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HYDROLOGICAL ASPECTS OF DROUGHT
UPTO
1987-88
A Case Study in Gujarat

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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 droughts 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 initiatted 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 Gujarat state. These districts are: Rajkot,Jamnagar,Ahmedabad,Surendranagar, Amreli & Bhavnagar. Scientific teams of the Institute undertook visits to Gujarat state and contacted the relevant state/central Govt. agencies for collecting the required data. The study includes various kinds of analysis of rainfall data, stream flow data & ground water level data for assesing drought impacts.

Based on the analysis, inferences, highlighting hydrological aspects of the recent droughts, have been drawn up. The study has been carried out by Shri V.K.Lohani, Scientist'C', Shri Sudhir Kumar Goel, Scientist 'B', Sh. Yatveer Singh ,R.A., Sh. Mukesh Kumar Sharma,SRA, & Shri Tanveer Ahmad ,R.A. under the guidence of Dr. G.C. Mishra, Scientist 'F'. The manuscript has been typed by Mrs. Mary D'souza, stenographer & K.C.Katheria,LDC.

SATISH CHANDRA

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ABSTRACT

In the recent past droughts of exceptional severity have caused major hardship in many areas of the country. The problem of droughts in the country has wider dimensions and is recurrent in nature. Nearly 1/3rd of the country's area (i.e. 107 million ha.) spread over 99 districts in 13 states is either affected by or prone to drought comprising of about 39 percent of the cultivable area of the country (CWC, 1982). In recent years droughts were experienced in the country for three successive years viz. 1985-86, 86-87 and 87-88. The recurring incidents of droughts lead to reduction in streamflow, 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.

The present report describes the results of studies carried out for the year 1987-88 in six districts namely Rajkot, Jamnagar, Ahmedabad, Surendranagar, Amreli & Bhavnagar of Gujarat.

These districts lie in Saurashtra region which has mostly black soils which is poor in fertility causing the area prone to drought. These drought affected districts lie in cotton -dry wheat zone and ground nut zone. The Saurashtra region are under rocks hence no tubewells are there for groundwater development.

The report includes analysis of rainfall and groundwater level data for finding effects of deficit of rainfall and trend of groundwater table as a result of drought incidents. The rainfall data have been analysed using various techniques for classification of drought. The report also includes description of land use, population pattern, soils, geology water resources statistics etc. of the state.

The results of rainfall departure analysis shows that all six districts selected for the study faced more than 60% seasonal deficiency and more than 50% deficiency in individual monsoon months. The probability analysis of annual rainfall for two taluks in each of the six districts and district as a whole has been carried out. The group range of annual rainfall at 75% of normal rainfall in all the six districts namely, Jamnagar, Rajkot, Ahmedabad, Surendranagar, Amreli and Bhavnagar were found as 60,63,63,59,57 and 63% respectively which are all below 80% further certifying the drought proneness of the districts.

The analysis of monthly rainfall data using Herbst's approach indicated that all the six districts except Bhavnagar had drought spells during 1984-87. The district of Rajkot showed highest intensity of drought during 1985-87. All districts experienced 6-9 drought spells during the period 1959-87. The dry spell analysis which is done for one selected taluk in each of the six

districts, indicated that for all the six taluks, the duration of the dry spell ranged from 21-28 days at 75% level of probability. A dry spell was assumed as period during which rainfall does not exceed 5mm for at least 2 weeks. The groundwater level analysis carried out for all the six districts showed a declining trend as a result of reduced rainfall. The water table trend lines for pre and post monsoon periods in 1987-88 showed greater effects on water table as a result of monsoon failure as compared to previous years. The steepest fall in groundwater levels was found in Jamnagar district which was followed by Rajkot and Amreli. The district of Ahmedabad, however, showed lowest rate of decline in pre and post monsoon levels. The study will continue for year 1988-89 to compare status of hydrological parameters for drought and non-drought years.

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 standpoints (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 departures 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-divisions 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 streamflows, depletion of soil moisture storages, decline of reservoir and tank levels and fall in groundwater table. This in turn leads 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 the repeated occurrences of drought in the country, the hydrological 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 in year 1985. Keeping in view the successive drought years of 1985, 1986 and 1987, in major parts of the drought prone area of the country, study areas were choosen in six various states namely; A.P., Maharashtra, Karnataka, Rajasthan, Gujarat and Madhya Pradesh. Studies laying focus on hydrological aspects of drought for 1985-86 with two districts in each of choosen states and for 1986-87 with four districts have been completed. The studies for year 1987-88 were carried out in six districts each in 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 in all states in one volume.

The present report, therefore presents results of studies carried out in six districts of Gujarat state. It has been reported that the state has experienced 10 drought years since 1960. The districts included for studies are Jamnagar, Rajkot, Amreli, Bhavnagar, Surendranagar and Ahmedabad. The report includes analysis of rainfall and grounndwater level data for finding deficit

in rainfall and its consequent effects on groundwater tables. In order to evaluate the impacts on surface water storages, the storage figures in Kadana reservoir located in the state, have been included in the report. The report is an attempt towards developing a comprehensive hydrological drought index for characterising drought situations. List of offices and places from where data and information were collected in the State of Gujarat 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 and are shown in Fig.2.1. This report covers the study of six drought prone districts in Gujarat state namely; Jamnagar, Rajkot, Ahmedabad, Surendranagar, Amreli & Bhavnagar. The locations of the districts are shown on the state map as shown in Fig.2.2. The Gujarat state lies between the North latitude $20^{\circ}30'$ to $24^{\circ}30'$ and longitude of $68^{\circ}5'$ to $73^{\circ}20'$ and is the western most state of the country covering the area about 1,96,024 sq.kms.

In Gujarat, the average annual precipitation over different parts of the State varies widely from 300 mm in the Western half of Kutch to 1500 mm in the Southern parts of the Valsad Districts and Dengs. The monsoon usually commences by the middle of June and withdraws by the end of September.

2.2 Population - Man & Cattle

The state of Gujarat has the population 3,40,85,799 as per census of 1981. The growth of population in Gujarat is shown in Table 2.1. As is evident from the Table, over past decades the State has had a growth rate of 3.26%. Reliable sources indicate that in the state mostly the voluntary agencies have the responsibilities

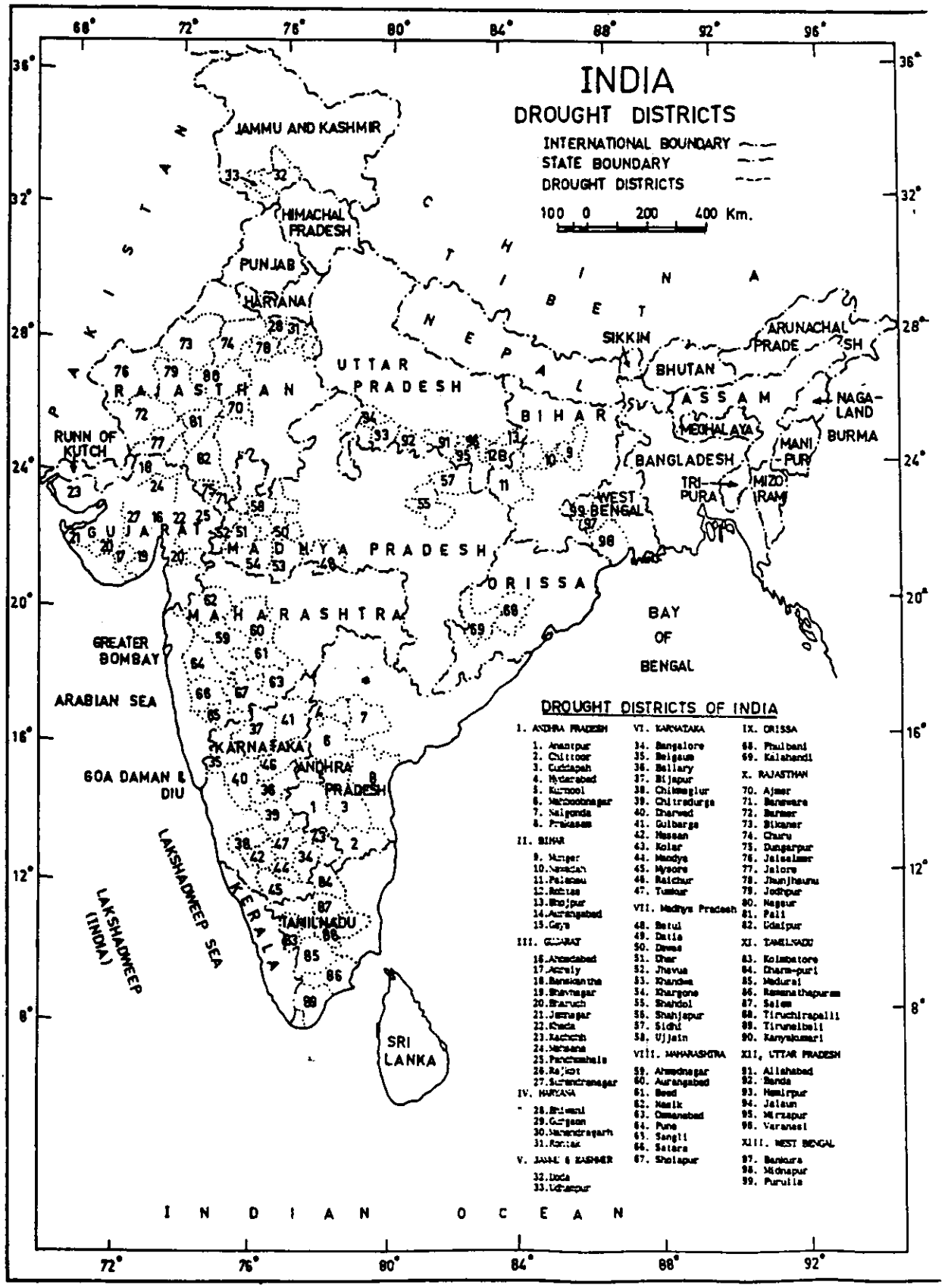


FIG. 2.1 : DROUGHT PRONE DISTRICTS IN INDIA

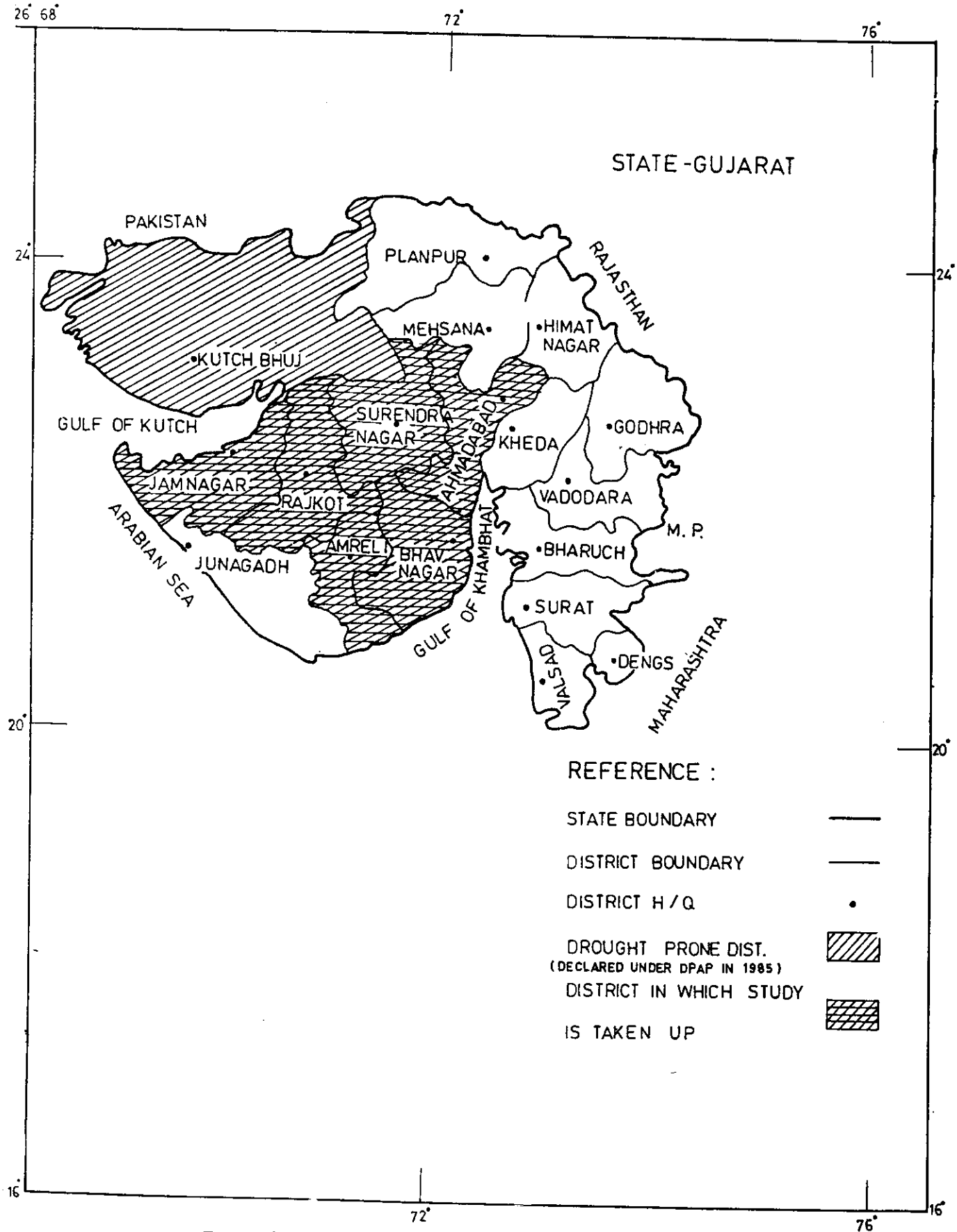


FIG. 2.2. DROUGHT PRONE DISTT. IN GUJARAT

to maintain the cattle camps etc.

Table 2.1 : Growth of population in the State of Gujarat

Year	Population
1961	2,06,33,350
1971	2,66,97,475
1981	3,40,85,799

During the year 1987-88, nearly 8 lakh cattle heads have been maintained in 1015 cattle camps specially opened by voluntary agencies for maintenance of cattle. Apart from cattle camps, gaushalas and Panjirapoles were also maintained for taking care of 2.22 lakh cattle heads. On the whole nearly 10 lakh cattle heads were brought under the umbrella of voluntary agencies in the year 1987-88 (Govt. of Gujarat, 1987-88).

2.3 Land Use and Vegetal Cover

Technical Bulletin No.111. The Directorate of Agriculture has compiled information on land use and vegetal cover statistics in the State. Accordingly, the areas under different land uses and their percentages to the reported geographical area for the year 1960-61 and 1982-83 are given in Table 2.2 & Fig. 2.3 (Technical Bulletin No.111, 1987).

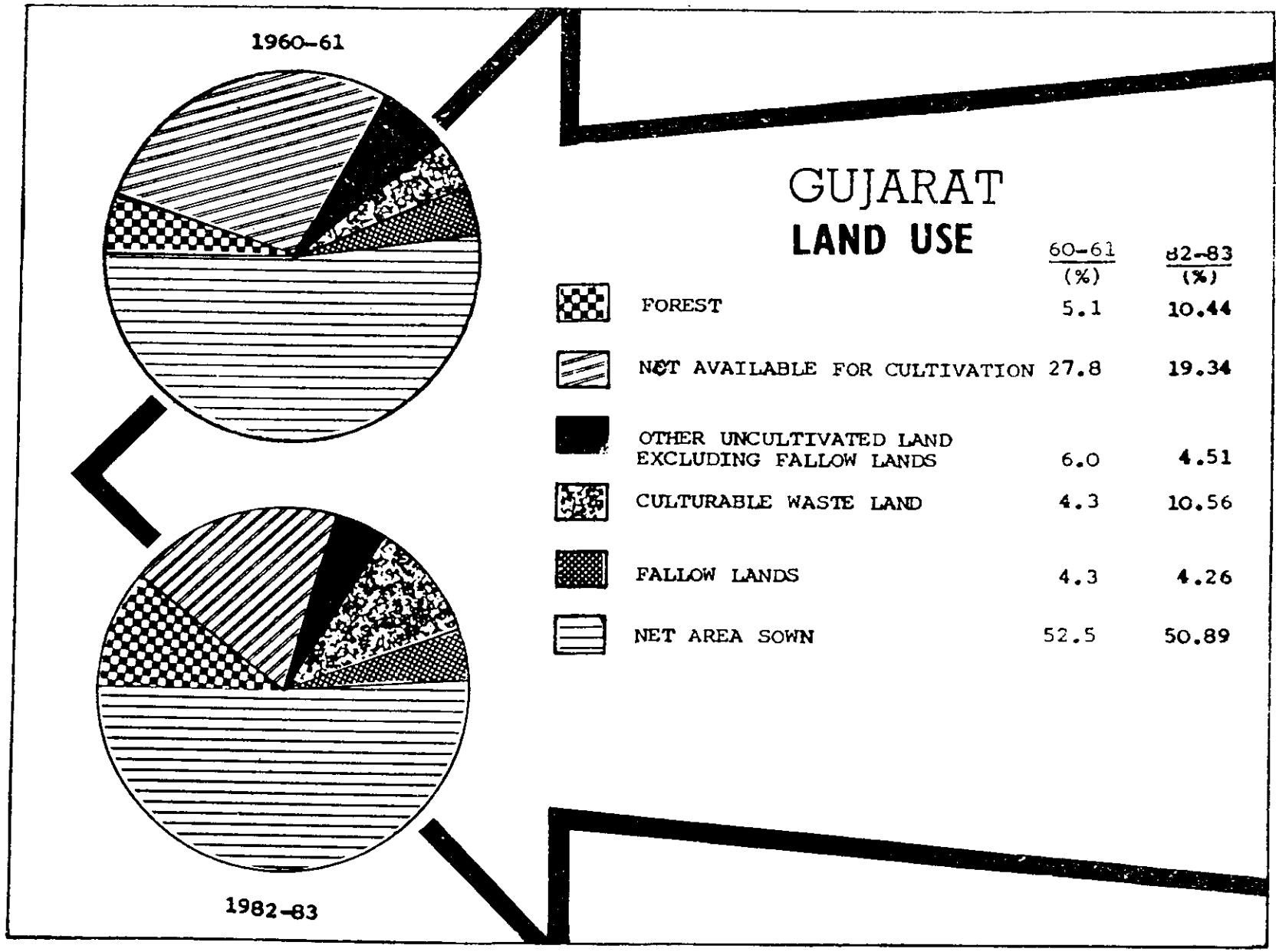


Fig. 2.3 : Details of Land use in Gujarat

Source : Technical Bulletin No.111, 1987, Govt. of Gujarat

Table 2.2 : Average Land Use Particulars in the State of Gujarat
(Unit : Lakhs)

Sl. No.	Type of Land	Area in Lakh ha.		Percentage with regard to reported geographical Area of the state	
		1960-61	1982-83	1960-61	1982-83
1.	Forest	9.22	19.66	5.15	10.44
2.	Barren and Unculti-vable Land	45.75	25.60	25.54	13.60
3.	Land put to non-agricultural use	4.05	10.81	2.26	5.74
4.	Culturable waste land	7.64	19.89	4.26	5.78
5.	Permanent pasture & grazing land	10.42	8.45	5.82	4.49
6.	Land Under Misc. trees, crops & groves	0.41	0.04	0.22	0.02
7.	Current fallows	3.41	7.26	1.90	3.86
8.	Other fallows	4.25	0.75	2.37	0.39
9.	Gross Sown Area	97.68	109.45	54.53	58.13
9(a)	Area sown more than once	3.71	13.62	2.07	7.23
9(b)	Net Area Sown	93.97	95.83	52.46	50.89

Source : Technical Bulletin No.111, 1987, Govt. of Gujarat.

From Fig. 2.3 and Table 2.2 it is evident that percentage of forest cover has increased from 1960-61 to 1982-83. The percentage of the land put to non agricultural use has increased to 5.74 in 1982-83 from 2.26 in 1960-61. However, it may be noted that there has been increase in culturable waste land during the period of record. Even the net area available for cultivation also got reduced to 19.34% in 82-83 which was reported as 27.8% in 60-61.

2.4 Soils

The soils of Gujarat can be broadly classified into nine

groups. These are black soils, mixed red and black soils, residual sand soils, alluvial soils, saline/alkali soils, lateritic soils, hilly soils, desert soils and forest soils. The soil map of the state is shown in Fig.2.4. As can be seen from the soil map, the Saurashtra region has mostly black soils which are poor in fertility causing this area prone to drought. The districts of Ahmedabad, Surendranagar, Rajkot, Jamnagar, Amreli & Bhavnagar which are taken up for study in this report have mostly black soils which are poor in fertility.

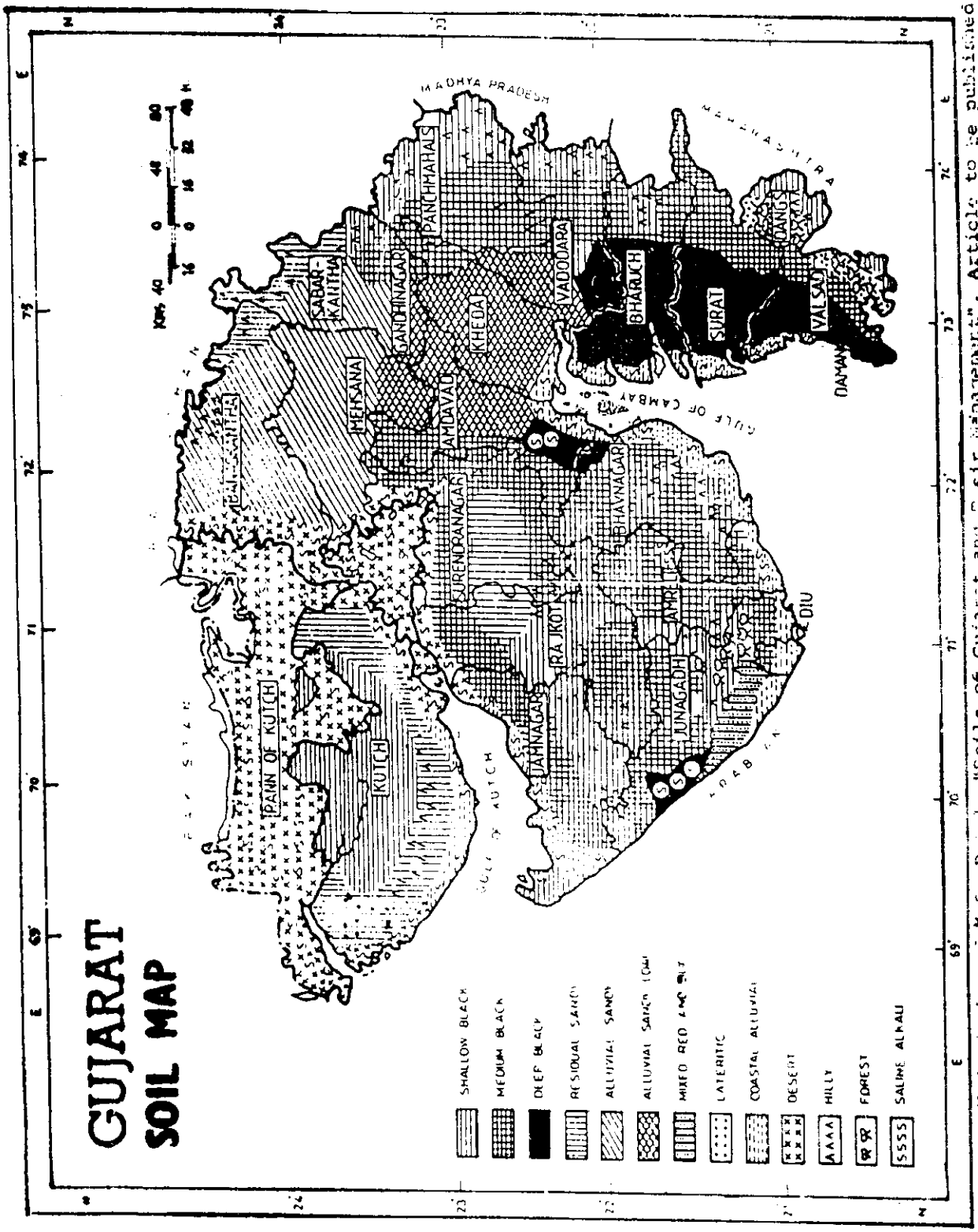
2.5 Surface Water Availability

In the State of Gujarat the ultimate and utilisable surface water availability in minor, medium and major irrigation schemes is of the order of 2.95 M.ha.m and for Sardar Sarovar project alone it is 2.03 M.ha.m. (Mistry & Goswami, 1988). The position of storages in the state for already completed, under completion and proposed projects are given in Table 2.3 (CWC, 1988).

Table 2.3 : Storages in the Projects of State Gujarat

Type of Projects	Gross in M.ha.m. Storage	Live in M.ha.m. Storage
1. Project completed	1.498	1.275
2. Projects under construction	1.353	0.931
3. Total	2.851	2.206
4. Proposed Projects	0.253	0.223

Source:- CWC report on Water Resources of India,1988.



Source: M.V.Kanzaria and K.S. Patel, "Soils of Gujarat and Their Management", Article to be published in the Book Soils of India and Their Management, Fertilizer Association of India, New Delhi.

Fig.2.4: Soil map of state Gujarat.

2.6 Ground Water Availability

It has been estimated that the total available ground water resources of the state are of the order of 1.73 M.ha.m. There are 16,935 wells and 3,615 tube wells spread over the state as per figure for the year 1982-83 given in Technical bulletin No.111 of Directoorate of Agriculture, Gujarat. However, there are no tubewells in the Saurashtra region of Gujarat as most of the area is under rocks.

The recurrent occurrences of droughts in the state have had impacts on the ground water resources. Studies conducted by the Central Ground Water Board reveal that the continued drought conditions have brought progressive reduction in recharge component which against the continued ground water withdrawals resulted in the emergence of a lowering trend of ground water levels. Since the pattern of rainfall recharge, ground water withdrawals and hydrogeological set up were different in different regions of the state, the magnitudes of ground water level decline have also been different. Results of studies on estimation of ground water recharge, draft and average decline in water levels as conducted in three distinct regions of the state, namely; Saurashtra, Kachchh and North Gujarat are presented in Table 2.4 (Mistry & Goswami, 1988). It can be observed that highest decline in water levels were observed in Kachchh followed by North Gujarat and Saurashtra in year 1987.

