केन्द्रीय भूमि जल बोर्ड
जल संसाधन, नदी विकास और गंगा संरक्षण
विभाग, जल शक्ति मंत्रालय
भारत सरकार
Central Ground Water Board
Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

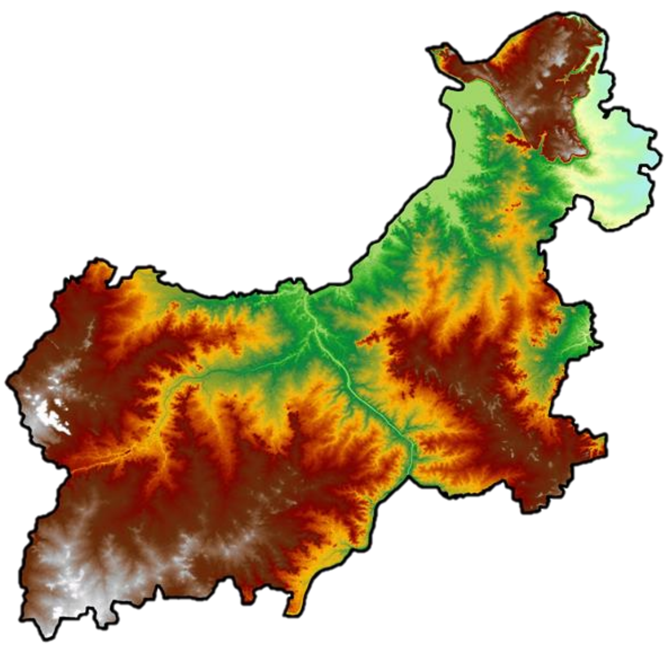
AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

MANDSAUR DISTRICT
MADHYA PRADESH

उत्तर मध्य क्षेत्र, भोपाल
North Central Region, Bhopal

REPORT ON

"AQUIFER MAPPING AND MANAGEMENT PLAN OF GROUNDWATER RESOURCES"
MANDSAUR DISTRICT, MADHYA PRADESH



SUBMITTED BY,

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PREFACE

Aquifer mapping can be defined as a scientific process, wherein a combination of geologic, geophysical, hydrologic, and chemical field and laboratory analyses are applied to characterize the quantity, quality, and sustainability of groundwater in aquifers. Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the portability of groundwater. Results of these studies will contribute significantly to resource management tools such as long-term aquifer monitoring networks and conceptual and quantitative regional ground-water-flow models used by planners, policymakers, and other stakeholders.

Under the project on National Aquifer Mapping (NAQUIM), Central Ground Water Board (CGWB) North Central Region, Bhopal has taken up Mandsaur district to prepare the Aquifer Maps for the entire district and formulate Aquifer Management Plan. Out of 552330 ha of geographical area, 499047 ha (90%) is ground water recharge worthy area and 53283 is hilly area (10%). Rivers of Chambal Sub-basin drain the entire Mandsaur district. Most part of the district is underlain mainly basaltic lava flows of Deccan trap. As per the Dynamic Ground Water Resource Assessment Report (March 2020), The annual extractable ground water resource of the district is 60359.85 ham and ground water extraction for all uses is 64748.93 ham, making stage of ground water extraction 107.27% as a whole for the district. After successful implementation of the supply-side and demand-side management plan the stage of extraction in Mandsaur district is expected to improve condition of the district in terms of ground water. The interventions suggested in the report will not only have a positive impact on the groundwater regime but would also play a key role in augmenting the net cropping area and would ultimately enhance the agricultural productivity and economy of the district.

I would like to place on record my appreciation of the untiring efforts **Ms. Maria Dominic, Scientist-B** for preparing the Aquifer maps and Management plan and compiling this informative report. I fondly hope that this report will serve as a valuable guide for the sustainable development of Ground Water in the Mandsaur District, Madhya Pradesh.

Rana Chatterjee
(Regional Director)

CONTENTS

ANNEXURES

LIST OF FIGURES

LIST OF TABLES

Chapter-1

INTRODUCTION

1.1 Location:

Mandsaur district is located on northwest part of Madhya Pradesh state. It is one of the important tribal district of Malwa regions of Madhya Pradesh. The district is bounded by Neemuch district in the north, Ratlam district in the south, Banswara district of Rajasthan state in the west and Jhalawar district of Rajasthan state in the east. The district area extends between the parallels of latitude 23^0 46' and 24^0 45' North and between the meridians of longitude 74^0 44' and 75^0 54' East, and it is falling in the Survey of India Topo Sheet No. 45P and 46M. In past three decades industries had rapidly grown up in the district. Mandsaur is mainly agriculture-based district and its cropping pattern is diversified. Mandsaur district is well connected by roads and rail. The total geographical area of the district is 5535 Sq.Km, with a population of 1340411 according to census 2011. The district is divided into 8 tehsils and 5 blocks. The details of administrative units are given in Table.1. The details of administrative units are also has been depicted in Fig.1.

Table.1: Administrative units of Mandsaur district

S.No	Block	Tehsil	Area in Sq Km	No. of Villages Panchayats
1	Bhanpura	Bhanpura	1051	45
2	Garoth	Garoth	1136	47
3	Malhargarh	Malhargarh	806	78
4	Mandsaur	Mandsaur	1266	119
5	Sitamau	Sitamau	1276	106
		Total	5535	439

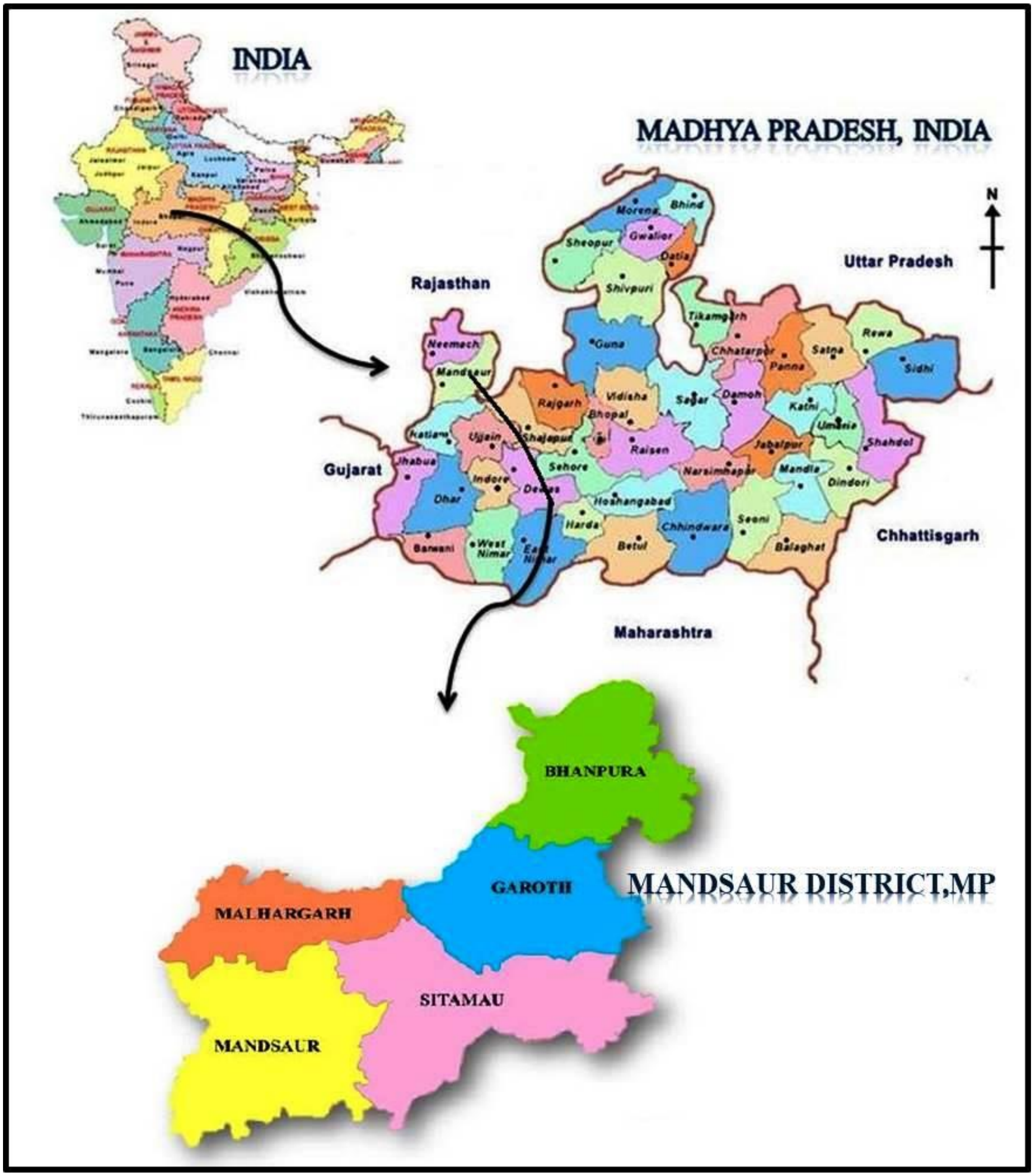

Fig.1 Index Map of Mandsaur District

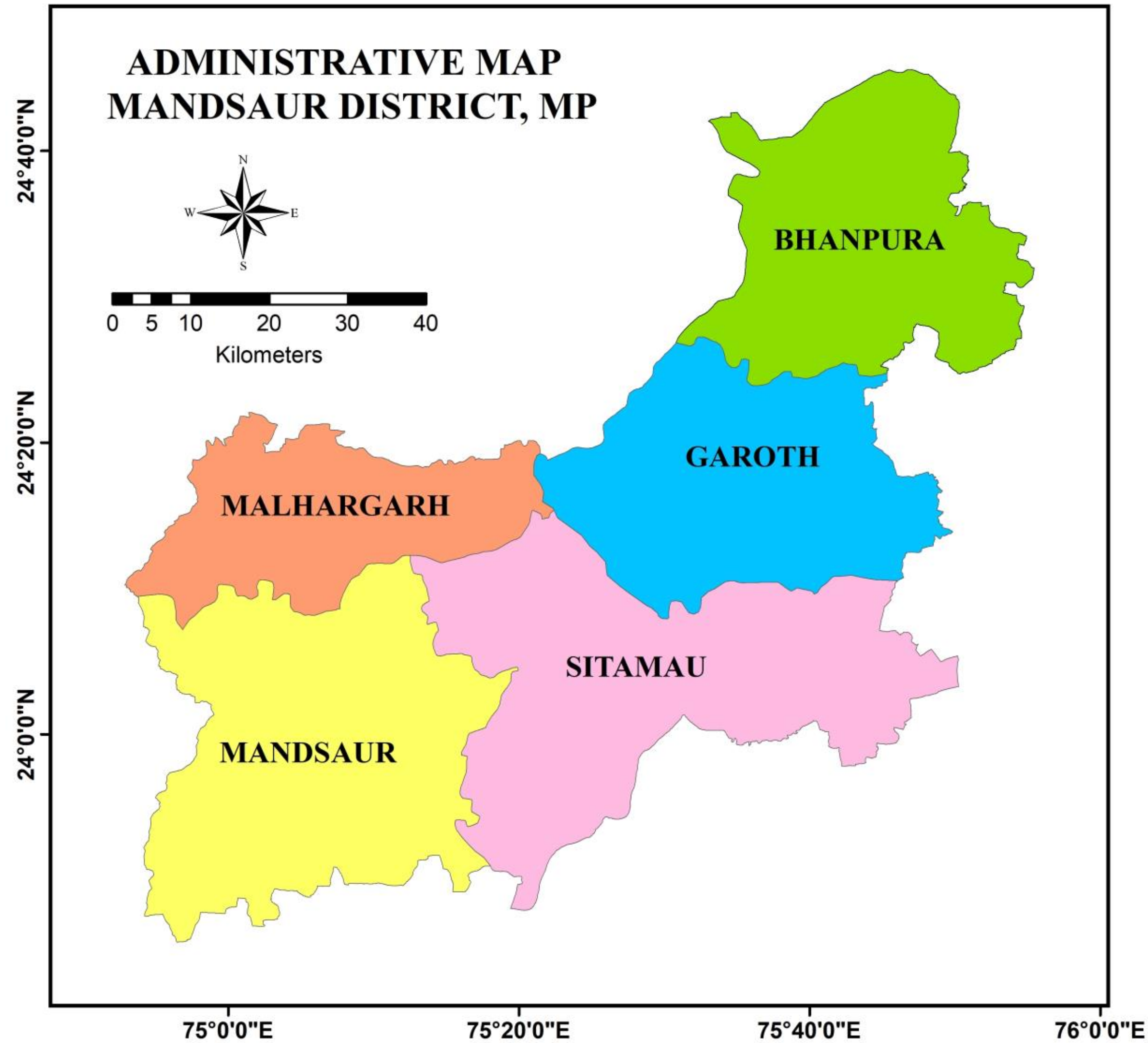

Fig.2 Administrative Map of Mandsaur District

1.2 Objectives and Approach:

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. By analyzing the existing data and the data generated, regional hydrogeological maps, thematic maps, water quality maps, cross-sections, 2-D and 3 –D aquifer dispositions were generated. The primary objective of the Aquifer is to "Know your Aquifer, Manage your Aquifer".

Aquifer Mapping can be envisaged as follows:

- **Data Compilation & Data Gap Analysis:**

One of the important aspect of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled, analysed, examined, synthesized and interpreted from available sources. These sources were predominantly non computerized data, which was converted into computer based GIS data sets. On the basis of available data, Data Gaps were identified.

- **Data Generation:**

There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping.

- **Previous studies:**

Prior to this study, the groundwater hydrogeology has been studied only in separate parts with many areas left untouched. As a result, there was no hydrogeologic framework developed so as to understand the regional effects of groundwater development in the area .

- **Preparation of Plan:**

Preparation of Block wise ground water management plan of the Mandsaur district that will guide the planers to manage the ground water resources in judicious manner and improve the ground water scenario of the district.

1.3 Rainfall and Climate:

Decadal rainfall data from IMD were analyzed from the year 2010 to 2020 (Fig.3). The lowest annual rainfall was recorded in the year 2010 (mm) and the highest average rainfall was recorded in the year 2019 (mm). During the last decade highest rainfall of August was recorded in the year 2019 (788.93 mm) and lowest was recorded in the year 2010.

About 90 % of the rainfall takes place from June to September, only 5 - 8% takes place in the winter months and only about 2% in summer. It is only during the monsoon that surplus water for deep percolation is available in the district. The normal rainfall follows a normal distribution during the year.

