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# STATISTICAL ANALYSIS OF LOW FLOW IN TYPICAL RIVER BASIN TO INVESTIGATE DROUGHT CHARACTERISTICS


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A B S T R A C T

Low flow is a broadly used term to describe streamflows that are significantly below average or normal flow levels. In the traditional planning, design and operation of water related projects, the low flow characteristics of a river system have been important in determining the critical capacity of that system to provide adequate water supply and to meet power demands. This knowledge must be understood quantitatively. Furthermore, the question of quality of the environment often depends on the availability of low river flows particularly in areas of urban living, or on problems of public health, such as combating endemic diseases, as well as for thermal or chemical pollution. Thus, the connection between quantitative and qualitative aspects of water resources is especially sensitive during low water periods. For various reasons(health, environmental conditions), it is necessary to maintain a minimum discharge in river and, consequently, this water is not available for other water users.

The low flow computation methods can be divided into the three groups, namely, deterministic approach, statistical approach and stochastic approach. In the present report attempts have been made to carry statistical analysis of low flow using 20 years data (1966-86) for six selected sites in drought affected Krishna basin. The hydrologic drought characteristics have been investigated by developing/carrying out flow duration curve, frequency curves, low flow spell analysis and maximum deficit volume and maximum deficit duration analysis. The results of these analysis are presented herein.

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## 1.0 INTRODUCTION

Whipple (1966) defined a drought year as one in which the aggregate runoff is less than the long term average runoff. Yevjevich (1967) defined the term hydrologic drought as "the deficiency in water supply, or deficiency in precipitation, effective precipitation, runoff or in accumulated water in various storage capacities". Linsley et al (1975) defined hydrologic drought as a "period during which streamflows are inadequate to supply established uses under a given water management system". National Commission on Agriculture (1976) defined hydrological drought as meteorological drought, if prolonged results in hydrological drought with marked depletion of surface water and consequent drying up of reservoirs, lakes, stream/ rivers, cessation of spring flows and fall in groundwater levels. Hydrological drought may be reflected in depleted snowmelt due to poor snow fall in an earlier season and this may result in the curtailment of user needs and badly affect both the industry and the agriculture. Six types of hydrological drought have been distinguished based upon variations in the duration, season of year, or severity by Beran and Rodier (1985) mainly relating to agricultural and irrigation needs on the basis of runoff deficit.

The uncertainty about drought is reflected in the varied definition of drought as there is no standard and unified definition of drought. In spite of the lack of a unified definition of drought among the community of hydrologists, meteorologists and agriculturists, all tend to agree that it is basically a situation of water deficit for given use caused due to occurrence of below normal natural water availability. Drought is not solely a natural and statistical phenomenon, it is also determined by intended water use of the region or area or need for water compared to normal supplies which further complicates the problem of drought studies. The perception of drought varies even within each of the discipline or user or interest. Both the variability in the magnitude of water deficit below normal and its duration (i.e intense deficit of short duration and long duration of low deficit) are important depending upon whether the storage exists or not and amount of demand as fraction of normal supply.

The streamflow represents runoff from the basin and reflects the basic effects of rainfall deficiency as well as the changes in the basin both natural and man made due to drought conditions. The deficits in surface water are reflected through low stream flows which is a measure of drought. The drought phenomenon, can therefore be better studied by analysing low stream flows of a basin for which local singularities are also eliminated. The deterministic or statistical study of low flows may lead to drought characteristics related to low flow parameters. When low flow in a stream is either too low or extended over a significant period that it does not meet the need of specific user, it is said that the drought has set in. Hydrologists generally use analysis of low flow frequencies to define a hydrological drought on an annual basis. Keeping this in view an attempt has been made in this report to carry out statistical analysis of low flow for selected sites in drought affected Krishna Basin for year, (1966-86). The hydrologic drought characteristics have been investigated by developing/carrying out flow duration curves, frequency curves, low flow spell analysis, maximum deficit volume and maximum deficit duration analysis.

## 2.0 LOW FLOW CONCEPTS

It is evident from various definitions that stream flow is one of the important parameters to study drought as it represents the resulted runoff from a basin or catchment after various manifestations and gives the volume of water available in various water resources. The analysis of low flows leads to drought characteristics related to low flow parameters. Low flow may be absolute or relative. When the flow in the stream or river is relatively too low or to be more specific it is lower than the threshold level that it does not meet the requirement of the specified established uses in the area, it can be said that the drought has set in. The short period of low streamflow occuring on an annual basis is termed as lowflow and the period of atleast one year during which the average discharge for each year falls below the long term mean annual flow can be termed as drought event. The low flow in a stream during any year indicates the drought severity of that year. The magnitude of low flow determines the amount of water available for specified uses over a given period. The frequency of occurrence of low flow events reflects the risk of failure of a water supply scheme or project during drought. The concept of low flow, drought, highflow and flood is illustrated in figure-1.

### 2.1 Definition

Low flow is defined on a seasonal basis and is linked with the annual solar cycle and its regional or even local climatic conditions. It is also defined as the annual occurring minimum flow of short duration. For defining low flow three parameters magnitude, frequency and areal extent are needed.

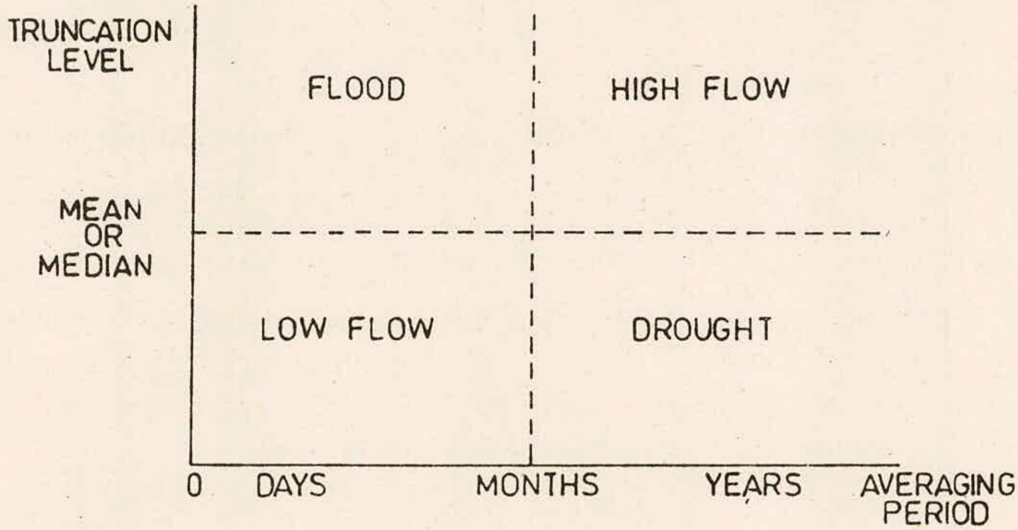


FIG. 1- CLASSIFICATION OF HYDROLOGIC EVENTS

## 2.2 Concepts of Low Flow

Several concepts relating to the study of low flow are given. A period of low flow as defined by Institute of Hydrology, (1980) is as given below:

* The duration, which is often equated to that of the dry season. This is defined as the season during which either there is no rain or the rainfall is low having regard to climate.
* The absolute minimum or lowest flow, which is almost always equated to the smallest mean daily flow during the year.
* A series of low flow which expresses a correspondence between fixed lengths of time (expressed as a number of day) and flows which have not been exceeded during an equivalent number of day, which may be either consecutive or non consecutive. Example are:-
  - discharge not exceeded for 7 days or 10 days.
  - discharge not exceeded for 15 days
  - discharge not exceeded for one month.

Low flow in a stream can be characterised by three main numerical characteristics which are as follows:-

(i) The minimum flow value averaged over in consecutive day ( n=1,3 5, 7, 10, 15, 30, 60, 90, 180 and one year) i.e. the magnitude of low flow.

(ii) The data of their occurrence and

(iii) The frequency of occurrence

The magnitude of low flow can be characterised by averaging flow over in days ( 7 days, 14 days, 30 days etc.). The most widely used criteria of low flow is 7 days 10 yr., low flow which is defined as the lowest average flow over a consecutive 7 days occurring at an average of once in 10 years. This criteria is mostly used for regulating waste disposal to streams. If there is a stream flow record of 15 yr., 20 yr. or more, one can obtain the annual minimum flow for 1, 3, 7, 14, 30, 60, 90, 120, 150 and 273 days using the computer and a frequency curve.

Another low flow characteristics is the duration, this gives idea about the length of record. This can be described by the duration curve, the lower end of which is an expression of the low flow characteristics of the stream. Another characteristics of low flow is the rate at which flow receeded in absence of rain. This can be described by the base flow recession curve which can be estimated from stream flow hydrograph. The frequency curve of annual low flows of a stream can be described both natural variation in stream flow and the variation due to regularities. Weisman (1978) characterised the low flow by defining the longest run length in a year below a given threshold flow as an extreme value run and prepare frequency curve of threshold flow for various run length.

## 2.3 Importance of Low Flow

The knowledge of low flow is important when supply is least able to meet the demands. Low flow of a stream vary annually, seasonally and daily. The low flow affects the society and create a situation of drought in following ways:

(a) When there is low flow in streams, the available water supply for domestic, municipal, industrial and agricultural uses gets reduced, which reduces reservoir storage thus indicating the situation of drought.

(b) Reservoir discharge and hydraulic head are reduced causing a reduction in the amount of hydroelectric power which may be generated during low flow period.

(c) Water quality of streams is degraded due to lack of sufficient water in stream during low flow or drought period.

(d) Diminished water quality and quantity affects the established life style and wild life during low flow period.

Therefore, it is clear from above consideration that the study of low flow which is an indication of hydrologic drought is an essential aspect of water resources analysis. Whipple (1966) also stated "under prevailing conditions, there is no part of the science of hydrology which is more important than the quantitative analysis of drought runoff of the stream". So it is very important to have a knowledge of low flow during periods of droughts.

## 2.4 METHODOLOGY FOR LOW FLOW COMPUTATION

The methodology for low flow computation can be divided into three main groups:

i) Deterministic approach

ii) Statistical approach

iii) Stochastic approach

In this report the analysis of low flow has been done by statistical approach.

For analysis of low flow, hydrologists need magnitude, duration and frequency of low flow. Low flow data are normally specified in terms of the magnitude of low flow for a given time interval within a year or season. For describing a low flow, Salas (1980) defined the low flow variables as low flow volume, low flow discharge, low flow stage and low flow durations. The low flow variables describing the different aspects of low flow for drought analysis as shown in figure 2 are:

i) low flow volume (V) is the minimum volume (V) for a given time interval t inside a specified time unit period Tu.

ii) Low flow discharge (Q) at a particular site is the minimum instantaneous flow during a period $T_u$.

iii) Low flow stage (H) is the water stage corresponding to the low flow discharge (Q) and

iv) Low flow duration (D) is the total time for which the flows are smaller than a specified discharge $q_o$ or stage $h_o$ during Tu. The deficit volume (DV) has been described as one of the low flow measures alongwith deficit duration by Institute of Hydrology (1980).

(i) Statistical approach:

There are various statistical approaches available in the literature to analyse low flows both for gauged and ungauged catchments which include low flow duration curve. Low flow frequency analysis either using annual or partial series, study of deficit volume of stream flow below a threshold and reservoir capacity yield analysis. These techniques can be employed to determine frequency of drought and variation in duration i.e. periods using past historical data. Some of the techniques and studies available in the literature have been reviewed for both gauged and ungauged catchments by Singh (1987).

2.4.1 Low flow duration curve

In analysing the stream flow droughts, one of the simplest techniques is to construct a flow duration curve for given river or stream. It is a cumulative frequency curve that shows the percentage of time during which specified discharge were equalled or exceeded during the

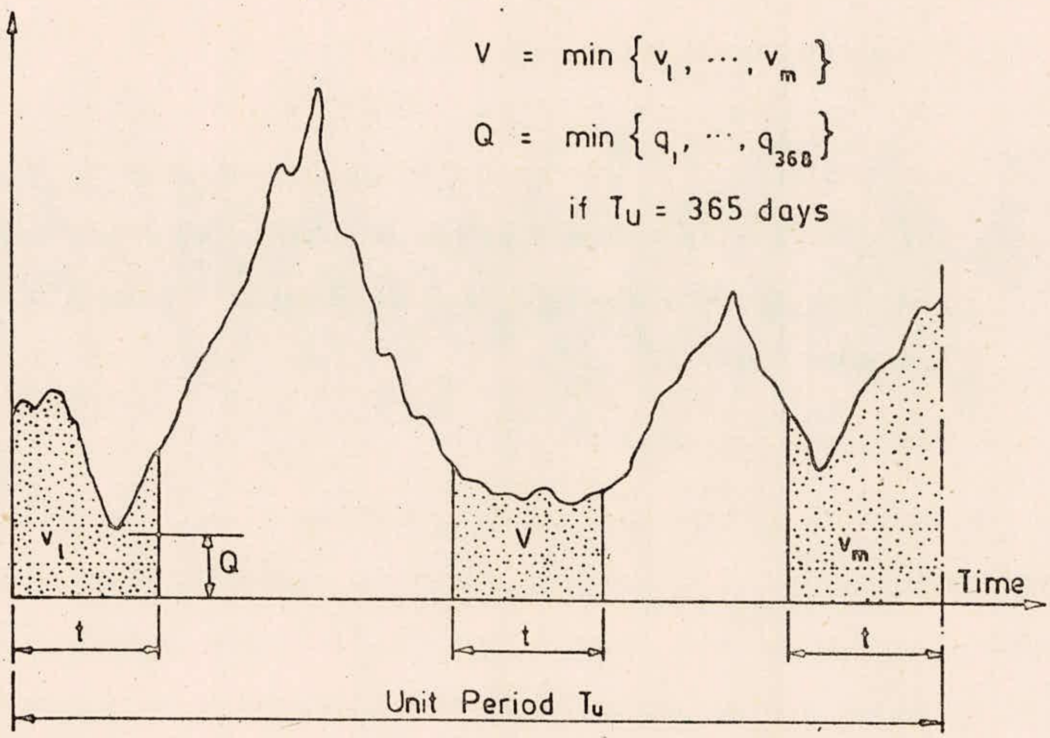


FIG. 2 - GRAPHICAL REPRESENTATION OF THE DEFINITION OF LOW FLOW VOLUME AND LOW FLOW DISCHARGE

period of record. One way is to analyse the low flows over a given number of consecutive days and to estimate the recurrence interval of these events. This analysis is repeated for various periods of consecutive dry days to build up a series of curves.

The procedure of constructing flow duration curve is given by Institute of Hydrology (1980) depending upon the record of data. The guidelines suggested by Institute of Hydrology (1980) are as follows:

- If the data are more than two year, then these data will not need any adjustment or standardisation as these data record will provide as accurate flow duration curve.
- If data is between two to ten years than one have to divide flow data by average flow over the period of record before analysis. This overcome to great extent the departures due to wet or dry years.
- If the period of record is less than two year, then one can use the empirical method to estimate the data and then draw flow duration curve.

The weakness of flow duration curve is that it deals only with discrete value of flow and reveals nothing about the sequence of low flow nor wheather the low flow occurred consecutively over a few week or were scattered through the year.

Flow duration value of 90, 95 and 99% are used as measure of stream low flow potential in hydrologic drought studies. Cross (1949) found that 90% value can be used as a measure of groundwater contribution to streamflow. Scarcy (1959) also used 90% value as a measure of runoff river hydropower potential value (cited from McMohan et al 1982) Flow duration urve is also used to define low flow index (LFI) as the 10 days average flow which is exceeded 95% of time of the duration of series (Institute of Hydrology,1980) or Low Flow Index (LFI) = $(Q_{10})_{95}$

The low flow index can be used for planning in drought conditions.

2.4.2 Low flow frequency analysis

(a) Flow frequency curves:

The flow frequency curve is a graphical technique for estimating the probability that a year will contain an annual minima less than a given discharge. The probability is commonly expressed in terms of a return period, that is the interval in years between the occurrence of an event of a specified or more extreme severity. The curve can be drawn from daily or monthly flow data or from minima of any consecutive D day or month period. It is frequently used for assessing the severity of extreme events and has applications in economic studies where the risk of any event occurring in a given design period can be calculated from the curve and used in cost benefit analysis. The flow frequency curves differ from the flow duration curves as the former shows the proportion of years or equivalently the average interval between years (return period), in which the river falls below a given discharge, while the flow duration curve is concerned with the proportion of time that a flow is exceeded. Unlike flow duration curves, low flow frequency curves use data sequences that are independent and homogeneous and therefore can be used to determine the possibility of occurrence of a flow event of specified magnitude. In practice, two types of low flow frequency curve are used. One type - the annual series is based on the minimum flow event in each years of record and is used for events of less than 12 months duration. The second type - the partial series is used where frequencies of events lesser than 12 months duration are required. Both these procedures are discussed herein detail. In general, the following steps are involved in drawing the annual flow frequency curve:

i) Find the lowest flow in each year (from the moving average data where required).

ii) Rank them from highest to lowest

iii) Assign a plotting position to each ranking

iv) Plot the discharge against the plotting position and

v) Draw a smooth curve through the points

2.4.2.1 Institute of Hydrology approach

Institute of Hydrology (1980) suggested guidelines for the estimation procedure depending on the availability of data at or near the site of interest. These are summarized below:

More than 20 years data:

The flow frequency curve may be directly constructed using the data in cumec units. If return periods in excess of twice the length of records are being estimated then the type curves can be used for extending the curve beyond the range of data.

10-20 years data:

The flow frequency curve can be plotted by dividing the daily flow data by the average daily flow (ADF) over the period of record and the discharge scale expressed as a % of ADF. This overcomes to a great extent departures due to wet or dry years. If return periods in excess of the length of record are being estimated then the type curves can be used for extending the curve beyond the range of data.

5-10 yrs. data:

The daily or monthly flow must be divided by the average daily flow over the period of record before analysis. This overcomes to a great extent the departures due to wet or dry years. The value of the mean annual minimum as % ADF is then used in conjunction with the type curves.

Less than 2 years data:

If the availability is less than 2 years., then the computational procedure for ungauged catchments may be used to establish this plot.

The procedure for constructing the flow frequency curve recommended by Institute of Hydrology is given as follows:

(a) Assembly of data:

(i) From the average flow data calculate the long term average discharge (ADF).

(ii) For each calender year of record extract the minimum discharge over D consecutive days, where D is the duration of interest.

(iii) Divide by the ADF/100 to yield units of % ADF, if the other procedures are recommended for plotting the flow duration curve.

(b) Preparation of probability paper:

Plot the annual minimum values, obtained from the previous step, an special probability paper which has been found to linearise flow data in many cases. In fact the paper linearises a standardized Weibull variate', W, so the horizontal axis is marked primarily by the linear axis from -1.0 to +3.0. To increase the usefulness of the paper it is useful to also mark a return period scale.