TABLE 2.4 : IMPACT ON GROUND WATER RESOURCE DURING DROUGHT YEARS

Year	Rainfall in mm.	Ground water Recharge in MCM.	Ground water Draft in MCM.	Average decline (May) in water levels in m (Since May, 1984).
1	2	3	4	5
		SAURASHTRA		
		(Average annual rainfall : 550 mm; Area : 64,339 sq.km.)		
1984	506	6426	3737	-
1985	291	3400	3830 (Overdraft)	1.30
1986	398	4650	3925	2.50
1987	140	1635	2757 (Overdraft)	2.50
		KACHCHH		
		(Average annual rainfall : 350 mm; Area :54,652 sq.km.)		
1984	335	803	282	-
1985	222	509	289	1.3
1986	164	422	296	2.5
1987	Nil	Nil	148 (Overdraft)	5.7
		NORTH GUJARAT		
1984	706	4535	2292	-
1985	381	2764	2063	1.5
1986	299	2169	1856	3.3
1987	175	1269	1763 (Overdraft)	4.5

Source : Mistry and Goswami (1988)

2.7 Water Use

The annual requirement of water in the state for domestic and live stock purposes during 1981 was of the order of 0.085 M.ha.m which has been estimated to increase to a level of 0.1332 M.ha.m by year 1991 (CWC, 1988). Important major irrigation projects completed in the Table include Ukai, Kadana, Kakrapar, Mahi Right Bank Canal Project-I, Shatruni (Paliatana), Dantiwada, Hathmati, Meshwa and Bhadar. Besides, reservoirs have been constructed on Sabarmati at Dharoi and the Panam near Kadana. Works on Daman ganga, Karjan, Sukhi and Watrak projects are in full swing and preliminary works on Sardar Sarovar (Narmada) Project are in progress. Also districtwise irrigation project utilisation of Major and Medium Irrigation Projects in the state at the end of year 1980-81 to 1984-85 is given in Table 2.5. The districtwise area irrigated by wells and tube wells in 1981-82 and 1982-83 (Provisional) has been shown in Table 2.6. The water availability and water requirement figures for drought prone districts of the state are given in Table 2.7.

2.8 Crops & Fodder

On the whole the state has been divided in to 12 crop zones. (fig.2.5) Most of the drought affected districts lie in crop zone Nos. VIII & IX which are cotton-dry wheat zone and ground nut zone, respectively. Table 2.8 shows important crops grown in each district seasonwise. Table 2.9 gives the figures of area production and

Table 2.5: Irrigation project Utilization of Major and medium Irrigation Projects in Gujarat State

Sr. No.	Name of the project District	Achievement at the end of year 1980-81 Potential	1980-81 Utilization	1981-82 Potential	1981-82 Utilization	1982-83 Potential	1982-83 Utilization	1983-84 Potential	1983-84 Utilization	1984-85 Potential	1984-85 Utilization
12		13	14	15	16	17	18	19	20	21	22
1.	A'bad	29.15	28.08	29.15	30.24	17.88	30.24	17.88	30.24	17.88	30.71
2.	B'kantha	44.52	31.78	44.52	31.78	44.52	31.78	44.52	31.78	44.52	31.78
3.	Vadodara	10.91	9.39	11.03	9.39	12.65	9.62	12.65	9.67	12.65	9.98
4.	Bharuch	-	-	1.67	-	2.18	-	2.63	-	3.25	-
5.	Valsad	-	-	2.00	-	9.40	-	13.09	-	22.87	-
6.	Kheda	261.40	112.57	261.40	118.55	201.00	134.69	201.00	134.69	203.00	134.69
7.	Mehsana	29.87	5.71	43.26	5.71	49.40	13.75	49.87	14.03	51.47	21.02
8.	P.mhal	56.86	17.26	65.22	19.90	70.99	29.12	77.83	29.29	96.87	33.69
9.	S'kantha	46.85	32.28	47.59	37.90	41.09	38.38	41.20	39.29	47.68	39.97
10.	Surat	378.71	182.02	382.71	183.55	330.51	163.55	332.05	187.56	334.58	195.08
11.	Amreli	11.52	11.96	11.52	11.96	9.29	11.96	9.29	11.98	9.29	11.98
12.	Bhavnagar	51.70	46.43	51.72	46.66	52.11	46.66	54.79	50.45	55.26	50.45
13.	Jamnagar	10.03	9.94	10.22	10.07	10.95	10.07	10.95	10.07	11.15	10.07
14.	Junagarh	23.69	6.78	25.64	7.23	27.97	8.75	29.52	9.45	32.77	10.50
15.	Kutch	14.63	11.45	14.64	11.98	15.50	12.20	15.60	12.21	18.04	13.20
16.	Rajkot	44.48	40.06	45.54	45.50	46.22	45.56	47.12	45.73	48.62	45.89
17.	S'nagar	20.09	9.99	20.26	10.08	12.77	20.91	13.17	20.91	13.57	20.91
G.Total											
Major & Medium		1035.29	575.15	1075.38	591.68	925.86	629.74	1001.00	640.38	1060.61	663.35
Minor		-	47.86	NA	50.62	NA	40.86	NA	47.35	NA	43.25

Source: Technical Bulletin No.111,1987.

Table 2.6: Districtwise Area irrigated by Wells and Tube-wells

(Area in 00 hectares)

Sr. No.	District	1981-82						1982-83 (Prov.)					
		Wells			Tube wells			Wells			Tubewells		
		Net	More than once	gro-ss	Net	More than once	gro. ss	Net	More than once	gro. ss	Net	More than once	gro ss
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Ahmedabad	387	39	426	272	74	346	359	35	394	322	57	379
2.	Banaskantha	1800	71	1871	195	5	200	1918	76	1994	160	5	165
3.	Baroda	927	79	1006	165	20	185	944	86	1030	181	25	206
4.	Bharuch	221	4	225	86	1	89	206	5	211	74	5	79
5.	Valsad	233	21	254	-	-	-	335	23	258	-	-	-
6.	Dangs	1	-	1	-	-	-	1	-	1	-	-	-
7.	Gandhinagar	90	10	100	164	25	189	67	5	72	160	25	185
8.	Kaira	1067	453	1520	192	63	255	1032	395	1427	243	75	318
9.	Mehsana	1083	199	1282	1752	365	2117	1078	181	1259	1812	429	2241
10.	Panchmahal	225	29	254	-	-	-	299	26	325	-	-	-
11.	Sabarkantha	1459	116	1575	11	-	11	1445	128	1573	13	-	13
12.	Surat	264	15	279	-	-	-	271	20	291	-	-	-
13.	Amreli	685	16	701	-	-	-	826	7	833	-	-	-
14.	Bhavnagar	1019	15	1034	-	-	-	1205	18	1223	-	-	-
15.	Jamnagar	996	725	1721	-	-	-	953	625	1578	-	-	-
16.	Junagarh	1155	289	1444	-	-	-	1245	257	1502	-	-	-
17.	Kutch	306	165	471	18	9	27	333	217	550	17	9	26
18.	Rajkot	1460	181	1641	-	-	-	1397	170	1567	-	-	-
19.	Surendranagar	661	29	690	-	-	-	777	70	847	3	-	3
Total....		14039	2456	16495	2857	562	3419	14591	2344	16935	2985	630	3615

Source: Technical Bulletin No.111,1987.

Table 2.7 : Water Availability and Water Requirement for DP Districts

Unit : Cubic Km.

Sl.No.	District	Water Availability		Total Requirements
		50% Dependability	75% Dependability	
1.	Ahmedabad	4.57	3.88	2.71
2.	Amreli	0.39	0.34	3.32
3.	Banaskantha	3.37	2.61	2.40
4.	Bhavnagar	0.68	0.68	0.72
5.	Bharauch	3.03	2.11	2.53
6.	Jamnagar	0.45	0.41	0.51
7.	Kheda	4.53	3.92	3.45
8.	Kachch	1.29	0.90	0.90
9.	Mehsana	1.62	1.45	1.94
10.	Panchmahal	2.93	1.80	1.61
11.	Rajkot	2.21	1.28	1.24
12.	Surendranagar	2.48	2.48	2.39

Source : CWC, 1988

Table 2.8 : List of important crops grown in each district (Seasonwise)

Sr. No.	District	Kharif crops	Rabi crops	Hot-weather crops
1	2	3	4	5
1.	Ahmedabad	Paddy, Bajri, G'nut Jowar, Hy.Castor Cotton deshi & Hy.	Wheat (Dry), Wheat (Irri.) Gram, Mustard, Cumin	Bajri
2.	Banaskantha	Bajri, Jowar, Pulse Guwar, Castor, Cotton, Maize/ Fennel	Wheat, Mustard, Cumin, Isabgul, Gram, Potato	Bajri, Mug
3.	Baroda	Cotton, Paddy, Jowar Bajri, Tobacco, G'nut Pulse, Vegetable Pegionpea (Tur) Soyabean	Rabi Jowar, Wheat, Gram Maize, Mustard Vegetable	Bajri, G'nut (Erract) Maize Vegetables Mug
4.	Bharuch	Cotton, Jowar, Paddy Pegion Pea (Tur) Bajri Soyabean	Wheat (Dry), Wheat (Irri.) Jowar, Gram, Sunflower Vegetables/ Pulse	
5.	Bulsar	Paddy, Sugarcane Maize, Kharsani	Limabean, Sugarcane Wheat, Vegetables Jowar, Pegion pea (Tur)	Sugarcane Paddy, Cowpea, Mug
6.	Dangs	Paddy, Nagli, Wari	Gram, Wheat	
7.	Gandhinagar	Bajri, Paddy, Castor Pulse, Vegetables Cotton	Wheat, Mustard, Gram, Vege-tables, Grass	Bajri, Pulse Vegetables
8.	Kheda	Paddy, Bajri, Tobacco, Cotton, Maize, Pegion pea (Tur) Ginger Turmeric, Jowar, Fennel	Wheat, Mustard Potato, Tobacco (Calcutti) Vegetable Sunflower, Chilly, Onion Grass	Mug, Cowpea Grass, H,W. G'nut (Erract) Hy.Bajri

Contd...

1	2	3	4	5
9.	Mehsana	Hy.Bajri, Hy.Castor Cotton, Jowar, Pulse Sesamum, Vegetable Chilly/Fennel	Wheat, Cumin, Mustard, Isabgul, F.grick, Tobacco Lucern, Cow-pea	Hy. Bajri G'nut, Pulse Mug
10.	Panchmahal	Maize, Paddy, G'nut Hy.Bajri, Cotton, Jowar	Wheat, Mustard, Gram, Cumin, Maize	Bajri, Maize G'nut (Errect) Pulse, Mug, Cow-pea.
11.	Sabarkantha	Cotton, Maize, Bajri, G'nut, Paddy, Pegion pea (Tur), Pulse, Sesamum, Castor	Wheat, Mustard, Gram, Cumin, Maize, Isabgul	Bajri, Maize G'nut (Errect) Pulse, Mug Cow-pea
12.	Surat	Sugarcane, Paddy Hy.Cotton, Jowar, G'nut, Pegion pea Pulse, Banana	Wheat, Gram, Pulse, Jowar, Limabean	G'nut, Paddy, Mug, Cow-pea
13.	Amreli	G'nut, Bajri, Jowar, Cotton, Seasamum	Wheat, Mustard Cumin	G'nut, Pulse
14.	Bhavnagar	G'nut, Bajri, Cotton Sesamum, Jowar Soyabean	Wheat, Cumin, Onion	G'nut
15.	Jamnagar	G'nut, Bajri, Cotton, (Dry & Irri.), Chilly Pulse, Sesamum, Castor, Sugarcane, Sunflower, Soya-bean	Potato, Wheat, Garlic, Onion, Gram, Mustard, Cumin, Isabgul	G'nut, Bajri
16.	Junagadh	G'nut, Hy. Bajri, Cotton, Jowar, Pulse, Sunflower	Wheat, Mustard, Cumin, Gram, Sugarcane, Jowar, Vegetable Garlic/ Onion	G'nut, Bajri,
17.	Kutch	G'nut, Bajri, Pulse, Cotton, (Dry & Irri), Jowar, Castor, Sesamum	Wheat, Mustard	G'nut, Bajri,

CONTD..

1	2	3	4	5
18.	Rajkot	G'nut, Cotton, Bajri, Jowar, Sunflower,	Wheat, Mustard, Cumin, Sugarcane, Garlic	G'nut, Bajri
19.	Surendranagar	Cotton, Bajri, Jowar, Sesamum, G'nut, Vegetable	Wheat, Mustard, Gram, Vegetable Maize, Cumin	G'nut, Bajri Jowar, Maize

Source : Technical Bulletin No.111, 1987, Govt. of Gujarat

Table 2.9 : Statement showing the figures of Area, Production & Yield per hectre of important food and non-food crops in Gujarat State for the years 1981-82 to 1986-87.

Unit : i) Area in Hundred Hectares
ii) Production in Hundred M. tonnes
iii) Yield per hectare in Kg.

Year	Rice			Wheat			Jowar			Bajri		
	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	Prod.	Y./H.
1981-82	6101	9196	1507	6755	13850	2010	11058	6601	597	15134	15050	994
1982-83	5912	6150	1040	6384	14395	2255	11296	5437	481	14900	12078	811
1983-84	5403	7543	1396	7412	16260	2194	9476	5620	614	14366	16075	1119
1984-85	5661	8382	1481	6369	13293	2087	8744	4997	571	13726	15353	1118
1985-86	4917	4552	924	4314	7828	1815	8935	3549	397	13155	6349	483
1986-87	5111	4460	873	3151	6617	2100	8821	2451	278	12744	10269	806

Year	Maize			Ragi			Kodra			Barley			Other cereals		
	*A.	*P.	Yield hect.	*A.	*P.	Yield hect.	*A.	*P.	Yield hec.	*A.	*P.	Yield hect.	*A.	*P.	Yield hect.
1981-82	3204	4076	1272	530	510	962	759	575	757	139	151	1104	769	406	528
1982-83	3279	3331	1016	467	395	848	607	249	410	134	121	904	826	296	358
1983-84	3185	4756	1493	450	491	1092	582	482	828	68	97	1434	582	318	546
1984-85	3100	3836	1237	446	442	992	536	391	729	66	61	920	534	256	479
1985-86	3165	1143	361	448	334	744	519	80	155	67	68	1015	584	85	146
1986-87	3138	4350	1386	407	222	547	466	117	251	-	-	-	490	49	100

Year	Total Cereals			Gram			Tur			Other Pulses		
	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	Prod.	Y./H.
1981-82	44449	50145	1128	1015	927	914	3054	2511	823	4550	2127	469
1982-83	43785	42452	970	1432	1148	802	3401	2506	737	4323	1982	458
1983-84	41524	51840	1248	1221	1174	961	2995	2053	688	384	2360	620
1984-85	39182	47011	1200	1157	1012	875	3288	2511	764	3841	2037	530
1985-86	36104	23979	664	808	455	563	3025	2234	738	3729	695	186
1986-87	34328	28535	831	436	291	645	3187	1461	458	363	89	245

Note : 1981-82 to 1986-87 figures are based on final forecast reports.

*A=Area *P=Production

Contd...

Year	Total Pulses			Total Food-grains			Sugarcane			Chillies		
	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	*Prod.	Y./H.	Area	Prod.	Y./H.
1981-82	8607	5567	647	53056	55710	1050	1167	8280	7040	210	234	1114
1982-83	9156	5636	616	52941	48088	908	1194	8707	7292	269	244	907
1983-84	8021	5587	647	49545	55727	1159	1026	7746	7547	156	946	938
1984-85	8286	5560	671	47468	52571	1108	1033	7542	7342	146	140	990
1985-86	7562	3384	448	43666	27362	627	908	6490	7144	137	94	683
1986-87	7079	2354	333	41407	30889	746	692	5566	8045	126	108	855

Year	Potatoes			Groundnut			Castor			Sesamum		
	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	Prod.	Y./H.
1981-82	94	2320	24719	21775	21756	999	1955	2299	1170	1307	426	326
1982-83	122	3043	24853	21055	12854	610	2067	2942	1423	1464	432	295
1983-84	106	2995	29125	21466	18101	842	2022	2811	1390	1268	461	363
1984-85	98	3226	32918	20611	15723	763	2582	3486	1350	1440	499	346
1985-86	81	1531	18800	17935	4482	250	2399	2023	843	1268	196	155
1986-87	110	2536	23117	18245	12917	708	2088	1293	619	1335	124	92

Year	Rape & Mustard			Total Oilseeds			Cotton			Tobacco		
	Area	Prod.	Y./H.	Area	Prod.	Y./H.	Area	**Prod.	Y./H.	Area	Prod.	Y./H.
1981-82	1963	3339	1701	26980	27820	1031	15137	20397	229	1196	2632	2201
1982-83	2135	2447	1146	26721	18675	699	15116	16286	183	1074	1981	1751
1983-84	1736	2359	1359	26522	23732	895	13990	14444	170	1083	1869	1725
1984-85	1953	2393	1226	26580	22101	831	13834	20688	245	1084	1735	1600
1985-86	1924	2089	1085	23526	8790	374	14040	19867	241	1062	1678	1580
1986-87	1817	2349	1293	23475	16683	711	13662	10934	136	1104	1828	1656

*Prod. of Sugarcane is in terms of "Gur"

**Prod. of Cotton is in "00" bales of 170 kgs. lint each.

Source : Margdarshika No.179, Gujarat (1988).

yield per hectare of important food and non food crops in the state for the year 1981-82 to 1986-87. (Margdarshika,179,Gujarat ,1988)

Table 2.10 shows the districtwise information of target and achievement of growing green fodder in the year 1987-88. It is clear from the table that the total targets were short of achievements approximately by 7 lakh million tonnes due to drought in the year.

Table 2.10 : Districtwise information of Target & Achievement of Growing Green Fodder in the year 1987-88

Units : Area in Ha. : Production in Million tonnes

Sl. No.	Name of District	Target		Achievement	
		Area	Total quantity of Green Fodder	Area	Total quantity of Green Fodder
1.	Mehsana	96,532	28,06,157	42,741	36,96,957
2.	Sabarkantha	50,000	14,06,750	29,534	25,46,040
3.	Banaskantha	35,000	14,06,750	42,200	7,71,160
4.	Ahmedabad	30,000	3,49,300	34,930	1,73,510
5.	Kheda	1,56,181	30,00,000	74,928	16,89,137
6.	Vadodara	29,030	8,70,000	33,622	10,00,000
7.	Gandhinagar	5,000	2,16,900	5,044	1,89,845
8.	Amreli	10,000	4,00,000	10,159	4,06,360
9.	Surendranagar	59,000	10,71,000	17,562	69,286
10.	Valsad	925	38,960	718	38,960
11.	Surat	47,700	-	1,845	14,136
12.	Panchmahal	4,500	1,07,500	9,954	2,29,000
13.	Bharauch	25,000	-	12,300	2,55,530
14.	Junagadh	6,505	39,000	6,505	39,030
15.	Rajkot	Nil	-	-	-
16.	Bhavnagar	Nil	-	-	-
17.	Jamnagar	Nil	-	-	-
18.	Kutch	10,233	4,27,660	10,233	4,27,660
19.	Dangs	Nil	-	-	-
	Total	5,65,606	1,21,36,977	3,31,653	1,14,46,611

Source : Status Report on Drought 1987-88, Govt. of Gujarat.

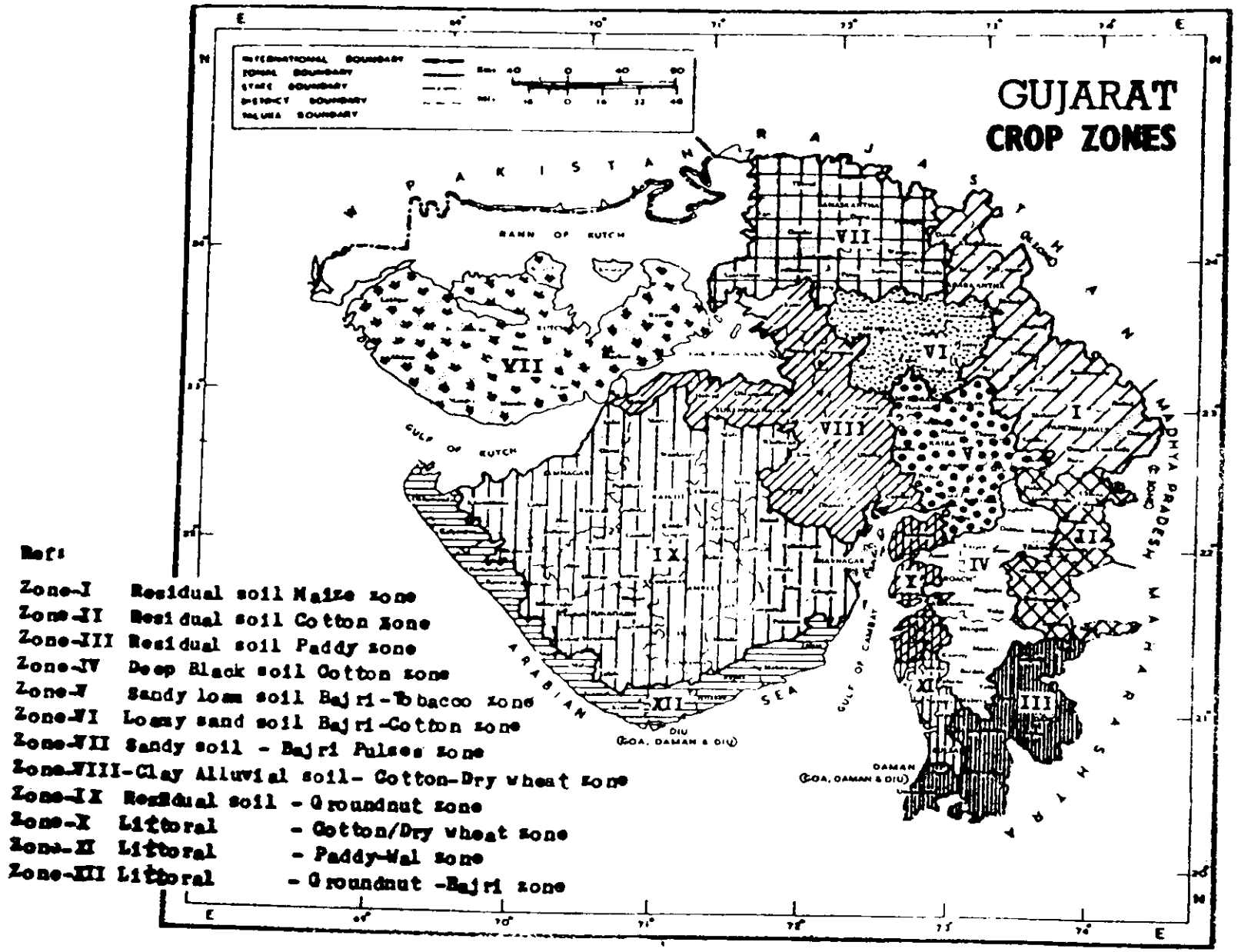


Fig. 2.5: Crop zones of state Gujarat.

Source: Technical Bulletin No.III, Govt. of Gujarat,1987.

2.9 Description of Districts

The details about the state in respect of physiography, climate, soils, landuse, crops and water resources availability have been presented in above sections. This section gives brief summary of various such details in respect of the districts choosen for study, as follows:

2.9.1 Jamnagar:

The district of Jamnagar forms a part of Saurashtra region and the Irrigation Commission (1972) and other agencies have identified it as drought prone. The district has an area of 10143 sq.km. and a population of 1390125 according to the census figures of 1981. The district comprises of nine taluks i.e. Bhanwan, Dhrol, Jamjodhpur, Jamnagar, Jodia, Kalwad, Kalyanpur, Khambhalia Lalpur , and Okhamandal.

The normal rainfall of all the taluks is generally less than 750 mm. The district gets about 93 percent of the total rainfall from south-west monsoon. The district is mainly drained by 14 rivers. The soils of the district are broadly classified as Alluvial black, alluvial light brown and alkaline soil. The evaporation and evapotranspiration losses in the district vary between 245.4 mm to 94.4 mm from summer to winter months. Most of the villages of the district depend for their domestic water requirements on wells. In summer months many wells go dry due to the lowering of water table. In drought years particularly, this problem gets very much aggravated and severe. There are two cropping seasons i.e. Kharif from June to October and Rabi from October to April. More than 91 percent of crops are fed by monsoon rains in Kharif season. The rest of the 9 percent of cropped area comes under Rabi cultivation. The main crop of the district are Jowar,, Paddy, Bajra, Cotton, Groundnut and Wheat. The

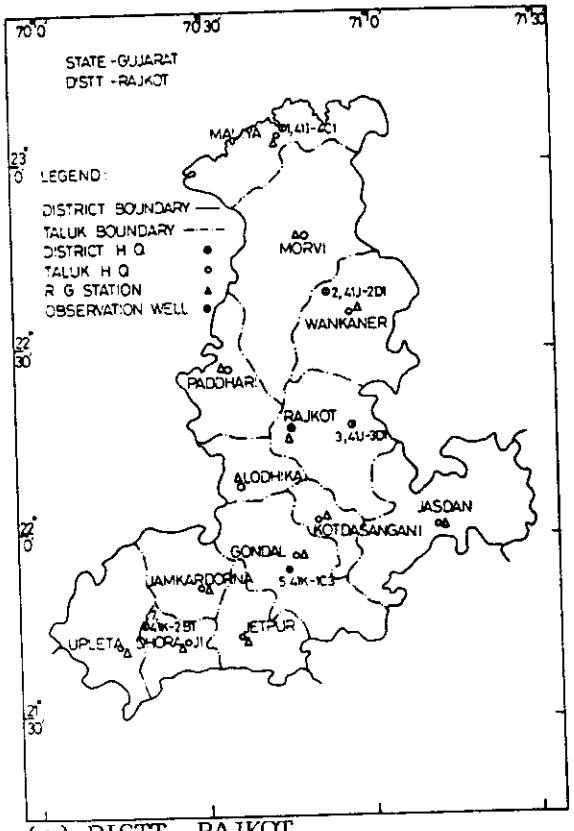
map of district showing location of raingauges and groundwater observation wells which have been chosen for analysis is shown in Figure 2.6.

2.9.2 Rajkot

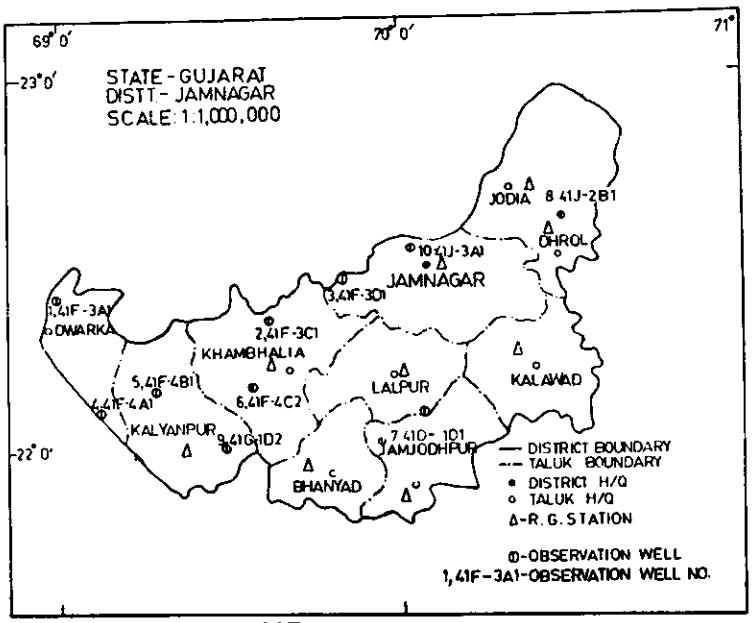
The district of Rajkot forms a part of Saurashtra region & the Irrigation Commission (1972) and other agencies have identified it as drought prone. The district has an area of 11152.3 sq.km. and a population of 2058136 according to the provisional census figures of 1981. The district comprises of 13 taluks viz. Dhoraji, Gondal, Jamkandorna, Jasdan, Jetpur, Kotda-Sangani, Lodhika, Morvi, Malia, Paddhari, Rajkot, Uplete and Wankaner. The normal rainfall of all the taluks is generally less than 750 mm except Paddhari taluk. The district gets about 93 percent of the total rainfall from South-West monsoon. The district is mainly drained by the river Bhaolan, Machhu & Aji. The soil of the district are broadly classified as medium black, Alluvial black(Salty) and mixed red soil. The evaporation and evapotranspiration losses in the district vary between 302.4 mm to 113.6 mm from summer to winter months. In the villages of the district,the domestic water requirements is mostly met by wells which go dry due to the lowering of water table in summer. The main crops of the district are Jowar, Paddy, Bajra, Cotton, Groundnut and Wheat. The location of raingauges and groundwater observation wells is shown in the district map given as Fig. 2.6.

