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

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1990-91

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ABSTRACT

Drought is a dreadfully familiar word in India. In recent years the country faced three drought years in succession namely 1985, 1986 & 1987. It has been reported intensity wise the drought of year 1987 ranked second in the 20th century, the first one being in year 1918. Statistics on areal coverage indicate that out of the country's total geographic area of 328 m.ha., 107 m.ha. or about one third of the area and 29 percent of the population are affected by drought.

The recurring incidents of drought lead to reduction in streamflows, depletion of soil moisture storages, decline of reservoir and tank levels and fall in groundwater tank. This is turn lead to reduced agriculture and fodder production.

In this report the results of studies carried out for the year 1987-88, for the six selected drought prone districts namely: Jhabua, Khargone, Dhar, Sidhi, Betul & Shahdol of state Madhya Pradesh, have been described. The report includes analysis of rainfall and groundwater level data for finding deficit of rainfall and trend of groundwater table as a result of drought incidents.

The seasonal rainfall departure analysis shows deficiency in all the six selected districts with the extremes lying between 30 percent to 65 percent except Sidhi and Shahdol. Monthly rainfall departure analysis shows that all the six districts recorded deficient rainfall ranging from 10% to 60% except Sidhi.

The frequency analysis of rainfall showed that the probability values of occurrence of 75% normal rainfall in all the six selected districts namely Jhabua, Khargone & Dhar of state

Madhya Pradesh are 78, 76 & 76 respectively i.e. below 80, indicating drought proneness of districts based on this analysis as per IMD criteria. However, in case of district Sidhi, Betul & Shahdol the probability values of occurrence of 75% normal rainfall are 84, 87 & 89 indicating that out of 100 years, 16, 13 &11 years will experience 75% of the normal rainfall and so less drought prone. Herbst analysis of monthly rainfall data of the districts has shown over two dry spells during 1984-87. The district of Sidhi showed maximum no. of drought spells and in general 4-5 spells were found in all districts since 1951. The maximum drought intensity was found in case of Khargone district while the longest spell of 94 days was observed in Betul district during 1978-86. The dry spell analysis, which has been done for one taluk in each of six districts, showed that at 75% probability level, the duration of dry spell ranges from 21-28 days, except the taluks of Dhar (Dhar) and Banas (Sidhi) were the duration of dry spell as expected at 75% probability ranges from 14-21 days.

The groundwater level analysis has been carried out in the districts of Jhabua, Khargone, Dhar, Shahdol & Betul. All the five districts experienced rainfall deficiency during 1987-88 ranging from 33-43%. As a result of declining trend of rainfall over the last three successive years, all the five districts except Shahdol have indicated a falling trend in pre and post monsoon water table levels and in most of the cases the rate of decline has been observed more than the previous year. This continuous decline can be attributed to continued deficient seasonal rainfall and over pumpage of ground water for various usages. The studies are continuing for year 1988-89.

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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 characterization 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 departure in monsoon rainfall over the drought affected region (Upadhyay & Gupta, 1989). Sampath (1989) has reported that during 1987, 21 meteorological sub-divisions out

of 35 recorded deficient/scanty rains leading to drought conditions. It has been further reported that these sub-divisions account for about 53% of the total food grains production in the country. A quick glance of food grains 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 food grain production clearly show dependability of agricultural activities on the rainfall.

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

1.2 Objectives of the Study

In spite of the repeated occurrence of drought in the country, the hydrologic aspects of droughts have not been studied to the desired extent. Such studies have a direct bearing involving strategies for planning judicious use of water resources.

The institute had initiated studies to lay emphasis on hydrological aspects of droughts starting year 1985 as these aspects were by and large neglected in past studies whatever carried out. Keeping in view the successive three drought years since 1985-86, in major parts of the drought prone area of the

country, study areas were chosen 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 chosen states and for 1986-87 with four districts in each of chosen states have been completed and the study reports have been widely circulated. Since the studies for the year 1987-88 covered six districts each in six states, it was decided to bring out separate reports for each of the six states. The present report, therefore, describes results of studies carried out for year 1987-88 with six districts chosen in the state of Madhya Pradesh. The report includes analysis of rainfall and ground water level data for finding the impacts of deficit of rainfall and trend of groundwater tables. The status of storages in Tawa and Gandhisagar reservoirs, located in the state during drought period has been included in the report. The report is an attempt towards developing a comprehensive drought index for characterizing hydrologic drought situations.

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. There are 45 districts in the state of M.P. out of which 11 districts covering an area of about 87300 sq km have been declared drought prone by Central Water Commission (1982). This report covers the study of six drought prone districts of state of Madhya Pradesh namely: Jhabua, Khargone, Dhar, Sidhi, Betul and Shahdol. The locations of districts are shown on the state map as shown in Fig.2.2. The state of M.P. lies between the latitude 74 degree 2 minutes East to 84 degree 2 minutes East and longitude 17 degree 48 minutes North to 26 degree 52 minutes North and is the central part of the country. It has 12 revenue divisions and 9 land record regions spread over an area of about 443750 sq km. The state can be broadly classified into 6 distinct physical regions i.e. i) Northern low lying plains, ii) the Malwa and Vindyan Plateau, iii) Narmada valley, iV) Satpura stretch, v) Chhattisgarh plains and vi) Bastar Plateau. In the tabular form the topography of the state is given in Table 2.1.

Table 2.1: TOPOGRAPHY OF THE STATE MADHYA PRADESH

Region	Topography	Districts	Rainfall range in mm	Major crops
North West M.P.	Lowlying plains (Chambal Ravines)	Gwalior,Morena, Bhind, Datia	750 to 850	Wheat and Jowar
North-Central MP	-do-	Chatarpur,Tikamgarh	750 to 850	-do-
North Malwa upland	Undulating plains with dotted hills	Guna,Shivpuri	750 to 850	-do-

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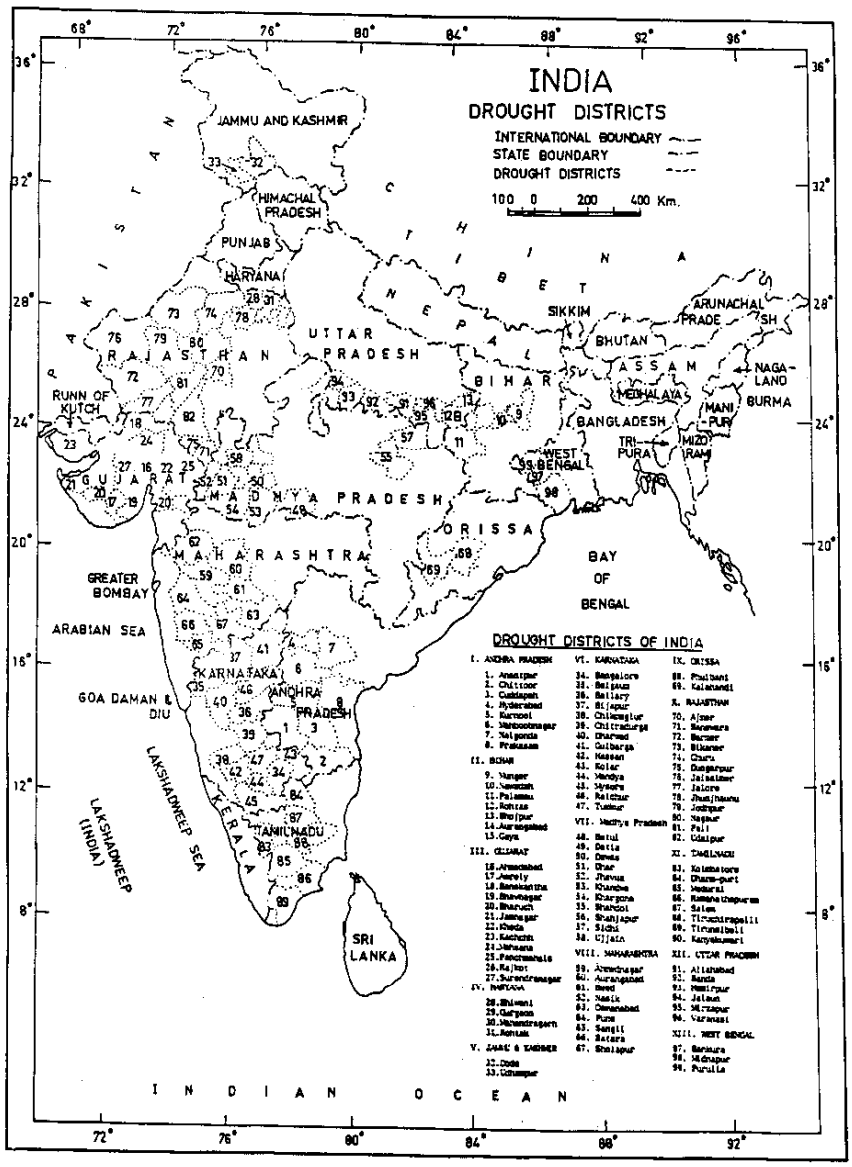

FIG. 2.1 : DROUGHT PRONE DISTRICTS IN INDIA

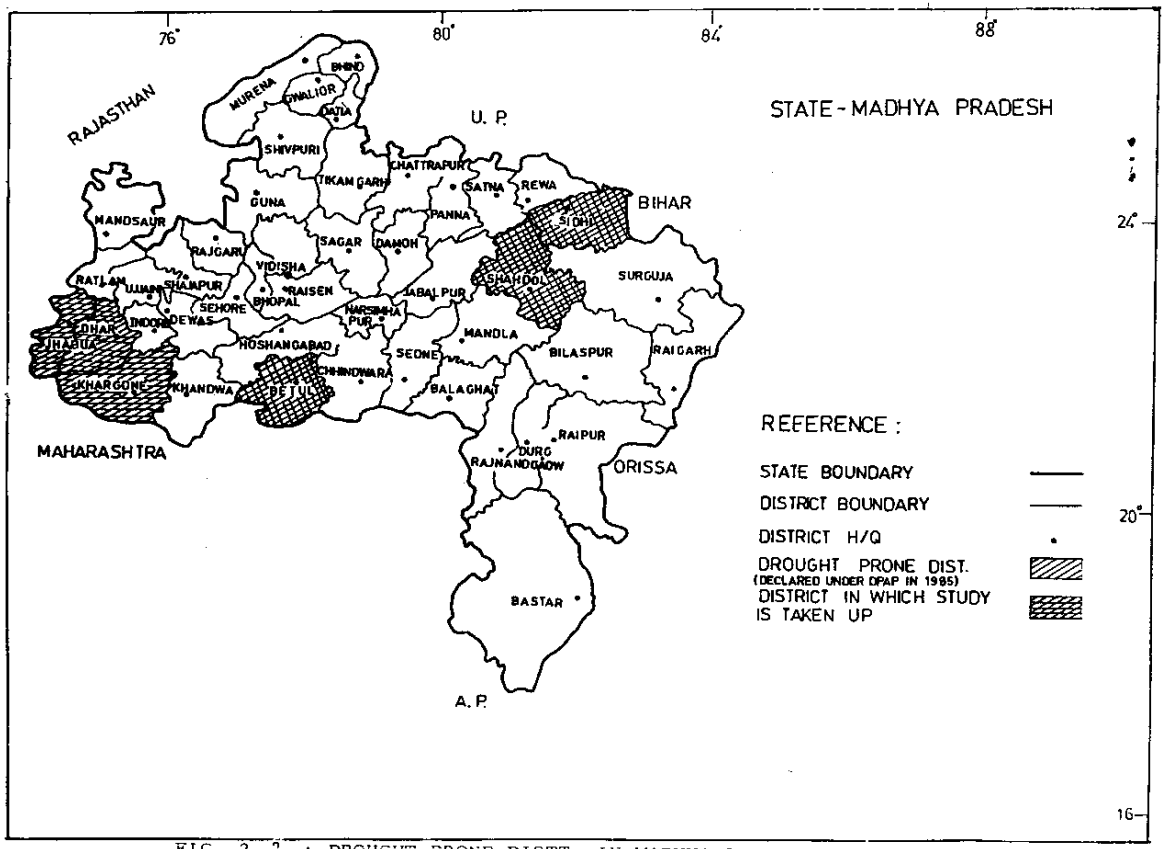

FIG. 2.2 : DROUGHT PRONE DISTT. IN MADHYA PRADESH

Malwa plateau		Rajgarh,Mandsaur Dewas,Ratlam,Dhar Jhabua,Indore Ujjain,Shajapur	750 to 1250	Cotton and Jowar
Vindhyas	Hilly plateau	Vidisha,Raisen, Sehore,Bhopal, Saugar,Domoh,	1050 to 1350	Wheat
		Panna,Satna, Rewa	1050 to 1350	Wheat & Rice
Narmada valley	Narmada valley	Jabalpur,Narsimhpur, Hoshangabad	1250 to 1350	Wheat
Western Satpura	..	Khargone,Khandwa	1050 to 1350	Cotton & Jowar
Central Satpura	Satpura hilly Range	Seoni,Chhindwara, Betul	1350 to 1450	Seoni-Wheat Mandla-Rice
Eastern Satpura	..	Mandla,Balaghat	1600 to 1750	*
	(*Balaghat - Rice; Chhindwara-Wheat & Jowar, Betual - Wheat and Jowar)			
Bundelkhand plateau	Plains plateau	Shahdol,Sidhi, Surguja	1050 to 1250	Paddy
Chhattisgarh	..	Durg,Rajnandgaon, Raipur,Bilaspur, Raigarh	1500 to 1800	Paddy
Danka Karanya	..	Bastar	1600 to 1800	Paddy

2.2 Population Man and Cattle

The state of Madhya Pradesh has the total population of man and women 521.79 lakhs as per the 1981 census. Out of which there are 268.86 lakhs male and 252.93 lakhs female. Only 27.87

percent people are literate out of total population of the state M.P. However about 40 percent male and 15 % female are literate as per 1981 census. The details of live stock are shown in Table 2.2.

Table 2.2: DETAILS OF LIVE STOCK 1986-87

Particulars		Number (in thousands)	Percentage
Cattle (Cow Bullocks)	Male over 3 yrs.	10243.5	24.1
	female over 3 yrs	7714.6	18.1
Cattle young stock		8336.7	19.6
	Total cattle	26294.8	61.8
Buffaloes			
	Male over three years	1333.8	3.1
	Female over three years	2652.3	6.2
	Buffalo young stock	2847.0	6.7
	Total Buffalo	6833.1	16.0
Sheep		1121.0	2.6
Goats		7583.4	17.8
Horse and Ponies		109.0	0.3
Pigs		545.4	1.3
Camel		12.7	0.0
Other live stock	63.1		0.2
Total livestock		12562.5	100.0

2.3 Land Use and Vegetal Cover

Report on Land Record Statistics, 1986-87 (M.P.) has compiled the details on land use and vegetal cover statistics in the state of M.P. The areas under different land uses and their percentages to the geographical area for the year 1986-87 are given in Table 2.3. According to the table there is about 31.4% forest and the net area sown in about 43.5 percent of the total geographical area. Fig.2.3 shows the details of land use as per the year 1986-87.

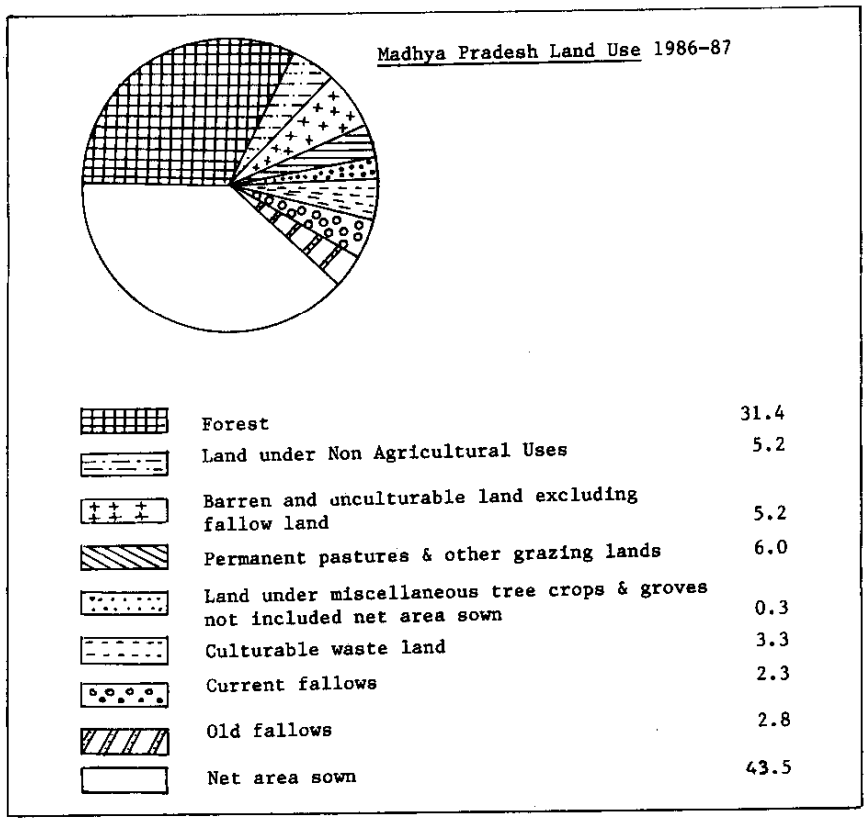

Fig. 2.3 : Land Use Statistics 1986-87 of State M.P.

2.4 Soils

The soils of state M.P. can be broadly classified into seven groups. These are i) Red and yellow soils ii) Gravelly soil, iii) Deep black soil, iv) Light black soil , v) Medium black soil, vi) Alluvial soil, vii) Mixed red and black soil. The soil map of the state is shown in Fig. 2.4.As can be seen from the soil map most of the drought prone distraict lies under black soil.

Table 2.3: LAND USE STATISTICS -1986-87

Details of land use	Area in lakh Hectares	Percent-age
1. Forest	138.96	31.4
2. Land Under Non-agricultural uses	22.88	5.2
3. Barron and unculturable land excluding fallow and	23.15	5.2
4. Permanent pastures & other grazing land	27.85	6.0
5. Land under miscellaneous tree crops, & groves not included in net area sown	1.42	0.3
6. Culturable waste land	16.87	3.3
7. Current fallows	10.21	2.3
8. Old fallows	8.67	2.8
9. Net Area sown	192.09	43.5
Total geographical area	442.10	100.0
Gist of Special Information		
i) Gross Area Sown	223.21	50.5
ii) Area Sown more than once	31.12	7.0
iii) Net Irrigated Area	33.46	17.4*
iv) Gross Irrigated Area	34.57	15.5**

* Percentage to net area sown
** Percentage to gross area sown
Source: Land Use Statistiacs, 1987, M.P. Govt.

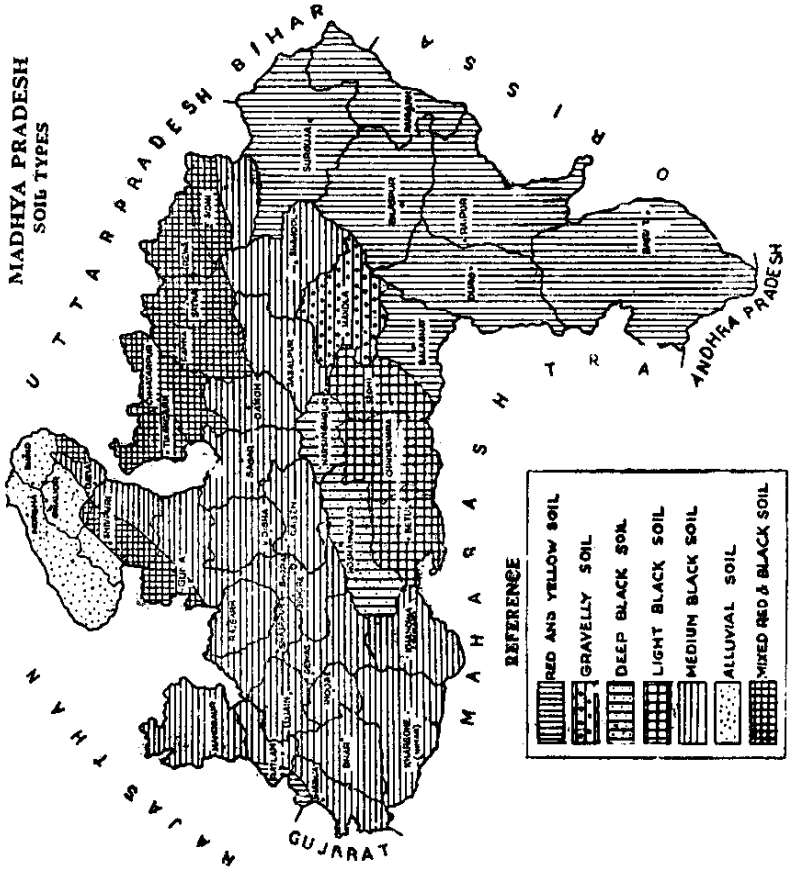

Fig.2.4 : Soil types in Madhya Pradesh

2.5 Surface Water Availability

The position of storages in the state of Madhya Pradesh already completed, under completion and proposed projects are given in Table 2.4 (CWC, 1988).

Table 2.4: STORAGES IN THE PROJECTS OF STATE MADHYA PRADESH

S.No.	Type of Projects	Gross storage in M.ha.m.	Live storage in M.ha.m.
1.	Project compeleted	1.496	1.331
2.	Projects under construction	2.182	1.796
3.	Total	3.678	3.326
4.	Proposed Projects	0.326	0.275

Source: CWC Report on Water Resources of India, 1988.