The conversion to a return period scale is:

$$T = 1 - \exp [ - (1 - \frac{W}{4})^4 ]^{-1} - 1 \quad ...(1)$$

or

$$W = 4 [ 1 - ( - \mathrm{In} \; (T-1)/T )^{\frac{1}{4}} ] \quad ...(2)$$

The vertical axis is labelled linearly as discharge in cumecs or in % ADF. A third alternative is to express the discharge as a multiple of the mean annual minimum MAM (D). This latter form of the frequency curve can be compared directly with the low flow frequency type curves.

(c) Plotting annual minima :

(i) Calculate the exceedence probability P from the N number of annual minima as follows:

$$P = ( i - 0.44)/ (N + 0.12) \quad ...(3)$$

where i represents the ith rank in ranked annual minimum series from highest ( i = 1 ) to lowest.

(ii) Compute the standarized Weibull variate W using the equation:

$$W = 4 [ 1 - ( \ln P)^{\frac{1}{4}} ] \quad ...(4)$$

(iii) Plot the ranked flows against the corresponding W value on linearized scale.

(d) Curve for different durations:

Curves for different durations can be plotted using the above procedure.

2.4.3 Use of low flow frequency curves:

The low flow frequency curve are useful for reservoir capacity yield analysis and for estimation of recurrence interval of any low flow condition. These curve are mostly used for streamflow quality.

### 2.4.4 Analysis of low flow spells

Generally it is of interest both in amenity and water quality work to know for how long a low flow is maintained and how large a defict can build up. Thus while the 95% flow on the flow duration curve is defined to be exceed 95% of the time. In other words, in a period of 100 years there will be 1826 day ( 5% x 365 x 100 ) when the flow is lower, no information is available on how these days occur. These 1826 days may be divided into many short spells or alternatively into fewer long spells. Institute of Hydrology (1980) described the spell durations and deficiency volumes which provide this information.

The frequency of spell durations and deficit volume was expressed in two ways:

a) frequency per 100 years of an event

b) proportion of years in which a deficit duration or volume is exceeded.

#### 2.4.4.1 Analysis for frequency of spell duration and frequency of deficiency volumes :

The analysis procedure has the following steps:

(i) Select a number of class interval (in days) with chosen lower and upper class limits in days for duration of spells below given threshold.

(ii) Consider a threshold discharge ($q_o$) as some percentage of average daily flow ( 5, 10, 20, 40, 60, 80%) or at the discharge corresponding to 95% percentile from the 10 daily flow duration curve.

(iii) Find out the frequency of spell durations expressed as the number of events in class interval per 100 years.

(iv) Plot the frequency of spells per 100 years for given durations versus duration of spells below given threshold in days.

(v) Cummulative sum yield data for the number of occasions when spells of longer than a given duration occur.

(vi) Repeat step (i) to (iii) for frequency of deficit volumes.

(vii) Plot the frequency of deficiency volume versus the deficiency volume as percentage annual runoff volume.

(viii) Repeat step (v) for the frequency of deficiency volume to yield data for the number of occasions when deficit volume larger than a given deficit volume occur.

2.4.5 Analysis of annual maximum durations of low flow spells and annual maximum deficiency volume of low flow spells

The analysis procedure has the following steps:

(i) Consider a threhold discharg ($q_o$)

(ii) Find out the annual maximum durations of low flow spells i.e. the longest duration, for which the flow is below a threshold discharge ($q_o$) within that year.

(iii) Repeat step (i) and (ii) for different threshold discharge ($q_o$) to get different series of annual maximum duration.

(iv) Similarly find out the annual maximum deficit volumes relative to some specific threshold discharge ($q_o$). At the end of each positive element the net deficit is calculated and when this becomes negative the drought is deemed to be over. When demand level (threshold discharge) is high there may be two or three separate drought events in any year, each having one or more elements but when threshold discharge $q_o$ is low there is usually only one drought or perhaps none.

(v) Repeat step (iv) for different threshold discharge ($q_o$). Thus different series of annual maximum drought volume (deficit volume) are resulted taking different percentage of threshold discharge.

After having the series of annual maximum duration of low flow spells and annual maximum deficit volumes of low flow spells from the N years of recorded daily flow data, the spell frequency curves are drawn as follows:

(i) Rank the annual maximum duration series (or the annual maximum deficiency volumes) in increasing order.

(ii) Assign an appropriate probability plotting position to each ranked values in the series. For example, if normal probability plotting position assigned then the plotting position formula can be used. This formula is

$$F_i = \frac{i - 0.375}{N + 0.25} \qquad \ldots(5)$$

However, Gringorton formula is appropriate if extreme value probability plotting position is to be used. This formula is given as:

$$F_i = \frac{i - 0.44}{N + 0.12} \qquad \ldots(6)$$

(iii) Plot the annual maximum durations (or annual maximum deficiency volume) on the appropriate probability paper (for example Normal or extreme value).

If the annual maximum spell durations are distributed log normally then a logarithmic duration (or deficit volume) axis may be used.

In this case the plotted points would lie along a straight line.

(iv) Repeat step (i) to (iii) for each threshold level.

(v) Find out the frequency of occurrance of any spell duration (or deficiency volume) relative to any threshold level using the corresponding spell frequency curves obtained from step (iii).

2.4.6 Use of spell frequency curves:

The usefulness of spell frequency curves are as follows:

(i) It can be used to compare synthetically generated flow sequences with recorded data to assess time series models.

(ii) It could be useful measure for amenity purposes because it shows the frequency with which the flow is below a threshold for given periods.

(iii) It may also be relevant to assessing dilution requirements than the use of the simple flow duration curve.

(iv) Deficit volume data may be used in regulating reservoir design works and also in validating the performance of time series models.

## 3.0 DESCRIPTION OF CATCHMENT AREA

From the time of the Aitareya Brahmana (2,000 BC) through the region of the Satbahanas, Chalukyas, Vijaynagars etc. down to the Nizam Shahis and present days, the Krishna flows majestically through the passage of time in the vibrant youthful company of Bhima and Tungabhadra. Spatially, the Krishna originating in the dizzy heights of the Sahyadri (Western Ghats) at Mahabaleshwar passes through the Nallamalai gorge (near Atrnakur) at the base of the Srisailam temples, through the Shrines of the Nagarjuna-Konda and strides into the wide coastal plains to fan out into a tight delta before ending its journey into the Bay of Bengal. The Krishna is the third longest river within India, yet has a rather poor water wealth because of fairly low rainfall in the basin (Pune 661 mm Kurnool 607 mm, and Machiliapatnam 1070 mm). The Tungabhadra river, although a tributary, has a significant length and discharge. The Krishna has two large tributaries - the Bhima (861 Km/76, 614 Sq Km/12,690 million cu m) and the Tungabhadra (531/71, 417/16,000), and four smaller tributaries - the Ghatprabha (283/8,829/5,380), the Malprabha (306/11.549/1,980) the Musi (240/11,212/1, 410) and the Muneru (235/10,409/1,980).

### 3.1 Location

Krishna basin (fig. 3) lies between $13^{O}30'$to $18^{O}44'$N latitude to $73^{O}12'$ to $81^{O}36'10''$ E longitude, covering parts of Maharashtra, Karnataka and Andhra Pradesh State.

### 3.2 Climate

The climate of the basin is characterised by a hot summer and general dryness during the major part of the year except during Southwest monsoon. The cold season in the basin commences from the middle of November and ends in the month of February. December is the coldest month

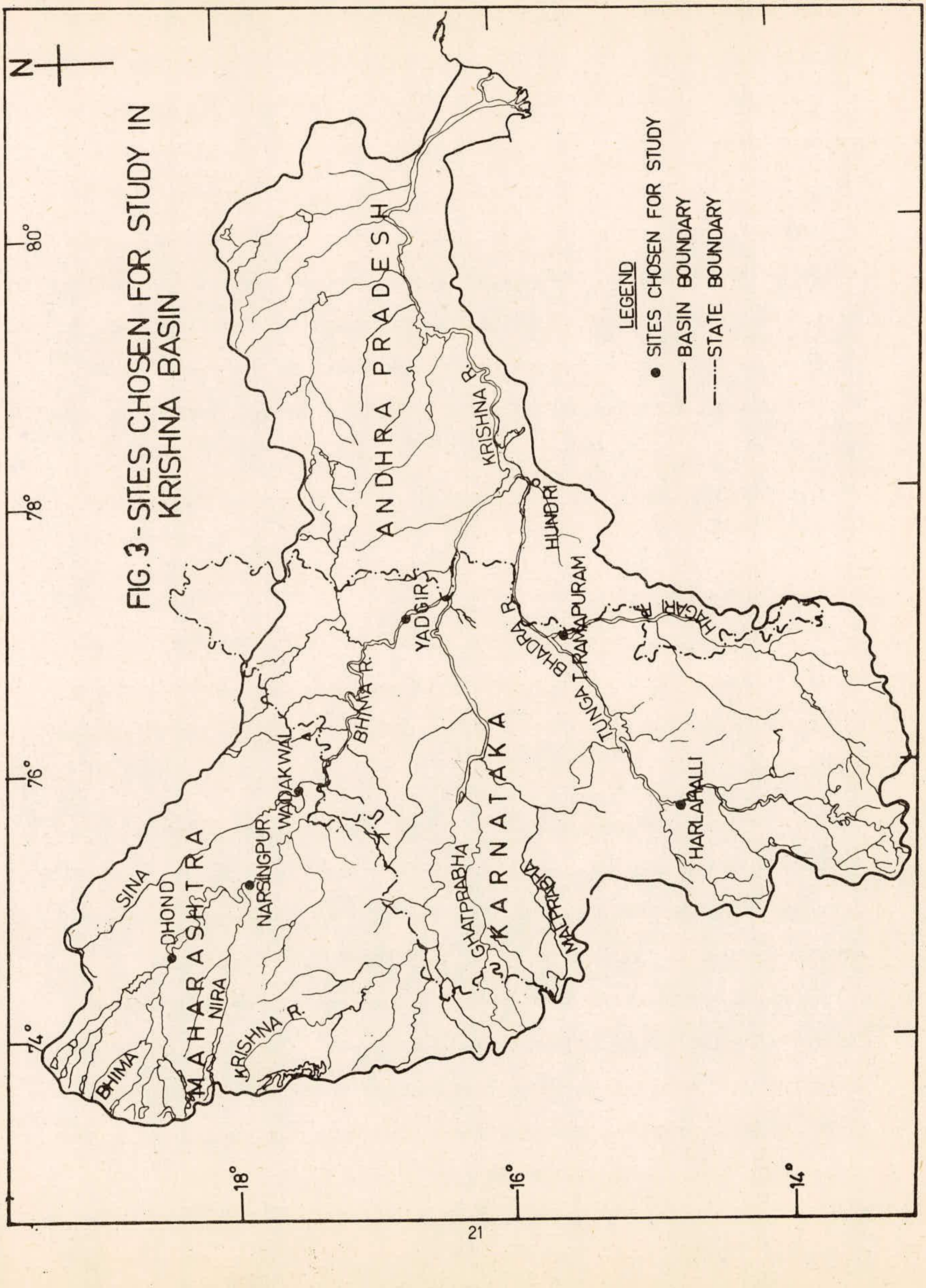


FIG. 3 - SITES CHOSEN FOR STUDY IN KRISHNA BASIN

of the year with mean daily maximum temperature of 29.12°C and mean daily minimum temperature of 17.2 ° C. During the cold season the basin is sometimes affected by cold wave in association with the passage of western disturbances across north India causing drop of temperature of 4° C to 5°C. From March to the break of Southwest monsoon, the day temperature increases progressively, the nights remaining comparatively cool. In the hot season, the swettering heat of the afternood is sometimes relived by thunder storms. The period from March to the first week of June is the hot season. May is the hottest month of the year with mean daily maximum temperature 39°C and the mean daily minimum temperature at 22°C and on individual days,
during the hot weather period the temperature progressively goes upto 43°C or 44°C.

The rainy season generally commences in the month of June and lasts till October or so, with the withdrawal of the monsoon by about the first week of October the day temperature increases slightly. However, the night temperatures decrease steadily with the day after the withdrawal of monsoon.

The air is generally dry during the month from February to May, and particularly shows in the afternoon when the humidity is about 22 percent on the average. The relative humidity during the Southwest monsoon period is between 60 to 80 percent of the temperature. Storm occurs during the months from March to June and in the September and October the dust storm is very rare in the basin. The basin experiences cloudy to the overcast skies with widespread heavy rain in association with the monsoon depression that forms in the Bay of Bengal and moves across the central parts of the country.

Evaporanspiration losses in the basin vary between 90 mm to 220 mm from winter to summer months.

## 3.3 Rainfall

The drought occurrence in India is the result of large scale fluctuations and variations in the rainfall occurrence, both in quantum and time. The rainfall may be interspersed with prologed periods of dry spells. The rainfall in India is orographic in nature and is associated with two distinct season, i.e., the Southwest monsoon and the postmonsoon.

### (a) Southwest Monsoon:

Due to rapid rise of temperature in May over the Asian mainland, there is a corresponding drop in air pressure over the area. By the end of May the Asian high pressure region is replaced by a deep low pressure area which extends from Sudan in Africa through west Rajasthan to West Bengal. The air circulation in the Indian Ocean area and in the neighbouring seas becomes more and more vigorous, till, almost abruptly, the south east trade winds from the south of the Equator extend north-west into the Bay of Bengal and the Arabian sea. They are then caught up in the air circulation over India and deflected in-land as the south-west monsoon.

The Krishna basin comes under the influence of south-west monsoon and this season lasts over the basin till the end of September. Rainfall of about 564.88 mm which forms 72.08 percent of the total annual rainfall in the basin is received during the south-west monsoon season.

### (b) North-east monsoon:

By the middle of October the belt of low pressure is transferred to the centre of Bay of Bengal. Under its influence the retreating south-west monsoon current curves round as it is, deflected towards the peninsular from the north east. The retreating monsoon winds cause occasional showers. However, during October and November, cyclonic storm form in Bay of Bengal and when they strike the northern circars or the coromandel coast, they bring heavy rains.

The Krishna basin receives about 125.22 mm of rainfall which form 17.64 percent of the normal annual rainfall during the north east monsoon season.

3.4 Soil

The soil of the basin are mainly light soil, medium black, black cotton, red and laterite, deep black mixed red, red loamy soil, laterite, red comparising of clay loams, and red and grey sandy soils. The red earth soils are comparising loamy sands, sandy loams, and sandy clay loams. Regular or black cotton soils comprising clay loams and clay are also found in low lying areas, particularly in areas of flat topography and along side of the river Krishna and its tributaries. The red soils are generally non-saline, non-alkaline and excessively drained, while the black soils are moderately alkaline with high soluble salt content in the basin. The red soils are highly permeable and excessively drained, the application or organic manures like form yard manure, green manure and compost may be necessary to improve their water holding as well as productive capacity. The application nitrogenous fertilizers at frequent intervals in small doses may also be necessary for securing high yield of crops. The black soils, which contains higher proportion of clay, are inherently more fertile than the red soils. These soils, being calcereous require heavy application of super phosphate for high yield of paddy crop.

The soil of the Solapur district are clayey, moderately alkaline in reaction and contain moderate amount of calcium carbonate. The soils are saturated with divalent bases which constitute 90 percent of the total exchangeable bases. They are well supplied with nitrogen but are low in phosphate and potash. The soils of Ahmadnagar district are alkaline in reaction, clayey in texture, and quite high in calcium carbonate. They are base saturated divalentions accounting for more than 90 percent of the exchangeable bases. They are well supplied with nitrogen and available Potash.

## 3.5 Cropping Pattern

In Krishna basin, there are two agricultural seasons, viz. Rabi and Kharif like other parts of the country.

The Kharif season commences with 'Mrug Nakshatra'' which usually falls in June and continues upto and of October. The pre sowing preparatory tillage of the soil starts with early monsoon season showers of even before that and the actual sowing operations start with the regular southwest monsoon which generally begins in the second fortnight of June. Paddy, groundnut, bajra, ragi cotton, maize are the principal Kharif crops in the region.

The Rabi season starts from October onwards. The major rabi crops grown in the catchment are, wheat, gram, pulses, sugarcane, paddy and also maize. Wheat and gram are sown in non-irrigated fields in the middle of October. Sometimes, the sowing is continued till the first fortnight of November, Wheat and gram are ready for harvesting by March. The paddy crop in the basin is grown in both the seasons. The Kharif paddy cultivated between June and December is known as rabi crop in the region. Paddy is also sown between May and September by broadcasting the germinated seeds and is known as Khathera Paddy .

Besides the principal crops stated above, various other crops including fruits, vegetables, condiments etc. are grown in the region. Chillies, brinjals, tomatoes etc. are transplanted in the second fortnight of June or mostly in the first week of July.

3.6 Land Use Pattern

The areas under different land uses of six districts of Krishna basin, namely, Solapur, Ahmadnagar, Belgaum, Anantpur, Raichur and Jalgonda are given in the annexure-I.

3.7 Data & Study Sites

In order to carry out low flow analysis, twenty year daily flow data of few selected sites in Krishna basin have been analysed. The basin map showing the location of site and other details are shown in fig.3. The details of sites are given in table 1:

TABLE 1

DETAILS OF SITES CHOSEN FOR LOW FLOW STUDIES IN KRISHNA BASIN

| S.No. | Name of sites | District | State | Stream | Catchment area ($Km^2$) |
|---|---|---|---|---|---|
| 1. | Dhond | Poona | Maharashtra | Bhima | 11,660 |
| 2. | Narsinghpur | Solapur | -do- | Bhima | 22,856 |
| 3. | Yadgir | Gulburga | Karnataka | Bhima | 69,863 |
| 4. | Wadakbal | Sholapur | Maharashtra | Bhima | 12,092 |
| 5. | Haralahalli | Dharwar | Karnataka | Tungabhadra | 14,582 |
| 6. | Ṫ. Ramapuram | Bellary | Karnataka | Hagari | 23,500 |

The sites are chosen in such a way that it represent whole of the Krishna basin and should have virgin flow.

## 4.0 RESULT AND DISCUSSION

Low flow study has been carried out for the six sites of the Krishna basin namely, T. Ramapuram, Haralahalli, Wadakwal, Yadgir, Dhond and Narsingpur. The basin consists of parts of Maharashtra, Karnataka and Andhra Pradesh States. Description of catchment area is given in chapter-3 Chapter 2 deals with the definition of low flow, low concept and methods of low flow computation. The present chapter deals with the results of some statistical techniques described in chapter 2 for computation of low flow duration curves and flow frequency curves by utilizing 20 years stream flow data pertaining to all chosen sites of Krishna basin.

### 4.1 Flow Duration Curve

The flow duration curve technique is one of the simplest techniques among the available ones for analysing the stream flow drought. The flow duration curve shows graphical relationship between any given discharge and the percentage of time the discharge exceeded. The curves for all the chosen sites were drawn for 7,10,30,60 120 and 360 days period by using the method as given in section 2.4.1 and the resulting curves are shown in Figure-4 through Fig.-9.