2.9.3 Ahmedabad

The district of Ahmedabad forms a part of North Gujarat & the irrigation Commission (1972) and other agencies have identified it as drought prone. The district has an area of 87707 Sq.kms. and a population of 38,40,472 according to census figures of 1981. The



(a) DISTT. RAJKOT



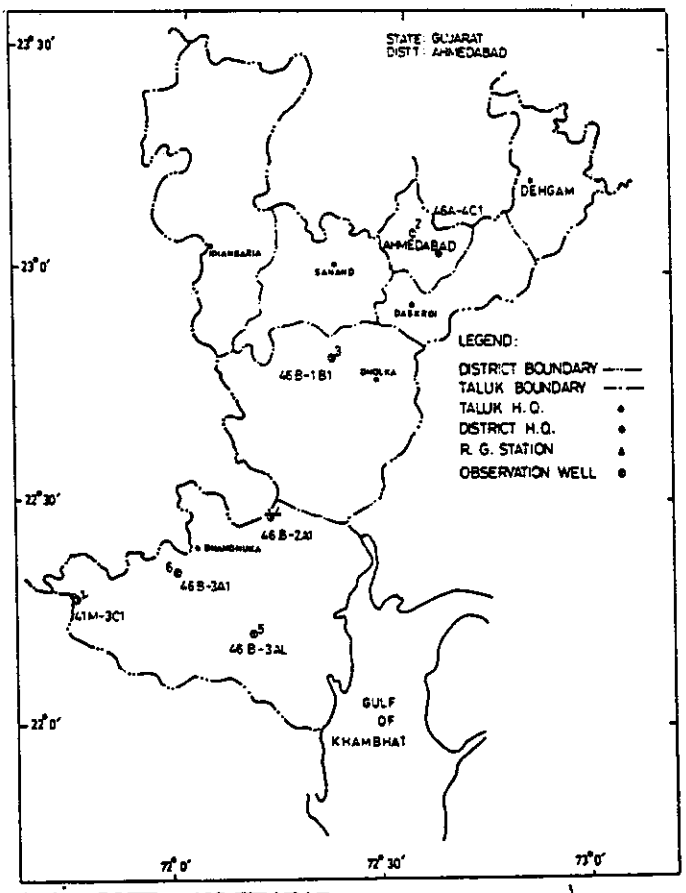
(b) DISTT. JAMNAGAR

DISTT. 2.6: LOCATION OF RAINGAUGE STATION AND GROUNDWATER WELL

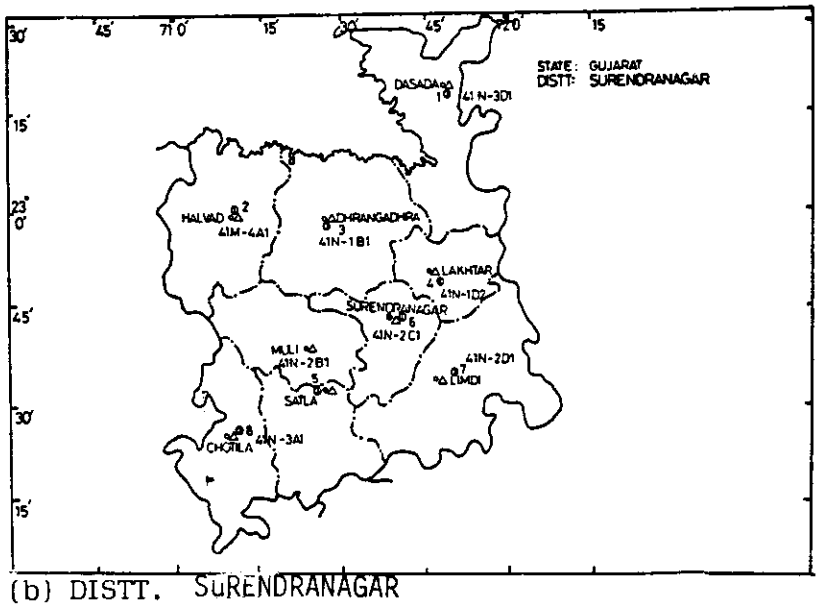
district comprises of seven taluka viz. Dehgam, Ahmedabad city, Daskroi Dholka, Dhandhuka, Sanand and Viramgam talukas. The normal annual rainfall of all the talukas is generally less than 750 mm except Ahmedabad city and Daskroi taluks in which it is marginally more than 750 mm. The district gets 675.1 mm rainfall (i.e.95.9 percent of the annual rainfall) from South-West monsoon. The district is mainly drained by the river Sabarmati alongwith its tributories Khari, Vatrau, Meshwo and Bhogawo. The soils of the district are broadly classified into five types viz i) Black soil ii) medium black soil iii) red clay or Goradu soil iv) red sand or Kyari soil and v) rocky soil or mixed saline Evaporation & evapotranspiration losses in the district vary between 234.8 mm to 73.9 mm from Summer to winter months, respectively. Most of the villages of the district depend for their domestic water requirements on 25,658 number of wells. The main crops of the district are Jowar, Paddy, Pulses, Wheat, Groundnut, Bajra, Castors & Cotton etc. The location of raingauges and groundwater observation wells is shown in the district map as given in figure 2.7 .

2.9.4 Suurendranagar District

The district of Surendranagar forms a part of Saurashtra region and the Irrigation Coimmission (1972) and other agencies have identified it as drought-prone. The district has an area of 10443.8 Sq.km. and a population of 1033423 according to the census figures of 1981. The district comprises of 9 taluka viz. Chotila, Dasada, Dharamgadhra Halvad, Lakhtar , Limbdi, Mali, Sayala and Wadhwan. The normal rainfall of the taluks is generally less than 750 mm. The district gets about 94.55 percent of the total rainfall from South-West monsoon. The district is mainly drained by the river Kankavati,



(a) DISTT. AHMEDABAD



(b) DISTT. SURENDRANAGAR

FIG. 2.7 : LOCATION OF RAINGAUGE STATION AND GROUND WATER WELL

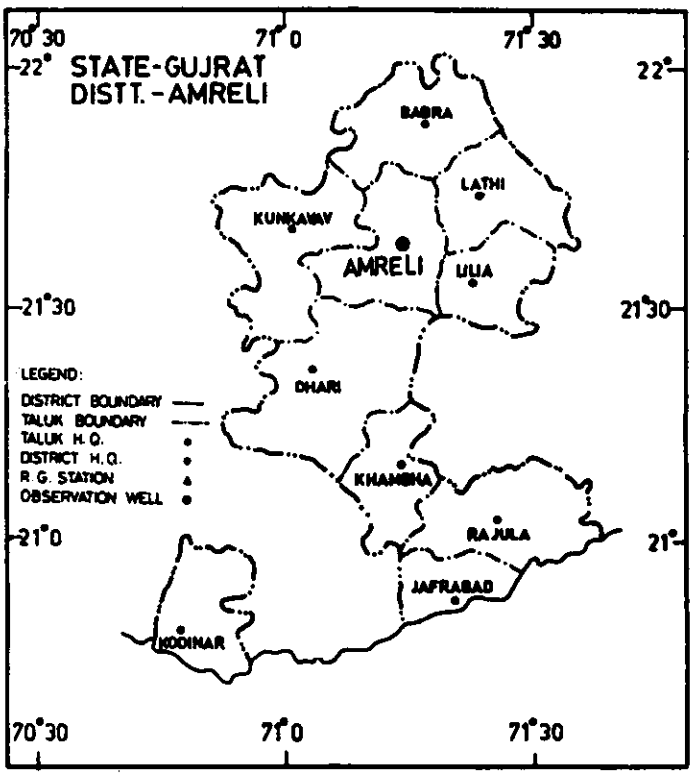
Limdi Bhogaro, Bhamini, Chandrabhaga & Falka. The soils of the distirct are broadly classified as Medium black, Light Sand soil, red soil, alluvial, and rocky soil.Evaporation and Evapotranspiration lossess in the district varies between 120.7 mm to 302.4 mm from winter to Summer months. The sOurceof drinking water in most of villages is groundwater. The main crops of the district are Jowar, Paddy, Bajra, Cotton, Groundnut and Wheat. Locations of raingauges and groundwater observation wells in the district map are shown in figure 2.7 .

2.9.5 Amreli

The district of Amreli forms a part of Saurashtra region and the Irrigation Commission(1972) and other agencies have identify it as drought prone. The district has an area of 6711.4 Sq.km. and a population of 10,75,766 according to the census figures of 1981. The district comprises of 10 talukas viz. Amreli, Babra, Dhari, Zafrabad,Khambat, Kodinar, Kankaravat, Lathi , Lilia and Rajula . The normal rainfall of all the talukas is generally less than 750 mm. The district gets about 91.01 percent of total rainfall from South-West monsoon.The district is mainly drained by the river Shetrunji, Ghelo and Kalubhar. The soils of the district are broadly classified as medium blacks, coastal alluvial, and rocky soil. The evaporation and evaporationspiration losses in the district vary between 302 mm to 136.6 mm from summer to winter months. The domestic water supply in the villages is by wells.The main crops of the district are Jowar, Paddy, Bajra, Cotton, Groundnut and Wheat. The figure 2.8 shows location of raingauges and groundwater observation wells which have been chosen for analysis.

2.9.6 Bhavnagar District

The district of Bhavnagar forms a part of Saurashtra region



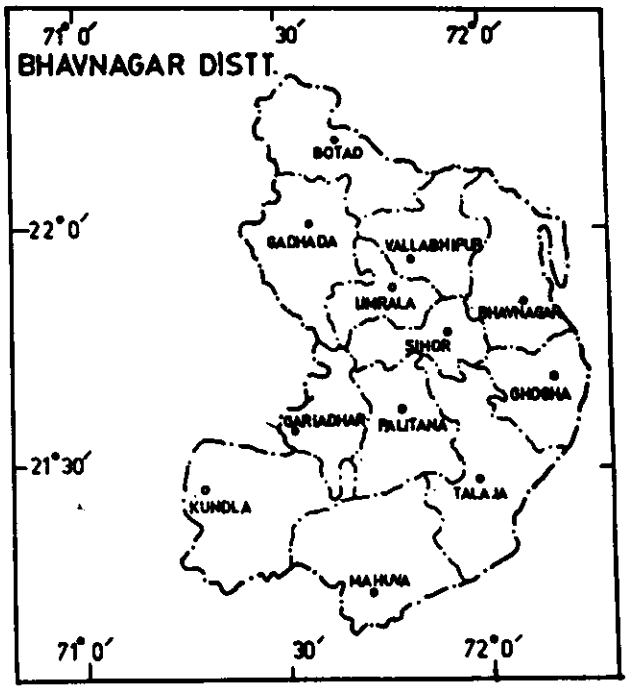


Fig.2.8 : LOCATION OF RAINGAUGE STATION AND GROUND WATER WELL

and the Irrigation Commission(1972) and other agencies have identified it drought prone. The district has an area of 9786.30 Sq.km. and a population of 18,76,471 according to the census figures of 1981. The district comprises of twelve talukas viz. Bhavnagar, Botad,Gadhada, Gariadhar, Ghogha, Mahuva, Palitana,Savarkundla,Sihor, Talaja, Umral and Vallabhipur. The normal rainfall of the talukas is generally less than 750 mm. The district gets about 92.27 percent of the total rainfall from South -West monsoon. The district is drained by 11 rivers namely: Shetrunji, Ghelo, Kalubhar, Vagad, Kalbi, Padala,Keri, Goma, Dhatarwadi, Surajvadi, Malan, Bagad & Ranghola. Ther soil of the district are broadly classified as medium black soil, coastal Sandy, alluvial soil, light murrain soil, clayey lime soil and clay alluvial soil. The evaporation and evapotranspiration losses in the district have been recorded to vary between 245.4 mm to 94.4 mm from summer to winter. The ground water is the main source of domestic water supply in most of the villages of the district. The main crops of the district are Jowar, Paddy, Bajra, Cotton, Groundnut and Wheat. Figure 2.8 draws location of raingauges and groundwater wells in the diistrict map.

3.0 Rainfall Analysis

3.1 General

As has already been described in chapter 2.0, Six district, namely Jamnagar, Rajkot, Ahmedabad, Surendranagar,Amreli & Bhavnagar from the state of Gujarat 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 present 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 Gujarat.

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 chosen six districts of Gujarat 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 account while estimating seasonal normals as the South-West monsoon is active for these four months in the state. 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 DEPARTURE FOR THE DISTRICTS OF JAMNAGAR, RAJKOT, AHMEDABAD, SURENDRANAGAR, AMRELI & BHAVNAGAR OF STATE GUJARAT.

	DISTT. JAMNAGAR (GUJARAT)			DISTT. RAJKOT (GUJARAT)		
YEAR	SEASONAL RAINFALL	SEASONAL NORMAL RAINFALL	% DEP.	SEASONAL RAINFALL	SEASONAL NORMAL RAINFALL	% DEP.
1970	821.94	557.14	+47.53	924.67	577.43	+60.14
1971	531.48		-04.61	490.60		-15.04
1972	261.86		-53.00	269.06		-53.4
1973	330.15		-40.74	400.51		-30.63
1974	182.07		-67.32	253.92		-56.02
1975	874.78		+57.01	687.43		+19.05
1976	604.39		+ 8.48	767.47		+32.91
1977	566.95		+ 1.76	635.11		+ 9.98
1978	515.88		- 7.41	481.17		-16.67
1979	1554.01		178.93	909.77		+57.55
1980	978.65		+75.66	725.59		+25.65
1981	863.67		+55.02	* 644.04		+11.53
1982	388.36		-30.29	431.25		-25.31
1983	1011.64		+81.58	796.98		+38.02
1984	449.24		-19.37	478.32		-17.16
1985	231.6		-58.43	241.9		-58.11
1986	275.9		-50.48	241.73		-58.14
1987	45.73		-91.79	123.90		-78.54

*Seasonal value was equivalent to Annual.
Hence annual value was taken for analysis.

contd.....

DISTT. AHMEDABAD (GUJARAT)

YEAR	SEASONAL RAINFALL	SEASONAL NORMALISED RAINFALL	PERCENT DEPARTURE
1970	818.62	650.70	25.81
1971	390.14	650.70	-40.04
1972	287.89	650.70	-55.76
1973	592.60	650.70	-8.93
1974	193.69	650.70	-70.23
1975	1068.71	650.70	64.24
1976	1314.66	650.70	102.04
1977	661.39	650.70	1.64
1978	579.64	650.70	-10.92
1979	629.04	650.70	-3.33
1980	447.04	650.70	-31.30
1981	836.80	650.70	28.60
1982	314.22	650.70	-51.71
1983	685.95	650.70	5.42
1984	563.78	650.70	-13.36
1985	273.36	650.70	-57.99
1986	370.66	650.70	-43.04
1987	181.49	650.70	-72.11

contd.....

DISTT. SURENDRANAGAR (GUJARAT)

YEAR	SEASONAL RAINFALL	SEASONAL NORMALISED RAINFALL	PERCENT DEPARTURE
1970	771.21	479.61	60.80
1971	306.00	479.61	-36.20
1972	128.13	479.61	-73.28
1973	325.88	479.61	-32.05
1974	136.31	479.61	-71.58
1975	488.94	479.61	1.95
1976	542.67	479.61	13.15
1977	443.85	479.61	-7.46
1978	304.79	479.61	-36.45
1979	699.13	479.61	45.77
1980	473.57	479.61	-1.26
1981	412.71	479.61	-13.95
1982	251.57	479.61	-47.55
1983	480.12	479.61	0.11
1984	359.01	479.61	-25.14
1985	217.23	479.61	-54.71
1986	210.58	479.61	-56.09
1987	97.61	479.61	-79.65

contd.....

DISTT. AMRELI (GUJARAT)

YEAR	SEASONAL RAINFALL	SEASONAL NORMALISED RAINFALL	PERCENT DEPARTURE
1970	666.66	526.86	26.54
1971	659.22	526.86	25.12
1972	236.70	526.86	-55.07
1973	510.37	526.86	-3.13
1974	293.05	526.86	-44.38
1975	454.93	526.86	-13.65
1976	576.87	526.86	9.49
1977	576.30	526.86	9.38
1978	431.34	526.86	-18.13
1979	684.49	526.86	29.92
1980	615.52	526.86	16.83
1981	730.40	526.86	38.63
1982	340.49	526.86	-35.37
1983	853.76	526.86	62.05
1984	318.99	526.86	-39.45
1985	180.85	526.86	-65.67
1986	298.00	526.86	-43.44
1987	175.56	526.86	-66.68

contd.....

DISTT. BHAVNAGAR (GUJARAT)

YEAR	SEASONAL RAINFALL	SEASONAL NORMALISED RAINFALL	PERCENT DEPARTURE
1970	945.10	563.24	67.80
1971	656.77	563.24	16.61
1972	259.55	563.24	-53.92
1973	651.87	563.24	15.74
1974	272.70	563.24	-51.58
1975	567.11	563.24	0.69
1976	920.29	563.24	63.39
1977	576.13	563.24	2.29
1978	370.78	563.24	-34.17
1979	677.49	563.24	20.28
1980	466.98	563.24	-17.09
1981	567.92	563.24	0.83
1982	259.40	563.24	-53.94
1983	770.86	563.24	36.86
1984	408.49	563.24	-27.47
1985	230.85	563.24	-59.01
1986	239.46	563.24	-57.48
1987	192.28	563.24	-65.86

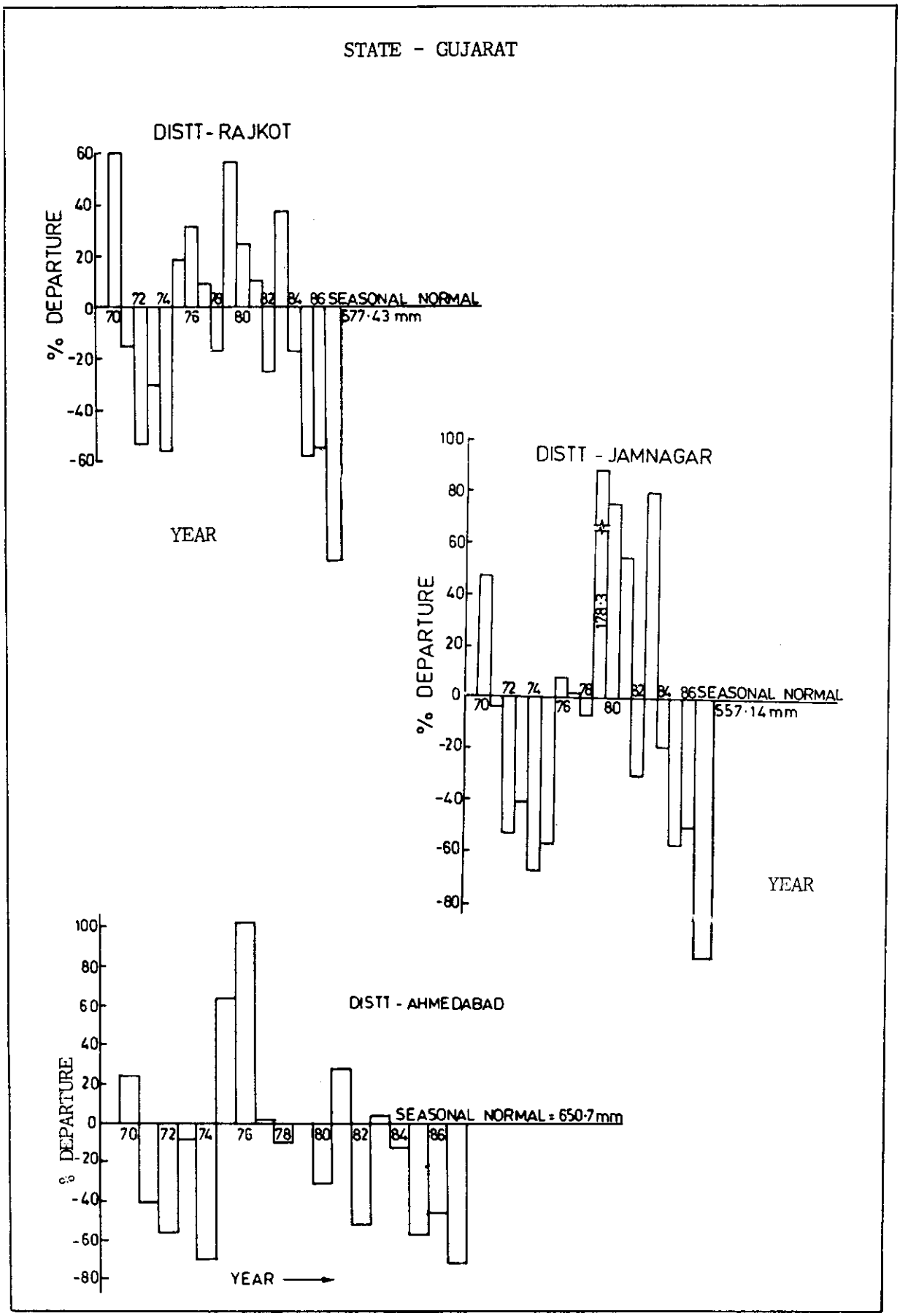


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

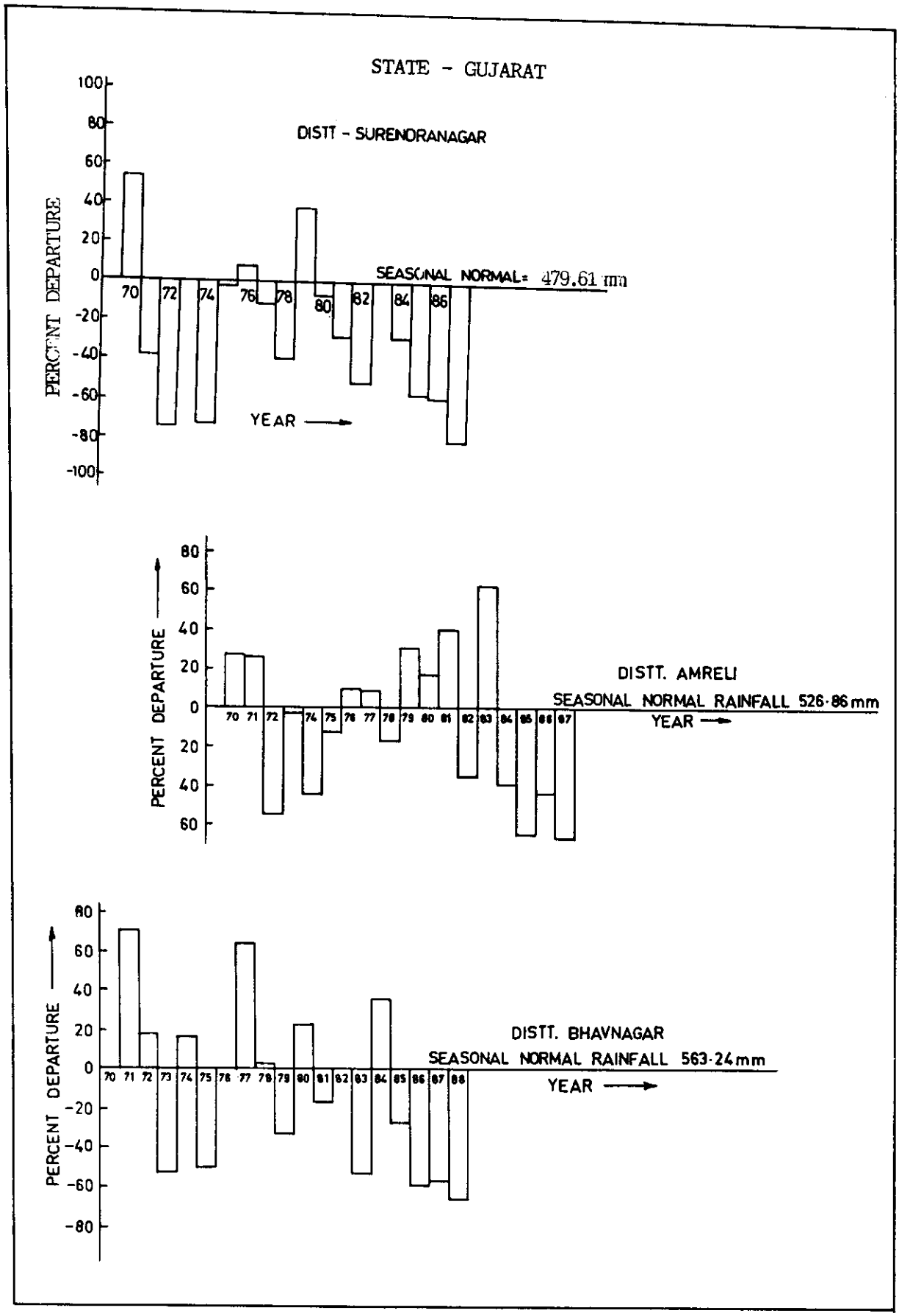


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

All the six selected districts namely Jamnagar, Rajkot, Ahmedabad, Surendranagar,Amreli & Bhavnagar experienced more than 60% deficiency in the seasonal rainfall during year 1987-88. It was also observed that all the districts in the state have been experiencing seasonal rainfall deficits of more than 20% since water year 1984-85 indicating continued occurence of water shortages in these districts which is adversely affecting the economy of the region in these districts.

