CS-43

HYDROLOGICAL ASPECTS OF DROUGHT UPTO 1987-88 - A CASE STUDY IN KARNATAKA

National Institute of Hydrology
Jal Vigyan Bhawan
Roorkee-247667 (U.P.)
INDIA

1990-91

PREFACE

A most important factor in understanding droughts, often not included in definition, is that it is a supply and demand phenomenon. Though a no. of definitions of drought pertaining to various uses have been developed, however, a definition which does not include reference to water requirement or demand can be regarded as inadequate. To a hydrologist drought means below average availability of flow in streams and below average storages in reservoirs, lakes, tanks, ground water aquifers and soil moisture in soil column. The various hydrological variables which can be used to study hydrological aspects of drought include rainfall, groundwater levels, surface water storages and soil moisture.

The problem of drought in the country has been recurrent in nature. In late 80's the country has faced drought for three years in succession. Reliable estimates indicate that the drought of year 1987 is ranked second in the century, the first one being in year 1918. It has been estimated that about 1/3rd of the geographical area of the country (107 M ha) spread over 99 districts, are drought prone. The Central Water Commission (CWC) has carried out studies in these 99 districts for identifying drought proneness.

The National Institute of Hydrology initiated drought studies in the year 1986 with the major objectives to lay emphasis on hydrological aspects of drought and to develop suitable drought indices alongwith evolving short and long term drought management strategies. In this venture the institute has already carried out studies on various aspects of drought. In order to study the gravity of problem studies have been taken up using the field data

to evaluate impacts of drought. In this pursuit the institute has chosen six states namely, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra & Rajasthan. The present report covers the study of six districts of state Karnataka. These districts are Bijapur, Belgaum, Gulburga, Raichur, Bellary & Dharwar.

The scientific teams of the institute undertook visits to the state of Karnataka and contacted the relevant state/central govt. agencies for collecting the required data. The study includes various kinds of analysis of rainfall data and ground water level data for assessing drought impacts. Based on the analysis, inferences, highlighting the hydrological aspects of the recent droughts, have been drawn up.

The study team included of group of scientists & scientific staff are Sri V.K.Lohani, Scientist 'C', Shri Sudhir Kumar Goyal, Scientist 'B', Sri Tanveer Ahmed, R.A., Shri Yatveer Singh, R.A. Shri Mukesh Kumar Sharma, S.R.A. under the guidance of Dr.G.C.Mishra, Scientist 'F'. The manuscript has been typed by Shri Rajneesh Kumar Goel, L.D.C.

Satish Chandra
(SATISH CHANDRA)

CONTENTS

ABSTRACT

The occurrence of drought in India is not a recent phenomenon. In recent years the country faced three drought years in succession namely 1985, 1986 & 1987. It has been reported intensitywise the drought of year 1987 ranks second in the 20th century, the first one being in the year 1918. Statistics on areal coverage indicate that out of the country, total geographical area of 328 m.ha., 107 m.ha. or about one third of the area and 29 percent of the population are affected by drought.

In view of severity of drought problem and less understanding the hydrological aspects associated with the droughts, the National Institute of Hydrology started studies in the year 1986 to better understand the drought impacts from hydrology point of view. In this venture the institute started collection, from field organisations, of the data concerning rainfall, streamflow and groundwater in selected areas, covering the period 1951 to 1988. Six states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Madhya Pradesh & Rajasthan were selected for the study. This report covers the analysis of rainfall, groundwater, & reservoir level data in respect of six selected districts Bijapur, Belgaum, Gulburga, Raichur, Bellary & Dharwar of state Karnataka for the assessment of drought impacts.

List of Figures

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 General

In spite of all the inconveniences that drought causes all around the world, many drought phenomena are still insufficiently understood in terms of the characterisation and impact assessment. There have been difficulties encountered in finding a generally accepted drought definition. The definitions currently in use are derived either on professional stand points (meteorology, hydrology, geography etc.), or on the economic activity affected (agriculture, power, production, water supply etc.). A most important factor in understanding drought, often not included in definitions, that it is a "supply and demand" phenomena. A definition of drought which does not include reference to water requirement or demand can be regarded as inadequate. In general terms, the chief characteristics of drought is associated with a decrease of water availability in a particular period and over a particular area for specified use(s).

In India, the problem of droughts is recurrent. Estimates indicate that about one-third of the geographical area of the country (107 m.ha.) spread over 99 districts are affected by drought. In recent times, the country faced three drought years in succession namely, 1985, 1986 and 1987. It has been reported that intensity wise the drought of 1987 ranks second in the century, the first one being in year 1918. During the drought of 1987 about 50% of country's area was affected by drought with about 18% negative departure in monsoon rainfall all over India and about 45% negative departure in monsoon rainfall over the drought affected region (Upadhyay & Gupta, 1989). Sampath (1989)

has reported that during 1987, 21 meteorological sub-divisions out of 35 recorded deficient/scanty rains leading to drought conditions. It has been further reported that these sub-division account for about 53% of the total food grains production in the country. A quick glance of foodgrains production figures indicates that during year 1987-88 the production was 138.41 million tonnes while in 1988-89 it was estimated to be about 172.0 million tonnes. The years 1985-86 through 1987-88 saw declining trend of food grains production which fell from 150.4 million tonnes in 1985-86 to 138.41 million tonnes in 1987-88. The fluctuation of foodgrain production clearly show dependability of agricultural activities on the rainfall.

The incidents of drought lead to reduction in stream flows, depletion of soil moisture storages, decline of reservoir and tank levels and fall in groundwater table. This in turn lead to reduced agriculture and fodder production. The drought characteristics and the associated problems vary from area to area depending upon the amount of variability of available water supplies and the demand of water for specified users.

1.2 Objectives of the Study

Inspite of repeated occurrence of droughts in the country, the hydrologic aspects of droughts have not been studied to the desired extent. Such studies have a direct bearing on evolving strategies for planning judicious use of scarce water resources.

The Institute therefore, initiated studies to lay emphasis on Hydrological Aspects of Droughts starting year 1985. Keeping in view the successive three drought years since 1985, 1986, and 1987, in major parts of the drought prone area of the country, study areas were chosen in six states namely: Andhra

Pradesh, Maharashtra, Karnataka, Rajasthan, Gujarat and Madhya Pradesh. Studies laying focus on hydrological aspects of drought for 1985-86 with two districts in each of chosen states and for 1986-87 with four districts have been completed. The studies for year 1987-88 were carried out in six districts in each of the six states and in view of wider aerial coverage in each state it was decided to prepare separate study reports contrary to the earlier study reports which presented results of studies for all the six states in one volume.

The present report, therefore, presents results of studies carried out for six districts of State Karnataka. The districts included for the study are Belgaum, Bijapur, Gulburga, Raichur, Bellary and Dharwar. The report includes analysis of rainfall & groundwater level data for finding the impacts of deficit in rainfall and its consequent effects on groundwater tables. In order to evaluate the impacts on surface water storages, the storage figures in Tungbhadra reservoir & Ghatprabha reservoir located in the state, have been included in the report. The stream flow analysis for the sites, of Krishna & Godavari basin, lying in the state Karnataka has been done basinwise and has been presented in the report 'Hydrological Aspects of Drought 1987-88 - A Case Study (CS-37).

The report is an attempt towards developing a comprehensive hydrological drought indices for characterising drought situations. List of offices and places from where data and information have been collected in the state of Karnataka are shown in Appendix-II.

2.0 DESCRIPTION OF STUDY AREA

2.1 General

There are 99 districts spread over 13 states which have been identified as drought prone districts in the country as shown in Fig. 2.1. This report covers the study of six selected drought prone districts of state Karnataka namely: Bijapur, Belgaum, Gulburga, Raichur, Bellary & Dharwar. The location of districts are shown on the state map as shown in fig. 2.2. The physiographic divisions into which the state can be divided are : Coastal region which is again subdivided into coastal plains, Western Ghats & the Karnataka Plateau. Karnataka State extends over an area of 1.92 lakh sq.kms. which is about 5.84 percent of the total geographical area of the country. Karnataka state lies between 74°-$78^{\circ}30'$E longitude and $10^{\circ}58'$-$18^{\circ}30'$N latitude in the peninsular India. In terms of area it holds 8th place among the states of the country.

2.2 Population

The population of the state according to 1981 census is 371.36 lakhs comprising 189.23 lakhs of males and 182.13 lakhs of females. Of the total population, 264.06 lakhs live in the villages and the rest comprising 107.30 lakhs live in the urban towns and cities. Out of the total population of the state as many as 49.44 lakhs or 40 percent are workers. Out of working force around 60 percent are engaged in agricultural occupation. The growth rate of population annually is estimated at 2.67% and the population are given in table 2.1 below:

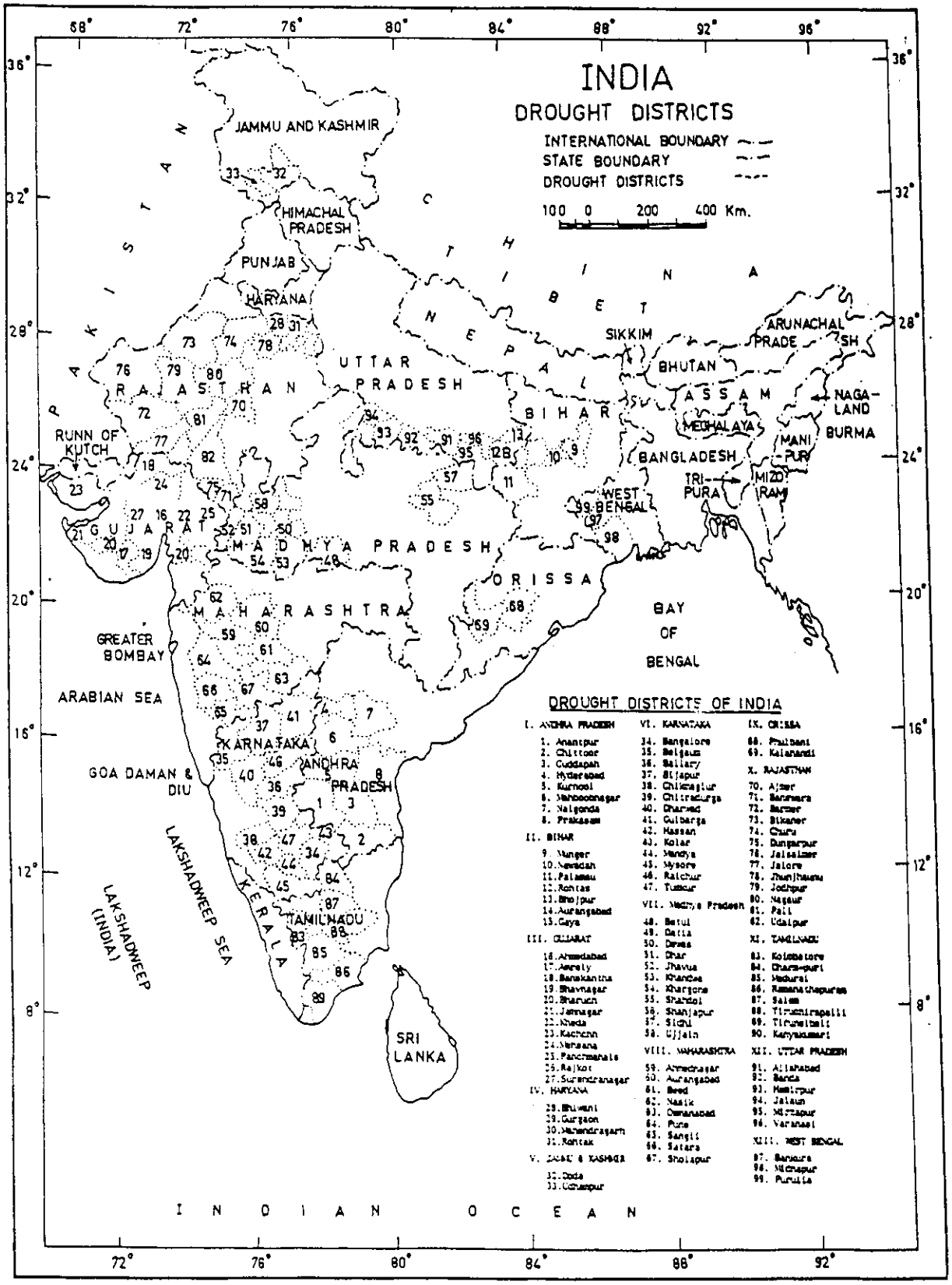


FIG. 2.1 : DROUGHT PRONE DISTRICTS IN INDIA

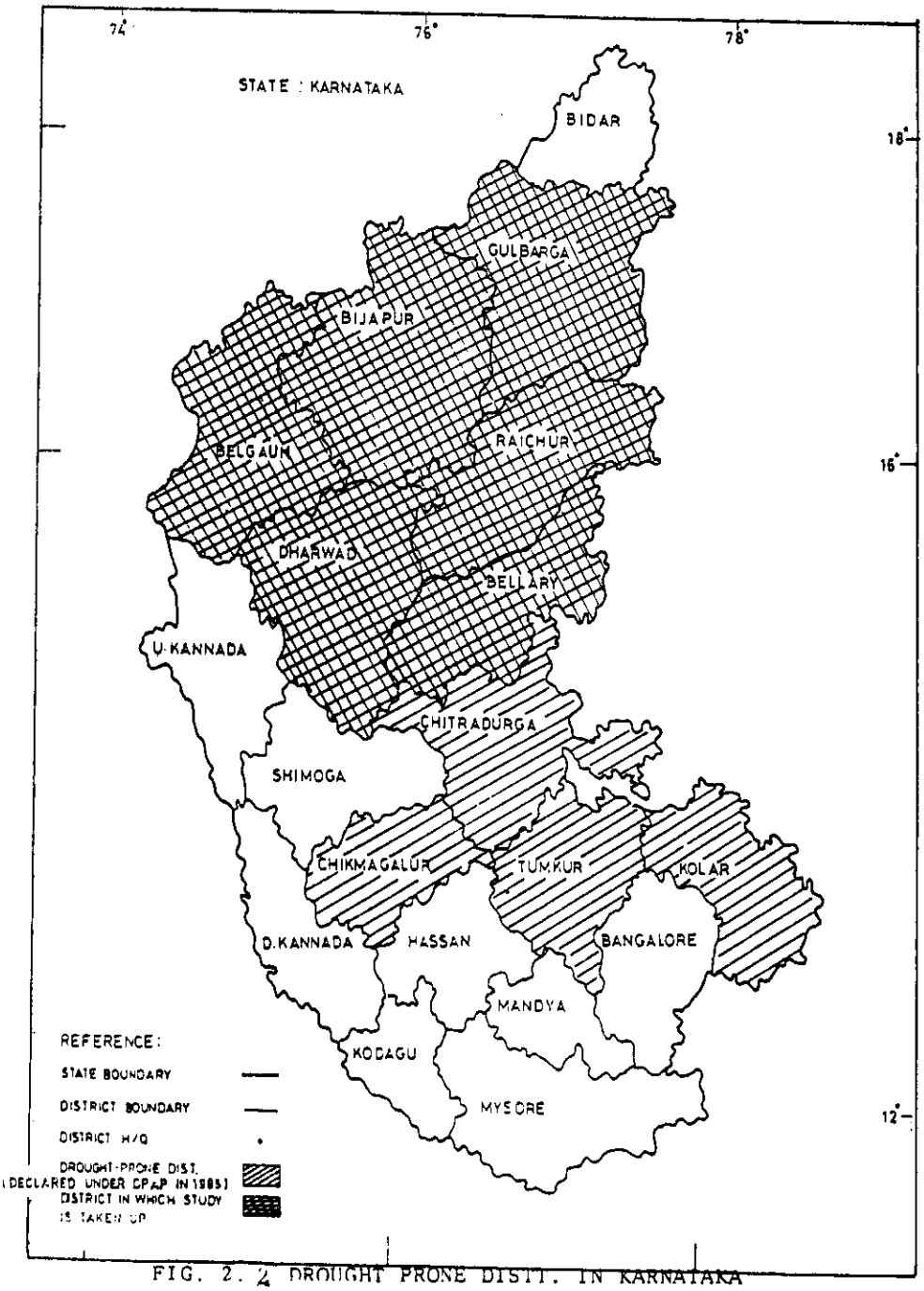


FIG. 2.2 DROUGHT PRONE DISTT. IN KARNATAKA

Table 2.1 : Details of Population Growth

Sl. No.	Year of census	States total population (million)	Approx. rural population (million)	Av.annual growth rate (%)
1.	1951	19.40	14.95	1.93
2.	1961	23.59	18.32	2.16
3.	1971	29.30	22.18	2.42
4.	1981	37.13	26.40	2.67

2.3 Land Use & Vegetal Cover

The status of land utilization over 25 years span of development from the year of formation of enlarged Karnataka in 1956-57 and the year 1981-82 is presented in table 2.2. From the table 2.2 it can be seen that the percentage of net area sown moved up by hardly one percent from the level of 54 percent to the corresponding geographical area in 1981-82 after 25 years of development. This situation can be attributed to the impact of the vagaries of monsoon as large extent of area are cultivated under rainfed condition in the state.

2.4 Soils

More than three-fourth of the area in the state is covered by most ancient crystallive schists and granite rocks of Archean system. At present, 8 important rock formations are recognised in the state which give rise to different soils. Mainly six broad soil groups have been identified and details of their distribution in the state are shown in fig. 2.3. These soil groups are :

(A) Black Soils

i) Shallow black soils

ii) Medium black soils

iii) Deep black soils

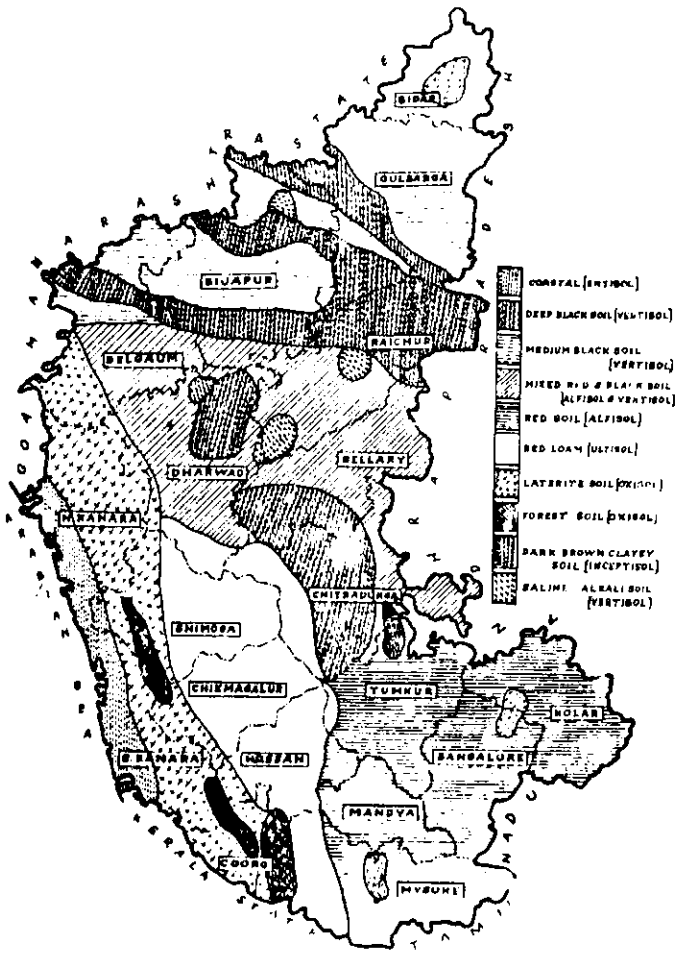


Fig 2 . 3*Soils of Karnataka*

Source : Soils of India & Their Management, 1985

(B) Red Soils

(C) Red Loam Soils

(D) Mixed Red and Black Soils

(E) Laterite Soils

(F) Coastal Alluvials

(G) Dark Brown Clayey Soils

Table 2.2 : Comparative Status of Land Utilization in Karnataka

Sl. No.	Land use particulars	1956-57 Area (in lakh hectares)	1956-57 %age to geographical area	1981-82 Area (in lakh hectares)	1981-82 %age fo geographical area
1.	Forest	26.9	14	30.3	16
2.	Land not available for cultivation	16.7	10	19.3	10
3.	Other uncultivated land (excluding fallows)	28.6	15	21.4	11
4.	Fallow land	13.8	7	15.6	8
5.	Net area sown	100.8	54	103.9	55
6.	Geographical area (by village papers)	186.8	100	190.5	100

Source : Directorate of Economics & Statistics, Bengalore, 1984.

2.5 Surface Water Availability

The average annual flow of all the river systems in India is of the under of 1,700,000 M.cum. Karnataka shares around 6 percent of the water resources of India through the several river systems that drain the state. The average annual flow in the state is estimated to be of the order of 97,800 or around 1,00,000

M.cum. Out of this, about 60 percent or 60,000 M.cum., is available in the East flowing rivers and the remaining 40 percent or 40,000 M.cum. is drained into the Arabian Sea, from the narrow coastal belt through the west flowing rivers. This available water resources is amenable for utilization as source of irrigation (consumptive) and as source of hydropower development (non-consumptive) through projects.

The river flows that are available as water resources and that can be put to use on a dependable basis in the different river systems of the state through projects has been presented in table 2.3.

Table 2.3 : Utilisable Water Resources in the State Karnataka

S.No.	Water Resources	Estimated Average flow in M.cum.	Estimated Utilisable Water Resources through Projects (approximate)
1.	Krishna System	27,500	26,800
2.	Godavari System	1,400	560
3.	The Cauvery System	11,000	11,000
4.	The West Flowing Rivers	57,000	22,000
5.	The Palar North Pennar and South Pennar	900	900.
6.	Total Water Resources Available	97,800	61,260

Source : Water Resources & Development Organisation, Bangalore

It may be seen from the estimates worked out in the table 2.3 that only around 70 percent of the surface water resources available through the flow of the different river systems in the state is utilisable on a dependable basis leaving the balance of 40 percent not amenable for utilization and allowed to flow as runoff.

2.6 Ground Water Availability

Ground water in the state occur, under water table conditions, under the hard rocks of the state. The state with an average elevation of 700 m above the mean sea level is almost wholly composed of metamorphic hard, compact and dry-stalline rocks which are weathered and decomposed near surface due to continuous exposure to action of rain and water and have become sufficiently porous to hold moderate quantities of groundwater. But, due to greater part of the state being arid with an average annual rainfall below 750 mm together with tne climate, sets a limit to the occurence and circulation of groundwater in the state.

Groundwater get annually recharged mainly as a result of infiltration of rain water and to a limited extent through seepage water available from the surface water sources like streams, tanks, reservoirs and water applied as irrigation. The fluctuation in the water-table experienced during the dry seasons indicates good recharge potential of the groundwater under metamorphic bed rocks of the state.

Studies carried out by state groundwater all have estimated the districtwise groundwater recharge through infiltration of rainfall, discharge potential and extent of utilization. Table 2.4 gives the districtwise estimates of groundwater potential & utilization. As per estimates worked out the overall utilization of the groundwater of the state is hardly 25 percent or one fourth of its availability.

Table 2.4 : Districtwise Ground Water Potential and Utilisation in Karnataka

Sl. No.	District	Normal rain-fall (in mm)	Infiltra-tion (in percent)	Recharge (in cu. mm)	Discharge (in cu. mm)	Availa-ble po-tential (in cu. mm)	Percentage of utili-sation
1	2	3	4	5	6	7	8
1.	Bangalore	793.6	8	509	262	247	51
2.	Belgaum	784.7	7	740	300	440	41
3.	Bellary	574.9	8	439	61	378	14
4.	Bidar	907.5	10	495	175	320	35
5.	Bijapur	552.8	6	568	281	287	49
6.	Chikmagalur	1989.8	4.5	637	17	620	3
7.	Chitradurga	579.3	8	500	162	338	32
8.	Dakshina Kannada	3932.4	3	1073	251	822	23
9.	Dharwad	691.1	8	751	95	656	13
10.	Gulbarga	702.3	8	905	94	811	10
11.	Hassan	1040.7	7.5	512	17	495	3
12.	Kodagu	2725.5	3	336	3	333	0.9
13.	Kolar	730.5	8	432	302	130	70
14.	Mandya	691.2	8	275	242	233	15
15.	Mysore	761.9	8	680	70	610	10
16.	Raichur	601.6	8	671	120	551	18
17.	Shimoga	1526.3	3	476	30	446	6
18.	Tumkur	687.9	8	584	351	233	60
19.	Uttara Kannada	2764.1	3	843	108	735	13
	Karnataka	1354.7		11,426	2,941	8,685	24.57

Source: Department of Mines and Geology, Groundwater Cell, Bangalore

2.7 Water Use

The annual water requirement of water in the state for domestic & live stock purposes during 1981 was of the order of 0.0868 M.ha.m. which has been estimated to increase to a level of 0.1365 M.ha.m. by the year 1991 (CWC, 1988). The details of water availability and water requirement for drought prone districts of state Karnataka are given in table 2.5.

Table 2.5 : Water Availability and Water Requirement for Drought Prone Districts of State Karnataka

Sl. No.	District	Water Availability		Total Requirements
		50% dependability	75% dependability	
1	2	3	4	5
1.	Bangalore	1.87	1.38	1.27
2.	Belgaum	4.00	3.28	2.86
3.	Bellary	2.39	2.04	1.78
4.	Bijapur	5.38	4.85	4.54
5.	Chikmagalur	3.48	2.65	1.98
6.	Chitradurga	2.21	2.01	1.78
7.	Dharwad	4.03	3.78	1.63
8.	Gulburga	6.36	5.40	3.28
9.	Hassan	1.83	1.47	1.20
10.	Kolar	0.98	0.86	0.89
11.	Mandya	2.92	2.76	2.57
12.	Mysore	3.33	3.03	3.19
13.	Raichur	5.93	5.21	4.88
14.	Tumkur	2.54	1.98	1.87

Source : Water Resources of India, CWC, 1988.