In hydrologic studies, flow duration values of 90, 95 and 99% are used as measures of a stream's low flow potential. The 90% value is used as a measure of groundwater contribution to streamflow. The 10 days average

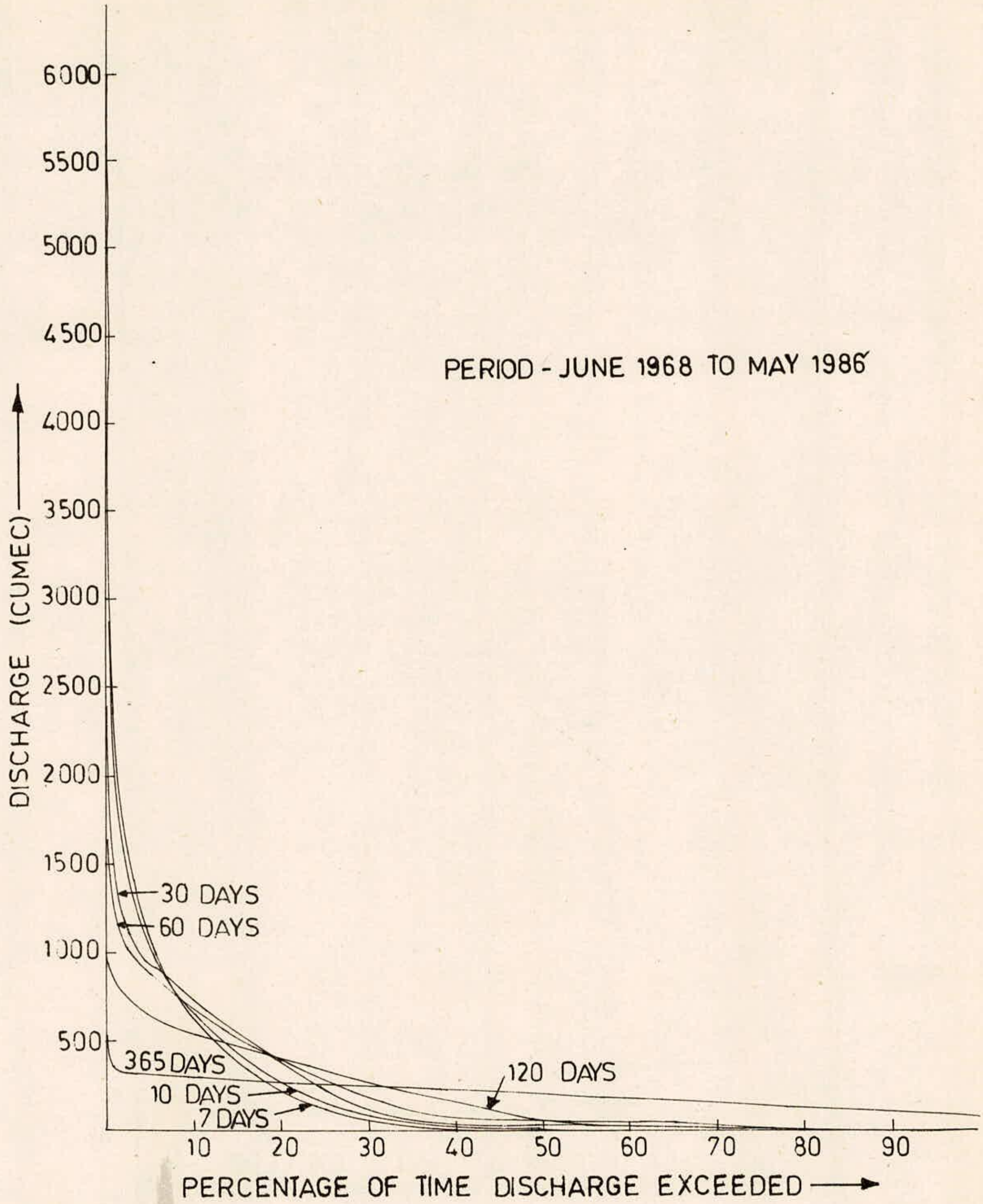


FIG. 4 - FLOW DURATION CURVE FOR BHIMA AT DHOND

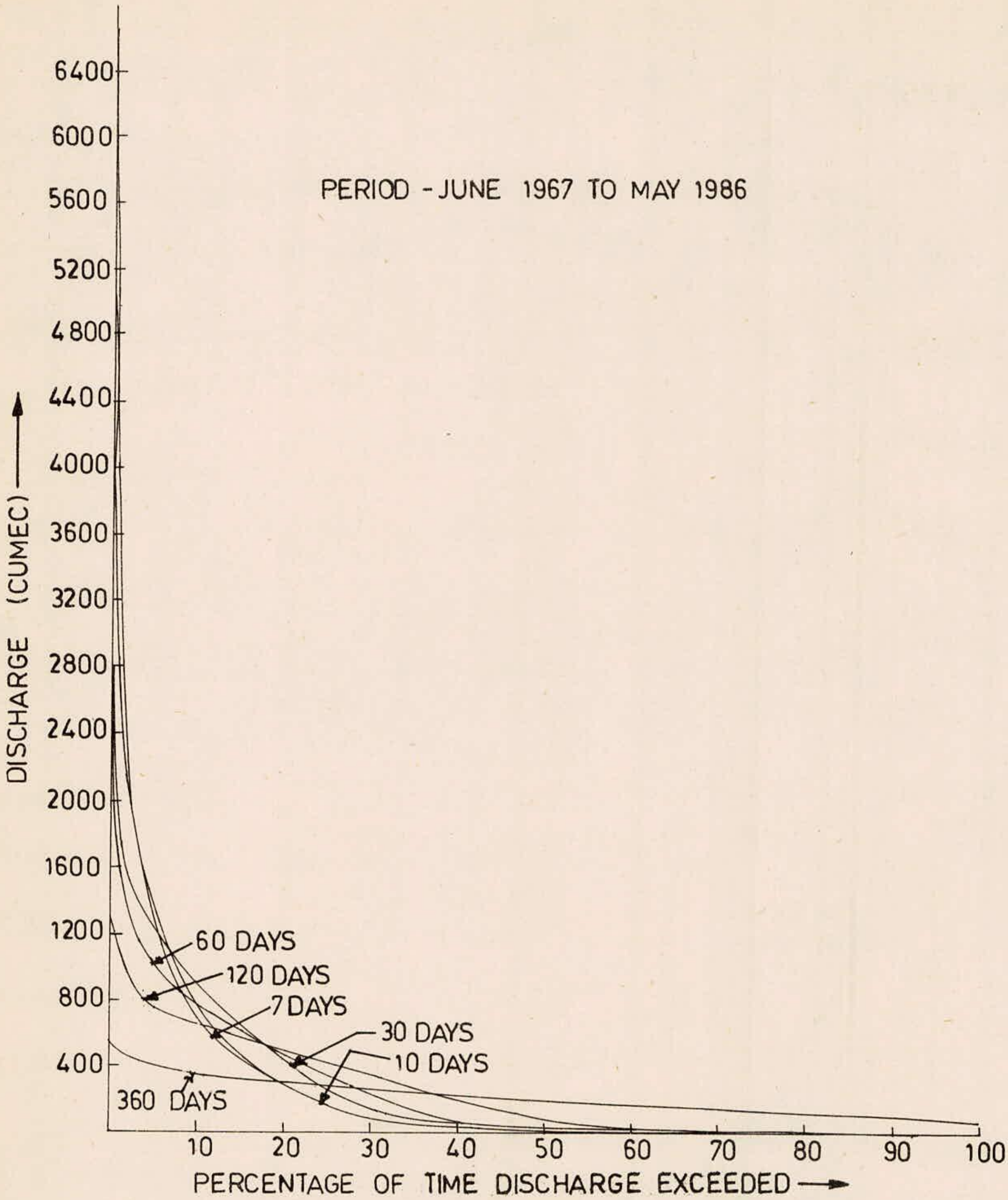


FIG. 5 - FLOW DURATION CURVE FOR BHIMA AT NARSINGPUR

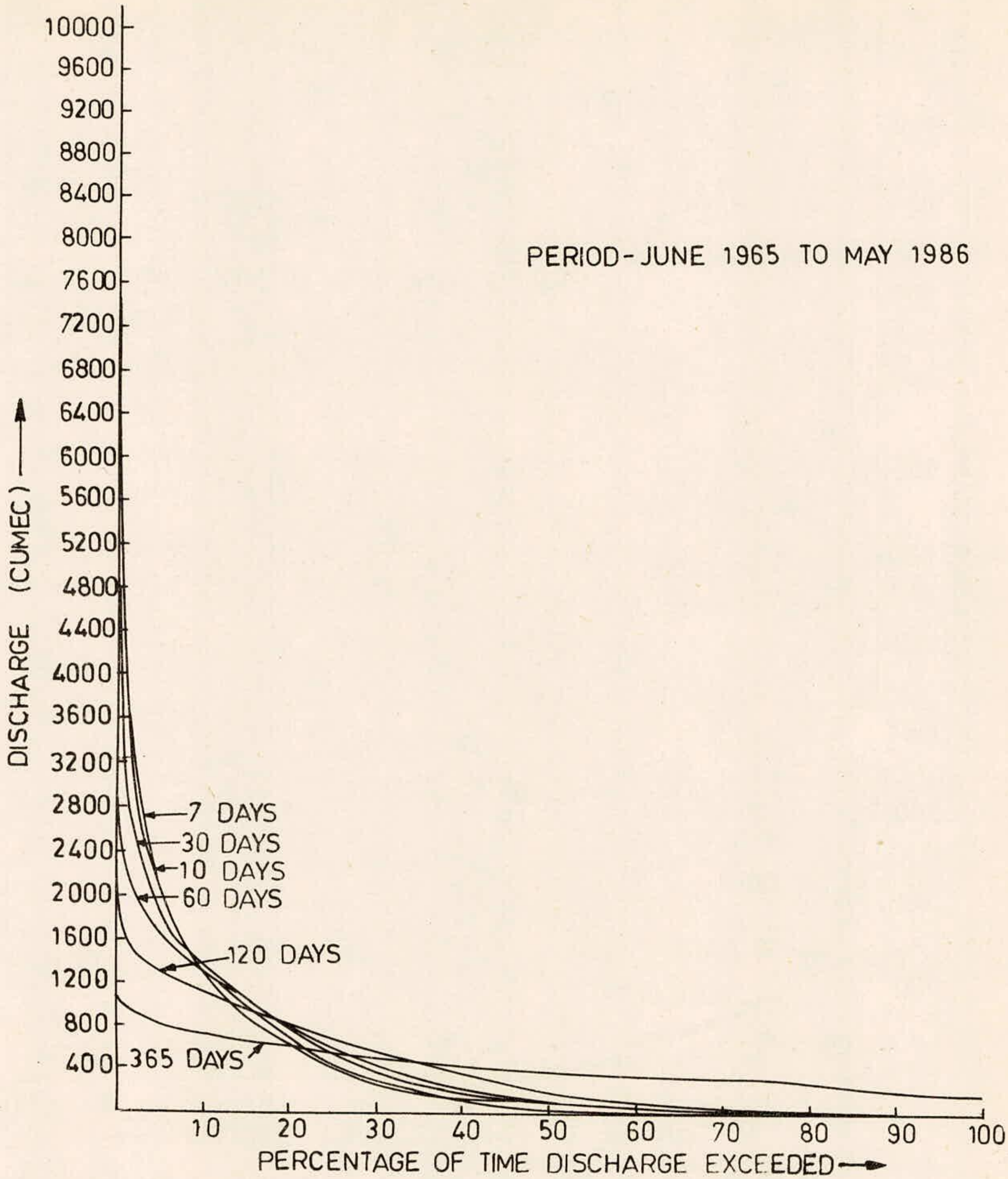


FIG.6-FLOW DURATION CURVE FOR BHIMA AT YADGIR

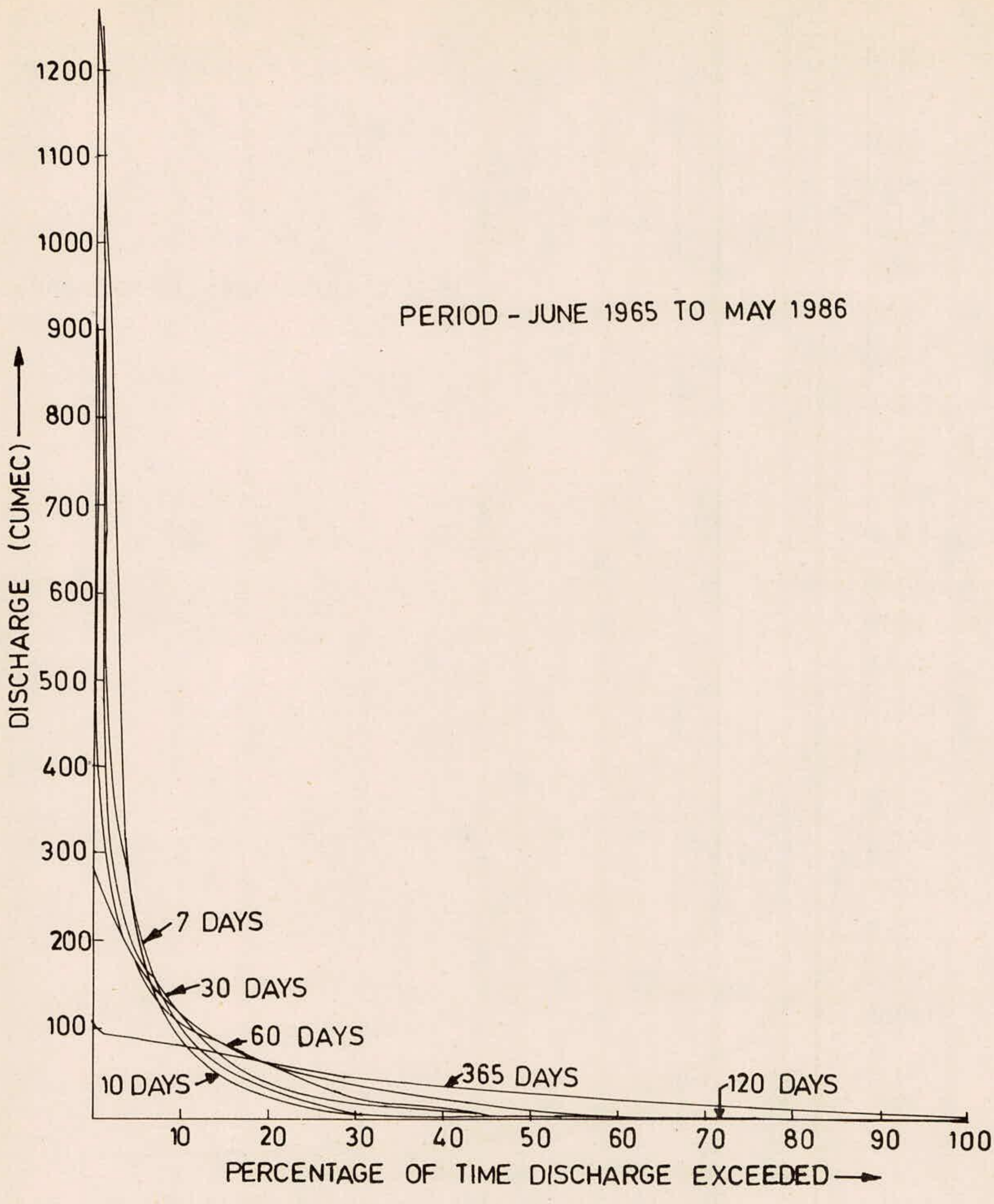


FIG. 7- FLOW DURATION CURVE FOR BHIMA AT WADAKBAL

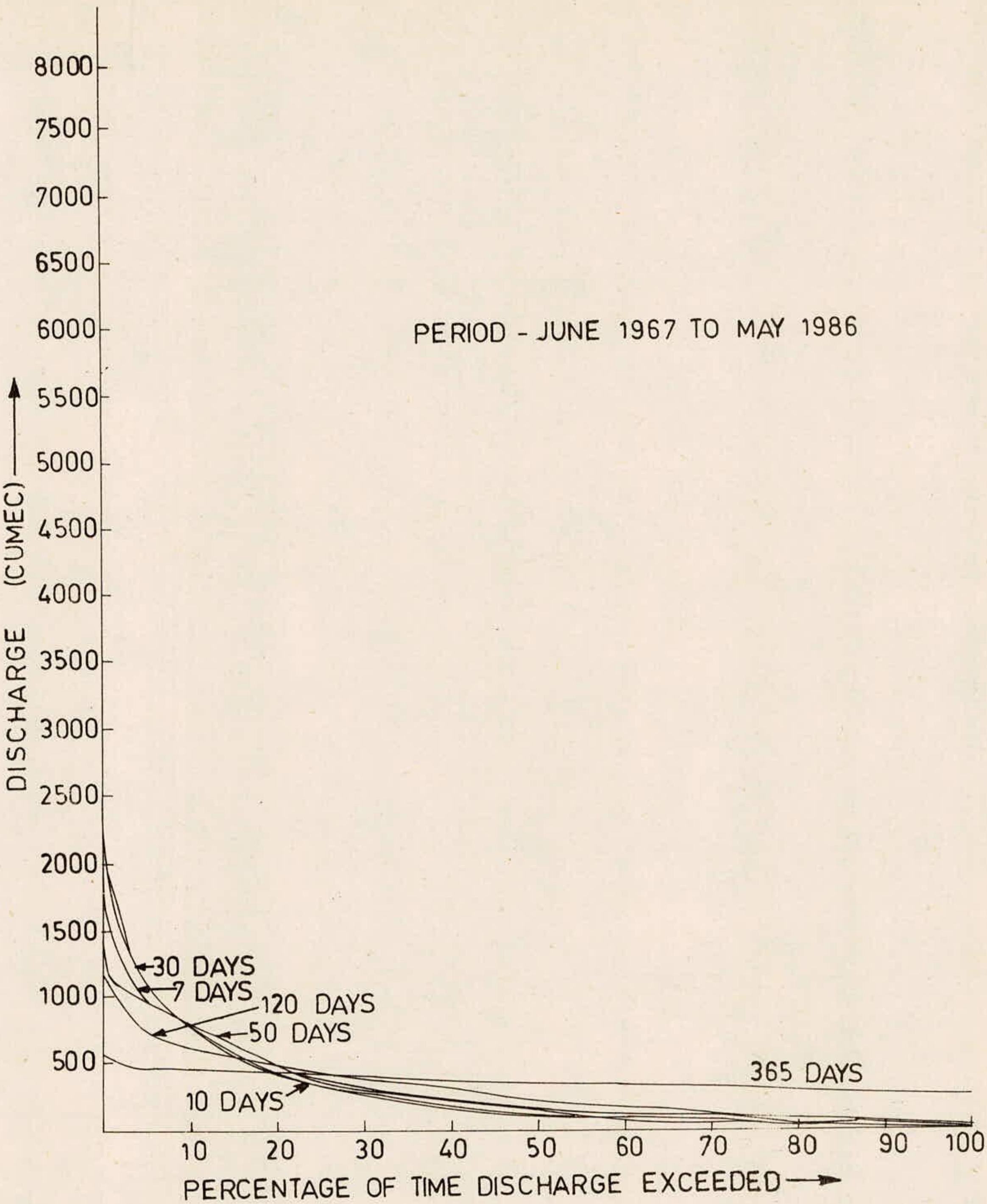


FIG. 8- FLOW DURATION CURVE FOR TUNGABHADRA AT HARALAHALLI

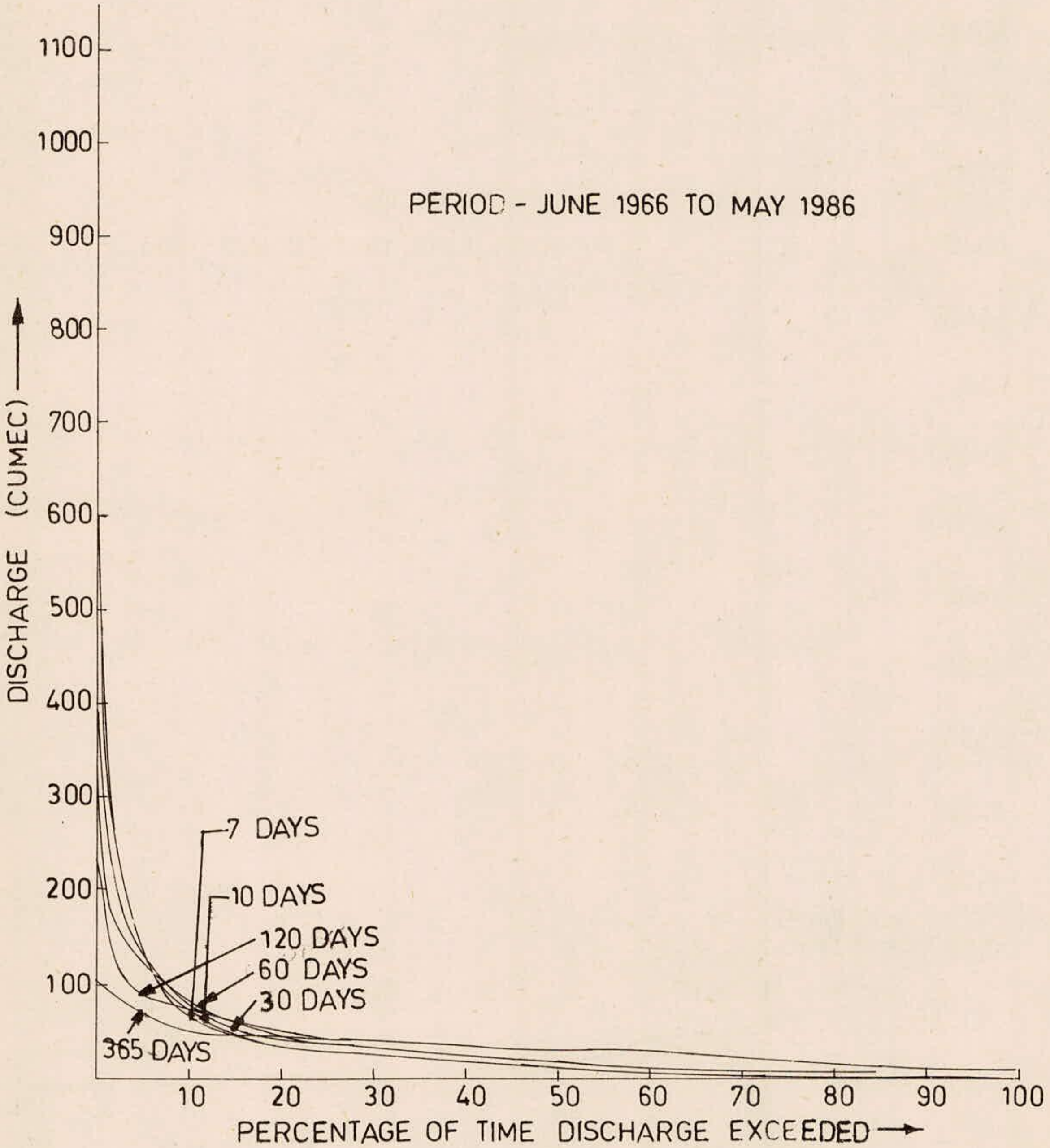


FIG. 9 - FLOW DURATION CURVE FOR HAGARI AT T.RAMAPURAM

flow when exceeded 95% of time of the duration of series called low flow index. The low flow index values were estimated from 10 days flow duration curves and given in Table 2:

TABLE 2

LOW FLOW INDEX FOR SELECTED SITES OF KRISHNA BASIN

| Sl.No. | Site | Period of Analysis (Year) | L.F.I. ($10^4 m^3/Km^2$) |
|---|---|---|---|
| 1. | Dhond | 1968-86 | 1.33 |
| 2. | Narsinghpur | 1967-86 | 1.264 |
| 3. | Yadgir | 1965-86 | 0.310 |
| 4. | Wadakwal | 1965-86 | 0.289 |
| 5. | Haralahalli | 1967-86 | 1.586 |
| 6. | T. Ramapuram | 1966-86 | 0.629 |

The low flow portion of the curve is an index of the amount of groundwater being contributed to stream-flow from natural catchment storage. If the slope of the curve in the low flow portion is flat, groundwater contributions are significant. On the other hand a steep curve indicates poor base flows and probable cease to flow conditions.

4.2 Flow Frequency Curve

The flow frequency curve shows the proportion of years or equivalently the average interval between years (return period), in which the river falls below a given discharge, while the flow duration curve is concerned with the proportion of time that a flow is exceeded. The flow frequency curve for all chosen site have been developed by using Institute of Hydrology, technique and shown in fig. 10 through Fig. 15. These curves can be used to estimate recurrence interval of any flow and can also be used to estimate the probability and return period of low flow condition. It is clear from Fig. 10 through Fig. 15 that the minimum flow has the largest return period.

## 4.3 Low Flow Spell

The low flow spell generally expressed in two ways namely, deficit volume of low flow spell and duration of low flow spell. Low flow duration is the total time for which the flows are smaller than a specified discharge ($q_1$) or stage ($h_o$) during a time unit period ($T_u$). If for a given $q_i$ or ($h_o$) and $T_u$ there are K times in which the flows fall below $q_o$ then the low flow duration is $D = d_1 + d_2 + \ldots + d_k$. The deficit volume is one of the low flow measures alongwith the deficit duration. The deficit duration is the same as the durations $d_1, d_2 \ldots d_k$ etc. While the deficit volume is the volume relative to some demand flow (threshold discharge) required at beginning of the drought to prevent flow from falling below the demand levels for the duration of the drought. The methodology for computation of frequency of spell durations and deficit volume is described in section 2.4.4 Frequency curves for max. deficit volume is shown in Fig. 16 through Fig. 21.