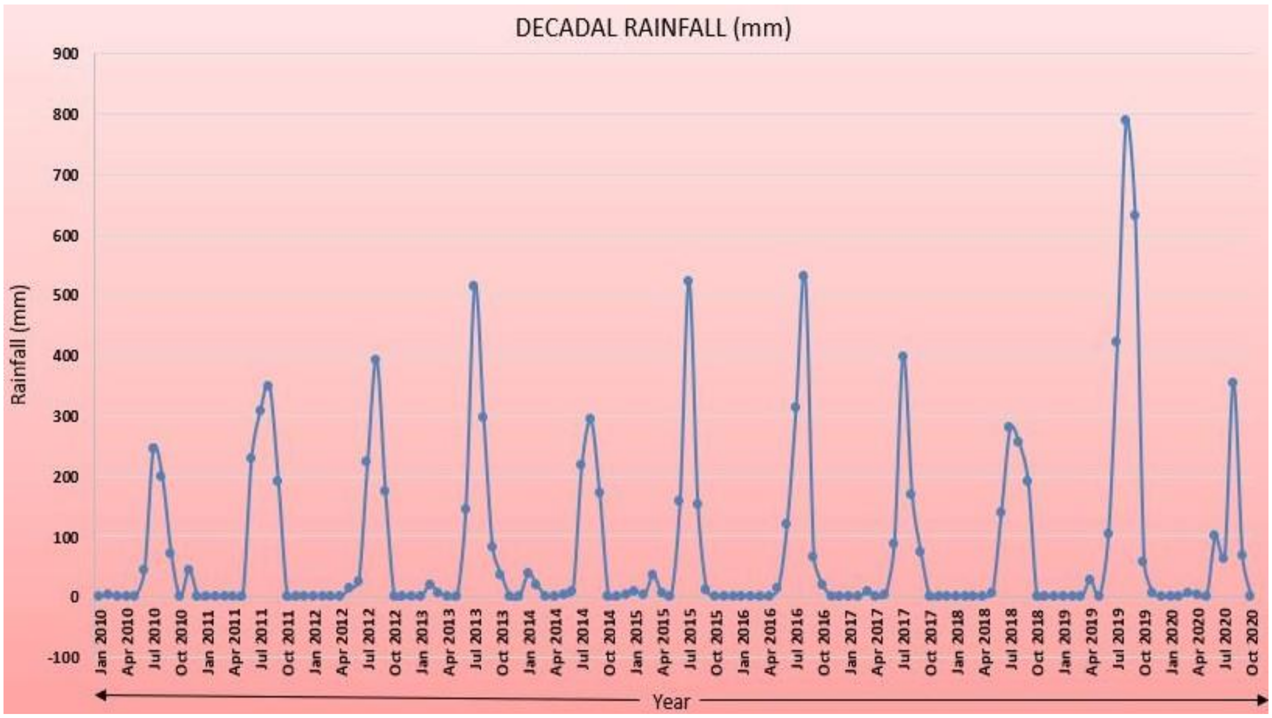

Fig.3 Decadal Rainfall map of Mandsaur district

The climate of the Mandsaur district is semi-tropical characterized by hot summer and well-distributed rainfall during the southwest monsoon. The year can be divided in four seasons. The winter commences from December and last up to February. January is the coldest month with temperature falling 9.8^0 C. The period from March to first week of June is the summer season. May is the hottest month when the temperature may go up to 39.8 ^{0} C. The monsoon starts from middle of June to the first week of October. October and November constitute the post monsoon or retreating monsoon period. During the southwest monsoon season the relative humidity generally exceeds 87 % (August month). The driest part of the year is the summer season, when relative humidity is less 26%. April is the driest month of the year.

The wind velocity is higher during the pre-monsoon period as compared to post monsoon period. The maximum wind velocity 16.7 km/hr observed during the month of June and minimum 4.7 km/hr during the month of November. The average normal annual wind velocity of Mandsaur district is 9.2 km/hr.

1.4 Geomorphology and Soil Types:

Physiographically, the major parts of the district covered by Malwa Plateau, by gently sloping topography ranging the elevation between 445 m and 518 m above mean sea level. Topographic high plateau form surface water divides. Main surface water divide separates Chambal sub basin from Shiva micro-basin. Shivna is tributary of Chambal River is running ENE-WSW direction in southwestern parts of the area. Physiography map of Mandsaur district is given in fig.4.

The highest elevation of the area is noticed on northwest corner of the area near village Rewas Dewda (24^0 07': 74^0 57') with an elevation of 560 m above mean sea level, which represent hills comprising sedimentary formation. The lowest elevation is 416 m above mean sea level marked north of village Pipalda (24^0 37': 75^0 38') in northern parts of the district. Prominent isolated residual hillocks formed of Deccan Trap basalt are observed in north part of Bhanpura town is forming northern plateau area, consisting of Vindhyan formation. Northern plateau area is highly undulating in topography and forming escarp running northwest, southeast direction. Highest elevation of the escarpment is 510 m above mean sea level, located north of village Kotri.

The soils in the district are generally of four types:

1. Black cotton soil
2. Red loamy soil
3. Laterite soil
4. Alluvial soil

Black cotton soil is derived from weathering and disintegration of basaltic lava flow. Major parts of the district are covered by black cotton soil. Red loamy soils consist of sandy loam to clayey loam and brick in colour. This soil is derived from Vindhyan sandstone and shales and occurring in valley portion on the plateau and adjacent to hill composed of Vindhyan sandstone. This type of soil covers a northern part of the district. Laterite soil dark brown to pink coloured lateritic soil is found as capping over hillocks of basaltic terrain. Alluvial soil is greyish yellow to brownish yellow in colour and occupy along the major rivers. Fig. 5 represents the soil map of the district.

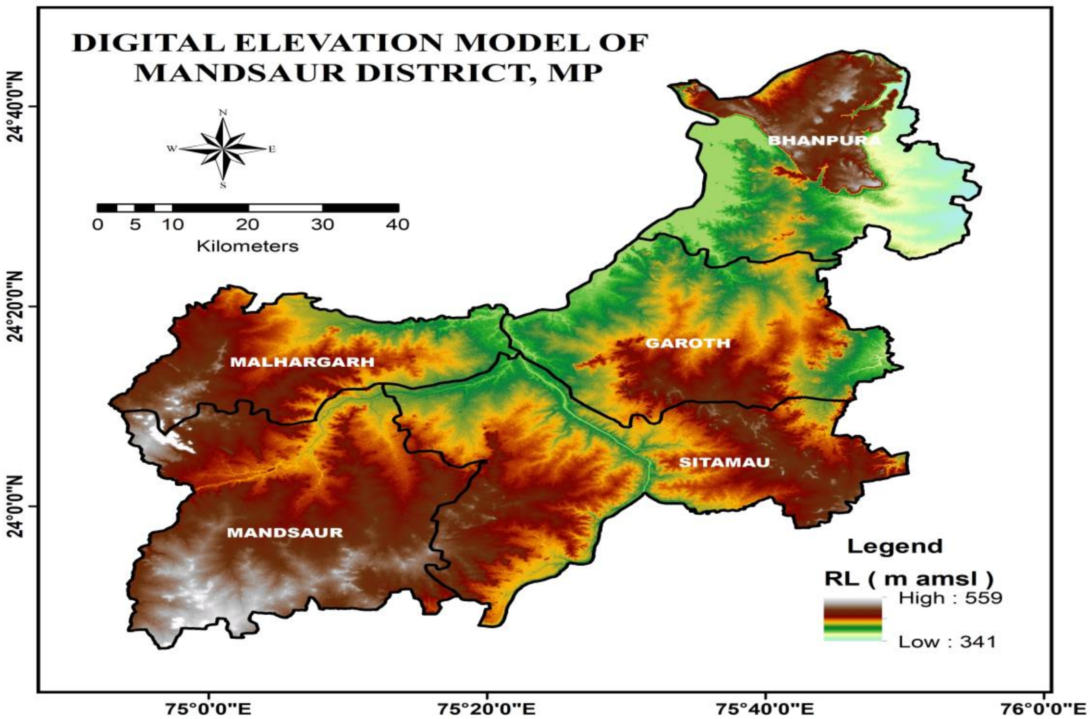

Fig.4 Physiography map of Mandsaur district

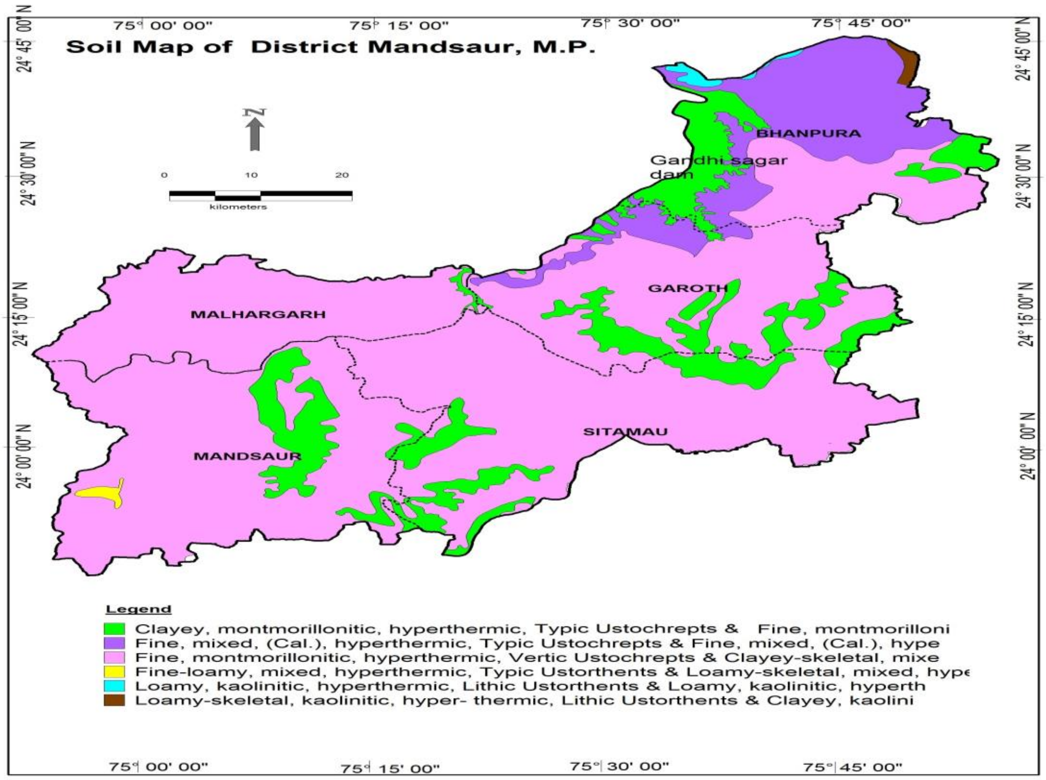

Fig.5 Soil map of Mandsaur district

1.5 Drainage:

Mandsaur district falls under Chambal river sub-basins (Fig.6). The river is broad, flat shallow valley with low gradient because the Chambal has reached the base level of erosion. Vertical erosion has reached and lateral erosion is taking place. Other tributaries of Chambal River are Retam, Shivna and Chhoti Kali Sindh.

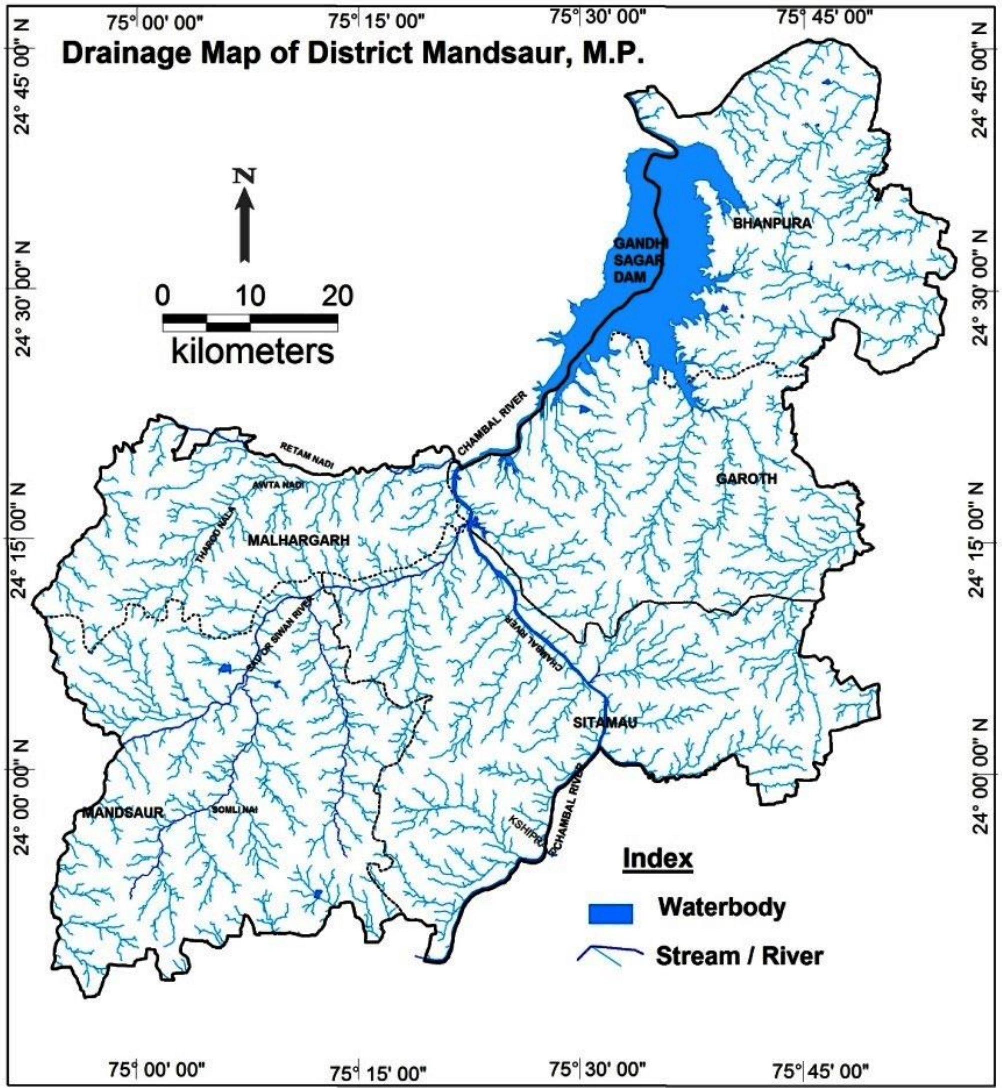

Fig.6 Drainage map

1.6 Irrigation and Cropping pattern

As shown in table 2, Gross sown area of Mandsaur district is 616418 ha. Area irrigated by different sources is given in table 3.