2.8 Crops & Fodder

Due to large scale variations in topography, climate, soils, vegetation & crops, rainfall etc., the state has been divided into 10 agroclimate zones as shown in fig. 2.4. It may be seen from the figure that in as many as 10 districts more than one agroclimatic characteristics as per the criteria is noticed. The cropping pattern of the state Karnataka is shown in table 2.6. Also the major crops grown in different agroclimatic zones regions, districts and soils have been detailed in table 2.7.

The status of irrigation in the state according to the different sources is presented in the table 2.8.

Table 2.6 : Status of Cropping Pattern in State Karnataka

Sl. Mo.	Crops	1956-57		1981-82	
		Area (in lakh) hectares	Percentage to total cropped area	Area (in lakh) hectares	Percentage to total cropped area
1	2	3	4	5	6
A.	FOOD CROPS				
I	Cereals				
1.	Paddy	9.2	9	11.7	10
2.	Jowar	25.0	25	21.1	19
3.	Ragi	8.8	8	11.5	10
4.	Maize	0.1	Neg	1.6	1
5.	Bajra	5.3	5	6.4	6
6.	Wheat	3.1	3	3.3	3
7.	Other Cereals	4.8	5	3.8	4
	Total	57.1	55	59.4	53

II Pulses				
8. Bengalgram	1.6	1	1.4	1
9. Tur	2.9	3	3.7	4
10. Other pulses	8.3	8	10.4	9
Total Pulses	12.8	12	15.5	14
Total food grains	69.9	67	74.9	67
11. Other food crops	3.9	4	6.5	6
Total food crops	73.8	71	81.4	73
B NON FOOD CROPS				
III Oil seeds				
12. Groundnut	9.4	9	8.6	8
13. Sesamum	0.6	2	1.1	1
14. Other oil seeds	4.0	4	5.8	5
Total oil seeds	14.0	14	15.5	14
15. Cotton	11.8	11	10.4	9
16. Other Fibres	0.4	Neg	0.3	Neg
17. Other non crops	4.0	4	4.6	4
Total non food crops	30.2	29	30.8	27
Total of all Crops	104.0	100	112.2	100

Source : Directorate of Economics & statistics, Bangalore, 1984.

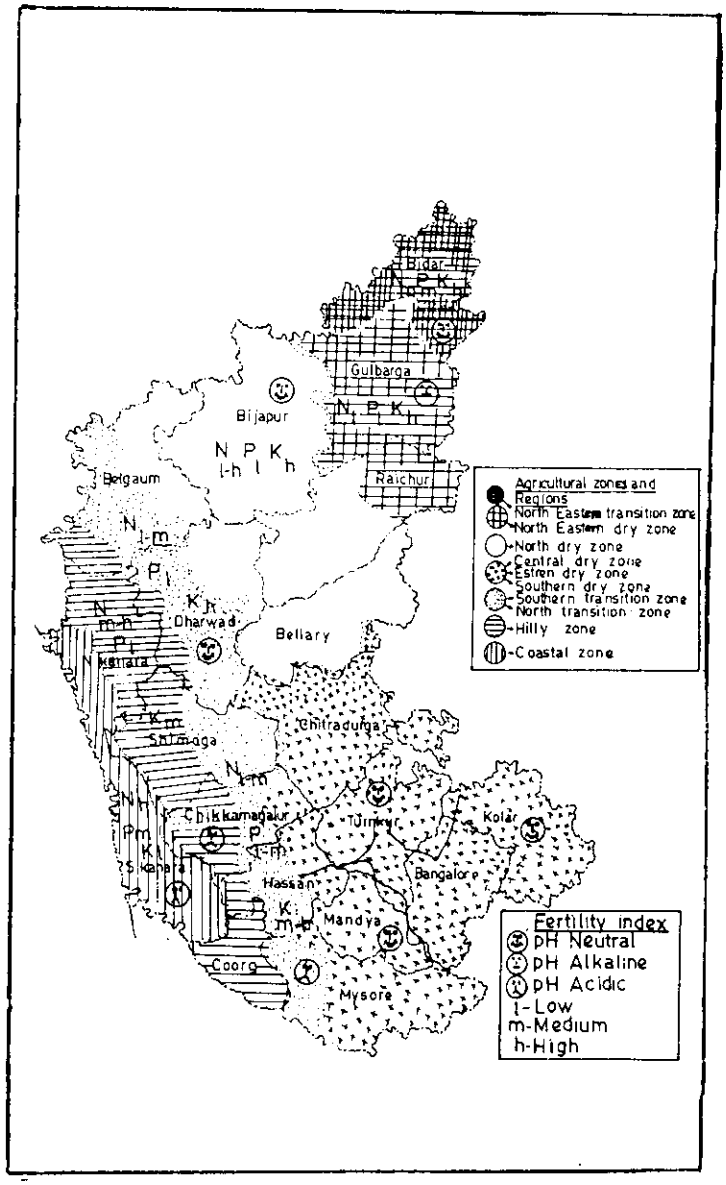


Fig 2.4Agricultural zones of Karnataka

Source : Soil of India & Their Management, 1985

Table 2.7 : Major Crops Generally Grown in Different Agro-Climatic Zones, Districts and Soils

Region	Zone	District	Traditional Nomenclature of soil	Major crops grown
I	1,2	Bidar, Gulbarga and parts of Raichur	Red soil, Laterite soil, Black soil	Sorghum,red gram,bengal gram,groundnut,saf-flower,niger,pearl millet,rice,cotton, sugarcane and chillies.
II	3	Bijapur,Bellary and parts of Raichur, Dharwad and Belgaum	Black soil,Red soil	Sorghum,pearl millet, groundnut,bengal gram, cotton,wheat and sunflower.
III	4,5,6	Chitradurga,Tumkur, Mandya,Bangalore, Kolar and parts of Hassan Chikma-nglur and Mysore	Black soil,Red soil,Red Sandy soil,Laterite soil	Finger millet,pulses, sorghum(Kharif),rice, groundnut,sugarcane, cotton and millets
IV	7,8	Parts of Belgaum, Dharwad,Shimoga, Chikmagalur,Hassan and Mysore	Red soil,Red sandy soil, Laterite soil Black soil	Sorghum,finger millet, rice,oilseeds,pulses, cotton,wheat,tobacco, millets and aromatic plants
V	9	Coorg and parts of Hassan,Chikmangalur Shimoga,Uttara Kannada and Dharwad	Red soil, Red sandy soil, Laterite soil	Rice,plantation and horticultural crops
VI	10	Dakshina Kannada and parts of Uttara Kannada	Red soil Alluvial soil,Laterite soil	Rice,pulses,groundnut, plantation and horti-cultural crops

Source : Soils of India and Their Management, 1985

Table 2.8 : Status of Irrigation in Karnataka

Sl. No.	Source of Irrigation	1901		1956-57		1981-82	
		Area (lakh hecta-res)	Percent-age to total	Area (lakh hecta-res)	Percent-age to total	Area (lakh hecta-res)	Percent-age to total
1	2	3	4	5	6	7	8
1.	Canals	0.56	11	1.65	22	5.80	40
2.	Tanks	2.60	52	3.28	44	3.21	22
3.	Wells	0.60	12	1.29	18	4.01	27
4.	Other sources	1.28	25	1.18	16	1.68	11
Total of all sources		5.04	100	7.40	100	14.70	100

Source : Directorate of Economics & Statistics, Bangalore, 1984

2.9 Districts Choosen for Study

The following section include description of individual districts taken up for study in the state Karnataka.

2.9.1 Belgaum

Belgaum district is situated in the northern part of Karnataka state. Its geographical location is between $15^{o}22'$N and $16^{o}58'$N latitude and $74^{o}2'$E and $75^{o}25'$E longitude. It has a geographical area of 13460.8 sq.km. The district consists of ten talukas. The district has 1158 inhabited villages, 6 uninhabited villages and 19 towns. The population of the district is found to be 2974861 and the density of the population is found to be 221 persons per sq.km. as per 1981 census data. The soil of the district is generally of five types viz. Medium black. Deep black, mixed black and red soil, Red loamy soil and Laterite soil.

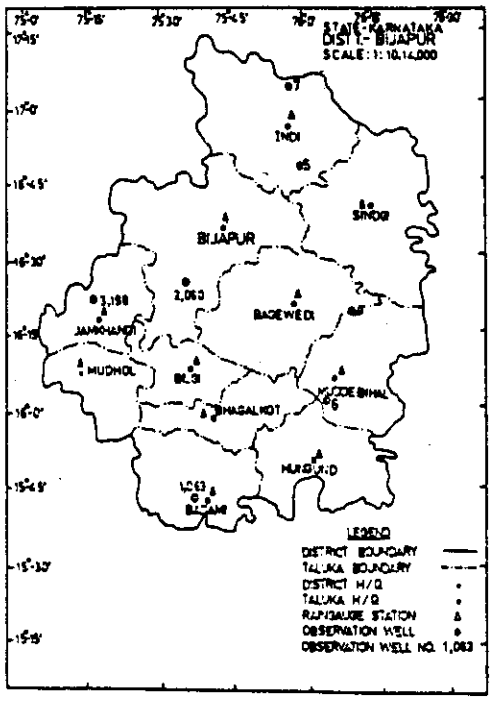
The land use in the district is, forests in 191095 ha, barren and uncultivable lands 47117 ha, land put to non-agricultural uses 50841 ha and culturable area, 1027281 ha. as per data from 1971-72 to 1979-80. The total irrigated area in the district is 127932 ha. The main river flowing through Belgaum district is Krishna. As per CWC studies of 1982, the normal annual rainfall of the district is 813.74 mm. Normally there are 52.75 rainy days in a year according to the data analysis for 1901-1980. There are 36 raingauge stations located in the District and density of raingauge station is 373.91 sq.km. per raingauge station as per data of year 1982. The maximum annual rainfall in the district is reported as 1220.36 mm in 1914. The south west monsoon gives about 67.33% of annual rainfall in the district. The coefficient of variation for annual rainfall has been estimated to be 24.31% for the district. As per C.G.W.B. data, the ground water potential of the district of one year is that the annual recharge of ground water is of order of 718.74 M.cum. while the draft is 302.9 m.cum. and surplus is 416.84 m.cum. in one year. The district faced 8 hydrological drought years during the period 1981 to 1980 according to CWC (1982) observation. The map of the district showing location of raingauges and groundwater observation wells which have been choosen for analysis is shown in fig. 2.5.

2.9.2 Bijapur

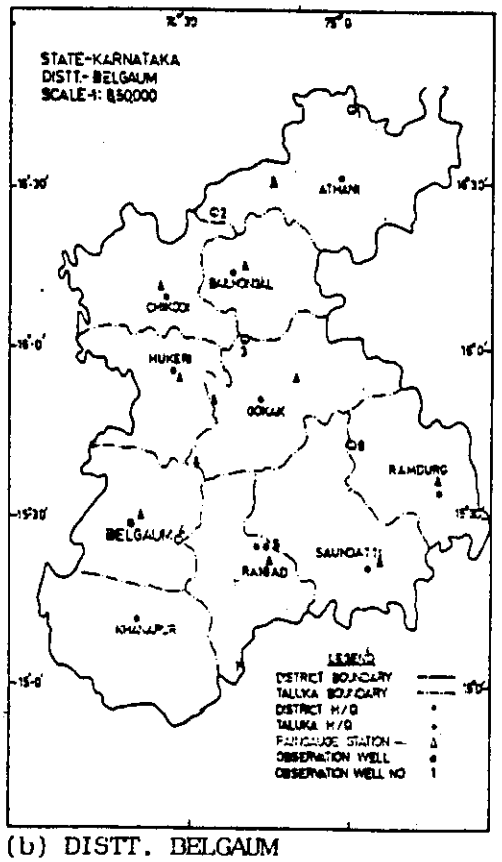
Bijapur district exist in the northern plain of Karnataka state. Geographically, it is located between $15^{o}20'$N to $17^{o}28'$N latitude and $74^{o}50'$E to $76^{o}28'$E longitude. The geographical area of the district is 17069 sq.km. The district consists of eleven talukas and has 1239 inhabited villages, 29 uninhabited villages and 17 towns. The population of the district

is estimated to be 23,99,124 and the density of population is reported as 140 persons per sq.km. according to the data available in 1981. There are two types of soils generally found in the district viz., Black, Mixed red and black soils. The land use in the district as per data from 1971-72 to 1980-81 is forests in 831103 ha., barren and uncultivable lands 51344 ha, land put to non-agricultural uses 44881 ha and culturable area 1515921 ha. The total irrigated area in the district is 96410 ha with the sourcewise distribution of 35137 ha. by surface water and 61273 ha. by ground water. The main rivers flowing through Bijapur district are Krishna and Bhima. The catchment area of mair Krishna river in the district is 8620 sq.km.

As per CWC studies of 1982, the normal annual rainfall of the district is 575.31 mm. Normally there are 44.06 rainy days in a year according to the data analysis from 1901 to 1980. There are 52 raingauge stations located in the district and density of raingauge station is 328.71 sq.km. per raingauge station as per data of year 1982. The maximum annual rainfall in the district was measured as 1097.00 mm in 1916. The south west monsoon gives about 63.74% of annual rainfall in the district. The coefficient of variation for annual rainfall has been found to be 24.55% for the district. As per C.G.W.B. data, the groundwater potential of the district of one year is that the annual recharge of groundwater is of order of 360.46 m.cum. while the draft is 275.06 m.cum. and surplus is 113.30 m.cum. in one year. The district faced 13 hydrological drought years during the period 1951 to 1980 according to CWC (1982) observation. The map of the district showing location of raingauges and groundwater observation wells which have been choosen for analysis is shown in figure 2.5.



(a) DISTT. BIJAPUR



(b) DISTT. BELGAUM

FIG. 2.5 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

2.9.3 Gulburga

Gulburga district lies in the northern part of Karnataka state and the geographical location of the district is between $16^{\circ}12'$ to $17^{\circ}46'$ latitudes and $76^{\circ}04'$ to $77^{\circ}42'$ longitudes. The district has geographical area of 16167.8 sq.km. and this district is one of the drought affected districts of the state. The district consists of ten talukas and has 1305 inhabited villages, 82 uninhabited villages and 14 towns. The population of Gulburga district is 2075368 & density of population is 128 persons per sq.km. according data available in 1981.

It has been reported that generally the district has three types of soils viz. red soils, black soils and alluvial soils. The land use in the district as per data from 1970-71 to 1979-80 is forests in 70172 ha., land put to non agricultural uses 47538 ha., barren & unculturable land 75059 ha. and culturable area 1,362,577 ha. As per the data available from 1970-71 to 1979-80 the total irrigated area in the district is 26598 ha. with the source wise distribution of 10314 ha. by surface water and 16284 ha. by groundwater. Through Bulburga district the main rivers flow include the Krishna and Bhima.

As per CWC studies of 1982 the normal annual rainfall of the district is 768.63 mm. Normally there are 51.49 rainy days in a year according to analysis of data from 1901 to 1980. There are 53 raingauge stations located in the district and density of rain gauge station is 305.05 sq.km./ per raingauge station as per data of year 1982. The maximum annual rainfall in the district was experienced as 1431.9 mm in year 1903. The south-west monsoon gives about 76.28% of annual rainfall in the district. The coefficient of variation for annual rainfall has been reported as 27.26% for the district. The groundwater potential of the

district as per CGWB data of one year is that the annual recharge to groundwater is of the order of 1295.76 m.cum. while the draft is 183.60 m.cum. and surplus is 1112.16 m.cum. in one year. As per CWC (1982) observations the district faced 12 hydrological drought years during the period 1951 to 1980. The map of the district showing location of raingauges and groundwater observation wells which have been selected for analysis are shown in fig. 2.6.

2.9.4 Raichur

Raichur district is situated in the North Eastern fringe of Karnataka state. The geographical location of the district is between $15^{o}9'$ to $16^{o}34'$ N latitudes and $75^{o}46'$E to $77^{o}35'$E longitudes. The area of the district is 14005 sq.km. The district consists of nine talukas and has 1387 inhabited villages, 129, uninhabited village and 10 towns. The population of Raichur district is 1779942 & density of population 127 person per sq.km. as per 1981 census.

The soils in the district are generally three types viz. black cotton, red, & grey sandy soils. The land use in the district as per data from 1970-71 to 1978-79 is, forests in 32424 ha., land put to non agricultural uses 51717 ha., barren & unculturable land 51385 ha., and culturable area 1213479 ha. The total irrigated area in the district is 153381 ha. with the source-wise distribution of 138894 ha. by surface water and 13793 ha. by ground water 698 ha. by other sources. Krishna & Tungabhadra are the two main rivers flowing through the Raichur district. The catchment areas of these river basins in the district are 4221 sq.km. for Krishna 9617 sq.km. for Tungbhadra.

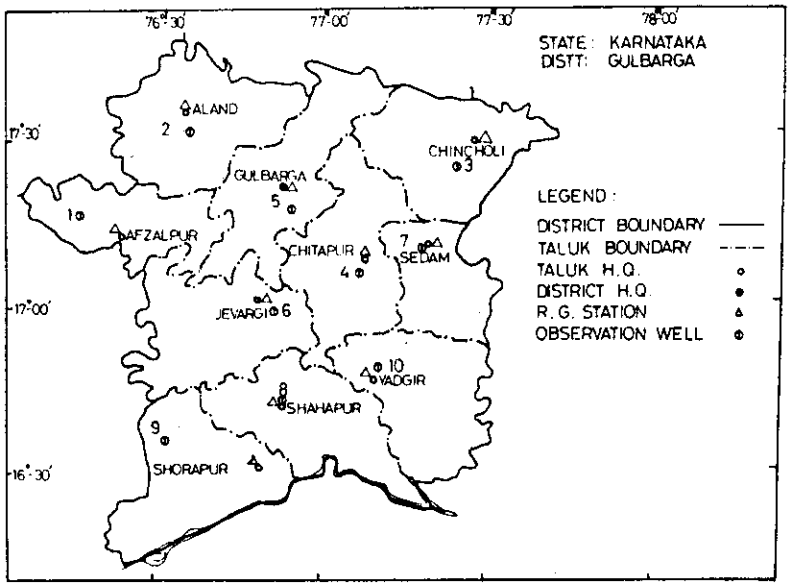
As per CWC studies of 1982 the normal annual rainfall of the district is 604.21 mm. Normally there are 40.08 rainy days

in a year according to analysis of data from 1901 to 1980. There are 43 raingauge stations located in the district and density of rain gauge station is 325.70 sq.km. per raingauge station as per data of year 1982. The maximum annual rainfall in the district was experienced as 1224.02 mm in year 1916. The south-west monsoon gives about 69.66% of annual rainfall in the district. The coefficient of variation for annual rainfall has been reported as 25.90% for the district. The groundwater potential of the district as per CGWB data of one year is that the annual recharge to groundwater is 296.05 m.cum. while the draft is 124.84 m.cum. and surplus is 176.84 m.cum. in one year. As per CWC (1982) observations the district faced 14 hydrological drought years during the period 1951 to 1980. The map of the district showing location of raingauges and groundwater observation wells which have been choosen for analysis is shown in fig. 2.6.

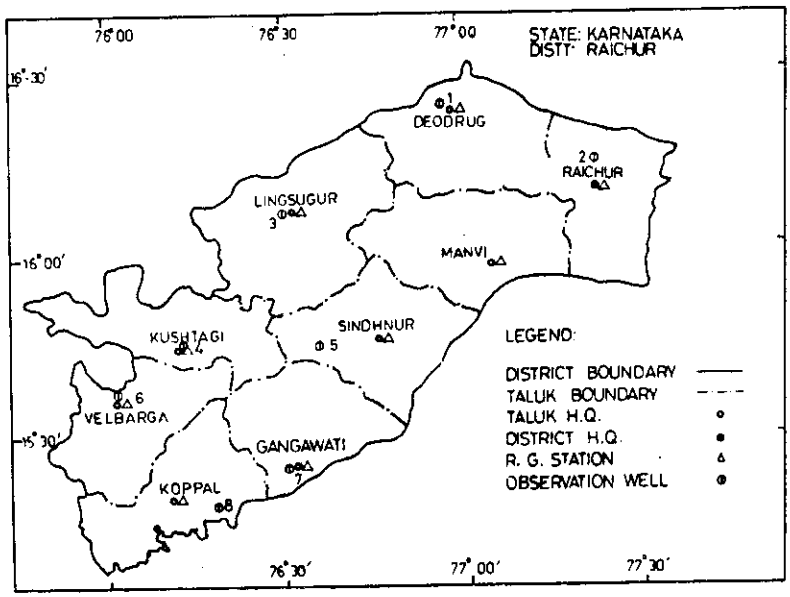
2.9.5 Bellary

Bellary district is situated in the North Eastern fringe of Karnataka state. Its geographical location is between $14^{\circ}30'$ to $15^{\circ}50'$ N latitudes and $75^{\circ}40'$E to $77^{\circ}11'$E longitudes. The geographical area of the district is 9898 sq.km. The district consists of eight talukas and has 589 inhabited villages, 34 uninhabited village and 12 towns. The population of district is 1487062 & the density of population is calculated to be 150 persons per sq.km. as per data of 1981 census.

Three types of soils are generally found in the district viz. Red, & Black soils, and mixed soils. The land use in the district as per data from 1976-77 to 1979-80 is, forests in 117,416ha., barren and uncultivable lands 61554 ha, land put to non agricultural uses 79649 ha., and culturable area 690615 ha. The total irrigated area in the district is 97223 ha. with the



(a) DISTT. GULBARGA



(b) DISTT. RAICHUR

FIG. 2.6 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

sources wise distribution of 79395 ha. by canals, 6899 ha. by tanks, 10960 ha. by wells and 2969 ha, by other sources. The main rivers flowing through the Bellary districts Tungabhadra. The catchment areas of the main Tungabhadra is 6780 sq.km.

As per CWC studies of 1982, the normal annual rainfall of the district is 629.45 mm. Normally there are 43.23 rainy days in a year according to analysis of data from 1901 to 1980. There are 36 raingauge stations located in the district and density of rain gauge station is 274.94 sq.km. per raingauge station as per data of year 1982. The maximum annual rainfall in the district was measured as 964.02 mm in year 1933. The normal annual rainfall in the south monsoon is 59.79% in the district. The coefficient of variation for annual rainfall has been found to be 21.62% for the district.

The groundwater potential of the district of one year is that the annual recharge to groundwater is of order of 261.93 m.cum. while the draft is 81.93 m.cum. and surplus is 182.09 m.cum. in one year as per C.G.W.B data of 1982. The district faced 10 hydrological drought years during the period from 1951 to 1980 according the CWC (1982) observation. The map of the district showing the location of raingauges and groundwater observation wells which have been choosen for analysis is shown in fig. 2.7.

2.9.6 Dharwad

Dharwad, a district of Karnataka exist in the Northern plain of state. The geographical location of the district is $14^{o}17'$N to $15^{o}50'$N latitudes and $75^{o}48'$E to $76^{o}0'$E longitudes. The geographical area of the district is 13738 sq.km. The district consists of seventeen talukas and has 1337 inhabited villages, 112 uninhabited village and 18 towns. The population of district is reported to be 2939988 and the density of population

is found to be 214 persons per sq.km. as per data available of 1981. Three types of soils are generally found in the district viz. Black, and Mixed Red & Black soils and Red sandy soils. The land use in the district as per data from 1971-72 to 1980-81 is,forests in 111866 ha., barren and uncultivable lands 29909 ha, land put to non agricultural uses 27962 ha., and culturable area 1170465 ha. The total irrigated area in the district is 80300 ha. with the sources wise distribution of 69250 ha. by surface water and 11050 ha. by groundwater. The main river flowing through Dharwad district is Krishna. The catchment areas of the main Tungabhadra river with in the district is 3382 sq.km.

As per CWC studies of 1982, the normal annual rainfall of the district is measured to be 729.61 mm. and normally, there are 55.45 rainy days in a year according to the data analysis from 1901 to 1980. There are 66 raingauge stations located in the district and density of rain gauge station is 208.15 sq.km. per raingauge station as per data of year 1982. The maximum annual rainfall in the district was reported as 996.29 mm in year 1979. The southwest monsoon contributes about 60.21% of normal annual rainfall in the district. The coefficient of variation for annual rainfall has been measured as 17.10% for the district.

As per C.G.W.B. data, the groundwater potential of the district of one year is that the annual recharge to groundwater is of order of 576.88 m.cum. while the draft is 101.71 m.cum. and surplus is 485.18 m.cum. in one year. The district faced 10 hydrological drought years during the period from 1951 to 1980 according the CWC (1982) observation. The map of the district showing the location of raingauges and groundwater observation wells which have been choosen for analysis is shown in fig. 2.7.