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 raingauges of various taluks have been considered for the prupose.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 all the six districts are shown in appendix - III-I

The results of monthly departure analysis for the district as a whole are presented in Table 3.2Based on monthly departure values, two categories. of

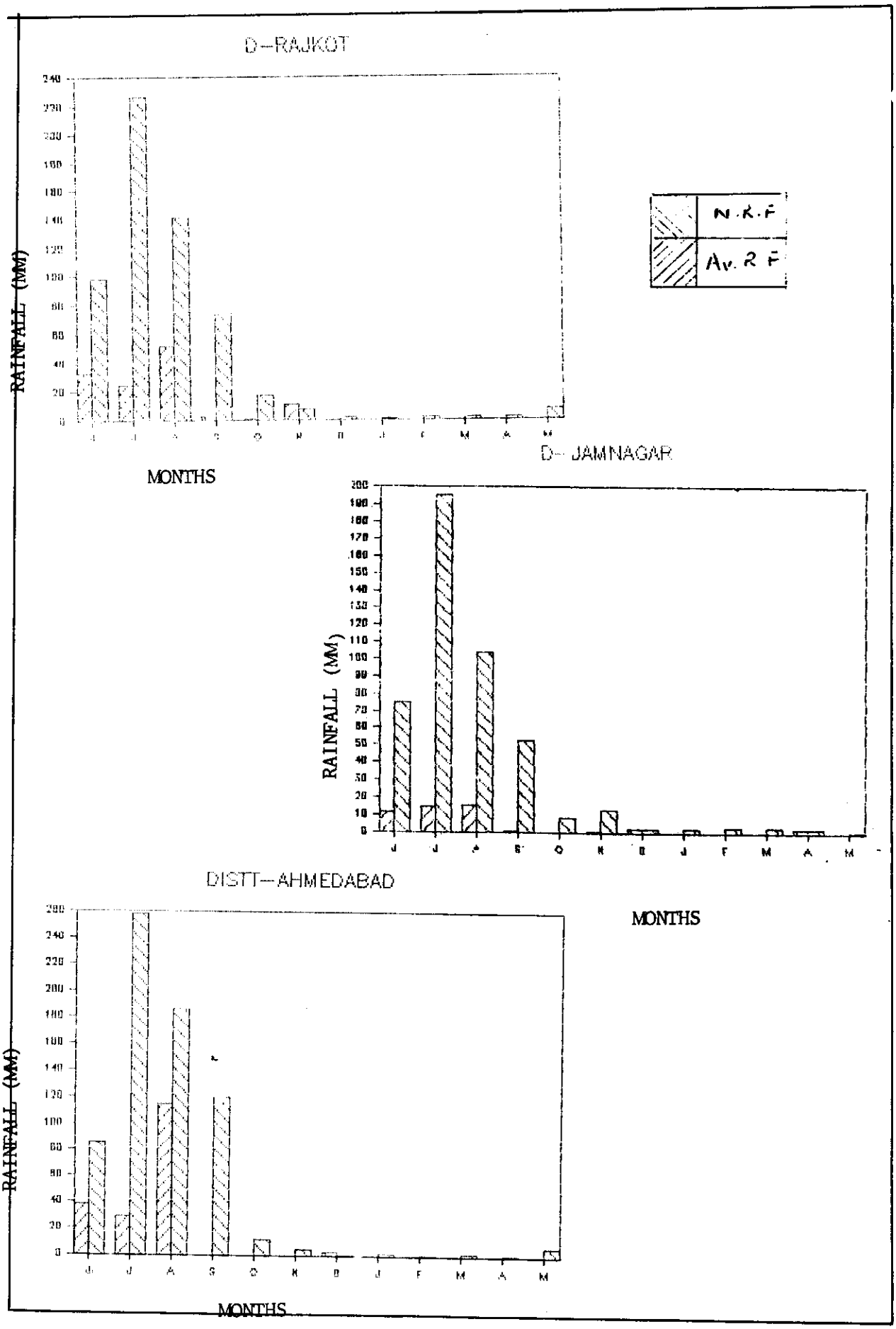


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

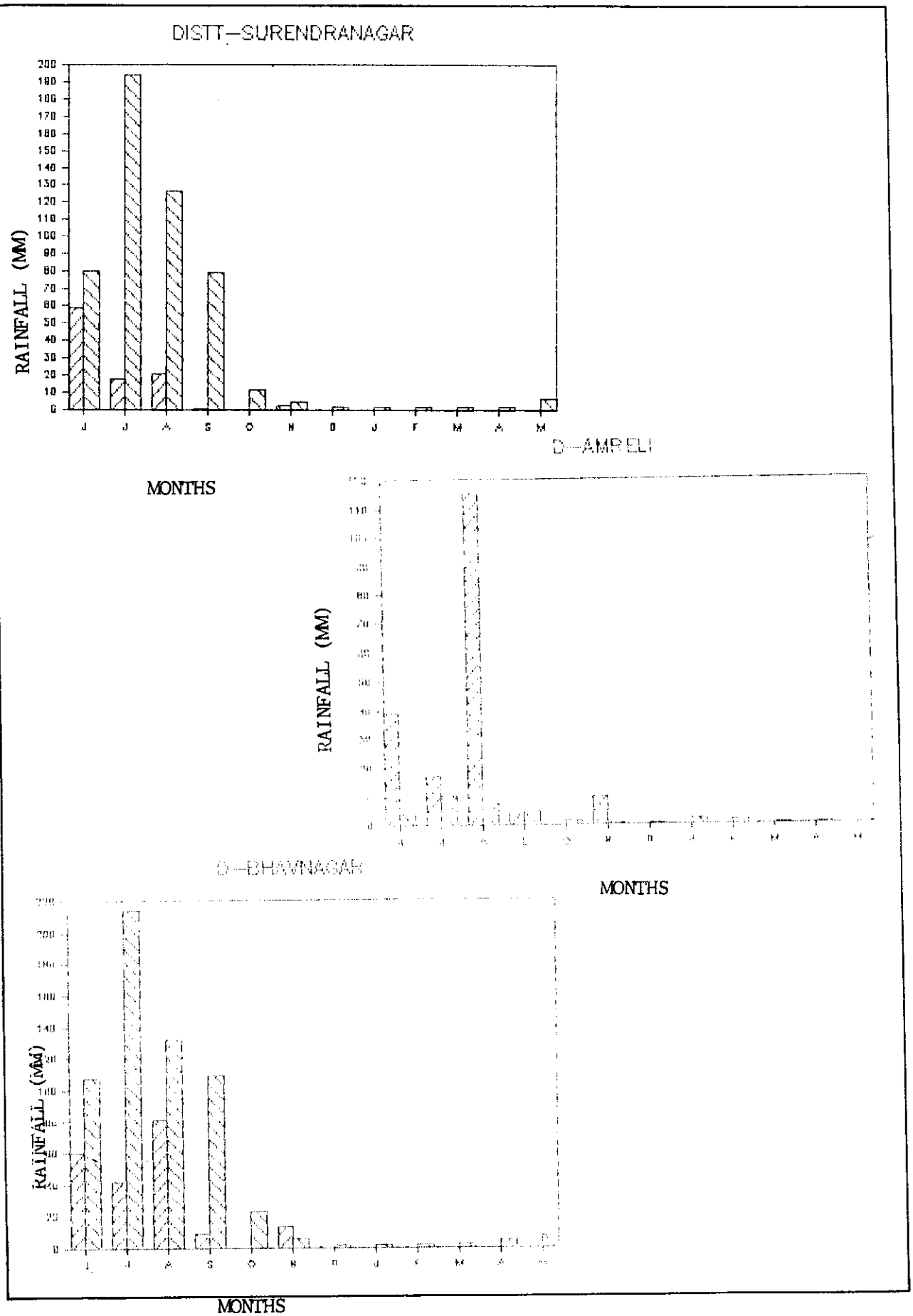


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

monthly departures i.e 20-50% & 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-I and table 3.2.

In the state of Gujarat the montly departure analysis indicated that all six districts chosen for study experienced severe monthly deficits during the monsoon months of 1987. The departure values ranged from 20% to 100% during monsoon months. Out of the six districts, Bhavnagar had the maximum rainfall & Rajkot had the minimum monthly rainfalls during the year.The deficiency pattern were similar for Surendranagar & Bhavnagar districts while the district of Rajkot & Amreli exhibited similar deficiency seenario.

Table: 3.2 Monthly Rainfall Deficits in District as a whole during 1987-88

State	Months	Group of range of deficiency in rainfall (expressed in percentage of normals)	
		20 to 50%	50% and above
Gujarat (No. of districts taken 6)	June'87	Bhavnagar Surendranagar	Rajkot, Jamnagar, Ahmedabad
	July		Bhavnagar, Rajkot, Jamnagar Surendranagar, Ahmedabad

contd...

August	Bhavnagar	Rajkot, Jamnagar, Surendrana-
	Ahmedabad	gar
September	Amreli	Bhavnagar, Rajkot, Jamnagar
		Surendranagar, Ahmedabad
October		Amreli, Bhavnagar, Rajkot,
		Jamnagar, Surendranagar,
		Ahmedabad
November		Jamnagar, Surendranagar
		Ahmedabad
December		Amreli, Rajkot
		Surendranagar
January'88		Amreli, Bhavnagar,
		Rajkot, Jamnagar,
		Surendranagar, Ahmedabad
February		Amreli, Bhavnagar, Rajkot,
		Jamnagar, Surendranagar,
		Ahmedabad
March		Amreli, Bhavnagar, Rajkot
		Jamnagar, Surendranagar,
		Ahmedabad
April		Amreli, Bhavnagar, Rajkot
		Surendranagar, Ahmedabad
May		Amreli, Bhavnagar, Rajkot
		Jamnagar, Surendranagar,
		Ahmedabad

3.3 Frequency of Rainfall

3.3.1 Probability analysis of annual rainfall

Probability is a constant charaterising 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 occurence 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 graphs 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 estabilshed using these graphs and such values for all districts and two taluks in each district are given in Table 3.3. In order to find the drought prone-

TABLE 3.3: Probability Distribution of Annual Rainfall

Sl. No.	District (State)	Name of Taluks	At 75% Probability and above (Range in mm)	Probability of occurrence of rainfall equivalent to 75 percent Normal (in %age)
1	2	3	4	5
1.	Jamnagar (Gujarat)	1. Jamnagar	300-400	63
		2. Kalyanpur	100-200	55
		3. District as a whole	300-400	60
2.	Rajkot (Gujarat)	1. Rajkot	400-500	72
		2. Morbi	200-300	68
		3. District as a whole	400-500	75
3.	Ahmedabad (Gujarat)	1. Ahmedabad	500-600	73
		2. Sanand	500-600	78
		3. District as a whole	500-600	74
4.	Surendranagar (Gujrat)	1. Wadhwan	400-500	77
		2. Dharangadhra	300-400	55
		3. District as a whole	200-300	59
5.	Bhavnagar (Gujarat)	1. Bhavnagar	400-500	79
		2. Ghogha	400-500	77
		3. District as a whole	400-500	79
6.	Amreli (Gujarat)	1. Jaforabad	400-500	79
		2. Rajula	300-400	55
		3. District as a whole	400-500	73

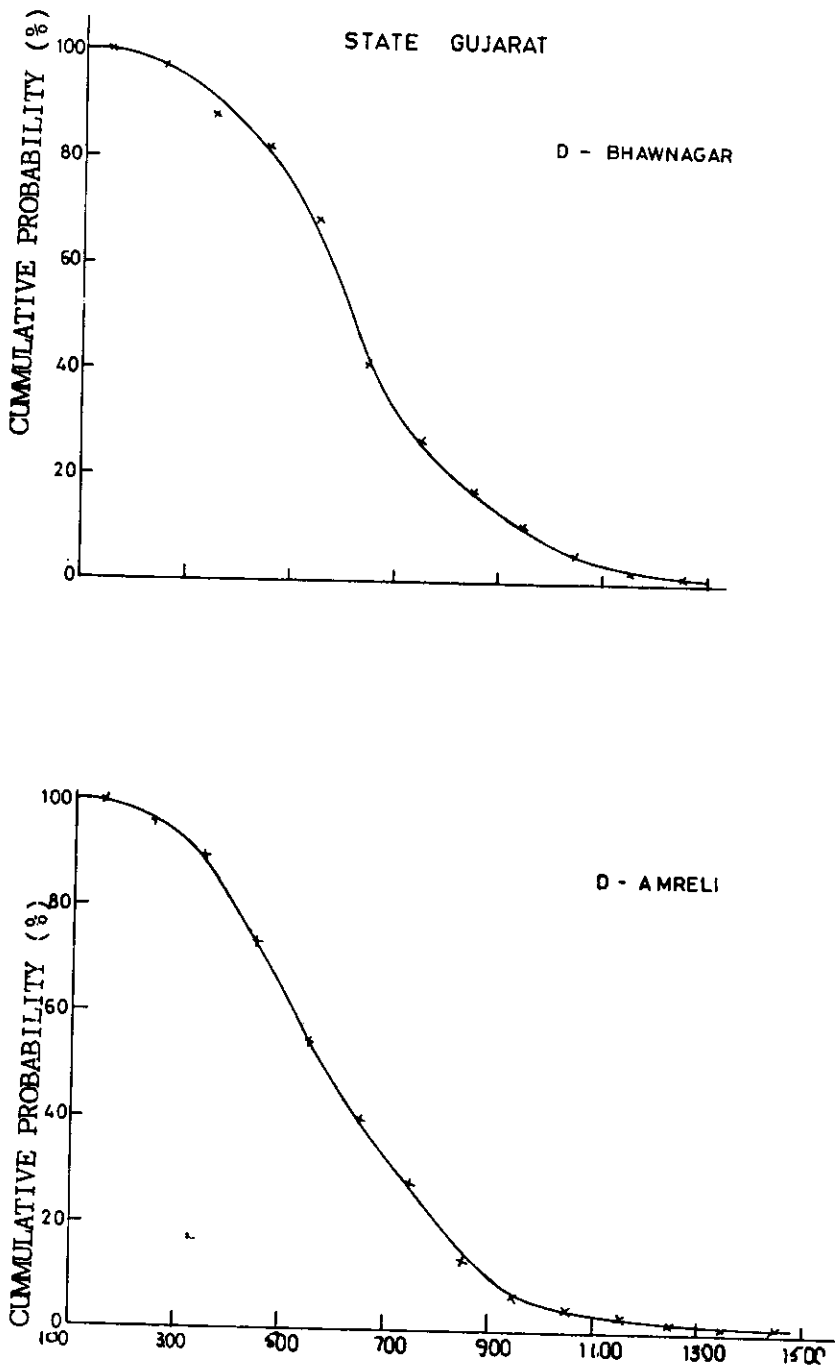


Fig. 3.3 : Districtwise Probability of Annual Rainfall

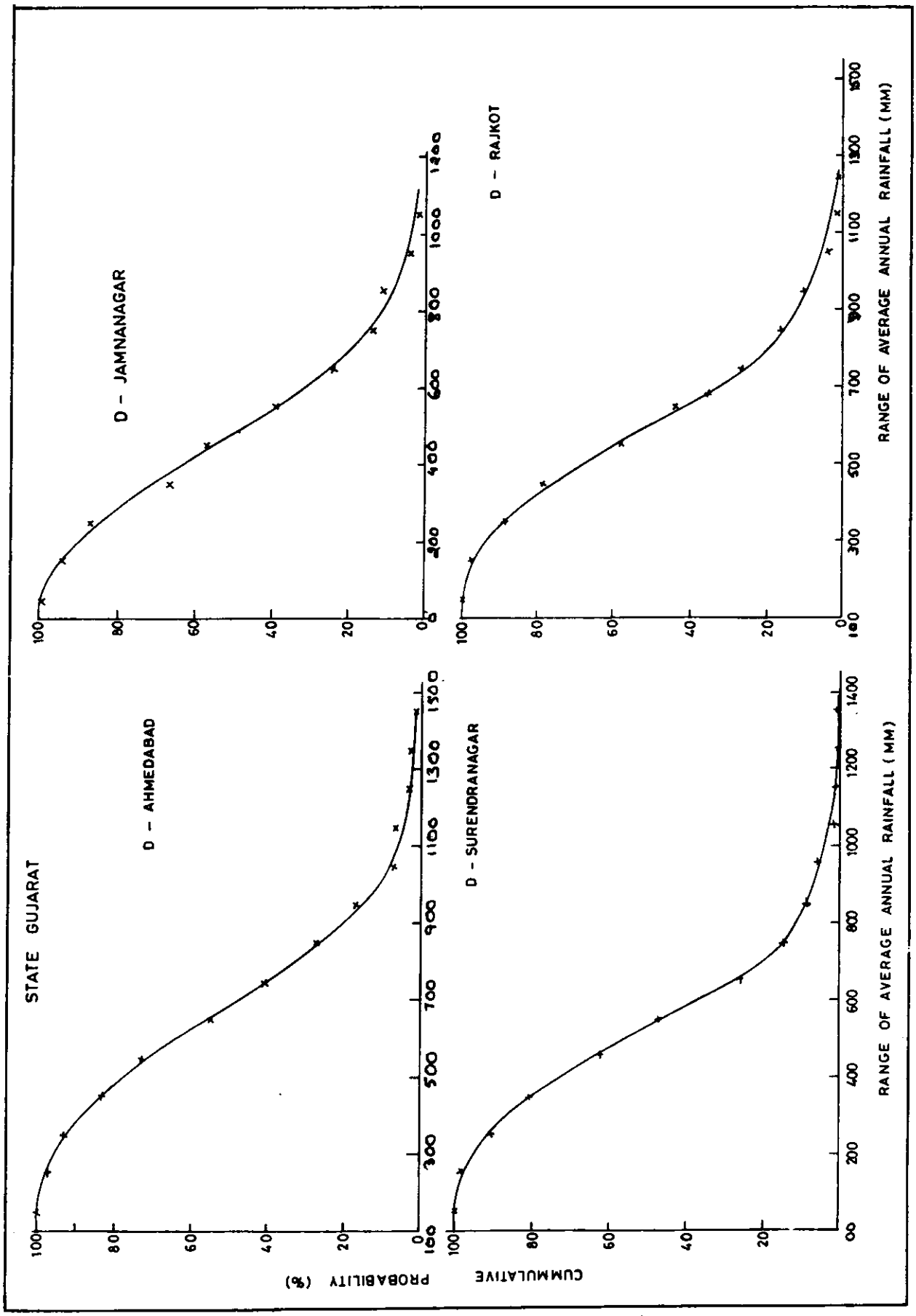


Fig. 3.3 : Districtwise Probability of Annual Rainfall

ness of the districts, the percentage probability of occurrence of 75% of normal rainfall of the district has been marked out and the results are given in table 3.3. It can be seen from table that all districts have less than 80% of probability of getting 75% of normal rainfall indicating proneness of the districts for drought conditions. This also indicates that all these districts faced scarcity conditions for more than 20% of the years.

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 Jamnagar,Rajkot,Ahmedabad,Surendranagar,Amreli & Bhavnagar are 60% 75% , 74%, 59%,73% & 79% respectively which are all below 80% indicating that all the districts are drought prone based on this analysis as per IMD criteria. This infers that the districts of

Jamnagar, Rajkot, Ahmedabad , Surendranagar,, Amreli and Bhavnagar experienced rainfall less than 75% of normal in 40,25,26,41,27 & 21 percent of years, respectively .The taluks of all the six districts showed similar results indicating that these taluks as well as as a whole are drought affected 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 rainfall,MMR) is calculated

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

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.

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

where NMN = Number of months in a year

C. Calculation of Effective Rainfall

For calculation of drought criteria, the carryover effects from month to month is considered. For this purpose, the mean monthly rainfall for a month,say (J) is subtracted 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 algebrically 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).

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

W(J) = Weighting factor for J^{th} month.

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

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

$$ER(I,J) = RF(I,J) + CO(I,J-1)*W(J) \qquad -(5)$$

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,

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

Thereupon 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'.

$$DIFF(I,J) = ER(I,J) - MMR(J)$$

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. $MD(I,J) = 0.0$;for $DIFF(I,J) \geq 0.0$

$MD(I,J) = DIFF(I,J)$;for $DIFF(I,J) < 0.0$

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

$$MMD(J) = \left[\sum_{I=1}^{NYR} MD(I,J)\right] * \frac{1}{NYT} \qquad -(7)$$

The summation of Mean Monthly Deficits yields

Mean Annual Deficit (MAD) or,

$$MAD = \sum_{J}^{NMN} MMD(J) \qquad -(8)$$

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 upto the sum of mean monthly rainfall of all the months yielding a value equal to Mean Annual Rainfall.

F. 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 $\geq$ 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 MMR+(J-1)x, a drought is deemed to have started from the first month.

Case (B) Delete negative difference $\geqslant$ MMMR

In this case when the delete negative difference is greater than or equal to MMR, the drought is deemed to have started 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 atleast 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 summed 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 months 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 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

$$\text{Drought Intensity (I)} = \frac{\sum_{J=IDST}^{IDEND} [MMR(J)-ER(J)] - MMD(J)}{\sum_{J=IDST}^{IDEND} [MMD(J)]} \quad -(9)$$

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), then nominator is equalled to zero for calculation of drought intensity.

Severity Index : Severity Index is defined as product of drought intensity and drought duration

$$SI = I \times D \quad -(10)$$

This analysis has been performed for all the six selected districts. Monthly rainfall data for the period 1951 to 1987 of selected raingauge stations located at taluk headquarters of each district have been used for analysis. A computer program using the above approach has been developed for the analysis. The distinct spells of drought alongwith monthly and 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 and Appendix III-3):

The Herbst's analysis has resulted in finding drought spells in all but one districts during years 84-87. The district of Bhavnagar, however, did not have drought spell during 84-87 and the last spell experienced in the district was during 80-83 as per Herbst's criteria. The pattern of intensity and duration of drought spells in the districts of Ahmedabad and Amreli were found similar during 84-87. The highest intensity of drought spell was, however, found in Rajkot district during 1985-87. In general all districts experienced 6-9 drought spells during the period of 1951-87. As has been shown in Figure 3.4 and Appendix-III-3,that monthly intensities are sometimes much greater than the average intensity over the entire drought period. Figure 3.4 clearly shows that monthly intensity values of drought during year 1987 are much greater than years '85 and '86 indicating thereby that droughts in year 1987 was