Table 2: Gross Sown Area of Mandsaur District

Area	Type of soil	Gross Area sown (ha) (2014-15)	Area irrigated by surface water (ha) (2014-15)	Area Irrigated by GW (ha) (2014-15)
Mandsaur Distict	Black Cotton soil, mixed soil, gravelly sandy soil and Red Loamy soil	616418	23987	219009

Table 3: Area Irrigated by Different Sources in Mandsaur District

Block	Area Irrigated by Dug Well	Area Irrigated by Tube Well	Total Area Irrigated by Ground Water Area in Ha	Area Irrigated by tanks & other sources in Ha	Area Irrigated by Canals in Ha	Total Area Irrigated by Surface Water Area in Ha
Bhanpura	20734	2519	23253	2718	1406	4124
Garoth	47273	1010	48283	4158	284	4442
Malhargarh	31922	3487	35409	2151	3308	5459
Mandsaur	49253	9887	59140	4376	1503	5879
Sitamau	50754	2170	52924	4713	Nil	4713
Total	**199936**	**19073**	**219009**	**18116**	**6501**	**24617**

1.7 Land Use and Land cover:

As per the land use land cover information (2015-16), 72% of the district is mainly covered by crop land, fallow and plantation (Fig.7). Out of 5535 sq.km, 4000 sq.km is used as agricultural purpose. 9.48% of the total district area (525sq.km) is covered by water body. 7% of the area is covered by forest and 8.9% of the area is wasteland /barren area. landuse/land cover classification of the district is given in table 4.

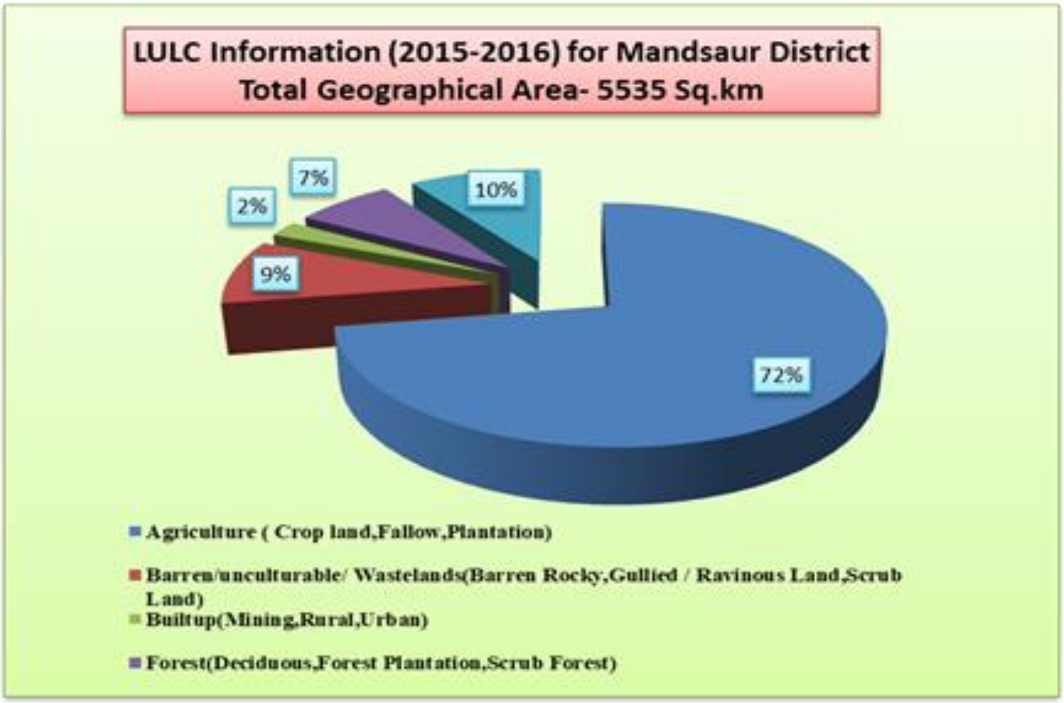

Fig.7 Pie Diagram showing Land use/ Land Cover distribution

Table 4: Landuse/Landcover classification of Mandsaur district

Sl.No	LULC Class	Area (Sq.km)	Area covered (%)
1	Agriculture (Crop land,Fallow,Plantation)	4001.95	72.30
2	Barren/unculturable/ Wastelands(Barren Rocky,Gullied / Ravinous Land,Scrub Land)	497.57	8.99
3	Builtup(Mining,Rural,Urban)	120.53	2.18
4	Forest(Deciduous,Forest Plantation,Scrub Forest)	390.07	7.05
5	Wet lands / Water bodies/River/Stream/Canals,	524.89	9.48

Chapter-2

DATA COLLECTION AND GENERATION

2.1 Hydrogeology - Aquifer System and Aquifer Parameters

Geologically major parts of the Mandsaur district is occupied by Deccan Trap basalts except narrow patch of alluvium and sedimentary rocks of Vindhyans super group in isolated patches, which are forming different type of aquifer in the area. Occurrence and movement of groundwater in hard rock is mainly controlled by secondary porosity through joints and fractures. Presences of vesicle in basaltic lava flow of Deccan Traps play an important role in groundwater movement. Groundwater in general occurs under unconfined to semi-confined conditions. The general hydrogeological conditions of the district are depicted in fig.8 and formation wise settings are discussed below.

Vindhyan:

The Vindhyan sandstone has primary porosity, but this depends on the degree of compaction. Ground water availability in sandstone is controlled by secondary porosity generated by weathering, jointing and fracturing. Ground water is sandstone occurs under confined conditions. Yield of Vindhyans sandstone formation is generally poor to moderate and less than 2 liters per second.

Deccan Trap:

The basalts underlie a major part of the district and generally groundwater occurs under phreatic conditions in shallow weathered, jointed and fractured horizons. Basalts does not exhibits uniform occurrence of groundwater both vertically and latterly. Physiographic location, thickness of weathered mantle, degree of jointing, fracture or shear zones, characteristics of vesicular horizons and their inter connection are important factor, which play a deciding role in the yield capacity of open wells tapping shallow aquifers. The deeper aquifer system appear to be under unconfined to semi-confined conditions while visualizing lava flow sequence which shows alternate units of vesicular and massive horizons. The hydrogeological regime in different tires, deeper aquifer is more likely to be governed by the secondary porosity jointed/fractured form of massive units is creating possibilities of their acting as leaky confining bed consequently resulting into semi-confined condition for water bearing vesicular units occurring below it. Yield of basalts in this is reported low to moderates (1 to 5 lps).

Dug wells in this formation range in depth from 12 – 26.5 m having diameters between 2 - 11m. Ground water occurs mainly under water table conditions.

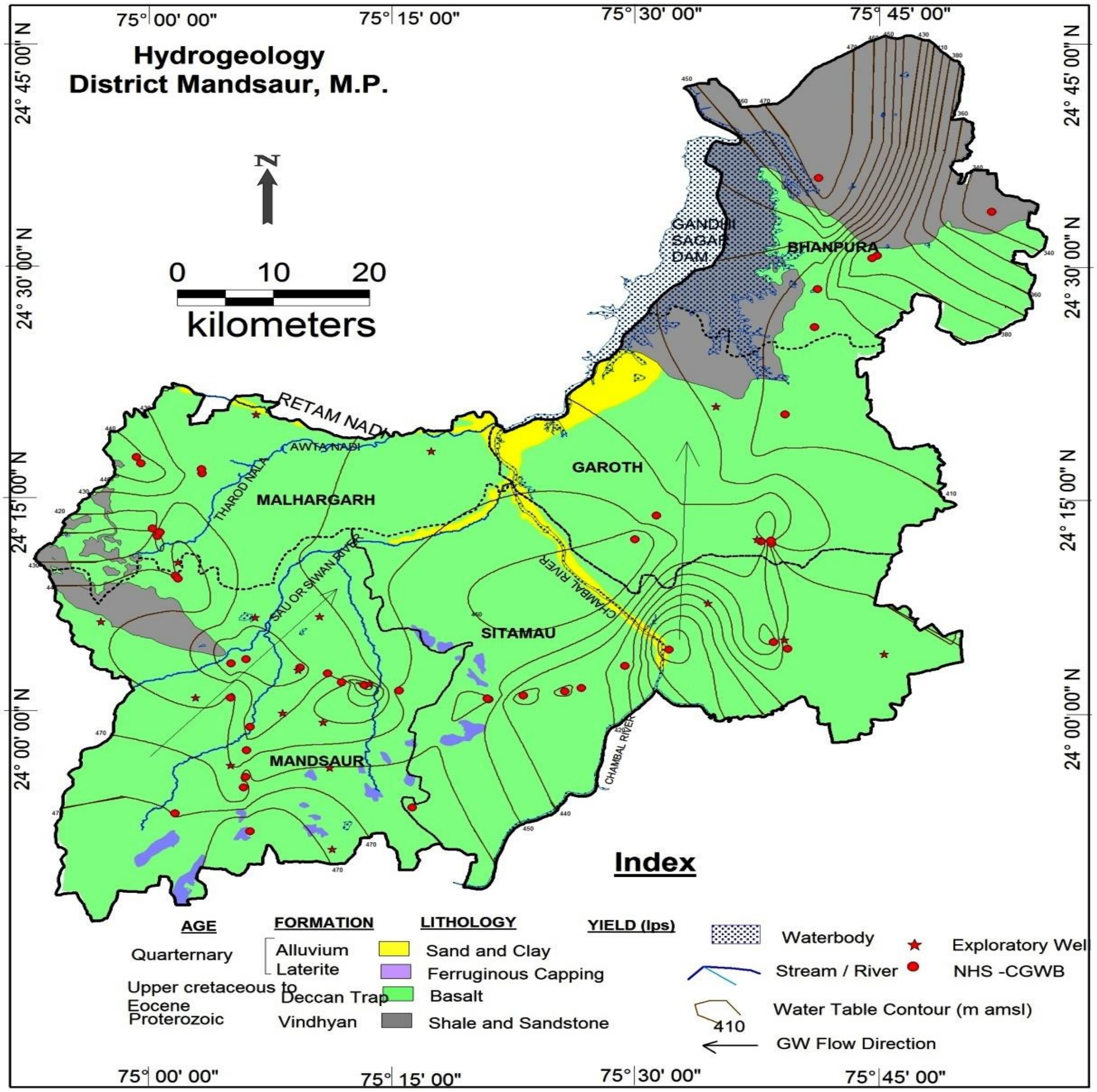

Fig.8 Hydrogeological map of Mandsaur district

Alluvium:

The alluvium deposits are restricted to narrow linear along the river courses of Chambal and Shivna. The thickness of alluvium varies from 5 to 10 meters, which is proportionately thinning away from the river line. The thickness of alluvium along the Chambal River reported about 20 meter thick. The alluvium deposits consists series of consolidated, fine to medium grained sand admix in varying proportion and yield varies from 1 to 8 liters per second. Ground water occurs under water table conditions.

2.2 Depth to Water Levels:

Periodic monitoring of the ground water levels to generate long-term data is an essential prerequisite for effective utilization, development, and management of the available ground water resources. This continuous monitoring provides a valuable tool to decipher the seasonal and long-term changes in ground water levels, and in turn helps in managing the ground water resources in a scientific and effective manner. Central Ground Water Board, North Central Region, Bhopal monitors ground water levels through a network of 24 dug wells and 25 peizometers all over Mandsaur district. These ground water monitoring wells are monitored four times in a hydrological year in the months of May (pre-monsoon), August, November (post-monsoon) and January. The present report gives an overview of the status of ground water levels in Mandsaur district, MP.

Pre-monsoon (May 2020):

Depth to water level (DTW) during May 2020 ranged from 4.3m bgl at Bhanpura observation well to 22.8 (mbgl) at Bhasakeda observation well in Mandsaur district .Depth to water levels between 7-11 m bgl is the most prominent over the entire State. Water level more than 18 m bgl is recorded in isolated pockets of Sitamau and Mandsaur block. Pre- monsoon depth to water level map for the year 2020 for Mandsaur district is shown in fig 9.

Post-monsoon (November 2019):

During post-monsoon period, November 2019 due to heavy rainfall, depth to water level is shallow all over the district. Depth to water level ranges from 0.4 m bgl at Bhuniyakhedi observation well to 8.9 m bgl at Botalganj observation well. It is observed that in most part of the district the water level lies between 0-2 mbgl. Post- monsoon depth to water level map for the year 2019 for Mandsaur district is shown in fig 10.

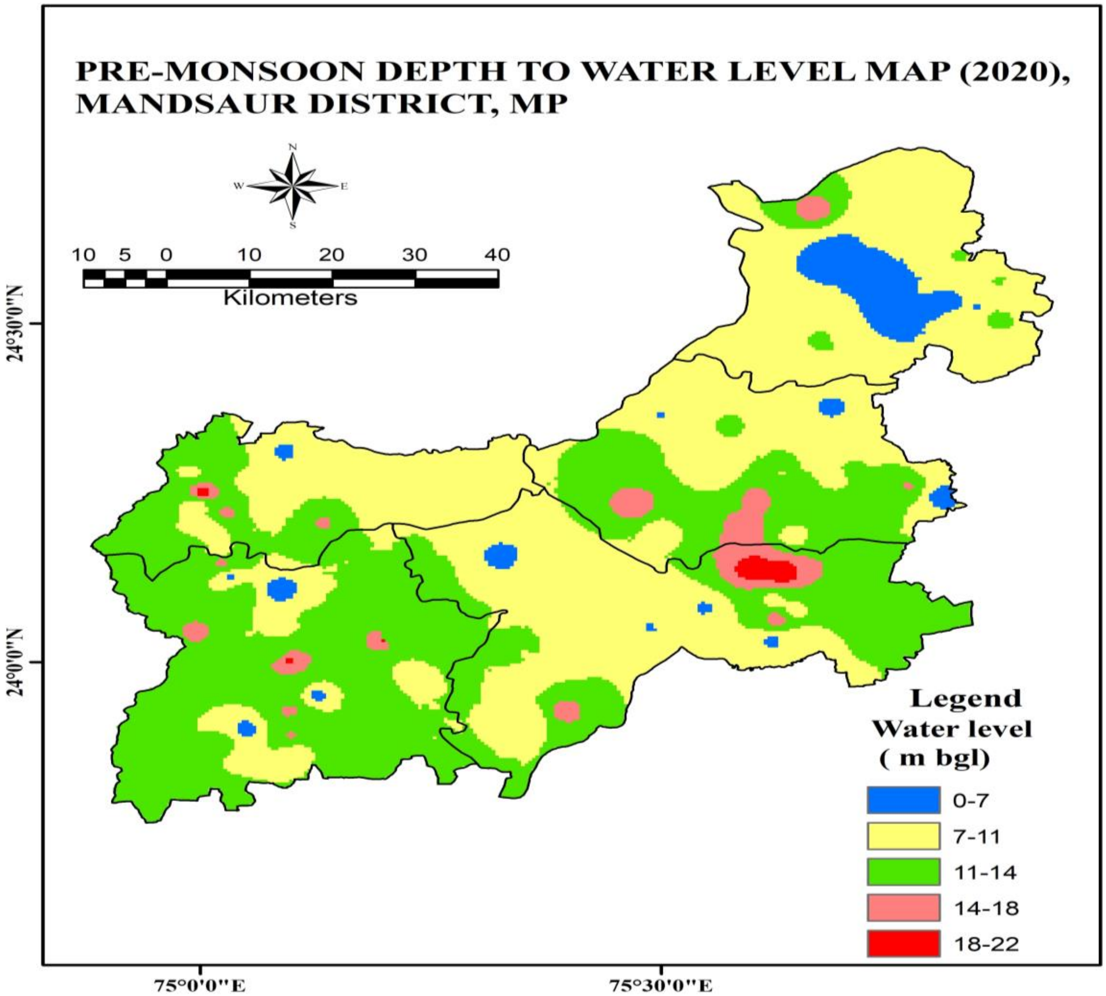

Fig.9 Depth to Water Level (Pre-monsoon)