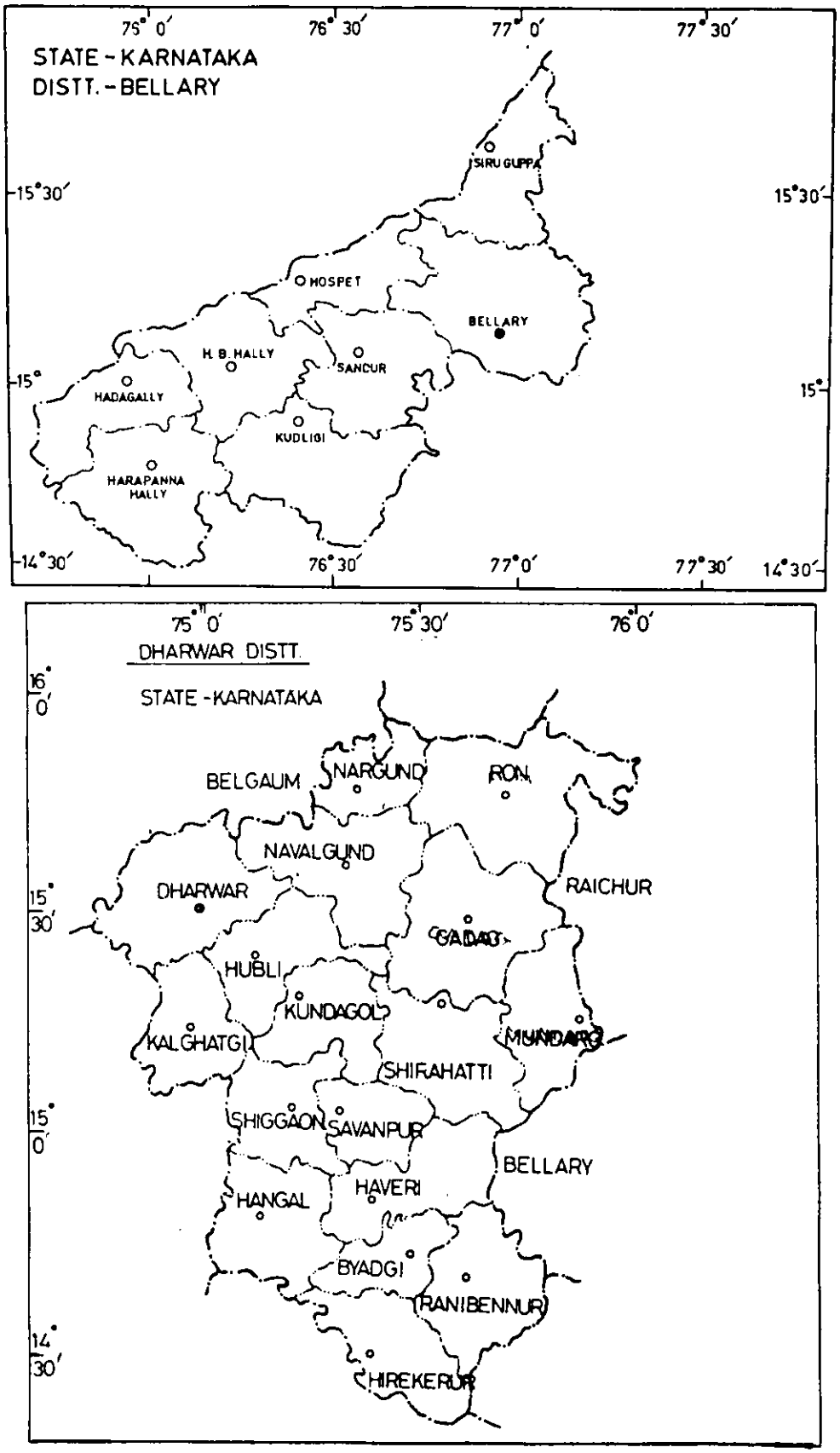


Fig.2.7 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

3.0 RAINFALL ANALYSIS

3.1 General

As has already been described in chapter 2.0, Six district, namely Belgaum, Bijapur, Gulburga, Raichur, Bellary & Dharwar from the state of Karnataka have been taken up for rainfall analysis in the present report. One representative raingauge station from each taluk in each of the six district has been selected for the study. The locations of raingauges on the district maps have been shown in figures presented in chapter 2.0. The raingauge stations selected for the study are the ones which were selected by Central Water Commission for carrying out studies for identification of drought prone areas in 1982. The analysis of rainfall data has been carried out with the data from year 1901-1988. The data from 1901 to 1980 have been extracted from CWC reports (CWC 1982). The remaining data from 1981 to 1988 have been collected during visits of scientific teams to various central/state Govt. offices in the state Karnataka.

3.2 Rainfall Departure Analysis

3.2.1 Seasonal rainfall departure

In order to compute the deficiency of rainfall on seasonal basis seasonal rainfall Departure analysis has been carried out. The data from period 1970-87 have been used for this analysis. Seasonal normals for the six chosen districts of Karnataka have been calculated as the summation of normals for the months (June to September) as provided in the CWC reports. Only four months i.e. June, July, August and September are taken in acccunt while estimating seasonal normals. The results of

analysis are given in table 3.1. The graphical representation of seasonal deficiencies are shown in Fig.3.1. The major inferences that could be drawn from the seasonal analysis are:

Table 3.1 : Seasonal Rainfall Analysis for the Districts of Bijapur, Belgaum, Gulburga, Raichur, Dharwar and Bellary of state Karnataka

District Bijapur (State Karnataka)			
Year	Seasonal rainfall	Seasonal normal rainfall	Percent departure
1970	620.73	537.47	+15.5
1971	591.3		+10.0
1972	335.3		-37.6
1973	635.56		+18.2
1974	689.21		+28.2
1975	869.36		+61.7
1976	356.38		-33.7
1977	657.16		+22.2
1978	703.79		+30.9
1979	688.81		+28.1
1980	397.32		-26.0
*1981	843.78		+56.99
1982	570.18		+ 6.08
*1983	534.0		- 0.65
1984	435.7		-19.06
1985	418.7		-22.22
1986	454.28		-15.48
1987	739.39		+37.56

*Based on average of Bijapur India, Bagalkot, Mudebihal & Mudhol taluks only. Other data not available

District Belgaum (State Karnataka)

1970	709.46	806.82	-21.0
1971	633.79		-21.4
1972	620.58		-23.1
1973	763.21		- 5.4
1974	886.65		+ 9.9
1975	1009.69		+25.1
1976	660.32		-18.1
1977	852.32		+ 5.6
1978	816.0		+ 1.1
1979	925.39		+14.7
1980	742.0		- 8.0
1981	** 360.6		+ 6.67
1982	** 688.02		-14.72
1983	763.1		- 5.4
1984	575.2		-29.08
1985	528.35		-34.51
1986	608.77		-24.55
1987	654.6		-18.87

**Values are based on average Rainfall of Belgaum, Chkodi, Athani and Gokak taluks only, since data for other taluks were not availabie.

District Gulbarga (State Karnataka)

1970	744.63	726.83	2.45
1971	415.96		-42.77
1972	379.75		-47.75
1973	947.02		30.30
1974	958.19		31.83
1975	1280.44		76.17
1976	705.74		- 2.90
1977	908.35		24.97
1978	1005.37		38.32
1979	833.88		14.73
1980	690.45		- 5.01
1981	1095.91		50.78
1982	792.16		8.99
1983	1185.27		63.07
1984	654.31		- 9.98
1985	618.54		-14.90
1986	556.77		-23.40
1987	814.29		12.03

District Raichur (State Karnataka)

1970	586.12	573.05	2.28
1971	397.63		-30.61
1972	341.76		-40.36
1973	570.93		- 0.37
1974	634.39		10.70
1975	532.54		- 7.07
1976	353.39		-38.33
1977	523.35		- 8.67
1978	580.95		1.38
1979	580.48		1.30
1980	381.23		-33.47
1981	691.11		20.60
1982	554.79		- 3.19
1983	622.47		8.62
1984	449.43		-21.57
1985	402.09		-29.83
1986	477.68		-16.64
1987	602.71		5.18

District Bellary (State Karnatka)

1970	723.95	582.32	24.32
1971	633.71		8.82
1972	525.08		- 9.83
1973	689.25		18.36
1974	666.03		14.38
1975	865.98		48.71
1976	280.54		-51.82
1977	621.08		6.66
1978	698.45		19.94
1979	594.76		2.14
1980	535.45		- 8.05
1981	816.14		40.15
1982	709.36		21.82
1983	783.93		34.62
1984	887.70		52.44
1985	390.61		-32.92
1986	690.51		18.58
1987	671.36		15.29

District Dharwar (State Karnataka)

1970	660.82	671.52	- 1.59
1971	593.42		-11.63
1972	518.54		-22.78
1973	613.38		- 8.66
1974	752.82		12.11
1975	809.09		20.49
1976	443.59		-33.94
1977	626.03		- 6.77
1978	794.08		18.25
1979	896.84		33.55
1980	706.02		5.14
1981	621.58		- 7.44
1982	717.22		6.81
1983	586.34		-12.69
1984	518.56		-22.78
1985	380.49		-43.34
1986	604.88		- 9.92
1987	677.69		0.92

All the six districts experienced deficient seasonal rainfall in three consequetive years i.e. 1984 to 1986 except district Bellary. However the scence of seasonal rainfall is quite different in the year 1987-88. Only one district of Belgaum were deficient in seasonal rainfall during 1987-88, out of six selected districts. Thus in the year 1987-88 almost all the six district did not experience drought conditions as per seasonal rainfall departure analysis is concerned.

3.2.2 Monthly rainfall departure for the year 1987-88

In order to observe deficiency in monthly rainfall during the year 1987-88, monthly departures have been worked out for the six districts. This analysis has been done for all the taluks and district as a whole. Monthly rainfall values from June'87 to May'88 alongwith monthly normals of representative

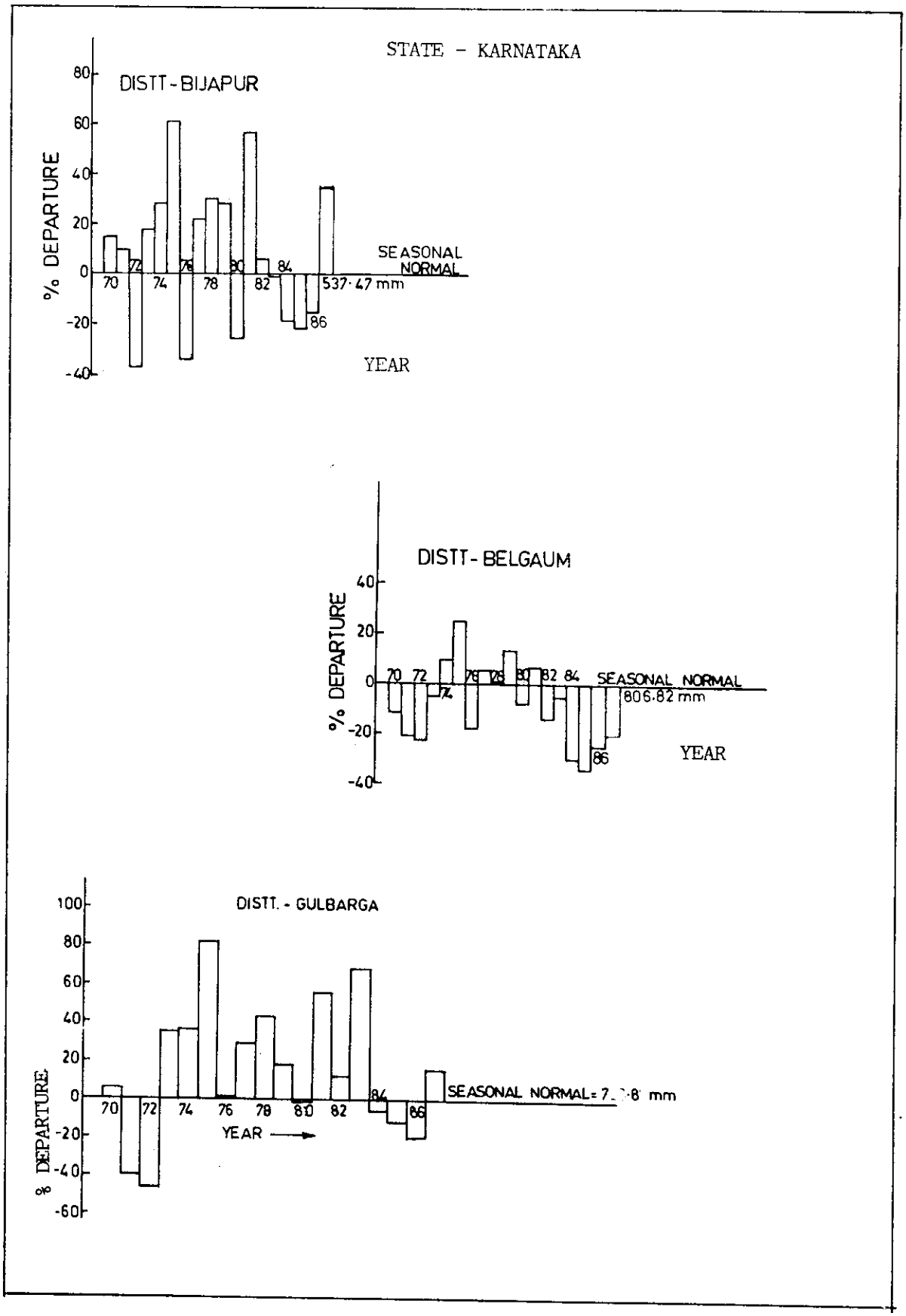


Fig. 3.1 : Distictwise Seasonal Rainfall Departure

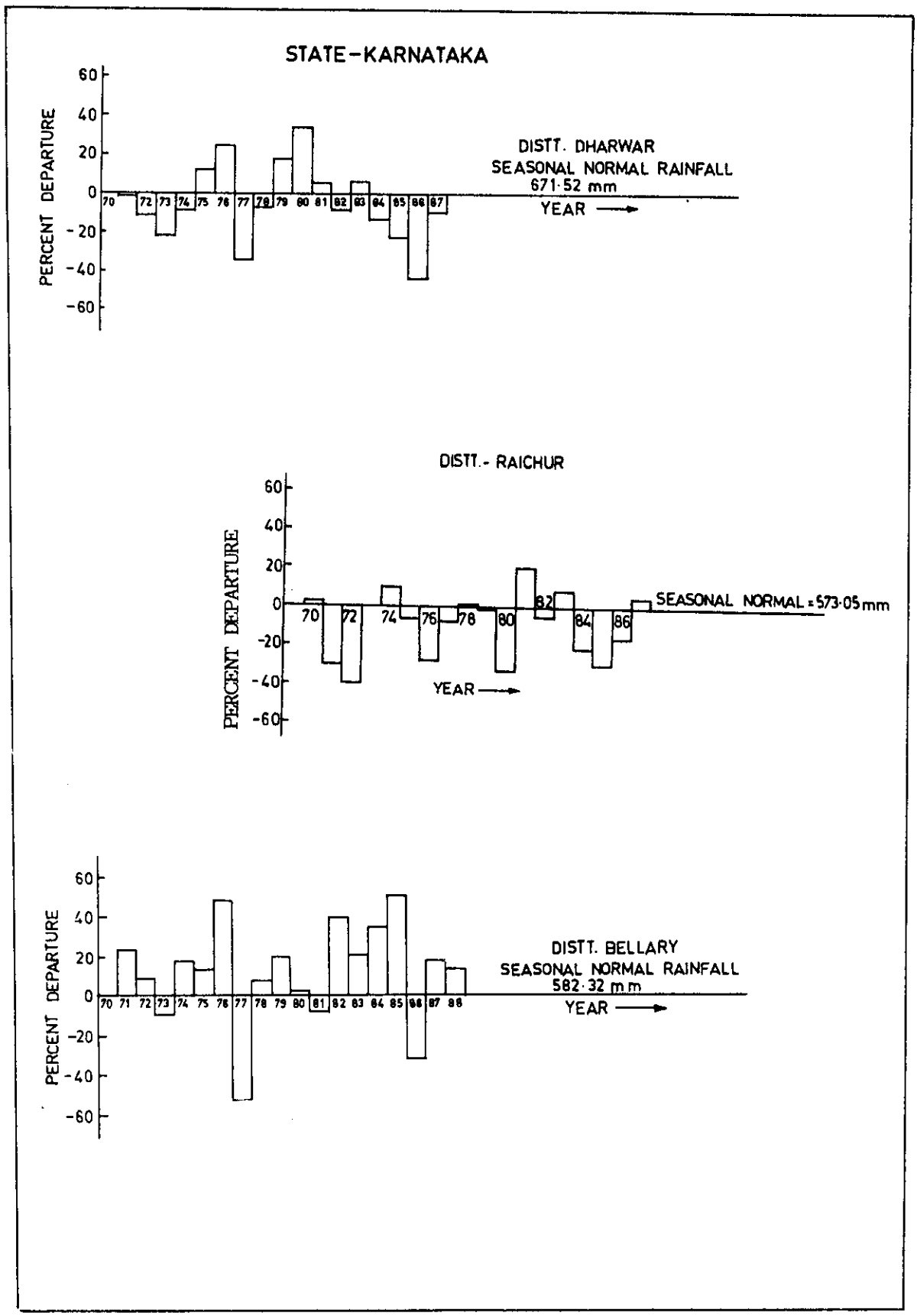


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

raingauges of various taluks have been considered for the purpose. Monthly rainfall values for a district from June'87 to May'88 have been computed as weighted average rainfall of all the taluks considered for analysis in the district. Monthly normals of districts have been directly taken from reports of CWC (CWC,1982). It may be mentioned that in case of some districts/taluks monthly departure analysis has been limited to some months only due to data availability constraints.

The variations in rainfall monthwise (monthly rainfall & corresponding normals) have been plotted for all the six districts for water year June'87 to May'88, and are shown in figures 3.2. The departure figures for one representative taluk of all the six districts are shown in Appendix III-1. The results of monthly departure analysis for the districts as a whole are presented in Table 3.2. Based on the monthly departure values, two categories of monthly departure i.e. 20-50% and more than 50% have been made for deriving monthly deficiency inferences. Table 3.2 gives description of districts in the state which experienced rainfall deficit during months of June'87 to May'88 in these two ranges viz. 20 to 50% and more than 50%. The following inferences can be drawn from the results shown/presented in figures 3.2, Appendix III-1 and Table 3.2.

In some of the districts of state Karnataka, for example Bellary, Dharwar & Bijapur positive departures in monthly rainfall have been recorded. Some districts have deficient monthly rainfall in the ranges of 20% to 50%. The deficiency pattern has been more or less similar in case of Bellary, Bijapur & Dharwar. The district of Belgaum recorded maximum deficient months in the year 1987-88. The overall picture of monthly rainfall departure analysis is similar to that of seasonal rainfall departure analysis for all the six selected district in the year 1987-88.

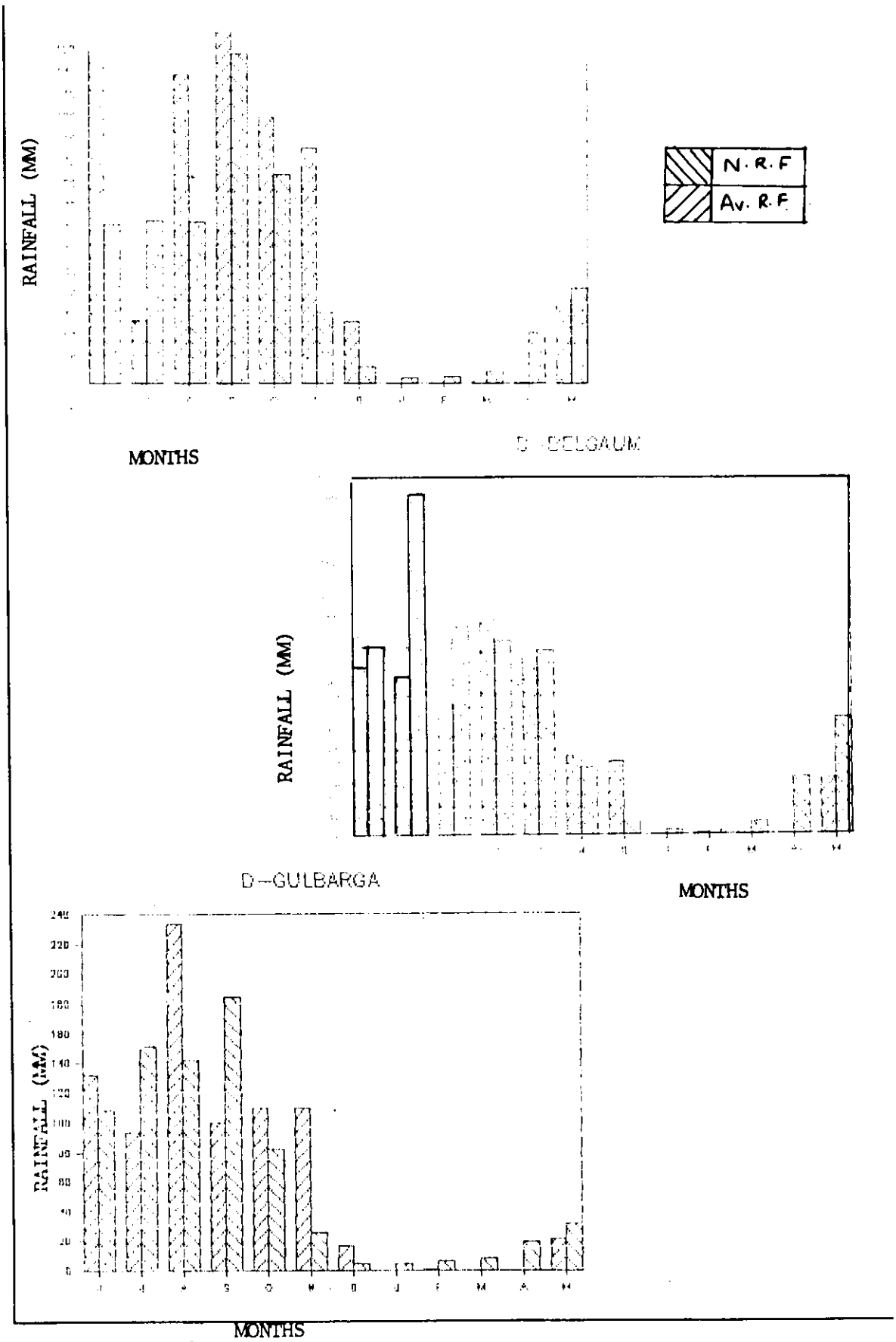


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

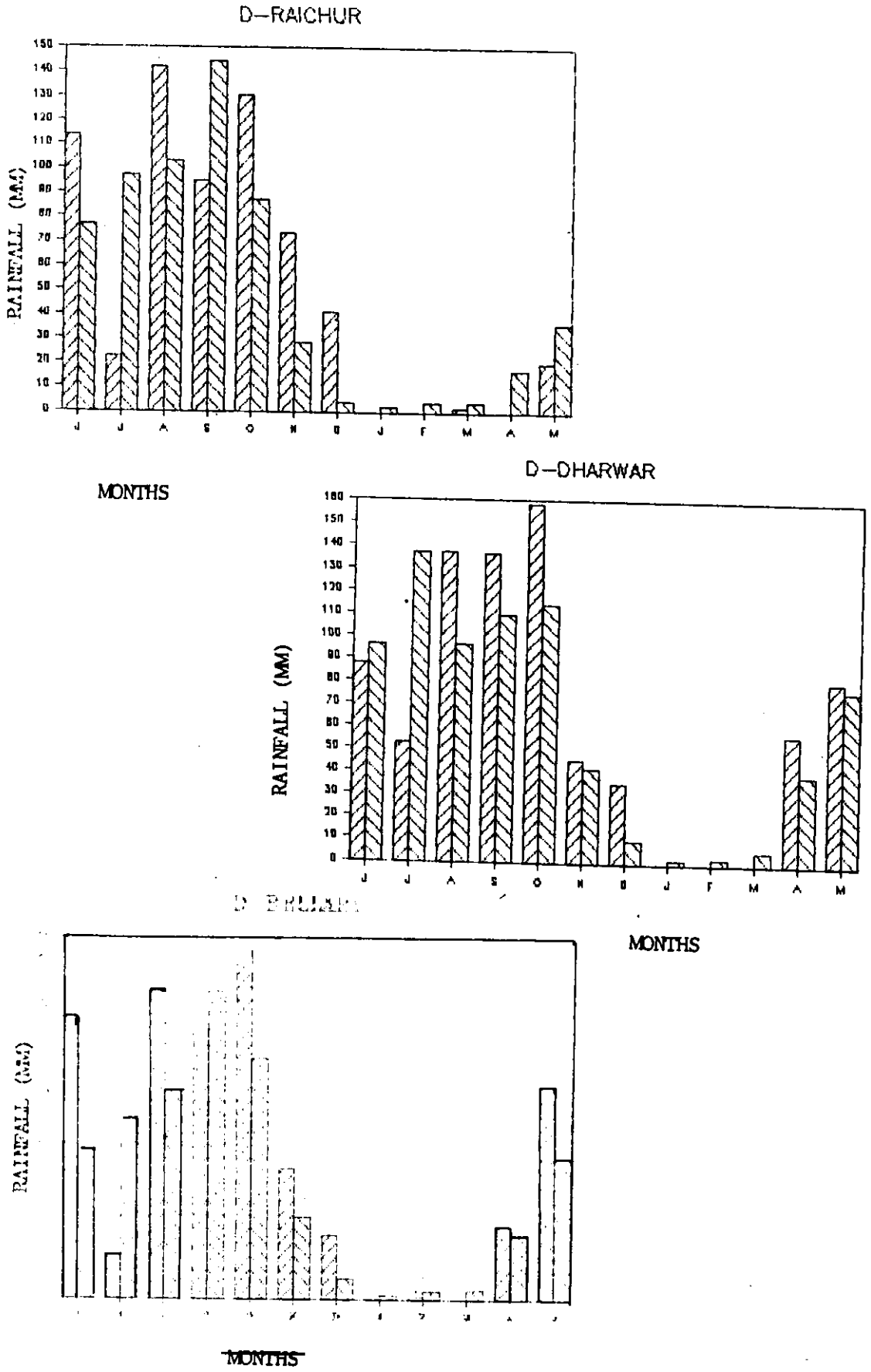


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

Table 3.2 : Monthly Rainfall Deficits in District as a Whole During 1987-88

State	Months	Group Range of Deficiency in rainfall (expressed percentage of normals)	
		20 to 50%	50% and above
Karnataka (Total distt. taken 6)	June'87		
	July	Gulburga	Bijapur,Dharwar, Belgaum,Bellary
	August	Belgaum	
	September	Gulburga	
	October		
	November		
	December		
	January'88		Bijapur,Gulburga, Dharwar,Belgaum, Bellary
	February		Bijapur, Gulburga, Dharwar,Belgaum, Bellary
	March		Bijapur, Gulburga, Dharwar, Belgaum, Bellary
	April		Bijapur, Gulburga, Belgaum
	May	Gulburga	Belgaum

3.3 Frequency of Rainfall

3.3.1 Probability analysis of annual rainfall

Probability is a constant characterising given set of objects or incidents in a particular period. The probability analysis of annual rainfall is useful to predict with reasonable accuracy the relative frequency of occurrence in different group intervals of annual rainfall. It is also possible to work out the percentage probability of occurrence of 75% of annual rainfall or more for identification of drought proneness of district/taluk/tehsil.