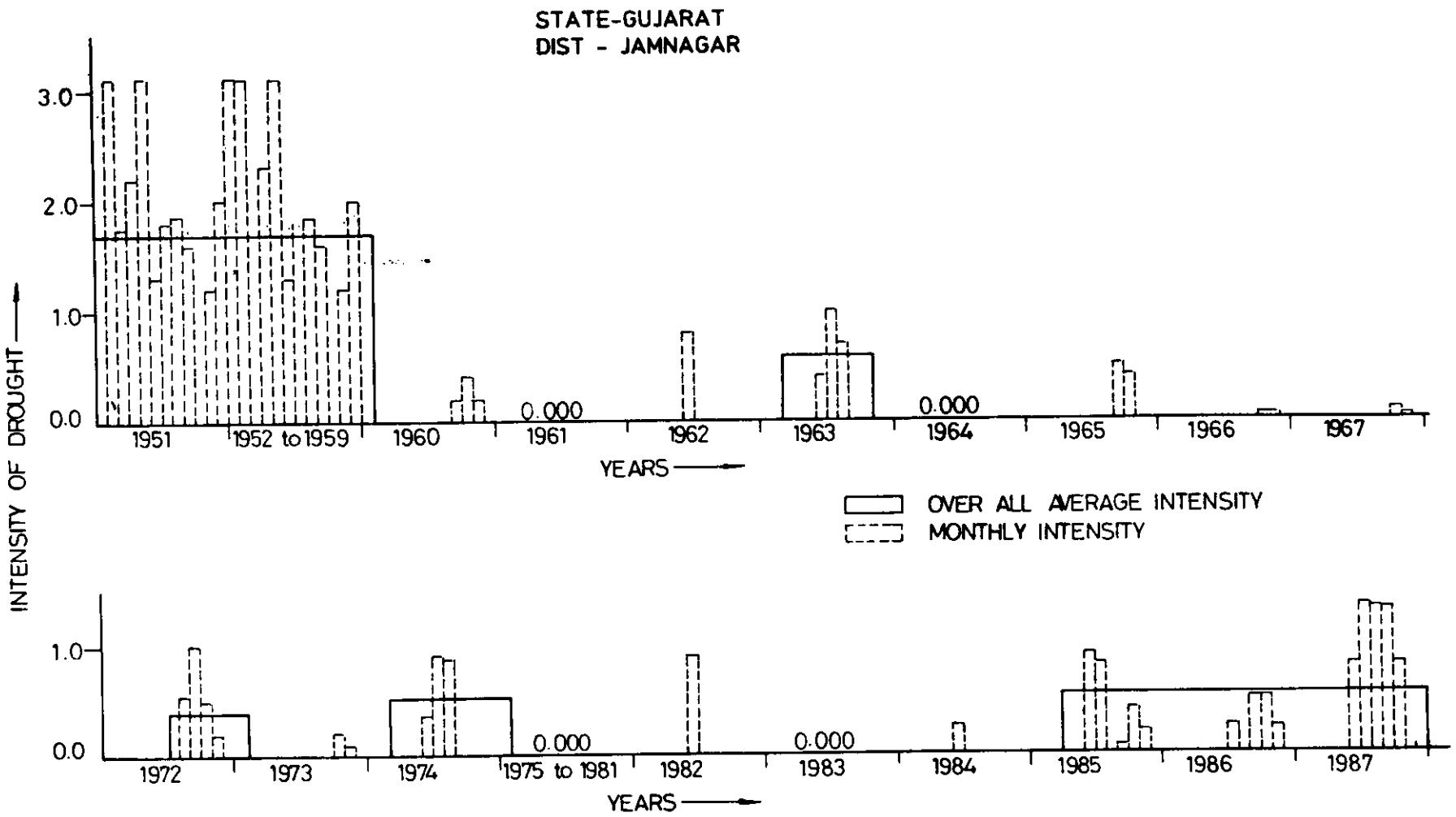


FIG. 3.4. OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

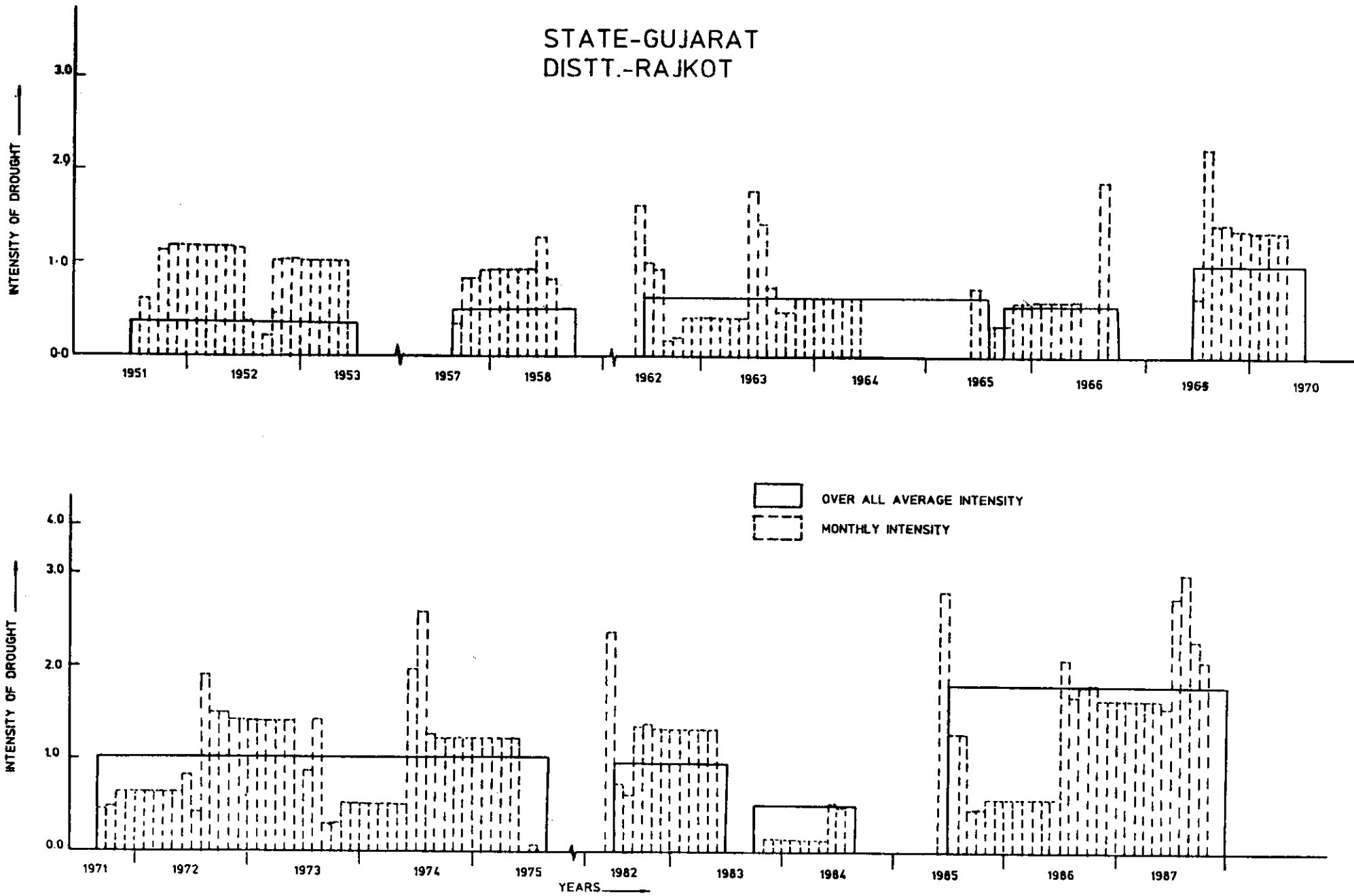


FIG. 3.4. OVER ALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

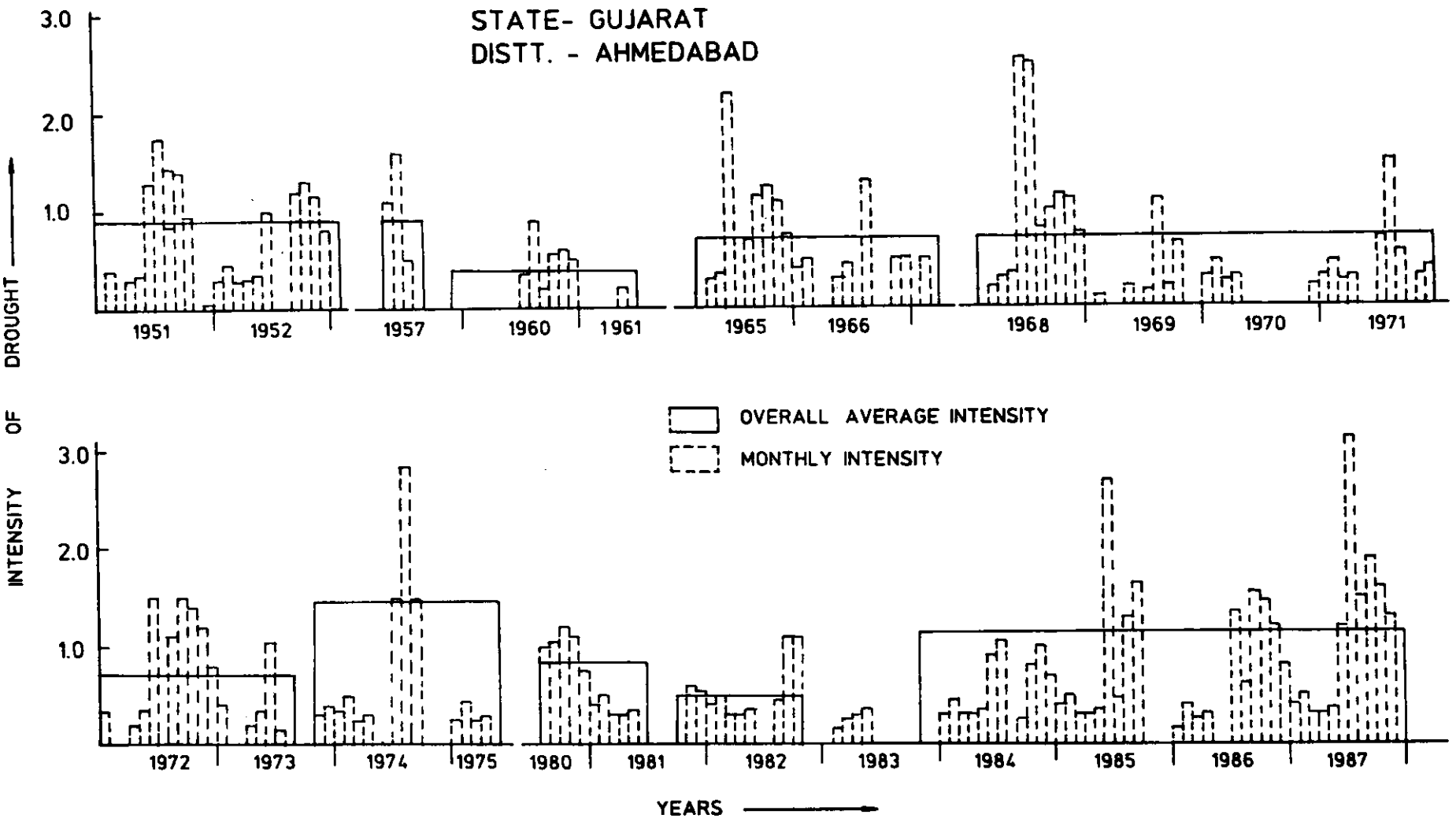


FIG. 3·4 OVERALL AVERAGE & MONTHLY INTENSITY OF DROUGHT

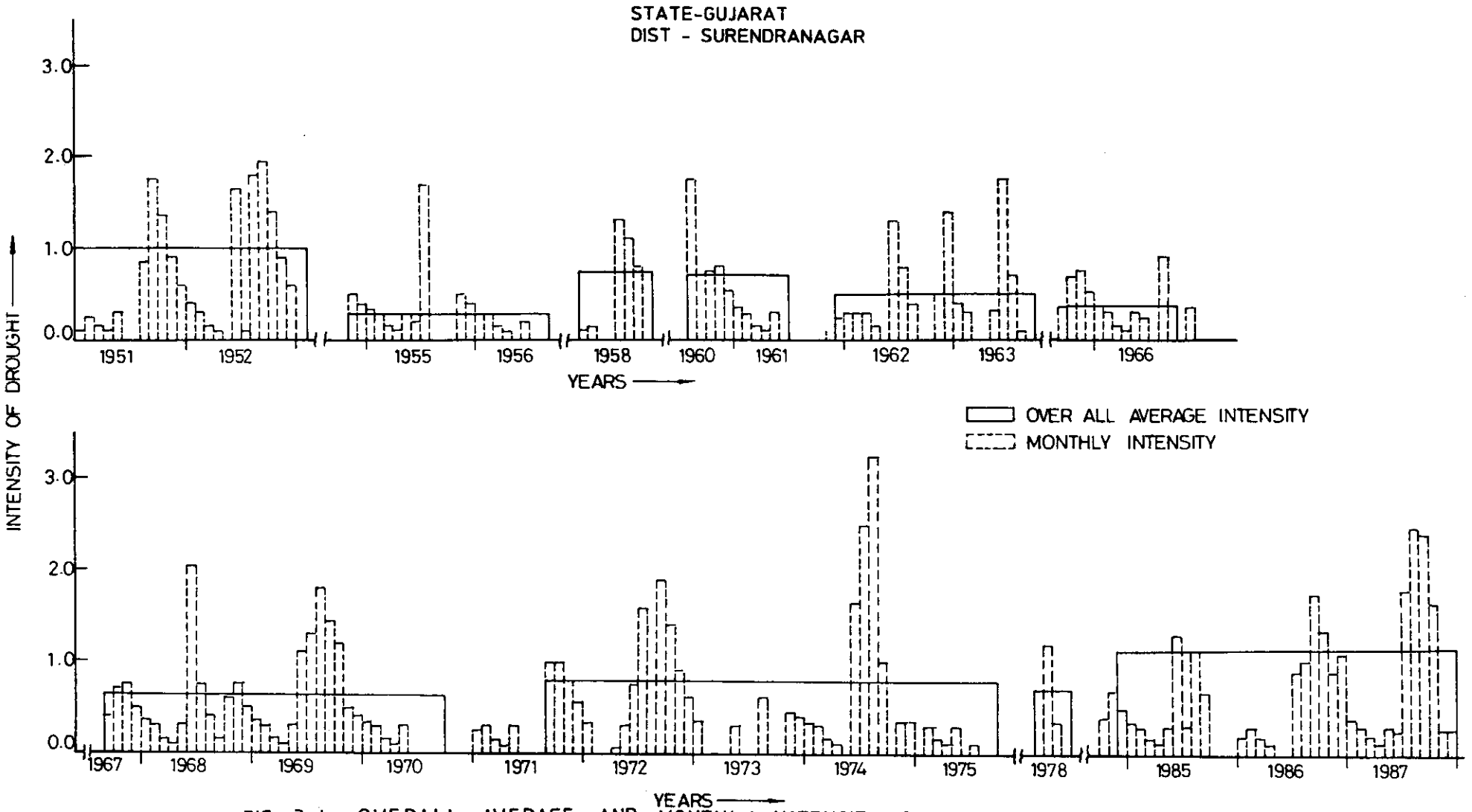


FIG 3.4 OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

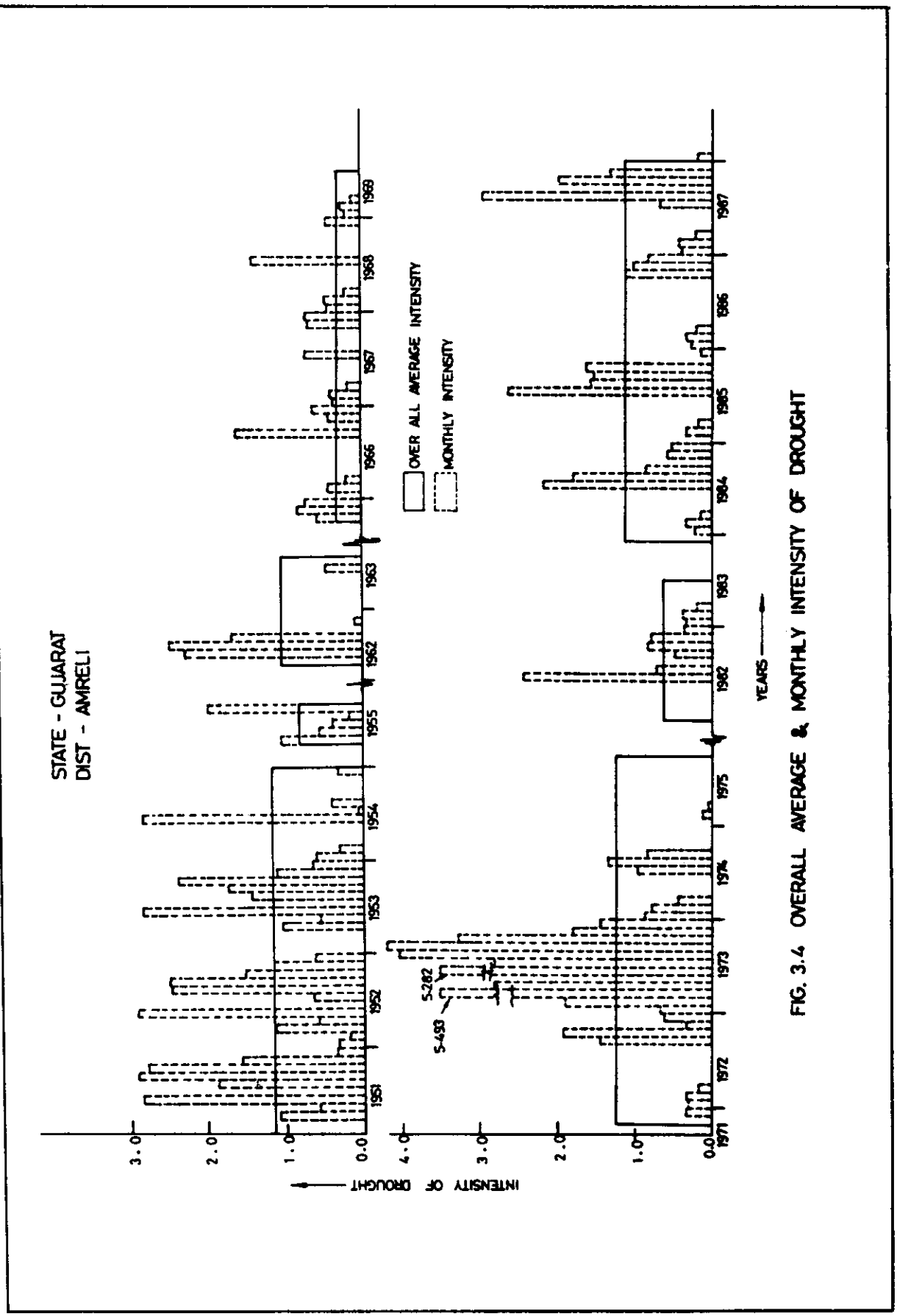


FIG. 3.4 OVERALL AVERAGE & MONTHLY INTENSITY OF DROUGHT

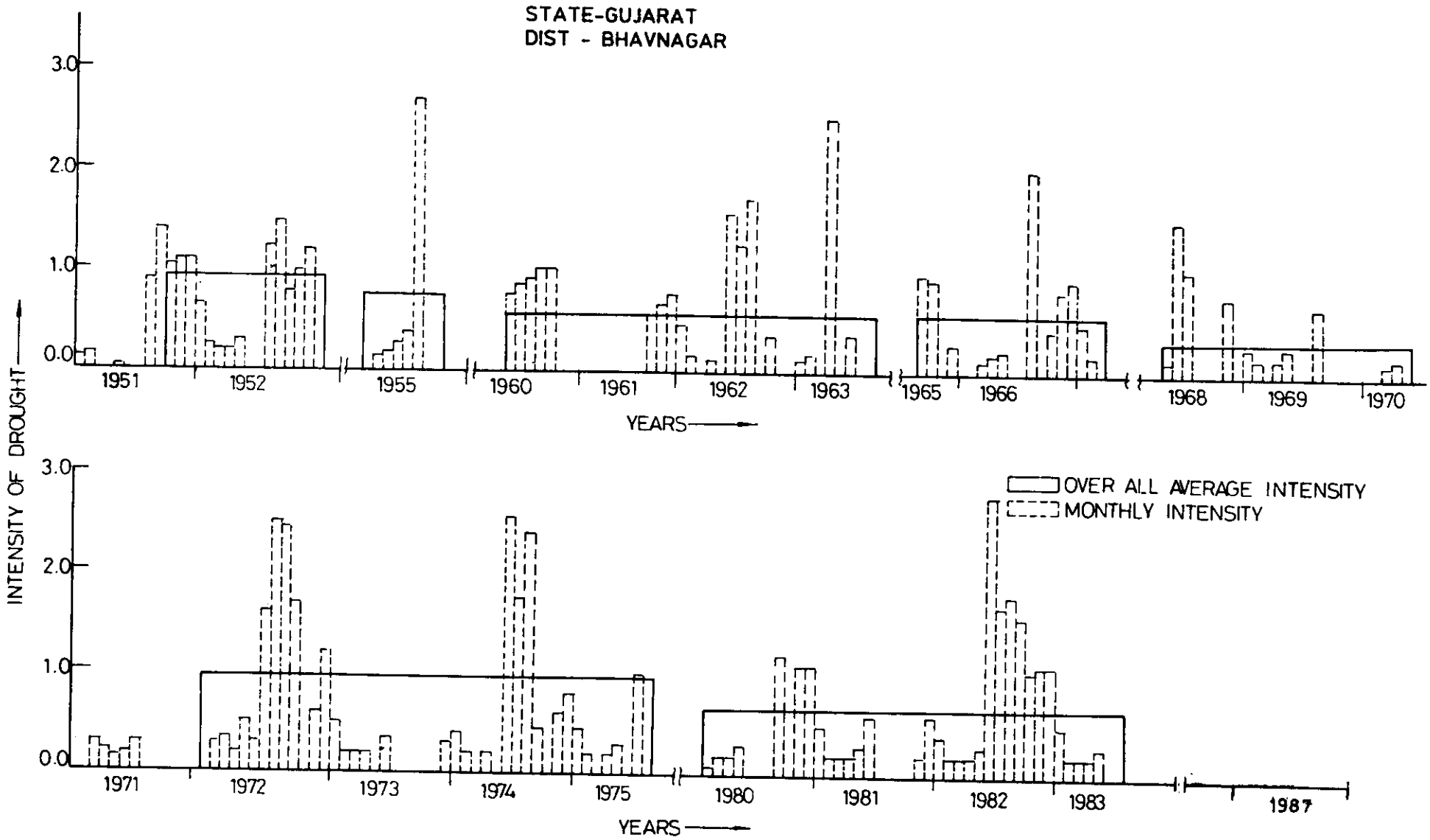


FIG.3·4. OVERALL AVERAGE & MONTHLY INTENSITY OF DROUGHT

more severe than in previous two years.The largest drought intensity values on monthly basis are found in 1987 after year 1975 in all districts except year Bhavnagar district. 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 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 stage . 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 significant 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 6 districts of state Gujarat.

The criteria for selection of dry spell is that the daily rainfall should be less than or equal to 5mm (as a day is assumed as rainy day if daily rainfall exceeds 5mm) 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 Gujarat 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 percentages(Appendix-III-3(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.

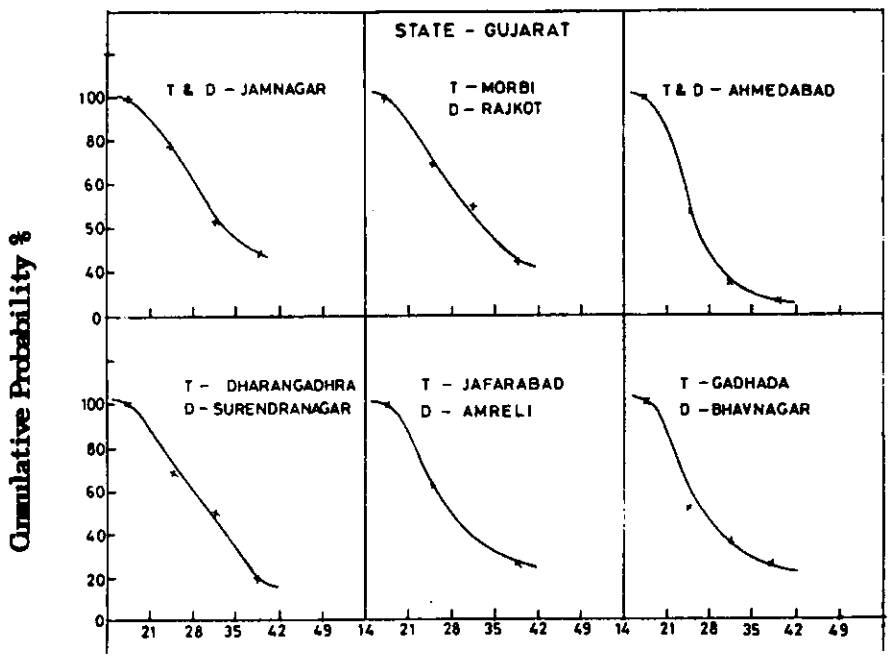


Fig. 3.5: Probability Distribution of Dry Spells.

Table 3.4: Range of Duration of dry spells for 75% probability of state Gujarat.

Sl.No.	Taluk	Distt.	At 75% probability,duration of dry spells(in days).
1.	Jamnagar	Jamnagar	21-28
2.	Morbi	Rajkot	21-28
3.	Ahmedabad	Ahmedabad	21-28
4.	Dharangadhra	Surendranagar	21-28
5.	Jafarabad	Amreli	21-28
6.	Gadhada	Bhavnagar	21-28

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 of precipitation and of 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 overexploited 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 observataions Besides, information regarding well , abstractions should be available for evaluating effects on water table on, 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 for all the 6 districts chosen in the state of Gujarat. However, 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 all the six districts, namely Jamnagar,Rajkot,Ahmedabad,Surendranagar,Amreli & Bhavnagar of state Gujarat. 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 Gujarat.

Sl.No.	Name of districts	Data available (four time in a year)	No. of wells taken	Source of data availability
!.	Ahmedabad	1979-88	6	CGWB
2.	Jamnagar	1979-88	10	- do -
3.	Rajkot	1979-88	5	- do -
4.	Surendranagar	1978-88	8	- do -
5.	Amreli	1978-88	6	- do -
6.	Bhavnagar	1978-88	8	- do -

As is evident from table 4.1, about 5-10 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 inthe 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 drought prone districts of Gujarat 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. An example of groundwater level calculation for the district of Surendranagar in Gujarat state is presented in Appendix IV-2. It can be observed that the Thiessen weight for the wells in the district were 0.115, 0.133,0.134,0.120,0.150,0.073,0.136 and 0.139 and average levels for these wells were computed with respect to MSL. Based on these values, average ground water level for the district was obtained. Similar computations were done for all the six districts and average/quarterly/seasonal values were derived. The values so obtained were plotted against each year to derive trend in ground water fluctuation. The trend was established for two periods namely, pre-monsoon and post monsoon. In order to see the trend in the rainfall, the seasonal rainfall was also plotted in the same graph showing the ground water level fluctuation. For this purpose,, the seasonal rainfall from June to September was used . A simple regression line was fitted to show the trend of rainfall in order to see the effect of deficit ground water levels. The plots showing trends of seasonal rainfall and average ground water fluctuations for all the districts are shown in figures 4.1 to 4.6.As has already been mentioned that due to non-availability of obstraction data, the effects caused due to over exploitation of ground water during drought periods could not be introduced in the study and it is preesumed that decline in the ground water level is caused solely due to failure of rainfall. Also a district has been taken as a unit for analysing drought impacts on ground water levels. Ideally, a hydrogeological boundary will need to be established for such an analysis. However , it has been presumed that the district has no inflow or outflow of ground water into/from its aquifer. Based on the analysis, following inferences can be drawn:

