOR T YEAR C
EVENTS AND STANDRAD ERROR FOR LOG-PEARSON TYPE 3 DISTRIBUTION
   REAL M1,M2,M3,K,NSX,L1,L2,L3
   DIMENSION SND(6),X(100)
   DIMENSION XT(6), TITLE(80),ST(6)
   REAL *8 SND,X,XT,ST
   OPEN(UNIT=5,FILE='DATA.DAT',STATUS='OLD')
   OPEN(UNIT=6,FILE='LP3.OUT',STATUS='NEW')
   SND(1)=0.0
   SND(2)=0.84162
   SND(3)=1.28155
   SND(4)=1.64485
   SND(5)=2.05375
   SND(6)=2.32635
   READ(5,16) TITLE
   READ(5,*) N
   XN=N
   READ(5,*) (X(I),I=1,N)
   C1=(SQRT(XN*(XN-1.0)))/(XN-2.0)
   C2=1.0+8.5/XN
   C3=XN/(XN-1.0)
   WRITE(6,19) TITLE
   WRITE(6,20)
   A=0.0
   B=0.0
   C=0.0
   DO 1 I=1,N
   A=A+X(I)
   B=B+X(I)**2
   C=C+X(I)**3
1  CONTINUE
   L1=A/XN
   L2=B/XN
   L3=C/XN
   M1=A/XN
   M2=(B/XN)-(A/XN)**2
   M3=(C/XN)+2.0*M1**3-3.0*M1*(B/XN)
   SKEW=M3/(M2**1.5)
   B=(ALOG(L3)-3.0*ALOG(L1))/(ALOG(L2)-2.0*ALOG(L1))
   WRITE(6,34) L1,M1
   WRITE(6,35) L2,M2
   WRITE(6,36) L3,SKEW
   C=1.0/(B-3.0)
   IF(B.GT.6.0) GOTO 3
   IF(B.LE.3.0) GOTO 3
```

```
      IF(B.LE.3.5) GOTO 2
      A=-0.23019+1.65262*C+0.20911*C**2-0.04557*C**3
      GOTO 4
2     A=-0.47157+1.99955*C
      GOTO 4
3     WRITE(6,21) B
      GOTO 6
4     ALPHA=1.0/(A+3.0)
      A1=ALOG(1.0-ALPHA)
      A2=ALOG(1.0-2.0*ALPHA)
      BETA=(ALOG(L2)-2.0*ALOG(L1))/(2.0*A1-A2)
      GAMMA=ALOG(L1)+BETA*A1
      M1=GAMMA+ALPHA*BETA
      M2=BETA*ALPHA**2
      SKEW=2.0/SQRT(BETA)
      WRITE(6,23) ALPHA,M1
      WRITE(6,24) BETA,M2
      WRITE(6,25) GAMMA,SKEW
      IF(SKEW.LT.0.0) WRITE(6,33)
      DO 5 J=1,6
      T=SND(J)
      T1=T
      T2=(T**2-1.0)/6.0
      T3=2.0*(T**3-6.0*T)/6.0**3
      T4=(T**2-1.0)/6.0**3
      T5=T/6.0**4
      T6=2.0/6.0**6
      K=T1+T2*SKEW+T3*SKEW**2-T4*SKEW**3+T5*SKEW**4-T6*SKEW**5
      SLOPE=T2+T3*2.0*SKEW-T4*3.0*SKEW**2+T5*4.0*SKEW**3-T6*5.0*SKEW**4
      T7=1.0
      T8=SKEW*K
      T9=(1.0+.75*SKEW**2)*((K**2)/2.0)
      T10=3.0*SLOPE*K*(SKEW+0.25*SKEW**3)
      T11=3.0*(SLOPE**2)*(2.0+3.0*SKEW**2+(5.0/8.0)*SKEW**4)
      DELTA=T7+T8+T9+T10+T11
      XT(J)=EXP(M1+K*SQRT(M2))
      SX=SQRT(M2*DELTA/XN)
      PSX=XT(J)*(EXP(SX)-1.0)
      NSX=-XT(J)*(EXP(-SX)-1.0)
      ST(J)=(PSX+NSX)/2.0
5     CONTINUE
      WRITE(6,26)
      WRITE(6,27) (XT(J),J=1,6)
      WRITE(6,28) (ST(J),J=1,6)
6     DO 7 I=1,N
7     X(I)=DLOG(X(I))
```

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