2.6 Ground Water Availability

The state ground water surveys, in the year 1978 have assessed that the annual ground water recharge in Madhya Pradesh (by rainfall infiltration Index Method) is of the order of 35 MAF (Million Acre Feet), of which about 17.5 MAF was considered as utilisable ground water recharge on an conservative and adhoc basis of 50 percent of the available recharge. This estimate was based on an infiltration idea of 9 percent for hard rock areas and 15 percent for alluvial areas. The evaluation of groundwater resources done for Madhya Pradesh on different occasions is described in the Table 2.5. (Irrigation Department, MP, 1990).

Table 2.5: EVALUATION OF GROUND WATER RESOURCES DONE AT DIFFERENT OCCASIONS.

Name of Agency	Amount of contribution of rainfall to G.W. recharge	Possible recharge due to canal infiltration	Total recharge	Losses due to evapotranspiration, sub-surface out flow.	MAF Net G.W.	Annual draft	Balance
1	2	3	4	5	6	7	8
Dr K V Raghavarao et.al (1969)	43.1	1.4	44.5	17.8 (40%)	26.7	4.22 (67-68)	22.5
Irrig.Commission Report (1972)	43.1	1.4	44.5	17.8	26.7	4.22	22.5
Narmada Tribunal (1975)	43.1	1.4	44.5	17.8	26.7	4.22	22.5
Sagar University (1979)	-	-	58.7	11.70	47.0	-	-
G.W. Surveys for for World Bank as per ARDC II Norms (1978)	40.74	0.55*	41.30	6.1	35.2	4.70	30.5
G.W. Surveys as per ARDC III Norms (1980)	66.45	1.49*	67.94	20.35	47.59	4.86	42.7

* Not due to canal infiltration but from infiltration due to Irrigation by ground water - Figure was under estimated as 0.55 MAF for earlier Ground Water Survey estimate.

Source: Report on Ground Water in M.P.1980 . Irrigation Department, MP.

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 0.1132 M.ha.m. which has been estimated to increase to level of 0.2041 M.ha.m. by the year 1991 (CWC, 1988). Table 2.6 gives the details of source-wise number and net irrigated area in M.P. in 1986-87.

Table 2.6: SOURCEWISE NUMBER AND NET IRRIGATED AREA IN M.P. IN 1986-87

S.No.	Name of Source	Number	Area (lakh hactres)
1.	Canals - Govt.	2762	13.92
	Private	99	0.02
2.	Tanks - Govt.	31544	1.82
	Private	16308	0.16
3.	Well - Govt.	42725	0.61
	Private	1050497	12.47
4.	Tube-wells- Govt.	1635	0.18
	Private	18087	1.01
5.	Other sources	-	3.21
	Total		33.40

The details of water availability and water requirement for drought prone distr-icts of state Madhya Pradesh are given in Table 2.7

Table 2.7: WATER AVAILABILITY AND WATER REQUIREMENT FOR DP DISTRICTS.

Unit = Cubic km.

S.No.	District	Water Availablility		Total
		50% dependability	75% depend-ability	requirement
1.	Betul	2.94	2.47	0.39
2.	Datia	0.88	0.64	0.46
3.	Dewas	1.63	0.91	0.27
4.	Dhar	0.93	0.50	0.67
5.	Jhabua	2.94	2.10	0.37
6.	Khandwa	3.76	2.65	0.28
7.	Khargone	4.50	3.56	1.56
8.	Shahdol	4.06	2.45	0.39
9.	Shajapur	1.85	1.05	0.27
10.	Sidhi	3.33	3.20	0.55
11.	Ujjain	0.77	0.09	0.28

Source: CWC, 1988

2.8 Crops and Fodder

The state of Madhya Pradesh can be sub-divided broadly into five crop zone i) Rice zone, ii) Wheat zone, iii) Wheat Rice zone , iv) Wheat Jowar zone, v) Cotton-Jowar zone. The map showing principal crop zones is shown in Fig.2.5. There are twelve agroclimatic zones inthe state of MP. These agroclimatic zones are shown in the Fig.2.6. Table 2.8 gives the figures of area and production of principal crops in the state for the year 1986-87 (Land Record Statistics, 1987). Table 2.9 shows the division-wise information of area under fodder production inthe year 1984-85.

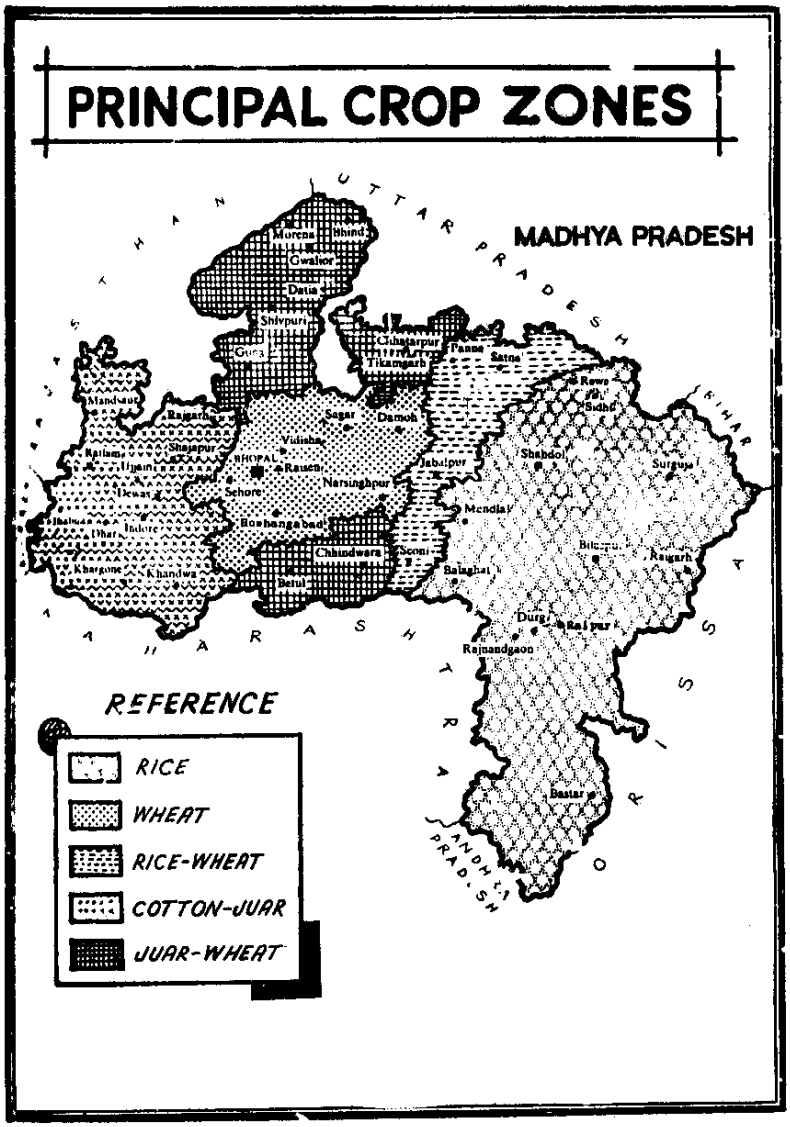

Fig.2.5 : Principal Crop Zones of State Madhya Pradesh

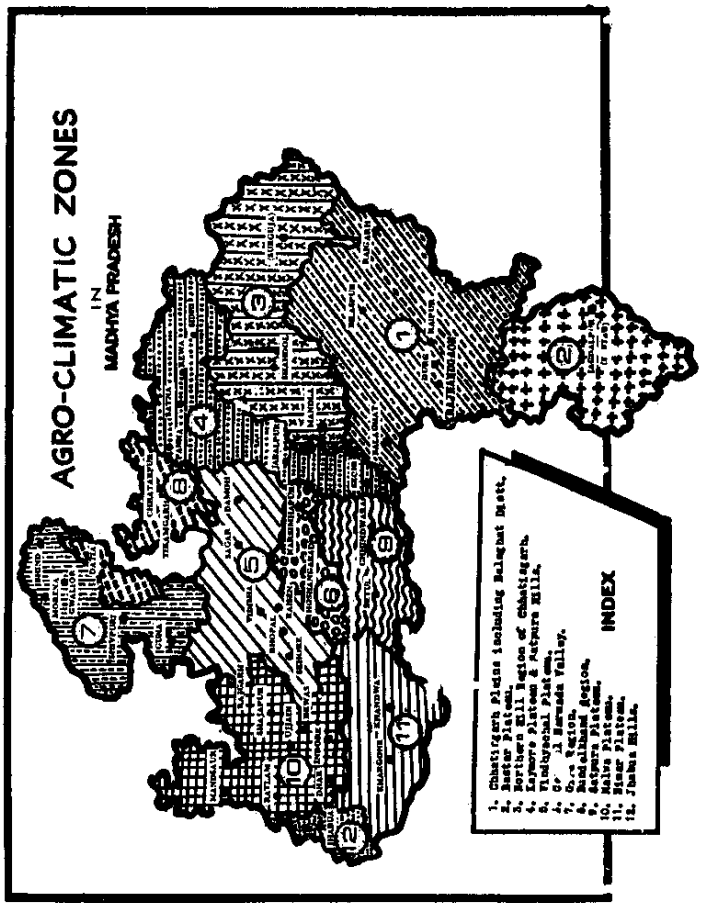

Fig.2.6 : Agroclimatic zones in Madhya Pradesh

Table 2.8: AREA AND PRODUCTION OF PRINCIPAL CROPS, 1986-87

Crops	In lakhs hectares		In lakh Metric tonnes	
	Area	Percentage	Production	Percentage
1. Rice	50.41	22.6	41.78	26.4
2. Jowar	19.12	8.6	13.01	8.2
3. Bajra	1.66	0.7	1.24	0.8
4. Maize	8.50	3.8	7.61	4.8
5. Koden-Kutki	10.74	4.8	1.92	1.2
6. Tur	4.37	2.0	4.13	2.6
7. Wheat	35.02	15.7	42.64	27.0
8. Barley	1.36	0.6	1.48	0.9
9. Gram	22.18	9.9	14.8	9.4
10.Other food-grain	23.79	10.7	6.6	4.2
Total food grain	177.15	79.4	135.21	85.5
11.Other food crops	4.13	1.8	9.95	6.3
Total food crops	181.28	81.2	145.16	91.8
12.Ground Nut	2.44	1.1	1.89	1.2
13 Sesamum	2.09	1.C	0.20	0.1
14.Rape and Mustard	3.31	1.5	2.08	1.3
15.Linseed	4.69	2.1	1.25	0.8
16.Soyabean	12.10	5.4	6.77	4.3
17.Other Oilseeds	2.83	1.3	0.33	0.2
Total oilseeds	27.46	12.4	12.52	7.9

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18.Cotton	5.23	2.3	0.41	0.3
19 Cther Fibres	0.23	0.1	0.06	-
20.Tobacco	0.01	-	-	-
21.Other Non-food crops	9.00	4.0	-	-
Total Non food crops	41.93	18.8	12.99	8.2
Total all crops	223.21	100.0	158.15	100.0

The production of other non-food crops is not available
Source: Land Record Statistics, 1987, MP.Govt.

Table 2.9: DIVISIONWISE INFORMATION OF AREA FODDER PRODUCTION 1984-85

S.No.	Division	Production of fodder (Area in Ha.)
1.	Raipur	431
2.	Bastar	44
3.	Bilaspur	195
4.	Jabalpur	9163
5.	Sagar	139744
6.	Rewa	591
7.	Indore	100351
8.	Ujjain	274117
9.	Chambal	12356
10.	Gwalior	130133
11.	Bhopal	190682
12.	Hoshangabad	25965
Total		883792

Source: Land Record Commission (1984-85)

2.9 Districts Chosen for Study :

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

2.9.1 Jhabua

The district Jhabua is one of the drought prone districts of Madhya Pradesh state. The district having an area of 6781 sq.km. is, located between 22^{o}-00' to 23^{o}-15' North latitudes and 74^{o}-2' to 75^{o}-01' East longitudes. It has got five tehsils namely Alirajpur, Jhabua, Jobat, Petlawad and Thandla. The district has 1326 inhabited villages, 39 uninhabited villages and six towns as per 1971 census.

The population of the district according to the 1981 census is 795,834 and the density of population of the district is 117 persons per sq.km. as per 1981 analysis.

It has been reported that generally three types soils are found in the district namely, skeletal red and yellow, skeletal mixed red and yellow and skeletal black. As per data from 1970-71 to 1977-78 the land use in the district include forests 113,838 ha., barren and uncultivable lands 104,673 ha. and land put to non-agricultural uses 36,795 ha. and 396,160 ha. with culturable area.

The total irrigated area of the district is 12,842 ha. and the sources wise distribution of irrigated areas are 2381 ha. by surface water, 7,413 ha. by ground water and 2520 ha. others sources. The two main rivers Narmada and Mahi are flowing through the district. The catchment area within the district of Narmada is 3119 sq.km. and of Mahi is 3674 sq.km.

As per CWC analysis of 1982, the normal annual rain fall of the district is 827.31 mm, and there are normally 43.04 rain days in a year. Twenty two number of raingauge stations are located in the district and the density of raingauge stations are 308.76 sq.km. per raingauge station as per data from 1901 to 1978. The south west monsoon gives about 93.59% of the annual

rainfall and the coefficient of variation for annual rainfall is 30.17 percent.

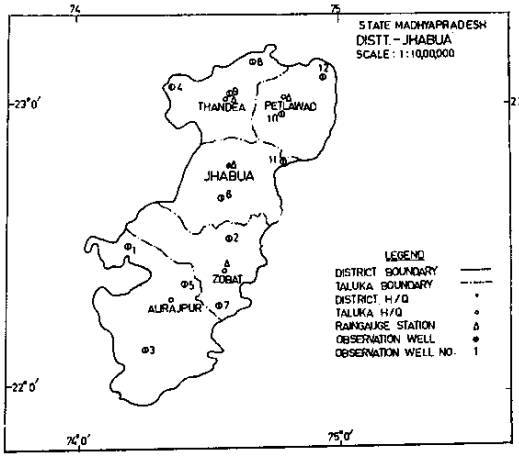
As per CGWB data the groundwater potential data estimate recharge to ground water of the order of 10.0 m.cum. and the draft 2.0 m.cum. and the surplus is 8.0 m.cum. As per CWC (1982) study the district faced 5 years of hydrological drought during the period 1940 to 1980. The map of the district showing location of raingauges and groundwater observation wells which have been chosen for analysis is shown in fig.2.7

2.9.2 Khargone

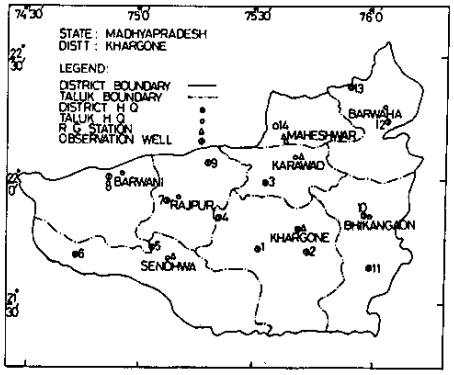
The district Khargone is one of the drought prone districts of Madhya Pradesh state. The district having an area of 1.35 m.ha., is located between $21^{o}22'$ to $22^{o}35'$ north latitudes and $74^{o}25'$ to $76^{o}14'$ east longitudes. It consists of eight tehsils namely Barwani, Barwah, Bhikangaon, Kasarawad, Maheshwar, Rajpur,Sendhwa and Khargone. The district has 1766 inhabited villages, 324 uninhabited villages and thirteen towns as per 1971 census.

The population of the district according to the 1981 census is 16,30,682 and the density of population of the district is 121 persons per sq.km. as per 1981 analysis.

It has been found that generally there are five types of soils in the district namely Kali-I, Kali-II, Kali-III, Halki Khadri and Bardi. As per data from 1970-71 to 1979-80, the land use in the district include forests 4,73,166 ha., barren and uncultivable lands 53,132 ha. and land put to non-agricultural uses 47,890 ha.



(a) DISTT. JHABUA



(b) DISTT. KHARGONE

FIG. 2.7 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

The total irrigated area of the district is 90,633 ha.and the source wise distribution of irrigated areas are 10,554 ha. by surface water, 71,813 ha. by ground water and 8,266 ha. by other sources.

The two main rivers Narmada and Tapi are flowing through the district. The catchment area with in the district of Narmada is 11,810 sq.km. and of Tapi is 11,680 sq.km.

As per CWC analysis of 1982, the normal annual rainfall of the district is 804.2 mm., and there are normally 41.6 rainy days in one year. There are thirty eight number of raingauge stations in the district and the density of raingauge stations are 257 sq.km. per raingauge station as per data from 1901-1980. The south-west monsoon gives about 91.2% of the annual rainfall and the coefficient of variation for annual rainfall is 21.3%.

As per SGWB data, the ground water potential is that annual recharge to ground water of the order of 874 m.cum. and the draft 168 m.cum. and the surplus is 706 m.cum. As per CWC (1982) study, the district faced 12 years of hydrological drought during the period 1957 to 1980. The location of raingauges and ground water observation wells is shown in district map given as in fig.2.7

2.9.3 Dhar

The district Dhar is one of the drought affected districts of Madhya Pradesh State. The district having an area of 8195.41 sq.km., is located between 22°-01' and 23°10' North latitudes and 74°-28' and 75°42' east longitude. It has got five taluks namely Badnawar, Dhar, Kukshi, Manawar, and Sardarpur. The district has 1484 inhabited villages and 87 uninhabited villages. This district consists of 6 towns and cities. The population of the district according to the 1981 census is

1055826. The rural population is 89.83% of the total population of the district. The density of population of the district is 129 persons per sq.km. as per 1982 census.

The soils of the district are generally medium to heavy black cotton soil with good water retaining capacity. The land use details of the district include forests 74981 ha., land put to non agricultural uses 39710 ha. and barren and unculturable land 112088 ha. The total irrigated area of the district is 57655 ha. and the source wise distribution of irrigated areas is 47947 ha. by groundwater (wells) and 4697 ha. by surface water and 5011 na. by others sources.

The three main rivers namely Narmada, Mahi, Chambal are flowing through the district. The catchment areas in the district of Narmada is 5030 sq.km. Mahi 1697 sq.km. and Chambal 1422 sq.km.

As per CWC study of 1982, the normal annual rainfall of the district is 837.8 mm and there are normally 43.11 rainy day in one year. Eleven no. of rain gauge stations are located in the district and the density of raingauge stations is one station per 795.04 sq.km. The south west monsoon gives about 92.3% of the annual rainfall as per data analysis from 1901 to 1980.

As per SGWB data, the groundwater potential in one year is that the annual recharge to ground water is of the order of 141.15 m.cum, while the draft 54.45 mcum., and the surplus is 86.7 M.Cum. As per CWC (1982) study the district faced 42 years of hydrological drought during the period 1901 to 1980. The location of raingauges and groundwater observation wells is shown in the district map as given in fig.2.8

2.9.4 Sidhi

The Sidhi district is located on the north eastern edge of Madhya Pradesh state. This is one of the drought affected

districts of the state as well as backward district. The district is situated between longitudes 81^{o}-18' to 82^{o}-49' east and latitudes 23^{o}-47' to 24^{o}-42' north. The geographical area of the district is 10390.75 sq.km. The district is divided into three talukas namely, Deosar, Gopadbanas and Singauli. According to 1971 census there are 1791 inhabited villages, 119 uninhabited villages and only one town in Sidhi district. The total population of the district is 988929 as per 1981 observation and the average density of population per sq.km. in 1981 was 95 persons.

As per the information available, the soils in the district may be classified as sandy to sand-loam with patches of clay loam in between. The land use details of the district as per data 1973-74 to 1977-78 include the forests 424296 ha., land put to non agricultural uses 49083 ha., barren and uncultivable land 125124 ha. and culturable areas is 440608. As per 1974-75 to 1976-77 data the total irrigated area was 4341 ha. in the district. The sources wise distribution includes 1956 ha. by ground water and 1440 ha. by surface water and 845 ha. by other sources.

The Sone and Tons are the main rivers that flow though the district. The catchment area of the Sone river in the district is of the order of 2241.6 sq.km.

As per CWC study of 1982 the district receives rainfall mainly from South-west monsoon. The normal annual rainfall in the district is 1245.82 mm. There are normally 54.46 rainy days in one year according to analysis from 1901 to 1980. About 89.57% of the annual rainfall is received during the south-west monsoon. Only three raingauge stations are located in the district and the density of raingauge stations is 1 station per 3510.67 sq.km.A maximum rainfall of 2081.5 mm was recorded in 1911 in the district

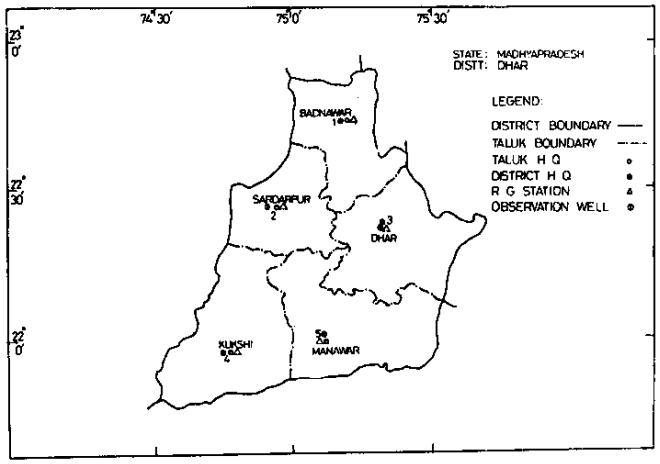
and the coefficient of annual rainfall is 27.39% during the period 1901 to 1980.