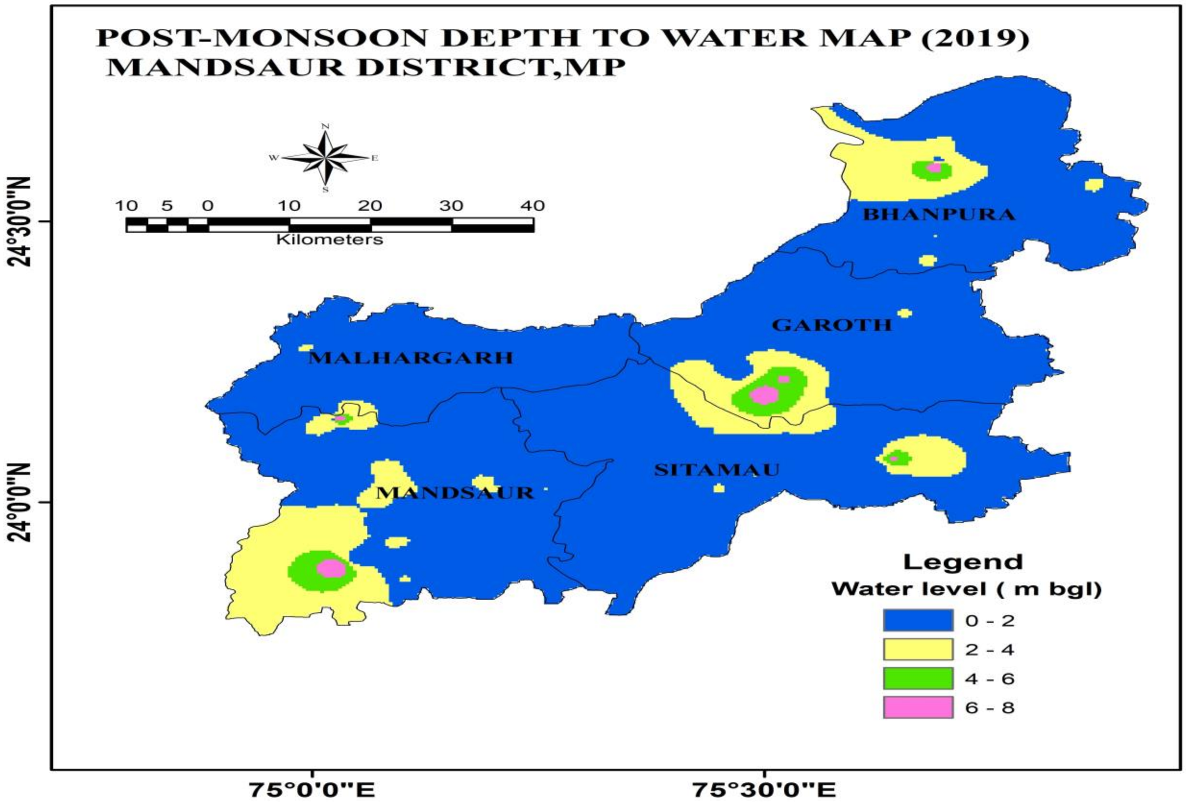

Fig.10 Depth to Water Level (Post-monsoon)

Annual Water level Fluctuation (May 2019-May 2020):

The ground water levels of monitoring wells during May 2020 were compared with those of May 2019 to decipher the changes that took place in the ground water regime. Water level is rising in northern and southern part of Mandsaur district, mainly in Bhanpura block. In bhanpura block water level rise more than 10m is observed. Fall in water level is observed mainly in Sitamau, Mandsaur blocks and part of Garoth and Malhargarh block.Declining water level >15 m is observed in southern part of Sitamau and Mandsaur block. Annual water level Fluctuation map is shown in fig 11.

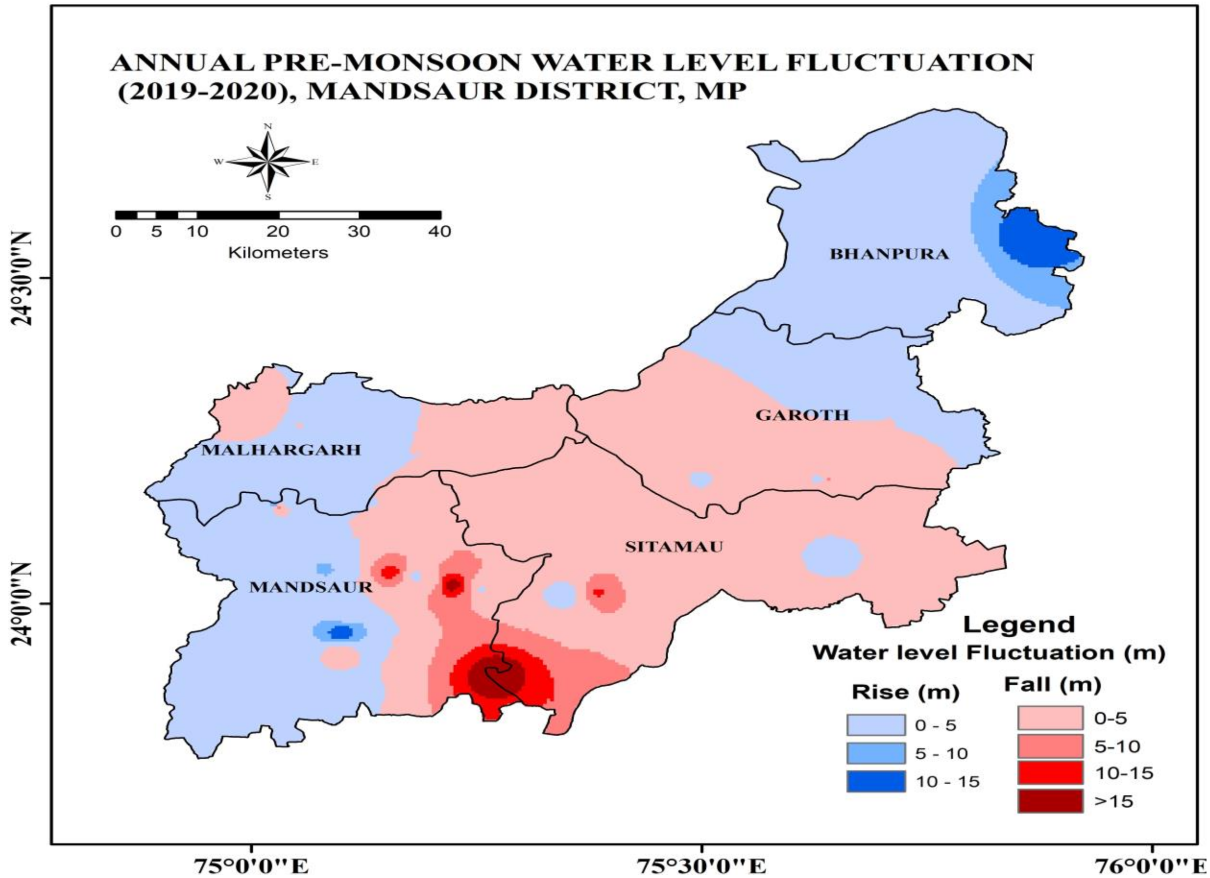

Fig.11 Water Level Fluctuation map

2.3 Exploratory Drilling:

CGWB under its exploration programme drilled 48 EW and 7 OW during 2017-19 exploratory drilling programme (Fig.12). On the basis of which litholog and aquifer perimeter sub surface lithology of the area is inferred and Sections of the district has been prepared.

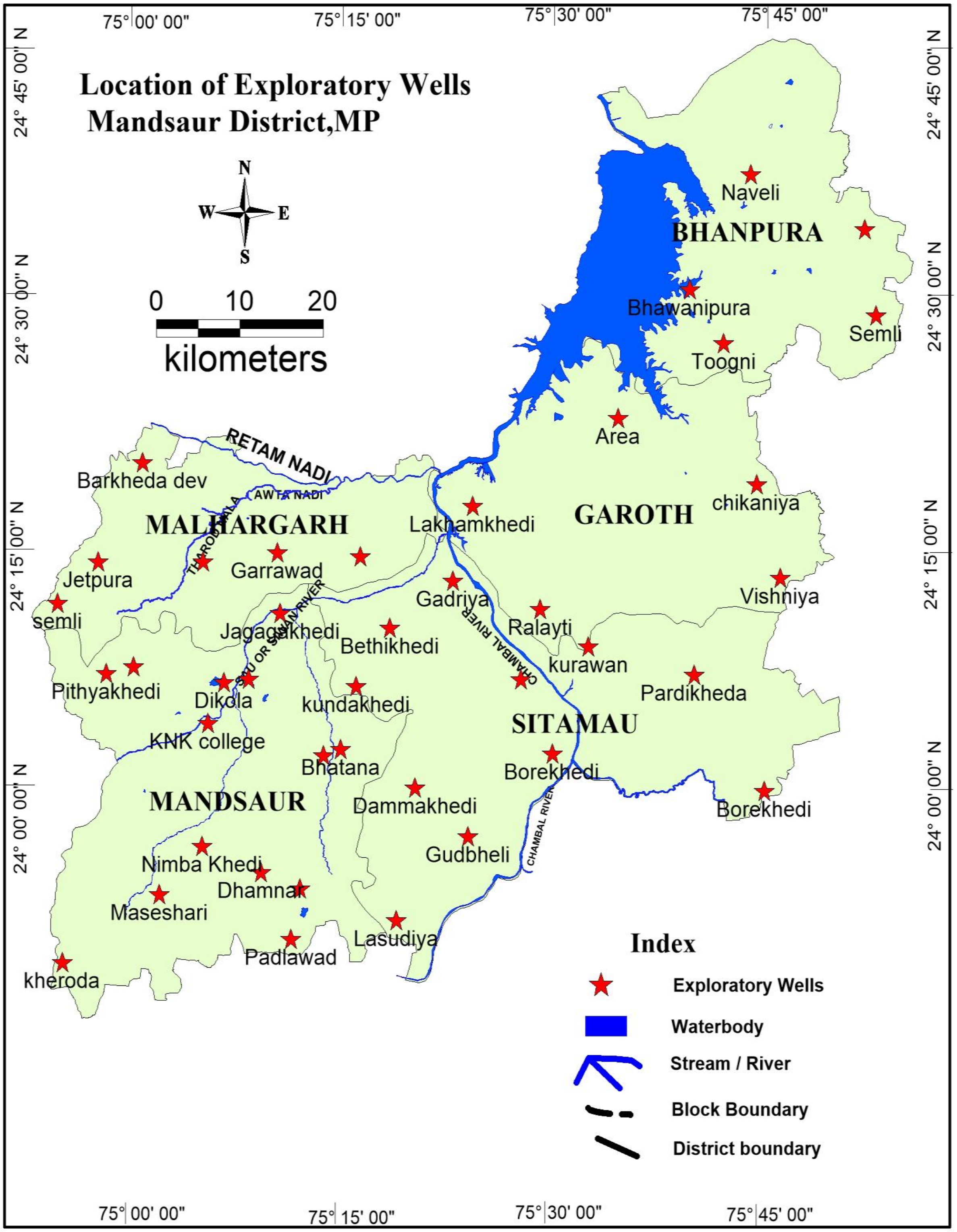

Fig.12 Location of Exploratory wells

Table 5: Details of Exploratory Bore wells drilled in Mandsaur District

S. No.	Village	Depth (mbgl)	Zones Encountered	Formation	Discharge during drilling (lps)	SWL (mbgl)	Transmissivity m^2/day	Storativity
1	Agoriya	203.1	53.6 – 56.6	Basalt/Granite	1.51	17.42		
2	Ajaipur	115.90	90 - 115	Basalt	8.50	20.60		
3	Borwan	200.90		Basalt	1.2	23.15		
4	Degaon Kalan	134.20	12-15, 17-20, 24-31	Basalt/Granite	6	9.67	64.52	2.4×10^{-4}
5	Dikola	200	47.50 – 50.50	Basalt				
6	Garoth	110	12 – 22.5	Basalt/SST	1.7	8.30		
7	Guradia Pratap	152.50	61.00-73.00 100.5-103.5	Basalt/SST	1.83	55.80		
8	Jaggakhedi	160.40	84.00 – 86.00	Basalt	< 0.1	80.00		
9	Jharda	96		Basalt	0.5	2.69		
10	Ladusa	66.29		Basalt	0.42	4.46		
11	Mandsaur	96						

S. No.	Village	Depth (mbgl)	Zones Encountered	Formation	Discharge during drilling (lps)	SWL (mbgl)	Transmissivity m^2/day	Storativity
12	Nimba Khedi	202.70	53.20 – 56.30	Basalt/SST	0.2	37.28		
13	Padlawad	202.30	69.2 – 72.2	Basalt	1.10	24.20		
14	Rupawali	200.20	130 - 133	Basalt/SST	0.1	39.45	-	-
15	Sanjeet	122	116 – 122	Basalt/SST	2.17	0.35 m agl		
16	Shamgarh	152.50		Basalt	0.43	11.20		
17	Tharad	97.60		Vesicular Basalt	1.83	4.48	149	0.4×10^{-3}

2.4 Ground Water Quality:

Ground Water Quality of Mandsaur District

The water samples were collected from National Hydrograph Stations in clean double stoppered poly ethylene bottles from 24 different locations of Mandsaur district during May 2019. Chemical quality data is given in table 6.