```
      WRITE(6,28) (ST(J),J=1,6)
      WRITE(6,29)
      WRITE(6,30)
      ICOUNT=0
      XMIN=10000000.
      DO 10 I=1,N
10    IF(X(I).LT.XMIN) XMIN=X(I)
      GML=XMIN*.99
11    ICOUNT=ICOUNT+1
      A=0.0
      B=0.0
      C=0.0
      R=0.0
      DO 12 I=1,N
      A=A+1.0/(X(I)-GML)
      B=B+(X(I)-GML)
      C=C+DLOG(X(I)-GML)
      R=R+1.0/((X(I)-GML)**2)
12    CONTINUE
      BETA=1.0/(1.0-(XN**2)/(B*A))
      ALPHA=(B/XN)-(XN/A)
      D=BETA+2.0
   PSI=ALOG(D)-(1.0/(2.0*D))-(1.0/(12.0*D**2))+(1./(120.*D**4))-1.
   10/(252.0*D**6)-(1./(BETA+1.))-(1./BETA)
   FCN=-XN*PSI+C-XN*ALOG(ALPHA)
   TRI=(1.0/D)+(1./(2.*D**2))+(1./(6.0*D**3))-(1.0/(30.*D**5))+(1
   2.0/(42.*D**7))-(1./(30.*D**9))+(1./((BETA+1.0)**2))+(1.0/(BETA
   3**2))
   V=A-(XN**2)/B
   U=A
   W=(B/XN)-(XN/A)
   DU=R
   DV=R-(XN**3)/(B**2)
   DW=-1.0+(XN*R)/(A**2)
   FPN=-XN*TRI*((V*DU-U*DV)/(V**2))-A-XN*DW/W
   AS=GML-(FCN/FPN)
   WRITE(6,31) ICOUNT,AS,FCN
   DELTA=ABS(0.00000001*AS)
   IF(ABS(AS-GML).LT.DELTA) GOTO 13
   IF (ABS(FCN).LT..001)GO TO 13
   IF(ICOUNT.GE.25) GOTO 15
   GML=AS
   GOTO11
13    CONTINUE
   GAMMA=AS
   M1=GAMMA+ALPHA*BETA
```