As per state groundwater organization data, the groundwater potential in one year is that the recharge to groundwater is of the order of 1394 m.cum. while the draft is 73.00 m.cum. and the surplus 1321 m.cum. According to 1982 study of CWC the Sidhi district faced 10 years of hydrological drought during the period 1951 to 1980. The location of raingauges and groundwater observation wells is snown in the district map as given in figure 2.8

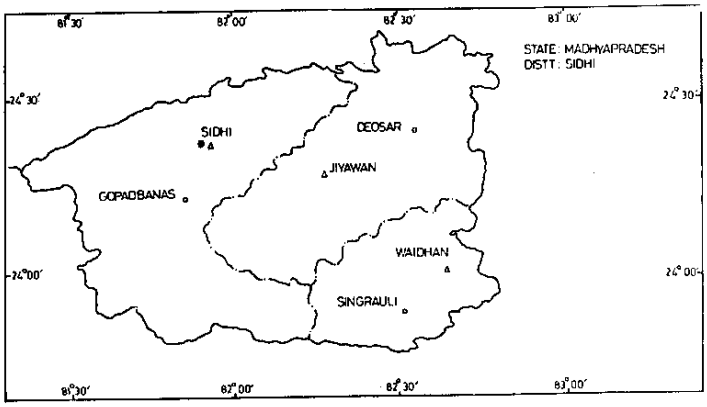
2.9.5 Betul

Betul district is one of the southern districts of Madhya Pradesh. The district has been identified as drought prone district and is a small district of Madhya Pradesh. The geographical location of Betul district which has an area of 10061 sq.km., is located between 21^{o}-22' N to 22^{o}-24' N latitudes and 77^{o}-04' E to 78^{o}-33' E longitudes. The district consists of three tehsils namely Betul, Bhainsdenni and Multai. The district has 1326 inhabited villages, 64 uninhabited villages and 5 towns. As per (1981) census the district had population of 924215 of which the rural population constituted 84.66%. The density of population is 91.86 persons per sq.km. in the district as per 1981 census.

It has been reported that generally superior black soil is found in the district. As per data from 1970-71 to 1976-77 the land use in the district include forests 415624 ha., barren and uncultivable land 26140 ha., land put to non-agricultural uses 41766 ha. and cultivable land 502070 ha. It has been reported that the total irrigated area of the district is 32179 ha. as per data 1960-61 to 1977-78. The sourcewise distribution of irrigated



(a) DISTT. DHAR



(b) DISTT. SIDHI

FIG. 2.8 LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

area is 27433 ha. by groundwater and 4746 ha. by surface water.

Through Betul district the main river which flow include the Narmada, Tapi and Godavari. The catchment areas of these river basins in the district are 3765 sq.km. for Narmada, 4077 sq.km. for Tapi and 2279 sq.km. for Godavari.

Accordingly to CWC study of 1982 the normal annual rainfall of the district is 1022.19 mm which is below the average annual rainfall of the state. The district gets 86.13% of the annual rainfall from the south west monsoon. Normally there are 54.80 rainy days in a year as per analysis of data from 1901-1980. The district has 15 raingauge stations and the density of raingauge station is 670.73 sq.km. per raingauge as per data of the coefficient of variation for annual rainfall has been reported as 25.76% for the district.

As per SGWB data for the groundwater potential is that annual recharge to groundwater is 861 m.cum., draft 189 m.cum.and balance 672 m.cum. in one year. The 1982 observations of CWC indicate that during 1951 to 1980 the district faced 11 hydrological drought years. The location of raingauges and groundwater observation wells is shown in the district map as given in figure 2.9.

2.9.6 Shahdol

The district Shahdol is one of the drought prone districts of Madhya Pradesh state. The district having a geographical area of 14028 sq km is located between 22°-38' to 24°-20' North latitude and 80°-28' to 82°-12' East longitude. It consists of four tehsils namely Bandogarh, Beohari, Pushparajgarh and Sohagpur. The district has 1981 inhabited villages, 169 uninhabited villages and ten towns as per 1971 census.

The population of the district according to the 1981 census is estimated to be 1,3,43,917 and the density of population of the district is 97 persons per sq kms. as per 1981 data. It has been reported that generally two types of soils are found in the district namely red and yellow soil, medium black soil and their sub-varieties. As per data from 1973-74 to 1977-78, the land use in the district include forests 405,581 ha. barren and uncultivable lands 69,791 ha, and land put to non-agricultural uses, 79,925 ha and 652,116 ha with culturable area.

The total irrigated area of the district is 5463 ha and the source-wise distribution of irrigated areas are 2755 ha by surface water, 1478 ha by ground water and 1230 ha by other sources. The main rivers flowing through the distract are Sone and Johilla. The catchment area within the district of Sone is 8142 sq. km and that of Johilla is 2513 sq km.

As per CWC Analysis of 1982, the normal annual rainfall of the district is 1232.28 mm and there are normally 63.65 rainy days in one year. Four number of raingauge stations are located in the district and the density of raingauge station are 3507 sq.km. per raingauge statioin as per data based from 1901 to 1980 . The south-west monsoon gives about 87.22% of the annual rainfall and the coefficient of variation for annual rainfall is 21.67%.

As per CGWB data, the groundwater potential data estimate recharge to ground water of the order of 1426 m cum. and the draft is 32.00 m cum. and the surplus is 8.0 m cum. As per CWC (1982) study the district faced 5 hydrological drought years during the period 1941 to 1980. The location of raingauges and ground water observation wells is shown in the district map as given in figure. 2.9

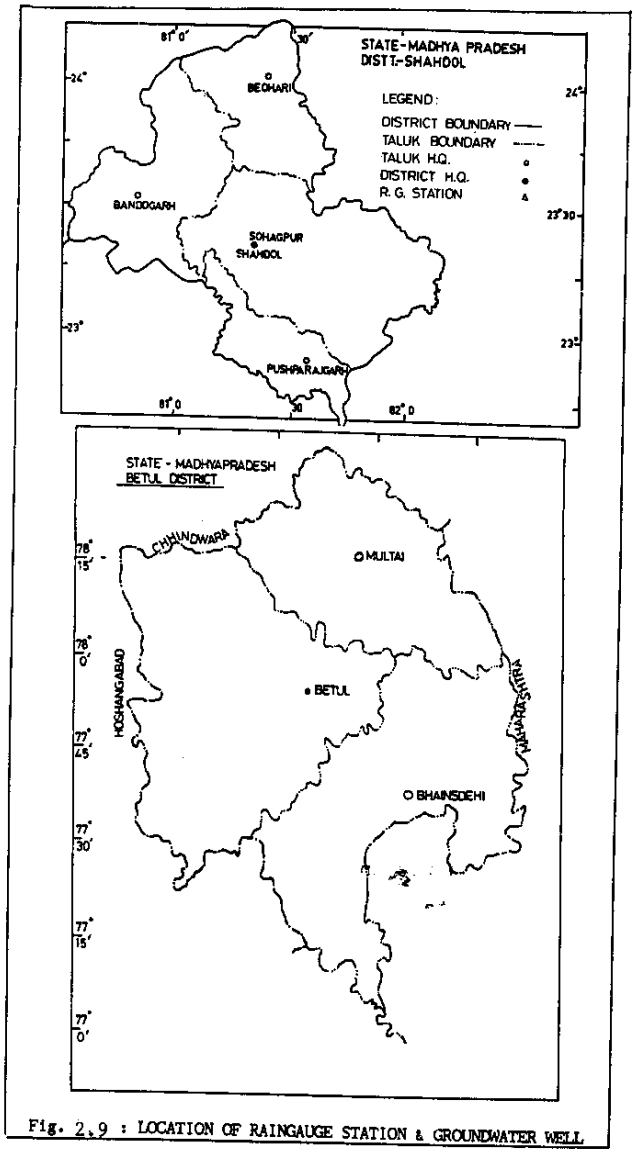


Fig. 2.9 : LOCATION OF RAINGAUGE STATION & GROUNDWATER WELL

3.0 RAINFALL ANALYSIS

3.1 General

As has already been described in chapter 2.0, six districts namely, Jhabua, Khargone, Dhar, Sidhi, Betul and Shahdol have been taken up for rainfall analysis in the present report. One representative raingauge station from each taluk in each of six districts has been selected for the study. The location of raingauges in various taluks on the district map has been shown in figures presented in chapter 2.0. The raingauge stations selected for the study are the ones which were selected by Central Water Commission for carrying out studies for identification of drought prone areas in 1982. The rainfall analysis has been carried out with the data from year 1901-88. The data from 1901-80 have been taken from CWC reports (CWC 1982). The rainfall data from 1981 to 1988 have been collected during visits of scientific teams to various central/state Govt. offices of state of MP, as has been mentioned in chapter 2.0.

3.2 Rainfall Departure Analysis

3.2.1 Seasonal Rainfall Departure

In order to see 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 above mentioned six districts of MP have been calculated as the summation of normals for the months (June to September) provided in CWC reports. Only four months i.e. June, July, August and September are taken into account while

estimating seasonal normals for the six selected districts, as the South-West monsoon is active for four months in the state of Madhya Pradesh. Analysis of seasonal rainfall departure to all the six districts i.e. Jhabua, Khargone, Dhar, Sidhi, Betul and Shahdol are given in table 3.1. The graphical presentation of results have been shown in Fig.3.1

Table 3.1: SEASONAL RAINFALL ANALYSIS FOR THE DISTRICTS JHABUA, KHARGONE, DHAR, SIDHI, BETUL & SHAHDOL OF STATE MADHYA PRADESH

District Jhabua (M.P.)

Year	Seasonal rainfall	Seasonal normal rainfall	Percent departure
1970	1123.36	833.68	-34.75
1971	976.66		+17.15
1972	528.46		-36.61
1973	N.A.		-
1974	615.60		-26.16
1975	608.18		-27.05
1976	1337.16		+60.39
1977	1175.76		+41.03
1978	1033.98		+24.03
1979	729.48		-12.50
1980	776.70		- 6.83
1981	1017.10		+22.00
1982	731.60		-12.24
1983	1034.64		+24.10
1984	763.10		- 8.47
1985	423.84		-49.16
1986	587.58		-29.52
1987	581.72		-30.22

District Khargone (M.P.)

1970	1132.89	792.74	+42.91
1971	698.47		-11.89
1972	457.13		- 42.34
1973	1186.00		+49.61
1974	592.19		-25.30
1975	801.68		+ 1.13
1976	907.96		+14.53
1977	679.77		-14.25
1978	790.69		- 0.26
1979	726.31		- 8.38
1980	609.99		-23.05
1981	976.60		+23.19
1982	530.90		-33.03
1983	819.10		+ 3.33
1984	561.80		-29.13
1985	440.70		-44.41
1986	619.83		-21.81
1987	536.74		-32.29

District Dhar (M.P.)

1970	1106.28	773.60	43.00
1971	865.02		11.82
1972	563.12		-27.21
1973	1208.36		56.20
1974	475.98		-38.47
1975	504.26		-34.82
1976	1020.93		31.97
1977	806.64		4.27
1978	800.74		3.51
1979	583.75		-24.54
1980	675.90		-12.63
1981	1025.20		32.52
1982	469.87		-39.26
1983	790.33		2.16
1984	762.39		- 1.45
1985	451.41		-41.65
1986	607.59		-21.46
1987	539.40		-30.27

District Sidhi (M.P.)

1970	978.68	1115.82	-12.29
1971	1465.79		31.36
1972	932.25		-16.45
1973	794.37		-28.81
1974	710.77		-36.30
1975	1149.55		3.02
1976	837.54		-24.94
1977	1188.90		6.55
1978	1185.33		6.23
1979	619.50		-44.48
1980	1313.49		17.71
1981	1151.88		3.23
1982	1296.57		16.20
1983	1079.71		- 3.24
1984	909.84		-18.46
1985	1272.66		14.06
1986	768.34		-31.14
1987	1214.92		8.88

District Betul (M.P.)

1970	1064.74	880.53	20.92
1971	735.64		-16.45
1972	704.16		-20.03
1973	1340.88		52.28
1974	716.06		-18.68
1975	1184.13		34.48
1976	552.85		-37.21
1977	702.69		-20.20
1978	581.60		-33.95
1979	719.30		-18.31
1980	682.76		-22.46
1981	833.02		- 5.40
1982	833.02		- 5.40
1983	833.02		- 5.40
1984	833.02		- 5.40
1985	697.15		-20.83
1986	979.40		11.23
1987	475.05		-46.05

District Shahdol (M.P.)

1970	1020.20	1074.83	- 5.08
1971	1187.32		10.47
1972	1040.92		- 3.15
1973	521.85		-51.45
1974	830.79		-22.71
1975	1422.61		32.36
1976	393.26		-63.41
1977	1195.50		11.23
1978	1240.43		15.41
1979	581.44		-45.90
1980	1423.71		32.46
1981	784.80		-26.98
1982	956.26		-11.03
1983	1186.32		10.37
1984	1153.78		7.35
1985	1052.81		- 2.05
1986	1014.22		- 5.64
1987	1023.14		- 4.81

The major inferences that could be drawn from seasonal analysis are below:

The districts in M.P. experienced seasonal rainfall deficiency with the extremes lying between 30 percent to 65 percent. Only two districts of Sidhi and Shahdol are on the eastern side of the state showed departure by +10 percent and -5% respectively in seasonal rainfall. The deficiency pattern in the district shows by and large scarcity of seasonal rain since 1985 in all the six distracts, except Shahdol and Sidhi chosen for study particularly in western districts of the state.

3.2.2 Monthly Rainfall Departure for the year 1987-88

In order to find deficiency in monthly rainfall during the year 1987-88, monthly departures have been worked out for 6 districts selected in the state Madhya Pradesh. The departure analysis has been done for all the taluks and district as a whole,

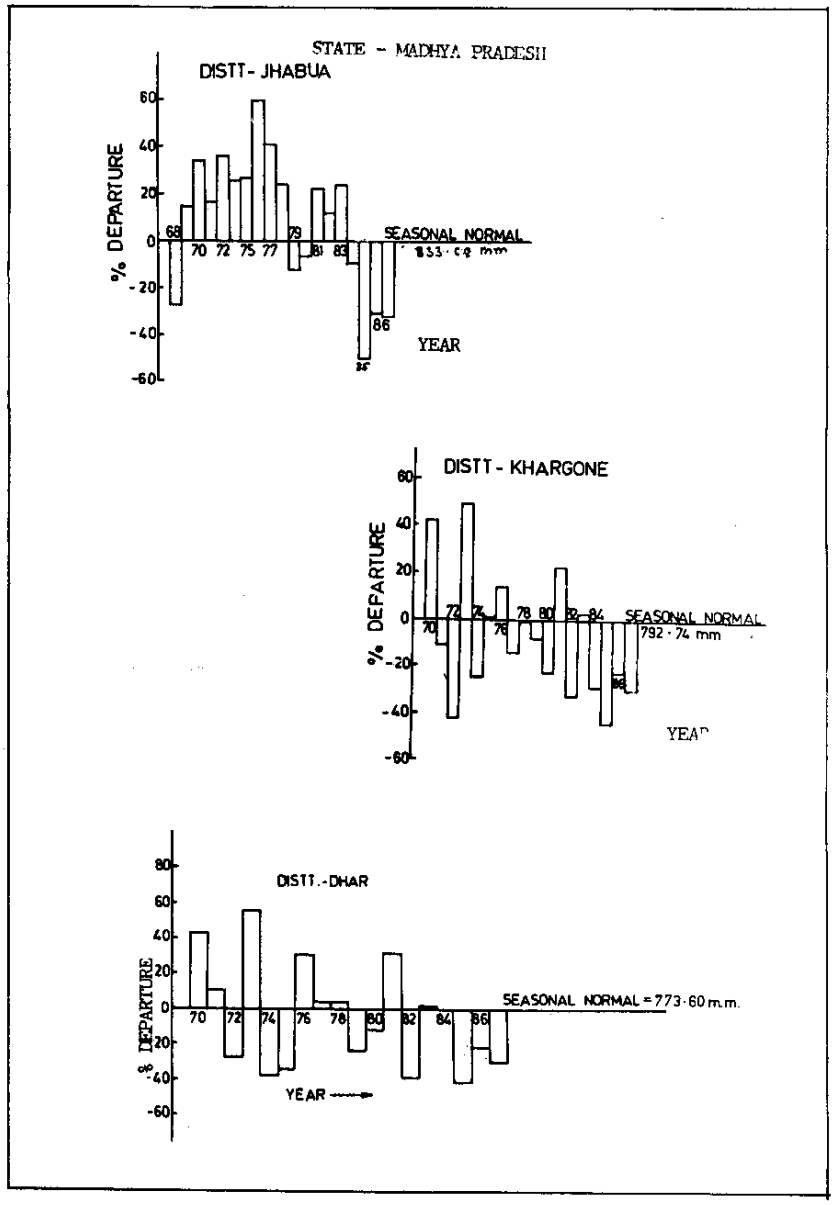


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

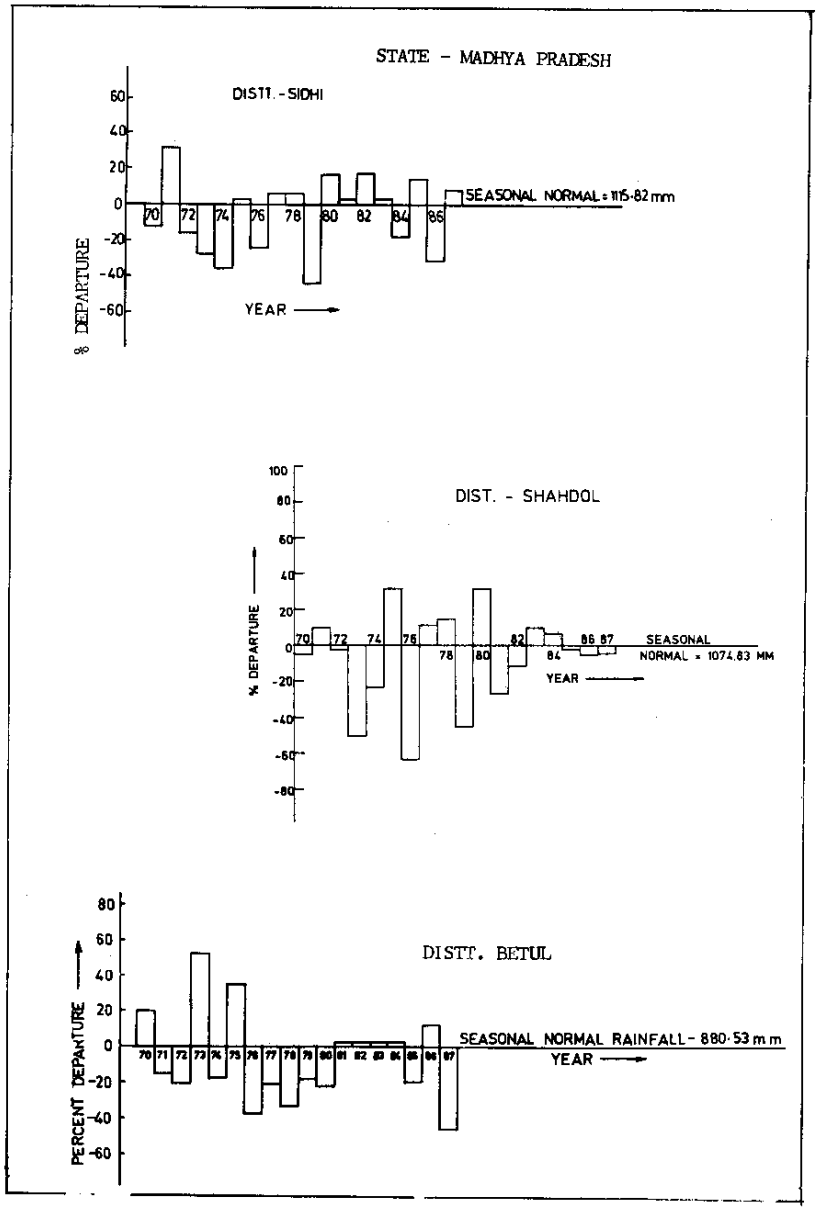


Fig. 3.1 : Districtwise Seasonal Rainfall Departure

but to reduce the bulk of report only results of one taluk and district as a whole are included in the report. Monthly rainfall values from June 1987 to May 1988 along with monthly normals of various representative raingauges of various taluks have been considered for the analysis. Monthly rainfall values for a district from June 1987 to May 1988 have been taken 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 variability of rainfall monthwise (monthly rainfall and corresponding normals) have been plotted for all the six districts for water year June 1987 to May 1988, and are shown in Fig.3.2. The departure figures for one selected taluk in each district are included as Appendix III-1. Based on the monthly departure values, two categories of monthly departures i.e. 20-50% and more than 50% have been established for deriving monthly deficiency inferences. Table 3.2 gives six districts of M.P. state which experienced rainfall deficit during months of June 1987 to May 1988 in these two ranges viz. 20 to 50% and 50% and above. The following inferences can be drawn from the results shown/presented in Figures 3.2, Appendix III-1 and Table 3.2.