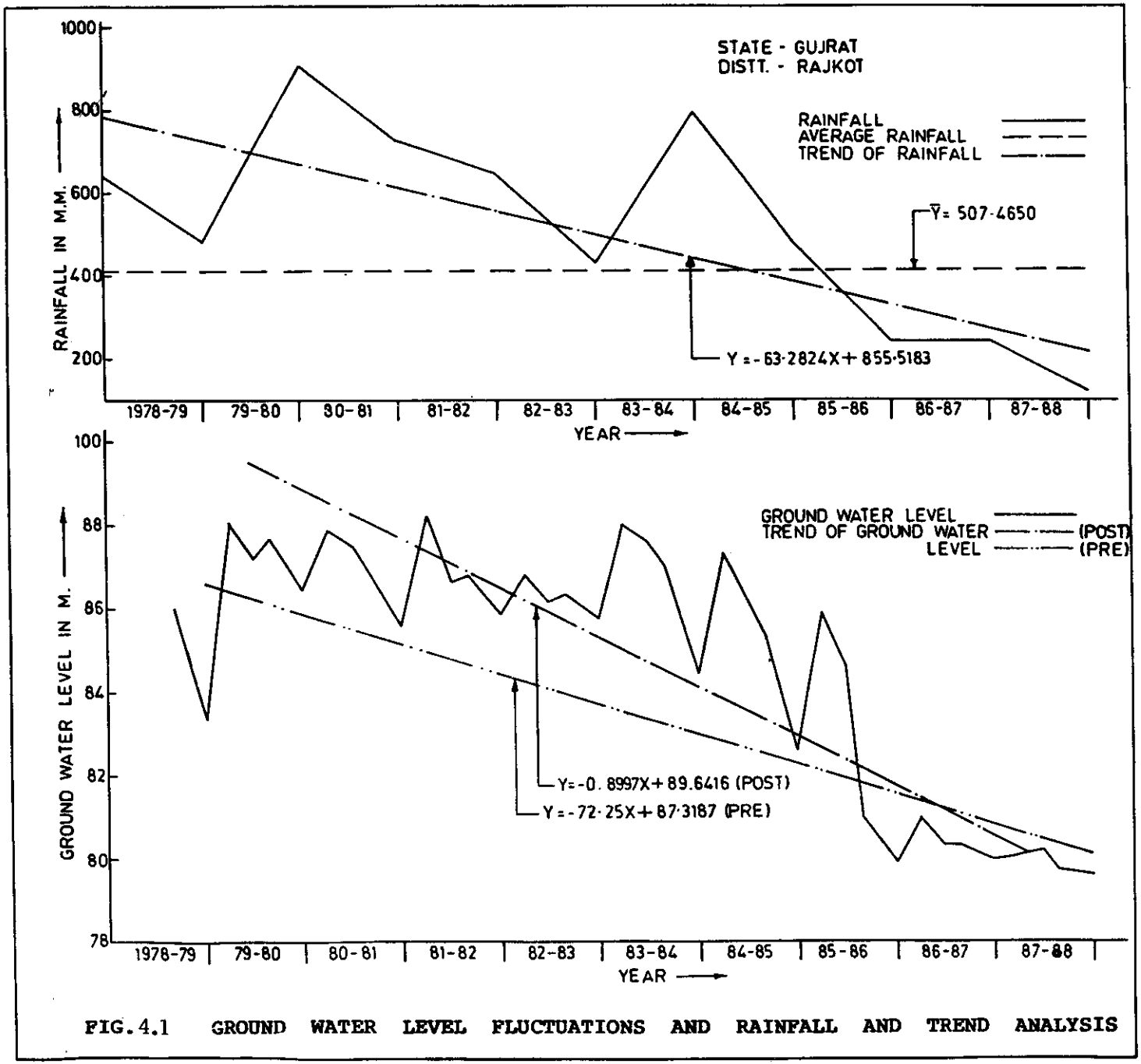


FIG. 4.1 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

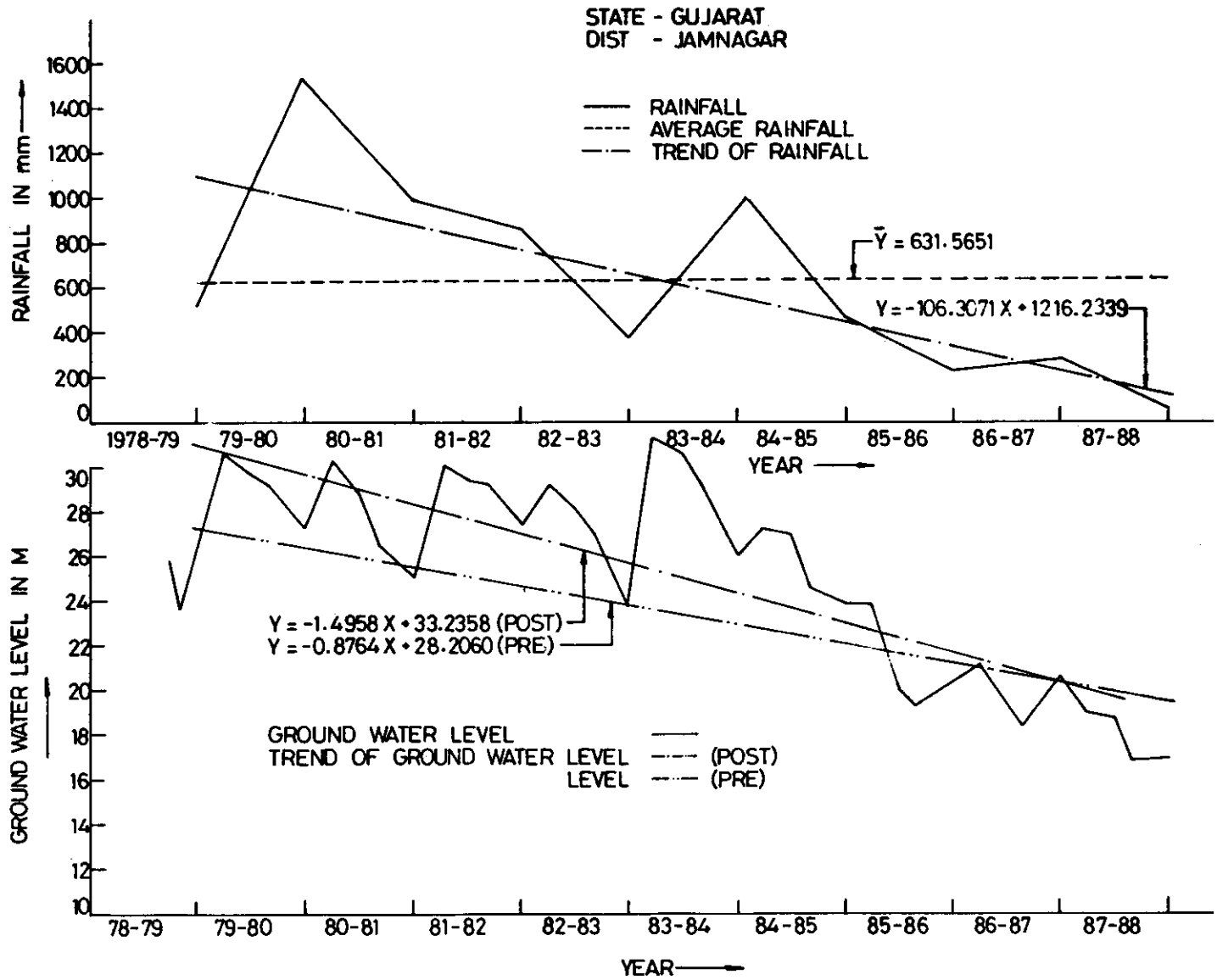


FIG. 4.2 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

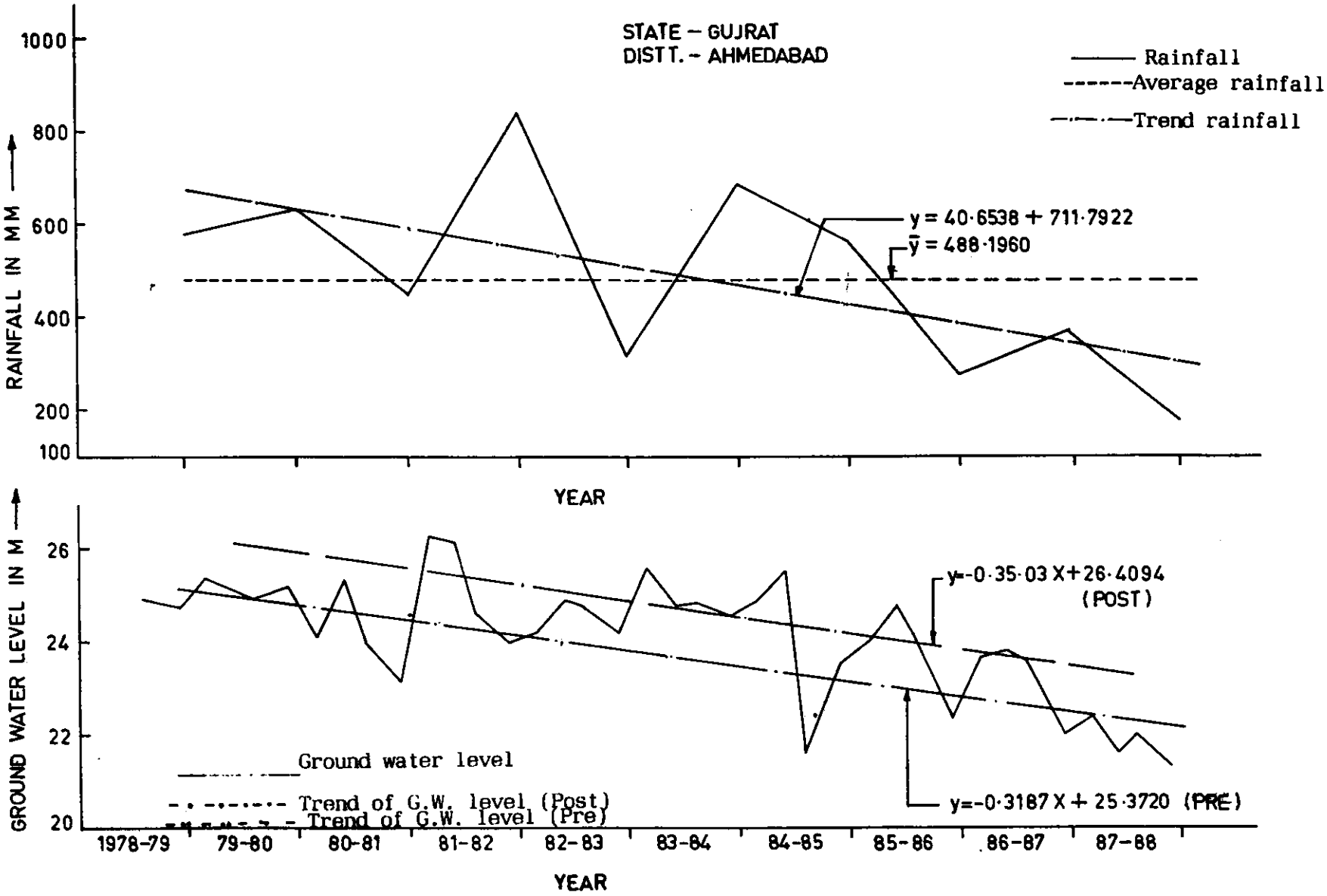


Fig.4.3: Ground water level Fluctuations and Rainfall and Trend Analysis.

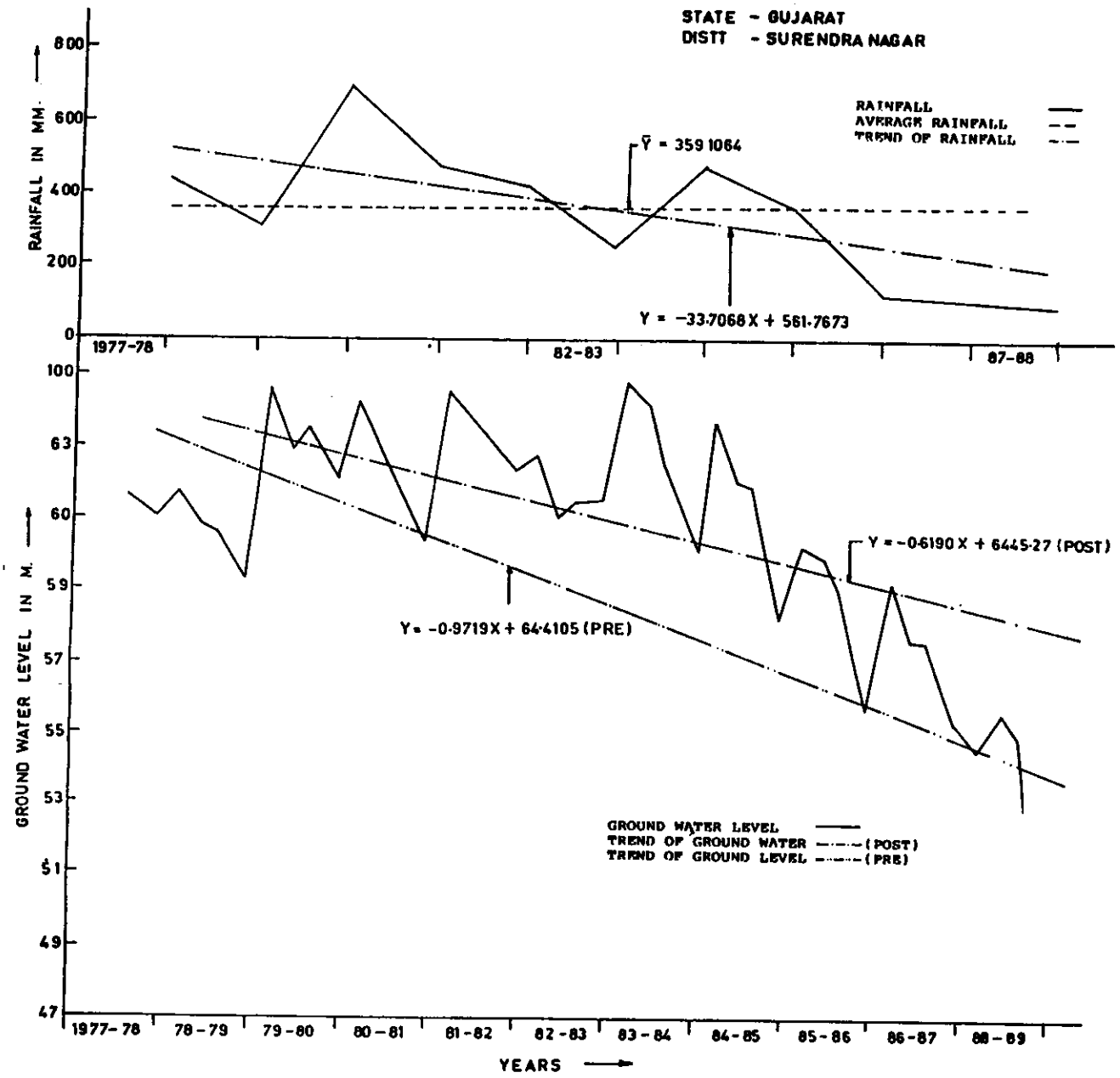


FIG. 4.4 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

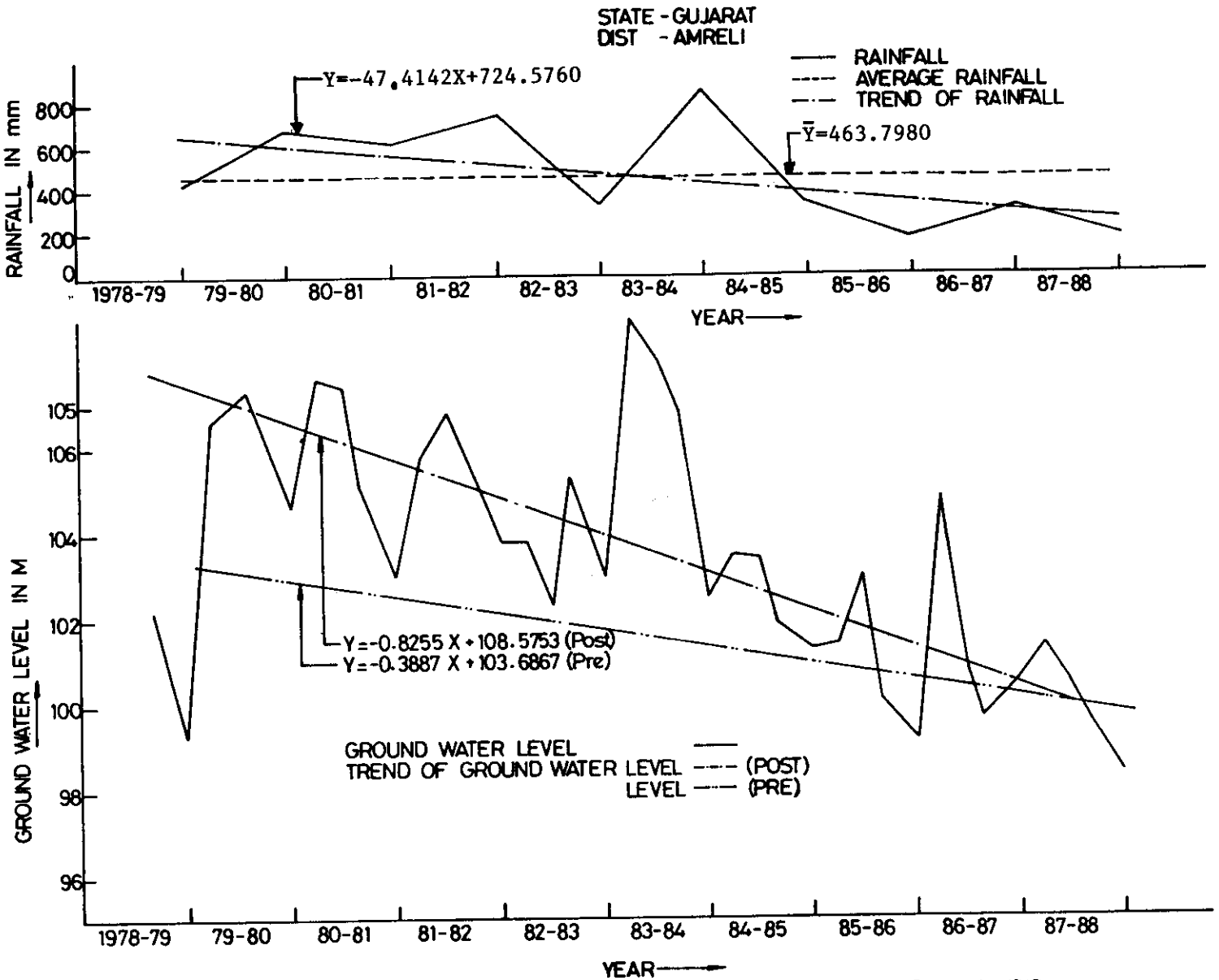


Fig. 4.5 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

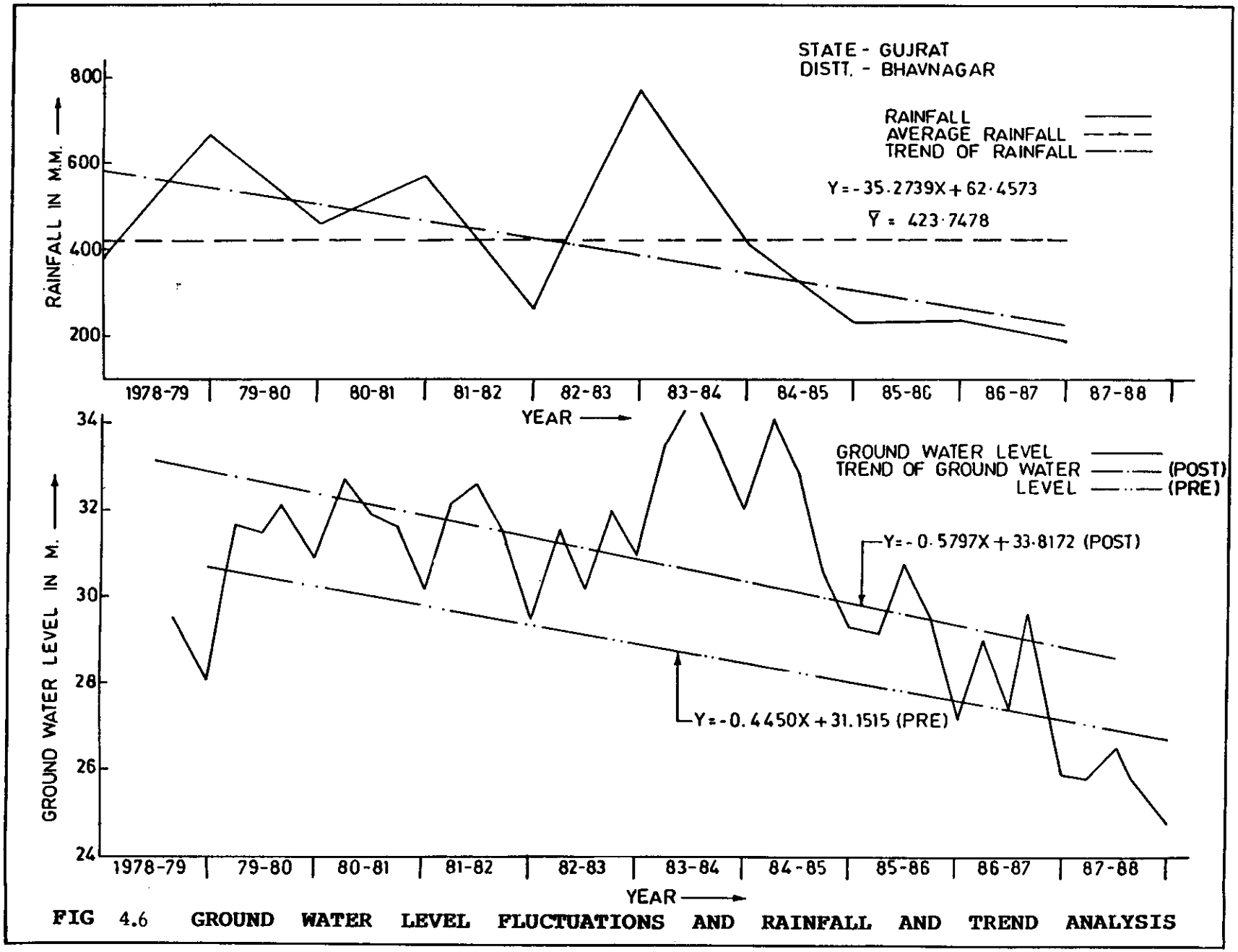


FIG 4.6 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

In the present analysis of state Gujarat, pre and post monsoon levels have been analysed for six districts of Jamnagar, Rajkot, Ahmedabad, Surendranagar,Bhavnagar and Amreli. (Reference Fig.4 .1 to Fig.4.6). The seasonal rainfall in all six districts was deficient by more than 50%. It can be observed from figures that during the year 1987-88 the rainfall trend for all districts have comparatively steeper declining trend than that of previous years. The dificiency of seasonal rainfall have also shown similar trend. As a result, the ground water table recorded falling trend in all the districts. The trend lines of pre and post monsoon for year 1987-88 have shown greater effects on water table as a result of monsoon failure as compared to previous years. The district of Jamnagar followed by Rajkot and Amreli showed highest rate of decline in post monsoon grondwater levels for 1987-88. The pre monsoon level was observed falling at highest rate in the district of Surendranagar followed by Jamnagar. The district of Ahmedabad recorded lowest rate of decline in pre and post water table levels. As in the case of rainfall, the ground water regime also seems to have been severely affected in six chosen districts of Gujarat.

The analysis of groundwater levels based on the water-table fluctuation data of post 10-12 years has yielded in knowing the groundwater level trends (pre & post) as a result of seasonal rainfall depature. 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.

5.0 Analysis of Reservoir Storage

In order to illustrate the impact of failure of monsoon on storagaes of reservoirs, an attempt has been made to compare the storages only for one selected Kadana Reservoir on Mahi river. For this purpose, the live storages and corresponding reservoir levels in some selected months have been plotted against time. The weekly reservoir level data supplied by Central Water Commission from 1984 till 1987 have been used for the present analysis. Figure 5.1 shows the position of storages during 1984 to 87 in the Kadona Reservoir.

The inferences that can be drawn from the fig.5.1 are as below:

The storages position as indicated in the fig.5.1 shows that impact of rainfall failure had been more or less same on reservoir storages during the years 1986 and 1987 except the months of May and August showing little difference. The live storage in the reservoir at the mid of Oct.'87 was 114% to the last years storage Based on these results, it can be inferred that drought impact on reservoir storages were more pronounced during the year 1986.

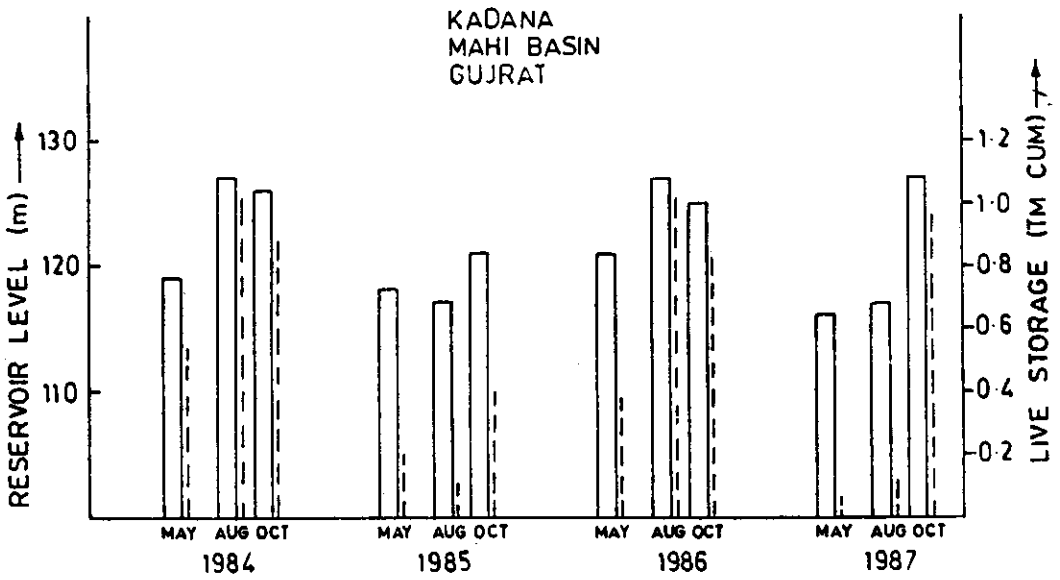


Fig.5.1 : **Reservoir levels and storages for Kadana Reservoir of State Gujarat.**

6.0 Conclusions

i) The analysis of daily, monthly and annual rainfall data has been presented in the present report in a bid to classify the drought situation in the state of Gujarat during year 1987-88. The data have been either collected by undertaking field visits to the study area or taken from the published reports by the state and central government organisations.

ii) The analysis of rainfall on seasonal basis indicates that all selected districts, namely, Jamnagar, Rajkot, Ahmedabad, Surendranagar, Amreli and Bhavnagar experienced more than 60% deficiency in seasonal rainfall during year 1987-88. It was further observed that all these districts have been facing rainfall deficiency of more than 20% since water year 1984-85.

iii) The values of monthly departures during year 87-88 showed that deficiencies ranged from 20-100%. During the monsoon months, most of the districts had more than 50% deficiency on monthly basis.

iv) The probability analysis of annual rainfall for 2 taluks in each district and district as a whole has been carried out. The group range of annual rainfall at 75% probability level has been found from 400-500 mm in most of the cases. The probability of occurrence of 75% of normal rainfall in all the six districts namely, Jamnagar, Rajkot, Ahmedabad, Surendranagar, Amreli and Bhavnagar were found as 60,75, 74,59,73 and 79%, respectively which are all below 80%, further certifying the drought proneness of the districts.

v) The analysis of monthly rainfall data using Herbst's

approach indicated that all districts had drought spells during year 1984-87 except Bhavnagar. The district of Rajkot showed highest intensity of drought during 1985-87. All districts experienced 6-9 drought spells during the period 1959-87. The monthly intensities of drought were found highest in year 1987 as compared with 1985 and 1986.

vi) The dry spell analysis indicated that for all taluks the duration of the dry spell ranged from 21-28 days at 75% level of probability. A dry spell was assumed as a period during which daily rainfall does not exced 5 mm for at least 2 weeks.

vii) The groundwater level analysis carried out for all the six districts showed a declining trend as a result of reduced rainfall. The water table trend lines for pre and post monsoon periods in 1987-88 showed greater effects on water table as a result of monsson failure as compared to previous years. The steepest fall in groundwater levels was found in Jamnagar district which was followed by Rajkot and Amreli. The district of Ahmedabad, however, showed lowest rate of decline in pre and post monsoon levels. Since the analysis has been done without considering the effects of groundwater withdrawal, the results have further scope of improvement.

ix) The positions of live storage in Kadana reservoir were compared during years 1984-87. The post and pre monsoon storages were found least during 1985 as compared with other years. In year 1987, the storage position was improved significantly during August to October while in 1986, the storage got reduced during this period.

x) The analysis needs to be extended to a basin to facilitate in deriving interrelationships between monsoon failure and its impacts on groundwater and streamflow regimes.

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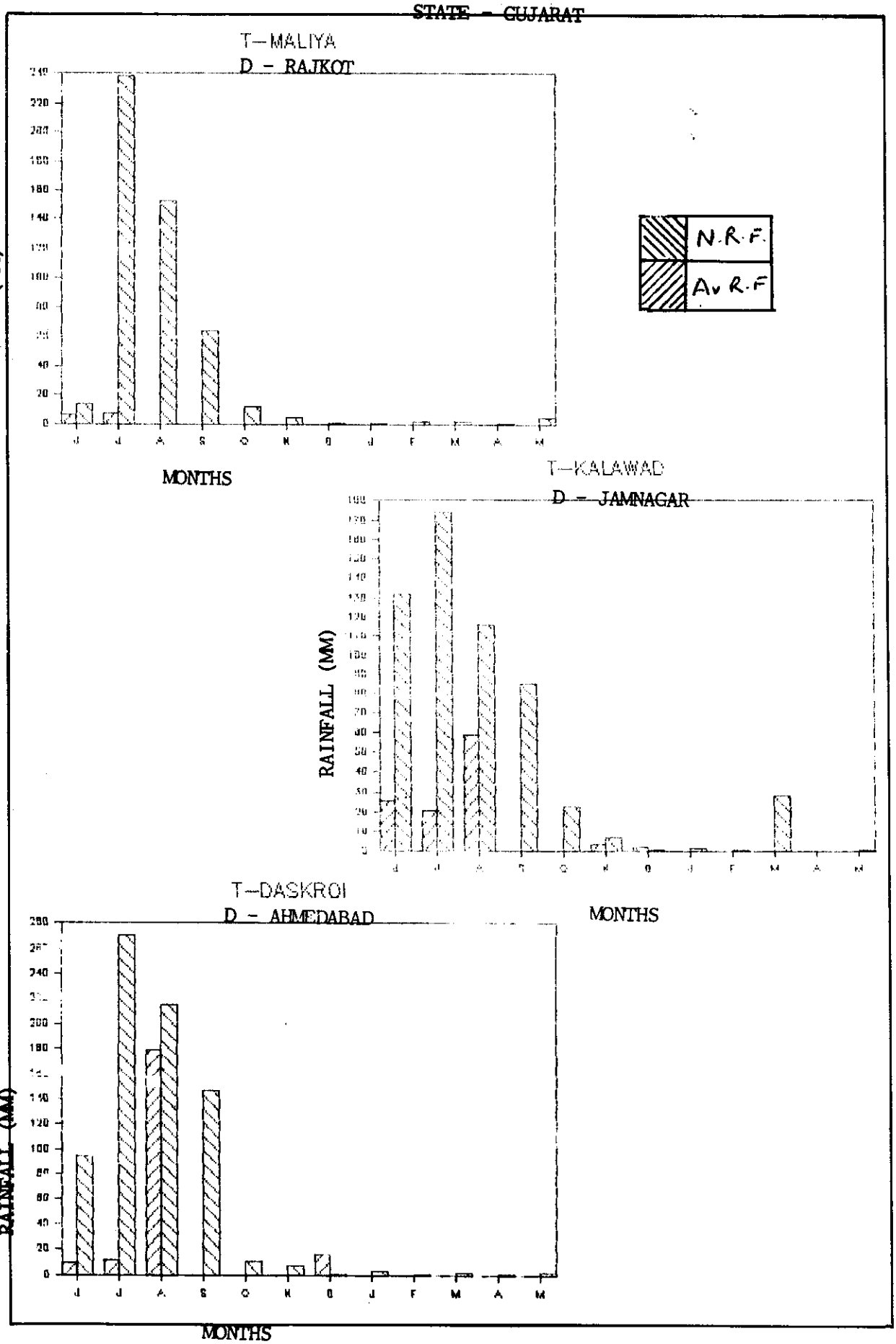
APPENDIX-II

LIST OF OFFICES AND PLACES FROM WHERE DATA & INFORMATION WERE COLLECTED IN THE STATE OF GUJARAT.