```
      M2=BETA*ALPHA**2
      SKEW=2.0/SQRT(BETA)
      WRITE(6,32)
      WRITE(6,23) ALPHA,M1
      WRITE(6,24) BETA,M2
      WRITE(6,25) GAMMA,SKEW
      IF(SKEW.LT.0.0) WRITE (6,33)
      D=BETA+2.0
      TRI=(1.0/D)+(1.0/(2.0*D**2))+(1.0/(6.0*D**3))-(1.0/(30.0*D**5))+
     1(1.0/(42.*D**7))-(1./(30*D**9))+(1./((BETA+1.)**2))+
     1(1./(BETA**2))
      H=(BETA-2.0)*ALPHA**4
      P=2.0*TRI-(2.0*BETA-3.)/((BETA-1.)**2)
      DET=P/H
      VARA=(1./(XN*(ALPHA**2)*DET))*((TRI/(BETA-2.0))-1.0/
     1((BETA-1.0)**42))
      VARB=2.0/(XN*DET*(BETA-2.0)*ALPHA**4)
      VARG=(BETA*TRI-1.0)/(XN*DET*ALPHA**2)
      COVAB=(-1.0/(XN*DET*ALPHA*83))*((1.0/(BETA-2.0))-(1.0/
     1(BETA-1.0)))
      COVBG=(-1.0/(XN*DET*ALPHA**3))*((BETA/(BETA-1.0))-1.0)
      DO 14 J=1,6
      T=SND(J)
      E=BETA**(1./3.)-1.0/(9.0*BETA**(2./3.))+T/(3.0*BETA**(1./6.))
      F=1.0/(3.*BETA**(2./3.))+2.0/(27.*BETA**(5./3.))-T/(18.0*BETA**(
     57./6.))
      XT(J)=EXP(ALPHA*E**3+GAMMA)
      DXDA=E**3
      DXDB=3.0*ALPHA*E**2*F
      DXDG=1.0
      SX=SQRT(VARA*DXDA**2+VARB*DXDB**2+VARG*DXDG**2+2.*DXDA*DXDB*COVAB
     5+2.0*DXDA*DXDG*COVAG+2.0*DXDB*DXDG*COVBG)
        PSX=XT(J)*(EXP(SX)-1.0)
        NSX=-XT(J)*(EXP(-SX)-1.0)
        ST(J)=(PSX+NSX)/2.0
 14     CONTINUE
        WRITE(6,26)
        WRITE(6,27) (XT(J),J=1,6)
        WRITE(6,28) (ST(J),J=1,6)
 15     CONTINUE
        STOP
 16     FORMAT(80A1)
 17     FORMAT(I5)
 18     FORMAT(8F10.0)
 19     FORMAT(1H1,80A1,/,24X,31HLOG-PEARSON TYPE 3 DISTRIBUTION,/)
 20     FORMAT(28X,26HMETHOD OF MOMENTS (DIRECT),/)
```

```
21    FORMAT(/,3X,43HMETHOD NOT APPLICABLE BECAUSE OF VALUE
      1 OF,9X,E12.5,/)
22    FORMAT(27X,28HMETHOD OF MOMENTS (INDIRECT),/)
23    FORMAT(9X,5HALPHA,5X,E12.5,14X,4HM1  ,6X,E12.5)
24    FORMAT(9X,'BETA',5X,E12.5,14X,'M2  ',6X,E12.5)
25    FORMAT(9X,'GAMMA',5X,E12.5,14X,'SKEW',6X,E12.5,/)
26    FORMAT(3X,'HT,YEARS',4X,1H2,11X,1H5,10X,2H10,10X,2H20,10X,
      12H50,9X,3H100,/)
27    FORMAT(3X,1HX,3X,6E12.5,/,4X,1HT)
28    FORMAT(3X,1HS,3X,6E12.5,/,4X,1HT,/)
29    FORMAT(27X,'MAXIMUMLIKLIHOOD PROCEDURE',/)
30    FORMAT(21X,'TRIAL',11X,1HG,11X,4HF(G),/)
31    FORMAT(22X,I2,8X,E12.5,1X,E12.5)
32    FORMAT(/)
33    FORMAT(/,3X,'SKEW IS NEGATIVE- DISTIBUTION HAS AN UPPER',
      1BOUND'/)
34    FORMAT(9X,'LI  ',5X,E12.5,14X,'M1  ',6X,E12.5)
35    FORMAT(9X,'L2  ',5X,E12.5,14X,'M2  ',6X,E12.5)
36    FORMAT(9X,'L3  ',5X,E12.5,14X,'SKEW',6X,E12.5,/)
   END
```