In the state of M.P. monthly rainfall analysis has been done for all the 6 districts chosen for study. The results indicate that except Sidhi all districts, recorded deficient rainfall months with the deficiency ranging from 10% to 60%. The districts of Jhabua recorded maximum deficient months and the pattern of deficiency was similar in jhabua, Dhar and Khargone districts. The analysis also indicated that in the month of August the actual rainfall was in surplus of the normal rainfall almost

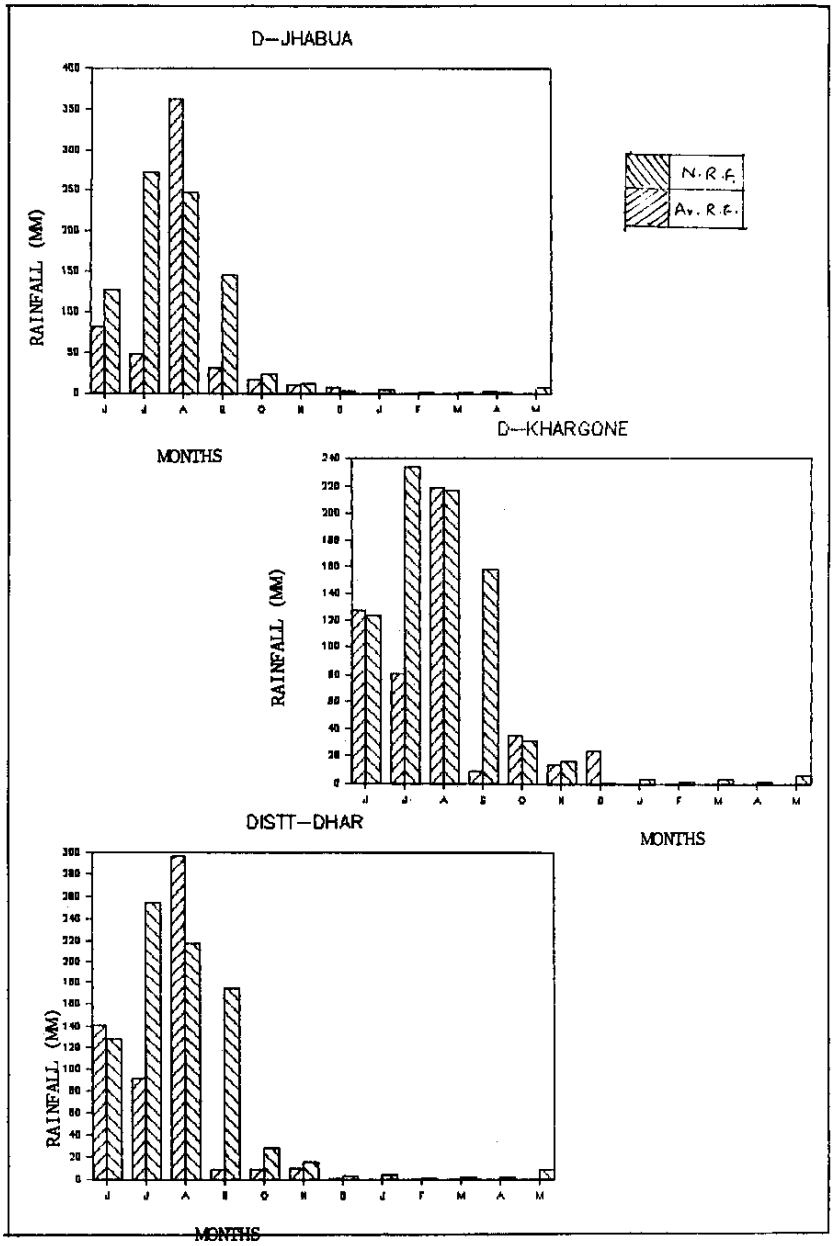


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

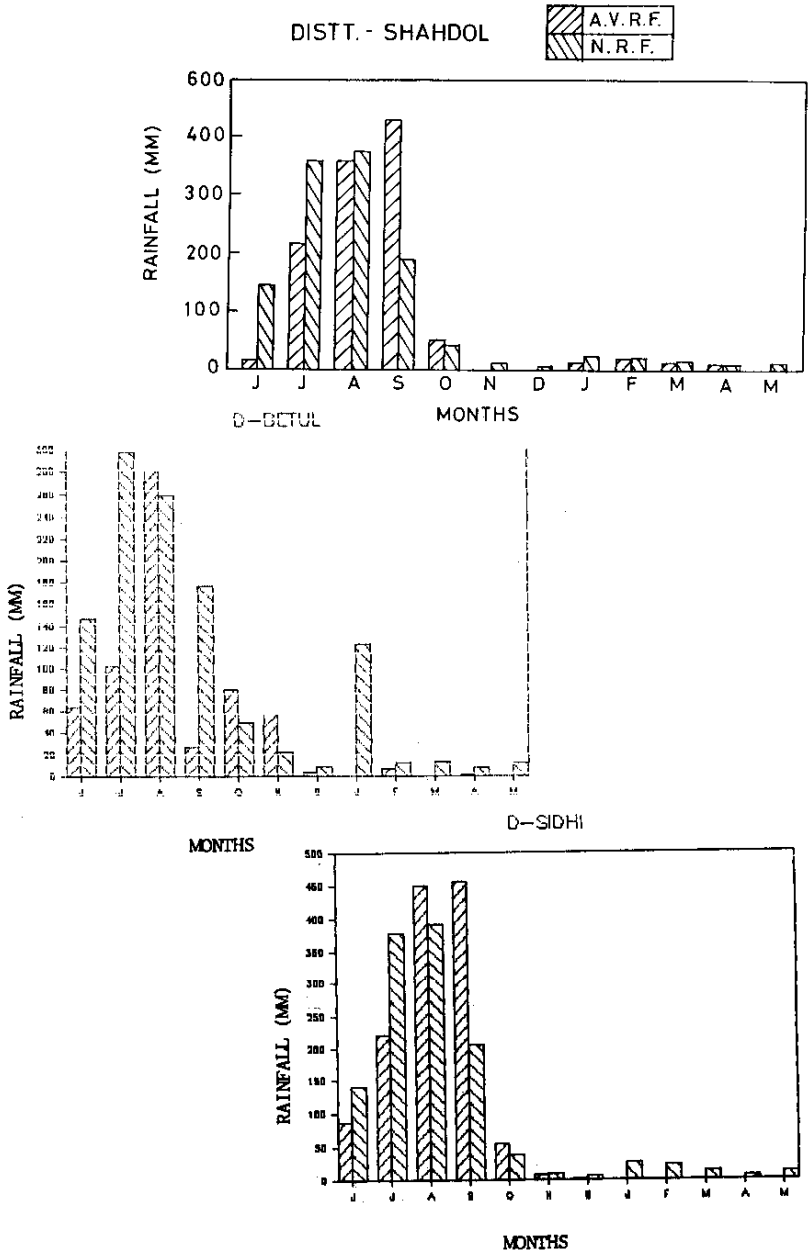


Fig. 3.2 : Districtwise Monthly Rainfall Departure for year 1987-88

in all the districts chosen for study with the excess lying between 10% to 50%.The departure trend in Sidhi was different than the other district of the state perhaps because of the spatial variation in the rainfall.

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
M.P.	June 1987	Jhabua,Sidhi	Betul, Shahdol
(No. of distr-icts taken - six)	July	Sidhi, Shahdol	Betul, Jhabua, Dhar, Khargone
	August		
	September		Betul, Jhabua,Dhar, Khargone
	October	Jhabua	Dhar
	November	Dhar,Sidhi	Shahdol
	December		Betul,Dhar,Sidhi, Shahdol
	January,1988	Shahdol	Betul,Jhabua,Dhar, Khargone, Sidhi
	February	Betul	Jhabua,Dhar,Khargone, Sidhi
	March		Betul,Jhabua,Dhar, Khargone, Sidhi
	April		Betul, Dhar, Khargone Sidhi
	May		Betul, Jhabua,Dhar, Khargone, Sidhi, Shahdol

3.3 Frequency of Rainfall

3.3.1 Probability analysis of annual rainfall

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

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

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

Probability graphs for all the six districts and also for two selected taluks of each district have been shown in figure 3.3 and appendix III-2 respectively.

The range of rainfall group for the taluks and districts which have a probability distribution graphs and tabulated in table 3.3. It can be seen from table that probability of occurrence of rainfall equivalent to 75 percent normal in districts Jhabua,& Khargone and Sidhi & Shahdol are in

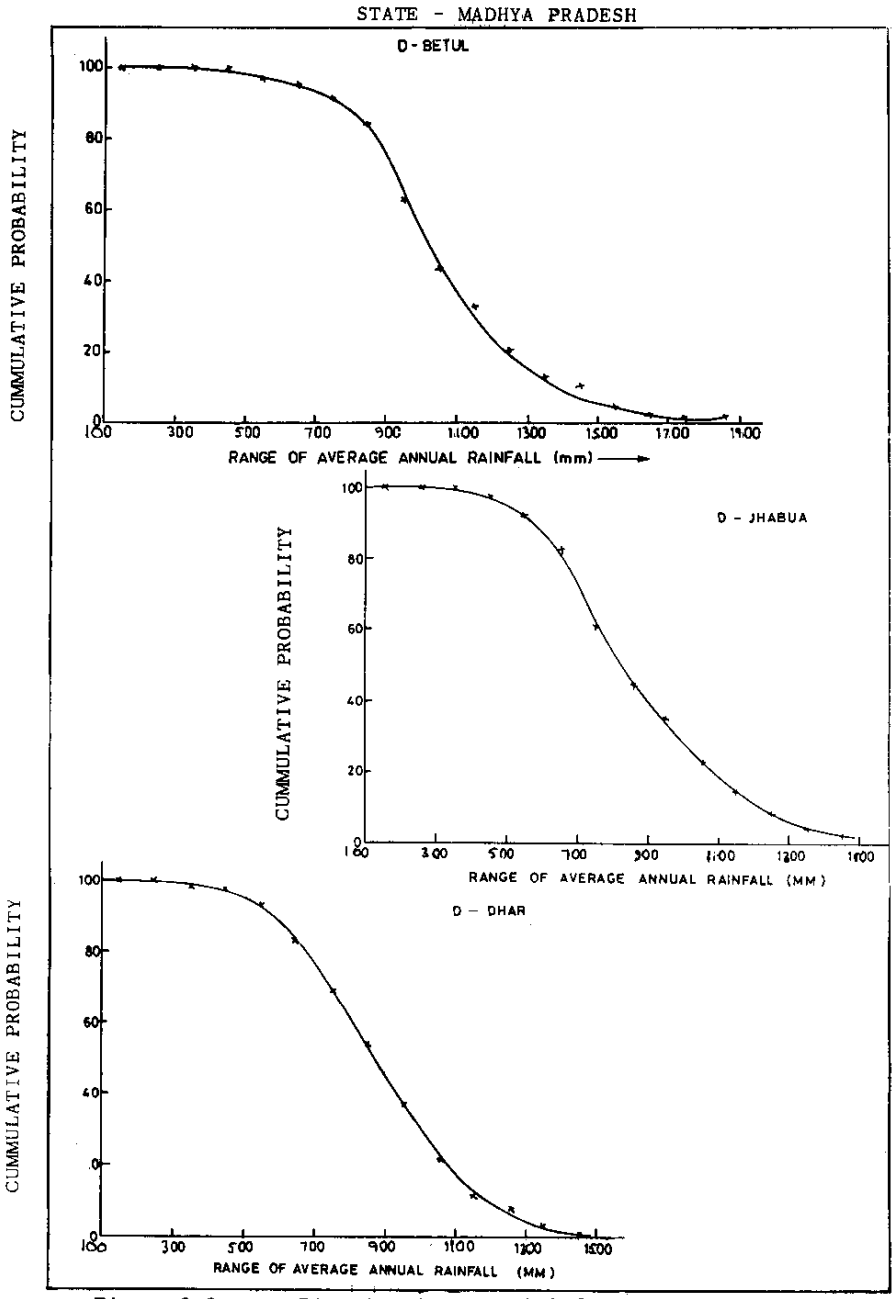
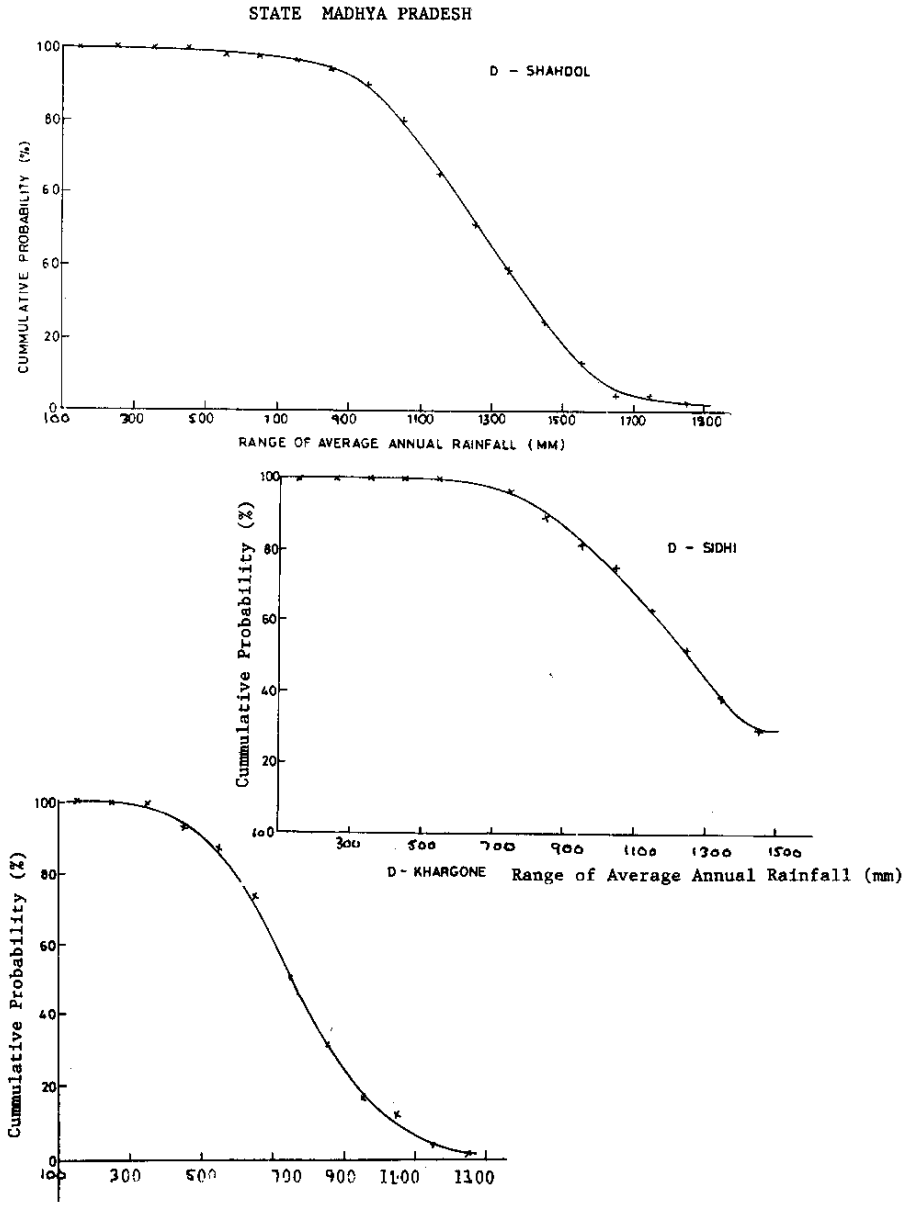


Fig. 3.3 : Districtwise Probability Distribution of Annual Rainfall



Range of Average Annual Rainfall (mm)

Fig.3.3 : Districtwise Probability Distribution of Annual Rainfall

the group range of 600-700 and 1000-1100 mm respectively. Similar inferences can be drawn for other districts and their taluks from table 3.3 which is self explanatory.

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 figure 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 in 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 districts namely Jhabua, Khargone,& Dhar, of State Madhya Pradesh are 78, 76, & 76 respectively i.e. below 80, indicating that above mentioned 3 districts are drought prone based on this analysis as per IMD criteria. It can also be stated that all the three districts i.e. Jhabua, Khargone,& Dhar,experienced rainfall less than 75% of normal in 22,24, & 24 percent of years respectively. However in case of districts of Betul,Sidhi & Shahdol the probability value of occurrence of 75% normal rainfall is 87,84 & 89 respectively i.e. above 80, indicating the district can not be classified as drought prone based on this analysis as per IMD criteria. The taluks of the six districts showed similar results indicating that these taluks as

Table 3.3 : Probability Distribution of Annual Rainfall of State Madhya Pradesh

Sl. No.	District (State)	Name of Taluks	At 75% Probability and above (Range in mm)	Probability of occurrence of rainfall equivalent to 75% Normal(in %age)
1	2	3	4	5
1.	Jhabua	1. Jhabua	600-700	79
		2. Alirajpur	600-700	76
		3. District as a whole	600-700	76
2.	Khargone	1. Khargone	600-700	83
		2. Barwani	600-700	84
		3. District as a whole	600-700	76
3.	Dhar	1. Dhar	800-900	78
		2. Kukshi	400-500	72
		3. District as a whole	700-800	76
4.	Sidhi	1. Gopad Banas	1100-1200	85
		2. Singrauli	700-800	79
		3. District as a whole	1000-1100	84
5.	Betul	1. Multai	800-900	83
		2. Betul	900-1000	84
		3. District as a whole	900-1000	87
6.	Shahdol	1. Pushprajgarh	1100-1200	84
		2. Sohagpur	1000-1100	87
		3. District as a whole	1000-1100	89

well as district 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 monthly rainfall, MMR) is calculated:

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

Here MMR = Mean monthly rainfall

RF = Rainfall

NYR = Number of years of record

Suffix I and J denote years and months respectively.

B. Calculation of mean annual precipitation (MAP)

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

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

where NMN = Number of months in a year

C. Calculation of Effective Rainfall

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

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

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

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

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

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

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

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,

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

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

D. Calculation of mean annual deficit

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

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

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

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

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

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

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

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

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

Here MD = Monthly deficits or monthly differences

MMD = Mean monthly deficit

MAD = Mean annual deficit

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

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

E Test to Determine onset of drought

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

Case (A) Delete negative difference < MMMR

Case (B) Delete negative difference > MMMR

Case (A) Delete negative difference < MMMR

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

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

Case (B) Delete negative difference ≥ MMMR

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

F Tests to determine the termination of drought

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

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

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

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

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

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

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

(G) Evaluation of drought index

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

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

WHERE IDST = Month of start of drought

IDEND = Month of termination of drought

In above equation if nominator is less than 0.0 (i.e., negative), 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=IxD ... (13)

This analysis has been performed for six selected districts of state Madhya Pradesh. Monthly rainfall data for period 1951 to 1987 of selected raingauge station located at taluk headquarters of each district have been used for analysis. As has been described in earlier section the computational program using the approach has been developed at the institute. The analysis has yielded in monthly and overall drought intensity values. The results of drought intensity (monthly and average) are given/shown in Appendix III-3 and figures 3.4 in respect of all the six selected districts i.e. Jhabua, Khargone, Dhar, Sidhi , Betul,and Shahdol of State M.P.

The following inferences can be drawn from the analysis:

All the six districts have shown over two drought spells during 1984-87. The district of Sidhi showed maximum number of drought spells and in general 4-5 spells were found in all districts since 1951. The maximum drought intensity was found in case of Khargone district while the longest spell was observed Betul district during 78-86.

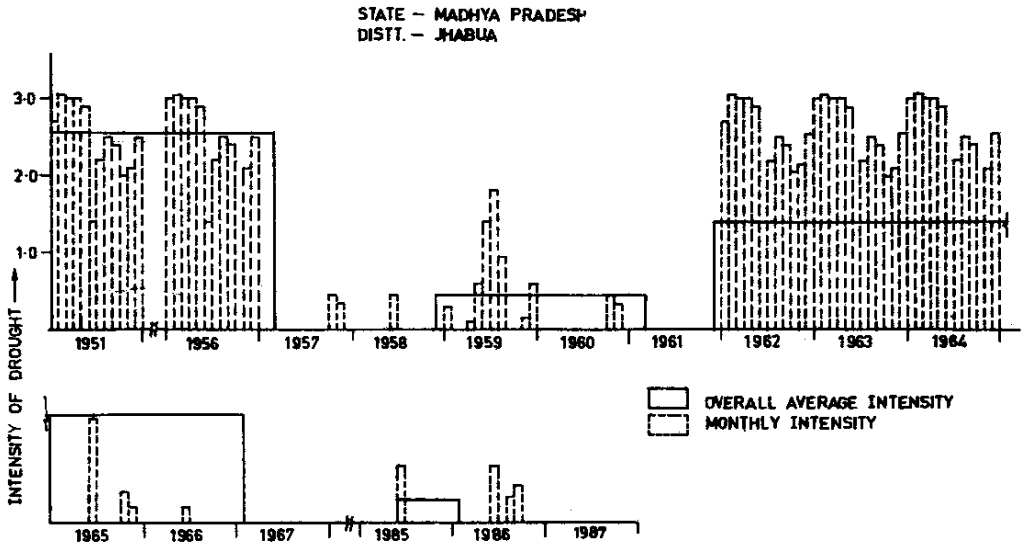


FIG. 3·4 – OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

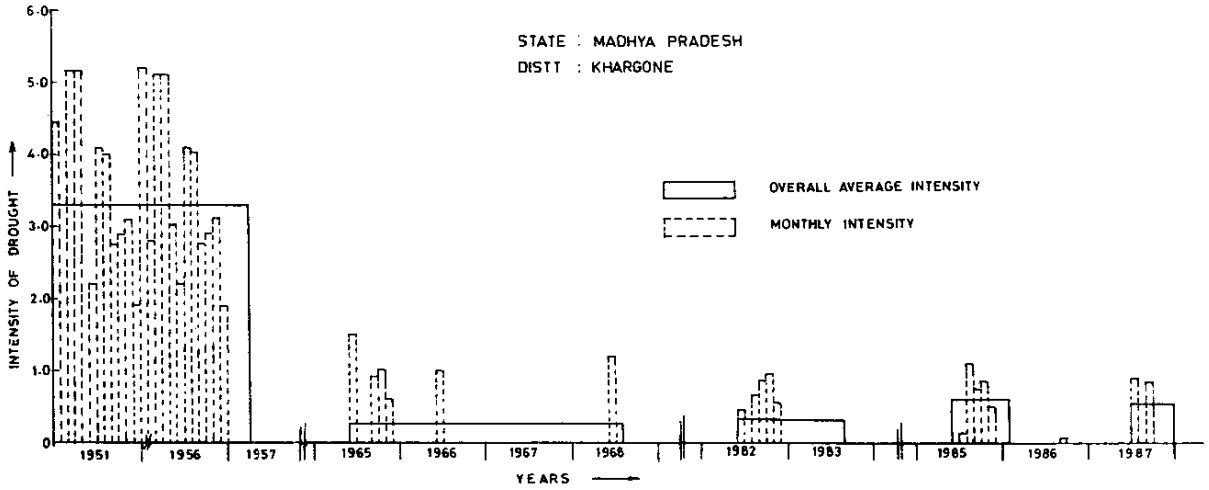


FIG. 3.4 OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT.