Two taluks from each district and district as a whole have been selected for probability analysis of annual rainfall. The analysis has been carried out based on the data available from 1901 to 1987 and probability expressed both in number of years of occurrence and the percentage of years for each group interval. Group interval of 100 mm has been considered for the analysis.

The probability distribution curves have been drawn by plotting the values of percentage of cummulative probability in respect of various groups at their corresponding midpoint. The cummulative percentage have been worked out starting from the maximum rainfall group downwards adding the successive percentage.

Probability groups for all the six districts and also for two selected taluks in each districts of the state have been shown in figure 3.3 and appendix III-2 respectively. The range of annual rainfall at 75% probability level can be established using these graphs and such values for all districts and two taluks in district are given in Table 3.3. In order to find the drought proneness of the districts, the percentage probability of occurrence of 75% normal rainfall of the district has also been worked out and the results are given in table 3.3. It can be seen

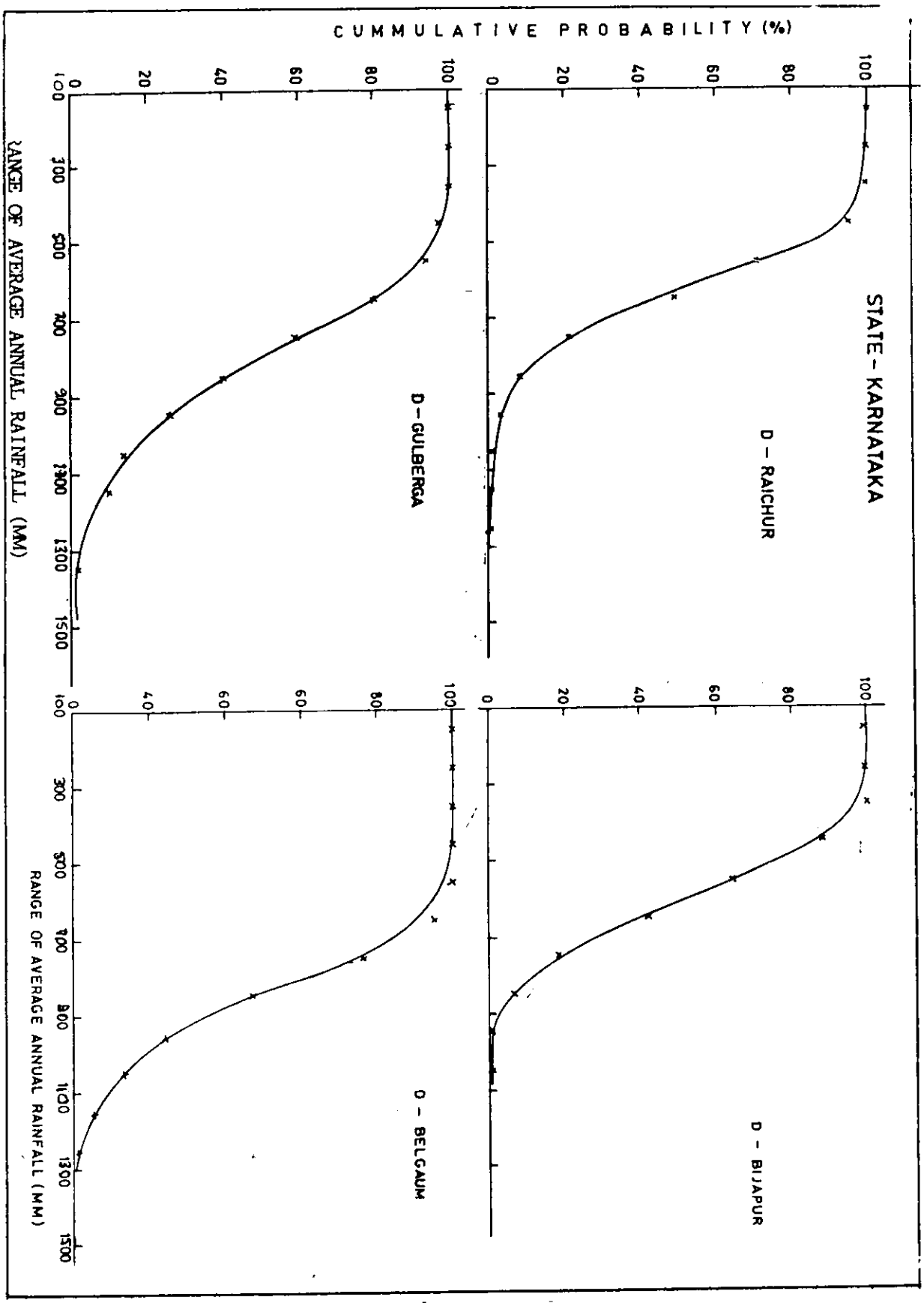


Fig. 3.3 : Districtwise Probability of Annual Rainfall

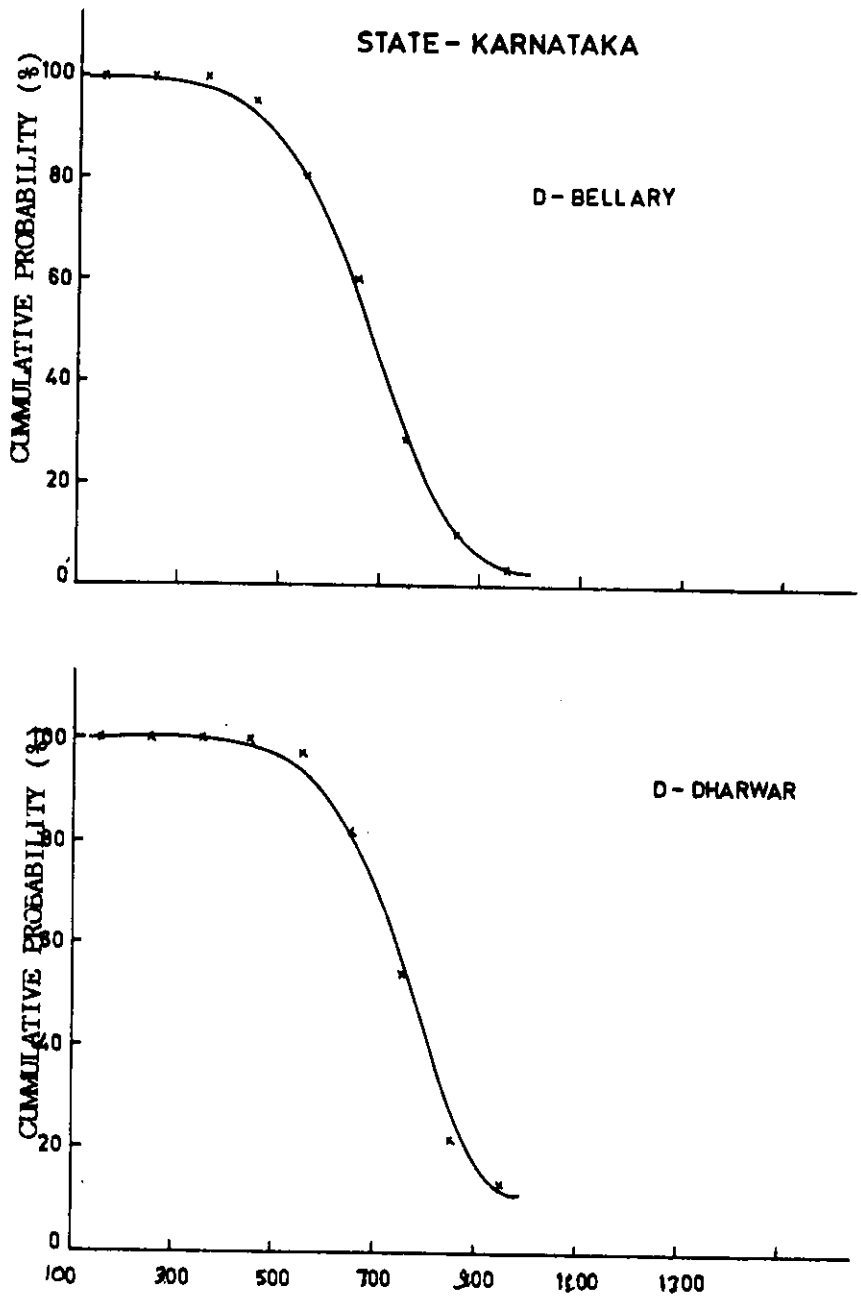


Fig.3.3 : Districtwise Probability of Annual Rainfall

from table that all the six districts have more than 80% of probability of getting 75% of normal rainfall indicating that the districts are less prone to drought conditions.

Table 3.3 : Probability Distribution of Annual Rainfall of State Karnataka

Sl.	District	Name of Taluks	75% probability & above (Range in mm)	Probability of occurrence of rainfall equivalent to 75 percent normal (in %age)
1.	Bijapur	Bijapur	[illegible]-500	79
		Bagalkot	500-600	82
		District as a whole	500-600	83
2.	Belgaum	Belgaum	1100-1200	83
		Chikodi	500-600	84
		District as a whole	700-800	82
3	Gulburga	Gulburga	600-700	83
		Afjalpur	500-600	78
		District as a whole	600-700	83
4.	Raichur	Raichur	500-600	84
		Koppal	500-600	80
		District as a whole	500-600	84
5.	Bellary	Bellary	400-500	83
		Harapan shalle	500-600	82
		District as a whole	500-600	84
6.	Dharwad	Dharwad	700-800	84
		Hanagal	800-900	84
		District as a whole	600-700	86

3.3.2 Probability of occurrence of rainfall equivalent to 75% of the normal rainfall

For identification of drought proneness of the district/taluk, the percentage probability of occurrence of rainfall equivalent to the 75% of normal rainfall or more has also been worked out from the Figures 3.3 and Appendix III-2 and the values are presented in Table 3.3. As per IMD criteria, an area would be classified as drought prone if probability of rainfall equivalent to 75% of normal is below 80% indicating that more than 20% of years, the area experienced scarcity of rain. Central Water Commission has carried out analysis and identified drought prone areas on this ground (CWC, 1982). Using this criteria, inferences drawn from values in table 3.3 are as below:

The probability values of occurrence of 75% normal rainfall in all the six districts namely Belgaum, Bijapur, Gulburga, Raichur, Bellary & Dharwar are 82, 83, 83, 84, 84 & 86 respectively which are all above 80%indicating that the district are not drought prone based on this analysis as per IMD criteria. This infers that the districts of Belgaum, Bijapur, Gulburga, Raichur, Bellary and Dharwar experienced rainfall less than 75% of normal in 18, 17, 17, 16, 16 & 14 percent of year respectively. The taluks of all the six districts showed similar results indicating that these taluks as well as district as a whole are less prone drought as per IMD criteria.

3.4 Excess/Deficit Rainfall Using Herbst Approach

3.4.1 model Description

Herbst et al (1966) evolved a new method of drought analysis using monthly rainfall data, whereby it was possible to determine the duration and intensity of droughts and their months of onset and termination.

The model uses the following steps to calculate indices to evaluate onset and termination of droughts.

A. Calculation of mean monthly rainfall, MMR

From the long record of monthly rainfall, the mean rainfall for all the months (i.e. mean monthly rainfall, MMR) is calculated:

$$MMR(J) = \sum_{I=1}^{NYR} \frac{RF(I,J)}{NYR} \qquad \ldots(1)$$

Here MMR = Mean monthly rainfall

RF = Rainfall

NYR = Number of years of record

Suffix I and J denote years and months respectively.

B. Calculation of mean annual precipitation (MAP)

Mean annual precipitation (MAP) is calculated for entire period of record.

$$MAP = \sum_{J=1}^{NMN} MMR(J) \qquad \ldots(2)$$

where NMN = Number of months in a year

C. Calculation of Effective Rainfall

For calculation of drought criteria, the carry over effects from month to month is considered. For this purpose, the mean monthly rainfall for a month, say (J) is substracted from the actual rainfall for that month (J) so that deficit or excess for that month is obtained. This deficit or excess is multiplied by a 'weighting factor' for the next month (J+1) and the product whether negative or positive, is added algebraically to the rainfall figure of that month (J+1). This sum becomes the 'Effective rainfall' (ER) for that month (J+1).

The 'weighting factor' for a month used to calculate carryover effects is derived from an empirical formula as suggested by Herbst et al (1966).

$$W(J) = 0.1^{*} \left[1 + \frac{MMR(J)}{1/12 * MAP} \right] \qquad \ldots(3)$$

W(J) = weighting factor for j^{th} month

The carry over for j^{th} month and corresponcing effective rainfall is calculated as under:

$$CO(I,J) = ER(I,J-1) - MMR(J-1) \qquad \ldots(4)$$

$$ER(I,J) = RF(I,J) + CO(I,J) * W(J) \qquad \ldots(5)$$

Here CO = Carry over factor

For the first month of first year of record, the effective rainfall has been assumed as equal to monthly rainfall. Thus for I = 1 and J = 1,

$$ER(1,1) = RF(1,1) \qquad \ldots(6)$$

There upon the effective rainfall for each month of every year was calculated by allowing for the carry over effect of a surplus or deficit of rainfall in the preceding month. The process is continued to obtain the effective monthly rainfall for the full period of record.

D. Calculation of mean annual deficit

The difference of effective rainfall for a month and 'Mean Monthly Rainfall' for that month is obtained for full period of record and termed as 'Difference'.

$$DIFF(I,J) = ER(J,J) - MMR(J) \qquad ...(7)$$

These 'differences' for various months of the record, if greater than or equal to zero, were reported as zero. Thus the 'Mean Monthly Deficits (MMD)' were based not only on those months in which a negative difference occurred, for positive differences (i.e., negative deficits) were taken as zero and thus also included in the computation.

$$MD(I,J) = 0.0; \text{ for } DIFF(I,J) > 0.0 \qquad ...(8)$$

$$MD(I,J) = DIFF(I,J); \text{ for } DIFF(I,J) < 0.0 \qquad ...(9)$$

In this way 'Mean Monthly Deficit' for each month of every year was calculated:

$$MMD(J) = \left[\sum_{J=1}^{NYR} MD\ (I,J) \right] * \frac{1}{NYR} \qquad ....(10)$$

The summation of Mean Monthly Deficits yields Mean annual deficit (MAD) or,

$$MAD = \sum_{J}^{NMN} MMD(J) \qquad ...(11)$$

Here MD = Monthly deficits or monthly differences

MMD = Mean monthly deficit

MAD = Mean annual deficit

Mean annual deficit is used in testing for onset and termination of drought.

The analysis includes establishment of another set of termination drought. This includes maximum parameters used for test of start and termination drought. This includes maximum of Mean Monthly Rainfall (MMMR), the sum of two highest values of mean monthly rainfall, the sum of three highest values of mean monthly rainfall and so on up to the sum of mean monthly rainfall of all the months yielding a value equal to mean annual rainfall.

E Test to Determine onset of drought

From the given record, a month with a negative difference is found, while inspecting delete negative difference, the following two cases may arise.

Case (A) Delete negative difference < MMMR

Case (B) Delete negative difference > MMMR

Case (A) Delete negative difference < MMMR

If delete negative difference is less than MMMR, the difference of the next month is inspected and if negative is added to the negative difference of the previous month and compared with the second values on the sliding scale, (MMMR + x). If sum of these two delete negative difference exceeds (MMMR + x), the drought is deemed to have started from the previous month. In this manner the absolute value of sum of all negative differences occurring from the first month over a period of a year is tested sequentially against the twelve values of the sliding scale. If at any time the summed value of delete negative difference from

the first to the J^{th} month exceeds the value MMMR+(J-1)x, drought is deemed to have started from the first month.

Case (B) Delete negative difference ≥ MMMR

In this case when the delete negative difference is greater than or equal to MMMR, the drought is deemed to have stated from this month.

F Tests to determine the termination of drought

Once the start of the drought is found, the program begins to search for a month with a positive difference.

A precondition to be satisfied is that at least one of the two months following the initial month with a positive difference should also have a positive difference. Once this condition is met. then only the initial month is qualified for further testing for termination of drought. Thus for further testing for termination of drought a precondition to be satisfied is that two consecutive months should have positive difference.

Once this condition is met, the following two tests are carried out for testing for termination of drought:

i) In this test the differences are algebrically summed up from the month, the drought started to the month of the termination test. If the sum became positive, the drought is deemed to have terminated otherwise second test is carried out for testing of termination.

ii) The second tests comprises of ten sequential tests. Firstly the actual rainfall values from the first to the third month of testing are mmed up and compared with the sum of three highest values of mean monthly rainfall. If the sum of actual rainfall is higher the

drought is considered to have been terminated. If the sum of actual rainfall is not exceeded, then the sum of actual rainfall of first four month is compared with the sum of the four highest values of mean monthly rainfall, and so on should the drought not yet have been terminated, upto a comparison of the sum of the rainfall of the rainfall of the twelve months following and including the month from which the test commenced, with the mean annual rainfall. By this stage either the drought had been terminated, in which case it was deemed to have ended in the month from which the multiple test had been initiated or the drought conditions prevailed over this period and test for the termination recommenced at the first month with a positive difference following that from which the previous unsuccessful test had proceeded.

Once a termination had occurred testing for the start of the next drought began at the first month with a negative difference following the month in which the drought ended.

(G) Evaluation of drought index

Drought intensity is evaluated by dividing the total deficits beyond the monthly mean deficit for the period of drought (D) by the sum of the mean monthly deficits for the same period.

$$\text{Drought Intensity (I)} = \frac{\sum_{J=IDST}^{IDEND} [MMR(J)-ER(J)] - MMD(J)}{\sum_{J=IDST}^{IDEND} [MMD(J)]} \quad \ldots(12)$$

WHERE IDST = Month of start of drought

IDEND = Month of termination of drought

In above equation if nominator is less than 0.0 (i.e., negative), than nominator is equalled to zero for calculation of drought intensity.

Severity Index (SI): Severity Index is defined as product of drought intensity and drought duration SI = I x D ..(13)

This analysis has been performed for six selected districts of state Karnataka. Monthly rainfall data for period 1951-1987 of raingauge station located at five selected taluk headquarters of each district have been used for analysis. A computer programme using the above approach has been developed for the analysis. The analysis has yielded in the distinct spells of drought alongwith monthly and the overall intensity of drought for all the spells. The results of analysis in tabular form for all districts are given in appendix III-3. The graphical representations of the drought spells with intensity for all districts are shown in figures 3.4. The following inferences can be drawn from the analysis (Reference fig. 3.4 & Appendix III-3).

All the six districts selected for study in state Karnataka recorded drought spells during the period 1984 to 1987. The district of Dharwar, however, experienced the longest duration of drought spell while in Bellary the spell duration was shortest amongst all. The intensity of drought was highest in case of Bellary and lowest for the Gulburga. In general, all the districts experienced 6 to 13 no. of drought spells during the period of 1951-87. Over the entire period, the district of Gulburga experienced longest drought spell from 1962-72 while the