```
C  MASTER MULTIPLE REGRESSION
      DIMENSION XBAR(40),STD(40),D(40),RY(40),ISAVE(40),B(40),
     1SB(40),T(40),W(40),AW(40)
      DIMENSION RX(1600),R(820),ANS(10),TITLE(80)
      OPEN(UNIT=5,FILE='MREG.DAT',STATUS='OLD')
      OPEN(UNIT=6,FILE='MREG.OUT',STATUS='NEW')
      OPEN(UNIT=13,FILE='R.DAT',STATUS='NEW',DISPOSE='DELETE')
1     FORMAT(80A1)
2     FORMAT(5X,'MULTIPLE REGRESSION......'//,6X,
     1'SELECTION......',I2//)
3     FORMAT(1X,'VARIABLE',3X,'MEAN',3X,'STANDARD',3X,
     1'CORRELATION',1X,'REGRESSION',1X,'STD. ERROR',2X,
     2'COMPUTED'/6H   NO.,13X,'DEVIATION',4X,6HX VS Y,4X,
     3'COEFFIENT',1X,'OF REG.COEF.',1X,7HT VALUE)
4     FORMAT(1H ,I4,6F11.3)
5     FORMAT(10H DEPENDENT)
6     FORMAT(1H0/10H INTERCEPT,10X,F16.5//' MULTIPLE'
     1CORRELATION  ',F13.5//' STD. ERROR OF ESTIMATE',F13.5//)
7     FORMAT(1H0,21X,' ANALYSIS OF VARIANCE FOR REGRESSION'//
     15X,'SOURCE OF VARIATION',7X,'DEGREES',7X,'SUM OF',10X,
     2'MEAN',6X,'F VALUE'/30X,'OF FREEDOM',4X,'SQUARES',9X,
     3'SQUARES')
8     FORMAT(' ATTRIBUTABLE TO REGRESSION  ',I6,2F16.3,F11.3/
     1'DEVIATION FROM REGRESSION   ',I6,2F16.3)
9     FORMAT(1H ,5X,5HTOTAL,19X,I6,F15.3)
10    FORMAT(36I2)
11    FORMAT(1H ,15X,'TABLE OF RESIDUALS'//' CASE NO.',5X,
     17HY VALUE,5X,10HY ESTIMATE,6X,8HRESIDUAL)
12    FORMAT(1H ,I6,F15.5,2F14.5)
13    FORMAT(' NUMBER OF SELECTION NOT SPECIFIED. JOB ',
     1'TERMINATED')
14    FORMAT(' THIS MATRIX IS SINGULAR. THIS SELECTION IS'
     1' SKIPPED')
17    FORMAT(13F10.5)
C     READ  PROBLEM PARAMETER CARD
100   READ(5,1)TITLE
      WRITE(6,1)TITLE
      READ(5,*)N,M,NS
      IO=0
      X=0.0
      CALL CORRE (N,M,IO,X,XBAR,STD,RX,R,D,B,T)
      REWIND 13
```

```
C  TEST NUMBER OF SELECTIONS
      IF(NS)108,108,109
108   WRITE(6,13)
      GO TO 300
109   DO 200 I=1,NS
      WRITE(6,2)I
      READ(5,10) NRESI,NDEP,K,(ISAVE(J),J=1,K)
C  NRESI=OPTION CODE FOR TABLE RESIDUALS
C        0 IF TABLE IS NOT REQUIRED
C        1 IF TABLE IS NOT RQUIRED
C NDEP =DEPENDENT VARIABLE
C K    =NO OF INDEPENDENT VARIABLES INCLUDED
C ISAVE=A VECTOR CONTAINING THE INDEPENDENT VARIABLES INCLUDED
      CALL ORDER (M,R,NDEP,K,ISAVE,RX,RY)
      CALL MINV(RX,K,DET,B,T)
C     TEST SINGULARITY OF MATRIX INVERTED
      IF(DET) 112,110,112
110   WRITE(6,14)
      GO TO 200
112   CALL MULTR(N,K,XBAR,STD,D,RX,RY,ISAVE,B,SB,T,ANS)
C     PRINT MEANS,STANDARD DEVIATIONS,INTERCORRELATIONS BETWEEN
C     X AND Y,REGRESSION COEFFICIENTS,STANDARD DEVIATIONS OF
C     REGRESSION COEFFICIENTS,AND COMPUTED T-VALUES
      MM=K+1
      WRITE(6,3)
      DO 115 J=1,K
      L=ISAVE(J)
115   WRITE(6,4) L,XBAR(L),STD(L),RY(J),B(J),SB(J),T(J)
      WRITE(6,5)
      L=ISAVE(MM)
      WRITE(6,4) L,XBAR(L),STD(L)
C     PRINT INTERCEPT,MULTIPLE CORRELATION COEFFICIENT,AND
C     STANDARD ERROR OF ESTIMATE
      WRITE(6,6)ANS(1),ANS(2),ANS(3)
C     PRINT ANALYSIS OF VARIANCE FOR REGRESSION
      WRITE(6,7)
      L=ANS(8)
      WRITE(6,8) K,ANS(4),ANS(6),ANS(10),L,ANS(7),ANS(9)
      L=N-1
      SUM=ANS(4)+ANS(7)
      WRITE(6,9) L,SUM
      IF(NRESI) 200,200,120
```