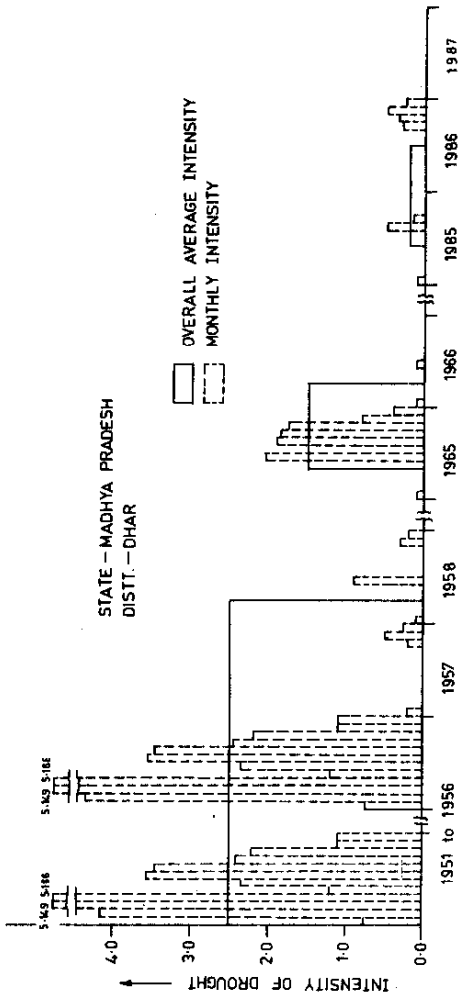


FIG. 3·4 – OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT.

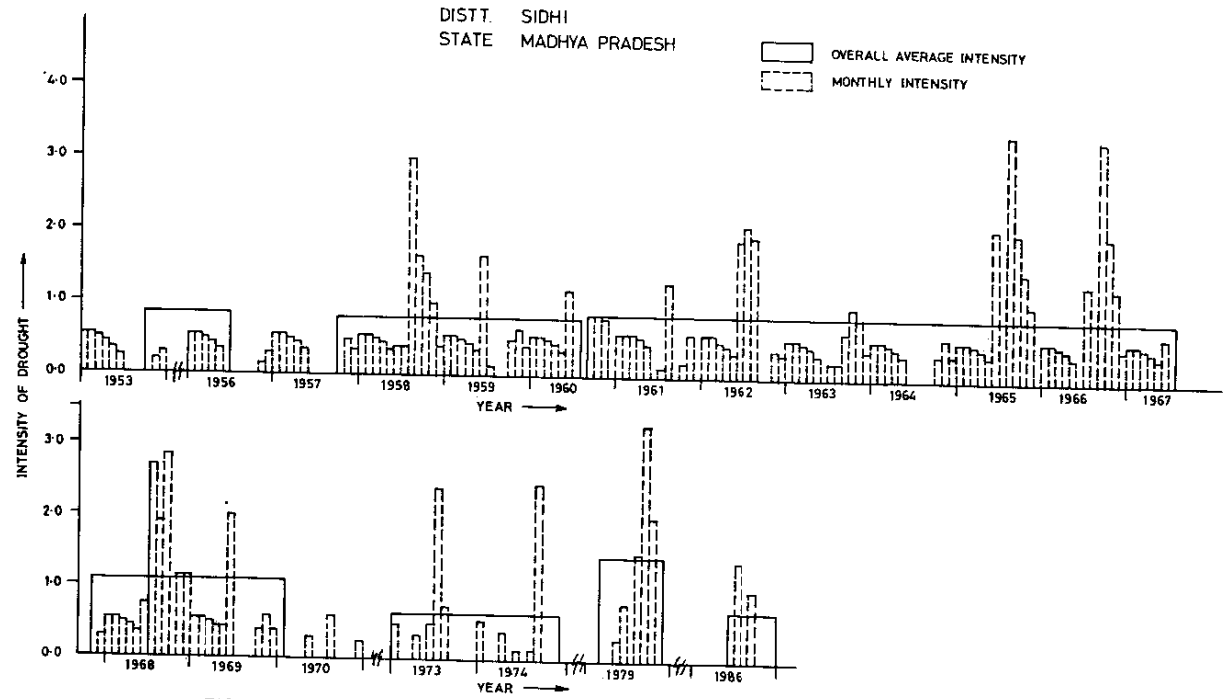


FIG. 3·4 – OVERALL AND AVERAGE INTENSITY OF DROUGHT

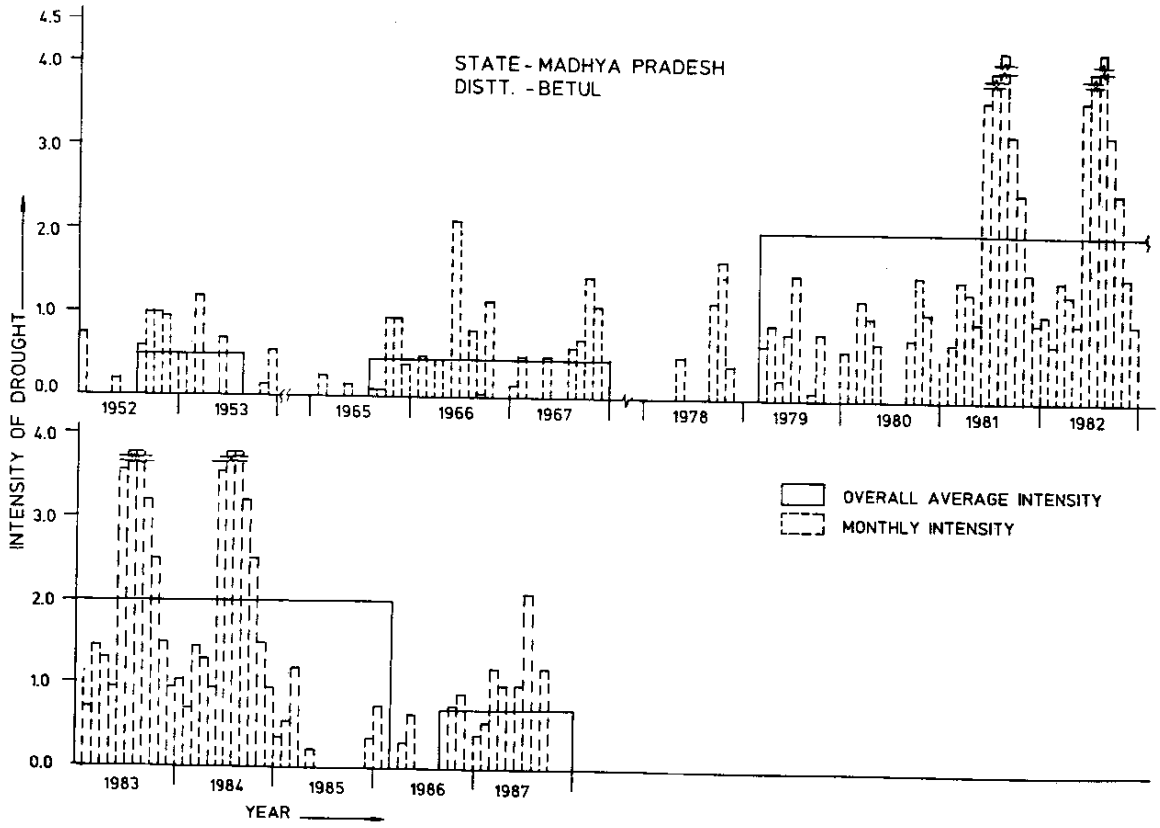


FIG. 3.4 OVERALL AVERAGE AND MONTHLY INTENSITY OF DROUGHT

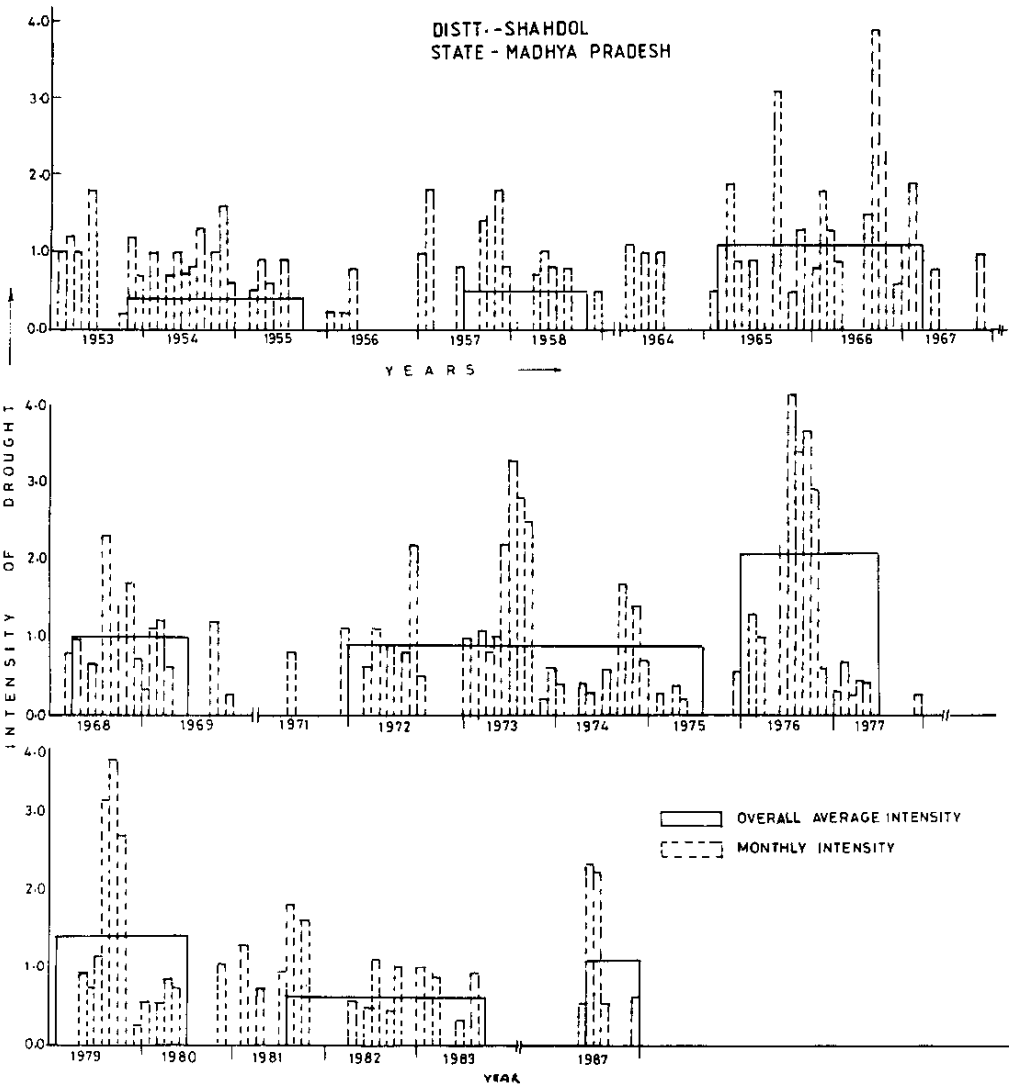


Fig.3.4 : Overall average and monthly intensity of drought

3.5 Dry Spell Analysis:

Agriculture is the worst sufferer of droughts as the ultimate effects of drought results in partial or total crop failure. Out of the various growing stages of crops, some are sensitive to moisture stress known as critical growing stages. Agricultural droughts are the result of occurrence of dry spells specially during critical growth stages of crops. Therefore the analysis of dry spells ($\geq$ 2 weeks) within monsoon season has importance specially for rainfed agriculture in the country. Therefore,an attempt has been made to identify the dry spells of two or more than two weeks duration during monsoon period (4th June to 15th September) by selecting one taluk from each of the 6 districts of the state of Madhya Pradesh.

The criteria for selection of dry spell is that the daily rainfall should be less than or equal to 5 mm (as a day is assumed as rainy day if daily rainfall exceeds 5 mm) occurring continuously for atleast two weeks (i.e. 14 days) or more. For counting number of spells the start of monsoon season has been assumed from fourth June of (beginning of 23rd standard week) every year. The duration and time of occurrence and number of such dry spells for all the six districts of state M.P. have been presented in Appendix III-3 (A). The number of dry spells have been counted starting from the monsoon season of 1981 to 1987. However, in case of some of the districts, the daily rainfall data for some of the years were not available and so the analysis could not be done.

For statistical analysis, the duration of dry spells were represented as range (in days) and no. of spells falling in that range were counted. The number of spells falling in various ranges of duration of spells were represented as percentage of total no. of spells occurring from 1981-1987 and cummulative

percentage was obtained starting from the maximum duration of dry spell group downwards adding successive percentage (Appendix III-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 selected taluks of all the six selected districts respectively except the taluks Dhar (Dhar) and Gopad Banas (Sidhi) where the duration dry spell was expected at 75% probability range from 14-21 days.

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

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

S.No.	Taluk (Distt.)	Stage	At 75% Probability, duration of dry spells (in days)
1.	Alirajpur (Jhabua)	M.P.	21-28
2.	Barwani (Khargone)	M.P.	21-28
3.	Dhar (Dhar)	M.P.	14-21
4.	Gopad Banas (Sidhi)	M.P.	14-21
5.	Betul (Betul)	M.P.	21-28
6.	Sohagpur (Shahdol)	M.P.	21-28

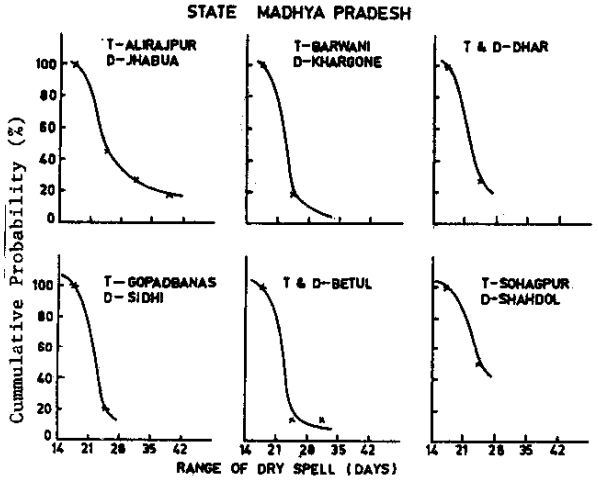


Fig.3.5 : Probability Distribution of Dry Spells

4.0 GROUND WATER DEFICIT

4.1 General

The main objective of ground water management is to ensure that ground water will be available at an appropriate time and in an appropriate quantity and quality to meet the most important demand of the society. The measurement of ground water level and their evaluation can play an important role in management of this underground resource of water. The fluctuations of water table, reflect the effects of infiltration, precipitation and of discharge of groundwater to streams and lakes or withdrawl 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 groundwater storages and sharp decline in groundwater levels are experienced. Because of improproer management of groundwater aquifers, after development numerous undesirable consequences such as the depletion of aquifers and groundwater mining emerge, expecially during drought years. Statistics recently compiled on the use of groundwater and surface water show that in a number of states groundwater is being over exploited in certain pockets resulting in a fall in the water table. During droughts, due to defficiency 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 withdrawl 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 measurements. Besides, information regarding well, abstractions, should be available for evaluating effects on water table due to reduced precipitation.

In order to see the effects of scarce rainfall as experienced during three successive drought years (1985-87) on groundwater regime, statistical analysis of groundwater level data vis-a-vis precipitation has been carried out for five districts namely Jhabua, Khargone, Dhar, Betul and Shahdol selected of Madhya Pradesh. However, due to non-availability of abstraction data, the effects of withdrawl could not be introduced in the analysis.

4.2 Groundwater level Analysis

The data concerning groundwater level fluctuations were collected in respect of observation well in all the five districts namely, Jhabua, Khargone, Dhar, Sidhi and Betul of state Madhya Pradesh. The information regarding period of data used, number of observatiion wells and the source of data is given in table 4.1.

Table 4.1: STATUS OF GROUNDWATER DATA OF STATE M.P.

S.No.	Name of district	Data available	Number of wells taken	Source of data availability
1.	Jhabua	1975-88 (Pre & Post)	11	State G.W. Board
2.	Khargone	-do-	14	-do-
3.	Dhar	1976-88(Pre&Post)	5	-do-
4.	Sidhi	Data not available	-	-
5.	Betul	1975-88(Pre&Post)	5	-do-
6.	Shahdol	1975-88(Pre & Post)	7	-do-

As can be seen from the table that about 3 to 14 wells evenly distributed over the district were choosen for the analysis keeping in view data availability constraints. The location of the wells on the district map have already been shown in the figures presented in chapter 2. The ground water level analysis for the five district namley Jhabua, Khargone, Dhar, Betul and Shahdol was attempted with the help of pre and post monsoon ground water level data collected from State Groundwater Board of Madhya Pradesh. Appendix V-1 gives the details of various observation wells spread over districts of Jhabua, Khargone, Dhar, Betul and Shahdol along with their latitude and longitude.

The analysis has been carried out for groundwater level data from 1975-87.

The water levels in the wells have been calcuated with respect to mean sea level and for each district average groundwater level has been calculated using Thiessen Polygon Method. The Thiessen weight of all the wells considered in each district was established and groundwater level calculated with

respect to mean sea level multiplied by Thiessen weight gave average groundwater level for the district. Based on the values of water levels in wells, computed with respect to MSL, average groundwater level for the district was obtained. The values so obtained were plotted against each year to derive trend in groundwater fluctuation. The trend was established for two periods namely, premonsoon and post monsoon. In order to see the trend in the rainfall, the seasonal rainfall was also plotted on the same graph showing the groundwater level fluctuations. For this purpose, the seasonal rainfall from June to September was used for all the five districts selected for study in the state of Madhya Pradesh. A simple regression line as fitted to show the trend of rainfall in order to see the effects of deficit in water levels. As has already been mentioned that due to non-availability of data the effects caused due to over exploitation of ground water during drought periods could not be introduced in the study and it is presumed that decline in ground water level is caused solely due to failure of rainfall. Also a district has been taken as a unit for analysis groundwater 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 outlfow of groundwater into & from its aquifer. Based on the analysis, following inferences can be drawn:

The ground water level analysis has been carried out in the district of Jhabua, Khargone, Dhar, Shahdol and Betul of state Madhya Pradesh. Due to non-availability of data for Sidhi district, it could not be included in the study. All districts have experienced seasonal rainfall deficiency during 1987-1988 ranging from 33-43%. The rainfall trends have also indicated continuous decline of seasonal rainfall as the rate of decline during 1987-88 has increased as compared to previous year. As a result all the five districts excep. Shahdol have indicated a

falling trend in pre and post monsoon water table levels and in most of the cases the rate of decline have been more than the previous year. In case of Shahdol district , the pre and post monsoon water table trends have shown slight positive slope of trend lines. The continuous decline in water table levels can be attributed to continued deficit seasonal rainfall over the last three successive years and over pumpage of groundwater for various usages. The trends of water table and seasonal rainfall in respect of five districts are shown in Fig 4.1 to 4.5.