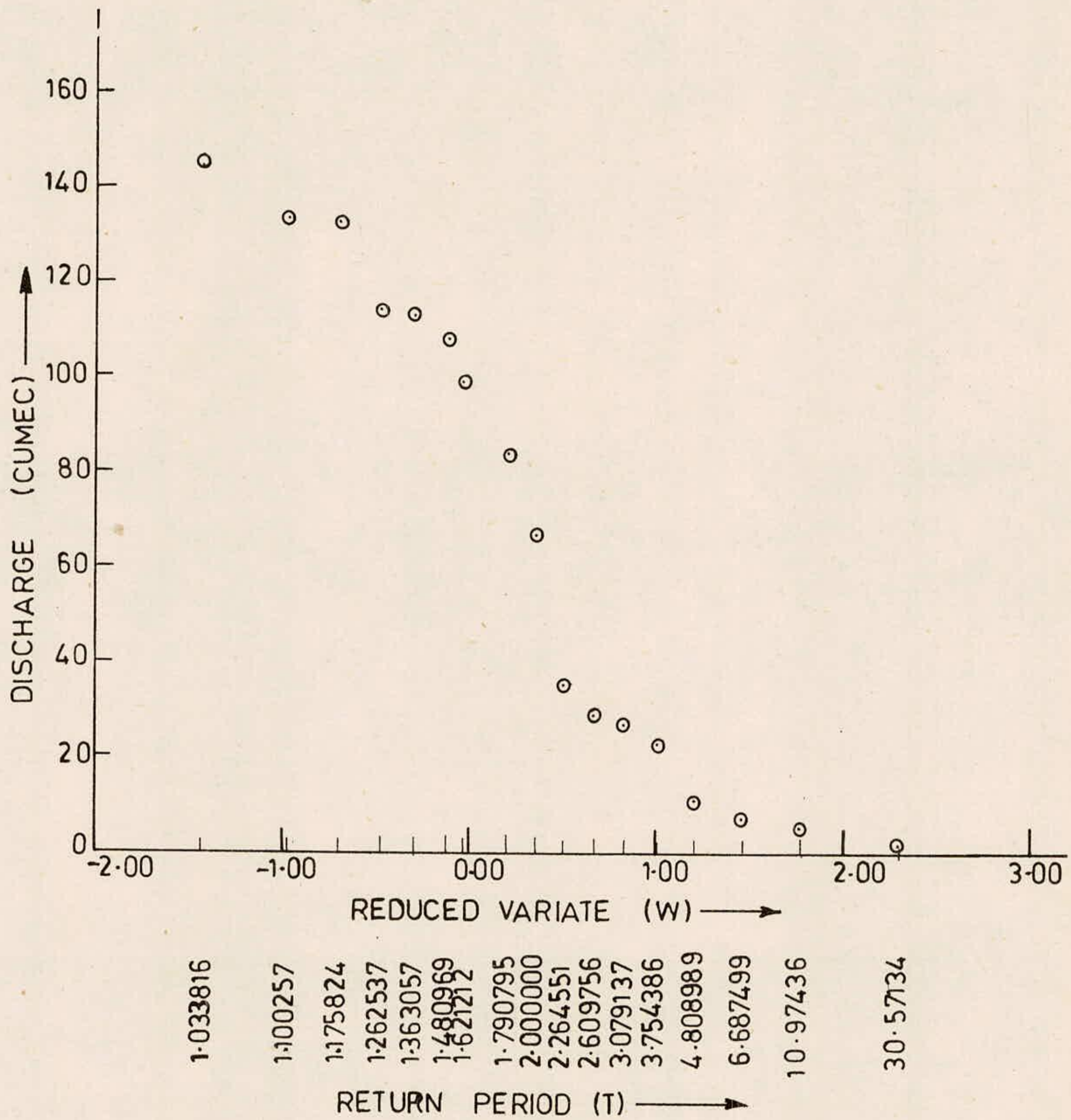


FIG.10- FLOW FREQUENCY CURVE FOR BHIMA AT DHOND

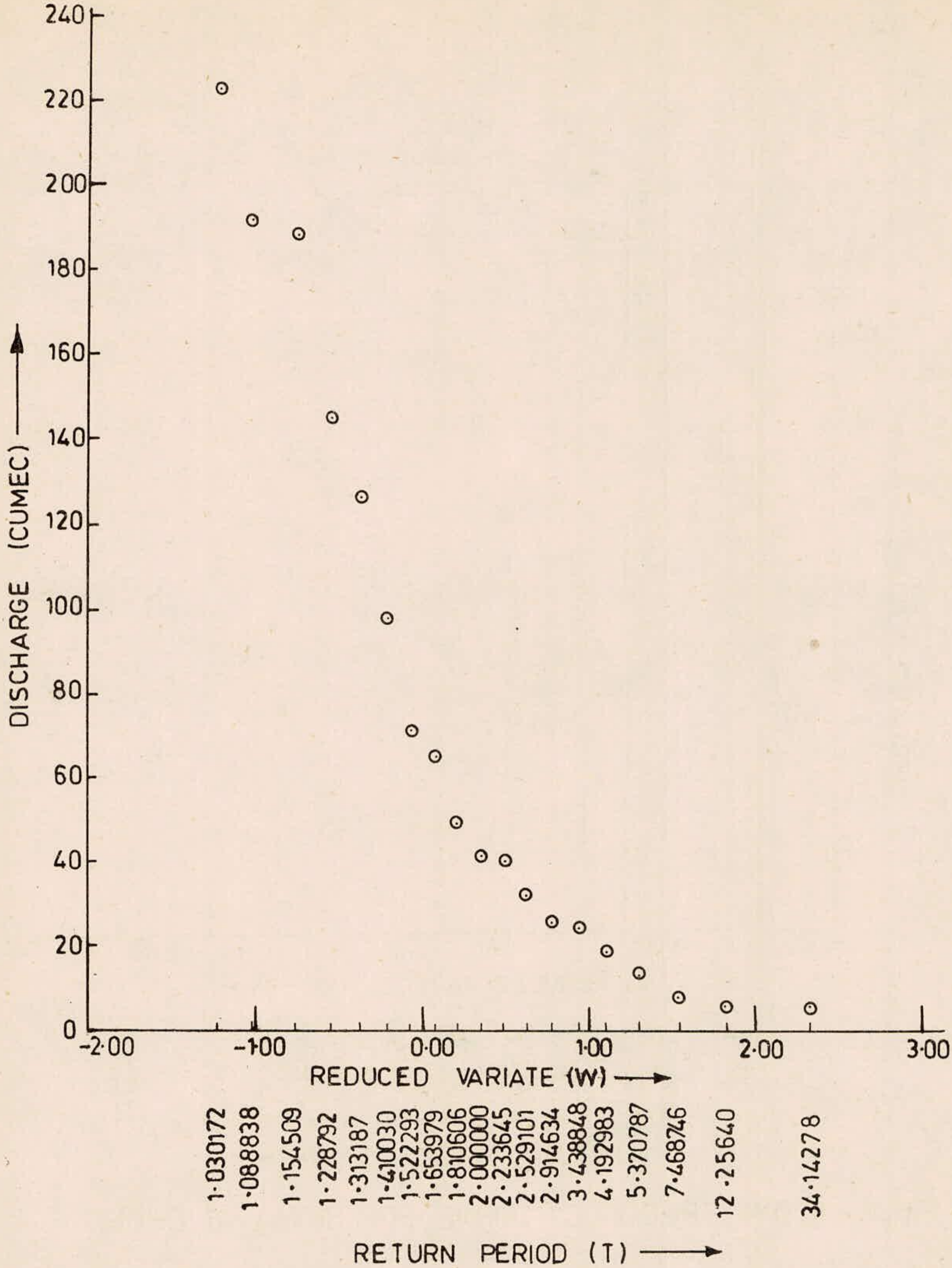


FIG. 11 - FLOW FREQUENCY CURVE FOR BHIMA AT NARSINGPUR

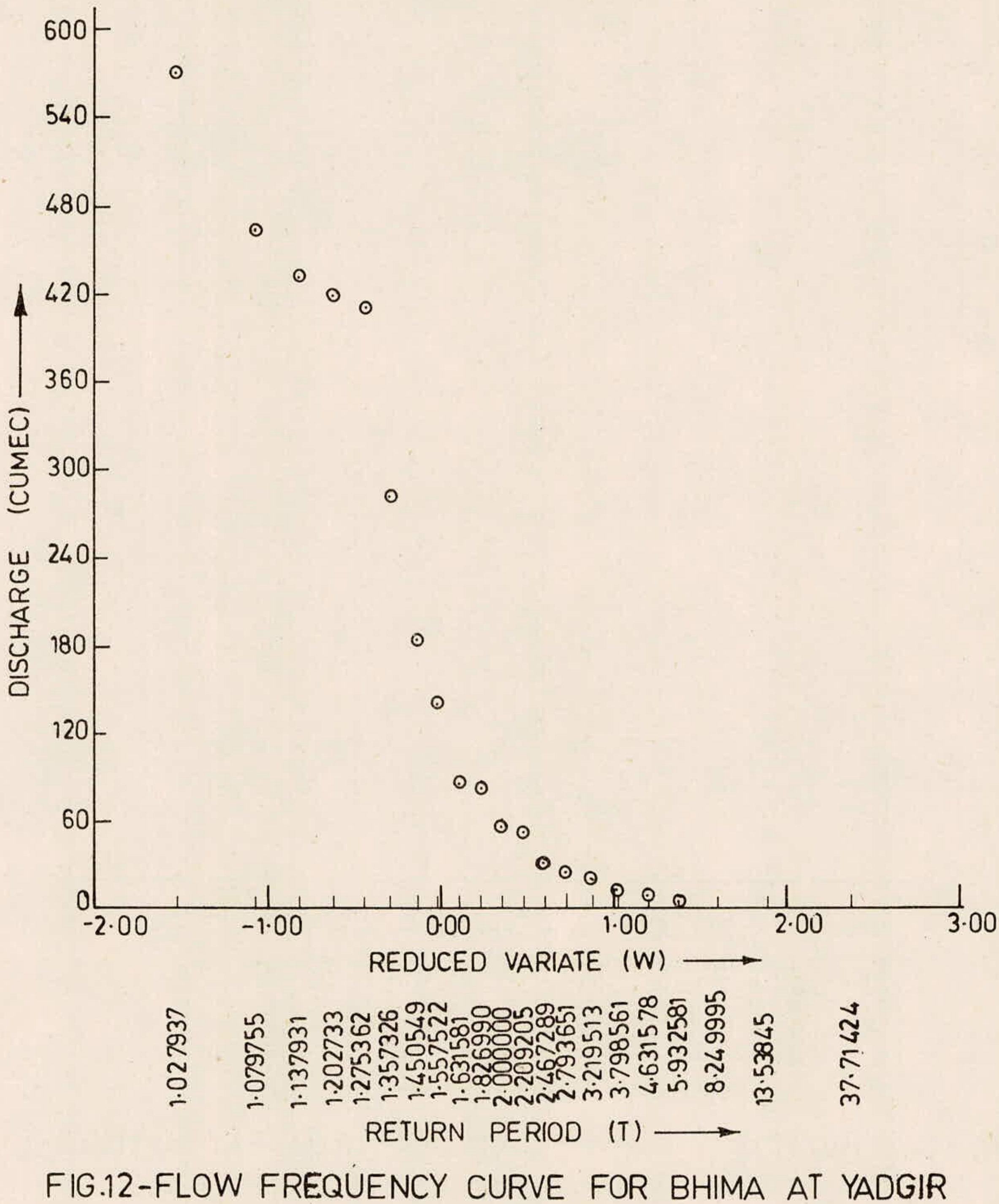


FIG.12-FLOW FREQUENCY CURVE FOR BHIMA AT YADGIR

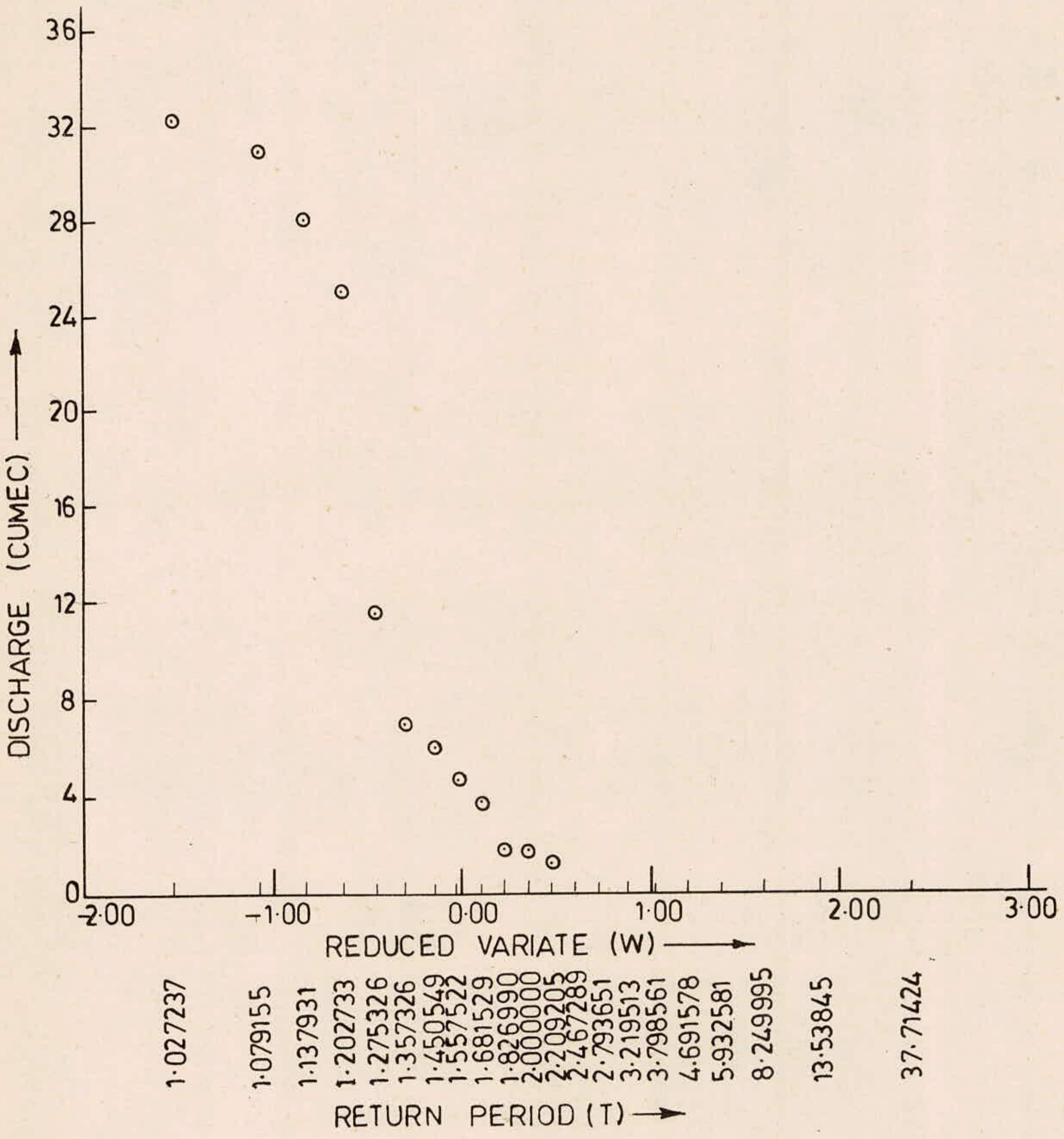


FIG. 13 - FLOW FREQUENCY CURVE FOR BHIMA AT WADAKBAL

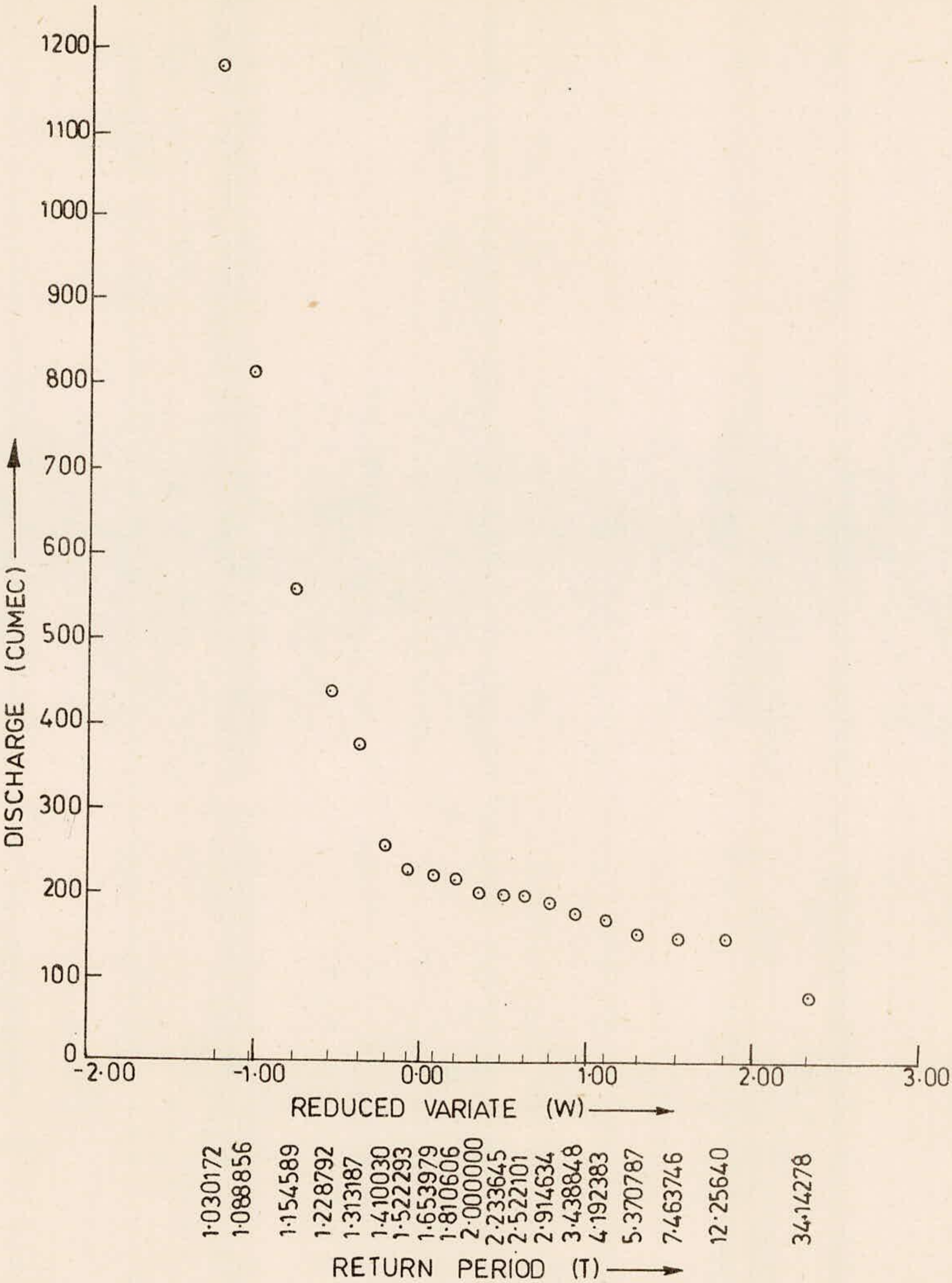


FIG.14 - FLOW FREQUENCY CURVE FOR TUNGABHADRA AT HARALAHALLI

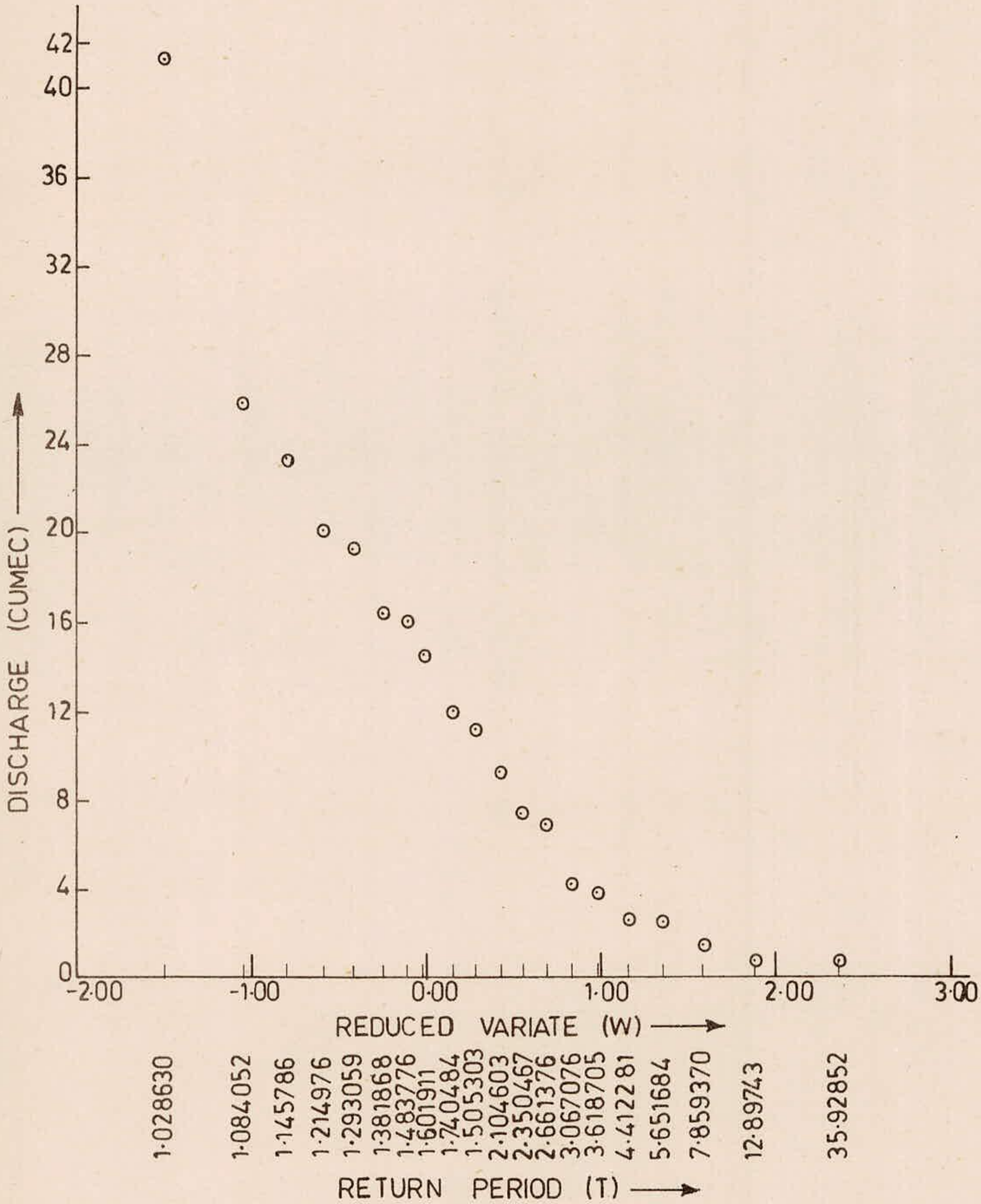


FIG. 15- FLOW FREQUENCY CURVE FOR HAGARI AT T.RAMAPURAM

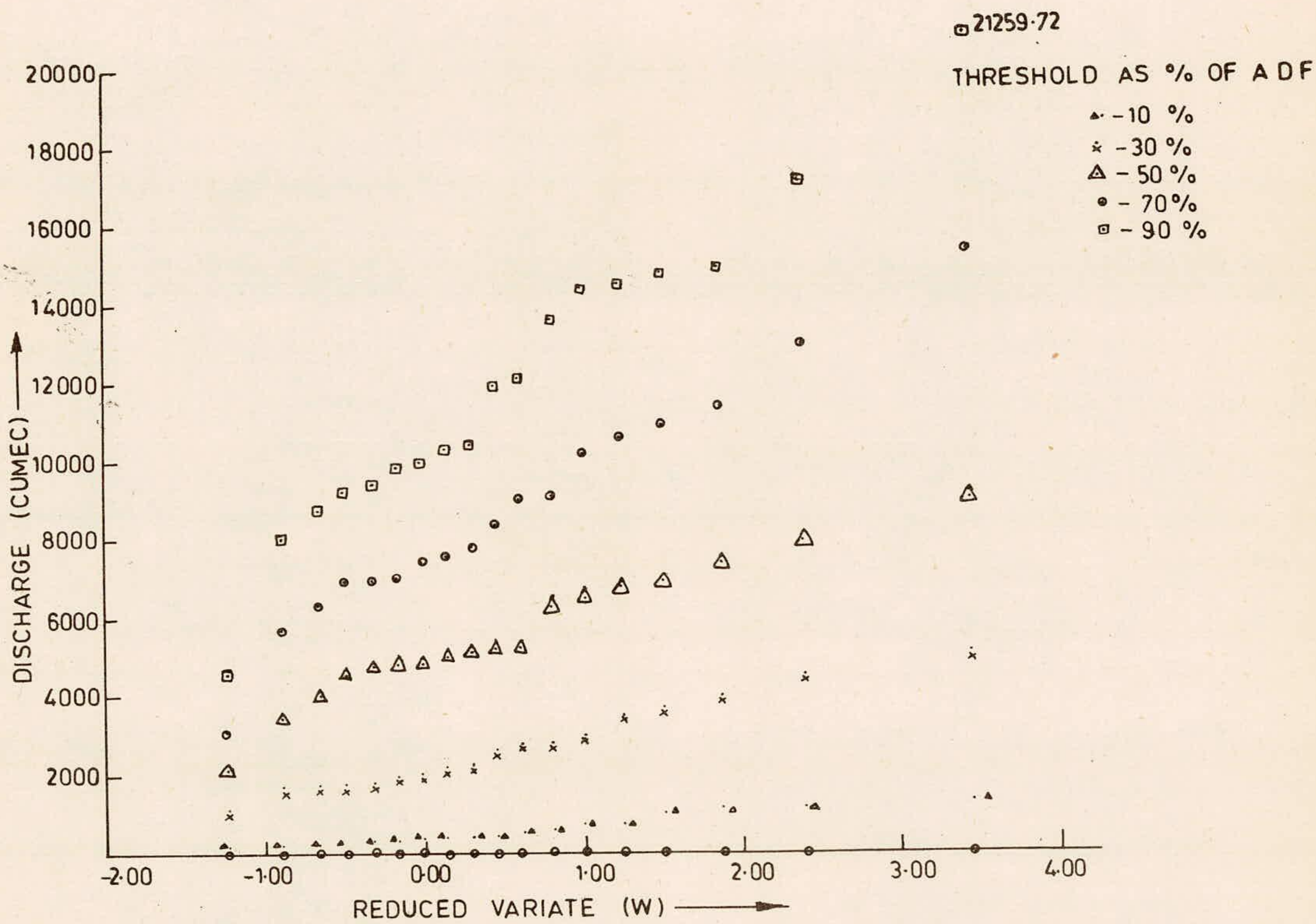

FIG. 16-FREQUENCY CURVES FOR MAXIMUM DEFICIT VOLUME FOR BHIMA AT DHOND

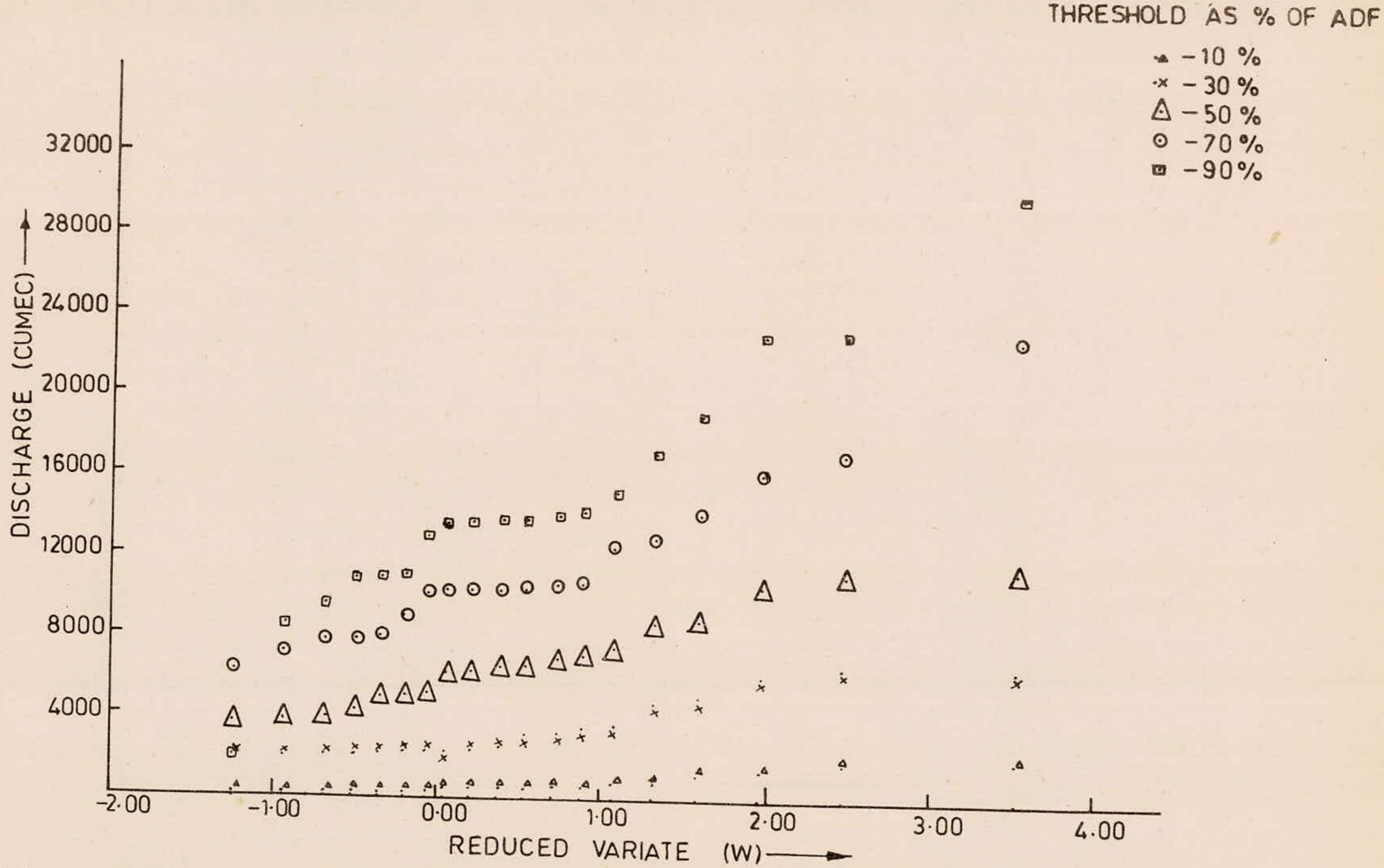


FIG. 17-FREQUENCY CURVES FOR MAXIMUM DEFICIT VOLUME FOR BHIMA AT NARSINGPUR