```
C     PRINT TABLE OF RESIDUALS
120   WRITE(6,2)I
      WRITE(6,11)
      MM=ISAVE(K+1)
      DO 140 II=1,N
      READ (13,*) (W(J),J=1,M)
      SUM=ANS(1)
      DO 130 J=1,K
      L=ISAVE(J)
130   SUM=SUM+W(L)*B(J)
      RESI=W(MM)-SUM
140   WRITE(6,12) II,W(MM),SUM,RESI
      REWIND 13
200   CONTINUE
300   CONTINUE
      END

      SUBROUTINE DATA(M,D)
      DIMENSION D(1)
1     FORMAT(3E18.4,3E10.3)
C     THIS SUBROUTINE IS CALLED BY SUBROUTINE CORRE
      READ(5,*)(D(I),I=1,M)
      WRITE(13,*)(D(I),I=1,M)
      RETURN
      END
      SUBROUTINE MINV(A,N,D,L,M)
      DIMENSION A(1),L(1),M(1)
C     SEARCH FOR LARGEST ELEMENT
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
10    IF(ABS(BIGA)-ABS(A(IJ))) 15,20,20
15    BIGA=A(IJ)
```

```
      L(K)=I
      M(K)=J
 20   CONTINUE
C     INTERCHANGE ROWS
      J=L(K)
      IF(J-K) 35,35,25
 25   KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
 30   A(JI)=HOLD
C     INTERCHANGE COLUMNS
 35   I=M(K)
      IF(I-K)45,45,38
 38   JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
 40   A(JI)=HOLD
C     DIVIDE COLUMNS BY MINUS PIVOT
 45   IF(BIGA)48,46,48
 46   D=0.0
      RETURN
 48   DO 55 I=1,N
      IF(I-K)50,55,50
 50   IK=NK+I
      A(IK)=A(IK)/(-BIGA)
 55   CONTINUE
C     REDUCE MATRIX
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K)60,65,60
 60   IF(J-K)62,65,62
 62   KJ=IJ-I+K
```

```
      A(IJ)=HOLD*A(KJ)+A(IJ)
 65   CONTINUE
C     DIVIDE ROW BY PIVOT
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K)70,75,70
 70   A(KJ)=A(KJ)/BIGA
 75   CONTINUE
C     PRODUCT OF PIVOTS
      D=D*BIGA
C     REPLACE PIVOT BY RECIPROCAL
      A(KK)=1.0/BIGA
 80   CONTINUE
C     FINAL ROW AND COLUMN INTERCHANGE
      K=N
100   K=(K-1)
      IF(K)150,150,105
105   I=L(K)
      IF(I-K)120,120,108
108   JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
      A(JK)=-A(JI)
110   A(JI)=HOLD
120   J=M(K)
      IF(J-K)100,100,125
125   KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
130   A(JI)=HOLD
      GO TO 100
150   RETURN
      END
      SUBROUTINE CORRE(N,M,IO,X,XBAR,STD,RX,R,B,D,T)
      DIMENSION X(1),XBAR(1),STD(1),RX(1),R(1),B(1),D(1),T(1)
```