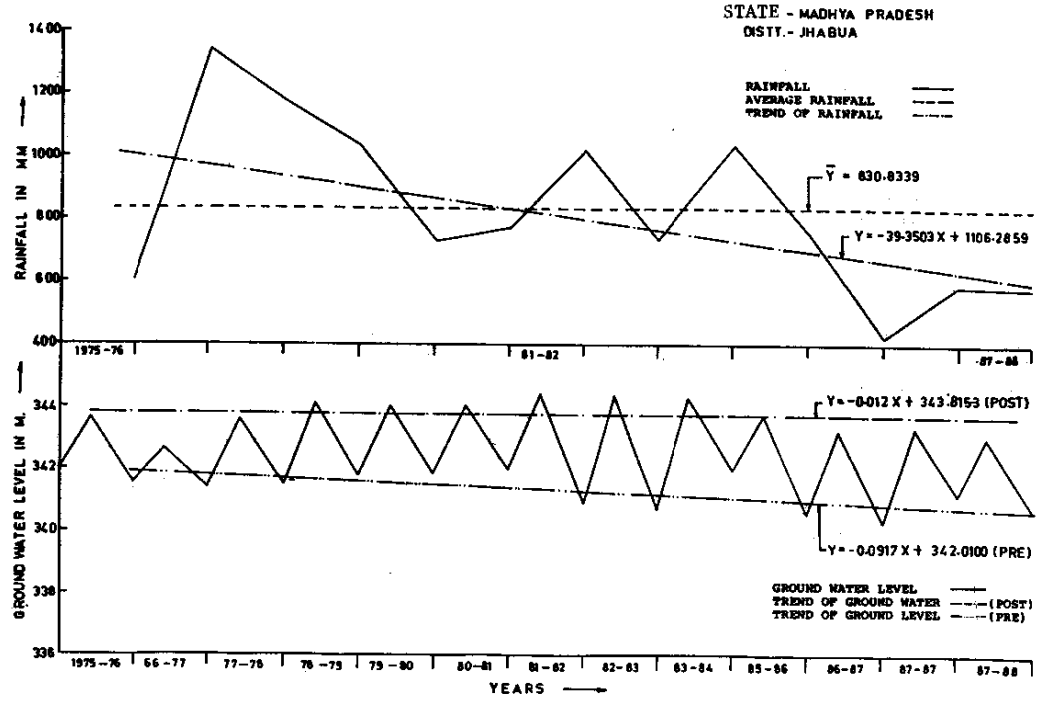


FIG. 4.1 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

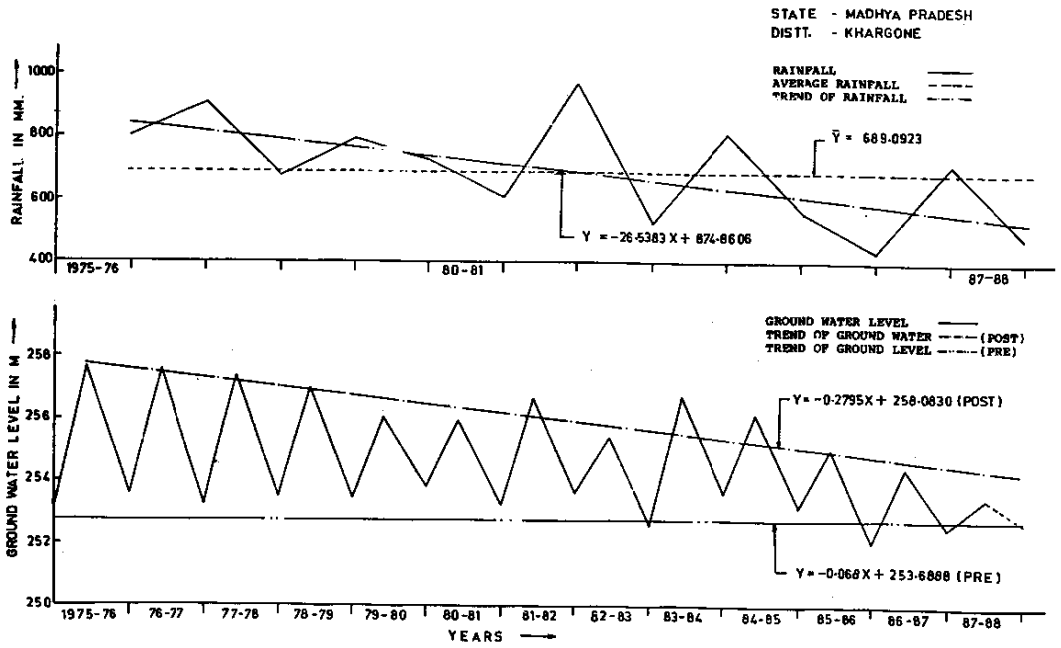


FIG. 4.2 -GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

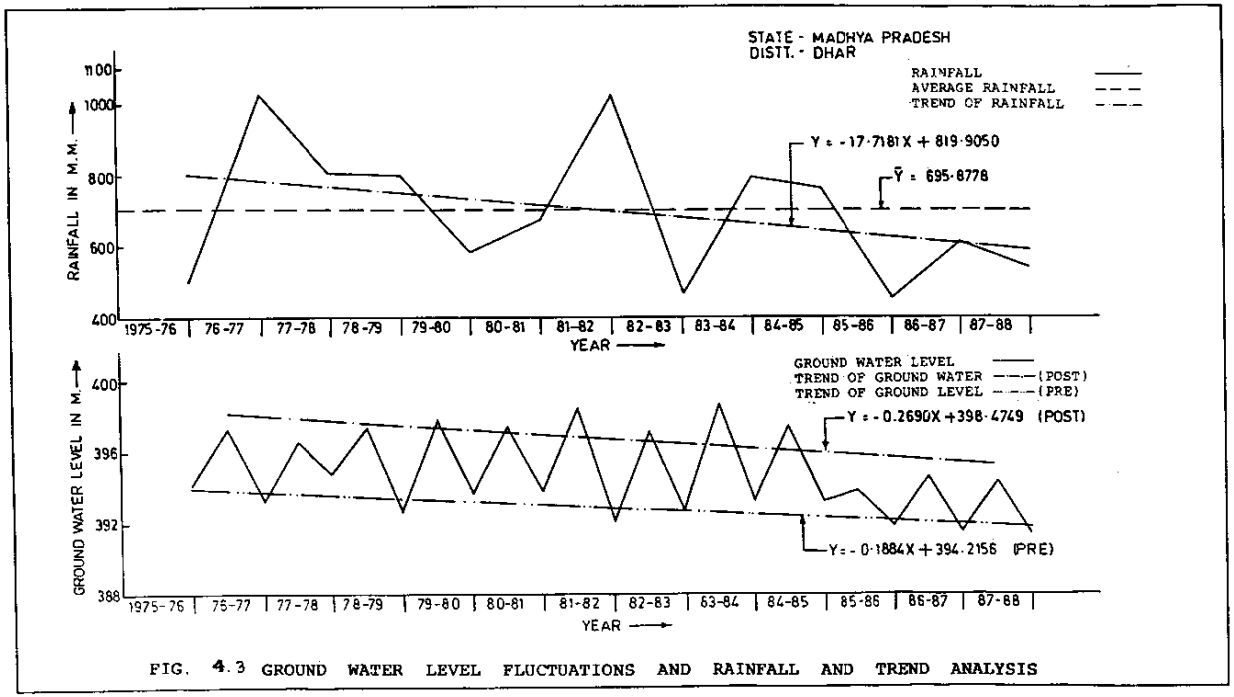


FIG. 4.3 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

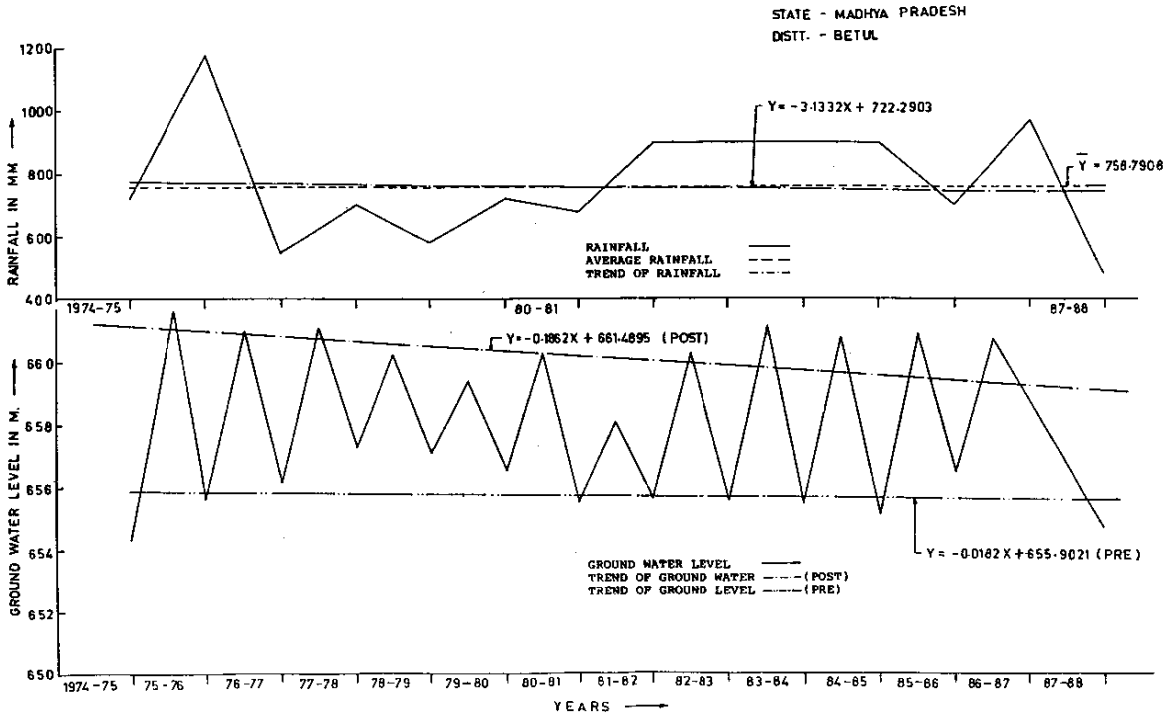


FIG. 4.4 GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

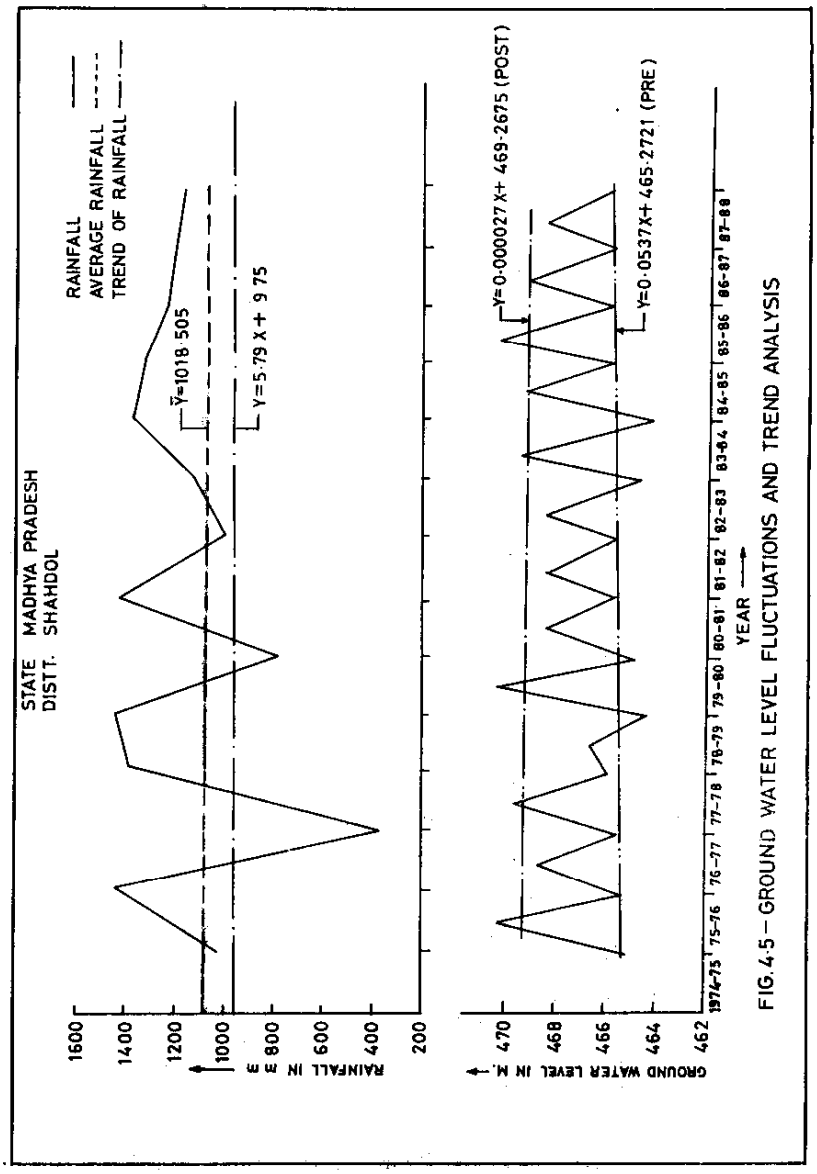


FIG. 4.5 – GROUND WATER LEVEL FLUCTUATIONS AND TREND ANALYSIS

5.0 ANALYSIS OF RESERVOIR STORAGE

In order to illustrate the impact of failure of monsoon on storage reservoirs, an attempt has been made to compare the storages only for two selected reservoirs, i) Tawa, Narmada Basin and ii) Gandhisagar, Chambal Basin. For this purpose, the live storages and corresponding reservoir level in some selected months have been plotted against time. The weekly reservoir level data as supplied by Central Water Commission from 1984 till 1987 have been used for the analysis. As can be observed from Fig.5.1 that in Gandhisagar reservoir during May 1986 the live storage was recorded lower than that of May 1987 and also than that of previous years. On the other hand, live storages during August and October 1987 were lower than previous years. The storages during October 1987 in Gandhisagar reservoir was 55% to previous years same time storage. In case of Tawa the May, 1984 live storage was lower than the conservative three years. The October 1987 storage in Tawa reservoir was 102% to the same time storage during previous year's storages.

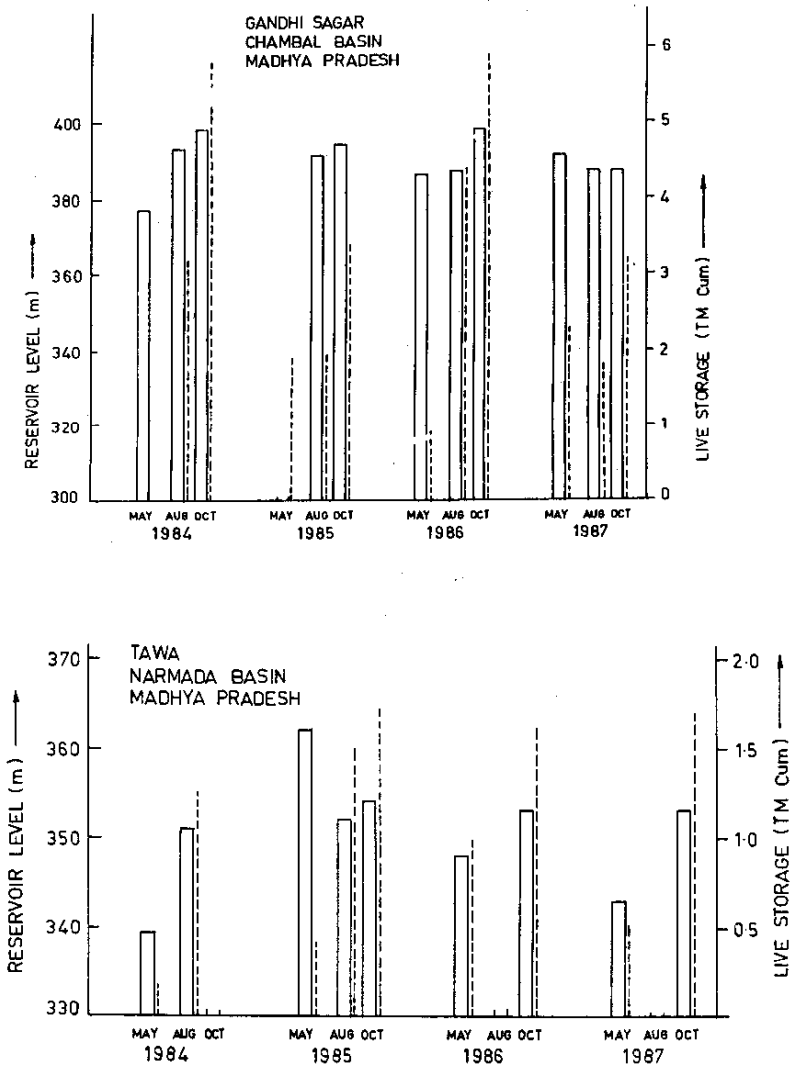


FIG. 5.1 - RESERVOIR LEVELS AND STORAGES FOR BHIMA AND TAWA RESERVOIRS

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. The present report presents the analysis of monthly/daily and seasonal rainfall data for six selected districts in the state of Madhya Pradesh, with the objective to find deficiency in the rainfall (monthly and seasonal) in order to classify drought conditions. The data have been collected by undertaking field trips from various government organisations.

2. The analysis of rainfall data on seasonal basis (June - September) for these districts indicate that a deficiency of the order of 30-65% was experienced on seasonal basis. However, in case of Sidhi and Shahdol, the departure from seasonal normal were not significant.

3. The monthly departure for the water year 1987-88 in rainfall values were also worked out for all districts and the departure values were characterised in two ranges from 20-50% and more than 50%. The departure values indicated that accept Sidhi all districts recorded deficiency in monthly rainfall of the order of 10-60%. It was further noticed that in the month of August, the actual rainfall was surplus by 10-50% from the normal rainfall in all the districts.

4. To work out probability of occurrence of annual rainfall at 75% level and occurrence of 75% of the normal rainfall for two taluks and district as a whole. The group range of 75% range of probability was worked out for all the districts and it has been found that for the districts of Jhabua & Khargone and Sidhi & Shahdol, the group range for rainfall lie in two

categories namely 600-700 mm and 1000-1100 mm. In order to identify drought proneness of the district, the percentage probability of occurrence of the 75% of the rainfall was worked out based on the probability of analysis. The results indicated that the corresponding probability actuals for the districts Jhabua, Khargone & Dhar are of the order of 78, 76 & 76 respectively. This indicates thereby that for more than 20 years in 100 years period, the rainfall would be less than 75% of the normal rainfall which further identifies drought proneness of these districts. The districts of Jhabua, Khargone & Dhar lie in the western part of the state, however, the districts Sidhi & Shahdol lie in the Eastern part of the state, which is the main reason for not showing similar results after the analysis.

5. The analysis based on monthly rainfall data using Herbst Approach was carried out. The results indicated that almost all six districts had more than two spells of drought during period 84-87. However the district of Sidhi showed a maximum number of dry spells while in general 4-5 spells of drought were experienced since 1951 in these districts. The maximum intensity of drought was found in case of Khargone district while the longest spell was experienced in Betul district, during analysis period.

6. The dry spell analysis was attempted to work out the dry spells likely to occur in the district at various probability levels it was found that at 75% level of probability duration of dry spell ranges from 21-28 days for all the six selected taluks of six selected districts of the state, except the selected taluks of Dhar and Sidhi districts. The results of these analysis may be useful for planning cropping pattern for these districts.

7. As per the objectives of the study, the impacts of drought on ground water regime were evaluated by analysing the data of observation wells as obtained from various departments of the state. The average water table levels in all the five districts at pre and post monsoon stages were recorded and it was attempted to fit a straight line representing pre and post monsoon levels. The trend of the best fit line was observed and a falling line indicating decline in water table due to less recharge from the surface as a result of rainfall failure. The continuous decline in water table can be attributed to successive decline in rainfall over the years. It was observed that except Shahdol all districts have shown a falling trend in pre and post monsoon levels and the rate has been higher than previous years.

8. In order to analyse impacts of droughts on surface storage conditions it was decided to compare as in Gandhisagar and Tawa reservoir during the year. It was observed that the storage during August and October 1987 was lower than previous years. As for Gandhisagar during October 1987, the storage was of the order of 55% as of the previous years. In the case of Tawa in October 1987 storage was about 102% of the storage during the previous years at the same time.

9. The analysis has been carried out in the state of M.P. taking district as the boundary. It would be however useful to extent the study on basin scale as water shed has been well deficient of the size for carrying out such investigations. Some stream flow sites should also be chosen to highlight impacts of drought on stream flow regime.

REFERENCES

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

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

3. 'Hydrological Aspects of Drought 1995-86' - A case study prepared by NIH (CS-21).

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

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

6. Land Use Statistics, 1987 Directorate of Economics & Statistics, M.P. Govt.

7. Land Record Statistics, 1987, Directorate of Economics & Statistics, M.P. Govt.

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

9. McMohan T.A. and Arenas A.D. (1982) Method of Computation of Low Stream Flow, UNESCO, Paris.

10. Report on Groundwater in M.P., 1980, Irrigation Deptt., M.P.

11. Sampath, T.V. (1989), 'Effect of Drought on Indian Agriculture' paper presented in International Symposium on Ground Water Resources Management in Drought Prone Areas, 27 Nov to 1 Dec. 1909, New Delhi.

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

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

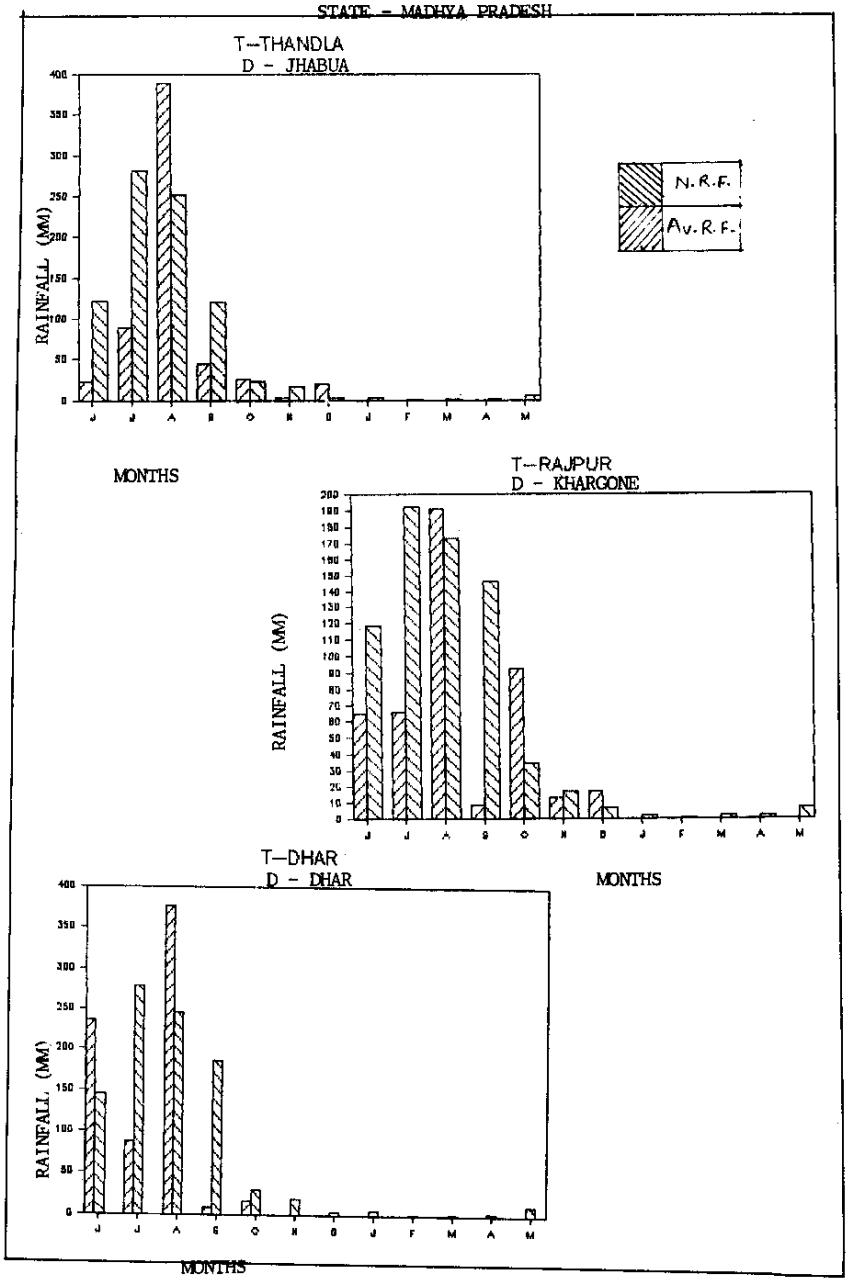
14. Water Resources of India, Central Water Commission (CWC) 1988.