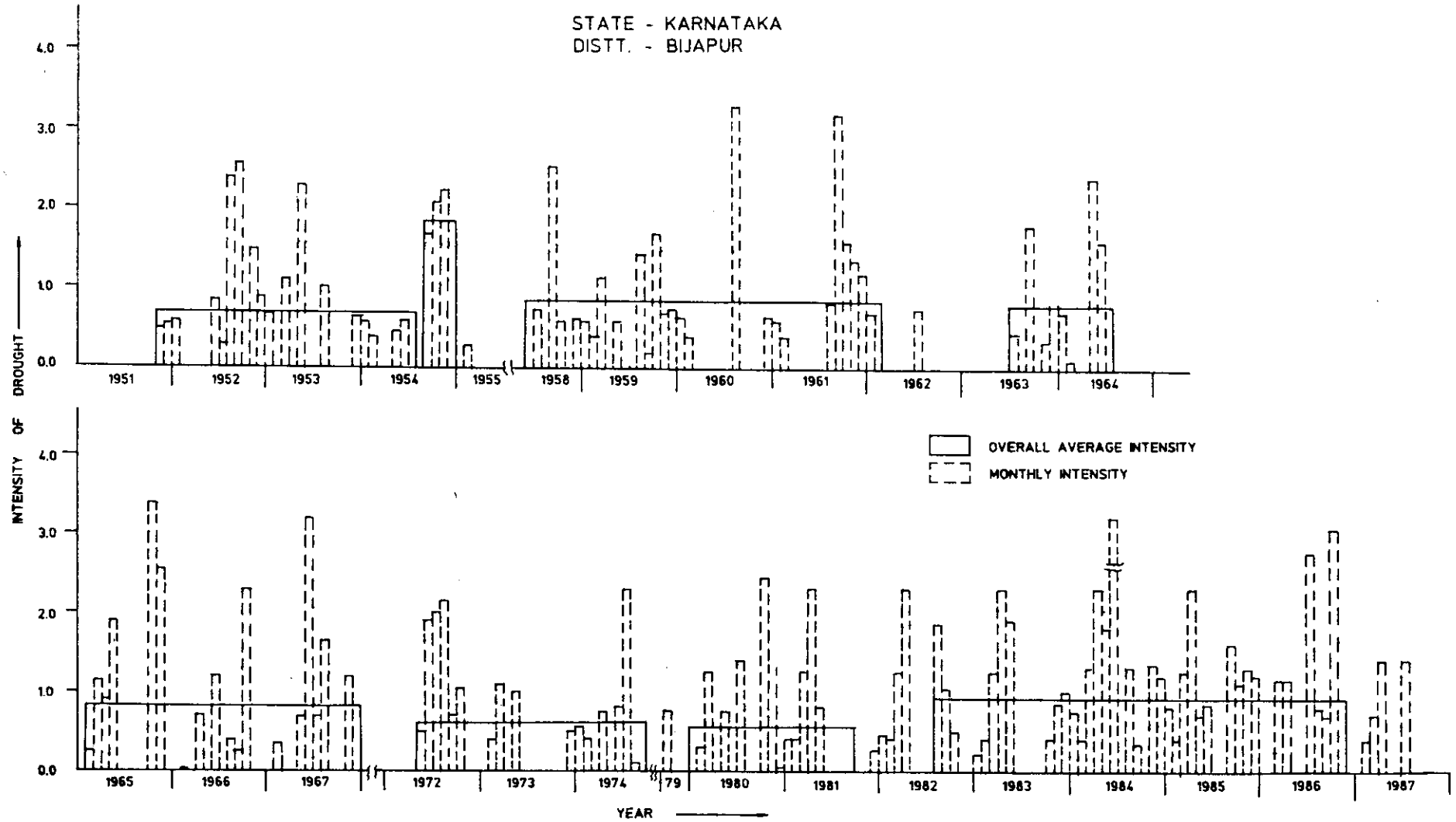


FIG. 3.4 OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

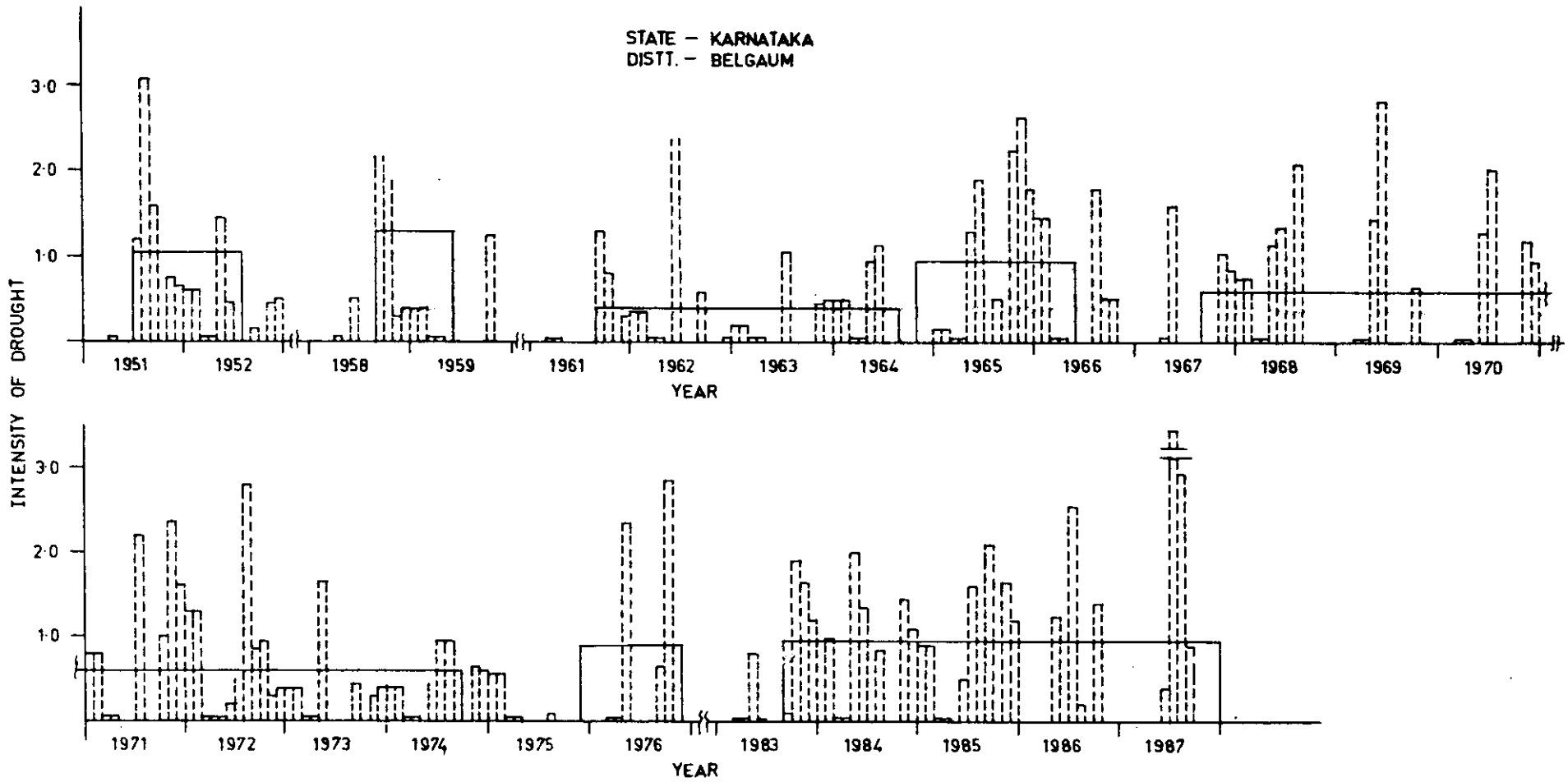


FIG. 3·4 – OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

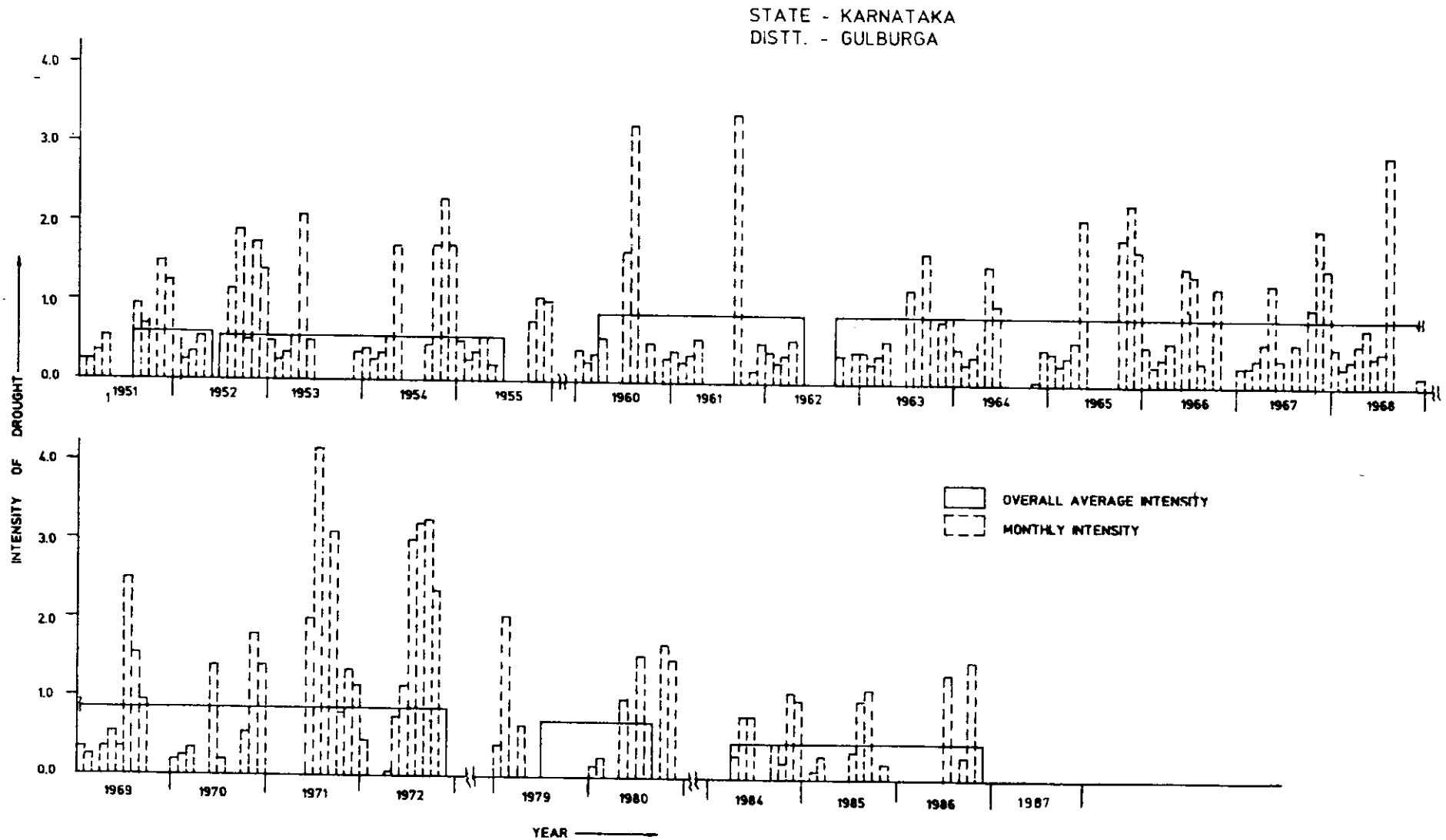


FIG. 3.4 OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

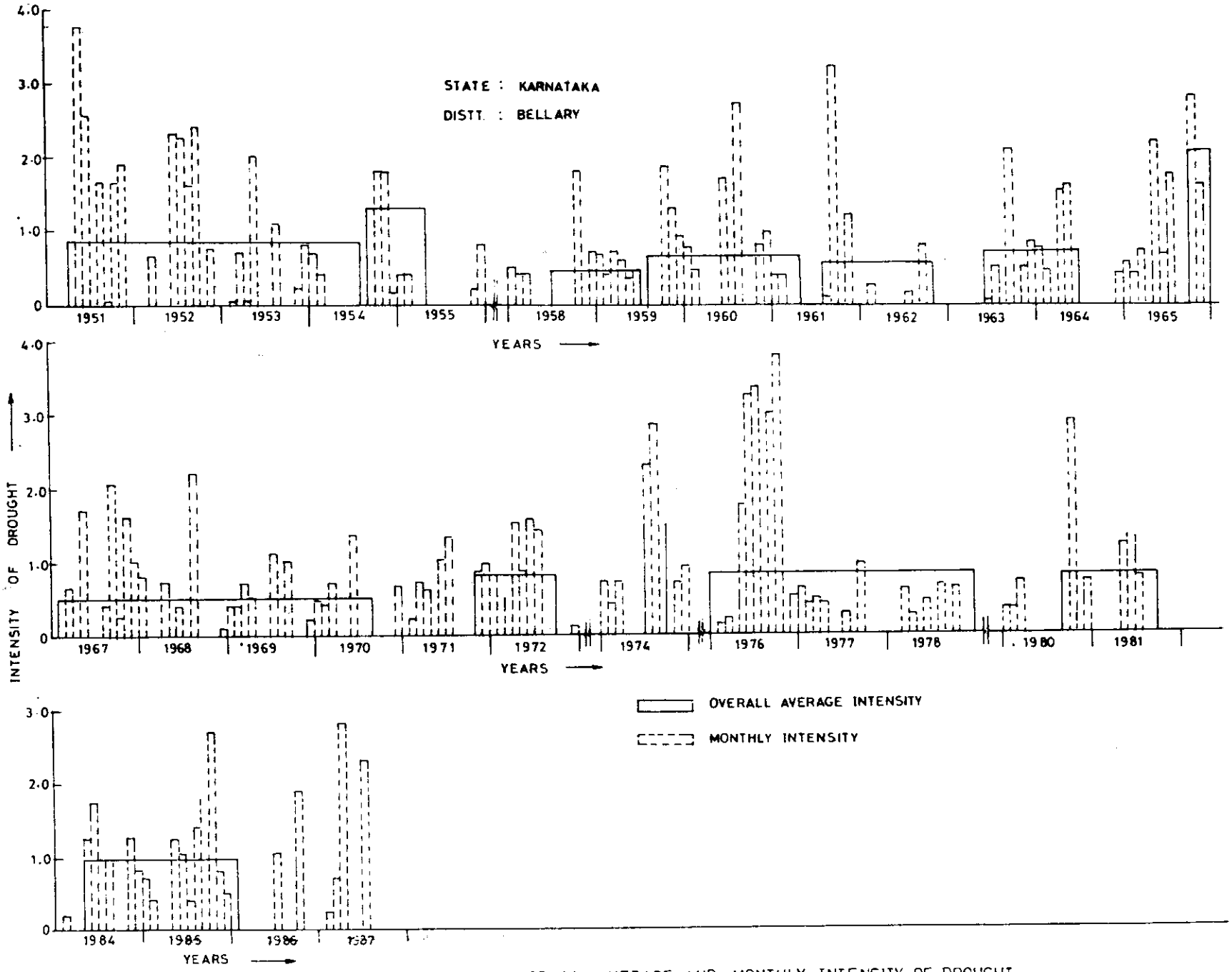


FIG. 3.4 - OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

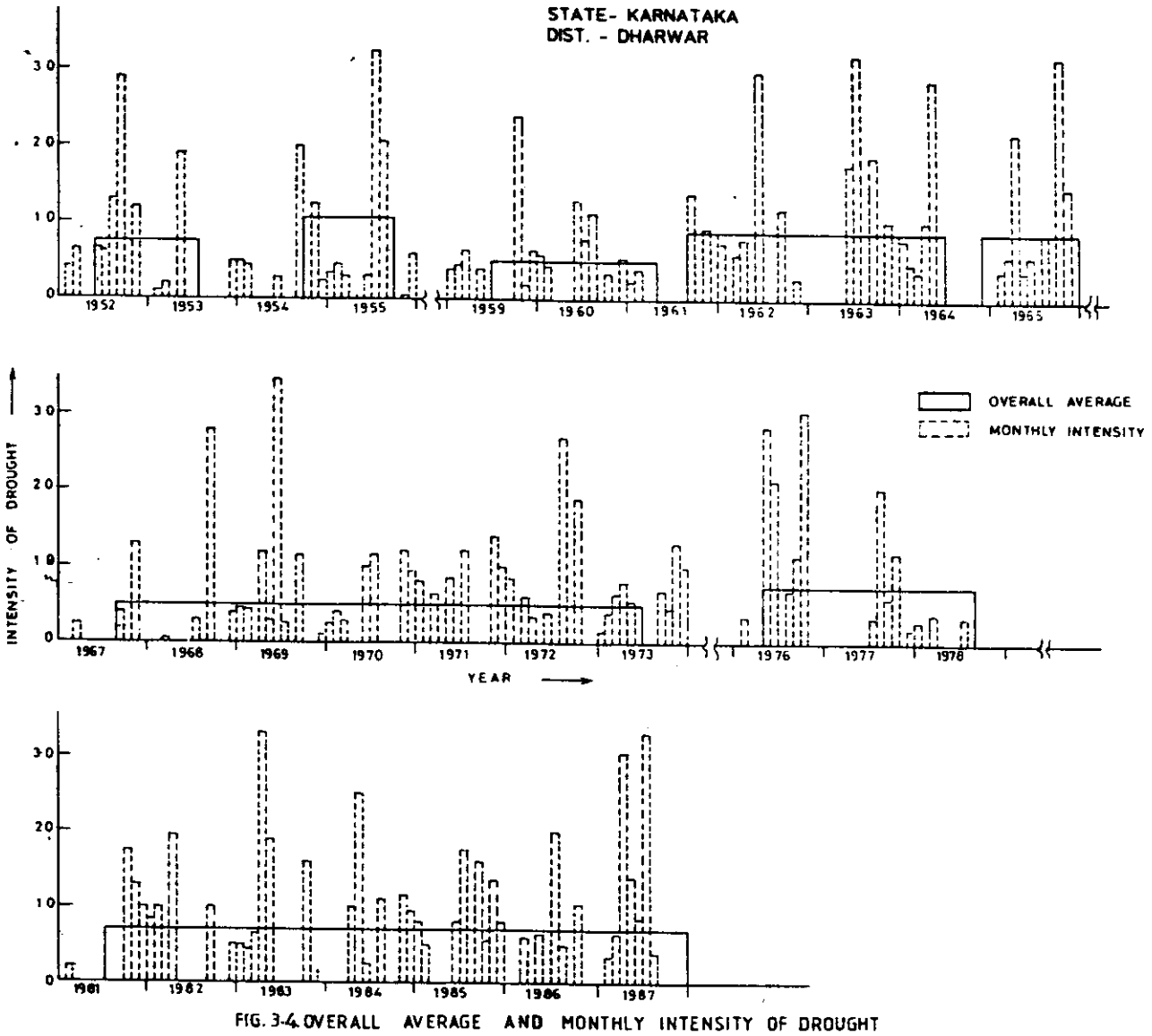


FIG. 3-4 OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

shortest duration drought spell was found in case of Bellary district. The pattern of drought spell was found similar in case of Raichur, Dharwar and Belgaum districts. The district of Gulburga experienced minimum no. of drought spells during the period of 1951-87.

The approach has yielded comparable results of drought analysis and has further scope for improvement taking into account the revision of monthly weightage factors keeping in view the agriculturally more important months in the state.

3.5 Dry Spell Analysis:

Agriculture is the worst sufferer of droughts as the ultimate effects of drought results in partial or total crop failure. Out of the various growing stages of crops, some are sensitive to moisture stress known as critical growing stages. Agricultural droughts are the result of occurrence of dry spells specially during critical growth stages of crops. Therefore the analysis of dry spells ($\geq$ 2 weeks) within monsoon season has importance specially for rainfed agriculture in the country. Therefore,an attempt has been made to identify the dry spells of two or more than two weeks duration during monsoon period (4th June to 15th September) by selecting one taluk from each of the six districts of state Karnataka.

The criteria for selection of dry spell is that the daily rainfall should be less than or equal to 5 mm (as a day is assumed as rainy day if daily rainfall exceeds 5 mm) occurring continuously for atleast two weeks (i.e. 14 days) or more. For counting number of spells the start of monsoon season has been assumed from fourth June of (beginning of 23rd standard week) every year. The duration and time of occurrence and number of

such dry spells for all the 6 districts of state Karnataka have been presented in Appendix III-4 (A). The number of dry spells have been counted starting from the monsoon season of 1981 to 1987. The study has been carried out for one taluk in each district.

For statistical analysis, the duration of dry spells were represented as range (in days) and no. of spells falling in that range were counted. The number of spells falling in various ranges of duration of spells were represented as percentage of total no. of spells occurring from 1981-1987 and cummulative percentage was obtained starting from the maximum duration of dry spell group downwards adding successive percentage (Appendix III-4(B). The probability curves have been drawn showing range of duration of dry spells on the abscissa and cummulative percentage of no. of spells as ordinates. The plots are shown in figure 3.5. Probability distribution graphs as shown in figure have been used to read the values of duration of dry spells (in days) at 75% probability level and have been given in table 3.4. It can be observed from the table that at 75% probability, the duration of dry spell ranges from 21-28 days for all the six taluks selected for all the six districts respectively.

This analysis is specially important from the view point of agriculture as it can give some idea about likelihood of dry spells during monsoon period based on which alternate arrangements can be made for providing water during critical growth stages to avoid hazardous effects on crop yields, especially in rainfed agriculture.

Table 3.4 : RANGE OF DURATION OF DRY SPELLS FOR 75% PROBABILITY

S.No.	Taluk (Distt.)	State	At 75% Probability, duration of dry spells (in days)
1.	Belgaum (Belgaum)	Karnataka	21-28
2.	Bijapur (Bijapur)	-do-	21-28
3.	Gulburga (Gulburga)	-do-	21-28
4.	Raichur (Raichur)	-do-	21-28
5.	Bellary (Bellary)	-do-	21-28
6.	Dharwar (Dharwad)	-do-	21-28

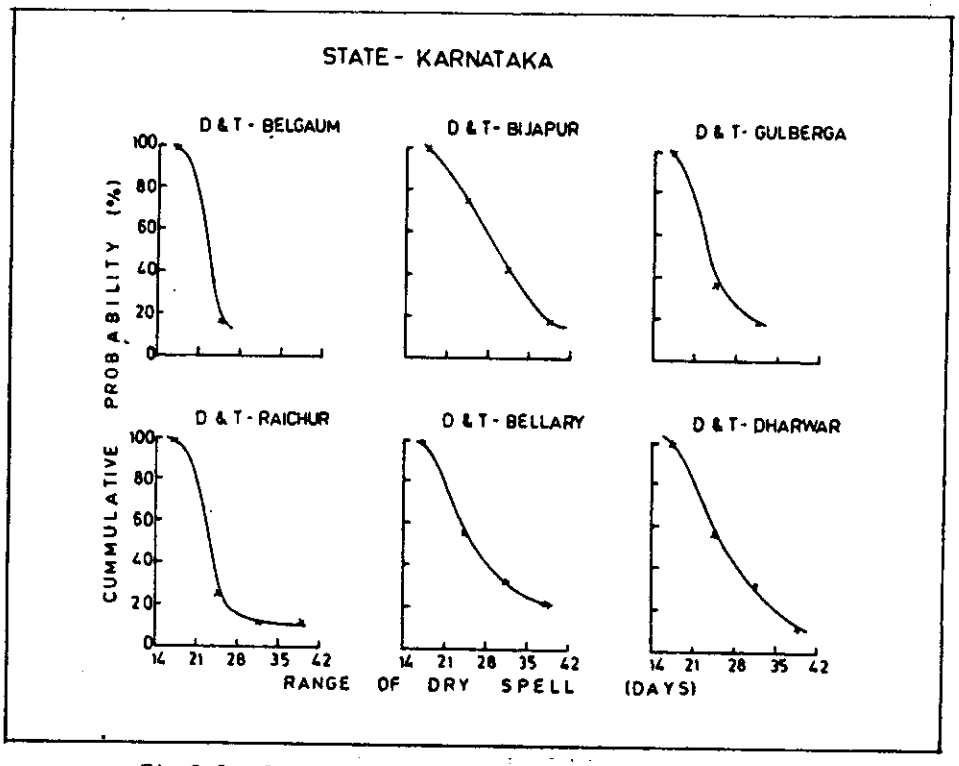


Fig.3.5 : Probability Distribution of Dry Spells

4.0 GROUND WATER DEFICIT

4.1 General

The main objective of groundwater management is to ensure that groundwater will be available at an appropriate time and in an appropriate quantity and quality to meet the most important demands of society. The measurement of groundwater levels and their evaluation can play an important role in management of this underground resource of water. The fluctuations of water table reflect the effects of infiltration, precipitation and discharge of groundwater to streams and lakes or withdrawal of water from wells. Usually the change in ground water storage is a seasonal phenomenon. However, during the period of scarcity of rains or droughts, more dependence comes on ground water storages and steep decline in groundwater levels are experienced. Because of improper management of groundwater aquifers after development, numerous undesirable consequences such as the depletion of aquifers and groundwater mining emerge, especially during drought years. Statistics recently compiled on the use of ground water and surface water show that in a number of states ground water is being over exploited in certain pockets resulting in a fall in the water table. During droughts, due to deficiency of rainfall and higher rate of evapotranspiration the demand for irrigation gets enhanced, thereby the water level goes down. This results in increased use of energy for pumping water from greater depths involving higher expenditure. As a policy, the withdrawal of groundwater should be restricted to average annual recharge. This will conserve water from over exploitation during drought periods.

Therefore, there is a long standing need to better understand the relationship between precipitation and groundwater

levels. The relationship can be developed by carrying out statistical analysis of precipitation data and well level observations. Besides, information regarding well, abstractions should be available for evaluating effects on water table only due to reduced precipitation.

In order to see the effects of scarce rainfall as experienced during three successive drought years (1985-1987) on groundwater regime, statistical analysis of groundwater level data vis a vis precipitation has been carried out. In the present analysis of state Karnataka, the groundwater level analysis was restricted to only four districts namely Bijapur, Belgaum, Bulbarga and Raichur. The analysis for Dharwar and Bellary could not be done due to lack of data. Due to non-availability of abstraction data, the effects of withdrawal could not be introduced in the analysis.

4.2 Ground Water Level Analysis

The data concerning groundwater level fluctuations were collected in respect of observation wells in the four districts, namely Belgaum, Bijapur, Bulbarga, and Raichur of state Karnataka. The informations regarding period of data used, no. of observation wells and the source of data is given in Table 4.1.

Table 4.1 : Status of Groundwater Data of State Karnataka

Sl. No.	Name of districts	Data available (four time in a year)	No. of wells taken	Source of data availability
1.	Belgaum	1976-88	6	State Groundwater Board
2.	Bijapur	1976-88	7	-do-
3.	Gulburga	1976-88	10	-do-
4.	Raichur	1976-88	8	-do-

As is evident from table 4.1, about 7-10 wells were chosen in each district for evaluating impacts on groundwater regime. It was kept in mind that these wells are evenly distributed within the district. The locations of the wells on the district map have already been shown in the figures presented in chapter 2.

The groundwater level analysis was attempted with the help of quarterly/seasonal data depending upon the frequency of the data collected from the central & state Govt. agencies of the state. Appendix IV-1 gives the details of various observation wells spread over 6 selected district prone districts of Karnataka state with their latitude and longitude. The analysis has been carried out for ground water level data from 1978-88.

The water levels in the wells have been calculated with respect to mean sea level and for each district average ground water level has been calculated using Thiessen method. The Thiessen weight of all wells considered in each district was established and groundwater level calculated with respect to mean sea level, multiplied by Thiessen weight, gave average ground water level for the district.

4.3 Inferences

The seasonal rainfall deficiency figures in the four districts indicate that except Belgaum, every where there has been some positive departure from normal seasonal rainfall. This is also evident from the rainfall trend which show relatively less rate of decline during 1987-88 as compared to previous years, which may be attributed to occurrence of rainfall. The premonsoon levels have also shown rather less rate of decline in water table during 1987-88 as compared with previous year. However, in case of Belgaum district due to deficiency of rainfall the groundwater

level trend did not undergo significant change, though the post monsoon scenerio was relatively better than previous year. The trend of water table and seasonal rainfall in respect of four districts are shown in fig. 4.1 to fig. 4.4.

The analysis of ground water levels based on the water-table fluctuation data of past 10-12 years has yielded in knowing the groundwater level trends (pre & post) as a result of seasonal rainfall departure. In most cases the water table has been recorded falling and the rate of recharge was found lesser in 1987-88 as compared to previous year. The continuous decline in water table is certainly attributed to failure of monsoon due to which the draft of ground water also gets increased because of increase in demand. The rise in water table as found in some cases can be attributed to the positive groundwater imbalances created by surface water irrigation projects. Better analysis to correlate rainfall failure and groundwater regime can be done by taking into account the well abstraction data, which has not been done in the present case due to non-availability of relevant data.