```
C     INITIALISATION
      DO 100 J=1,M
      B(J)=0.0
  100 T(J)=0.0
      K=(M*M+M)/2
      DO 102 I=1,K
  102 R(I)=0.0
      FN=N
      L=0
      IF(IO) 105,127,105
  105 DO 108 J=1,M
      DO 107 I=1,N
      L=L+1
  107 T(J)=T(J)+X(L)
      XBAR(J)=T(J)
  108 T(J)=T(J)/FN
      DO 115 I=1,N
      JK=0
      L=I-N
      DO 110 J=1,M
      L=L+N
      D(J)=X(L)-T(J)
  110 B(J)=B(J)+D(J)
      DO 115 J=1,M
      DO 115 K=1,J
      JK=JK+1
  115 R(JK)=R(JK)+D(J)*D(K)
      GO TO 205
  127 IF(N-M) 130,130,135
  130 KK=N
      GO TO 137
  135 KK=M
  137 DO 140 I=1,KK
      CALL DATA(M,D)
      DO 140 J=1,M
      T(J)=T(J)+D(J)
      L=L+1
  140 RX(L)=D(J)
      FKK=KK
      DO 150 J=1,M
      XBAR(J)=T(J)
  150 T(J)=T(J)/FKK
```

```
      L=0
      DO 180 I=1,KK
      JK=0
      DO 170 J=1,M
      L=L+1
170   D(J)=RX(L)-T(J)
      DO 180 J=1,M
      B(J)=B(J)+D(J)
      DO 180 K=1,J
      JK=JK+1
180   R(JK)=R(JK)+D(J)*D(K)
      IF(N-K) 205,205,185
185   KK=N-KK
      DO 200 I=1,KK
      JK=0
      CALL DATA(M,D)
      DO 190 J=1,M
      XBAR(J)=XBAR(J)+D(J)
      D(J)=D(J)-T(J)
190   B(J)=B(J)+D(J)
      DO 200 J=1,M
      DO 200 K=1,J
      JK=JK+1
200   R(JK)=R(JK)+D(J)*D(K)
205   JK=0
      DO 210 J=1,M
      XBAR(J)=XBAR(J)/FN
      DO 210 K=1,J
      JK=JK+1
210   R(JK)=R(JK)-B(J)*B(K)/FN
      JK=0
      DO 220 J=1,M
      JK=JK+J
220   STD(J)=SQRT(ABS(R(JK)))
      DO 230 J=1,M
      DO 230 K=J,M
      JK=J+(K*K-K)/2
      L=M*(J-1)+K
      RX(L)=R(JK)
      L=M*(K-1)+J
      RX(L)=R(JK)
      IF(STD(J)*STD(K))225,222,225
```

```
222  R(JK)=0.0
     GO TO 230
225  R(JK)=R(JK)/(STD(J)*STD(K))
230  CONTINUE
     FN=SQRT(FN-1.0)
     DO 240 J=1,M
240  STD(J)=STD(J)/FN
     L=-M
     DO 250 I=1,M
     L=L+M+1
250  B(I)=RX(L)
     RETURN
     END
C
     SUBROUTINE ORDER(M,R,NDEP,K,ISAVE,RX,RY)
     DIMENSION R(1),ISAVE(1),RX(1),RY(1)
     MM=0
     NN=1
50   FORMAT(/30X,'MATRIX AND VECTOR SELECTED BY ORDER'/)
     DO 140 J=1,K
     L2=ISAVE(J)
     IF(NDEP-L2)122,123,123
122  L=NDEP+(L2*L2-L2)/2
     GO TO 125
123  L=L2+(NDEP*NDEP-NDEP)/2
125  RY(J)=R(L)
     DO 130 I=1,K
     L1=ISAVE(I)
     IF(L1-L2)127,128,128
127  L=L1+(L2*L2-L2)/2
     GO TO 129
128  L=L2+(L1*L1-L1)/2
129  MM=MM+1
130  RX(MM)=R(L)
120  FORMAT(10F12.6)
     NN=NN+K
140  CONTINUE
150  FORMAT(//10F12.6)
     ISAVE(K+1)=NDEP
     RETURN
     END
C
```