Table 6: Chemical Quality Data of Mandsaur District

S. No.	District	Block	Location	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K
					µS/cm at 25°C	mg/l												
1	Mandsaur	Bhanpura	Babulda	7.55	1246	0	424	132	42	27	0.35	0.75	69	395	84	45	97	5.9
2	Mandsaur	Bhanpura	Badodiya	7.54	424	0	145	37	15	18	0.59	0.18	36	110	26	11	40	7.8
3	Mandsaur	Bhanpura	Bhanpura	7.77	1394	0	563	107	42	24	0.82	0.19	33	425	58	68	116	10.4
4	Mandsaur	Bhanpura	Dudhkheri	7.54	1456	0	478	147	51	63	0.76	0.12	28	415	70	58	133	9.8
5	Mandsaur	Bhanpura	Sandhara	7.55	840	0	224	90	26	82	0.56	0.11	43	315	68	35	38	11.2
6	Mandsaur	Garoth	Barkheranayak	7.49	1172	0	375	137	24	44	0.34	0.14	42	405	124	23	75	5.9
7	Mandsaur	Garoth	Dharmarajeswar	7.72	790	0	297	62	22	32	0.55	0.23	33	275	54	34	45	11.7
8	Mandsaur	Garoth	Garoth	7.72	1300	0	496	120	34	18	0.54	0.09	26	435	68	64	88	10.5
9	Mandsaur	Garoth	Shamgarh1	7.29	930	0	345	82	29	19	0.78	0.64	31	275	48	38	77	9.1
10	Mandsaur	Malhargarh	Malhargarh	7.79	682	0	175	100	27	18	0.54	0.09	32	185	42	19	67	5.3
11	Mandsaur	Malhargarh	Narayangarh	7.86	1256	0	405	135	59	22	0.75	0.09	29	375	60	55	105	9.8
12	Mandsaur	Malhargarh	Pipaliya	7.78	915	0	309	80	60	13	0.66	0.36	39	320	44	51	53	10.5
13	Mandsaur	Mandsaur	Basakheda	7.52	1916	0	593	197	65	115	0.45	0.18	36	545	106	68	177	11.1
14	Mandsaur	Mandsaur	Botalganj	7.79	1251	0	478	97	38	45	0.64	0.2	29	390	64	56	99	9.9
15	Mandsaur	Mandsaur	Chirmoliya	7.53	1308	0	448	130	53	32	0.78	0.11	41	345	42	58	131	11.3
16	Mandsaur	Mandsaur	Daloda1	7.44	1089	0	321	110	48	69	0.69	0.91	29	310	68	34	96	8.9
17	Mandsaur	Mandsaur	Kachnera	7.86	890	0	272	92	30	51	0.49	0.73	42	280	58	33	70	2.7
18	Mandsaur	Mandsaur	Mandsaur	8.09	852	0	260	97	28	38	0.69	0.11	51	215	56	18	92	3.4
19	Mandsaur	Mandsaur	Manpura	7.16	986	0	272	80	42	113	0.31	0.1	37	345	78	36	58	9.2
20	Mandsaur	Mandsaur	Nayakhera	7.05	2215	0	248	497	51	125	0.54	0.08	46	865	296	30	94	11.3
21	Mandsaur	Sitamau	Khejriya	7.02	1605	0	460	217	52	40	0.36	0.13	45	495	136	38	130	11.3
22	Mandsaur	Sitamau	Sitamau	7.3	1489	0	375	180	55	115	0.65	0.11	36	535	132	50	83	10.1
23	Mandsaur	Sitamau	Surjani	7.7	989	0	200	172	36	41	0.39	0.09	37	265	62	27	100	3.7
24	Mandsaur	Sitamau	Suwasara	7.4	1142	0	157	202	68	78	1.34	0.08	39	305	88	21	112	10.9

2.5 Geophysical Survey:

Geophysical surveys were conducted in all the five block of mandsaur district. Total 116 VES surveys were conducted in the district (Fig.13). In all 116 VES were conducted in Mandsaur district. Out of these, 99 VES sites are in basalt and the rest 17 VES are in Vindhyan Sandstone and Binota Shale (Aravallis). In these rock formations, the VES results reveal sporadic occurrences of deep weathering extending to depths around 40-45 m. However, it is mostly within 10 m. Though spatially sporadic, the thickening of weathered zone is observed mainly along the eastern boundary of Gandhi Sagar reservoir and the course of Shivana river. The weathered zone along the eastern boundary of Gandhi Sagar reservoir is associated with very low resistivity values at places, indicating deterioration in groundwater quality.

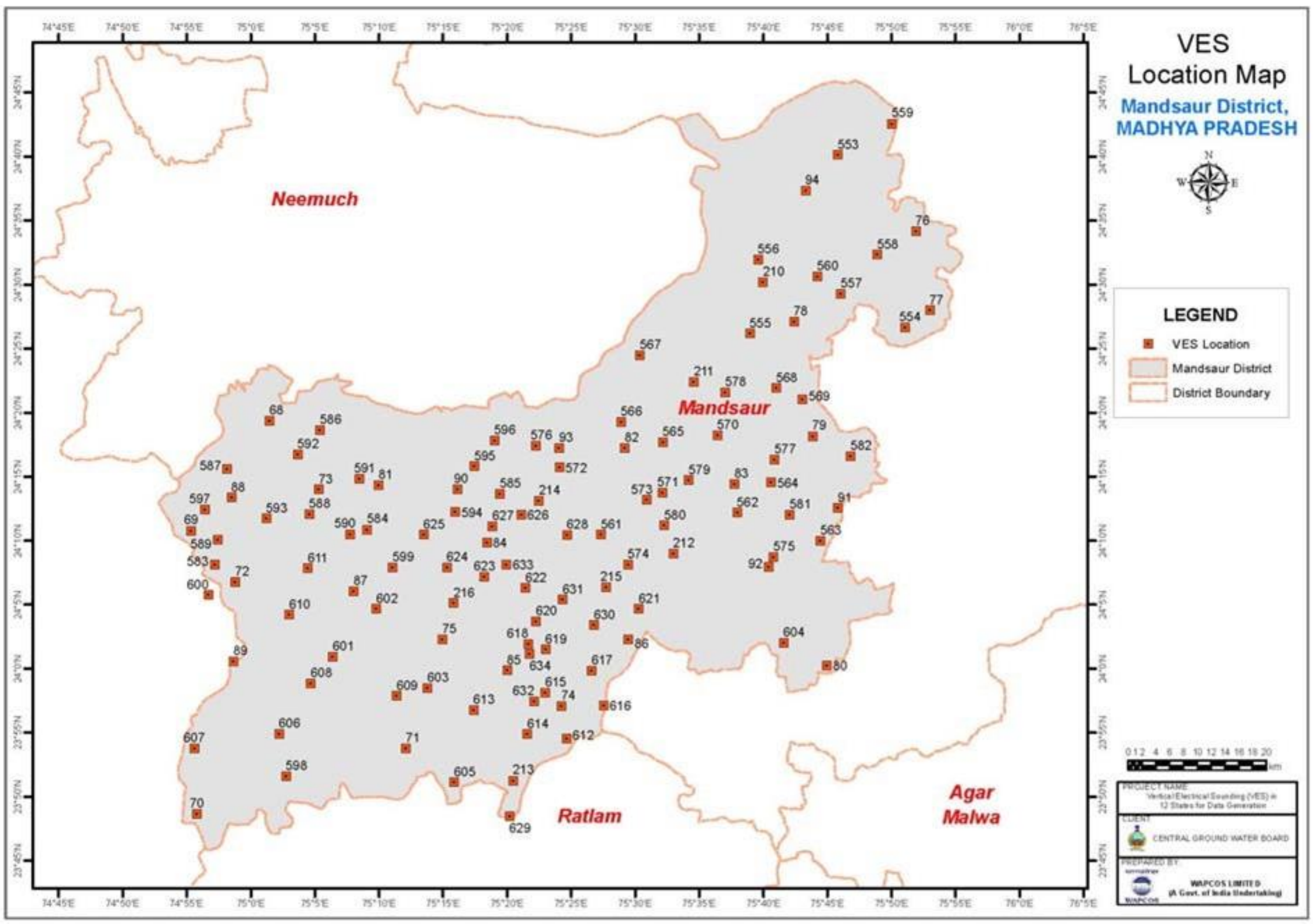

Fig. 13 VES locations in Mandsaur district

Chapter-3

DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Aquifer Disposition:

Based on the existing exploration dataset from 2012 to 2019, aquifer disposition in 3D, Fence diagram, and hydrogeological sections of Mandsaur district have been prepared for understanding the subsurface disposition of aquifer system.which is shown in Fig.14, 15, 16 &17.

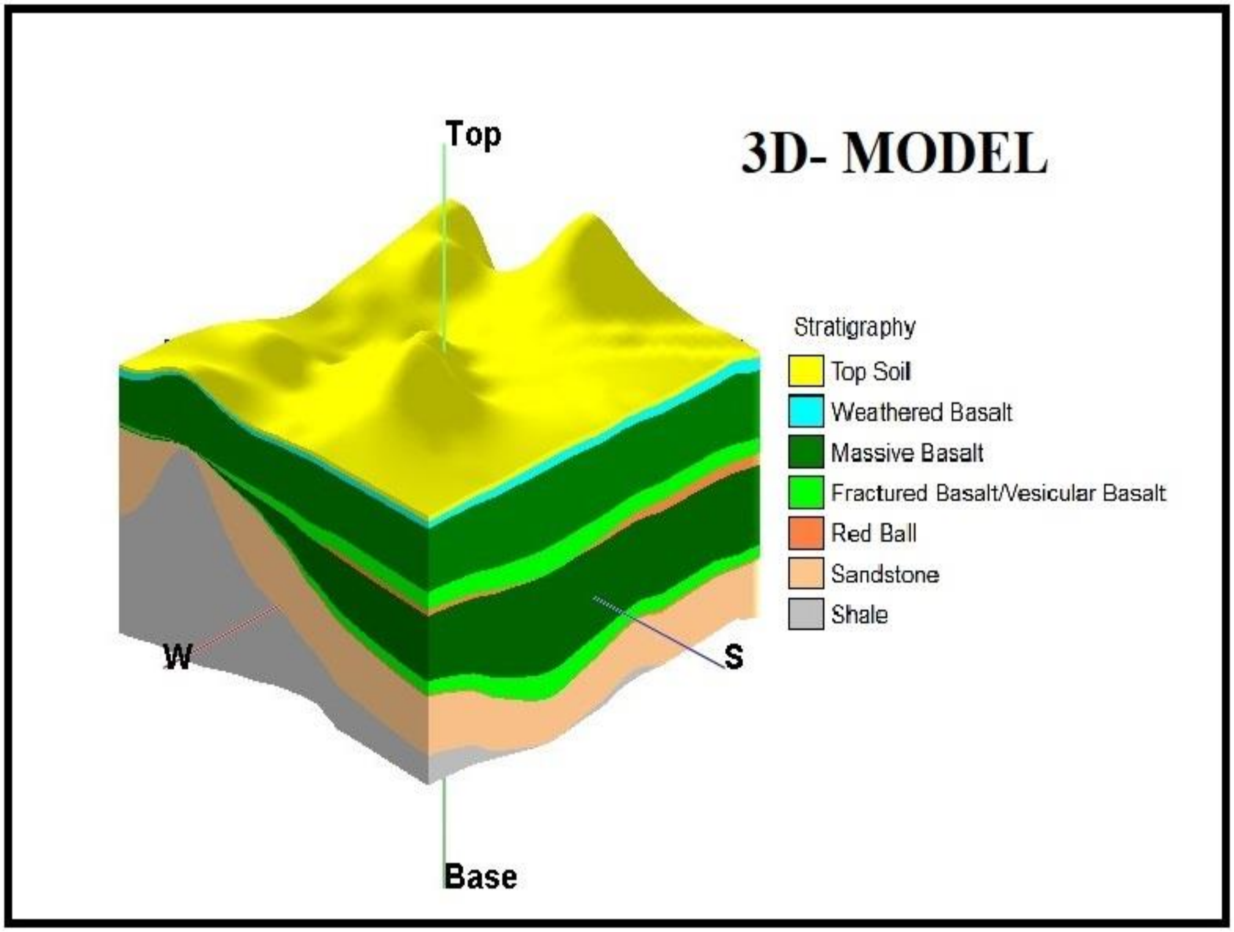

Fig.14 3D- Aquifer Disposition of Mandsaur District

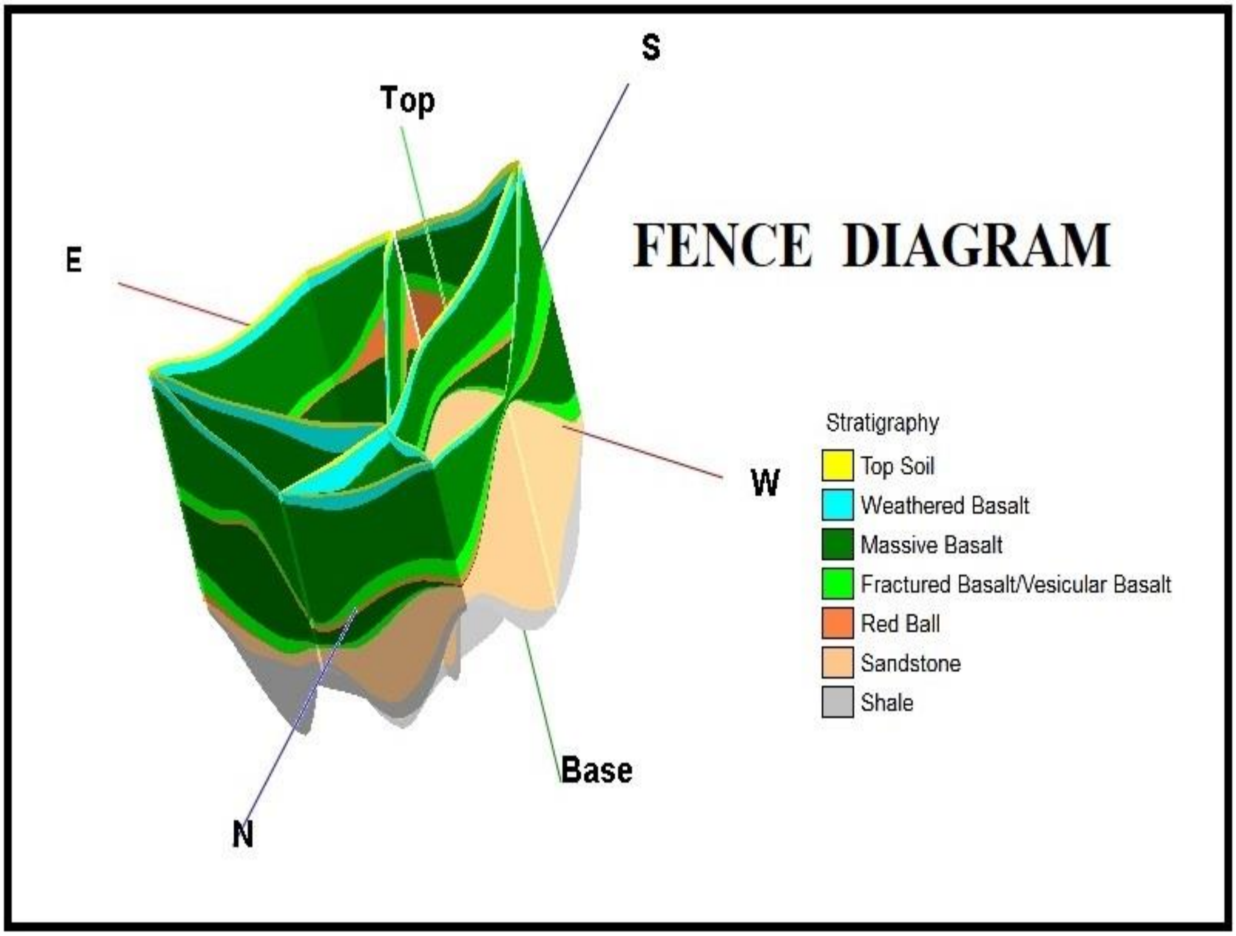

Fig.15 Fence Diagram of Mandsaur District

3-D interpretation of lithologs reveals that shallower and deeper weathered /fractured basalt is separated by red bole and massive basalt in the district. Water levels are observed at different depth of shallower as well as deeper fractured formation.