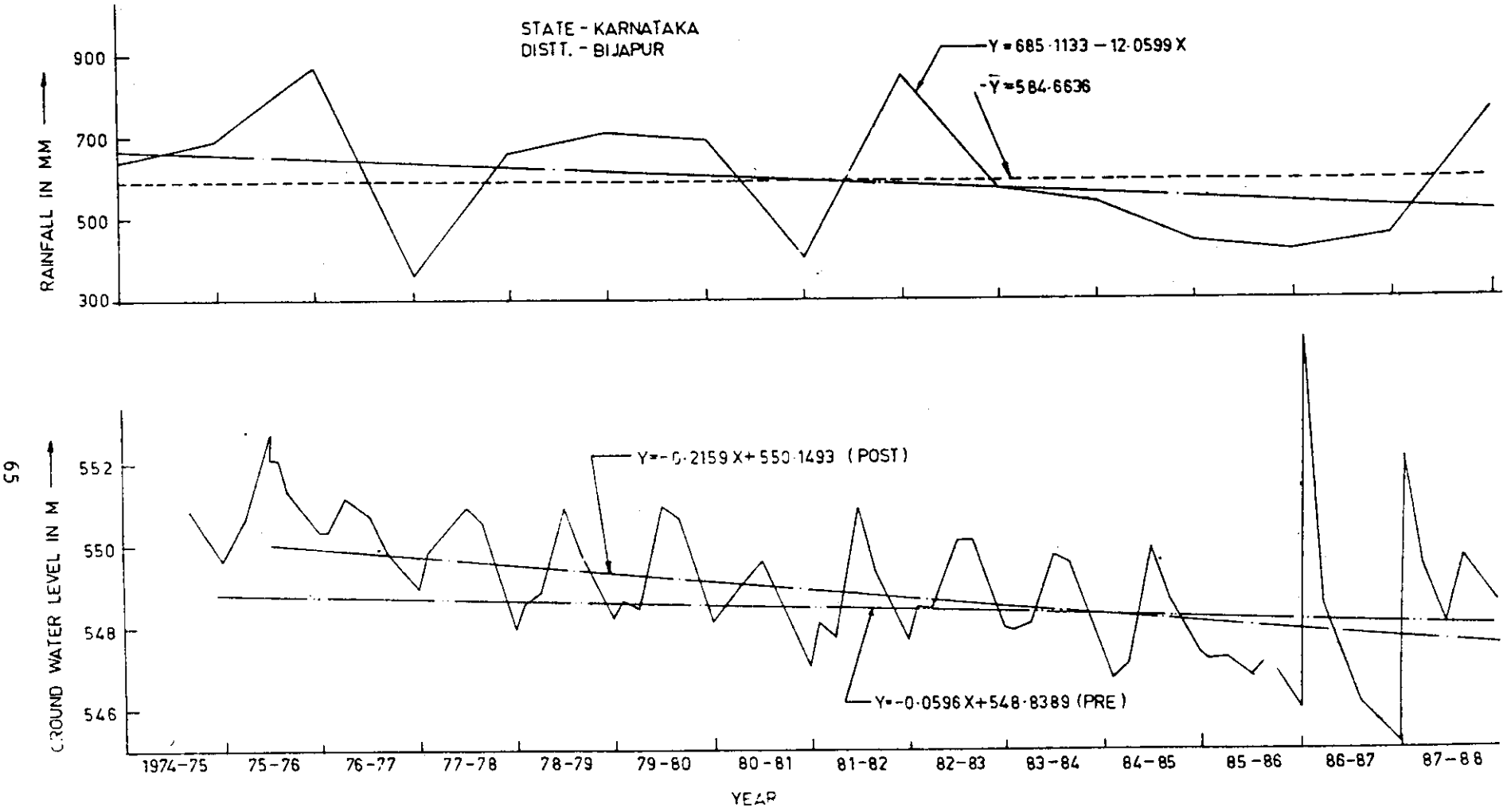


Fig. 4.1 : Ground Water Level Fluctuations and Rainfall and Trend Analysis

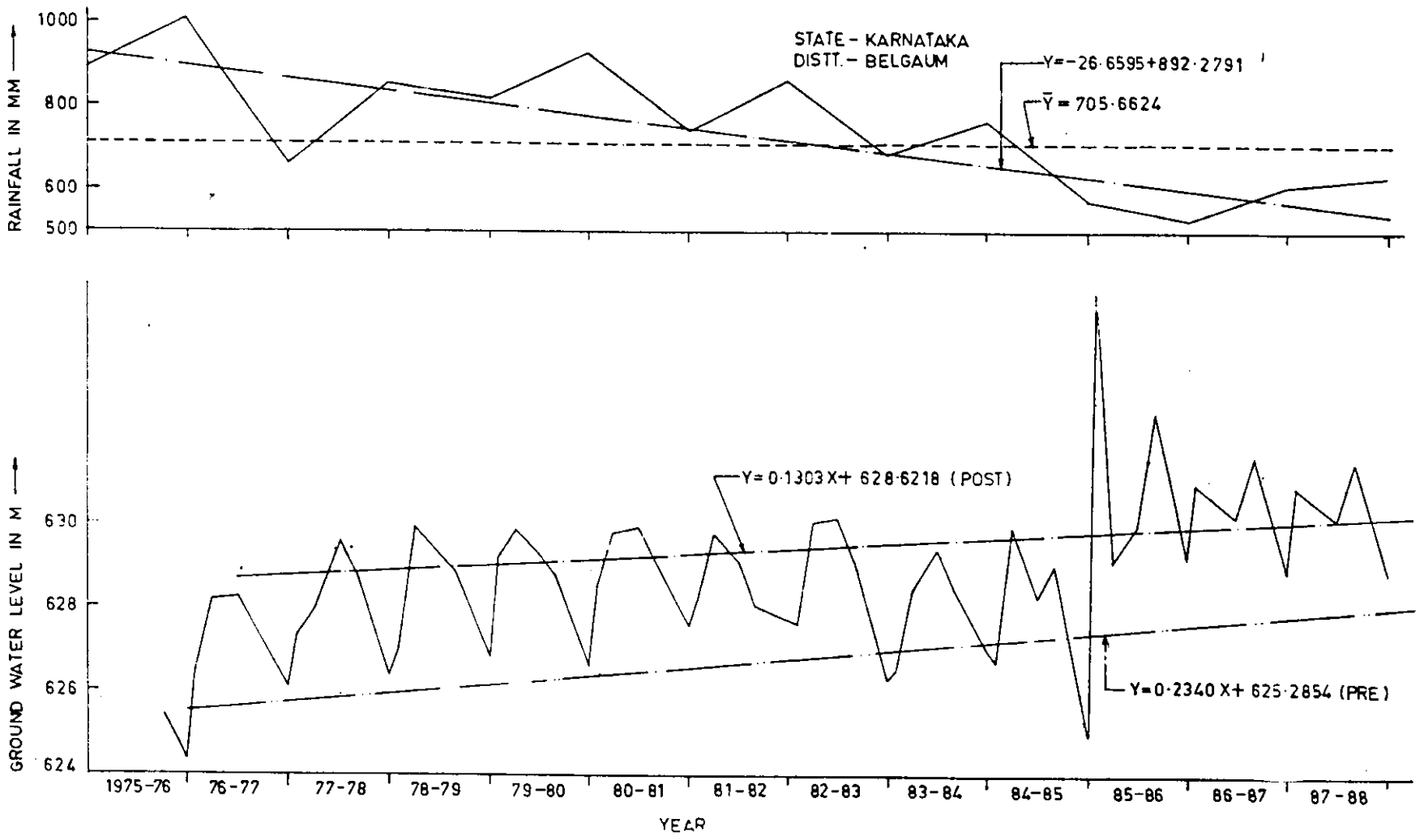


Fig. 4.2 : Ground Water Level Fluctuations and Rainfall and Trend Analysis

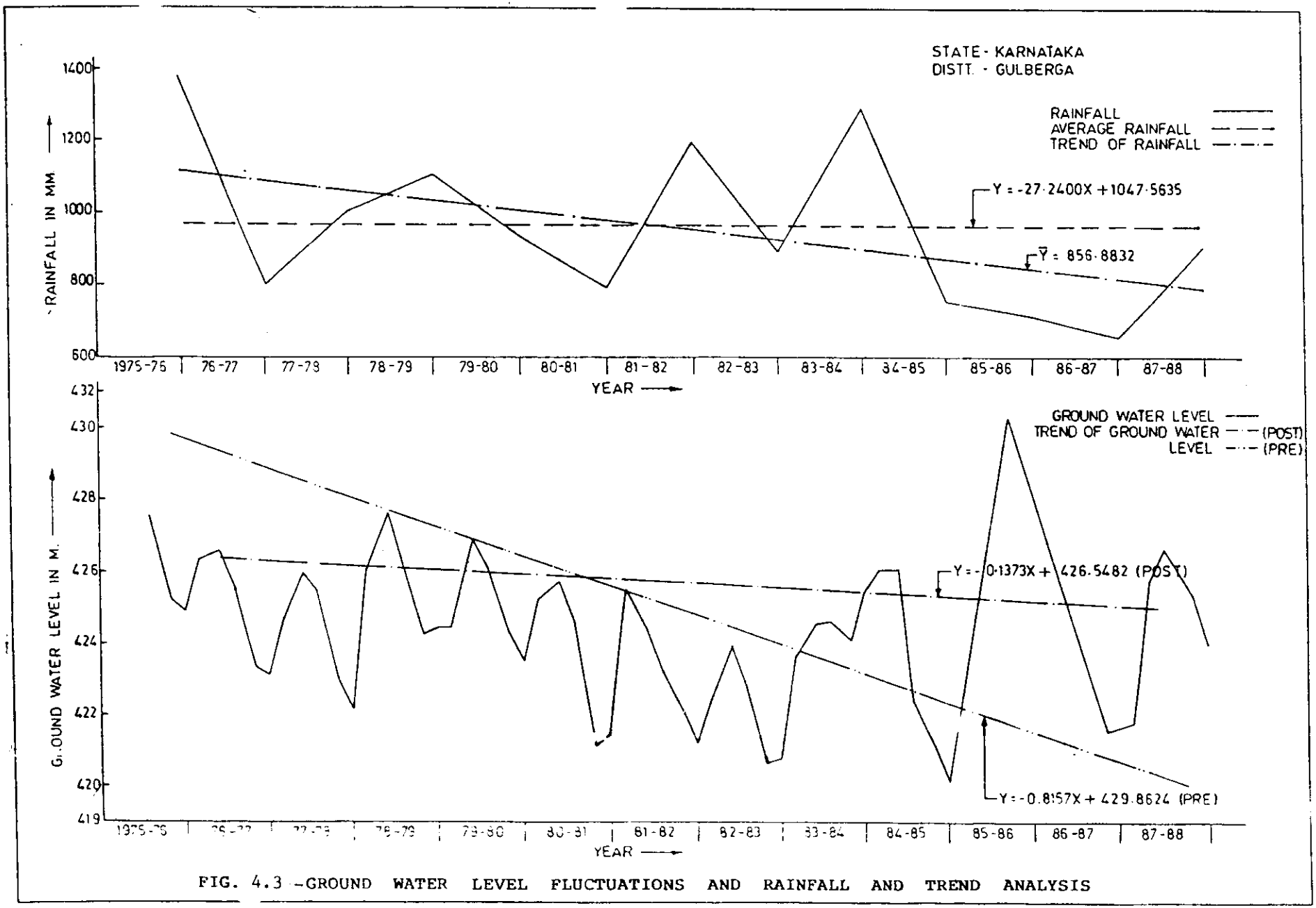


FIG. 4.3 –GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

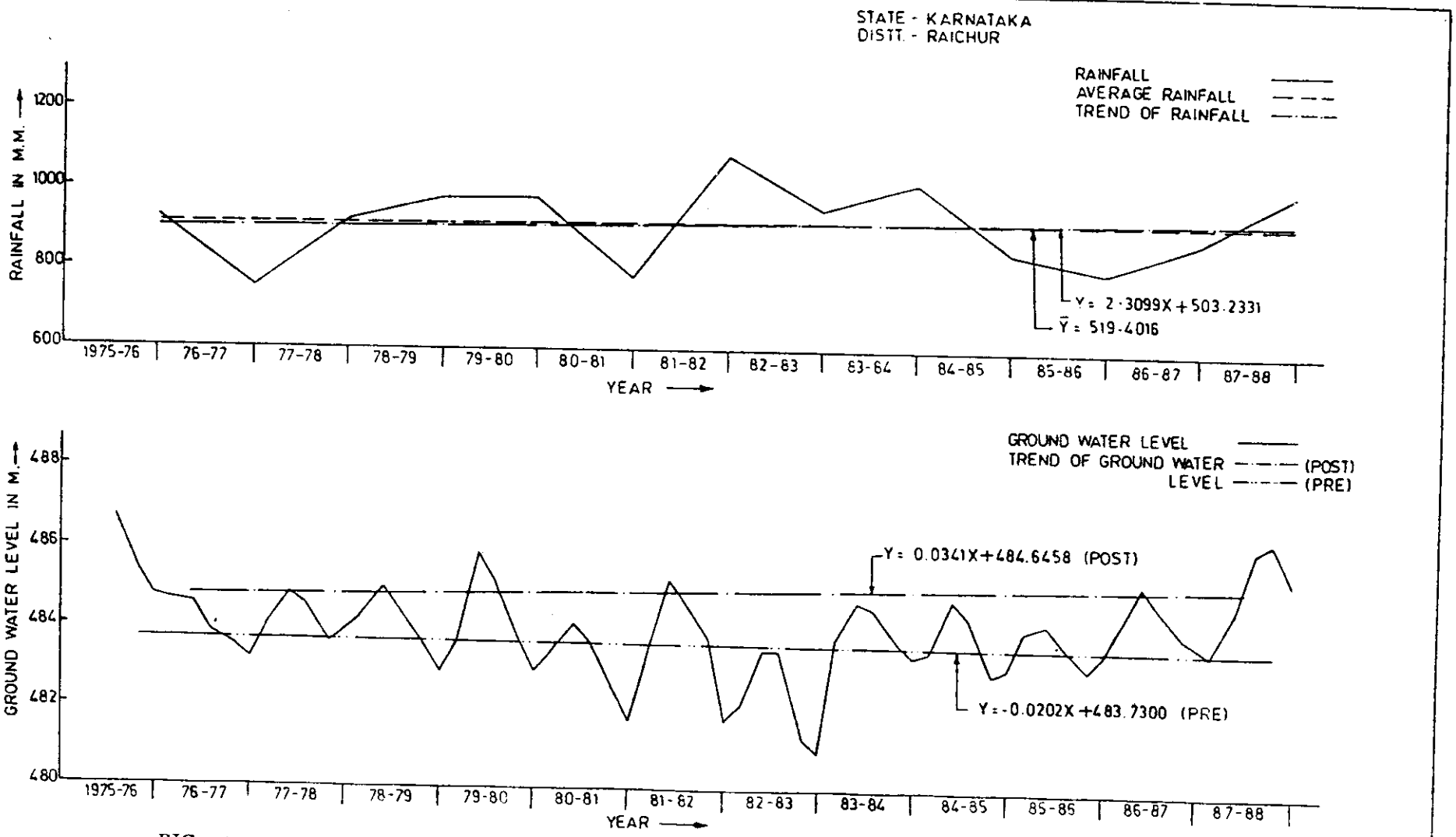


FIG. 4.4: GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

5.0 ANALYSIS OF RESERVOIR STORAGE

In order to illustrate the impact of failure of monsoon on storage reservoirs, an attempt has been made to compare the storages in Ghatprabha and Tungabhadra reservoirs of the state Karnataka. For this purpose, the live storages & corresponding reservoir level in some selected months have been plotted against time. The weekly reservoir level data as supplied by Central Water Commission (CWC) from 1984-1987 have been used for this analysis. Figures 5.1 shows the position of storages during 1984 to 1987 in the reservoir. The following inferences which can be drawn from the figure 5.1 are as below:

Both the reservoirs have shown less storage value during year 1987 as compared to previous three years. The storages by the end of Nov. in Tungabhadra reservoir during 1987 was 6.3% of previous year storage for the same period. In case of Ghatprabha the storage by Nov.87 57% of previous year storage. This indicates that the reservoir storages were affected more during year 1987 as compared to previous two-three years.

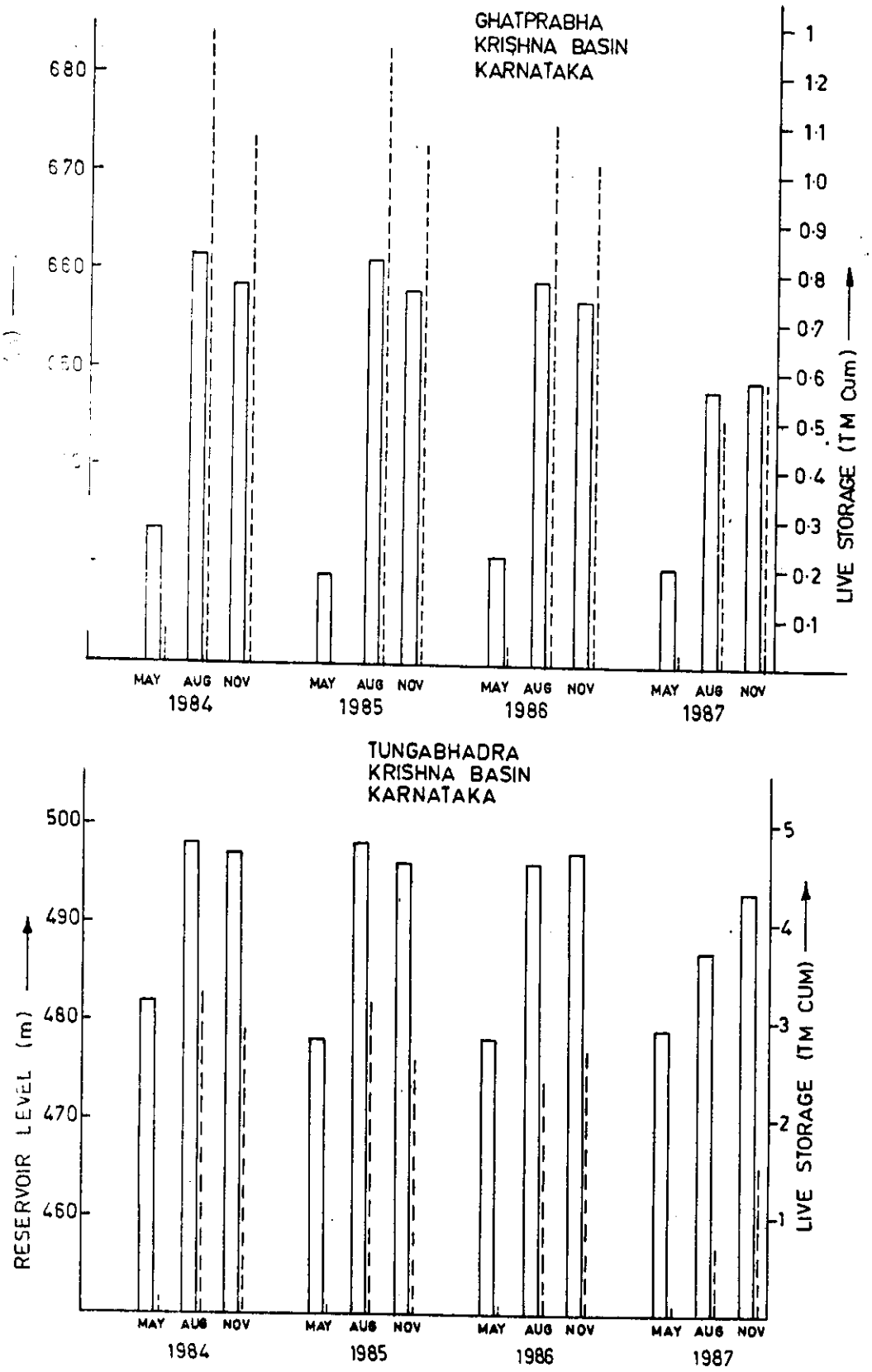


Fig. 5.1 : Reservoir Levels & Storages for Kadana & Tungabhadra Reservoirs.

6.0 CONCLUSIONS & RECOMMENDATIONS

1. The present report gives analysis of data to assess impacts of droughts in six selected districts of Karnataka state namely Belgaum, Bijapur, Bellary, Raichur, Dharwar & Bulbarga. The analysis of data included rainfall analysis, groundwater analysis and reservoir storage analysis.

2. The analysis of rainfall data on seasonal basis indicated for most of the districts, the departure in seasonal rainfall has been on positive side for five out of six districts. Only in case of district Belgaum deficiency in rainfall on seasonal basis have been observed.

3. Analysis of monthly rainfall data for all the six districts for the water year 1987-88 has been done by comparison by the monthly normal values. It has been observed that during the months of June 87, none of the six district's observed deficiency rainfall from monthly consideration. In the month of July'87, however, Gulburga had a deficiency in the order of 20-50% while Bijpur, Dharwar, Belgaum and Bellary had more than deficiency of 50%.

4. Probability analysis of annual rainfall data has been done using the available from 1901-87. In order to find the group range of rainfall like to occur in the districts of the probability. It has been found that for the districts of Bijapur, Gulburga and Bellary this range works out to be 500-600 mm. While for other three districts, it is in the range of 600-700 mm. This analysis has also yielded values of probability of occurrences of 75% annual rainfall in the district. It has been found that all the districts had the probability level more than 80% which means that for less than 20 years out of 100 years, the rainfall is likely to be less than 75% of the normal in these districts. The

district of Belgaum, Bijapur, Gulburga, Raichur, Bellary & Dharwar experienced 75% of normal rainfall in 18, 17, 17, 16, 16 & 14 percent of years, respectively, indicating that all the six district are less drought prone based on this analysis as per IMD criteria.

5. Analysis of monthly rainfall data using Herbst's Approach has been carried out to identify the drought spells for which data of year 1951-87 have been used. It was observed that all districts recorded drought spells during the period 1984-87. However, the district of Dharwar experienced longest duration of drought spell while Bellary seemed to have experienced shortest spell of drought as per this analysis. In general, 6-13 drought spells were observed in these district with Gulburga experiencing minimum no. of drought spells.

6. Analysis of rainfall data for dry spell identification has been carried out and duration of likely dry spells at 75% of probability has been worked out. It was found that most of the districts had 75% probability of having a dry spell of the duration of 21-28 days. A dry spell was assumed as a period in which daily rainfall is less than or equal to 5 m occurring continuously for two weeks.

7. Groundwater analysis for the districts was for evaluating the impacts of drought on groundwater regime. The analysis was restricted for one 4-5 districts namely Belgaum, Bijapur, Bellary, Raichur and Gulburga, in view of data availability studies. It was observed that for the districts of Bijapur, Bellary, Belgaum and Raichur, the post monsoon water levels were found to show less rate of decline of as compared to recent years. The pre monsoon levels have also shown the similar situation. However, in case of Belgaum district, due to rainfall deficiency, the ground water level did not undergo significant change.

REFERENCES

1. Central Water Commission (1982), 'Report on Identification of Drought Prone Areas for 99 districts', New Delhi.

2. Herbst, pH, D.B. Bredenkamp and M.H.G. Barker (1966), 'A Technique for the evaluation of Drought from Rainfall Data' Journal of Hydrology, 4, pp. 264-272.

3. Hydrological Aspects of Drought 1985-86 - A case study prepared by NIH (CS-21).

4. 'Hydrological Aspects of Droughts (1986-87)' - A case study prepared by NIH (CS-24).

5. Institute of Hydrology, Wallingford, OXON, (1980) Research Report, Low Flow Studies.

6. Linsley, R.K. Kohler, M.A. and Paulhus, J.L.H., Hydrology for Engineers 1975, Second Edition, McGraw Hill Publications.

7. McMohan T.A. and Arenas A.D. (1982) Method of Computation of Low stream flow, UNESCO, Paris.

8. Mistry, J.F., and Goswami M.R., (1988), Paper on "Need for Conjunctive Use and Surface and Groundwater legislation in Drought Prone Areas". Proc. of the National Seminar on 'Water Conservation and Management in Drought', Sept. 9-10, 1988, New Delhi, organised by IAH.

9. Sampath, T.V. (1989), 'Effect of Drought on Indian Agriculture' paper presented in International Symposium on Ground Water Resources Management in Drought Prone Areas, 27 Nov. to 1 Dec. 1990, New Delhi.

10. Singh, R.D. (1987) Hydrological Aspects of Drought R.N. 37, National Institute of Hydrology.

11. Soils of India and Their Management, Book published by The Fertiliser Assoc. of India, New Delhi, 1985.

12. Statistical Abstract, Directorate of Eco. & Statistics, Bangalore, 1984.

13. Water Resources of India, Central Water Commission (CWC), 1988.

14. Upadhyaya, D.S. & Gupta, D.K. (1989), 'Droughts in India' - A historical review Paper presented in International Symposium on Ground Water Resources Management in Drought Prone Areas', 27 Nov. to 1 Dec. , New Delhi.

APPENDIX - II

LIST OF OFFICES AND PLACES FROM WHERE DATA AND INFORMATION WERE COLLECTED

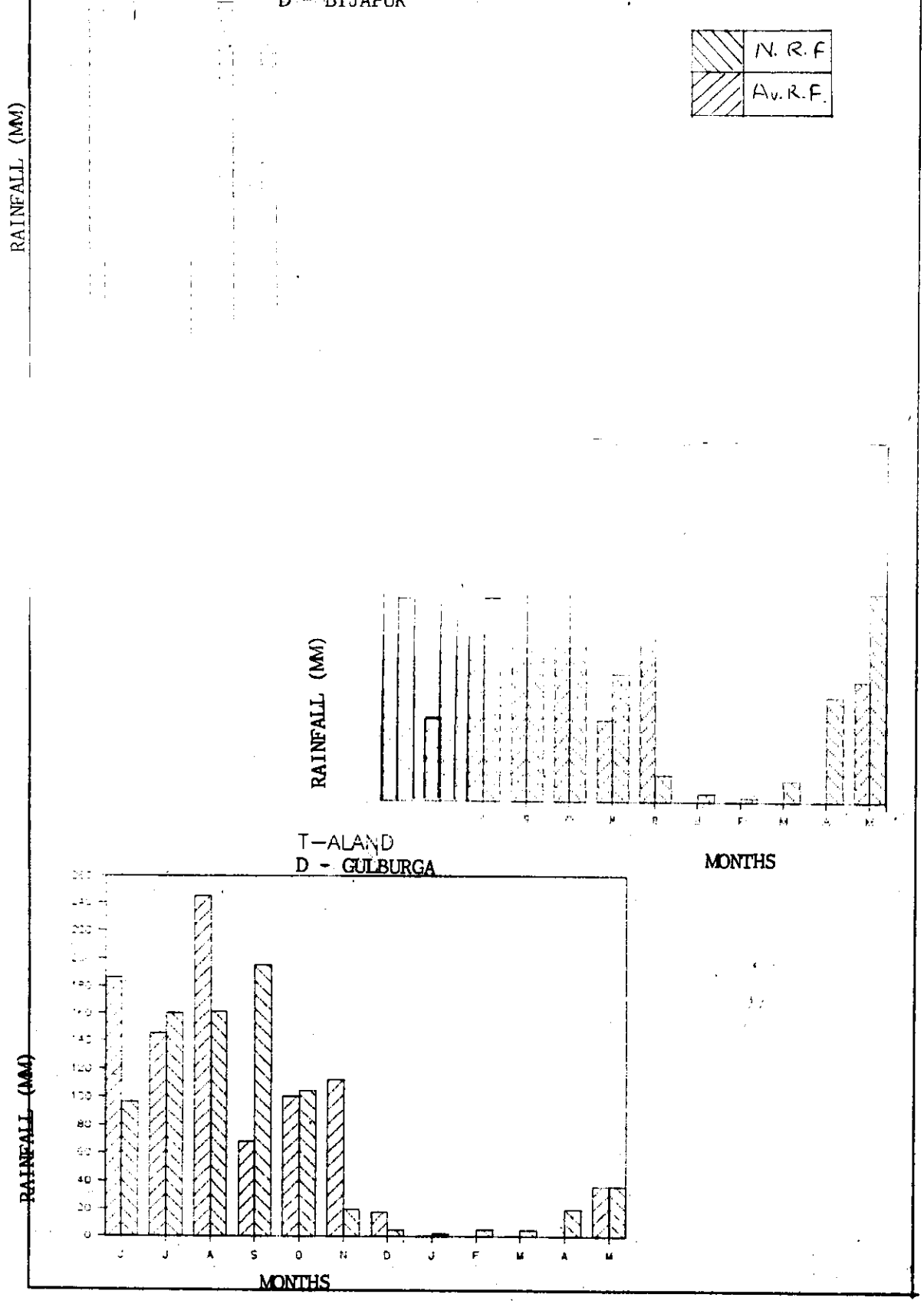
KARNATAKA

PLACE	
Bengalore	Director, Deptt. of Mines and Geology, Govt. of Karnataka.
	Director, C.G.W.B., South-Western Region
	Director, DPAP/Rural Development
	Chief Engineer, W.R.D.O.
	Director, Bureau of Economics & Statistics
	Chief Engineer, Minor Irrigation
	Director, Deptt. of Revenue
	Director, Deptt. of Agriculture, Govt. of Karnataka
	Directorate of Survey Settlement & Land Records
	Directorate of State, Groundwater Cell, R.C. Road
	C.E., Public Health Engg. & PWD, Govt. of Karnataka
	Central Water Commission
Kolar	E.E., Minor Irrigation
	Deputy Commissioner (Special)
	DRDA, Soil Conservation Deptt.
	Irrigation Deptt.