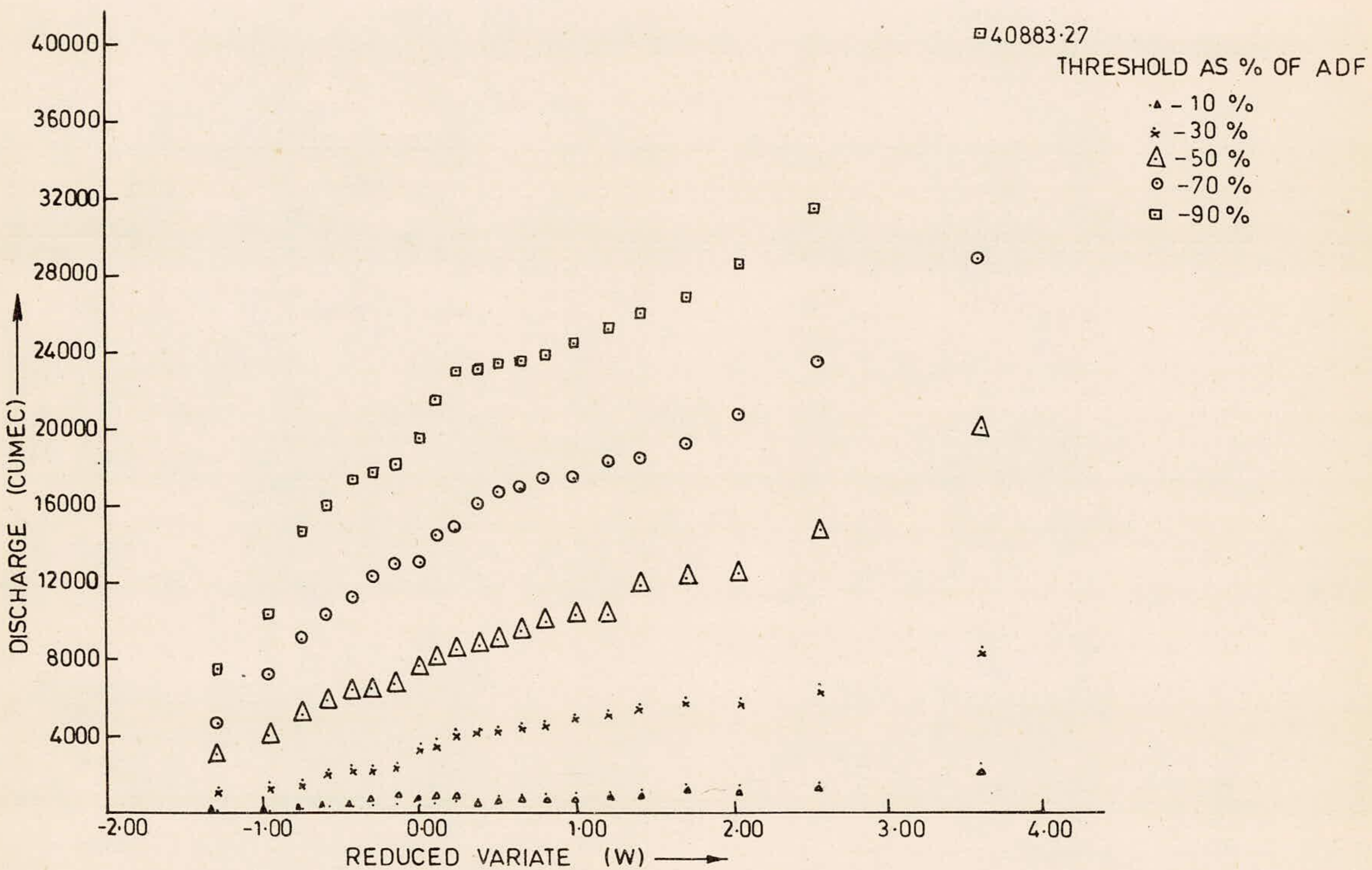


FIG. 18-FREQUENCY CURVES FOR MAXIMUM DEFICIT VOLUME FOR BHIMA AT YADGIR

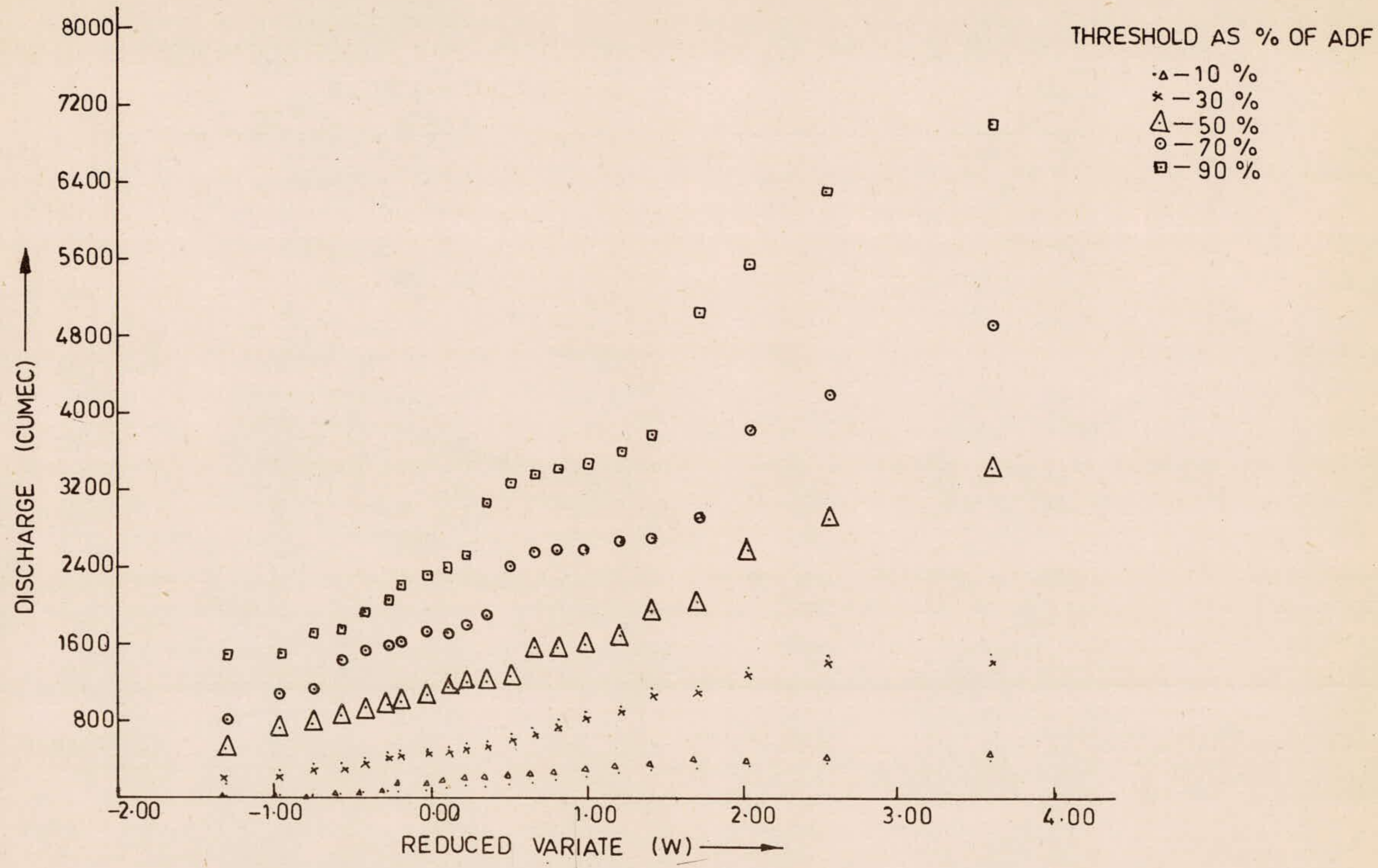


FIG. 19 - FREQUENCY CURVES FOR MAXIMUM DEFICIT VOLUME FOR BHIMA AT WADAKWAL

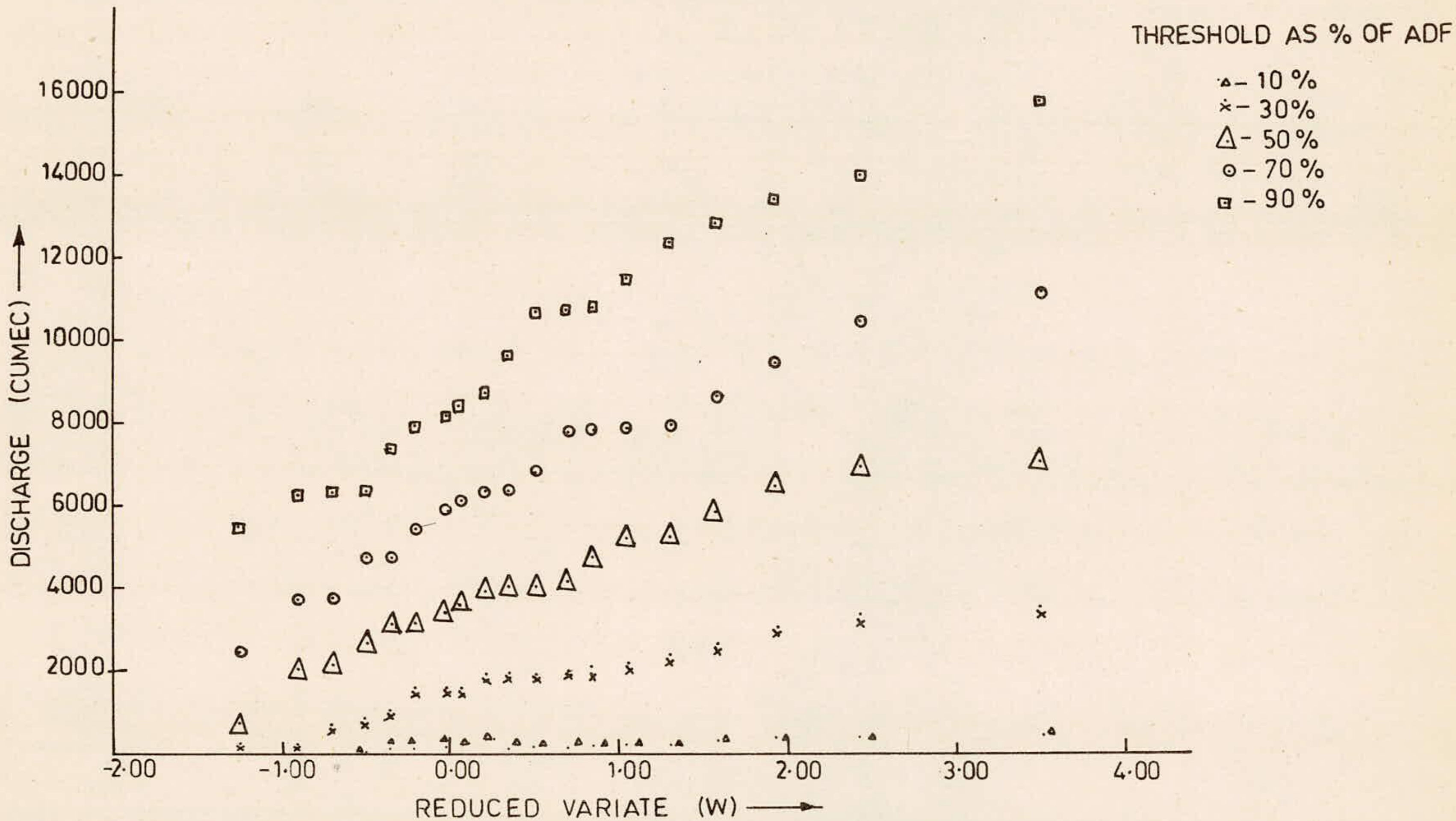


FIG. 20 - FREQUENCY CURVES FOR MAXIMUM DEFICIT VOLUME FOR TUNGABHADRA AT HARALAHALLI

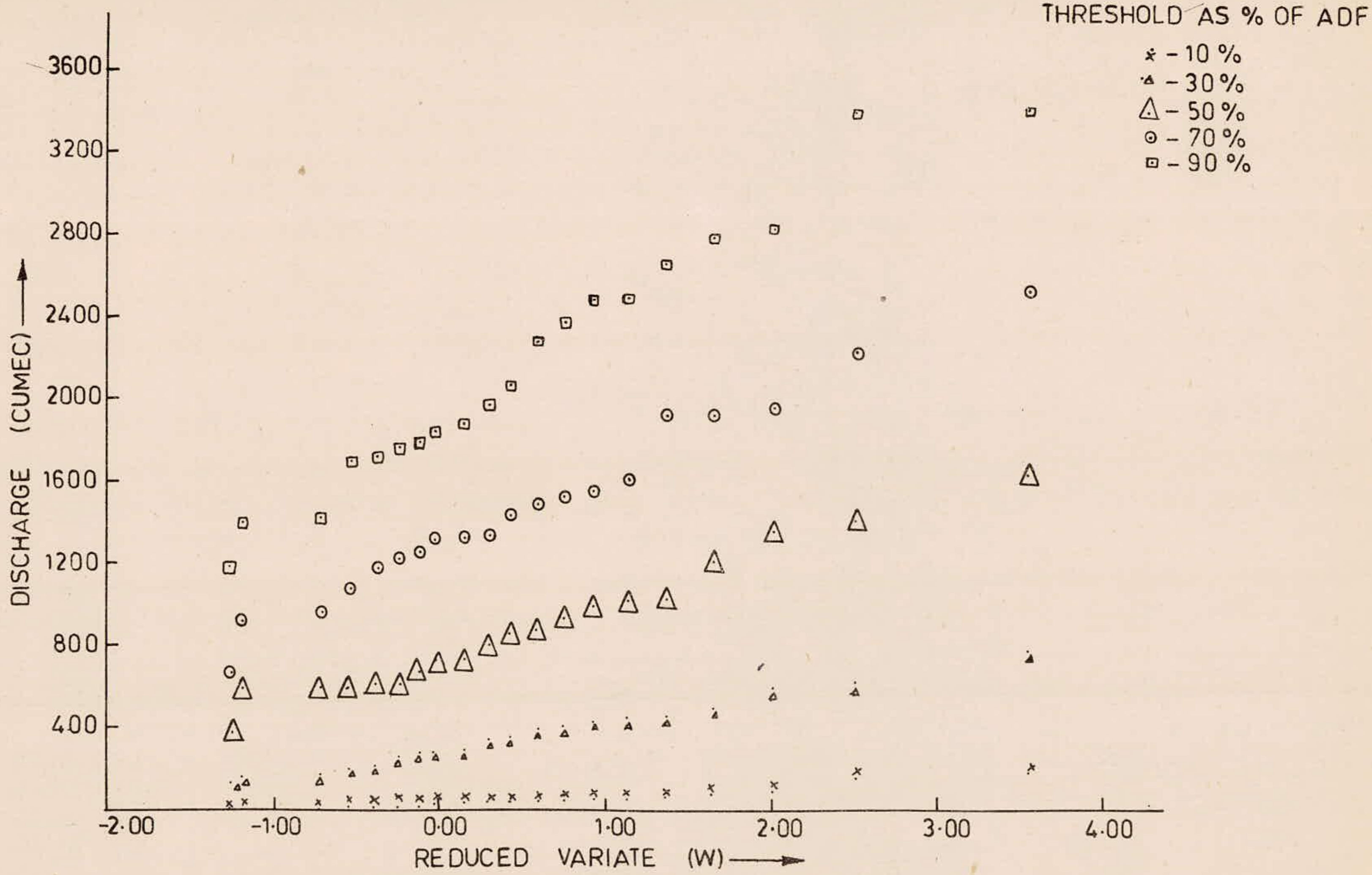


FIG. 21 – FREQUENCY CURVES FOR MAXIMUM DEFICIT VOLUME FOR HAGARI AT T. RAMAPURAM

In order to see the effect of monsoon, analysis have been performed using daily flow data of monsoon period (Ist June - 31st October) for different gauging sites namely, Dhond, Narsinghpur, Yadgir , Wadakbal, Haralhalli and T. Ramapuram. The average daily flow were computed using five months (June - October) daily flow data for the period of 20 years. Then the threshold discharge limit of 10%, 30%, 50%, 70% & 90% of average daily flow were considered. The maximum deficit volume and maximum deficit duration based on above methodology were computed at different threshold limit for all chosen sites. Table 3 through table 8 shows the maximum deficit volume and table 9 through table 14 shows the maximum deficit duration. It is observed from the table that during 1985-86, deficiency volume and deficit duration was maximum indicated that year as a severe drought year in comparison to previous years. Based on maximum deficit volume and maximum deficit duration drought intensity is estimated. This maximum during 1985-86 indicating that year as a drought year. The estimated drought intensity are given in Table 15 through 20.