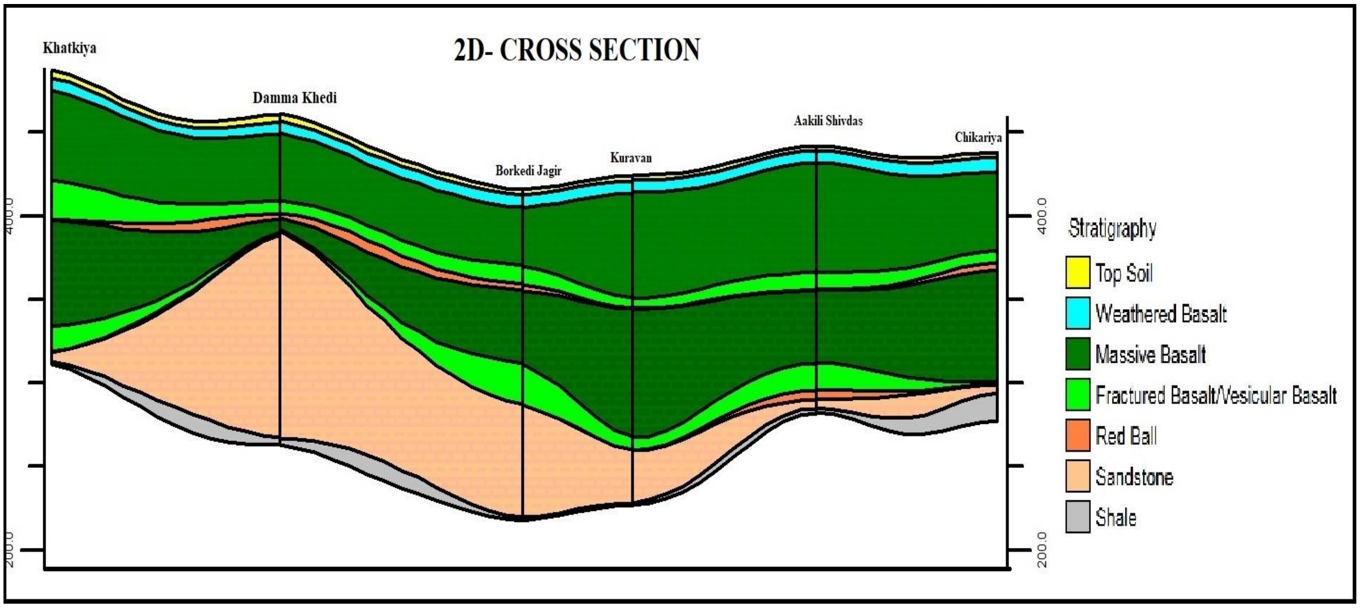

Fig.16 2D- Cross section-I of Mandsaur District

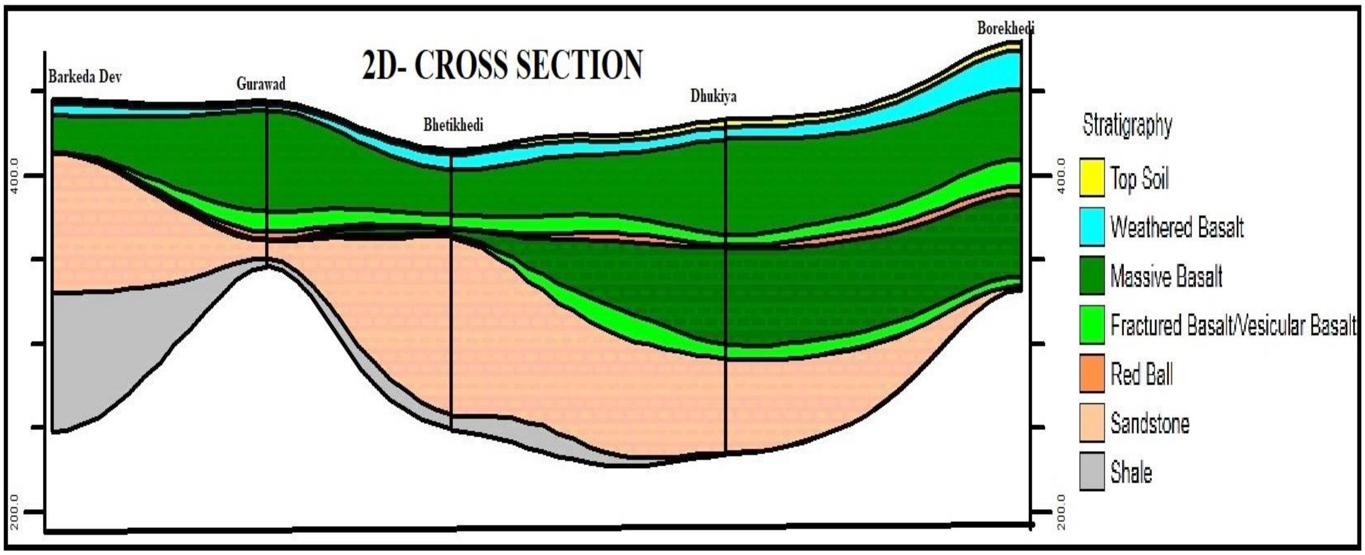

Fig.17 2D- Cross Section-II of Mandsaur District

Location details and lithology of Exploratory wells are given in Annexure –I and Annexure –II.

3.2 Hydrochemical Data Interpretation:

Quality of Ground Water for Drinking Purpose:

The ground water samples from Mandsaur district have varied range of pH from 7.02 to 8.09. As per BIS (IS 10500: 2012) recommendation, all the water samples have pH recorded within the permissible limits of 6.5 to 8.5, the maximum pH recorded in the water sample of Mandsaur (8.09). The ground water of the study area can be assessed as neutral to slightly alkaline. The electrical conductivity of ground water samples in Mandsaur district varies from 424 to 2215 µS/cm at 25°C. The maximum EC has been observed in the water sample of Nayakhera village (2214 µS/cm at 25°C). All water samples falls less than 2000 µS/cm at 25°C except Nayakhera village. So, the ground water quality in Mandsaur district is good.

The fluoride concentration in Mandsaur district lies in between 0.31 to 1.34 mg/l, which represent that all the samples are within the permissible limit i.e. 1.5 mg/l as per BIS (IS 10500 : 2012). The maximum concentration of fluoride has been observed at Suwasara (1.34 mg/l). Nitrate in ground water samples of Mandsaur district have varied range from 13 to 124 mg/l. It is observed that 38% samples have Nitrate concentration more than the acceptable limit i.e. 45 mg/l, while rest 63% samples have concentration less than acceptable limit. There is no permissible limit for Nitrate as per BIS (IS 10500: 2012). Highest nitrate concentration is reported from Nayakhera (125mg/l). High nitrate in ground water samples may be due to anthropogenic activities or excessive use of fertilizers. The range of Total Hardness (as $CaCO_3$) in ground water samples of study area is 110 to 865 mg/l. The maximum concentration of total hardness has been observed in sample of Nayakhera (865 mg/l). The concentration of total hardness in the district is within the permissible limit of 600 mg/l except Nayakhera village.

Piper diagram has three parts: a Cation triangle, an Anion triangle, and a Central diamond-shaped field. In Cation triangle, the relative percentages of the major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) are plotted. In Anion triangle the major anions (HCO_3^{-}+CO_3^{2-}, SO_4^{2-}, Cl^{-}) are plotted. These points are then projected to the central diamond shaped field.

As per the piper diagram of district (Fig.18), 29% of samples are Mixed type and 67% samples shows Calcium-Bicarbonate type nature of water, it shows temporary hardness and rest of 4% samples are calcium chloride type of water shows permanent hardness.

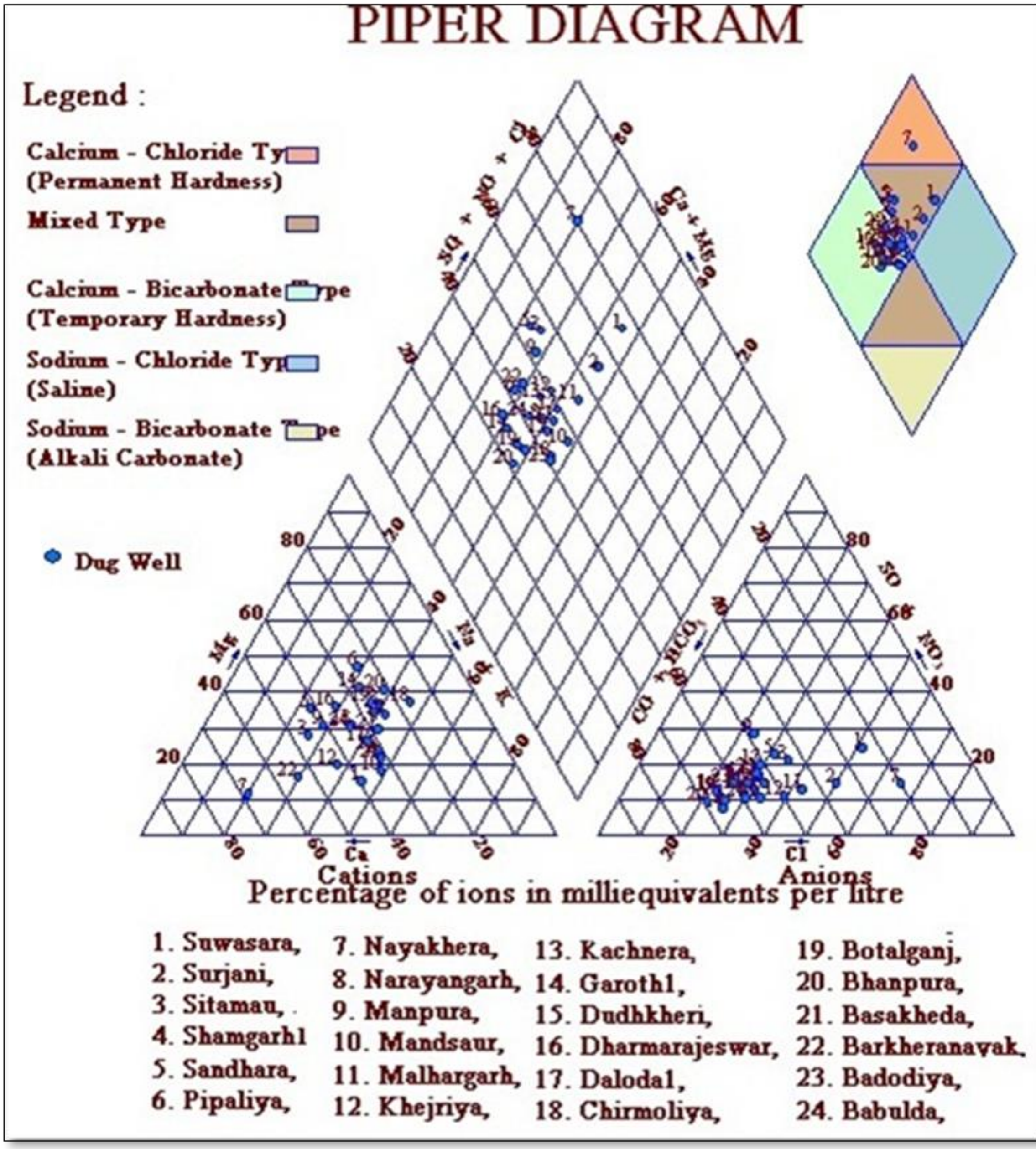

Fig.18 Hill Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Mandsaur District

Quality of Ground Water for Irrigation Purpose:

In classification of water for irrigation purpose, it is assumed that the water will be used for irrigation purpose based upon its soil texture, infiltration rate, drainage and climate. The chemical data of all the water samples from Mandsaur district is plotted on U.S. Salinity Laboratory diagram.

The US Salinity diagram (Fig.19) shows that approx. 8% wells are observed under C_2-S_1 Class (Medium Salinity & Low Sodium) which means that these waters can be used for irrigation purpose for most of the crops and 92% of total ground water samples fall under C_3-S_1 class (High Salinity & Low Sodium). Water from these areas can be used for irrigation, considering the salinity content of the ground water.

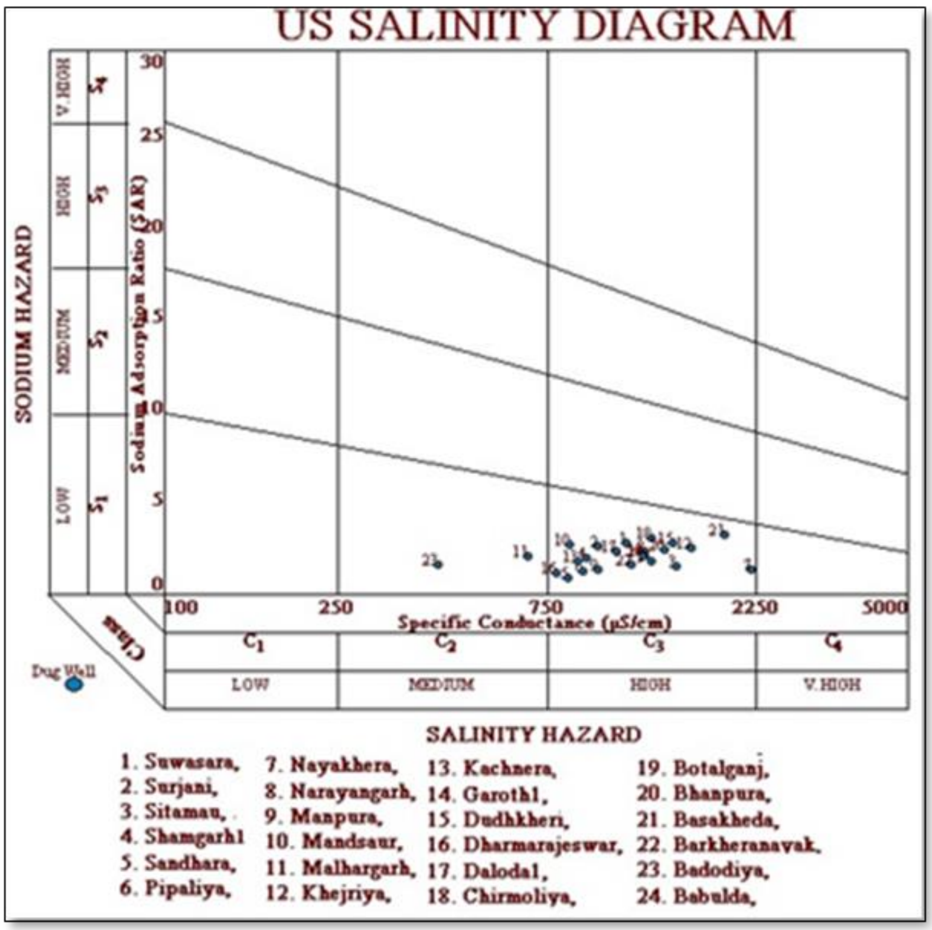

Fig.19 US Salinity Diagram for water samples collected from National Hydrograph Stations of Mandsaur District

3.3 Geophysical Studies:

Interpreted Results of VES:

Typical VES curve from basaltic terrain are shown in Fig.20. It shows a number of kinks and bumps in the curve. For a layered earth model, the VES curve has to be smoothed and can be interpreted as A or AA type. The interpreted results of VES are given in Annexure III.