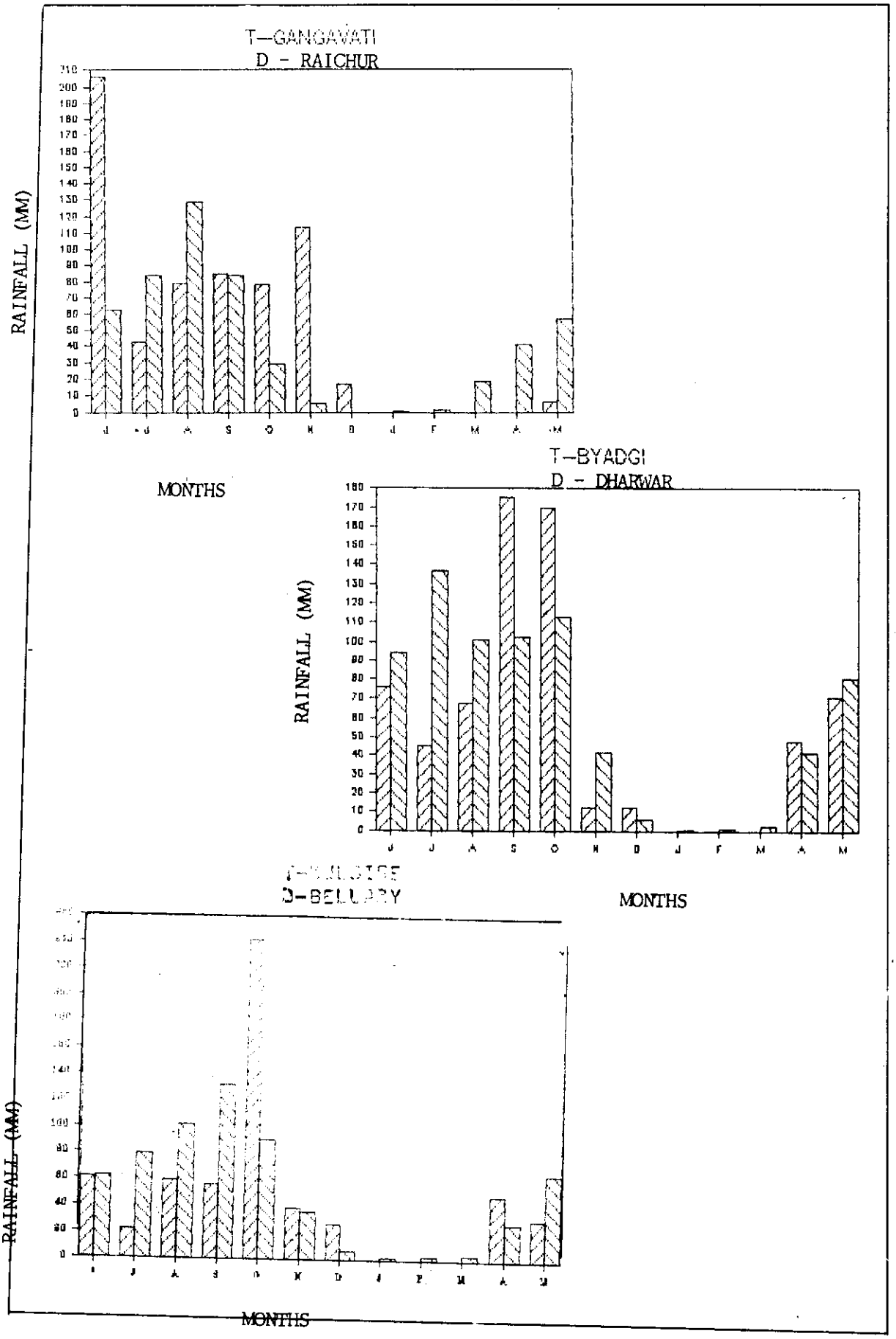
Tumkur	E.E., Minor Deputy Commisioner DRDA, Soil Conservation Deptt. Irrigation Deptt.
Chitradurga	E.E., Minor Irrigation] Incharge of the DPAP Projects DRDA, Soil Conservation Deptt. Irrigation Deptt.
Belgaum	E.E., Minor Irrigation Incharge of the DPAP Projects DRDA, Soil Conservation Deptt. Irrigation Deptt. Asstt.Geologist, SGWC,Belgaum
Dharwar	E.E., Minor Irrigation DRDA, Soil Conservation Deptt. Irrigation Deptt.

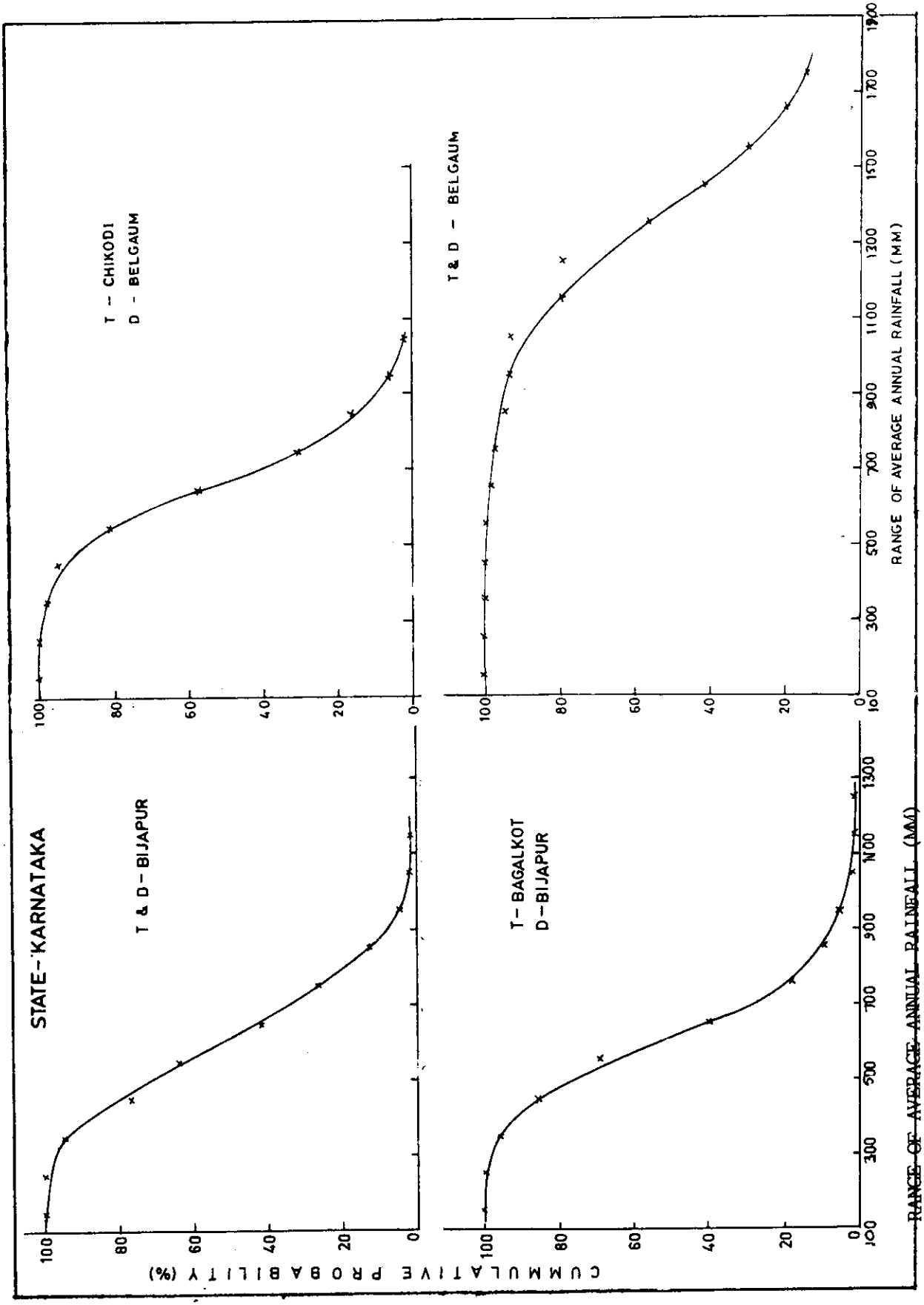
STATE - KARNATAKA

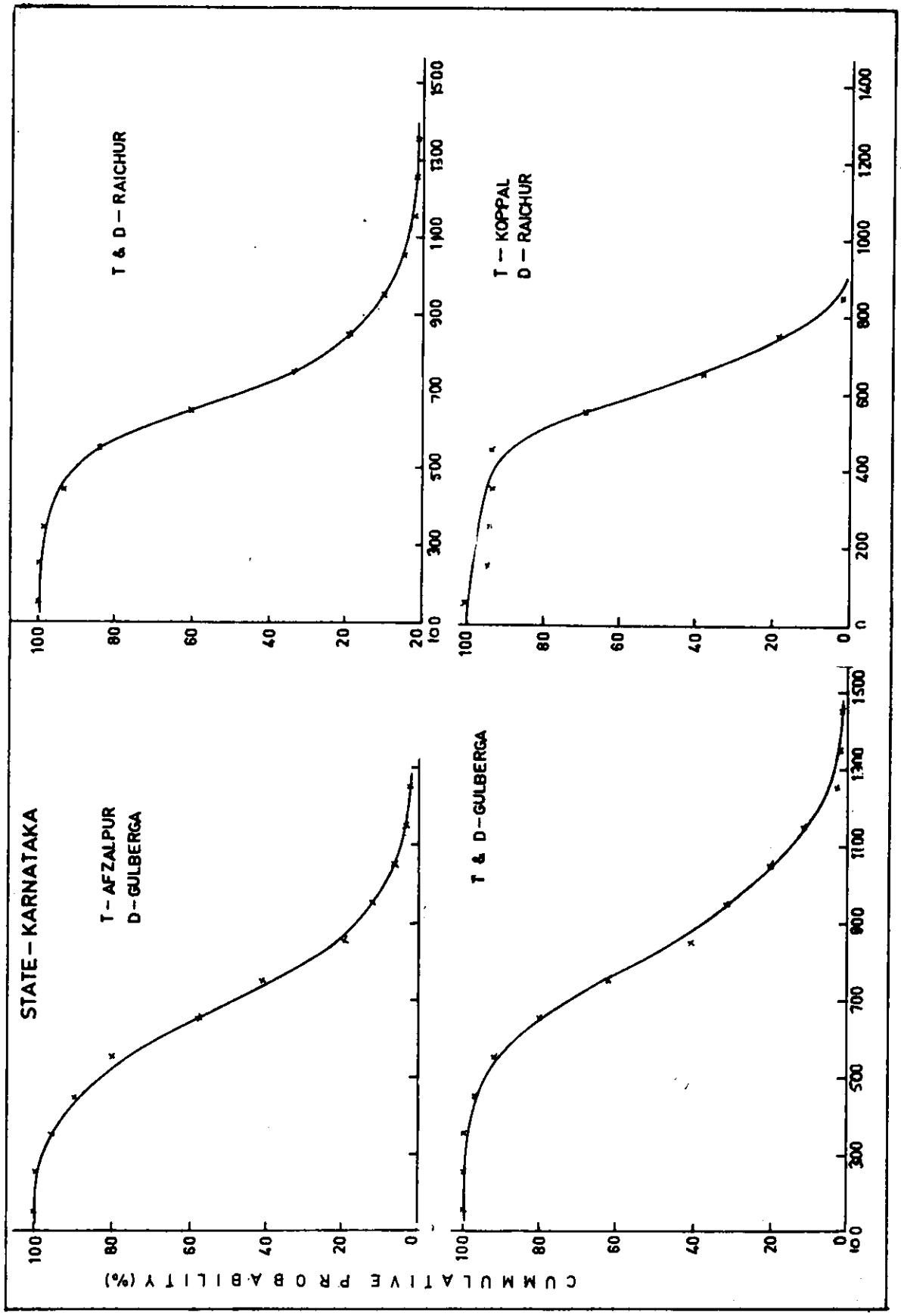
D - BIJAPUR

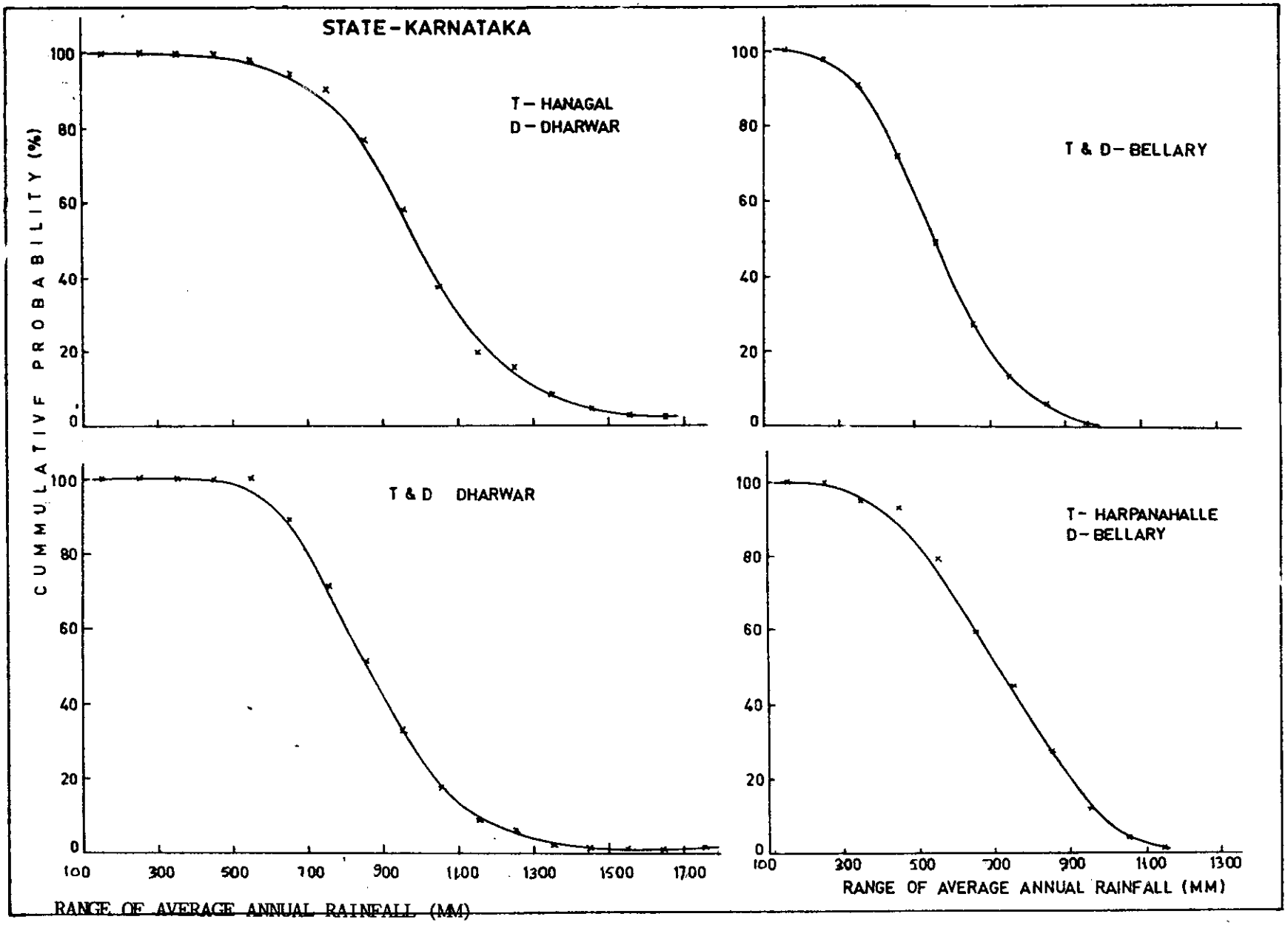


STATE - KARNATAKA




STATE-KARNATAKA
T & D-BIJAPUR
T - CHIKODI
D - BELGAUM
T-BAGALKOT
D-BIJAPUR
T & D - BELGAUM
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)


STATE – KARNATAKA
T – AFZALPUR
D – GULBERGA
T & D – GULBERGA
T & D – RAICHUR
T – KOPPAL
D – RAICHUR
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)


STATE - KARNATAKA
T - HANAGAL
D - DHARWAR
T & D - BELLARY
T & D DHARWAR
T - HARPANAHALLE
D - BELLARY
CUMMULATIVF PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE OF DISTRICT BELGAUM

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.000	0.024	0.057	0.000	0.000	1.221	5.199	1.602	0.000	0.747	0.65
1952	0.015	0.015	0.052	0.057	1.441	0.441	0.000	0.000	0.143	0.000	0.440	0.47
1953	0.401	0.401	0.041	0.057	2.104	0.000	0.000	0.000	0.000	0.000	0.000	0.191
1954	0.273	0.273	0.044	0.057	0.000	1.337	0.000	0.000	0.016	0.000	1.758	1.267
1955	0.000	0.000	0.034	0.057	0.000	0.000	0.309	0.093	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.033	0.057	0.000	0.243	0.000	0.000	0.221	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.056	0.000	0.000	0.000	0.000	0.631	0.000	0.000	0.000
1958	0.000	0.000	0.005	0.056	0.000	0.447	0.000	0.000	2.212	1.879	0.327	0.40
1959	0.451	0.451	0.047	0.057	0.000	0.000	0.000	0.000	0.000	1.239	0.000	0.00
1960	0.000	0.000	0.022	0.057	0.000	0.962	0.000	0.342	0.000	0.129	0.000	0.000
1961	0.000	0.000	0.033	0.057	0.000	0.000	0.000	0.000	1.327	0.859	0.125	0.286
1962	0.542	0.542	0.045	0.057	0.000	2.430	0.000	0.000	0.575	0.000	0.000	0.052
1963	0.171	0.171	0.042	0.057	0.000	0.000	1.045	0.000	0.000	0.000	0.448	0.48
1964	0.434	0.434	0.043	0.057	0.940	1.144	0.000	0.000	0.000	0.000	0.000	0.012
1965	0.143	0.143	0.041	0.057	1.524	1.921	0.000	0.520	0.196	2.242	2.635	1.794
1966	1.446	1.446	0.067	0.056	0.000	0.000	0.000	1.917	0.000	0.486	0.000	0.000
1967	0.000	0.000	0.000	0.055	1.609	0.000	0.000	0.000	0.000	1.051	0.842	0.000
1968	0.749	0.749	0.053	0.055	1.175	1.353	1.328	2.040	0.004	0.000	0.000	0.000
1969	0.000	0.000	0.054	0.057	1.474	2.354	0.000	0.000	0.000	0.641	0.000	0.000
1970	0.000	0.000	0.032	0.057	0.000	1.282	2.058	0.000	0.000	0.000	1.207	0.935
1971	0.616	0.616	0.054	0.056	0.000	0.000	2.229	0.000	0.000	1.016	2.363	1.659
1972	1.525	1.525	0.063	0.056	0.000	0.196	0.510	2.824	0.843	0.972	0.282	0.380
1973	0.411	0.411	0.046	0.057	1.454	0.000	0.000	0.000	0.463	0.000	0.279	0.378
1974	0.410	0.411	0.045	0.057	0.000	0.466	3.958	0.955	0.000	0.000	0.648	0.609
1975	0.572	0.572	0.050	0.057	0.000	0.000	0.000	0.074	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.033	0.057	2.366	0.000	0.000	0.000	0.541	2.867	0.000	0.000
1977	0.000	0.000	0.021	0.057	0.000	0.000	0.000	1.126	2.134	0.376	0.000	0.000
1978	0.000	0.000	0.000	0.056	0.000	0.000	1.546	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.027	0.057	0.059	0.000	1.200	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.091	0.056	1.553	0.007	0.000	0.000	0.000	1.580	0.523	0.524
1981	0.517	0.517	0.044	0.057	0.000	0.000	0.000	0.000	0.000	0.269	0.000	0.000
1982	0.000	0.000	0.025	0.057	0.000	0.000	0.000	0.000	0.603	0.000	0.000	0.000
1983	0.000	0.000	0.031	0.057	0.024	0.000	0.000	0.000	0.123	1.903	1.659	1.207
1984	1.016	1.016	0.058	0.058	1.982	1.353	0.000	0.858	0.000	0.000	1.474	1.094
1985	0.935	0.935	0.057	0.058	0.000	0.519	1.603	0.251	2.153	0.000	1.659	1.207
1986	0.000	0.000	0.000	0.000	1.257	0.000	2.570	0.155	0.000	1.389	0.000	0.000
1987	0.000	0.000	1.000	0.000	0.000	0.396	4.567	2.957	0.874	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
7	1951	7	1952	13	1.08	13.99
5	1953	5	1954	9	1.28	11.48
9	1951	8	1954	36	0.42	15.30
11	1954	5	1956	19	0.94	17.93
7	1957	2	1974	25	0.63	53.58
12	1975	11	1976	12	0.99	30.63
7	1983	12	1987	54	0.96	49.60

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE OF DISTRICT GULBERGA

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1951	0.[illegible]56	0.248	0.[illegible]	0.546	0.000	0.000	0.000	0.962	0.705	0.000	1.490	1.242
1952	0.478	0.263	0.553	0.546	0.000	0.000	0.000	1.143	1.925	0.473	1.750	1.336
1953	0.490	0.266	0.563	0.546	2.123	0.492	0.000	0.000	0.000	0.000	0.000	0.331
1954	0.[illegible]87	0.257	0.563	0.546	1.595	0.000	0.000	0.000	0.452	1.677	2.274	1.687
1955	0.[illegible]63	0.252	0.563	0.546	0.229	0.000	0.000	0.000	0.000	0.754	1.048	0.995
1956	0.[illegible]5[illegible]	0.262	0.564	0.546	0.000	0.449	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.158	0.248	0.[illegible]5[illegible]	0.545	0.000	0.000	0.000	0.000	0.000	0.000	0.185	0.520
1958	0.485	0.268	0.563	0.546	0.000	2.205	0.422	0.000	1.447	0.000	0.000	0.000
1959	0.[illegible]56	0.253	0.[illegible]62	0.546	0.382	0.000	0.000	0.000	0.000	0.000	0.000	0.413
1960	0.[illegible]95	0.253	0.563	0.546	0.000	0.000	1.653	3.254	0.000	0.499	0.000	0.315
1961	0.[illegible]00	0.257	0.[illegible]63	0.546	0.000	0.000	0.000	0.000	3.384	0.000	0.141	0.497
1962	0.402	0.253	0.563	0.546	0.000	0.000	0.000	0.000	0.000	0.307	0.000	0.397
1963	0.393	0.257	0.563	0.546	0.004	0.000	1.231	0.000	1.641	0.000	0.794	0.357
1964	0.459	0.261	0.564	0.546	1.499	1.017	0.000	0.000	0.000	0.000	0.053	0.448
1965	0.578	0.256	0.563	0.546	2.112	0.000	0.000	0.000	0.000	1.846	2.333	1.708
1966	0.522	0.266	0.565	0.546	0.000	1.515	1.406	0.512	0.000	1.271	0.000	0.000
1967	0.491	0.[illegible]5[illegible]	0.563	0.546	1.298	0.340	0.000	0.540	0.000	1.001	1.989	1.518
1968	0.503	0.265	0.565	0.546	0.753	0.428	0.443	2.935	0.000	0.000	0.000	0.157
1969	0.570	0.[illegible]55	0.562	0.[illegible]54	0.367	2.516	1.576	0.955	0.000	0.000	0.000	0.000
1970	0.[illegible]2[illegible]	0.[illegible]46	0.560	0.000	0.000	1.433	0.196	0.000	0.000	0.567	1.793	1.409
1971	0.000	0.000	0.000	0.000	0.000	1.989	4.152	1.777	3.127	0.811	1.356	1.168
1972	0.[illegible]79	0.000	0.000	0.052	0.743	1.159	3.077	3.217	3.251	2.354	0.000	0.000
1973	0.[illegible]70	0.259	0.557	0.000	0.954	0.000	0.641	0.000	0.000	0.000	0.000	0.000
1974	0.[illegible]45	0.[illegible]47	0.560	0.000	0.000	0.000	0.471	1.006	0.000	0.000	0.000	0.000
1975	0.[illegible]0[illegible]	0.000	0.000	0.000	0.000	1.714	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.047	0.000	0.000	0.956	1.029	0.000	0.000	0.000	1.939	0.000	0.000
1977	0.193	0.244	0.[illegible]03	0.000	0.000	0.000	0.000	0.000	2.391	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.000	0.000	0.000	0.001	0.378	2.064	0.000	0.662	0.000	0.000
1980	0.152	0.241	0.000	0.000	1.056	0.000	1.[illegible]62	0.000	0.000	1.713	0.991	0.000
1981	0.000	0.000	0.000	0.178	0.609	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.519	0.252	0.000	0.000	0.000	2.379	0.000	0.805	0.000	0.000	0.000	0.000
1983	0.000	0.[illegible]2[illegible]	0.[illegible]5[illegible]	0.[illegible]5[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.000	0.000	0.508	0.815	0.797	0.000	0.000	0.461	0.211	1.103	1.028
1985	0.000	0.[illegible]91	0.[illegible]1[illegible]	0.000	0.000	0.000	0.365	0.988	1.171	0.000	0.196	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	1.345	0.000	0.274	1.526	0.000	0.000
1987	0.000	0.223	0.[illegible]5[illegible]	0.546	0.000	0.000	0.097	0.000	0.000	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
6	1951	3	1952	10	0.59	5,90
7	1952	5	1955	36	0.57	20,47
4	1960	5	1962	26	0.[illegible]4	21,79
10	1962	11	1972	122	0.[illegible]7	106,12
7	1979	8	1[illegible]0	14	0.68	9,50
4	1984	11	1986	32	0.46	14,59