PLACE	
Gandhi Nagar	Secretary and Commissioner (RD), Govt. of Gujarat.
	Chief Engineer (Panchayat), Gujarat
	Secretary Irrigation, Gujarat
	Superintending Engineer, Gandhinagar Panchayat, Irrigation Circle
	Chief Engineer, Gujarat Irrigation Dept.
	Director, Gujarat Water Resources Development Corpn.
	Secretary, Gujarat Revenue Dept.
	Secretary, CADA, Gujarat Gujarat Water Supply & Sewerage Board..
Rajkot	Zilla Panchayat Raj, Rajkot
	Deputy Director, Agriculture
	Superintending Engineer, Minor Irrigation Rajkot Circle
	Soil Officer, Soil Survey Deptt.
	Superintending Engineer, P.H.E.D.
	Irrigation Department
Ahmedabad	W.R.I. Bhadra Fort
	Director, Agriculture Gujarat State
	Eastern Gauging Division, Central Water Commission
	Geohydrologist, Ground Water Division
	Flood Control Cell
	Additional Director of Agricultural Sciences
	Deputy Director, Central Flood Forecasting Division, Central Water Commission.

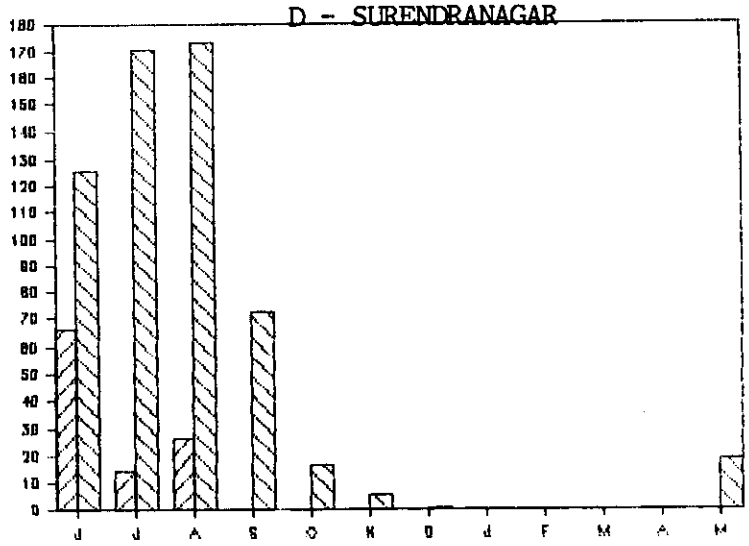
Talukwise monthly Rainfall Departures for the year 1987-88. Appendix-III-I

STATE - GUJARAT

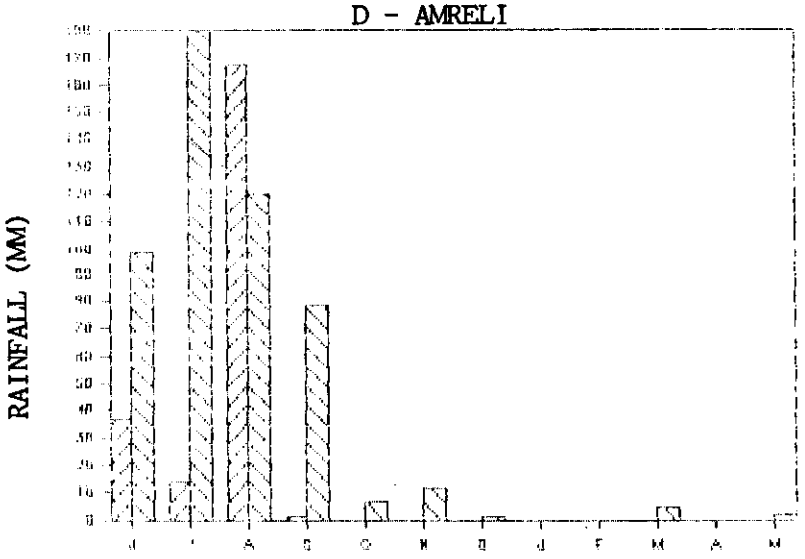


STATE - GUJARAT

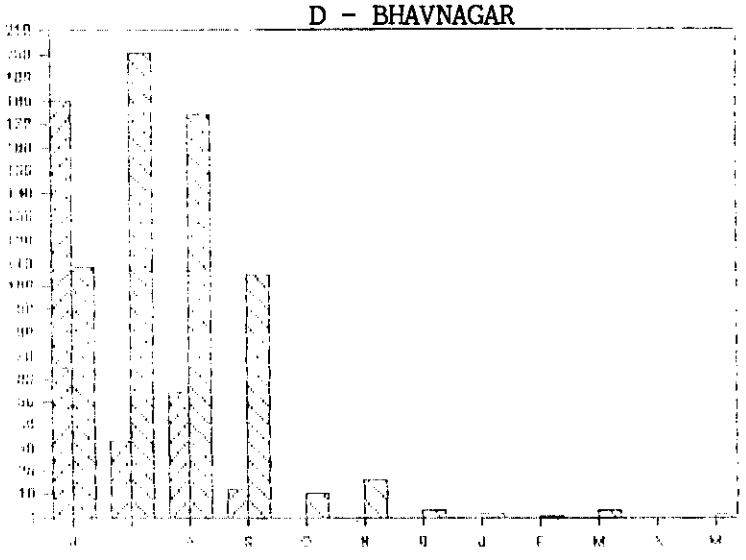
T-CHOTILA
D - SURENDRANAGAR

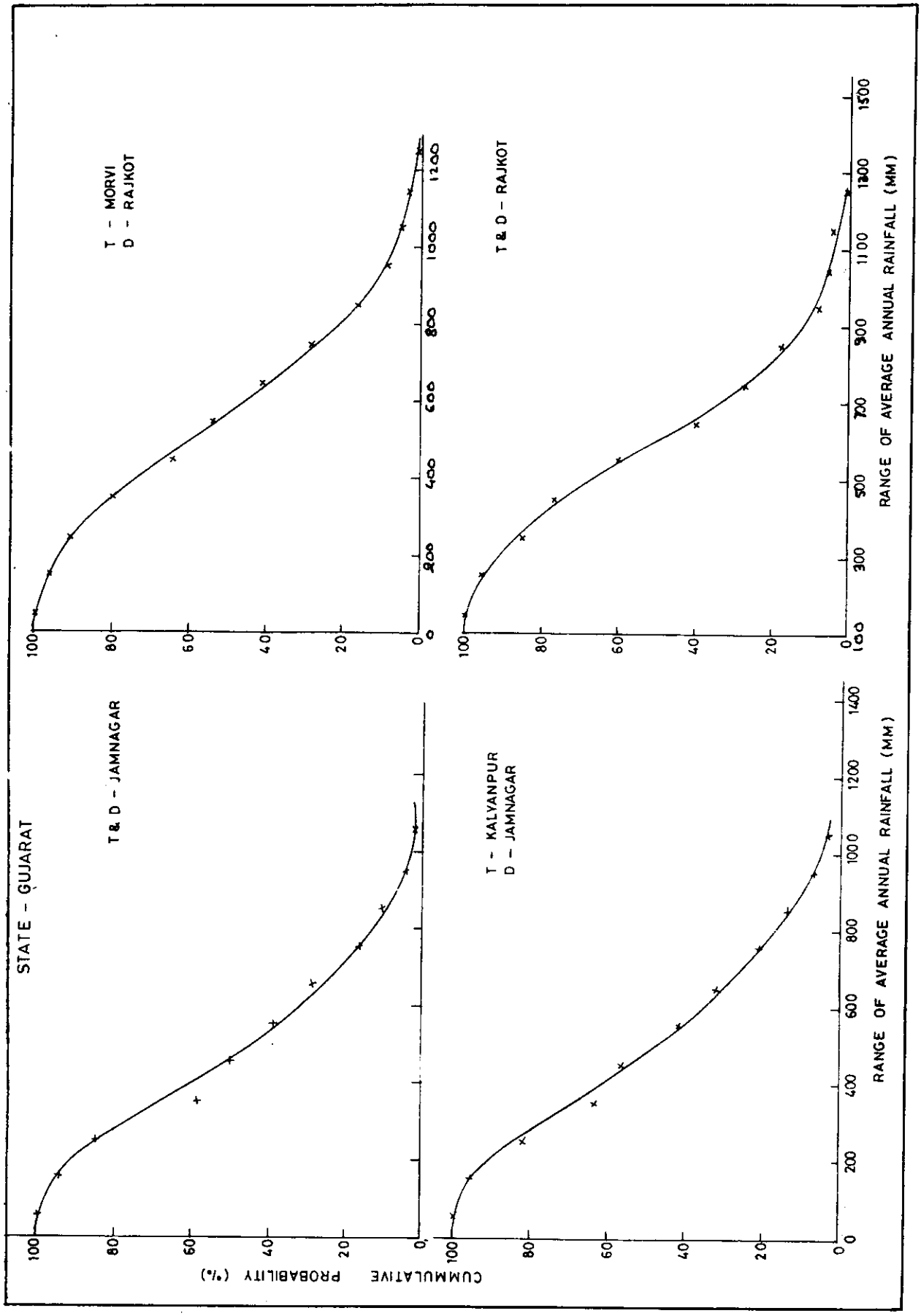


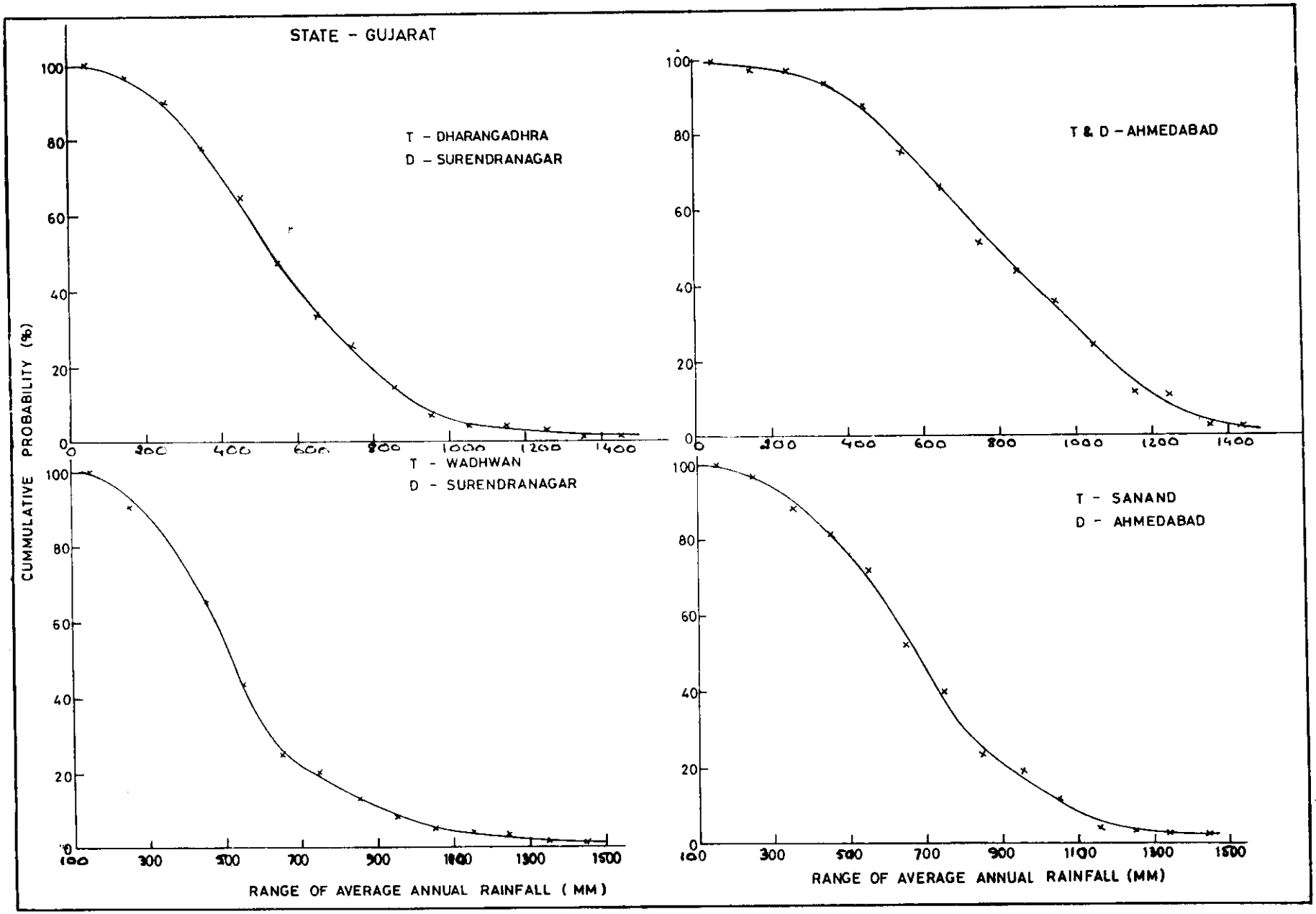
T-RAJULA
D - AMRELI



T-BOTAD
D - BHAVNAGAR




STATE - GUJARAT
T & D - JAMNAGAR
T - MORVI
D - RAJKOT
T & D - RAJKOT
T - KALYANPUR
D - JAMNAGAR
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)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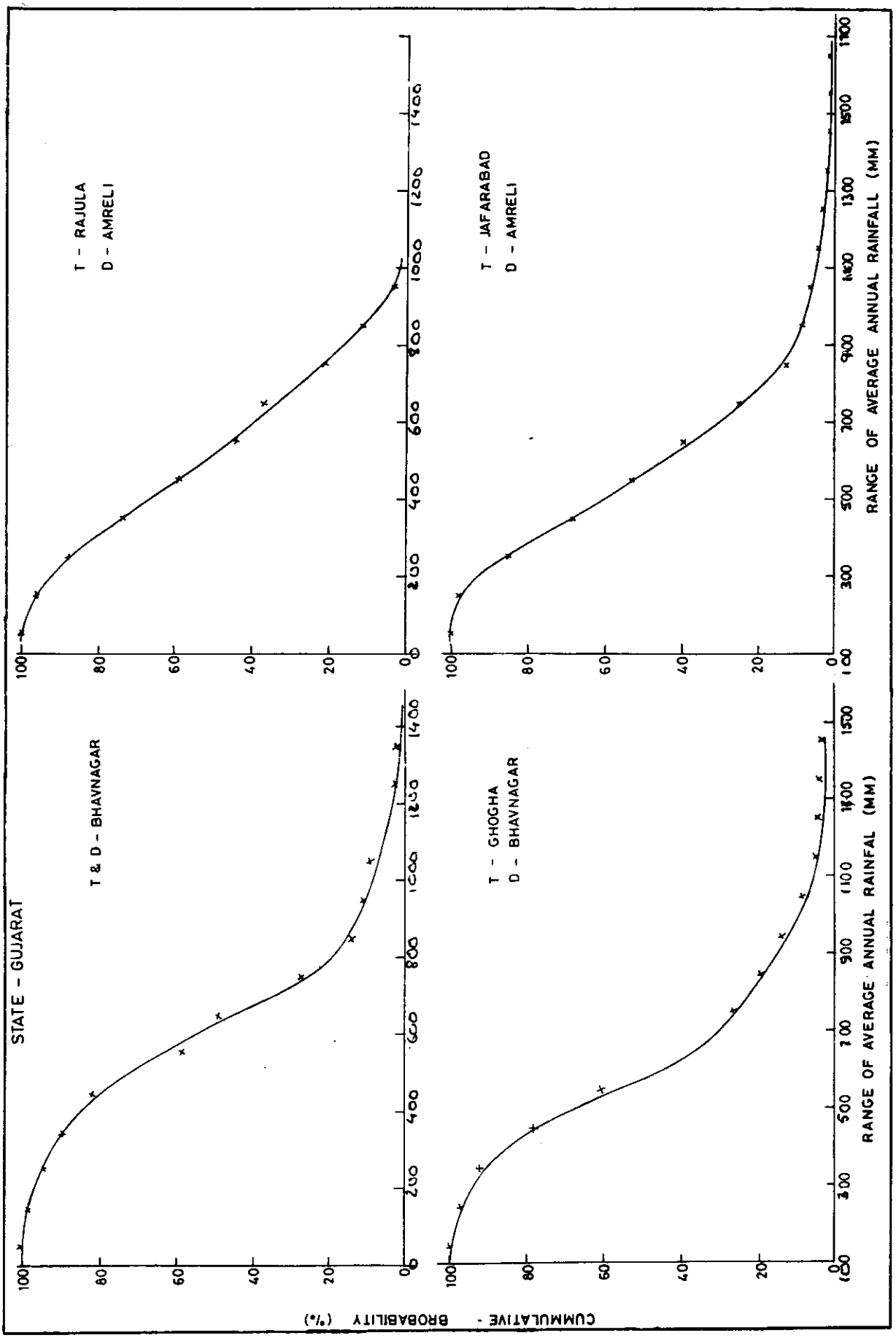
D - SURENDRANAGAR
T & D - AHMEDABAD
T - WADHWAN
D - SURENDRANAGAR
T - SANAND
D - AHMEDABAD
CUMMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)

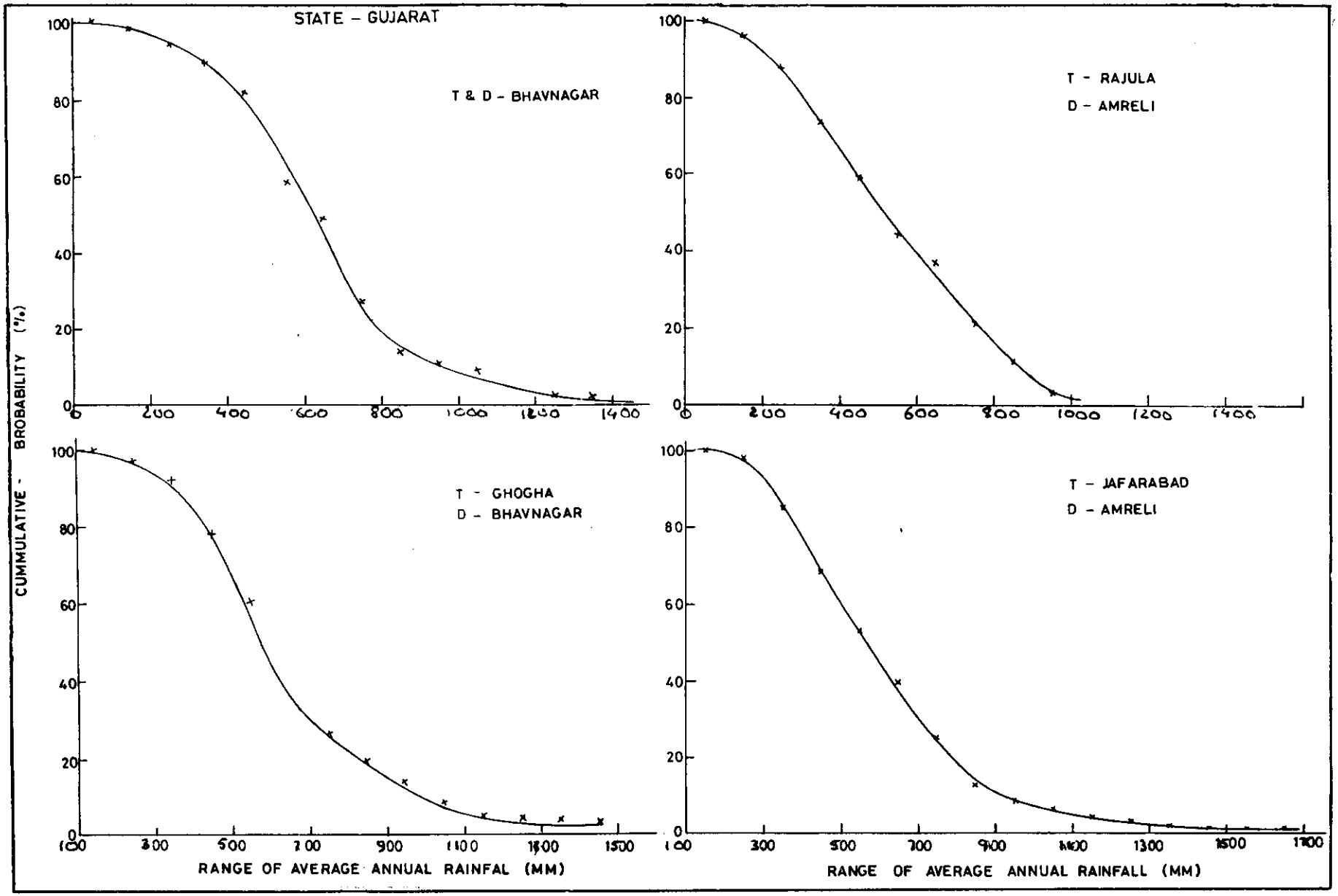

STATE - GUJARAT
T - RAJULA
D - AMRELI
T & D - BHAVNAGAR
T - JAFARABAD
D - AMRELI
T - GHOGHA
D - BHAVNAGAR
CUMMULATIVE - BROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFAL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)

DROUGHT ANALYSIS FOR JAMNAGAR DISTRICT OF GUJARAT

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	3.040	3.074	1.766	2.234	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1952	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1953	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1954	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1955	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1956	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1957	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1958	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1959	3.120	3.116	1.766	2.235	3.111	1.333	1.838	1.862	1.603	0.984	1.201	2.019
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.180	0.430	0.193	0.000
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.813	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.439	1.036	0.706	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.484	0.426	0.000	0.000
1966	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045	0.037	0.000
1967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071	0.048	0.000
1968	0.000	0.000	0.000	0.000	0.000	0.512	0.000	0.000	0.000	0.017	0.026	0.000
1969	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.359	0.492	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000
1972	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.552	0.976	0.458	0.204	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.195	0.098	0.000
1974	0.000	0.000	0.000	0.000	0.000	0.363	0.889	0.844	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.000	0.000	0.000	0.890	0.000	0.000	0.000	0.000	0.000	0.000
1983	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.000	0.000	0.000	0.000	0.256	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	0.922	0.806	0.000	0.076	0.394	0.178	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.242	0.000	0.511	0.545	0.239	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.781	1.340	1.325	1.330	0.830	0.050	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	1	1960	109	1.71	186.42
3	1963	10	1963	8	0.57	4.56
7	1972	1	1973	7	0.40	2.82
3	1974	1	1975	11	0.54	5.89
3	1985	12	1987	34	0.57	19.26


STATE – GUJARAT
T & D – BHAVNAGAR
T – RAJULA
D – AMRELI
T – GHOGHA
D – BHAVNAGAR
T – JAFARABAD
D – AMRELI
CUMMULATIVE - BROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFAL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)

DROUGHT ANALYSIS FOR RAJKOT DISTRICT OF STATE GUJARAT

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	0.000	0.000	0.624	0.149	1.174	1.186	1.183	1.183
1952	1.183	1.183	1.183	1.183	1.183	0.390	0.000	0.214	1.010	1.022	1.057	1.057
1953	1.057	1.057	1.057	1.057	1.057	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.414	0.001	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.870	1.218	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.327	0.857	0.868	0.939	0.939
1958	0.939	0.939	0.939	0.939	0.939	1.201	0.801	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.174	0.184	0.413	0.413
1961	0.413	0.413	0.413	0.413	0.413	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	1.616	0.983	0.920	0.165	0.175	0.406	0.406
1963	0.406	0.406	0.406	0.406	0.406	1.770	1.419	0.741	0.476	0.486	0.645	0.645
1964	0.645	0.645	0.645	0.645	0.645	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	0.772	0.000	0.000	0.363	0.373	0.559	0.559
1966	0.559	0.559	0.559	0.559	0.559	0.000	0.000	0.000	1.871	0.000	0.000	0.000
1967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.291	0.301	0.503	0.503
1968	0.503	0.503	0.503	0.503	0.503	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.000	0.000	0.000	0.613	2.236	1.399	1.412	1.357	1.357
1970	1.357	1.357	1.357	1.357	1.357	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.482	0.492	0.650	0.650
1972	0.650	0.650	0.650	0.650	0.650	0.943	0.415	1.894	1.478	1.491	1.418	1.418
1973	1.418	1.418	1.418	1.418	1.418	0.000	0.885	1.429	0.300	0.310	0.510	0.510
1974	0.510	0.510	0.510	0.510	0.510	1.973	2.595	2.945	1.258	1.271	1.249	1.249
1975	1.249	1.249	1.249	1.249	1.249	0.000	0.177	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.525	0.536	0.683	0.683
1979	0.683	0.683	0.683	0.683	0.683	0.000	1.279	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.301	0.311	0.511	0.511
1981	0.511	0.511	0.511	0.511	0.511	0.951	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.000	0.000	0.000	2.377	0.704	0.653	1.360	1.373	1.327	1.327
1983	1.327	1.327	1.327	1.327	1.327	0.000	0.000	0.000	0.000	0.000	0.143	0.143
1984	0.143	0.143	0.143	0.143	0.143	1.098	1.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	2.625	1.284	1.287	0.459	0.469	0.632	0.632
1986	0.632	0.632	0.632	0.632	0.632	0.000	2.100	1.695	1.801	1.815	1.666	1.666
1987	1.666	1.666	1.666	1.666	1.666	1.568	2.751	3.044	2.300	2.072	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
6	1951	6	1953	25	0.38	9.54
8	1957	9	1958	14	0.50	7.03
6	1962	7	1965	38	0.61	23.14
9	1965	9	1966	13	0.53	6.88
6	1969	6	1970	13	0.97	12.66
8	1971	8	1975	49	1.02	50.01
6	1982	6	1983	13	0.95	12.39
9	1983	8	1984	12	0.52	6.18
6	1986	12	1987	31	1.82	56.38