Appendix II

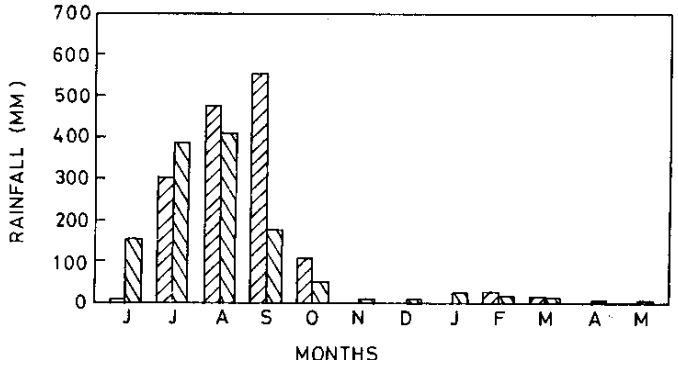
LIST OF OFFICES AND PLACES FROM WHERE DATA AND INFORMATION WERE COLLECTED IN STATE MADHYA PRADESH

Bhopal	Engineer in Chief, Irrigation Department.
	Director (D&H) Bodhi,Central Design Organization
	Chief Engineer,State Ground Water Survey Board
	Dy.Commissioner,Rural Development Commission
	Additional Director, Department of Agriculture
	Dy.Director Statistics, Department of Agriculture
	Chief Engineer, Public Health Engineering,Satpura
	Regional Meteorological Centre of IMD
	SE/EXN/AE,Narmada Tapti Basin,Irrig.Dept,Bhopal
	S.E.,Narmada Control Authority
	Regional Director, Central Ground Water Board
Dhar	District Collector
Jhabua	District Statistical Officer
Betul	Supdt.Land Records
Shahdol	
Sidhi	Superintending Engineer (Irrigation Circle)
	Deputy Director, Agriculture
	Assistant Geo-Hydrologist
	Executive Engineer, Public Health Engg.Division

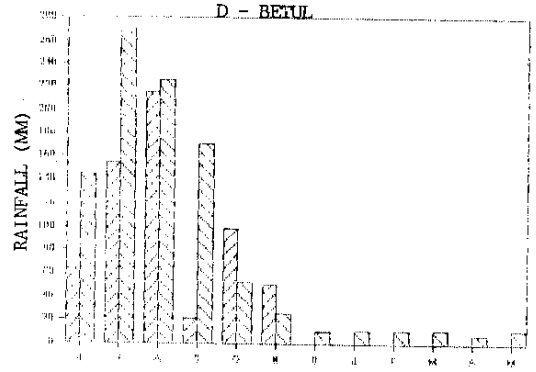
STATE - MADHYA PRADESH



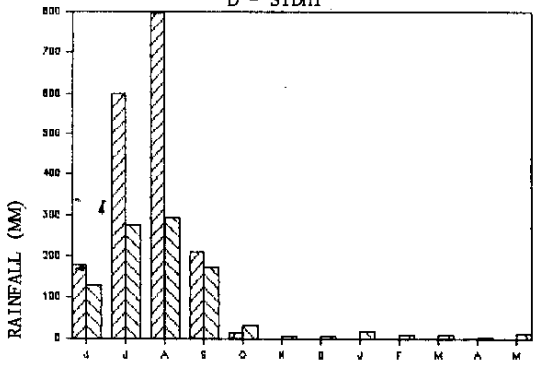
TALUK - BANDOGARH
DISTT. - SHAHDOL

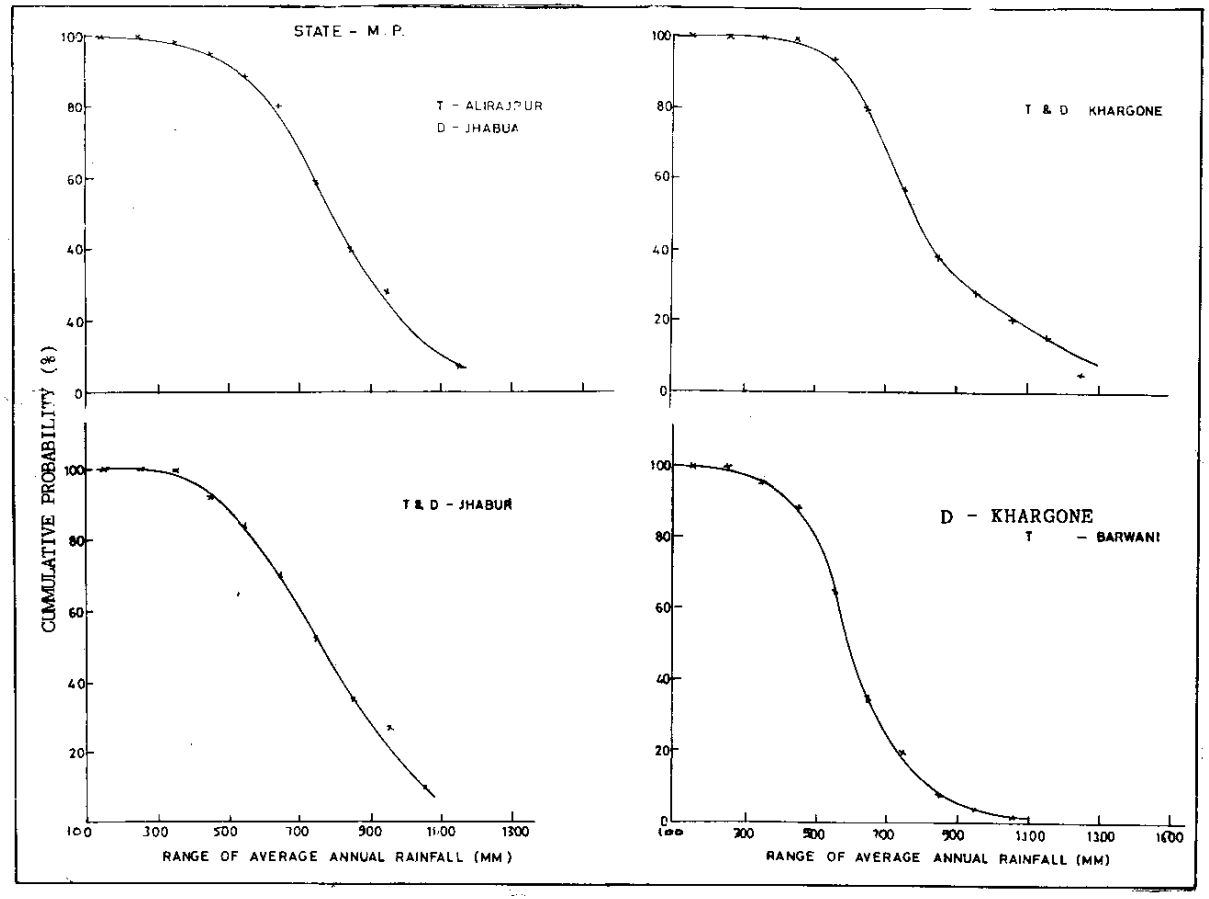


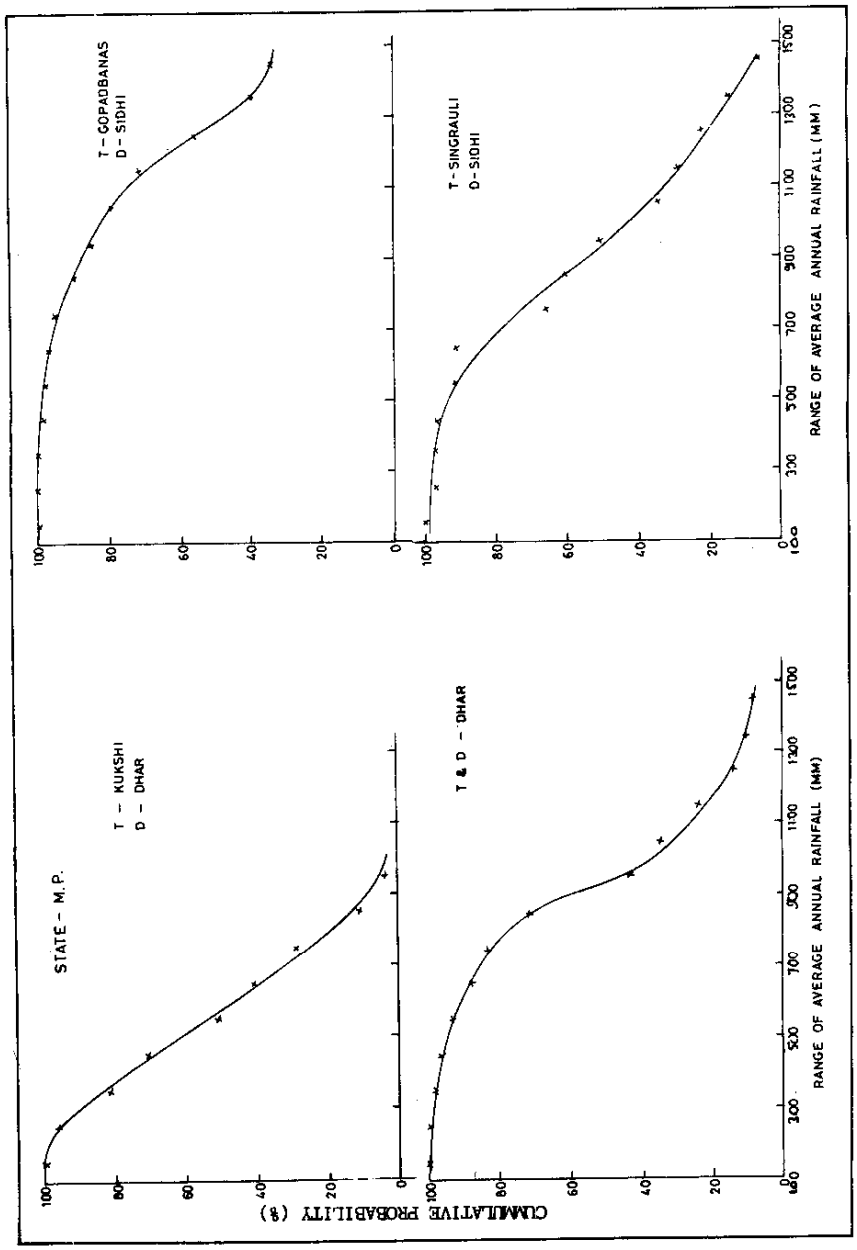
T-BHAINSDEHI
D - BETUL

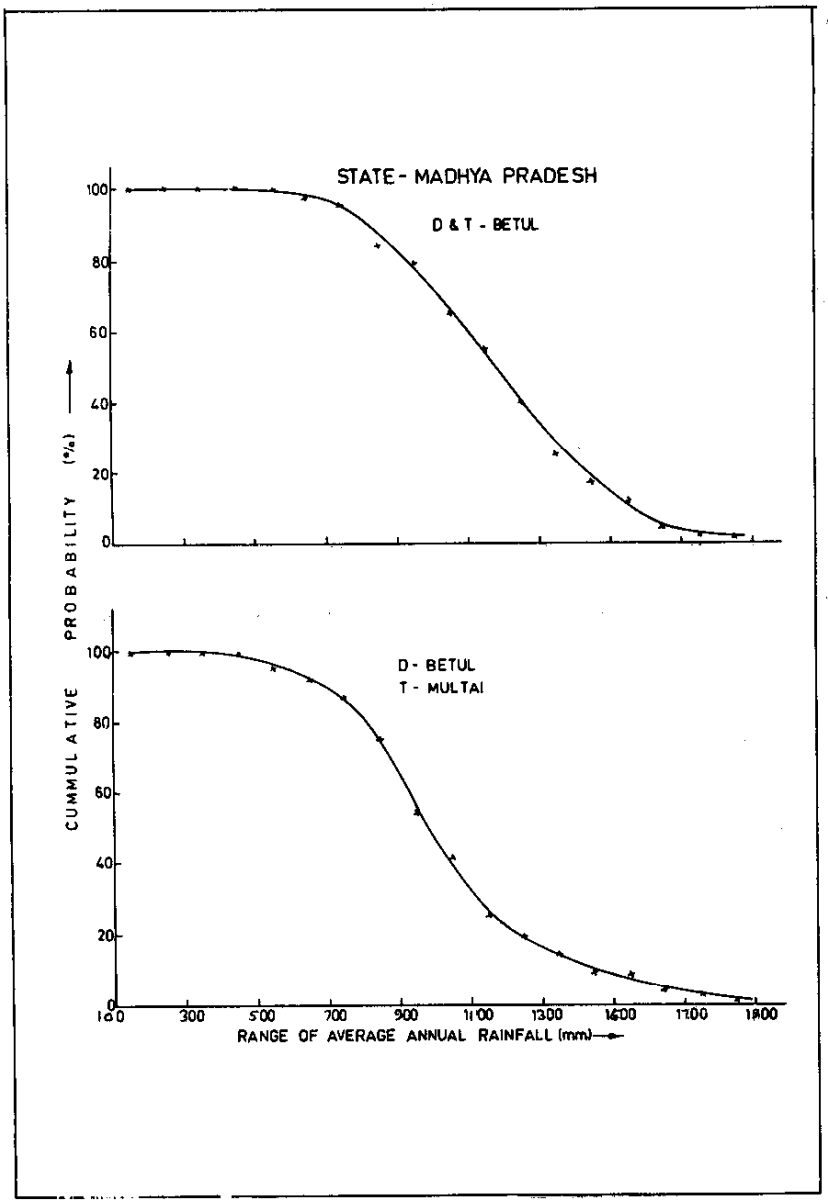


T-DEOSAR
D - SIDHI

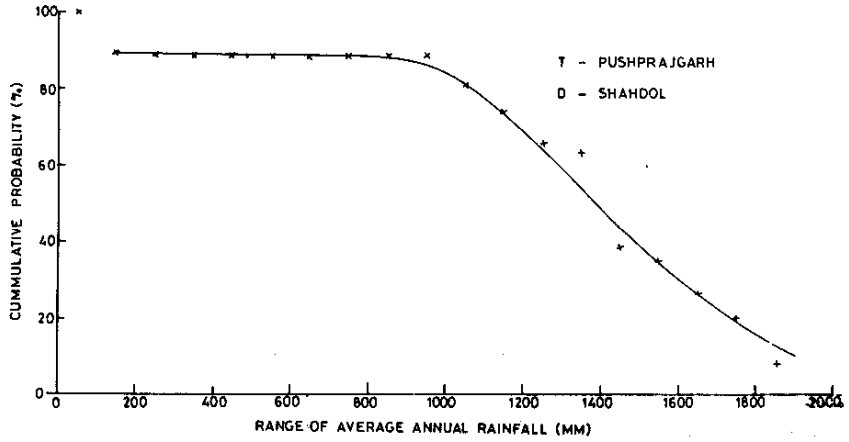


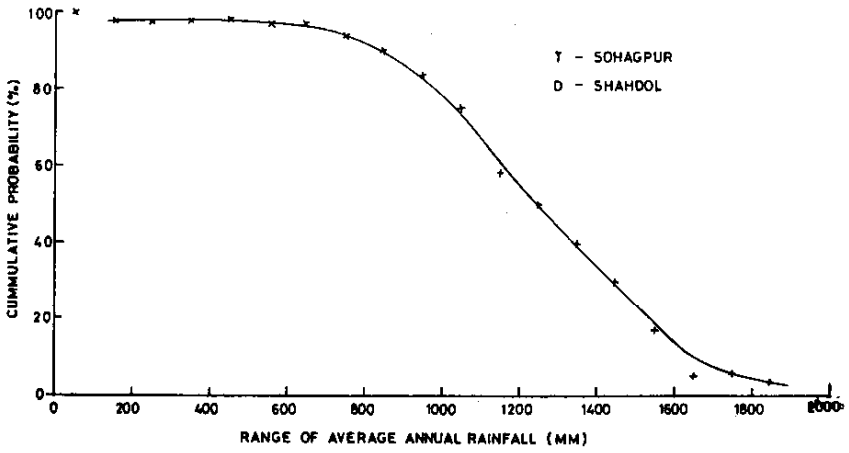

STATE - M. P.
T - ALIRAJPUR
D - JHABUA
T & D KHARGONE
T & D - JHABUA
D - KHARGONE
T - BARWANI
CUMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)


STATE - M.P.
T - KUKSHI
D - DHAR
T & D - DHAR
T - GOPADBANAS
D - SIDHI
T - SINGRAULI
D - SIDHI
CUMULATIVE PROBABILITY (%)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)
RANGE OF AVERAGE ANNUAL RAINFALL (MM)


STATE - MADHYA PRADESH
D & T - BETUL
D - BETUL
T - MULTAI
CUMMULATIVE PROBABILITY (%)
100
80
60
40
20
0
100
300
500
700
900
1100
1300
1600
1700
1900
RANGE OF AVERAGE ANNUAL RAINFALL (mm)

STATE MADHYA PRADESH





DROUGHT ANALYSIS FOR JHABUA DISTRICT OF STATE MADHYA PRADESH

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	2.703	3.053	3.013	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1952	2.979	3.056	3.015	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1953	2.979	3.056	3.015	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1954	2.979	3.056	3.015	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1955	2.979	3.056	3.015	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1956	2.979	3.056	3.015	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1957	0.000	0.000	0.000	0.000	0.000	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.447	0.346	0.000
1959	0.281	0.000	0.000	0.116	0.587	0.438	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	1.392	1.796	0.964	0.000	0.000	0.151	0.607
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.439	0.339	0.000
1962	2.727	3.053	3.013	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1963	2.979	3.056	3.015	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1964	2.979	3.056	3.015	2.987	2.910	1.419	2.214	2.514	2.407	2.033	2.129	2.548
1965	0.000	0.000	0.000	0.000	0.000	1.368	0.000	0.000	0.000	0.429	0.191	0.000
1966	0.000	0.000	0.000	0.000	0.000	0.166	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.000	0.811	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	0.000	0.000	0.000	0.000	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	0.000	0.000
1972	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.575	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	0.000	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	0.735	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.755	0.000	0.361	0.886	0.000	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.257	0.051	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.675	0.000	0.000	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	2	1957	74	2.26	167.38
12	1958	2	1961	27	0.47	12.68
12	1961	1	1967	62	1.40	86.99
6	1985	1	1986	8	0.33	2.64

DROUGHT ANALYSIS FOR KHARGONE DISTRICT OF STATE MADHYA PRADESH

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	[illegible]	2.793	5.162	5.166	2.983	2.200	4.132	4.059	2.755	2.917	3.137	1.885
1952	5.236	2.819	5.168	5.167	2.983	2.200	4.132	4.059	2.755	2.917	3.137	1.885
1953	5.236	2.819	5.168	5.167	2.983	2.200	4.132	4.059	2.755	2.917	3.137	1.885
1954	5.236	2.819	5.168	5.167	2.983	2.200	4.132	4.059	2.755	2.917	3.137	1.885
1955	5.236	2.819	5.168	5.167	2.983	2.200	4.132	4.059	2.755	2.917	3.137	1.885
1956	5.236	2.819	5.168	5.167	2.983	2.200	4.132	4.059	2.755	2.917	3.137	1.885
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	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	1.955	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	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	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	1.531	0.000	0.000	0.918	1.013	0.599	0.000
1966	0.000	0.000	0.000	0.000	0.000	0.993	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.000	1.204	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	0.000	0.000	0.000	0.000	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	0.000	0.000
1972	0.000	0.000	0.000	0.000	0.000	0.000	0.339	0.000	0.000	0.000	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000	1.591	0.000	0.000	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	0.016	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6.313	0.440	0.194	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	0.455	0.000	0.670	0.854	0.953	0.557	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	0.955	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	0.000	0.157	1.110	0.753	0.957	0.489	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.930	0.000	0.867	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	3	1957	75	3.36	251.97
5	1965	7	1968	39	0.26	10.12
5	1982	8	1983	16	0.33	5.27
5	1985	1	1986	9	0.61	5.52
7	1987	12	1987	6	0.54	3.21