```
      SUBROUTINE MULTR(N,K,XBAR,STD,D,RX,RY,ISAVE,B,SB,T,ANS)
      DIMENSION XBAR(1),STD(1),RX(1),RY(1),D(1),ISAVE(1),
     1B(1),SB(1),T(1),ANS(1)
      MM=K+1
C     BETA WEIGHTS
      DO 100 J=1,K
100   B(J)=0.0
      DO 110 J=1,K
      L1=K*(J-1)
      DO 110 I=1,K
      L=L1+I
110   B(J)=B(J)+RY(I)*RX(L)
      RM=0.0
      BO=0.0
      L1=ISAVE(MM)
C     COEFFICIENTS OF DETERMINATION
      DO 120 I=1,K
      RM=RM+B(I)*RY(I)
C     REGRESSION COEFFICIENTS
      L=ISAVE(I)
      B(I)=B(I)*(STD(L1)/STD(L))
C     INTERCEPT
120   BO=BO+B(I)*XBAR(L)
      BO=XBAR(L1)-BO
C     SUM OF SQUARES ATTRIBUTABLE TO REGRESSION
      SSAR=RM*D(L1)
C     MULTIPLE CORRELATION COEFFICIENT
122   RM=SQRT(ABS(RM))
C     SUM OF SQUARES OF DEVIATIONS FROM REGRESSION
      SSDR=D(L1)-SSAR
C     VARIANCE OF ESSTIMATE
      FN=N-K-1
      SY=SSDR/FN
C     STANDARD DEVIATIONS OF REGRESSION COEFFICIENTS
      DO 130 J=1,K
      L1=K*(J-1)+J
      L=ISAVE(J)
125   SB(J)=SQRT(ABS((RX(L1)/D(L))*SY))
C     COMPUTED T-VALUES
130   T(J)=B(J)/SB(J)
C     STANDARD ERROR OF ESTIMATE
135   SY=SQRT(ABS(SY))
```

```
C     F VALUE
      FK=K
      SSARM=SSAR/FK
      SSDRM=SSDR/FN
      F=SSARM/SSDRM
      ANS(1)=BO
      ANS(2)=RM
      ANS(3)=SY
      ANS(4)=SSAR
      ANS(5)=FK
      ANS(6)=SSARM
      ANS(7)=SSDR
      ANS(8)=FN
      ANS(9)=SSDRM
      ANS(10)=F
      RETURN
      END
```

Data File MREG.DAT