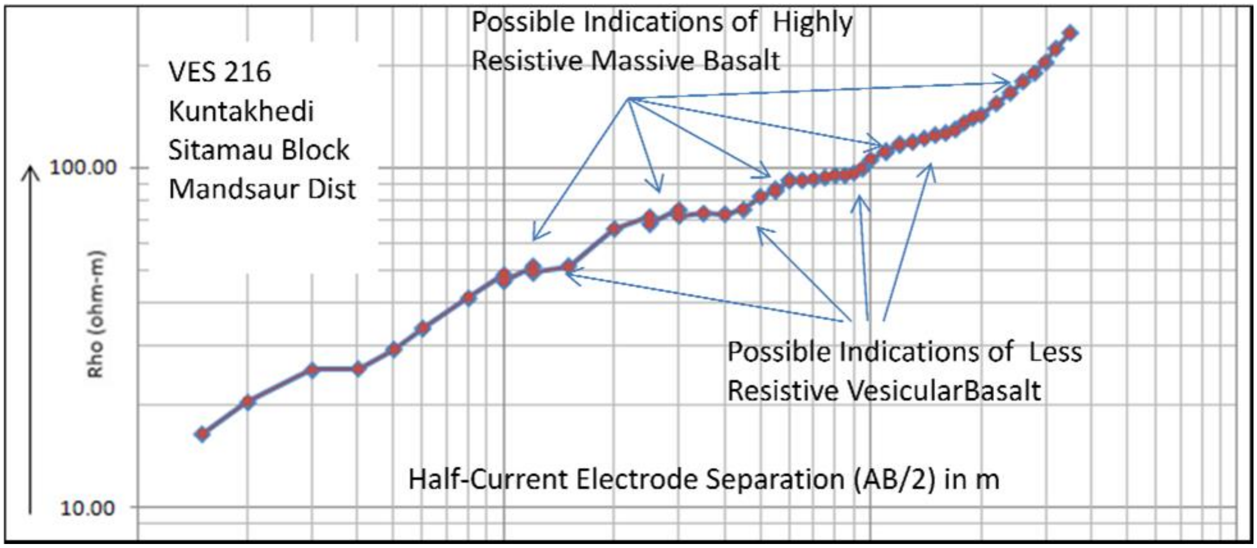

Fig.20 Typical VES curve-I from basaltic terrain

The kinks and bumps in the VES curve may not be due to cultural noise and perhaps represent the subsurface geological condition, but in layered earth interpretation all the these kinks and bumps cannot be considered. Another VES curve from basaltic terrain is shown in Fig. 21. Out of 116 VES sites, weathered zone is absent in 40 sites. For 76 VES sites, the resistivity of the weathered zone varies from less than 2 ohm-m to 51 ohm-m. Mostly, the weathered zone resistivity is less than 10 ohm-m (33 sites) and 11-20 ohm-m (26 sites). In some VES sites, weathered zone resistivity around 2 ohm-m is observed. It indicates deterioration in groundwater quality (in terms of salinity). The depth to the bottom of weathered zone is maximum around 48 m and mostly it is less than 10 m (at 47 sites).

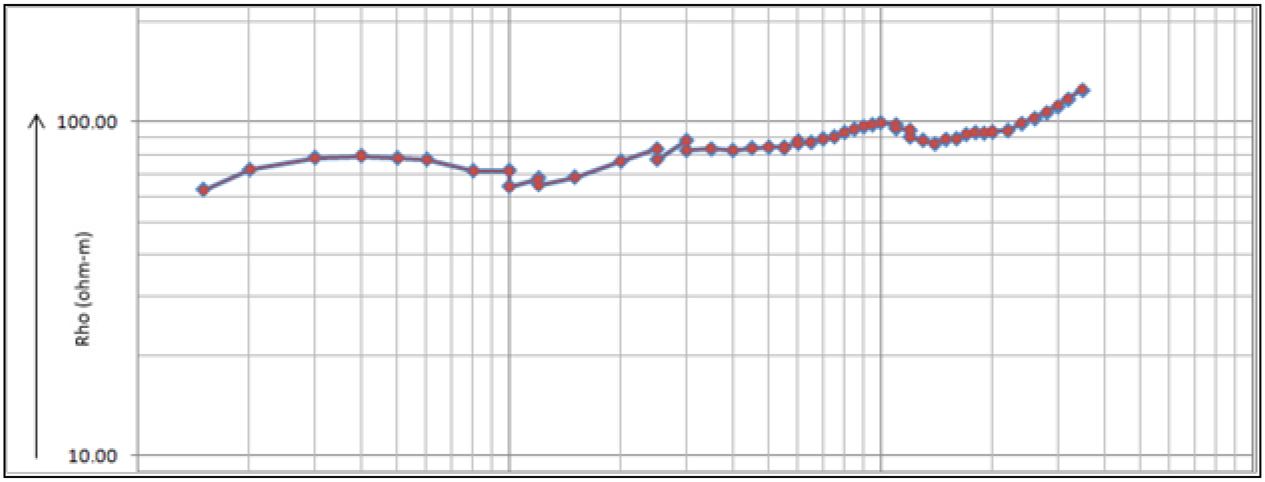

Fig.21 Typical VES curve-II from basaltic terrain

Conclusions and Recommendations:

Out of 116 VES conducted in Mandsaur district, 99 VES sites are in basalt and the rest 17 VES are in Vindhyan Sandstone and Binota Shale (Aravallis). In these rock formations, the VES results reveal sporadic occurrences of deep weathering extending to a depth of 40-45 m. However, it is mostly within 10 m. Though spatially sporadic, the thickening of weathered zone is observed mainly along the eastern boundary of Gandhi Sagar reservoir and the course of Shivana river. The weathered zone along the eastern boundary of Gandhi Sagar reservoir is associated with very low resistivity values at places, indicating deterioration in groundwater quality. The VES sites where the weathered zone can form potential aquifer and can be tapped is presented in Annexure-III, Annexure-IV. The criteria for selection are minimum depth to the bottom of weathered zone as 10 m and it minimum resistivity 7 ohm-m. The VES sites where fractured zone aquifers are expected to occur are listed in Annexure-V.

Chapter-4

GROUND WATER RESOURCES

4.1 Dynamic Ground Water Resources:

The dynamic ground water resources of the Madhya Pradesh State assessed jointly by the CGWB and State Ground Water Departments under the supervision of the State level Committees. The base year of computation of the resources is March 2020.

The dynamic ground water resources are also known as Annual Replenishable Ground Water Resources since it gets replenished/ recharged every year. Annual extractable ground water resource of Mandsaur district has been assessed as 60359.85 ham. The major source of ground water recharge is the monsoon rainfall. Block -wise Ground Water Resources of Mandsaur District as on March, 2020 is given in Table 7 and the presents the over-all scenario of ground water resource utilization and availability of the District. The contribution from other sources such as canal seepage, return flow from irrigation, seepage from water bodies etc in annual replenishable Ground Water Resource is more than of 24 % in the state.

The assessment of ground water extraction is carried out based on the Minor Irrigation Census data and sample surveys carried out by the State Ground Water Departments.

The Annual Ground Water extraction of the entire district on March 2020 has been estimated as 64748.93 ham. Agriculture sector remained the predominant consumer of ground water resources. Total annual ground water extraction i.e. 61437.69 ham is for irrigation use. Only 3311.25 ham is for Domestic use. An analysis of ground water extraction figures indicate that in the district **107.27%** is stage of ground water extraction.

The stage of ground water extraction is very high in the two blocks i.e Mandsaur (109.29%) and Sitamau (135.16%), which implies that in these blocks the annual ground water consumption is more than annual ground water recharge.

In rest of the block the stage of ground water development is between 80 to 100 %. The ground water development activities have increased generally in the areas where future scope for ground water development existed. This has resulted in increase in stage of ground water development.

Table 7: Dynamic Ground Water Resources

Assessment Unit	Ground water extraction for irrigation use (Ham)	Ground water extraction for domestic use (Ham)	Total Extraction (Ham)	Annual GW allocation for domestic use as on 2025 (Ham)	Net Ground water Availability for future use (Ham)	Stage of Ground water extraction (%)	Categorization
Bhanpura	5202.4	369.43	5571.83	398.1	375.85	93.23	critical
Garoth	11404.23	707.17	12111.39	824.61	1406.84	88.82	semi_critical
Malahargarh	9080.21	483.61	9563.83	510.9	629.81	93.57	critical
Mandsaur	14790.81	1079.30	15870.11	1154.43	0	109.29	over_exploited
Sitamau	20960.04	671.74	21631.77	716.86	0	135.16	over_exploited
District total	**61437.69**	**3311.25**	**64748.93**	**3604.9**	**2412.5**	**107.27**	

Chapter-5

GROUND WATER RELATED ISSUES

5.1 Ground Water Depletion

Groundwater is the only source of irrigation in the entire area. Farmers solely depend on groundwater for irrigation. Every year number and depth of bore wells are increasing. The yield of the dug wells in shallow aquifer (0-30 mbgl) is reduced due to over development of deep fractured aquifer by bore wells. The phreatic aquifer is recharged during monsoon and the dug wells sustains for 3 to 4 months only The dug wells sustain only for 2 to 3 hours of pumping with a drawdown of 2 to 5 m. In the year 2020 Ground water resource of District was computed and data reveals that Mandsaur block having stage of ground water extraction 109.29% and Sitamau Block 135.16% and they were categorized as Over Exploited blocks.

5.2 Ground Water Quality:

The ground water of the study area can be assessed as neutral to slightly alkaline. The electrical conductivity of ground water samples in Mandsaur district varies from 424 to 2215 µS/cm at 25°C. The maximum EC has been observed in the water sample of Nayakhera village (2214 µS/cm at 25°C). The maximum concentration of fluoride has been observed at Suwasara (1.34 mg/l). Nitrate in ground water samples of Mandsaur district have varied range from 13 to 124 mg/l. It is observed that 38% samples have Nitrate concentration more than the acceptable limit i.e. 45 mg/l.

Chapter-6

GROUND WATER MANAGEMENT STRATEGIES

6.1 District Ground Water Management Plan:

The demand of fresh water for agriculture, drinking and industrial uses etc. has significantly increased due to population growth and socio-economic development. As surface water resources in the district are in-adequate, the dependability on ground water resources has increased substantially. This has resulted in rapid exploitation of ground water resources and depletion of ground water levels in various parts of the State.

The District Mandsaur is one of the under stress rapid exploitation of ground water resources in the district, ground water resources in the area are under continuous depletion. Thus there is urgent need for taking up suitable water management interventions based on integrated approach, which on one hand includes augmentation of ground water resources through appropriate techniques, and on the other hand requires the adoption of suitable water conservation measures, such as ensuring water use efficiency through creation of additional water storage facility, maintenance/ renovation of existing water bodies etc. Water awareness and capacity building of the stakeholders are also the important attributes of water management interventions as envisaged in the National Water Policy.

Artificial recharge to ground water is one of the most efficient, scientifically proven and cost effective technology to mitigate the problems of over exploitation of ground water resources. The technology serves as a means for restoring the depleted ground water storage, ameliorate the ground water quality problems and also enhance the sustainability of wells in the affected areas. A detailed knowledge of geology, hydrogeology, land use pattern, geomorphology and hydro-meteorological features are however, essential for selection of appropriate artificial recharge techniques as well as design and sites of ground water recharge structures.

As per directions of Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India, preparation of Aquifer Management Plan for Mandsaur district in the State has been prepared block wise as shown in Table 8 and financial out lay plan is also shown in Table 9. Each Plan discusses the broad framework of ground water situation in the block, status of water availability (both surface and ground water), identification of feasible areas for interventions, feasibility of artificial recharge and other water conservation structures, their design considerations, numbers and cost estimates. The expected outcomes of the proposed interventions have also been elucidated and given in table 11. As Mandsaur district having **Stage of extraction 107.27%,** after proposed intervention **Stage Of extraction will be 73.56%.**

Table 8: Block Wise Management Plan, Mandsaur District
(Source Water for Artificial Recharge and number of Recharge Structure)

Block	Area (Sq Km)	Area suitable for recharge (Sq Km)	Rainfall (m)	Average post-monsoon water level (m)	Un saturated zone (m)	Avg. SP Yield (%)	Sub-surface storage (mcm)	Surface water requi-red (mcm)	Surface water Run-off (mcm)	Non-committed Run-off (mcm)	Percolation tank	Recharge shaft / Tube well	NB/ CD/ CP	No of Village Ponds
Bhanpura	1051.18	506.48	0.9312	4.32	1.32	0.02	13.371	17.78	252.28	75.68	18	62	124	86
Garoth	1136	1136	1.0566	4.6	1.6	0.02	36.352	48.35	272.64	81.79	48	97	338	195
Malhargarh	806	806	0.891	4.32	1.32	0.02	21.278	28.30	193.44	58.03	28	57	198	168
Mandsaur	1266	1266	0.7826	5.17	2.17	0.02	68.500	91.11	303.84	91.15	91	182	638	223
Sitamau	1276	1276	1.0865	4.45	1.45	0.02	37.004	49.22	306.24	91.87	49	98	345	234
TOTAL	**5535.18**	**4990.48**		**4.57**	**1.57**	**0.02**	**176.505**	**234.75**	**1328.44**	**398.53**	**234**	**496**	**1643**	**906**

Table 9: Financial Outlay Plan

District	Area Suitable for AR	Volume of Surface Water available for AR (MCM)	Volume of Water required for recharge (MCM)	Percolation Tanks		NB/ CD/ CP		Recharge shaft/ Tube well		Renovation of Village Ponds		Total Cost of RS in crores
				Nos	cost (crores)	Nos	cost (crores)	Nos	cost (crores)	Nos	cost (crores)	
Bhanpura	506.48	252.28	17.78	18	3.6	124	12.45	62	0.62	86	1.72	18.39
Garoth	1136	272.64	48.35	48	9.6	338	33.84	97	0.97	195	3.9	48.31
Malhargarh	806	193.44	28.30	28	5.6	198	19.81	57	0.57	168	3.36	29.34
Mandsaur	1266	303.84	91.11	91	18.2	638	63.77	182	1.82	223	4.46	88.25
Sitamau	1276	306.24	49.22	49	9.8	345	34.45	98	0.98	234	4.68	49.91
TOTAL	**4990.48**	**1328.44**	**234.75**	**234**	**46.8**	**1643**	**164.33**	**496**	**4.96**	**906**	**18.12**	**234.21**

6.2 Intervention of Technology:

The drip irrigation technology

Rising demand for irrigation water amid concerns of rowing water scarcity has brought into renewed focus the need for improving water use efficiency and raising crop water productivity. Great emphasis is being made on achieving water conservation through various demand side management interventions encompassing technological options and policy measures. Given the difficulties and political concerns associated with bringing about effective policy reforms to achieve the objective of water conservation, this emphasis has generally focused on technological solutions backed by soft policy interventions to aid and facilitate adoption of technological solutions by farmers.