DROUGHT ANALYSIS FOR DHAR DISTRICT OF STATE MADHYA PRADESH

MONTHLY INTENSITY OF EXCESS DEFICIT

Month Year	JAN	FEB	MARCH	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1951	[illegible]	[illegible]	[illegible]	[illegible]	1.180	2.349	3.562	3.443	2.419	2.194	1.098	1.080
1952	[illegible]	[illegible]	[illegible]	[illegible]	1.180	2.349	3.562	3.443	2.419	2.194	1.098	1.080
1953	[illegible]	[illegible]	[illegible]	[illegible]	1.180	2.349	3.562	3.443	2.419	2.194	1.098	1.080
1954	[illegible]	[illegible]	[illegible]	[illegible]	1.180	2.349	3.562	3.443	2.419	2.194	1.098	1.080
1955	[illegible]	[illegible]	[illegible]	[illegible]	1.180	2.349	3.562	3.443	2.419	2.194	1.098	1.080
1956	[illegible]	[illegible]	[illegible]	[illegible]	1.180	2.349	3.562	3.443	2.419	2.194	1.098	1.080
1957	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.180	0.478	0.255
1958	[illegible]	0.000	0.000	0.000	0.000	0.921	0.000	0.000	0.000	0.000	0.305	0.169
1959	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	[illegible]	0.000	0.000	0.000	0.000	0.000	0.181	0.000	0.000	0.516	0.555	0.268
1961	0.104	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.057	0.000	0.000	0.000	0.000	1.608	0.000	0.000	0.000	0.000	0.232	0.155
1963	0.076	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.411	0.232
1964	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.332	0.189
1965	[illegible]	0.000	0.000	0.000	0.000	2.054	0.000	1.937	1.856	1.761	0.845	0.400
1966	0.120	0.000	0.000	0.000	0.000	0.079	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.171	0.000	0.235	0.490	0.262
1968	[illegible]	0.000	0.000	0.000	0.000	1.393	0.000	0.000	0.000	0.000	0.282	0.196
1969	0.390	0.000	0.000	0.000	0.000	0.325	0.000	0.000	0.000	0.000	0.000	0.057
1970	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1972	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.318	0.767	0.613	0.310
1973	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	[illegible]	0.000	0.000	0.000	0.000	0.222	0.000	0.000	0.026	0.000	0.000	0.000
1975	[illegible]	0.000	0.000	0.000	0.000	0.000	0.731	0.000	0.000	0.000	0.069	0.099
1976	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	[illegible]	0.000	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.258	0.000	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.074	0.609	0.203	0.000
1981	[illegible]	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	0.000	0.000	0.000	6.595	0.000	0.000	0.000
1983	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.407	0.230
1985	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.506	0.173	0.000	0.000	0.000
1986	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.302	0.366	0.521	0.274
1987	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.623	0.000	0.556	0.305	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
1	1951	3	1958	87	2.45	215.52
5	1965	3	1966	11	1.47	16.18
3	1955	5	1956	14	0.18	2.54

DROUGHT ANALYSIS FOR SIDHI DISTRICT OF STATE MADHYA PRADESH

MONTHLY INTENSITY OF EXCESS DEFICIT

MON / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1951	0.539	0.571	0.511	0.453	0.348	0.000	1.749	0.000	0.000	0.000	0.408	0.348
1952	0.575	0.576	0.513	0.454	0.348	0.000	0.000	0.000	1.256	1.228	0.962	0.429
1953	0.577	0.576	0.513	0.454	0.348	0.265	0.000	0.000	0.000	0.000	0.194	0.317
1954	0.574	0.575	0.513	0.454	0.348	0.763	2.784	3.745	0.563	0.963	0.853	0.413
1955	0.577	0.576	0.513	0.454	0.348	0.000	0.000	0.000	0.000	0.670	0.732	0.395
1956	0.576	0.576	0.513	0.454	0.348	0.000	0.000	0.000	0.000	0.000	0.133	0.308
1957	0.574	0.575	0.513	0.454	0.348	0.000	0.000	0.000	0.000	0.165	0.523	0.365
1958	0.575	0.576	0.513	0.454	0.348	0.393	0.396	3.020	1.683	1.392	1.030	0.438
1959	0.577	0.576	0.513	0.454	0.348	1.643	0.148	0.000	0.000	0.515	0.668	0.386
1960	0.576	0.576	0.513	0.454	0.348	1.205	0.000	0.000	0.328	0.872	0.815	0.407
1961	0.600	0.598	0.596	0.558	0.459	0.000	0.152	1.293	0.000	0.226	0.623	0.503
1962	0.579	0.576	0.513	0.454	0.348	1.899	2.134	1.942	0.000	0.000	0.374	0.343
1963	0.573	0.576	0.513	0.454	0.348	0.000	0.253	0.066	0.666	1.002	0.869	0.415
1964	0.577	0.576	0.513	0.454	0.348	0.000	0.000	0.000	0.000	0.342	0.596	0.375
1965	0.576	0.576	0.513	0.454	0.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	0.577	0.576	0.513	0.454	0.348	2.135	1.936	3.404	2.064	1.538	1.090	0.447
1967	0.578	0.576	0.513	0.454	0.348	0.000	1.350	0.088	3.344	2.028	1.293	0.477
1968	0.573	0.575	0.513	0.454	0.348	0.654	0.000	0.000	0.000	0.000	0.000	0.285
1969	0.578	0.576	0.513	0.454	0.348	0.772	2.728	1.884	2.845	1.837	1.214	0.465
1970	0.000	0.000	0.000	0.000	0.290	0.000	0.068	0.000	0.000	0.391	0.617	0.378
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.615	0.000	0.000	0.000	0.264
1972	0.571	0.000	0.000	0.339	0.342	0.765	0.000	0.000	0.000	0.000	0.000	0.222
1973	0.539	0.000	0.000	0.369	0.000	0.536	2.411	0.754	0.000	0.000	0.000	0.000
1974	0.565	0.000	0.015	0.379	0.000	0.174	0.000	0.155	2.442	0.000	0.000	0.000
1975	0.000	0.080	0.000	0.000	0.292	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.336	0.000	0.000	1.088	0.000	0.363	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	0.682	0.737	0.396
1978	0.000	0.000	0.000	0.000	0.158	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.000	0.000	0.305	0.813	0.498	1.518	3.326	2.022	0.000	0.145
1980	0.000	0.316	0.448	0.444	0.058	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	0.000	0.000	0.000	0.000	0.335	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	0.000	0.000	0.804	0.000	0.000	0.000	0.000
1985	0.000	0.404	0.470	0.253	0.000	0.000	0.945	0.000	0.397	0.000	0.000	0.273
1986	0.000	0.000	0.000	0.000	0.165	0.486	0.000	0.000	0.000	0.000	0.000	0.171
1987	0.000	0.000	0.000	0.000	0.000	0.000	1.395	0.667	0.973	0.000	0.000	0.000
						0.361	1.245	0.000	0.000	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
10	1953	6	1956	33	0.87	28.60
10	1957	7	1960	34	0.78	26.63
9	1960	7	1967	83	0.84	69.88
11	1967	1	1970	27	1.10	29.80
1	1973	11	1974	23	0.67	15.48
3	1979	11	1979	0	1.44	12.97
0	1986	12	1986	7	0.72	5.07

DROUGHT ANALYSIS FOR BETUL DISTRICT OF STATE MADHYA PRADESH

MONTHLY INTENSITY OF EXCESS DEFICIT

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951	0.000	0.111	0.000	0.162	0.448	0.000	0.000	0.000	0.000	0.000	0.000	0.358
1952	0.751	0.000	0.000	0.000	0.219	0.000	0.000	0.614	0.981	0.987	0.968	0.523
1953	0.512	0.520	1.220	0.000	0.000	0.715	0.000	0.000	0.000	0.000	0.176	0.553
1954	0.000	0.000	0.000	0.313	0.000	0.000	0.000	0.000	0.000	0.000	0.285	0.573
1955	0.000	0.164	0.000	0.000	0.417	0.000	0.000	0.000	0.000	0.000	0.000	0.358
1956	0.330	0.382	1.006	0.955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	1.482	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.500	1.557	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.329	0.581
1959	0.000	0.483	1.213	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019
1960	0.000	0.000	0.000	0.127	0.268	0.000	0.000	0.000	0.000	0.000	0.000	0.172
1961	0.323	0.000	0.284	0.000	0.000	0.000	0.000	0.000	0.773	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	2.333	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	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	0.128	0.000	0.000	0.000	0.129	0.544
1965	0.000	0.243	0.000	0.000	0.592	0.000	0.000	0.000	0.000	0.000	0.605	0.631
1966	0.000	0.508	0.000	0.000	0.145	0.000	0.000	0.071	0.071	0.946	0.955	0.395
1967	0.144	0.529	0.000	0.467	0.000	2.099	0.000	0.794	0.050	1.169	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.631	0.000	0.000	0.602	0.691	1.458	1.115	0.000
1969	0.000	0.394	1.198	0.983	0.111	0.000	0.000	0.000	0.000	0.563	0.836	0.647
1970	0.000	0.460	0.000	0.000	0.661	0.157	0.000	0.000	0.000	0.086	0.000	0.361
1971	0.784	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.378	0.590
1972	0.783	0.578	1.230	0.988	0.000	0.000	0.000	0.000	0.000	0.000	0.340	0.583
1973	0.614	0.000	0.000	0.743	0.710	0.000	0.000	0.000	0.000	0.331	0.000	0.000
1974	0.753	0.373	1.194	0.943	0.691	0.000	0.000	0.000	0.000	0.000	0.026	0.375
1975	0.356	0.000	0.000	0.681	0.000	0.977	0.000	0.000	0.042	0.000	0.000	0.401
1976	0.638	0.567	0.000	0.000	0.439	0.000	0.000	0.000	0.000	0.000	0.000	0.436
1977	0.649	0.508	0.000	0.352	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	0.448	0.000	0.631	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.655	0.904	0.479	0.000	0.000	0.000	1.177	1.658	0.417	0.000
1980	0.626	0.566	1.228	0.988	0.248	0.839	1.490	0.000	0.090	0.808	0.000	0.000
1981	0.539	0.695	1.465	1.306	0.710	0.000	0.000	0.000	0.760	1.486	1.078	0.000
1982	1.043	0.733	1.472	1.307	0.949	3.583	4.711	5.253	3.210	2.531	1.546	0.955
1983	1.043	0.733	1.472	1.307	0.949	3.583	4.711	5.253	3.210	2.531	1.546	0.955
1984	1.043	0.733	1.472	1.307	0.949	3.583	4.711	5.253	3.210	2.531	1.546	0.955
1985	0.345	0.544	1.224	0.000	0.228	0.000	0.000	0.000	0.000	0.000	0.000	0.358
1986	0.751	0.000	0.000	0.341	0.659	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.379	0.547	1.225	0.987	0.710	0.972	2.099	0.000	1.202	0.000	0.000	0.000

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
8	1952	8	1953	13	0.52	6.75
8	1965	12	1967	29	0.46	13.32
5	1978	2	1986	94	1.99	187.01
9	1986	12	1987	16	0.68	10.85

DROUGHT ANALYSIS FOR SHAHDOL DISTRICT OF STATE MADHYA PRADESH

Monthly Intensity of Excess Deficit

Month / Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1951	0.336	0.000	0.000	0.000	0.000	0.000	1.369	0.000	0.000	0.000	0.066	0.636
1952	1.085	0.000	0.000	0.001	0.525	0.000	0.000	0.000	0.000	0.368	1.253	0.145
1953	0.216	1.066	1.216	1.029	1.019	1.906	0.000	0.000	0.000	0.174	1.161	0.722
1954	0.000	0.663	0.000	0.696	0.996	0.718	0.776	1.271	0.000	1.014	1.555	0.562
1955	0.000	0.000	0.462	0.879	0.629	0.000	0.398	0.000	0.000	0.000	0.000	0.529
1956	0.221	0.000	0.227	0.826	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.965	1.816	0.000	0.000	0.000	0.767	0.000	0.000	1.412	1.500	1.783	0.771
1958	0.080	0.000	0.000	0.710	0.997	0.819	0.000	0.843	0.000	0.000	0.000	0.517
1959	0.000	0.833	1.165	1.024	0.000	1.225	0.000	0.000	0.000	0.000	0.330	0.657
1960	0.000	0.858	0.000	0.396	0.977	0.187	0.000	0.000	0.881	0.000	0.000	0.595
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	1.036	0.000	0.000	0.060	0.376	0.879	0.000	0.000	0.000	1.516	1.791	0.000
1963	0.470	0.203	0.491	0.000	0.000	0.000	0.157	0.253	0.000	0.000	0.000	0.092
1964	1.064	0.000	1.037	0.994	0.739	0.000	0.000	0.000	0.000	0.000	0.000	0.473
1965	1.079	1.845	0.671	0.426	0.939	0.000	0.095	3.061	0.000	0.476	1.303	0.000
1966	0.813	1.746	1.302	1.921	0.000	0.000	0.000	1.464	3.890	2.324	0.000	0.619
1967	1.085	1.842	0.000	0.000	0.751	0.000	0.000	0.000	0.000	0.000	0.946	0.000
1968	0.000	0.000	0.615	0.949	0.088	0.652	0.551	2.324	1.396	1.412	1.742	0.660
1969	0.314	1.075	1.216	0.611	0.000	0.000	0.000	0.000	0.000	1.178	0.000	0.253
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.406	0.000	0.000	0.314	0.327	0.066
1971	0.000	0.826	0.000	0.000	0.000	0.000	0.000	0.000	1.064	0.000	0.000	0.575
1972	1.083	0.000	0.943	0.000	0.761	2.184	0.460	0.000	0.000	0.000	0.000	0.000
1973	1.032	0.201	1.106	0.778	1.002	2.230	3.289	2.831	2.535	0.000	0.197	0.558
1974	0.366	0.000	0.000	0.409	0.322	0.000	0.690	0.000	1.666	0.598	1.360	0.738
1975	0.000	0.316	0.000	0.259	0.177	0.000	0.000	0.000	0.000	0.000	0.000	0.547
1976	0.000	1.316	0.979	0.000	0.020	2.183	4.152	3.412	3.680	2.836	0.576	0.000
1977	0.333	0.725	0.000	0.448	0.419	0.000	0.000	0.000	0.000	0.000	0.000	0.329
1978	0.367	0.000	0.522	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.008	0.036	0.000	0.676	0.757	1.091	3.142	3.648	2.646	0.000	0.206
1980	0.457	0.400	0.496	0.794	0.704	0.000	0.000	0.000	0.000	0.000	0.982	0.000
1981	0.000	1.255	0.000	0.719	0.000	0.000	0.857	1.843	0.981	1.626	0.000	0.000
1982	0.000	0.000	0.000	0.553	0.000	0.452	1.075	0.000	0.404	1.037	0.000	0.000
1983	1.032	0.000	0.645	0.000	0.000	0.267	0.000	0.904	0.000	0.000	0.000	0.000
1984	0.000	0.000	0.563	0.000	0.000	0.033	2.641	0.000	0.000	0.000	0.685	0.700
1985	0.000	0.000	0.735	0.105	0.703	0.000	0.000	0.000	0.000	0.516	0.948	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.536	2.257	2.175	0.535	0.000	0.000	0.000	0.570

DROUGHT BEGAN		DROUGHT TERMINATED		DROUGHT DURATION	DROUGHT INTENSITY	SEVERITY INDEX
MONTH	YEAR	MONTH	YEAR			
10	1953	9	1955	24	0.44	10.51
6	1957	10	1958	17	0.46	7.77
12	1964	3	1967	28	1.09	30.44
3	1968	6	1969	16	0.99	15.89
9	1971	7	1975	47	0.91	42.77
12	1975	6	1977	19	2.13	40.44
1	1979	8	1980	19	1.42	25.80
7	1981	9	1983	27	0.62	16.72
5	1987	12	1987	8	1.05	8.62

APPENDIX III-4(a)

DURATION & NUMBER OF DRY SPELLS DURING MONSOON (4 JUNE TO 15 SEP)

ALIRAJPUR (JHABUA)				BARWANI(KHARGONE)			
First day of monsoon	Date of beginning 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 beginning of dry spell	Duration dry spell (2 weeks in days	Total no.of dry spell in a year
24.6.81	4.6.81	20	1	24.6.81	4.6.81	20	2
					21.7.81	16	
20.6.82	4.6.82	16	3	20.6.82	4.6.82	16	3
	21.6.82	22			21.6.82	20	
	25.8.82	16			17.8.82	24	
3.7.83	4.6.83	29	1	16.6.83	31.8.83	15	1
18.6.84	4.6.84	14	2	15.6.84	16.6.84	15	1
	21.8.84	26					
7.6.85	8.6.85	38	2	24.6.85	4.6.85	20	4
	7.8.85	40			27.6.85	20	
					15.8.85	14	
					30.8.85	17	
6.6.86	No Dry Spell-			15.6.86	26.6.86	22	2
					17.8.86	30*	
17.6.87	18.7.87	19	2	16.6.87	18.6.87	21	3
	2.9.87	14*			16.7.87	14*	
					2.9.87		
			---				-----
			11				16
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GOPADBANAS (SIDHI)				DHAR(DHAR)			
6.6.81	7.6.81	16	1	24.6.81	4.6.81	20	2
					16.8.81	15	
5.6.82	-	-	Nil	16.6.82	23.6.82	16	2
					24.8.82	23	
13.6.83	-	-	-	16.6.83	-	-	-
11.6.84	-	-	-	9.6.84	16.6.84	14	1
12.6.85	13.6.85	14	1	6.6.85	8.6.85	19	1
					28.6.85	20	
					17.8.85	27	
21.6.86	4.6.87	17	1	16.6.86	29.8.86	18	1
29.6.87	4.6.87	25	2	15.7.87	9.7.87	28	2
	14.7.87	15			1.9.87	15*	
			5				11

BETUL (BETUL)				SOHAGPUR (SHAHDOL)			
21.6.81	4.6.81	17	2	Date Not available			
	17.8.81	16					
5.6.82	1.7.82	31	1	14.6.82	No dry spell		
12.6.83	-	-	-	9.6.83	No dry spell		
7.6.84	12.6.84	19	1	5.6.84	No dry spell		
6.6.85	-	-	-	26.6.85	4.6.85	22	1
19.6.86	4.6.86	15	2	20.6.86	4.6.86	16	2
	19.8.86	18			22.8.86	20	
16.6.87	14.7.87	15	1	26.6.87	4.6.87	22	1
			7				4

APPENDIX III-4 (b)

PROBABILITY ANALYSIS OF DRY SPELLS

Taluk/station (district)	Class Interval (in days)	No. of spells	Percentage	Cummul ative probability
Alirajpur (Jhabua)	14-21	6	54.5	100.0
	22-28	2	18.2	95.5
	29-35	1	9.1	27.3
	>735	2	18.1	18.2
		11		
Barwani (Khargone)	14-21	13	81.3	100.0
	22-28	2	12.5	18.8
	29-35	1	6.3	6.3
	>735	-	-	-
		16		
Dhar (Dhar)	14-21	8	72.7	100.0
	22-28	3	27.3	27.3
	29-35	-	-	-
	>735	-	-	-
		11		
Gopad Banas (Sidhi)	14-21	4	80.0	100.0
	22-28	1	20.0	20.0
	29-35	-	-	-
	>735	-	-	-
		5		
Betul (Betul)	14-21	6	85.7	100.0
	22-28	-	-	14.3
	29-35	1	14.3	14.3
	>735	-	-	-
		7		
Sohagpur (Shahdol)	14-21	2	50.0	100.0
	22-28	2	50.0	50.0
	29-35	-	-	-
	>735	-	-	-
		4		

LIST OF OBSERVATION WELL

STATE-MADHYA PRADESH
DISTT- BETUL

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1	42	MULTAI			757.360		0.2525
2	4	BHAINSDEHI			624.45		0.3267
3	25	BETUL			647.345		0.420

STATE-MADHYA PRADESH
DISTT- SHAHDOL

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	18	KHAIRAHA	23 08 00	81 26 00	504.011		0.2124
2.	25	JAISINGHNAGAR	23 41 30	81 23 30	503.018		0.1327
3.	32	BUDAWA	24 13 00	81 24 45	306.825		0.0973
4.	34	JAMUNIHA	23 17 45	81 47 30	522.271		0.1947
5.	40	BANDHAWABARA	23 18 00	81 14 30	471.277		0.0885
6.	43	SASTARA	23 24 00	80 58 15	450.703		0.1416
7.	49	TALA	23 43 00	81 02 00	472.329		0.1328

LIST OF OBSERVATION WELL

STATE-MADHYA PRADESH
DISTT-DHAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		BADNAWAR			560.350	1098	0.1340
2.		SARDARPUR			530.000	1480	0.1806
3.		KUKSHI			195.310	1464	0.1786
4.		MANAWAR			195.340	1859	0.2268
5.		DHAR			557.350	2295	0.2800

LIST OF OBSERVATION WELL

STATE-MADHYA PRADESH
DISTT-JHABUA

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		KATHIWADA	22 30 00	74 12 00	223.690	613.00	0.0904
2.		UDAIGARH	22 32 00	74 55 00	402.980	663.00	0.0978
3.		KATHIWAD	22 08 00	74 16 00	522.170	1133.00	0.1671
4.		DUNGRIPADA	22 03 00	74 42 00	284.165	246.00	0.0363
5.		ALIRAJPUR	22 18 00	74 22 00	279.230	621.00	0.0916
6.		RANAPUR	22 40 00	74 53 00	551.735	874.00	0.1289
7.		NANPUR	22 17 00	74 33 00	250.705	425.00	0.0627
8.		BHAMEL	23 08 00	74 41 00	395.745	279.00	0.0411
9.		THANDLA	23 02 00	74 35 00	398.180	589.00	0.0868
10.		RALIYAWAN	22 58 00	74 47 00	398.690	819.00	0.1208
11.		UMARKOT	22 44 00	74 49 00	496.355	519.00	0.0765

STATE-MADHYA PRADESH
DISTT-KHARGONE

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		BHASANER	21 44 00	75 31 00	267.250	1507	0.1117
2.		BISTAN	21 43 00	75 43 00	309.410	1317	0.0976
3.		BALKAWADA	22 00 00	75 32 00	216.930	928	0.0688
4.		SEGAON	21 51 00	75 21 00	270.360	661	0.0490
5.		SENDHWA	21 14 00	75 05 00	397.675	1314	0.0974
6.		KHETIYA	21 40 00	75 36 00	199.980	851	0.0631
7.		RAJPUR	21 56 00	75 06 00	234.900	611	0.0453
8.		BARWANI	22 02 00	74 52 00	179.095	924	0.0685
9.		DAWANA	22 05 00	75 17 00	162.670	517	0.0383
10.		BHIKANGAON	21 52 00	75 56 00	276.515	905	0.0671
11.		ZIRNA	21 39 00	75 57 00	303.150	1485	0.1101
12.		BARWAHA	22 15 00	76 04 00	188.660	1075	0.0797
13.		BARWAHA	22 24 00	75 53 00	240.285	642	0.0476
14.		MANDESHWAR	22 [illegible] 00	75 35 00	156.675	753	0.0558