DROUGHT ANALYSIS FOR AHMEDABAD DISTRICT OF STATE GUJARAT

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.135	0.417	0.269	0.317	0.350	1.326	1.769	0.842	1.408	0.961	0.000	0.067
1952	0.305	0.457	0.271	0.318	0.350	1.027	0.000	0.000	1.211	1.283	1.169	0.776
1953	0.000	0.000	0.000	0.236	0.000	0.144	0.000	0.000	0.000	0.000	0.384	0.463
1954	0.369	0.000	0.000	0.000	0.312	1.123	0.000	0.000	0.000	0.000	0.000	0.149
1955	0.318	0.460	0.000	0.000	0.000	0.000	1.890	0.000	0.000	0.000	0.123	0.359
1956	0.352	0.000	0.000	0.188	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.245	0.310	0.000	0.000	0.000	1.138	1.588	0.494	0.000	0.000
1958	0.000	0.364	0.267	0.316	0.350	0.277	0.307	0.660	0.000	0.000	0.000	0.000
1959	0.000	0.320	0.267	0.000	0.105	0.415	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.356	0.885	0.198	0.569	0.607	0.489
1961	0.000	0.000	0.000	0.000	0.191	0.000	0.000	0.000	0.000	0.000	0.200	0.326
1962	0.347	0.466	0.271	0.000	0.266	0.000	0.000	0.000	0.000	0.000	0.000	0.215
1963	0.000	0.346	0.266	0.000	0.000	0.921	0.057	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.373	0.267	0.317	0.000	0.972	0.000	0.133	0.000	0.045	0.722	0.598
1965	0.000	0.000	0.192	0.295	0.350	2.182	0.000	0.686	1.170	1.263	1.121	0.757
1966	0.416	0.463	0.000	0.000	0.333	0.470	0.000	1.339	0.000	0.000	0.504	0.511
1967	0.376	0.473	0.000	0.000	0.246	0.000	0.000	0.000	0.000	0.547	0.903	0.000
1968	0.000	0.000	0.225	0.304	0.350	2.553	2.507	0.839	0.975	1.169	1.128	0.760
1969	0.000	0.119	0.000	0.000	0.191	0.000	0.164	1.133	0.195	0.668	0.000	0.000
1970	0.292	0.454	0.271	0.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.229
1971	0.331	0.463	0.271	0.318	0.000	0.000	0.675	1.463	0.558	0.000	0.279	0.421
1972	0.362	0.000	0.000	0.137	0.349	1.533	1.014	1.094	1.519	1.431	1.222	0.797
1973	0.422	0.000	0.000	0.210	0.349	1.056	0.145	0.000	0.000	0.000	0.325	0.439
1974	0.365	0.471	0.271	0.318	0.000	0.021	1.536	2.862	1.506	0.000	0.000	0.000
1975	0.248	0.443	0.270	0.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.249	0.311	0.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.138	0.418	0.269	0.317	0.000	0.000	0.000	0.000	0.000	0.546	0.903	0.670
1978	0.402	0.000	0.000	0.000	0.340	0.000	0.000	0.000	0.033	0.645	0.000	0.000
1979	0.143	0.000	0.000	0.157	0.348	0.000	1.468	0.000	0.000	0.072	0.000	0.000
1980	0.225	0.438	0.270	0.317	0.350	0.000	0.000	1.000	1.059	1.210	1.142	0.765
1981	0.417	0.483	0.272	0.318	0.350	0.000	0.000	0.000	0.000	0.000	0.578	0.540
1982	0.381	0.474	0.272	0.318	0.350	0.000	0.000	0.468	1.131	1.128	0.000	0.000
1983	0.000	0.171	0.258	0.314	0.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.290	0.453	0.271	0.318	0.350	0.929	1.067	0.000	0.245	0.818	1.001	0.709
1985	0.406	0.481	0.272	0.318	0.350	2.706	0.460	1.323	1.660	0.000	0.000	0.000
1986	0.141	0.418	0.269	0.317	0.000	0.000	1.344	0.586	1.564	1.453	1.230	0.800
1987	0.423	0.484	0.272	0.318	0.350	1.221	3.170	1.521	1.873	1.601	1.284	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	1	1953	25	0.89	22.33
7	1957	11	1957	5	0.91	4.54
12	1959	6	1961	19	0.38	7.28
3	1965	3	1967	25	0.67	16.73
2	1968	8	1973	67	0.72	48.04
11	1973	5	1975	19	1.47	27.97
6	1980	6	1981	11	0.88	9.64
10	1981	11	1982	14	0.49	6.87
11	1983	12	1987	50	1.15	57.40

DROUGHT ANALYSIS FOR SURENDRANAGAR DISTRICT OF STATE GUJARAT

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.123	0.256	0.170	0.139	0.326	0.000	0.027	0.866	1.744	1.360	0.926	0.611
1952	0.375	0.303	0.174	0.139	0.135	1.666	0.123	1.834	1.952	1.416	0.939	0.617
1953	0.000	0.000	0.071	0.122	0.104	0.159	0.212	0.000	0.000	0.000	0.333	0.368
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.436
1955	0.347	0.298	0.173	0.139	0.302	0.183	1.679	0.000	0.000	0.000	0.484	0.411
1956	0.343	0.297	0.173	0.139	0.000	0.198	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.142	0.162	0.000	0.000	1.322	1.153	0.822	0.000	0.000	0.000	0.000
1959	0.000	0.162	0.164	0.000	0.156	0.159	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.083	0.000	0.000	0.000	1.765	0.466	0.765	0.785	0.554
1961	0.366	0.302	0.173	0.139	0.302	0.000	0.000	0.000	0.000	0.000	0.124	0.263
1962	0.320	0.293	0.282	0.157	0.000	1.275	0.833	0.432	0.000	0.034	0.504	0.924
1963	0.424	0.312	0.000	0.000	0.289	1.759	0.715	0.117	0.000	0.000	0.000	0.000
1964	0.513	0.607	0.750	0.650	0.396	0.000	0.000	0.000	0.000	0.194	0.689	1.342
1965	0.000	0.000	0.131	0.132	0.302	0.000	0.000	0.000	0.362	0.710	0.767	0.527
1966	0.362	0.301	0.173	0.139	0.302	0.250	0.000	0.887	0.000	0.000	0.352	0.000
1967	0.000	0.214	0.000	0.000	0.218	0.000	0.000	0.000	0.400	0.727	0.771	0.528
1968	0.362	0.301	0.175	0.139	0.302	2.064	0.744	0.429	0.171	0.621	0.746	0.518
1969	0.360	0.301	0.173	0.139	0.302	1.066	1.305	1.788	1.462	1.222	0.541	0.434
1970	0.347	0.298	0.173	0.139	0.302	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.250	0.280	0.172	0.138	0.302	0.000	0.000	0.000	1.000	1.006	0.837	0.556
1972	0.366	0.000	0.000	0.069	0.301	0.744	1.576	1.009	1.876	1.414	0.933	0.595
1973	0.372	0.000	0.000	0.000	0.300	0.000	0.000	0.574	0.000	0.000	0.458	0.400
1974	0.342	0.297	0.173	0.139	0.000	1.643	2.485	2.748	1.006	0.000	0.370	0.364
1975	0.336	0.296	0.173	0.139	0.302	0.000	0.089	0.000	0.000	0.000	0.000	0.098
1976	0.295	0.285	0.173	0.138	0.302	0.000	0.000	0.000	0.000	0.127	0.000	0.000
1977	0.000	0.000	0.120	0.130	0.000	0.000	0.000	0.000	0.000	0.438	0.357	0.359
1978	0.335	0.000	0.076	0.122	0.302	0.000	1.241	0.000	1.219	0.362	0.000	0.000
1979	0.000	0.000	0.000	0.000	0.300	0.000	0.317	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.125	0.131	0.302	0.000	0.000	0.000	0.000	0.491	0.000	0.000
1981	0.000	0.194	0.166	0.137	0.302	0.000	0.000	0.000	0.069	0.573	0.000	0.000
1982	0.413	0.273	0.172	0.138	0.000	2.335	0.000	0.000	0.866	0.582	0.000	0.000
1983	0.000	0.122	0.161	0.137	0.302	0.307	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.414	0.273	0.172	0.138	0.302	0.704	0.472	0.000	0.000	0.430	0.700	0.500
1985	0.357	0.300	0.173	0.139	0.302	1.306	0.299	1.144	0.672	0.000	0.000	0.000
1986	0.419	0.274	0.172	0.138	0.000	0.000	0.937	0.971	1.755	1.358	0.920	0.590
1987	0.371	0.303	0.173	0.139	0.302	0.000	1.812	2.446	2.401	1.659	0.095	0.247

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	1	1953	25	1.04	26.06
10	1954	8	1956	23	0.27	6.24
1	1958	9	1958	9	0.76	6.85
7	1960	6	1961	12	0.69	8.28
11	1961	9	1963	23	0.51	11.65
9	1965	9	1966	13	0.37	4.77
8	1967	9	1970	38	0.64	24.31
8	1971	9	1975	50	0.81	40.31
7	1976	11	1978	5	0.69	3.46
11	1984	12	1987	38	1.15	43.77

DROUGHT ANALYSIS FOR AMRELI DISTRICT OF STATE GUJARAT

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.000	1.106	0.553	2.839	0.063	1.187	2.910	2.781	1.598	0.000	0.311
1952	0.360	0.174	1.114	0.554	2.839	0.000	0.630	2.464	2.495	1.515	1.122	0.608
1953	0.000	0.000	1.065	0.548	2.839	0.000	1.439	1.730	2.338	1.469	1.109	0.606
1954	0.394	0.297	0.000	0.000	2.815	0.061	0.351	0.000	0.000	0.000	0.623	0.000
1955	0.000	0.000	1.039	0.546	0.368	0.146	1.987	0.000	0.000	0.000	0.000	0.110
1956	0.000	0.000	0.781	0.517	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.155
1957	0.236	0.109	1.113	0.554	2.839	0.580	0.000	0.000	1.526	1.231	1.040	0.000
1958	0.012	0.000	1.112	0.554	0.368	0.000	0.000	0.000	0.000	0.000	0.093	0.284
1959	0.338	0.163	1.114	0.554	0.368	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.283	0.000	0.218
1961	0.286	0.135	0.082	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.289	0.314
1962	0.362	0.175	0.000	0.000	0.000	2.288	2.425	1.686	0.000	0.095	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.493	0.000	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.460	0.325
1965	0.000	0.000	0.000	0.000	0.000	0.678	0.000	0.000	0.566	0.881	0.770	0.383
1966	0.417	0.204	0.000	0.000	0.000	0.000	0.000	1.623	0.000	0.429	0.638	0.358
1967	0.397	0.194	0.000	0.000	0.000	0.744	0.000	0.000	0.000	0.696	0.719	0.464
1968	0.481	0.238	0.000	0.000	0.000	1.438	0.000	0.000	0.000	0.000	0.459	0.209
1969	0.279	0.131	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.619	0.000	0.113
1970	0.203	0.092	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.214
1971	0.262	0.133	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.348	0.305
1972	0.355	0.171	0.000	0.000	0.000	0.000	0.055	1.443	1.943	0.314	0.604	0.352
1973	1.916	5.493	2.769	1.892	5.282	2.789	4.030	4.178	3.273	1.799	1.370	0.839
1974	0.779	0.394	0.000	0.000	0.000	0.970	1.354	0.857	0.000	0.000	0.000	0.000
1975	0.104	0.040	0.000	0.000	0.000	0.000	0.053	0.000	0.000	0.000	0.000	0.000
1976	0.047	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.153	0.000	0.000	0.000
1979	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.609	0.690	0.000
1981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.000	0.000	0.000	2.365	0.670	0.000	0.473	0.854	0.762	0.381
1983	0.416	0.203	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.240
1984	0.303	0.144	0.000	0.000	0.000	2.160	1.780	0.857	0.000	0.059	0.530	0.338
1985	0.361	0.155	0.000	0.000	0.000	2.626	1.583	1.568	1.634	0.000	0.142	0.266
1986	0.324	0.155	0.000	0.000	0.000	0.000	0.000	0.000	1.111	1.040	0.816	0.391
1987	0.424	0.208	0.000	0.000	0.000	0.666	2.956	1.095	1.976	1.293	0.000	0.178

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	12	1954	48	1.15	55.13
3	1955	8	1955	6	0.82	4.93
5	1962	7	1963	15	1.06	15.94
9	1965	6	1969	46	0.33	15.00
10	1971	9	1975	48	1.22	58.79
12	1981	6	1983	19	0.63	12.03
11	1983	12	1987	50	1.12	55.96

Drought Analysis of Bhavnagar District of State Gujarat.
Monthly Intensity of excess deficit.

Month/Year	Jan	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
1951	0.138	0.165	0.000	0.000	0.063	0.000	0.000	0.890	1.418	1.082	1.126	1.114
1952	0.000	0.234	0.205	0.234	0.297	0.000	0.000	1.266	1.528	0.817	1.042	1.184
1953	0.000	0.000	0.000	0.000	0.258	0.000	0.000	0.000	0.000	0.000	0.204	0.582
1954	0.425	0.000	0.000	0.000	0.230	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.019	0.175	0.213	0.288	0.392	2.720	0.000	0.000	0.000	0.012	0.470
1956	0.405	0.000	0.169	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.120	0.164	0.177	0.215	0.288	0.000	0.000	0.000	0.192	0.619	0.633	0.000
1958	0.169	0.168	0.177	0.216	0.288	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.144	0.176	0.215	0.288	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.145	0.176	0.215	0.000	0.000	0.000	0.782	0.883	0.936	1.062	1.077
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.583	0.715	0.877
1962	0.479	0.196	0.065	0.143	0.000	1.586	1.325	1.753	0.000	0.421	0.000	0.000
1963	0.000	0.000	0.163	0.207	0.000	2.540	0.427	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.141	0.176	0.215	0.288	0.000	0.000	0.000	0.000	0.000	0.553	0.783
1965	0.000	0.000	0.147	0.198	0.000	0.869	0.000	0.000	0.972	0.959	0.000	0.288
1966	0.000	0.000	0.171	0.212	0.236	0.000	0.000	2.080	0.000	0.465	0.856	0.958
1967	0.494	0.195	0.000	0.000	0.000	0.000	0.000	0.000	0.779	0.878	1.036	0.000
1968	0.000	0.000	0.000	0.000	0.157	1.571	1.070	0.000	0.000	0.342	0.802	0.000
1969	0.293	0.179	0.177	0.216	0.288	0.000	0.000	0.728	0.000	0.022	0.000	0.000
1970	0.000	0.000	0.165	0.209	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.315	0.181	0.177	0.215	0.288	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1972	0.525	0.363	0.216	0.501	0.324	1.634	2.528	2.459	1.689	0.000	0.639	1.197
1973	0.537	0.202	0.178	0.216	0.000	0.363	0.000	0.000	0.000	0.000	0.000	0.337
1974	0.380	0.187	0.177	0.216	0.000	2.559	1.757	2.410	0.457	0.000	0.001	0.811
1975	0.467	0.195	0.177	0.216	0.288	0.000	0.971	0.000	0.000	0.000	0.000	0.000
1976	0.512	0.181	0.177	0.216	0.288	0.000	0.000	0.000	0.000	0.080	0.000	0.000
1977	0.000	0.092	0.175	0.214	0.000	0.000	0.000	0.000	0.000	0.497	0.644	0.835
1978	0.471	0.196	0.177	0.000	0.253	0.000	0.838	0.000	0.865	0.405	0.000	0.000
1979	0.094	0.161	0.177	0.215	0.288	0.000	0.000	0.000	0.000	0.325	0.000	0.000
1980	0.000	0.078	0.175	0.214	0.286	0.000	0.000	0.000	1.235	1.061	1.117	1.109
1981	0.521	0.200	0.179	0.217	0.288	0.606	0.000	0.000	0.000	0.000	0.227	0.595
1982	0.427	0.192	0.177	0.216	0.288	2.915	1.719	1.796	1.573	1.046	1.110	1.105
1983	0.520	0.200	0.178	0.216	0.288	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.140	0.165	0.177	0.216	0.288	1.143	0.000	0.705	0.194	0.642	0.933	1.003
1985	0.000	0.199	0.178	0.216	0.288	2.978	2.009	2.265	1.732	0.000	0.000	0.000
1986	0.000	0.155	0.178	0.215	0.288	0.000	2.954	1.697	2.095	1.368	1.251	1.186
1987	0.535	0.202	0.178	0.216	0.288	1.020	2.603	2.130	2.160	1.391	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
8	1951	1	1953	18	0.92	16.63
2	1955	9	1955	8	0.79	6.31
8	1960	8	1963	37	0.62	22.92
9	1966	7	1967	19	0.63	11.98
5	1966	5	1970	25	0.34	8.51
12	1971	8	1975	45	0.96	43.26
7	1976	11	1978	5	0.54	2.71
1	1980	7	1983	43	0.67	28.82

Duration and Number of dry spells during Monsoon (4th June to 15th Sept.)

MORVI (RAJKOT)				JAMNAGAR (JAMNAGAR)			
First day of Monsoon	Date of begining of dry spell	Duration of dry spell (2 weeks in days)	Total No. of dry spell in a year	First day of Monsoon	Date of begining of dry spell	Duration of dry spell (2 weeks in days)	Total No. of dry spell in a year
1	2	3	4	1	2	3	4
21.6.81	4.6.81 18.8.81	23 16	2	27.6.81	4.6.81 26.7.81 25.8.81	23 16 22	3
4.6.82	5.6.82 14.8.82	36 33	2	1.7.82	4.6.82 22.8.82	27 17	2
18.6.83	4.6.83 21.8.83	14 26*	2	19.6.83	4.6.83 12.8.83	15 35	2
15.6.84	17.6.84 5.7.84 24.8.84	15 14 20	3	15.6.84	14.8.84	31	1
13.7.85	4.6.85 15.8.85	39 35	2	17.7.85	4.6.85 20.8.85	43 27*	2
18.6.86	29.6.86 11.8.86	30 36*	2	19.6.86	24.6.86 8.8.86	44 26	2
12.6.87	13.6.87 17.7.87 18.8.87	33 31 28*	3	16.7.87	4.6.87 24.7.87	42 54*	2
			16				14

* indicates the continuation of dry spell after 15th September.

DHARANGADHRA (SURENDRANAGAR)				AHMEDABAD (AHMEDABAD)			
1	2	3	4	1	2	3	4
26.6.81	4.6.81 26.8.81	22 21*	2	26.6.81	4.6.81 19.7.81	22 22	2
21.7.82	4.6.82 26.7.82 23.8.82	47 18 24*	3	13.6.82	14.6.82 23.8.82	17 24*	2
13.6.83	19.8.83	19	1	21.6.83	4.6.83	17	1
3.7.84	4.6.84 19.7.84 12.8.84	29 16 33	3	-	-	-	-
17.7.85	4.6.85 6.8.85	43 41	2	14.7.85	4.6.85 4.8.85 2.9.85	40 17	3
9.6.86	26.6.86 17.8.86	34 30	2	17.6.86	27.6.86 18.8.86	20 29*	2
12.6.87	13.6.87 15.7.87 17.8.87	15 26 30*	3	28.6.87	4.6.87 18.7.87 28.8.87	24 20 19*	3
			16				13

* Dry spell after 15th Sept., f the year continued.

AMRELI (JAFARABAD)				GADHADA (BHAVNAGAR)			
1	2	3	4	1	2	3	4
7.6.81	6.7.81 7.8.81 23.8.81	19 15 24	3	26.6.81	4.6.81 25.7.81 21.8.81	22 14 24	3
10.6.82	11.6.82 26.7.82 20.8.82	36 39 36*	3	11.7.82	4.6.82 23.7.82 15.8.82	37 18 15	3
19.6.83	4.6.83 20.6.83 15.8.83	15 19 32	3	19.6.83	4.6.83 18.8.83	15 21	2
2.7.84	4.6.84 20.8.84	28 24	2	4.7.84	4.6.84 21.7.84 13.8.84	30 14 30	3
17.7.85	4.6.85 14.8.85	43 33*	2	10.7.85	4.6.85 5.8.85	44 36	2
19.6.86	4.6.86 27.6.85 10.8.86	15 20 37*	3	19.6.86	27.6.86 9.8.86 31.8.86	40 20 16*	3
6.6.87	15.6.87 15.7.87 20.8.87	21 26 27*	3	10.6.87	4.6.87 29.6.87 21.8.87	14 47 22	3
			19				19

Probability Analysis of Dry Spells

Tuluk/Station (Distt.)	Class Interval (in Day)	No. of Spells	Percentage	Cummulative Probability
1	2	3	4	5
Jamnagar (Jamnagar)	14-21	3	21-4	180.0
	22-28	5	35-7	78.6
	29-35	2	14-7	42.9
	> 35	4	28.6	28.6
		14		
Morbi (Rajkot)	14-21	5	31.3	100.0
	22-28	3	18.8	68.8
	29-35	4	25.0	50.0
	> 35	4	25.0	25.0
		16		
Ahmedabad (Ahmedabad)	14-21	7	53.8	100.0
	22-28	4	30.8	46.2
	29-35	1	7.7	15.4
	> 35	1	7.7	7.7
		13		
Dharangedhra (Sundeanagar)	14-21	5	31.3	100.0
	22-28	3	18.8	68.8
	29-35	5	31.3	50.0
	> 35	3	18.8	18.8
		16		
Jagarabad (Amoli)	14-21	7	36.8	100.0
	22-28	5	26.3	63.1
	29-35	2	10.5	36.8
	> 35	5	26.3	26.3
		19		
Gadhada (Bhavnagar)	14-21	9	47.4	100.0
	22-28	3	15.8	52.6
	29-35	2	10.5	36.8
	> 35	5	26.3	26.3
		19		

LIST OF OBSERVATION WELL

STATE-GUJARAT
DISTT-JAMNAGAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	W.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	41F-5A1	SAR[illegible]SOR	22 2[illegible] [illegible]	[illegible]	[illegible]	591	0.0585
2.	41F-5C1	SALAYA	22 15 0[illegible]	[illegible] 47 0[illegible]	[illegible]	557	0.0549
3.	41F-5D1	[illegible]D	22 25 5[illegible]	[illegible] 4 [illegible]	1[illegible].260	59[illegible]	0.0589
4.	41F-4A1	UKHAMADIN	[illegible]	[illegible] 17 [illegible]	4.[illegible]	317	0.0312
5.	41F-4[illegible]1	[illegible]HATIYA	22 05 00	[illegible] 17 [illegible]	[illegible]	72[illegible]	0.0710
6.	41F-4C2	BHAUTHOK	22 05 0[illegible]	[illegible]	5.16[illegible]	6[illegible]7	0.0660
7.	41J-1[illegible]1	A[illegible]BARDI	21 54 0[illegible]	[illegible] 52 [illegible]	74.5[illegible]0	[illegible]9	0.2552
8.	41J-2[illegible]1	DHROL	22 34 [illegible]	70 [illegible] 0[illegible]	25.01[illegible]	2474	0.2439
9.	41G-1[illegible]2	RAWAL	21 55 40	[illegible]	[illegible]	72[illegible]	0.0710
10.	41J-3A1	JAMNAGAR	22 27 5[illegible]	70 04 45	11.[illegible]	1110	0.1094

STATE-GUJARAT
DISTT-RAJKOT

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	W.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	41I-4C1	MALIYA	23 0[illegible] 5[illegible]	70 45 30	10.20	134[illegible]	0.1209
2.	41J-2D1	WANKANER	22 37 00	70 52 00	[illegible]0.0[illegible]	[illegible]055	0.1643
3.	41J-5D1	RAJKOT	22 1[illegible] [illegible]	70 46 00	1[illegible].96	[illegible]1[illegible]	0.3244
4.	41K-2B1	UPLETA	21 44 20	70 17 1[illegible]	41.54	1[illegible]69	0.1676
5.	41K-1C3	GONDAL	21 54 5[illegible]	70 44 [illegible]	1[illegible].9[illegible]	2252	0.2028

LIST OF OBSERVATION WELL

STATE-GUJARAT
DISTT-AHMEDABAD

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	EL.OF G.P.(MSL)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	41N-3D1	RAMPUR	22 15 00	71 45 0	55. 5	435	0.0500
2.	40M-4C1	GHATLODIA	23 00 0	72 32 3	51.215	2721	0.0125
3.	40D-1E1	DHOLA	22 44 0	72 22 00	.72.	2443	0.2 12
4.	40E-2A1	BAGODRA	22 25 30	72 12 0	14.3 3	1376	0.1500
5.	40C-3H2	DHA-IYAD	22 17 3	72 11 00	7.3 3	1167	0.1375
6.	40D-3H1	ADHEL	22 11 32	72 10 01	14.350	599	0.0 67

STATE-GUJARAT
DISTT-SURENDRA NAGAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	EL.OF G.P.(MSL)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	41N-5D1	DASADA	23 1 30	71 49 30	46.171	1201	0.1150
2.	41M-4A1	HALVAD	23 1 00	71 11 00	44.750	1368	0.1350
3.	41N-1B1	DHANGADHRA	22 59 30	71 27 45	5 .455	1 99	0.1340
4.	41N-1D2	LAKHTAR	22 51 30	71 27 30	45.163	1253	0.1200
5.	41N-2B1	SAYLA	22 51 00	71 2 00	5 .350	1367	0.1500
6.	41N-2C1	SURENDRA-NAGAR	22 47 30	71 38 00	50.450	72	0.0750
7.	41N-2D1	LIMDI	22 34 1	71 4 30	43. 15	1421	0.1500
8.	41N-3A1	CHUDELA	22 45 30	71 11 45	48.270	1452	0.1390

LIST OF OBSERVATION WELL

STATE-GUJARAT
DISTT-AMRELI

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	PERIOD (YEARS)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	410-1S1				15.70		0.1176
2.	410-2M1				15.00		0.2200
3.	410-2L1				11.37		0.1412
4.	410-3M2				17.73		0.2529
5.	41L-1G2				12.20		0.0624
6.	41P-1S1				5.00		0.0359

STATE-GUJARAT
DISTT-BHAVNAGAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	PERIOD (YEARS)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	410-1S1				17.00		0.3045
2.	410-2S1				15.00		0.0535
3.	410-2S2				6.00		0.1104
4.	410-3S2				11.110		0.1125
5.	410-4S1				11.170		0.1125
6.	46C-1S1				17.500		0.0502
7.	46C-2S1				14.700		0.0525
8.	46C-3S2				11.700		0.1177

APPENDIX - IV-2

AVERAGE GROUNDWATER LEVEL (IN METRES) FROM M.S.L. FOR DISTRICT SURENDRANAGAR, GUJARAT

Sl. No.	Name of Obs. Well	R.L. of M.P.	Area Influenced by well	Area Weight	1987-88 Aug.	Nov.	Jan.	May
1.	DASADA	28.170	1201	0.1150	6.94*	7.18	7.64	8.10
					21.23**	20.99	20.53	20.07
					2.44***	2.42	2.36	2.30
2.	HALVAD	44.750	1389	0.1330	23.50	22.05	23.37	23.43
					21.07	22.52	21.20	21.14
					2.80	2.99	2.81	2.81
3.	DHAGANDHRA	50.955	1399	0.1340	21.90	19.60	21.50	22.70
					29.05	31.35	29.45	28.25
					3.89	4.20	3.94	3.78
4.	LAKHTAR	43.125	1253	0.1200	10.52	11.00	11.00	10.66
					32.60	32.12	32.12	32.46
					3.91	3.85	3.85	3.89
5.	SALAYA	50.5000	1567	0.1500	9.24	10.35	11.00	10.28
					41.26	40.15	39.50	40.22
					6.23	6.06	6.96	6.07
6.	SURENDRA-NAGAR	66.966	762	0.0730	9.83	8.67	10.50	8.13
					15.13	58.29	56.46	58.83
					4.17	4.25	4.12	4.29
7.	LIMDI	43.685	1420	0.1360	10.40	8.90	9.50	11.79
					33.28	34.78	34.18	31.89
					4.52	4.73	4.64	4.33
8.	CHOTILA	205.270	1452	0.1390	18.00	11.03	11.05	19.00
					187.27	194.24	194.22	186.27
					26.03	26.99	26.99	25.89
					53.99	55.49	55.69	53.56

* Observed groundwater level from measuring point
** Groundwater level calculated with respect to mean sea level (M.S.L.)
*** Groundwater level calculated with respect to M.S.L. multiplied by Area weight (Thiessen Weight).

The analysis for the year 1977-78 to 1986-87 is given in CS-24.

IV-2-1/1