TABLE 3: MAXIMUM DEFICIT VOLUME OF LOW FLOW SPELLS

Site: Dhond — Average daily flow : 379.5000 Cumecs

Base Period: Ist June to 31st October

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% | 7 day low Flow |
|---|---|---|---|---|---|---|
| | | | Volumes in Cumec days | | | |
| 1968 | 1176.72 | 4572.26 | 7988.57 | 11404.88 | 14821.19 | 0.00 |
| 1969 | 450.55 | 3004.98 | 5206.60 | 9054.22 | 12142.57 | 26.80 |
| 1970 | 427.80 | 2295.00 | 5263.33 | 7844.54 | 10425.75 | 66.80 |
| 1971 | 173.07 | 1144.30 | 2131.23 | 3118.16 | 4598.75 | 108.00 |
| 1972 | 1123.78 | 4025.28 | 7454.37 | 10972.41 | 14540.56 | 7.30 |
| 1973 | 614.12 | 3510.84 | 6319.81 | 9128.78 | 11937.74 | 22.80 |
| 1974 | 778.97 | 2805.67 | 4853.46 | 6970.67 | 10308.75 | 35.40 |
| 1975 | 133.00 | 1722.71 | 3496.37 | 5698.30 | 8051.76 | 144.60 |
| 1976 | 402.58 | 2148.42 | 4858.84 | 8041.78 | 13636.87 | 99.20 |
| 1977 | 338.20 | 1007.91 | 6850.05 | 10631.05 | 14426.95 | 114.60 |
| 1978 | 237.56 | 2208.28 | 4577.14 | 7006.51 | 9435.89 | 133.40 |
| 1979 | 522.45 | 2648.15 | 4773.86 | 6952.39 | 9229.93 | 112.80 |
| 1980 | 342.52 | 1997.34 | 3994.16 | 6333.51 | 8762.89 | 132.50 |
| 1981 | 206.53 | 1701.16 | 5131.84 | 7561.21 | 9990.59 | 84.10 |
| 1982 | 1077.34 | 5145.50 | 9093.23 | 13040.97 | 17153.40 | 28.80 |
| 1983 | 758.47 | 3770.47 | 6975.78 | 10225.65 | 14987.55 | 5.30 |
| 1984 | 286.07 | 1756.20 | 5025.64 | 7455.01 | 9884.39 | 10.70 |
| 1985 | 476.96 | 2837.93 | 6563.86 | 15407.40 | 21259.71 | 1.70 |

TABLE 4: MAXIMUM DEFICIT VOLUME OF LOW FLOW SPELLS

Site : Narsingpur

Base period : Ist June to 31st October

Average daily flow: 464.3876 Cumec

| Threshold Limit % ADF / Period | 10% | 30% | 50% | 70% | 90% | 7 day low flow |
|---|---|---|---|---|---|---|
| | | | Volume in Cumec days | | | |
| 1967 | 615.52 | 2157.49 | 7495.87 | 14102.98 | 19025.48 | 25.50 |
| 1968 | 360.84 | 1963.49 | 4395.23 | 9017.19 | 12921.40 | 18.70 |
| 1969 | 559.24 | 3242.08 | 6503.15 | 10125.38 | 13747.60 | 13.00 |
| 1970 | 237.32 | 3533.58 | 6877.17 | 10220.76 | 13564.35 | 145.10 |
| 1971 | 270.34 | 1953.40 | 3718.08 | 7152.45 | 9567.26 | 89.40 |
| 1972 | 1429.85 | 4739.26 | 8805.42 | 12921.71 | 17101.10 | 7.90 |
| 1973 | 580.47 | 3206.87 | 6230.00 | 10314.91 | 13844.25 | 24.30 |
| 1974 | 947.94 | 3615.67 | 7075.67 | 10410.26 | 13762.85 | 32.29 |
| 1975 | 274.82 | 2369.29 | 4928.02 | 7896.98 | 10933.11 | 188.40 |
| 1976 | 296.05 | 2287.20 | 6182.62 | 10636.03 | 15185.84 | 192.00 |
| 1977 | 538.97 | 2118.60 | 3883.27 | 10606.03 | 14042.50 | 40.30 |
| 1978 | 136.02 | 2538.50 | 6522.54 | 10330.52 | 14197.05 | 223.30 |
| 1979 | 1245.85 | 6524.56 | 11447.07 | 17142.79 | 23016.52 | 49.20 |
| 1980 | 538.28 | 2275.29 | 5059.61 | 7845.94 | 10986.06 | 71.40 |
| 1981 | 260.44 | 2273.40 | 5168.41 | 7982.71 | 10914.51 | 126.70 |
| 1982 | 1996.80 | 6547.79 | 11098.79 | 16108.01 | 23082.83 | 5.70 |
| 1983 | 826.39 | 5009.05 | 8724.15 | 12454.32 | 20230.93 | 41.30 |
| 1984 | 543.55 | 2122.47 | 3966.24 | 6288.18 | 8610.12 | 64.90 |
| 1985 | 1844.09 | 6167.46 | 10532.70 | 22960.35 | 30003.71 | 5.70 |

TABLE 5 : MAXIMUM DEFICIT VOLUME OF LOW FLOW SPELLS

Site : Yadgir
Base Period: Ist June to 31st Oct.

Average daily flow (ADF): 760.1973 Cumec

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% | 7 day low flow |
|---|---|---|---|---|---|---|
| | | | Volume in Cumec days | | | |
| 1965 | 814.85 | 4722.71 | 11839.34 | 18529.07 | 25218.81 | 57.00 |
| 1966 | 998.47 | 4420.02 | 9717.64 | 16011.13 | 28657.09 | 52.50 |
| 1967 | 1215.42 | 3800.10 | 6384.77 | 19377.87 | 26067.61 | 0.00 |
| 1968 | 995.14 | 4817.02 | 9930.12 | 17416.77 | 23802.43 | 12.00 |
| 1969 | 431.67 | 4342.59 | 8534.66 | 13070.28 | 17783.50 | 140.10 |
| 1970 | 67.43 | 4557.69 | 10278.94 | 16733.76 | 22967.38 | 468.70 |
| 1971 | 164.11 | 1368.23 | 4070.87 | 7194.86 | 10382.42 | 392.60 |
| 1972 | 2558.08 | 8639.66 | 14721.24 | 20802.82 | 26884.40 | 0.00 |
| 1973 | 336.21 | 5645.27 | 10206.45 | 14817.58 | 19530.81 | 0.00 |
| 1974 | 64.85 | 1606.12 | 6724.95 | 11286.14 | 23466.04 | 571.30 |
| 1975 | 369.31 | 3616.09 | 7994.14 | 16907.37 | 23597.11 | 430.80 |
| 1976 | 754.29 | 2571.12 | 7674.14 | 14466.85 | 21502.04 | 3.50 |
| 1977 | 577.35 | 2567.78 | 5111.87 | 8062.16 | 17378.54 | 19.68 |
| 1978 | 112.97 | 2304.92 | 5941.66 | 10270.00 | 14679.15 | 420.40 |
| 1979 | 1439.31 | 6707.73 | 20119.02 | 28937.31 | 40883.27 | 25.30 |
| 1980 | 438.31 | 2660.28 | 6503.56 | 12949.69 | 18119.03 | 281.70 |
| 1981 | 504.15 | 1720.47 | 2936.78 | 4687.68 | 7489.97 | 82.20 |
| 1982 | 1069.39 | 6059.04 | 12237.54 | 18319.11 | 24424.88 | 184.20 |
| 1983 | 1448.47 | 5097.43 | 8746.36 | 12395.31 | 16044.26 | 7.30 |
| 1984 | 1608.47 | 5257.42 | 9038.56 | 17372.64 | 23150.14 | 30.30 |
| 1985 | 844.79 | 6083.98 | 12469.74 | 23624.17 | 31930.23 | 86.70 |

TABLE 6 : MAXIMUM DEFICIT VOLUME OF LOW FLOW SPELLS

Site: Wadakbal
Base Period: Ist June to 31st Oct.

Average daily flow (ADF)=73.16883 Cumec

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% | 7 day low flow |
|---|---|---|---|---|---|---|
| | | | Volume in Cumec days | | | |
| 1965 | 52.78 | 514.27 | 1060.40 | 1623.33 | 2203.67 | 25.10 |
| 1966 | 119.65 | 502.47 | 1143.09 | 1727.72 | 2313.07 | 3.80 |
| 1967 | 116.27 | 412.81 | 775.31 | 1141.15 | 1519.55 | 0.00 |
| 1968 | 100.50 | 591.77 | 1275.03 | 1904.28 | 2533.53 | 1.25 |
| 1969 | 67.46 | 294.71 | 1001.03 | 1527.85 | 2054.67 | 11.55 |
| 1970 | 20.50 | 135.15 | 509.87 | 817.18 | 1714.91 | 31.00 |
| 1971 | 347.44 | 1188.13 | 2048.18 | 2911.57 | 3774.96 | 1.90 |
| 1972 | 358.99 | 1490.00 | 3416.60 | 4865.53 | 6314.09 | 6.00 |
| 1973 | 77.48 | 370.91 | 715.52 | 1076.45 | 1494.80 | 7.00 |
| 1974 | 75.53 | 469.92 | 939.58 | 1436.51 | 1946.61 | 4.70 |
| 1975 | 74.78 | 668.52 | 1195.33 | 1722.15 | 3067.90 | 1.80 |
| 1976 | 163.98 | 910.03 | 1689.25 | 2565.95 | 3415.46 | 0.00 |
| 1977 | 144.02 | 534.06 | 1196.56 | 1796.54 | 2396.53 | 0.00 |
| 1978 | 18.91 | 371.82 | 860.90 | 2661.10 | 3626.92 | 32.30 |
| 1979 | 297.79 | 1142.13 | 1932.35 | 2722.58 | 3512.80 | 0.00 |
| 1980 | 27.68 | 737.78 | 1567.29 | 2423.07 | 3286.46 | 28.10 |
| 1981 | 222.79 | 1417.89 | 2581.90 | 3822.99 | 5022.96 | 0.00 |
| 1982 | 392.49 | 1370.94 | 2908.43 | 4196.20 | 7026.57 | 0.00 |
| 1983 | 190.25 | 585.36 | 980.47 | 1575.59 | 1770.70 | 0.00 |
| 1984 | 321.94 | 965.82 | 1609.71 | 2578.61 | 3364.15 | 0.00 |
| 1985 | 257.05 | 827.77 | 1582.88 | 2573.50 | 5554.37 | 0.00 |

TABLE 7 : MAXIMUM DEFICIT VOLUME OF LOW FLOW SPELLS

Site: Haralahalli
Base Period : Ist June to 31st Oct.

Average daily flow(ADF):491.7371 Cumecs

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% | 7 day low flow |
|---|---|---|---|---|---|---|
| | | | Volume in Cumec days | | | |
| 1967 | 394.95 | 3519.53 | 6469.95 | 9420.37 | 12383.36 | 147.40 |
| 1968 | 126.61 | 1941.48 | 4203.47 | 6799.90 | 10637.85 | 217.80 |
| 1969 | 150.66 | 2397.28 | 4739.74 | 7843.27 | 10793.70 | 204.00 |
| 1970 | 0.00 | 722.49 | 2168.22 | 3752.57 | 5470.94 | 558.10 |
| 1971 | 0.00 | 259.50 | 751.24 | 2481.97 | 7386.61 | 1179.30 |
| 1972 | 381.87 | 3092.49 | 5846.22 | 8619.16 | 11471.23 | 177.50 |
| 1973 | 101.29 | 1094.57 | 2712.25 | 7700.74 | 13380.47 | 441.20 |
| 1974 | 207.01 | 2284.46 | 6924.96 | 10465.47 | 14005.48 | 191.70 |
| 1975 | 119.49 | 1998.14 | 4063.44 | 6128.73 | 8194.03 | 226.00 |
| 1976 | 180.29 | 2075.80 | 7044.81 | 11138.97 | 15765.16 | 172.40 |
| 1977 | 346.00 | 2213.80 | 4082.40 | 6347.76 | 8700.02 | 115.00 |
| 1978 | 183.63 | 1607.63 | 3181.19 | 4754.75 | 6328.31 | 199.50 |
| 1979 | 216.43 | 2689.44 | 5246.48 | 7803.51 | 12715.77 | 149.80 |
| 1980 | 0.00 | 241.20 | 2006.53 | 3776.78 | 6250.44 | 812.50 |
| 1981 | 14.34 | 810.03 | 3468.07 | 5435.02 | 7938.94 | 375.20 |
| 1982 | 160.89 | 1615.13 | 3664.44 | 6368.99 | 9601.75 | 201.70 |
| 1983 | 439.00 | 1914.21 | 5215.55 | 7961.14 | 10777.43 | 82.50 |
| 1984 | 112.89 | 1602.13 | 3175.69 | 4749.25 | 6322.81 | 257.90 |
| 1985 | 124.99 | 1946.30 | 3898.27 | 5865.21 | 8417.07 | 222.40 |

TABLE 8: MAXIMUM DEFICIT VOLUME OF LOW FLOW SPELLS

Site: T. Ramapuram
Base Period: Ist June to 31st October

Average daily flow(ADF)= 49.14037 Cumec

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% | 7 day low flow |
|---|---|---|---|---|---|---|
| | Volume in Cumec days | | | | | |
| 1966 | 49.95 | 297.39 | 625.09 | 959.24 | 1403.88 | 1.40 |
| 1967 | 43.81 | 209.01 | 942.35 | 1608.59 | 2278.50 | 11.10 |
| 1968 | 37.00 | 445.31 | 881.06 | 1323.33 | 3376.56 | 19.30 |
| 1969 | 12.28 | 184.64 | 669.35 | 1184.61 | 1705.51 | 25.90 |
| 1970 | 12.41 | 163.31 | 593.63 | 1219.62 | 2489.14 | 22.50 |
| 1971 | 22.94 | 463.35 | 1413.66 | 2219.57 | 3025.48 | 16.40 |
| 1972 | 22.48 | 265.25 | 603.76 | 1915.98 | 2654.82 | 16.10 |
| 1973 | 4.81 | 139.64 | 384.89 | 658.53 | 1185.25 | 41.40 |
| 1974 | 25.04 | 424.93 | 860.83 | 1312.93 | 1765.02 | 14.60 |
| 1975 | 32.73 | 362.70 | 1028.02 | 1548.91 | 2069.81 | 20.10 |
| 1976 | 45.04 | 225.59 | 728.01 | 1339.31 | 1879.85 | 2.60 |
| 1977 | 13.34 | 290.20 | 602.95 | 918.65 | 1720.91 | 23.30 |
| 1978 | 49.53 | 399.57 | 738.56 | 1082.54 | 1426.53 | 6.90 |
| 1979 | 61.99 | 617.07 | 1635.03 | 2519.56 | 3404.09 | 4.20 |
| 1980 | 91.02 | 459.27 | 1212.37 | 1949.48 | 2780.22 | 7.40 |
| 1981 | 37.52 | 289.78 | 810.56 | 1252.83 | 1789.13 | 12.00 |
| 1982 | 85.38 | 352.18 | 627.38 | 1519.58 | 2376.34 | 3.90 |
| 1983 | 67.06 | 510.98 | 991.14 | 1479.12 | 1970.53 | 9.30 |
| 1984 | 191.69 | 604.47 | 1017.25 | 1430.03 | 1842.81 | 0.70 |
| 1985 | 160.77 | 785.56 | 1348.78 | 1918.81 | 2488.84 | 0.70 |

TABLE 9: MAXIMUM DURATION OF LOW FLOW SPELLS

Site: Dhond
Base period: Ist June to
31st October.

Average daily flow 379.5900 Cumec

| Threshold Limit %ADF period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| 1968 | 31.00 | 45.00 | 45.00 | 45.00 | 45.00 |
| 1969 | 23.00 | 29.00 | 29.00 | 40.00 | 41.00 |
| 1970 | 17.00 | 26.00 | 34.00 | 34.00 | 34.00 |
| 1971 | 8.00 | 13.00 | 13.00 | 15.00 | 18.00 |
| 1972 | 37.00 | 40.00 | 46.00 | 47.00 | 47.00 |
| 1973 | 19.00 | 37.00 | 37.00 | 37.00 | 37.00 |
| 1974 | 25.00 | 27.00 | 27.00 | 29.00 | 34.00 |
| 1975 | 12.00 | 21.00 | 26.00 | 31.00 | 31.00 |
| 1976 | 20.00 | 25.00 | 32.00 | 37.00 | 54.00 |
| 1977 | 17.00 | 25.00 | 49.00 | 50.00 | 50.00 |
| 1978 | 13.00 | 31.00 | 32.00 | 32.00 | 32.00 |
| 1979 | 28.00 | 28.00 | 28.00 | 30.00 | 32.00 |
| 1980 | 19.00 | 24.00 | 28.00 | 32.00 | 32.00 |
| 1981 | 9.00 | 19.00 | 32.00 | 35.00 | 38.00 |
| 1982 | 38.00 | 52.00 | 52.00 | 52.00 | 55.00 |
| 1983 | 25.00 | 40.00 | 42.00 | 43.00 | 50.00 |
| 1984 | 8.00 | 17.00 | 32.00 | 32.00 | 32.00 |
| 1985 | 18.00 | 29.00 | 48.00 | 77.00 | 78.00 |

TABLE 10: MAXIMUM DURATION OF LOW FLOW SPELLS

Site: Narsingpur
Base Period: Ist June to 31st October

Average daily flow: 464.3876 Cumec

| Threshold Limit %ADF Period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| | Duration in days | | | | |
| 1967 | 17 | 19 | 36 | 53 | 53 |
| 1968 | 9 | 24 | 27 | 42 | 43 |
| 1969 | 14 | 38 | 39 | 39 | 39 |
| 1970 | 11 | 36 | 36 | 36 | 38 |
| 1971 | 9 | 19 | 19 | 26 | 26 |
| 1972 | 35 | 41 | 44 | 45 | 45 |
| 1973 | 16 | 29 | 32 | 38 | 38 |
| 1974 | 27 | 29 | 36 | 36 | 36 |
| 1975 | 16 | 24 | 28 | 32 | 33 |
| 1976 | 17 | 25 | 44 | 48 | 50 |
| 1977 | 15 | 19 | 22 | 37 | 47 |
| 1978 | 11 | 25 | 41 | 41 | 42 |
| 1979 | 35 | 53 | 53 | 63 | 64 |
| 1980 | 15 | 24 | 30 | 30 | 30 |
| 1981 | 14 | 25 | 30 | 31 | 33 |
| 1982 | 49 | 49 | 49 | 52 | 62 |
| 1983 | 23 | 40 | 40 | 41 | 58 |
| 1984 | 17 | 17 | 25 | 25 | 25 |
| 1985 | 48 | 48 | 48 | 75 | 76 |

TABLE 11: MAXIMUM DURATION OF LOW FLOW SPELLS

Site: Yadgir
Base Period: Ist June to 31st October

Average daily flow: 760.1973 Cumecs

| Threshold Limit %ADF Period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| | | | Duration in days | | |
| 1965 | 16 | 34 | 44 | 44 | 44 |
| 1966 | 19 | 25 | 39 | 43 | 54 |
| 1967 | 17 | 18 | 26 | 44 | 44 |
| 1968 | 14 | 33 | 34 | 42 | 42 |
| 1969 | 9 | 27 | 28 | 31 | 36 |
| 1970 | 7 | 37 | 38 | 41 | 41 |
| 1971 | 6 | 10 | 17 | 20 | 21 |
| 1972 | 40 | 40 | 40 | 41 | 62 |
| 1973 | 14 | 30 | 30 | 31 | 31 |
| 1974 | 4 | 14 | 30 | 30 | 47 |
| 1975 | 6 | 27 | 30 | 44 | 44 |
| 1976 | 10 | 24 | 37 | 46 | 47 |
| 1977 | 11 | 17 | 18 | 20 | 38 |
| 1978 | 9 | 19 | 28 | 29 | 29 |
| 1979 | 26 | 36 | 58 | 58 | 68 |
| 1980 | 8 | 20 | 25 | 34 | 34 |
| 1981 | 8 | 9 | 14 | 18 | 19 |
| 1982 | 25 | 38 | 40 | 40 | 41 |
| 1983 | 24 | 24 | 24 | 24 | 24 |
| 1984 | 24 | 24 | 25 | 38 | 28 |
| 1985 | 15 | 42 | 43 | 52 | 52 |

## TABLE 12: MAXIMUM DURATION OF LOW FLOW SPELLS

Site: Wadakbal
Base Period: Ist June to
31st Oct.