```
MULTIPLE REGRESSION
5,10,1
  270.8929748535156        1.026113152503967        1.988115072250366
  1.052908201741630        2.040031024327476        3.952601540509079
  1.080402954186387        2.093302665578564        4.055816427323808
  7.858226697286116
  266.8519897460938        4.024205684661865        2.060599088668823
  16.19423139246487        8.292274566430137        4.246068604222785
  65.16891802828677        33.36981844900516        17.08705341457760
  8.749445096286773
  247.9530029296875        0.3869565725326538       1.304420471191406
 0.1497353890262190        0.5047540746736559       1.701512765663210
 5.7941092924429235E-02    0.1953179067076091       0.6584115479215924
  2.219488083524598
  241.1380004882813        1.039554715156555        1.372570276260376
  1.080674005804227        1.426861902570209        1.883949163273485
  1.123419758280906        1.483301018694114        1.958468235796198
  2.585852623494791
  256.6659851074219       -0.4969049990177155       1.264393448829651
 0.2469145780487958       -0.6282834254487035       1.598690793443339
-0.1226930881627965        0.3121971749054349      -0.7943974471455931
  2.021374165934034
  233.8549957275391        0.8888789415359497       1.065337061882019
 0.7901057727060703        0.9469556799447076       1.134943055419413
 0.7023083829444154        0.8417289624707073       1.008826981804784
  1.209096900063919
  252.1809997558594       -0.1476096510887146       0.7645952701568604
 2.1788609094532063E-02   -0.1128616410519356       0.5846059271462423
-3.2162089861522716E-03    1.6659467456975967E-02  -8.6293476930451328E-02
 0.4469869268016829
  245.3329925537109       -0.7301195859909058       0.5244232416152954
 0.5330746098475316       -0.3828916800521682       0.2750197363462945
-0.3892082134441434        0.2795567149190514      -0.2007972960404846
 0.1442267416429076
  240.4029998779297       -0.7637235522270203       0.2399099916219711
 0.5832736642262581       -0.1832249110162865       5.7556804080054258E-02
-0.4454598347633481        0.1399331798978380      -4.3957486866853691E-02
 1.3808452384633251E-02
  239.6360015869141       -0.3769527971744537      -0.2825980782508850
 0.1420934112976449        0.1065261360727963       7.9861673831093327E-02
-5.3562508848707354E-02   -4.0155324964827029E-02  -3.0104081337664503E-02
-2.2568755550565968E-02
  247.9199981689453        3.8590352982282639E-02   0.3848780989646912
 1.4892153432971705E-03    1.4852581694197342E-02   0.1481311510626746
 5.7469345764469028E-05    5.7316637027726493E-04   5.7164334071804450E-03
 5.7012435818453693E-02
  237.7660064697266        0.4474127292633057       0.1728388220071793
 0.2001781503068401        7.7330289076886771E-02   2.9873258392829394E-02
 8.9562252567663536E-02    3.4598555690610305E-02   1.3365676069523751E-02
```

5.1632587901327136E-03		
237.4589996337891	-1.459526777267456	-0.2166155129671097
2.130218413560726	0.3161561415470224	4.6922280458004062E-02
-3.109110816020080	-0.4614383543854393	-6.8484324778910401E-02
-1.0164093850997136E-02		
230.0190124511719	-0.4738932549953461	-0.3301950097084045
0.2245748171300841	0.1564771879339357	0.1090287444363334
-0.1064244910797602	-7.4153483922531292E-02	-5.1667986588989748E-02
-3.6000747327650255E-02		
236.2459869384766	0.1499015390872955	-0.2977379560470581
2.2470471420739990E-02	-4.4631377856159560E-02	8.8647890471079904E-02
3.3683582499860128E-03	-6.6903122322249586E-03	1.3288455218456877E-02
-2.6393841716742810E-02		
224.0019989013672	0.6681458353996277	-0.2328339517116547
0.4464188573618664	-0.1555670351757801	5.4211649069665135E-02
0.2982729003901914	-0.1039414666781648	3.6221287556042861E-02
-1.2622312481695581E-02		
235.6640014648438	-0.2503107786178589	-0.5032958984375000
6.2655485892278762E-02	0.1259803882130655	0.2533067613840103
-1.5683343458376570E-02	-3.1534249064192546E-02	-6.3405412671199812E-02
-0.1274882540510589		
216.7290039062500	0.8217020034790039	-0.4437946677207947
0.6751941825214089	-0.3646669675994758	0.1969537070974106
0.5548084125152100	-0.2996475778791023	0.1618372557145592
-8.7407004997674039E-02		
216.3850097656250	0.7161205410957336	-0.9360229372978210
0.5128286293792463	-0.6703052523357336	0.8761389391476406
0.3672471155604493	-0.4800193600019778	0.6274210911774505
-0.8200861433019715		
227.1300048828125	-0.2531911134719849	-1.049602389335632
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