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE OF DISTRICT RAICHUR

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.515	0.000	1.695	0.000	1.030	0.000	0.606	0.000	0.356	1.189	0.999
1952	0.781	0.000	1.354	0.378	0.000	0.399	0.020	1.520	1.906	0.000	0.532	0.000
1953	0.000	0.000	0.385	0.000	1.921	1.339	0.000	2.121	0.332	0.000	0.000	0.518
1954	0.549	0.374	0.250	0.000	0.000	1.421	0.000	0.000	1.112	0.011	1.433	0.588
1955	0.386	0.379	0.000	0.000	0.000	0.348	0.000	0.000	0.000	0.000	0.448	0.317
1956	0.454	0.559	0.556	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.175	0.000	1.033	0.000	0.000	0.000	0.000	1.251	0.000	0.000	0.454
1958	0.512	0.369	0.000	0.000	0.000	1.485	0.040	0.000	0.000	1.155	0.000	0.016
1959	0.662	0.536	0.553	0.000	0.343	0.000	0.000	0.421	0.000	3.206	2.392	1.177
1960	0.424	0.424	0.000	0.492	0.000	0.023	2.002	3.501	0.000	0.000	0.689	0.708
1961	0.000	0.228	0.000	0.000	0.000	0.000	0.000	0.559	4.005	0.634	1.178	0.843
1962	0.734	0.399	0.557	0.000	0.022	0.000	1.593	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.966	0.000	0.000	0.000	0.000	0.491
1964	0.583	1.372	0.556	0.082	2.005	0.961	0.000	0.000	0.000	0.000	0.074	0.539
1965	0.561	0.375	0.556	0.871	2.448	0.000	0.343	0.000	0.000	2.103	1.675	0.000
1966	0.000	0.000	0.514	1.523	0.689	2.627	0.716	0.000	0.000	0.854	0.000	0.000
1967	0.000	0.048	0.544	0.000	0.560	1.018	0.000	0.311	0.063	0.000	1.339	0.867
1968	0.759	0.000	0.464	0.000	0.000	0.000	0.000	2.578	0.000	0.000	0.000	0.189
1969	0.561	0.349	0.000	0.833	0.000	0.000	0.000	0.000	0.895	0.000	0.000	0.000
1970	0.000	0.203	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.051	0.809
1971	0.714	0.396	0.557	0.000	0.000	2.159	3.304	0.000	0.000	0.000	1.208	0.851
1972	0.739	0.000	0.495	0.000	0.000	0.000	1.748	2.598	0.000	1.046	0.672	0.310
1973	0.450	0.555	0.556	1.574	2.004	0.000	1.606	0.000	0.431	0.000	0.000	0.000
1974	0.061	0.512	0.554	0.560	0.000	0.000	1.989	1.749	0.000	0.000	0.000	0.341
1975	0.448	0.698	0.882	1.625	2.609	2.495	0.000	0.308	1.226	0.000	0.000	0.439
1976	0.504	0.368	0.000	0.000	0.122	0.403	0.694	0.000	1.499	3.871	0.218	0.579
1977	0.585	0.579	0.000	0.000	0.000	0.000	0.313	0.000	2.393	0.000	0.000	0.000
1978	0.000	0.000	0.472	0.000	0.000	1.049	0.000	0.000	0.000	0.728	0.000	0.000
1979	0.000	0.000	0.000	1.559	0.000	0.000	0.000	1.053	0.000	0.964	0.000	0.000
1980	0.002	0.301	0.554	0.000	0.105	0.000	0.591	0.000	0.955	3.828	0.000	0.000
1981	0.000	0.000	0.000	0.955	1.343	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.168	0.365	0.415	0.517	0.000	0.000	0.000	0.226	0.000	0.000	0.000	0.000
1983	0.000	0.274	0.553	1.740	0.000	0.000	0.000	0.000	0.000	0.000	0.747	0.000
1984	0.000	0.000	0.000	0.532	2.099	3.066	0.000	1.182	0.101	0.000	0.819	0.445
1985	0.567	0.365	0.556	0.000	0.005	0.000	0.000	1.302	1.797	0.000	1.050	0.483
1986	0.000	0.000	0.204	0.000	0.116	0.000	0.664	0.528	0.000	2.460	0.000	0.000
1987	0.000	0.059	0.545	1.740	0.711	0.000	1.395	0.000	0.982	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	7	1954	43	0.61	26.33
8	1955	8	1962	57	0.94	34.87
2	1966	9	1967	32	0.51	16.22
10	1971	10	1973	25	0.70	17.58
11	1974	12	1978	50	0.68	34.24
2	1980	9	1981	20	0.60	12.09
4	1984	11	1986	32	0.68	21.65

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE OF DISTRICT DHARWAR

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1951	0.000	0.546	0.661	0.000	0.000	0.000	0.000	1.751	0.000	0.000	0.000	0.000
1952	0.000	0.478	0.662	0.000	0.000	0.552	0.000	1.301	2.929	0.000	1.221	0.000
1953	0.000	0.130	0.204	0.000	1.696	0.000	0.000	0.000	0.000	0.000	0.000	0.488
1954	0.505	0.455	0.000	0.000	0.000	0.295	0.000	0.000	1.989	0.000	1.273	0.245
1955	0.543	0.437	0.521	0.000	0.000	0.324	3.271	2.064	0.000	0.000	0.066	0.621
1956	0.595	0.000	0.540	0.000	1.552	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.271	0.000	0.000	0.000	0.000	0.203	0.000	2.109	0.000	0.000	0.000
1958	0.194	0.418	0.420	0.000	0.000	0.000	0.000	0.000	0.456	0.077	0.127	0.320
1959	0.593	0.445	0.000	0.000	0.421	0.000	0.000	0.000	0.000	2.439	0.197	0.661
1960	0.622	0.497	0.000	0.000	0.000	1.300	0.779	1.178	0.000	0.343	0.000	0.546
1961	0.254	0.427	0.000	0.000	0.000	0.000	0.000	0.000	1.417	0.000	0.963	0.894
1962	0.776	0.000	0.651	0.309	0.000	5.096	0.000	0.000	1.182	0.000	0.285	0.000
1963	0.000	0.000	0.000	0.000	0.000	1.779	3.188	0.000	1.899	0.000	1.075	0.928
1964	0.798	0.467	0.529	1.056	2.898	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.580	0.652	2.258	0.410	0.582	0.000	0.923	0.000	3.240	1.507	0.000
1966	0.000	0.000	0.573	2.553	0.000	0.131	0.000	2.399	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.239	0.000	0.000	0.000	0.000	0.000	0.429	0.000	1.285	0.000
1968	0.000	0.000	0.053	0.000	0.000	0.000	0.282	2.794	0.000	0.000	0.000	0.404
1969	0.449	0.447	0.000	1.197	0.320	3.458	0.259	0.000	1.149	0.000	0.000	0.097
1970	0.244	0.426	0.291	0.000	0.000	0.983	1.165	0.000	0.000	0.000	1.205	0.968
1971	0.515	0.490	0.664	0.000	0.303	0.000	1.236	0.000	0.000	0.000	1.387	1.023
1972	0.662	0.474	0.611	0.364	0.000	0.411	0.000	2.725	0.000	1.881	0.000	0.000
1973	0.124	0.417	0.663	0.851	0.557	0.000	0.000	0.000	0.711	0.474	1.297	0.983
1974	0.654	0.491	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.548
1975	0.344	0.469	0.000	1.411	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.351	0.091	0.000	2.671	2.168	0.008	0.732	1.157	3.054	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.361	2.078	0.625	1.134	0.000	0.239
1978	0.557	0.000	0.594	0.000	0.000	0.000	0.552	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.048	0.000	0.570	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.247	0.000	0.552	0.000	0.000	0.000	0.000	1.911	0.000	0.094
1981	0.000	0.422	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.743	1.283	0.992
1982	0.000	0.492	0.071	1.944	0.000	0.000	0.000	0.000	0.988	0.000	0.000	0.495
1983	0.507	0.455	0.000	3.359	1.933	0.000	0.000	0.000	0.000	1.637	0.145	0.000
1984	0.000	0.000	0.000	1.313	2.479	0.241	0.000	1.106	0.000	0.000	1.172	0.958
1985	0.516	0.452	0.000	0.037	0.000	0.783	1.777	0.000	1.596	0.544	1.362	0.801
1986	0.000	0.000	0.000	0.000	0.654	0.000	1.947	0.513	0.000	1.064	0.000	0.000
1987	0.000	0.513	0.672	3.075	1.439	0.878	3.513	0.384	0.000	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
6	1952	7	1953	14	0.77	10.75
7	1954	9	1955	15	1.07	15.97
6	1957	4	1961	41	0.51	20.99
9	1961	7	1966	34	0.91	30.82
10	1964	10	1965	13	0.90	11.69
7	1967	6	1973	70	0.52	36.40
5	1976	8	1978	28	0.73	20.31
7	1981	10	1987	78	0.67	52.63

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE OF DISTRICT BELLARY

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.000	0.000	0.000	3.753	2.565	0.000	1.650	0.049	1.653	1.935	0.000
1952	0.000	0.000	1.645	0.000	0.000	2.295	2.273	1.636	2.884	0.000	0.741	0.000
1953	0.000	0.072	3.67	0.044	2.024	0.009	0.603	1.113	0.000	0.000	0.202	0.789
1954	0.702	1.437	0.000	0.000	0.000	0.000	0.000	0.000	1.472	1.790	1.782	0.146
1955	0.424	0.384	0.000	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.191	0.787
1956	0.707	1.437	0.000	0.000	0.000	0.000	0.000	0.430	0.000	0.000	0.000	0.000
1957	0.000	1.234	0.000	0.210	0.000	0.000	0.000	0.000	1.469	0.000	0.000	0.375
1958	0.822	0.405	1.410	0.000	0.000	0.000	0.000	0.000	0.000	1.817	0.000	0.721
1959	0.076	1.451	0.695	0.579	0.347	0.000	0.000	0.000	0.000	1.842	1.312	0.891
1960	1.755	0.445	0.000	0.000	0.000	1.707	0.000	2.703	0.000	0.000	0.812	0.941
1961	0.395	0.579	0.000	0.000	0.000	0.000	0.000	0.094	3.212	0.000	1.203	0.000
1962	0.000	1.255	0.000	0.000	0.000	0.909	0.158	0.000	0.616	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.043	0.478	0.000	2.141	0.000	0.520	0.369
1964	0.744	0.443	0.000	1.557	1.606	0.000	0.000	0.000	0.000	0.000	0.000	0.422
1965	0.546	0.437	0.594	0.000	2.196	0.546	1.755	0.000	0.000	2.833	1.599	0.000
1966	0.000	0.000	0.592	1.501	1.550	0.000	0.000	0.661	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.655	0.000	1.684	0.000	0.000	0.418	2.050	0.256	1.607	1.032
1968	0.916	0.000	0.000	0.724	0.000	0.431	0.000	2.182	0.000	0.000	0.000	0.121
1969	0.415	0.562	1.691	0.508	0.000	0.000	1.119	0.000	1.000	0.000	0.000	0.191
1970	0.444	0.566	0.691	0.000	0.000	1.552	0.000	0.000	0.000	0.000	0.000	0.656
1971	0.000	0.230	0.566	0.594	0.000	1.034	1.309	0.000	0.000	0.000	0.847	0.950
1972	0.770	0.000	0.000	1.463	0.000	0.867	1.566	1.399	0.000	0.000	0.000	0.106
1973	0.406	0.561	0.691	1.543	1.722	0.000	0.000	0.000	0.245	0.000	0.495	0.789
1974	0.705	0.457	0.693	0.000	0.000	0.000	2.293	2.847	0.000	0.000	0.730	0.921
1975	0.767	0.448	0.000	2.174	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.155	0.691	0.000	1.752	3.274	2.572	0.417	2.991	3.789	0.000	0.500
1977	0.561	0.413	0.472	0.355	0.000	0.000	0.246	0.000	0.951	0.000	0.000	0.000
1978	0.000	0.000	0.616	0.771	0.000	0.466	0.000	0.676	0.000	0.578	0.000	0.000
1979	0.000	0.000	0.000	0.000	0.969	0.000	0.709	0.000	0.000	0.996	0.000	0.000
1980	0.254	0.371	0.593	0.000	0.000	0.000	0.000	0.000	0.348	2.926	0.195	0.716
1981	0.000	0.000	0.000	0.000	1.208	1.329	0.753	0.000	0.000	0.000	0.000	0.000
1982	0.192	0.541	1.667	0.000	0.000	0.000	0.000	0.668	0.000	0.000	0.000	0.000
1983	0.629	0.529	1.693	2.775	0.000	0.000	0.000	0.000	0.000	0.000	0.296	0.000
1984	0.000	0.212	0.000	0.000	1.254	1.756	0.000	0.969	0.000	0.000	1.276	0.822
1985	0.762	0.439	0.000	0.000	1.242	1.945	0.426	1.588	1.792	2.719	0.499	0.807
1986	0.000	0.000	0.000	0.002	0.000	0.000	1.076	0.000	0.000	1.929	0.000	0.000
1987	0.000	0.258	0.658	2.775	0.000	0.000	2.303	0.000	0.000	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
4	1951	7	1954	40	0.87	34.99
9	1954	4	1955	8	1.31	10.47
7	1958	7	1959	12	0.44	5.22
6	1959	4	1961	21	0.66	13.91
8	1961	10	1962	15	0.57	8.62
6	1963	7	1964	13	1.70	9.13
10	1964	12	1965	3	2.07	6.22
6	1967	8	1970	45	0.49	20.87
11	1971	9	1972	11	0.80	8.85
7	1974	9	1974	3	1.52	4.57
1	1976	12	1978	36	0.83	29.72
9	1980	5	1981	15	0.79	10.28
5	1984	1	1986	21	0.97	20.43

DROUGHT ANALYSIS FOR DISTRICT AS A WHOLE OF DISTRICT BIJAPUR

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.488	0.569
1952	0.576	0.000	0.000	0.000	0.000	0.868	0.310	2.441	2.582	0.000	1.516	0.945
1953	0.725	0.420	1.477	0.000	2.505	0.000	0.000	1.077	0.000	0.000	0.000	0.67
1954	0.662	0.414	0.000	0.000	0.494	0.603	0.000	0.000	1.723	2.169	2.270	0.000
1955	0.000	0.504	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.407
1956	0.517	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.304	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.395	0.000	0.299	0.811
1958	0.673	0.417	0.000	0.000	0.000	1.946	0.752	0.000	2.560	0.617	0.000	0.630
1959	0.604	0.415	1.278	0.000	0.000	0.585	0.003	1.484	0.224	1.702	0.721	0.73
1960	0.645	0.415	0.000	0.000	0.000	0.000	0.000	3.302	0.000	0.000	0.000	0.652
1961	0.614	0.414	0.000	0.000	0.000	0.000	0.000	0.837	3.205	1.588	1.362	1.18
1962	0.718	0.000	0.000	0.000	0.000	0.000	0.752	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.451	0.000	1.824	0.000	0.359	0.837
1964	0.682	0.105	0.000	0.000	2.380	1.636	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.266	1.260	0.906	1.929	0.000	0.000	0.000	0.000	3.401	2.589	0.000
1966	0.000	0.035	0.000	0.758	0.000	1.218	0.000	0.388	0.240	2.334	0.000	0.000
1967	0.000	0.365	0.000	0.000	0.682	3.198	0.687	1.659	0.000	0.000	1.230	0.000
1968	0.000	0.000	0.000	0.000	1.103	0.000	0.000	2.838	0.000	0.000	0.000	0.000
1969	0.170	0.591	0.545	0.658	0.712	0.000	0.534	0.000	0.185	0.000	0.000	0.123
1970	0.000	0.580	1.473	0.000	0.000	1.459	1.337	0.000	0.000	0.560	1.534	1.249
1971	0.441	0.634	0.585	0.000	0.000	0.472	1.211	0.000	0.000	0.000	0.341	0.524
1972	0.000	0.000	0.000	0.000	0.511	1.912	2.012	2.157	0.695	1.070	0.000	0.000
1973	0.000	0.551	1.143	0.000	1.026	0.000	0.000	0.000	0.000	0.000	0.000	0.49
1974	0.552	0.411	0.000	0.751	0.000	0.794	2.301	0.097	0.000	0.000	0.119	0.747
1975	0.000	0.000	0.077	1.088	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.455	0.595	0.000	0.000	0.000	0.000	0.000	0.000	2.779	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.000	2.123	0.739	0.959	0.000	0.579	0.000	0.000	0.000	0.000
1980	0.000	0.339	1.267	0.000	0.772	0.000	1.413	0.000	0.000	2.451	1.340	0.056
1981	0.582	0.402	1.276	2.337	0.809	0.000	0.000	0.000	0.000	0.000	0.000	0.244
1982	0.454	0.406	1.277	2.337	0.000	0.000	0.000	1.847	1.043	0.312	0.000	0.000
1983	0.230	0.394	1.276	2.337	1.925	0.000	0.000	0.000	0.000	0.425	0.367	1.017
1984	0.751	0.421	1.279	2.337	1.852	3.705	0.000	1.296	0.375	0.000	1.341	1.181
1985	0.615	0.424	1.279	2.337	0.695	0.847	0.000	0.000	1.593	1.109	1.342	1.181
1986	0.000	0.000	1.171	1.172	0.000	0.000	2.762	0.819	0.713	3.045	0.000	0.000
1987	0.000	0.572	1.217	1.405	0.000	0.000	1.387	0.000	0.000	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
11	1951	7	1954	33	0.68	22.38
9	1954	12	1954	4	1.89	7.51
6	1954	2	1962	45	0.86	38.55
7	1962	7	1964	13	0.80	10.37
2	1965	12	1967	35	0.63	22.07
5	1972	9	1974	29	0.59	17.24
1	1980	9	1981	21	0.57	11.90
8	1982	11	1985	52	0.91	47.27

Duration and Number of Dry Spells during Monsoon (4th June to 15th Sept.)

Belgaum (Belgaum)

First day of monsoon	Date of beginning of dry spell	Duration of dry spells (2 weeks in days)	Total no. of dry spells in a year
1	2	3	4
5.6.81	-	-	-
14.6.82	31.8.82	16	1
16.6.83	3.7.83	15	2
	1.9.83	14	2
9.6.84	-	-	-
10.6.85	26.8.85	21	1
8.6.86	22.8.86	26	1
9.6.87	30.8.87	17	1
			6

Bijapur (Bijapur)

1	2	3	4
6.6.81	18.7.81	34	2
	6.8.81	29	
7.6.82	21.6.82	23	2
	30.8.82	17	
6.6.83	14.6.83	14	3
	15.7.83	23	
	9.7.83	24	
9.6.84	10.6.84	33	2
	3.8.84	30	
4.6.85	27.6.85	23	2
	26.7.85	19	
4.6.86	18.6.86	26	2
	23.7.86	55	
4.6.87	5.6.87	21	3
	27.6.87	33	
	18.8.87	29*	
			16

Gulburga (Gulburga)

1	2	3	4
4.6.81	6.7.81	17	2
	15.8.81	18	
17.6.82	18.6.82	16	2
	9.8.82	32	
5.6.83	25.6.83	17	1
11.6.84	18.6.84	15	2
	9.6.844	20	
6.6.85	19.6.85	32	1
4.6.86	22.6.86	25	2
	14.8.86	25	
15.6.87	18.7.87	20	1
			11

Raichur (Raichur)

1	2	3	4
7.6.81	8.7.81	15	1
22.6.82	4.6.82	18	3
	5.8.82	18	
	27.8.82	19	
16.6.83	-	-	-
10.6.84	6.8.84	36	1
15.6.85	1.7.85	18	3
	31.7.85	14	
	15.8.85	25	
1986	date not available		
1987	date not available		
			8

Dharwar (Dharwar)

1	2	3	4
4.6.81	-	-	-
8.6.82	21.6.82	25	2
	24.8.82	33*	
13.6.83	2.7.83	15	2
	26.7.83	15	
12.6.84	3.8.84	44	1
17.6.85	-	-	-
5.6.86	1.7.86	14	2
	14.8.86	33	
17.6.87	10.7.87	27	2
	26.8.87	20	
			9

Bellary (Bellary)

1	2	3	4
7.6.81	18.6.81	33	2
	3.8.81	23	
8.6.82	13.6.82	26	2
	3.8.82	43	
14.6.83	26.6.83	15	2
	26.7.83	17	
18.6.84	4.6.84	14	4
	27.6.84	16	
	3.8.84	20	
	1.9.84	15	
6.6.85	10.6.85	42	2
	29.7.85	41	
4.6.86	17.6.86	16	3
	4.7.86	28	
	6.8.86	35	
24.6.87	4.6.87	20	3
	29.6.87	37	
	16.8.87	20	
			18

Gulburga (Gulburga)

1	2	3	4
4.6.81	6.7.81	17	2
	15.8.81	18	
17.6.82	18.6.82	16	2
	9.8.82	32	
5.6.83	25.6.83	17	1
11.6.84	18.6.84	15	2
	9.6.844	20	
6.6.85	19.6.85	32	1
4.6.86	22.6.86	25	2
	14.8.86	25	
15.6.87	18.7.87	20	1
			11

Raichur (Raichur)

1	2	3	4
7.6.81	8.7.81	15	1
22.6.82	4.6.82	18	3
	5.8.82	18	
	27.8.82	19	
16.6.83	-	-	-
10.6.84	6.8.84	36	1
15.6.85	1.7.85	18	3
	31.7.85	14	
	15.8.85	25	
1986	date not available		
1987	date not available		
			8

Dharwar (Dharwar)

1	2	3	4
4.6.81	-	-	-
8.6.82	21.6.82	25	2
	24.8.82	33*	
13.6.83	2.7.83	15	2
	26.7.83	15	
12.6.84	3.8.84	44	1
17.6.85	-	-	-
5.6.86	1.7.86	14	2
	14.8.86	33	
17.6.87	10.7.87	27	2
	26.8.87	20	
			9

Bellary (Bellary)

1	2	3	4
7.6.81	18.6.81	33	2
	3.8.81	23	
8.6.82	13.6.82	26	2
	3.8.82	43	
14.6.83	26.6.83	15	2
	26.7.83	17	
18.6.84	4.6.84	14	4
	27.6.84	16	
	3.8.84	20	
	1.9.84	15	
6.6.85	10.6.85	42	2
	29.7.85	41	
4.6.86	17.6.86	16	3
	4.7.86	28	
	6.8.86	35	
24.6.87	4.6.87	20	3
	29.6.87	37	
	16.8.87	20	
			18

Probability Analysis of Dry Spells

Taluk/Station (Distt.)	Class Interval (in day)	No. of Spells	Percentage	Cummulative Probability
Belgaum	14-21	5	83.3	100.0
(Belgaum)	22-28	1	16.6	16.6
	29-35	-	-	-
	> 35	-	-	-
		6		
Bijapur	14-21	4	25.0	100.0
(Bijapur)	22-28	5	31.3	75.1
	29-35	4	25.0	43.8
	> 35	3	18.8	18.8
		16		
Gulburga	14-21	7	63.6	100.0
(Gulburga)	22-28	2	18.2	36.4
	29-35	2	18.2	18.2
	> 35	-	-	-
		11		
Raichur	14-21	6	75.0	100.0
(Raichur	22-28	1	12.5	25.0
	29-35	-	-	12.5
	> 35	-	-	12.5
		8		
Bellary	14-21	8	44.4	100.0
(Bellary)	22-28	4	22.2	55.4
	29-35	2	11.1	33.3
	> 35	4	22.2	22.2
		18		
Dharwar	14-21	4	44.4	100.0
(Dharwar)	22-28	2	22.2	55.5
	29-35	2	22.2	33.3
	> 35	1	11.1	11.1
		9		

LIST OF 33 KV SUB-STATIONS

STATE : KARNATAKA
DIST : BELGAUM

SL. NO.	NAME OF WELL	LAT.	LONG.	CAP. OF S.P.(MVA)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	[illegible]	15 54 00	74 37 00	50.00	1427	0.1457
2.	[illegible]	15 50 21	75 31 51	200.75	1393	0.1988
3.	[illegible]	15 51 2	75 15 34	251.00	1452	0.1085
4.	MUDDE [illegible]	15 47 14	75 30 [illegible]	315.10	1492	0.1577
5.	[illegible]	15 41 47	75 [illegible]	276.95	1446	0.1844
6.	[illegible]	15 45 2	74 45 46	276.70	2335	0.1397
7.	[illegible]	17 45 15	75 37 [illegible]	100.70	1113	0.0552

STATE : KARNATAKA
DIST : BELGAUM

SL. NO.	NAME OF WELL	LAT.	LONG.	CAP. OF S.P.(MVA)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	[illegible]	15 48 45	75 30 37	500.00	1529.51	0.1136
2.	[illegible]	15 42 [illegible]	74 [illegible]	345.00	1721.70	0.1279
3.	[illegible]	15 41 30	74 41 45	670.00	2824.25	0.2098
4.	[illegible]	15 48 [illegible]	74 [illegible]	315.00	3038.10	0.2257
5.	[illegible]	15 [illegible]	74 45 35	664.00	1835.85	0.1364
6.	[illegible]	15 48 55	75 01 [illegible]	655.00	2511.41	0.1866

[illegible]

STATE-[illegible]
DIST-[illegible]

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L. OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		[illegible]	[illegible]	[illegible]	[illegible]	1751	0.1250
2.		[illegible]	[illegible]	77 [illegible]	41[illegible]	255[illegible]	0.1667
3.		[illegible]	[illegible]	[illegible] 31 [illegible]	[illegible]	[illegible]	0.1417
4.		[illegible]	[illegible]	7[illegible] 11 1	[illegible]	1[illegible]1	0.1000
5.		[illegible]	[illegible] 13	[illegible]	[illegible]	[illegible]	0.1917
6.		[illegible]	[illegible]	[illegible]	[illegible]	1[illegible]17	0.1083
7.		[illegible]	[illegible] 23 [illegible]	[illegible]	[illegible]	[illegible]	0.0750
8.		[illegible]	[illegible]	[illegible]	[illegible]	12[illegible]	0.0916

STATE-[illegible]
DIST-[illegible]

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L. OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		[illegible]	1[illegible] 1[illegible]	[illegible] 13 [illegible]	599.00	[illegible]15	0.0566
2.		[illegible]	17 [illegible]	7[illegible]	[illegible]	[illegible]	0.1279
3.		[illegible]	17 [illegible]	77 [illegible]	4[illegible].00	1313	0.0936
4.		[illegible]ITTI-PUR	17 [illegible]	77 [illegible]	424.00	[illegible]1[illegible]	0.0506
5.		[illegible]	17 [illegible]	7[illegible]	457.50	2[illegible]15	0.1246
6.		[illegible]	17 [illegible]	7[illegible] 47 [illegible]	415.00	1754	0.1091
7.		[illegible]	17 10 [illegible]	77 17 [illegible]	450.00	1030	0.0657
8.		[illegible]	1[illegible] 42 [illegible]	7[illegible] 30 [illegible]	410.00	1499	0.0927
9.		[illegible]	1[illegible] 36 [illegible]	7[illegible] 29 [illegible]	500.00	1799	0.1113
10.		[illegible]	1[illegible] [illegible]	77 [illegible]	557.00	2747	0.1699