Average daily flow: 73.16883 Cumecs

| Threshold Limit %ADF Period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| 1965 | 18 | 35 | 38 | 40 | 40 |
| 1966 | 21 | 31 | 39 | 40 | 40 |
| 1967 | 16 | 24 | 25 | 25 | 26 |
| 1968 | 30 | 35 | 43 | 43 | 43 |
| 1969 | 10 | 22 | 36 | 36 | 36 |
| 1970 | 6 | 10 | 21 | 21 | 35 |
| 1971 | 56 | 58 | 59 | 59 | 59 |
| 1972 | 55 | 75 | 99 | 99 | 99 |
| 1973 | 17 | 22 | 24 | 25 | 27 |
| 1974 | 22 | 32 | 33 | 34 | 35 |
| 1975 | 15 | 36 | 36 | 36 | 54 |
| 1976 | 31 | 52 | 54 | 60 | 60 |
| 1977 | 25 | 27 | 41 | 41 | 41 |
| 1978 | 9 | 32 | 32 | 66 | 66 |
| 1979 | 41 | 54 | 54 | 54 | 54 |
| 1980 | 11 | 55 | 58 | 59 | 59 |
| 1981 | 35 | 75 | 77 | 82 | 82 |
| 1982 | 59 | 66 | 88 | 88 | 113 |
| 1983 | 27 | 27 | 27 | 27 | 27 |
| 1984 | 44 | 44 | 44 | 53 | 54 |
| 1985 | 39 | 39 | 46 | 55 | 90 |

TABLE 13: MAXIMUM DURATION OF LOW FLOW SPELLS

Site: Haralhalli
Base Period: Ist June to 31st Oct

Average daily flow: 491.7371 Cumecs

| Threshold Limit %ADF Period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| | Duration in days | | | | |
| 1967 | 17 | 30 | 30 | 30 | 33 |
| 1968 | 7 | 23 | 23 | 25 | 34 |
| 1969 | 9 | 23 | 24 | 30 | 30 |
| 1970 | 0 | 14 | 15 | 17 | 18 |
| 1971 | 0 | 5 | 11 | 17 | 35 |
| 1972 | 20 | 28 | 28 | 29 | 39 |
| 1973 | 4 | 13 | 30 | 53 | 58 |
| 1974 | 13 | 36 | 36 | 36 | 36 |
| 1975 | 8 | 21 | 21 | 21 | 26 |
| 1976 | 8 | 26 | 45 | 52 | 53 |
| 1977 | 15 | 19 | 19 | 23 | 24 |
| 1978 | 10 | 16 | 16 | 16 | 20 |
| 1979 | 10 | 26 | 26 | 29 | 50 |
| 1980 | 0 | 6 | 18 | 26 | 26 |
| 1981 | 2 | 11 | 20 | 20 | 26 |
| 1982 | 8 | 18 | 29 | 31 | 34 |
| 1983 | 15 | 15 | 27 | 28 | 29 |
| 1984 | 6 | 16 | 16 | 17 | 33 |
| 1985 | 8 | 19 | 25 | 34 | 39 |

TABLE 14: MAXIMUM DURATION OF LOW FLOW SPELLS

Site: T. Ramapuram
Base Period : Ist June to 31st October

Average daily flow(ADF)=49.14037 Cumec

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| 1966 | 13 | 33 | 34 | 34 | 37 |
| 1967 | 15 | 25 | 59 | 66 | 68 |
| 1968 | 22 | 43 | 45 | 45 | 89 |
| 1969 | 6 | 20 | 52 | 53 | 53 |
| 1970 | 11 | 17 | 36 | 50 | 73 |
| 1971 | 10 | 51 | 82 | 82 | 82 |
| 1972 | 13 | 32 | 35 | 75 | 76 |
| 1973 | 2 | 20 | 30 | 34 | 36 |
| 1974 | 14 | 41 | 46 | 46 | 46 |
| 1975 | 17 | 38 | 53 | 53 | 53 |
| 1976 | 10 | 26 | 43 | 55 | 64 |
| 1977 | 10 | 31 | 32 | 33 | 53 |
| 1978 | 17 | 35 | 35 | 35 | 35 |
| 1979 | 28 | 54 | 90 | 90 | 90 |
| 1980 | 30 | 42 | 75 | 75 | 80 |
| 1981 | 16 | 28 | 45 | 45 | 50 |
| 1982 | 27 | 28 | 31 | 77 | 77 |
| 1983 | 26 | 47 | 49 | 50 | 50 |
| 1984 | 42 | 42 | 42 | 42 | 42 |
| 1985 | 34 | 56 | 58 | 60 | 60 |

TABLE 16: DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

Site: Dhond

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| | Drought Intensity in Cumecs | | | | |
| 1968 | 37.95 | 101.60 | 177.52 | 253.44 | 329.35 |
| 1969 | 19.93 | 103.62 | 179.53 | 226.35 | 296.16 |
| 1970 | 25.16 | 88.26 | 154.80 | 230.72 | 306.64 |
| 1971 | 21.63 | 88.82 | 163.94 | 207.87 | 255.48 |
| 1972 | 30.37 | 100.63 | 162.05 | 233.45 | 309.37 |
| 1973 | 32.32 | 90.00 | 170.80 | 246.72 | 322.64 |
| 1974 | 31.15 | 103.91 | 179.83 | 240.36 | 303.19 |
| 1975 | 11.08 | 82.03 | 134.47 | 103.81 | 259.73 |
| 1976 | 20.12 | 85.93 | 151.83 | 217.34 | 252.53 |
| 1977 | 19.89 | 72.31 | 139.79 | 212.62 | 288.53 |
| 1978 | 18.27 | 71.23 | 143.03 | 218.95 | 294.87 |
| 1979 | 18.65 | 94.57 | 170.49 | 231.74 | 288.43 |
| 1980 | 18.02 | 83.22 | 142.64 | 197.92 | 273.84 |
| 1981 | 22.94 | 89.53 | 160.37 | 216.03 | 262.91 |
| 1982 | 28.35 | 98.95 | 174.87 | 250.78 | 311.88 |
| 1983 | 30.33 | 94.26 | 166.09 | 237.80 | 299.75 |
| 1984 | 35.75 | 103.30 | 157.05 | 232.96 | 308.88 |
| 1985 | 26.49 | 97.86 | 136.74 | 200.09 | 272.56 |

TABLE 16: DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

Site: Narsingpur

| Threshold Limit % ADF Period | 10% | 30% | Drought Intensity in Cumecs 50% | 70% | 90% |
|---|---|---|---|---|---|
| 1967 | 36.47 | 119.86 | 208.21 | 266.09 | 358.97 |
| 1968 | 40.09 | 81.81 | 162.78 | 214.69 | 300.49 |
| 1969 | 39.94 | 108.07 | 166.74 | 259.62 | 352.48 |
| 1970 | 21.57 | 98.15 | 191.03 | 283.91 | 376.78 |
| 1971 | 30.03 | 102.81 | 195.68 | 275.09 | 367.97 |
| 1972 | 40.84 | 115.59 | 200.12 | 287.14 | 380.02 |
| 1973 | 36.27 | 110.58 | 210.31 | 271.44 | 364.32 |
| 1974 | 35.10 | 124.67 | 196.53 | 289.42 | 382.30 |
| 1975 | 17.17 | 98.72 | 176.00 | 246.78 | 331.30 |
| 1976 | 17.41 | 91.48 | 148.51 | 221.58 | 303.71 |
| 1977 | 35.89 | 111.50 | 204.38 | 286.65 | 379.52 |
| 1978 | 12.36 | 101.54 | 159.08 | 251.96 | 338.02 |
| 1979 | 35.59 | 123.10 | 215.98 | 272.10 | 359.63 |
| 1980 | 35.95 | 94.80 | 168.65 | 261.53 | 366.20 |
| 1981 | 18.60 | 90.93 | 172.28 | 257.50 | 330.74 |
| 1982 | 40.75 | 133.62 | 226.50 | 309.76 | 372.30 |
| 1983 | 35.93 | 125.22 | 218.10 | 303.76 | 348.80 |
| 1984 | 31.97 | 124.85 | 158.65 | 251.52 | 344.40 |
| 1985 | 38.41 | 131.22 | 224.10 | 306.13 | 394.78 |

TABLE 17 : DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

Site: Yadgir

| Threshold Limit % ADF Period | 10% | 30% | Drought Intensity in Cumecs 50% | 70% | 90% |
|---|---|---|---|---|---|
| 1965 | 62.68 | 138.90 | 269.07 | 421.11 | 573.15 |
| 1966 | 52.51 | 184.16 | 249.17 | 372.35 | 530.68 |
| 1967 | 71.49 | 223.53 | 245.56 | 440.40 | 592.44 |
| 1968 | 71.08 | 145.97 | 292.06 | 414.68 | 566.72 |
| 1969 | 47.96 | 160.83 | 304.80 | 421.62 | 573.66 |
| 1970 | 9.63 | 61.59 | 270.50 | 408.14 | 560.18 |
| 1971 | 27.35 | 152.02 | 239.46 | 359.74 | 494.40 |
| 1972 | 63.95 | 215.99 | 368.03 | 520.07 | 672.11 |
| 1973 | 76.02 | 188.17 | 340.21 | 361.40 | 630.02 |
| 1974 | 21.62 | 114.72 | 224.16 | 376.20 | 499.27 |
| 1975 | 61.55 | 133.93 | 266.48 | 384.25 | 536.29 |
| 1976 | 75.43 | 107.13 | 207.40 | 314.49 | 457.49 |
| 1977 | 52.48 | 171.18 | 283.94 | 403.10 | 457.33 |
| 1978 | 12.55 | 121.31 | 212.20 | 354.13 | 506.17 |
| 1979 | 55.35 | 186.32 | 346.88 | 498.91 | 601.22 |
| 1980 | 73.05 | 133.01 | 260.14 | 380.87 | 532.91 |
| 1981 | 63.02 | 215.05 | 367.09 | 260.42 | 394.20 |
| 1982 | 42.77 | 159.44 | 305.93 | 457.98 | 595.72 |
| 1983 | 60.35 | 212.39 | 364.43 | 476.74 | 660.50 |
| 1984 | 67.02 | 219.05 | 361.54 | 457.17 | 609.21 |
| 1985 | 56.32 | 144.85 | 289.99 | 454.341 | 606.35 |

TABLE 18: DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

Site : Wadakbal

| Threshold Limit % ADF Period | 10% | 30% | Drought Intensity in Cumecs 50% | 70% | 90% |
|---|---|---|---|---|---|
| 1965 | 3.21 | 14.69 | 27.90 | 40.58 | 55.21 |
| 1966 | 5.69 | 16.20 | 29.31 | 43.19 | 57.82 |
| 1967 | 7.26 | 17.20 | 31.01 | 45.64 | 58.44 |
| 1968 | 3.35 | 16.98 | 29.65 | 44.28 | 58.91 |
| 1969 | 5.14 | 13.39 | 27.80 | 42.44 | 57.07 |
| 1970 | 3.41 | 13.51 | 24.27 | 38.91 | 48.99 |
| 1971 | 6.20 | 20.48 | 34.71 | 49.34 | 63.98 |
| 1972 | 6.52 | 19.85 | 34.51 | 49.14 | 63.67 |
| 1973 | 4.55 | 16.85 | 29.81 | 43.05 | 55.36 |
| 1974 | 5.39 | 14.68 | 28.57 | 42.25 | 55.60 |
| 1975 | 6.79 | 18.57 | 33.20 | 47.83 | 56.81 |
| 1976 | 7.12 | 17.50 | 31.28 | 42.76 | 57.89 |
| 1977 | 5.76 | 19.78 | 29.18 | 43.81 | 58.45 |
| 1978 | 2.70 | 11.61 | 26.90 | 40.31 | 54.95 |
| 1979 | 7.26 | 21.15 | 35.78 | 50.41 | 65.05 |
| 1980 | 2.51 | 13.41 | 27.02 | 41.06 | 55.70 |
| 1981 | 6.36 | 19.70 | 33.53 | 46.62 | 61.25 |
| 1982 | 6.65 | 20.77 | 33.05 | 47.68 | 62.18 |
| 1983 | 7.04 | 21.68 | 36.31 | 50.94 | 65.68 |
| 1984 | 7.31 | 21.95 | 36.58 | 48.65 | 62.29 |
| 1985 | 6.59 | 21.22 | 34.41 | 46.79 | 61.71 |

TABLE 19 : DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

Site: Haralahalli

| Threshold Limit % ADF Period | 10% | 30% | 50% | 70% | 90% |
|---|---|---|---|---|---|
| | | | Drought Intensity in Cumecs | | |
| 1967 | 23.23 | 117.31 | 215.66 | 314.01 | 375.25 |
| 1968 | 18.08 | 84.41 | 182.76 | 271.99 | 312.87 |
| 1969 | 17.40 | 104.23 | 197.48 | 261.44 | 359.79 |
| 1970 | 0.00 | 51.60 | 144.54 | 220.74 | 303.94 |
| 1971 | 0.00 | 51.09 | 68.29 | 145.99 | 211.04 |
| 1972 | 19.09 | 110.44 | 208.79 | 297.21 | 294.13 |
| 1973 | 25.32 | 84.19 | 75.34 | 146.80 | 267.61 |
| 1974 | 15.92 | 94.01 | 192.36 | 290.70 | 389.05 |
| 1975 | 14.93 | 95.15 | 193.49 | 291.84 | 315.15 |
| 1976 | 22.61 | 79.83 | 156.55 | 214.21 | 297.45 |
| 1977 | 23.06 | 116.51 | 214.86 | 275.99 | 362.50 |
| 1978 | 18.36 | 100.47 | 198.82 | 297.17 | 316.41 |
| 1979 | 21.64 | 103.44 | 201.78 | 269.08 | 254.31 |
| 1980 | 0.00 | 40.20 | 111.47 | 145.26 | 240.40 |
| 1981 | 7.17 | 73.64 | 173.40 | 271.75 | 305.34 |
| 1982 | 20.11 | 89.72 | 126.36 | 205.45 | 282.40 |
| 1983 | 29.26 | 127.61 | 193.16 | 284.32 | 371.61 |
| 1984 | 18.81 | 100.13 | 198.48 | 279.36 | 191.60 |
| 1985 | 15.74 | 102.43 | 155.93 | 172.50 | 215.82 |

TABLE 20: DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

Site: T. Ramapuram

| Threshold Limit % ADF Period | 10% | 30% | Drought Intensity in Cumecs 50% | 70% | 90% |
|---|---|---|---|---|---|
| 1966 | 4.54 | 9.01 | 18.33 | 28.21 | 37.94 |
| 1967 | 2.92 | 8.7 | 15.97 | 24.37 | 33.50 |
| 1968 | 1.68 | 10.35 | 19.57 | 29.40 | 37.93 |
| 1969 | 2.04 | 9.23 | 12.87 | 22.35 | 32.17 |
| 1970 | 1.55 | 9.60 | 16.48 | 24.39 | 34.09 |
| 1971 | 2.29 | 9.08 | 17.23 | 27.06 | 36.89 |
| 1972 | 1.72 | 8.28 | 17.25 | 25.54 | 34.93 |
| 1973 | 4.81 | 6.98 | 14.25 | 23.51 | 32.92 |
| 1974 | 2.50 | 10.36 | 18.71 | 28.54 | 38.37 |
| 1975 | 1.92 | 9.54 | 19.39 | 29.22 | 39.05 |
| 1976 | 4.50 | 8.67 | 16.93 | 24.35 | 29.37 |
| 1977 | 1.33 | 9.36 | 18.84 | 27.83 | 32.47 |
| 1978 | 2.91 | 11.27 | 21.10 | 30.92 | 40.75 |
| 1979 | 2.21 | 11.42 | 18.16 | 27.99 | 37.82 |
| 1980 | 3.03 | 10.93 | 16.16 | 25.99 | 34.75 |
| 1981 | 2.34 | 10.34 | 18.01 | 27.84 | 35.78 |
| 1982 | 2.30 | 12.57 | 22.40 | 21.03 | 30.86 |
| 1983 | 2.57 | 10.87 | 20.22 | 29.58 | 39.41 |
| 1984 | 4.56 | 14.39 | 24.22 | 34.04 | 43.87 |
| 1985 | 4.72 | 14.02 | 23.25 | 33.08 | 42.91 |

## 5.0 CONCLUSIONS

Reliable estimation of the drought flows in a stream is desired for the overall planning for navigation purposes. For example, accurate prediction of the rate and duration of low flows is important to design economically many water supply and waste disposal works, to determine the required capacity of storage reservoir for the supply fo water for various uses under drought conditions and to design economically hydraulic structures in the stream specially for silting of irrigation channels. The needed development of techniques for determination dilution requirements of water quality control in natural water courses involves an analysis of low flows that can be expected in the stream. In the previous chapters various statistical methods for computation of low flow has been described alongwith the results of analysis of 20 years (1966-86) stream flow data pertaining to six chosen sites of Krishna basin. On the basis of results described in chapter 4 following conclusions have been drawn:

1. The flow duration curves were developed for the site namely, T. Ramapuram, Wadakwal, Dhond, Haralahalli, Yadgir and Narsinghpur. With the help of these curves the probability of occurrence of a particular flow at the site can be established which is helpful in planning any water resources project. Also values of low flow index at all sites were determined which indicate the low flow potential of the concerned site.

2. The frequency analysis of low flow provide an estimate of the low flow for given recurrence interval. The maximum deficit volume and maximum deficit duration may also be computed for different recurrence interval at different demand levels by carrying out the frequency analysis of the maximum deficit duration and maximum deficit volume.

3. The deficit duration and deficit volume analysis at different demand levels has indicated the maximum deficit duration and maximum deficit volume in different low flow spells were highest for 1985-86 as compared with previous years with the exception of the values corresnponding to 10% ADF. The similar analysis carried out for only monsoon period also confirmed the same results. Similar analysis can be extended for other basins. This type of analysis gives an idea about the required storage in the reservoirs in order to fulfil the demands taken as some percentage of long term mean.

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ANNEXURE - I

LAND USE PATTERN IN SOME DISTRICTS OF KRISHNA BASIN

| S.No. | Land Use | Raichur (ha) | Nalgonda (ha) | Ahmadnagar (ha) | Anantpur (ha) | Belgaum (ha) | Solapur (ha) |
|---|---|---|---|---|---|---|---|
| 1. | Forests | 32424 | 87277 | 184500 | 194,003 | 191095 | 32800 |
| 2. | Land put to non agri-cultural use | 51717 | 78453 | 5300 | 149,900 | 47117 | 3300 |
| 3. | Barren & Uncultivable land | 51385 | 91491 | 157000 | 192,007 | 50841 | 68900 |
| 4. | Permanent Pastures and other gruzing land | 44232 | 110856 | 42100 | 25,997 | 30047 | 61900 |
| 5. | Land under miscella-neous crops and trees | 13132 | 5575 | 100 | 23,525 | 2033 | 4000 |
| 6. | Cultivable waste | 15316 | 26271 | 19600 | 140,358 | 19468 | 43100 |
| 7. | Other fallow land | 65967 | 101524 | 40700 | 113,291 | 27161 | 75500 |
| 8. | Current fallow | 126473 | 264277 | 39900 | 165,264 | 72230 | 129700 |
| 9. | Net area sown | 992591 | 656277 | 1211900 | 909,142 | 99391 | 1081800 |
| 10. | Gross sown area | 1028547 | 808888 | 1311600 | 943,172 | 986389 | 1146900 |
| 11. | Area sown more than cnce | 35956 | 155611 | 99700 | 34,030 | 927467 | 65100 |
| 12. | Geographical area | 1393237 | 1422324 | 170200 | 1913,492 | 21078 | 1501000 |
| 13. | Cultivable area | 1213479 | 1054247 | 1312700 | 1,351,580 | 1027281 | 1334100 |