Micro irrigation technologies such *drip and sprinkler* systems are being increasingly promoted as technological solutions for achieving water conservation. Of the two technologies, drip irrigation, in its various forms, has been a relatively more important mode of micro irrigation in India. Enough empirical evidences available from different parts of the country to suggest that drip technology saves water and is cost effective and has significant economic and social benefits.

Drip irrigation saves water and electricity for pumping water, useless labor and leads to higher crop productivity.

Farmers in India generally practice flood irrigation resulting in low water application and use efficiency. The estimated surface irrigation water use efficiency in India is 35-40%. With deteriorating surface water infrastructure and rapid declines in ground water tables in large parts of the country, and in the face of increasing demand for water from all sectors of the economy, there is a wide spread concern for using the available water more efficiently. Micro irrigation systems, comprised of drip and sprinkler technologies, have emerged as an effective tool for water conservation and improving water use efficiency. While drip irrigation is ideally suited for horticulture crops such as pomegranates, grapes, mangoes, bananas, guava, coconuts, amla, and cash crops such as sugarcane, it is being used for cultivation of other crops as well. Sprinklers are generally useful in undulating land planted with cereal crops. Despite substantial efforts in promoting demand side management technologies, in practice, drip and sprinkler technologies have been slow to be accepted by farmers. Of the two, drip irrigation is the more preferred technology.

Drip irrigation is an irrigation method which enables saving water by allowing water to drip slowly to the roots of plants, either on the soil surface or directly into the root zone. Drip irrigation methods range from simple bucket kit systems for small farms to automated systems linking release of water to soil moisture conditions measured continuously by tension meters. Drip Irrigation technologies can be categorized into two groups based on their technical, economic and social attributes. These are low cost drip irrigation technologies and pressurized systems. The low cost drip irrigation technologies include the"pepsee[3],"easydrip, various kinds of affordable drip irrigation systems designed by IDE, and micro tube rip systems.

To reduce the ground water draft in Mandsaur district it is proposed that total irrigated Area 254982 ha which is irrigated by ground water, if 50% of this area i.e 127491 ha is to be irrigated by using sprinkle then for saving about 101.99 MCM of groundwater . The block wise area proposed for irrigation through sprinkles is given in table no12.

Table 10: Irrigated Area (ha) proposed for irrigation through sprinkler, Mandsaur district

Block	Irrigated Area (ha)	50% Irrigated Area (ha) proposed for irrigation through sprinkler	No. of Sprinklers proposed/ha	Unit cost (Rs) of sprinkler /ha	Total cost (Rs in cr)	Saving by Sprinkler in MCM
Bhanpura	28449	14224.5	569	2000	0.1138	11.38
Garoth	53691	26845.5	1074	2000	0.21476	21.48
Malhargarh	42126	21063	843	2000	0.1685	16.85
Mandsaur	70698	35349	1414	2000	0.28279	28.28
Sitamau	60018	30009	1200	2000	0.24007	24.01
Total	**254982**	**127491**	**5100**	**10000**	**1.01993**	**101.99**

Table 11: Management Plan after Intervention, Mandsaur District

Block	Annual extractable ground water resource in MCM	GW extraction for Irrigation in MCM	GW extraction for Domestic in MCM	Total extraction in MCM	Stage of extraction (%)	Saving by Sprinkler in MCM	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Extraction after sprinkler	Stage of extraction (%)	Additional area irrigated by GW after intervention
Bhanpura	59.764	52.024	3.694	55.718	93.230	11.380	13.370	73.1340	5.35	49.688	67.941	1337
Garoth	136.357	114.042	7.071	121.113	88.82	21.480	36.350	172.7070	14.540	114.173	66.108	3635
Malahargarh	102.209	90.802	4.836	95.638	93.570	16.850	21.280	123.4890	8.510	87.298	70.693	2128
Mandsaur	145.218	147.908	10.793	158.701	109.290	28.280	68.500	213.7180		130.421	61.025	0
Sitamau	160.051	209.600	6.717	216.317	135.160	24.010	37.000	197.0510		192.307	97.593	0
Total	**603.598**	**614.370**	**33.112**	**647.489**	**107.270**	**102.000**	**176.510**	**780.1080**	**28.400**	**573.882**	**73.564**	**7100**

6.3 Management Plan of Bhanpura Block

Area in Sq Km	1051.18
Rainfall in m	0.9312
Area Suitable for Recharge in Sq Km	506.48
Average Post Monsoon DTW in mbgl	4.32
Unsaturated Zone in m	1.32
Average Specific Yield in	0.02
Sub Surface Storage Potential (MCM)	13.37
Surface Water Required (MCM)	17.78
Runoff Available (MCM)	252.28
Non committed Runoff available (MCM)	75.68

Table 12: Management plan of Bhanpura block

Items	Statics	Amount in Crore	Total Cost in Crore
No. of Recharge Shaft/ Tube Wells	62	**0.62**	**18.39**
No. of Percolation tanks	18	**3.6**	
No. of NB/CD/CP	124	**12.45**	
No . Of Village Ponds	86	**1.72**	

Block	Annual extractable ground water resource in MCM	GW extraction for Irrigation in MCM	GW extraction for Domestic in MCM	Total extraction in MCM	Stage of extraction (%)	Saving by Sprinkler in MCM	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Extraction after sprinkler	Stage of extraction (%)	Additional area irrigated by GW after intervention
Bhanpura	59.764	52.024	3.694	55.718	93.230	11.380	13.370	73.1340	5.35	49.688	67.941	1337

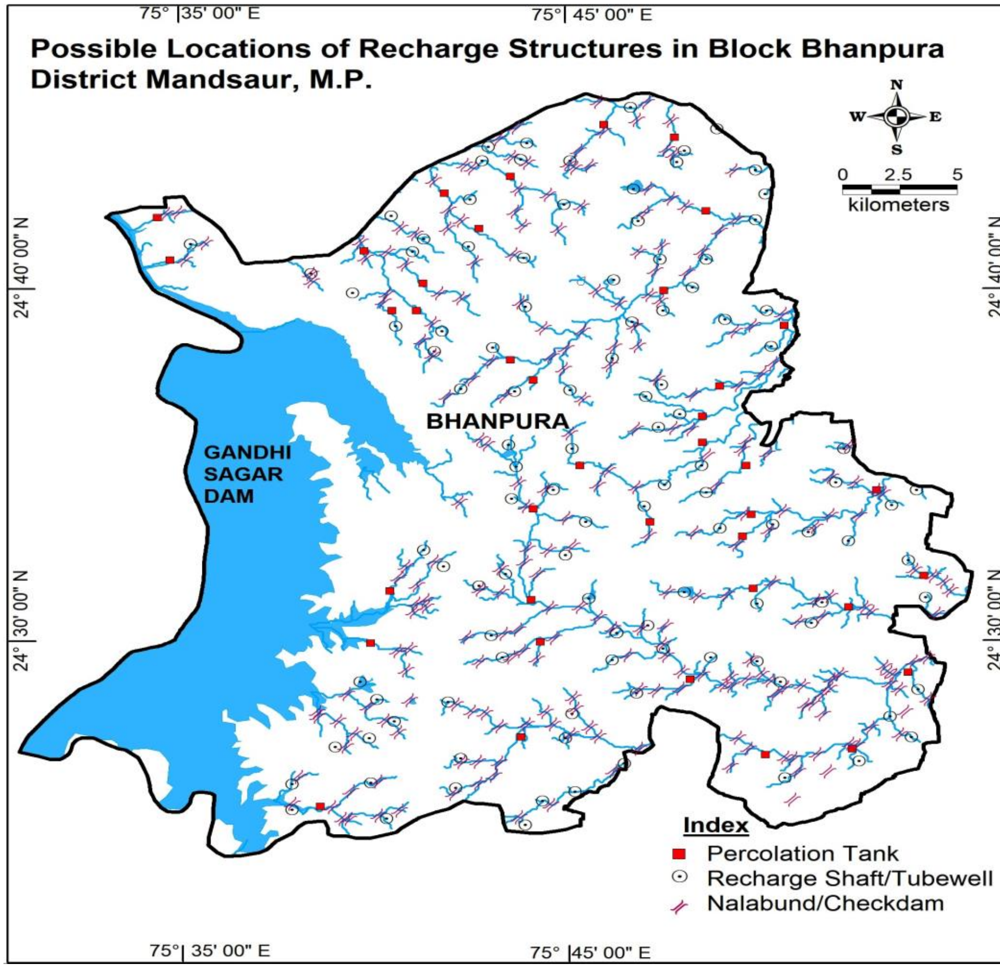

Fig. Possible locations of recharge structures in Bhanpura block

6.4 Management Plan of Garoth Block

Area in Sq Km	1136
Rainfall in m	1.0566
Area Suitable for Recharge in Sq Km	1136
Average Post Monsoon DTW in mbgl	4.6
Unsaturated Zone in m	1.6
Average Specific Yield	0.02
Sub Surface Storage Available (MCM)	36.352
Surface Water Required (MCM)	48.35
Runoff Available (MCM)	272.64
Non committed Runoff available (MCM)	81.79

Table 13: Management plan of Garoth Block

Items	Statics	Amount in Crore	Total Cost in Crore
No. of Recharge Shaft/ Tube Wells	97	**0.97**	**48.31**
No. of Percolation tanks	48	**9.6**	
No. of NB/CD/CP	338	**33.84**	
No of Village Pond	195	**3.90**	

Block	Annual extractable ground water resource in MCM	GW extraction for Irrigation in MCM	GW extraction for Domestic in MCM	Total extraction in MCM	Stage of extraction (%)	Saving by Sprinkler in MCM	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Extraction after sprinkler	Stage of extraction (%)	Additional area irrigated by GW after intervention
Garoth	136.357	114.042	7.071	121.113	88.82	21.480	36.350	172.7070	14.540	114.173	66.108	3635

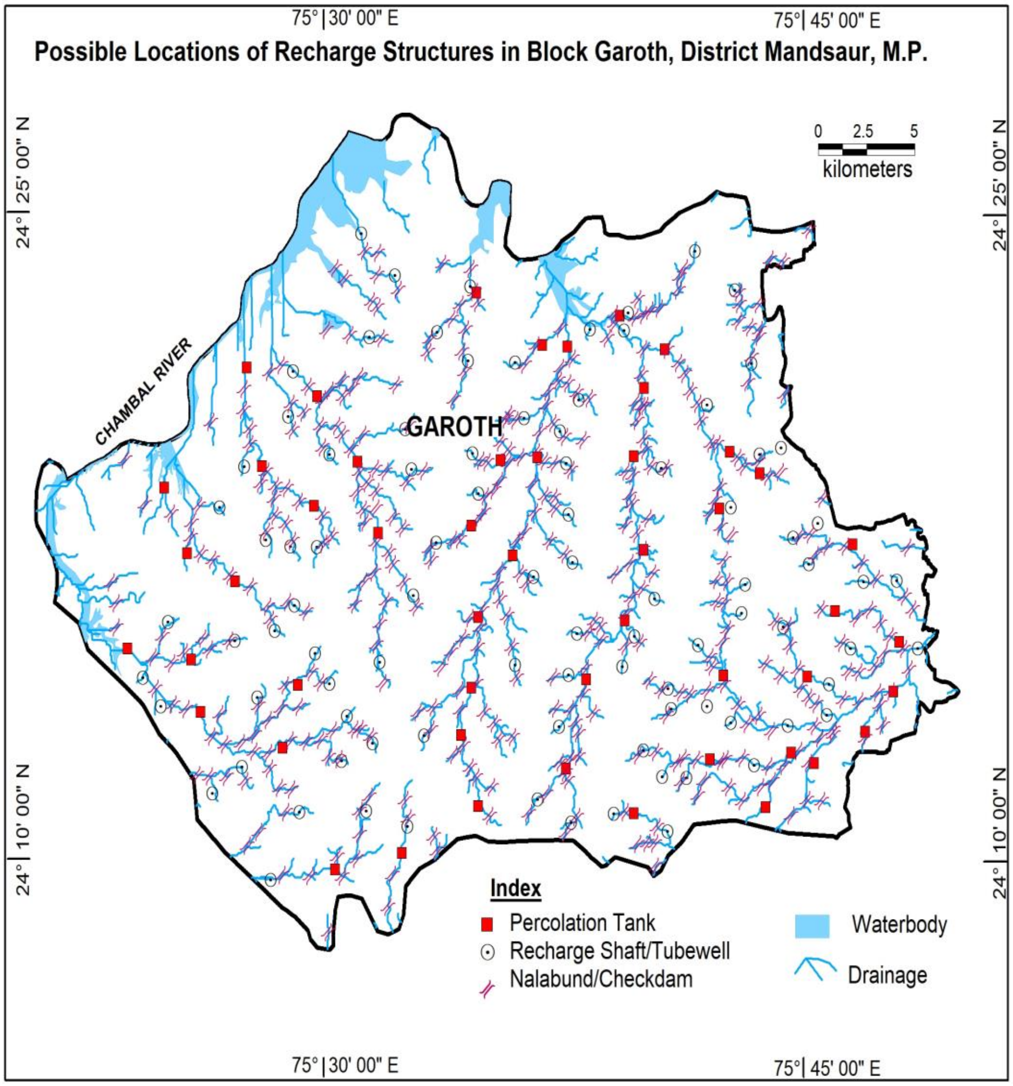

Fig. Possible locations of recharge structures in Garoth block

6.5 Management Plan of Malahargarh Block

Area in Sq Km	806
Rainfall in m	0.891
Area Suitable for Recharge in Sq Km	806
Average Post Monsoon DTW in mbgl	4.32
Unsaturated Zone in m	1.32
Average Specific Yield in	0.02
Sub Surface Storage Available (MCM)	21.278
Surface Water Required (MCM)	28.30
Runoff Available (MCM)	193.44
Non committed Runoff available (MCM)	58.03

Table 14: Management plan of Malahargarh Block

Items	Statics	Amount in Crore	Total Cost in Crore
No. of Recharge Shaft/ Tube Wells	57	0.57	29.34
No. of Percolation tanks	28	5.6	
No. of NB/CD/CP	198	19.81	
No of Village Pond	168	3.36	

Block	Annual extractable ground water resource in MCM	GW extraction for Irrigation in MCM	GW extraction for Domestic in MCM	Total extraction in MCM	Stage of extraction (%)	Saving by Sprinkler in MCM	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Extraction after sprinkler	Stage of extraction (%)	Additional area irrigated by GW after intervention
Malahargarh	102.209	90.802	4.836	95.638	93.570	16.850	21.280	123.4890	8.510	87.298	70.693	2128

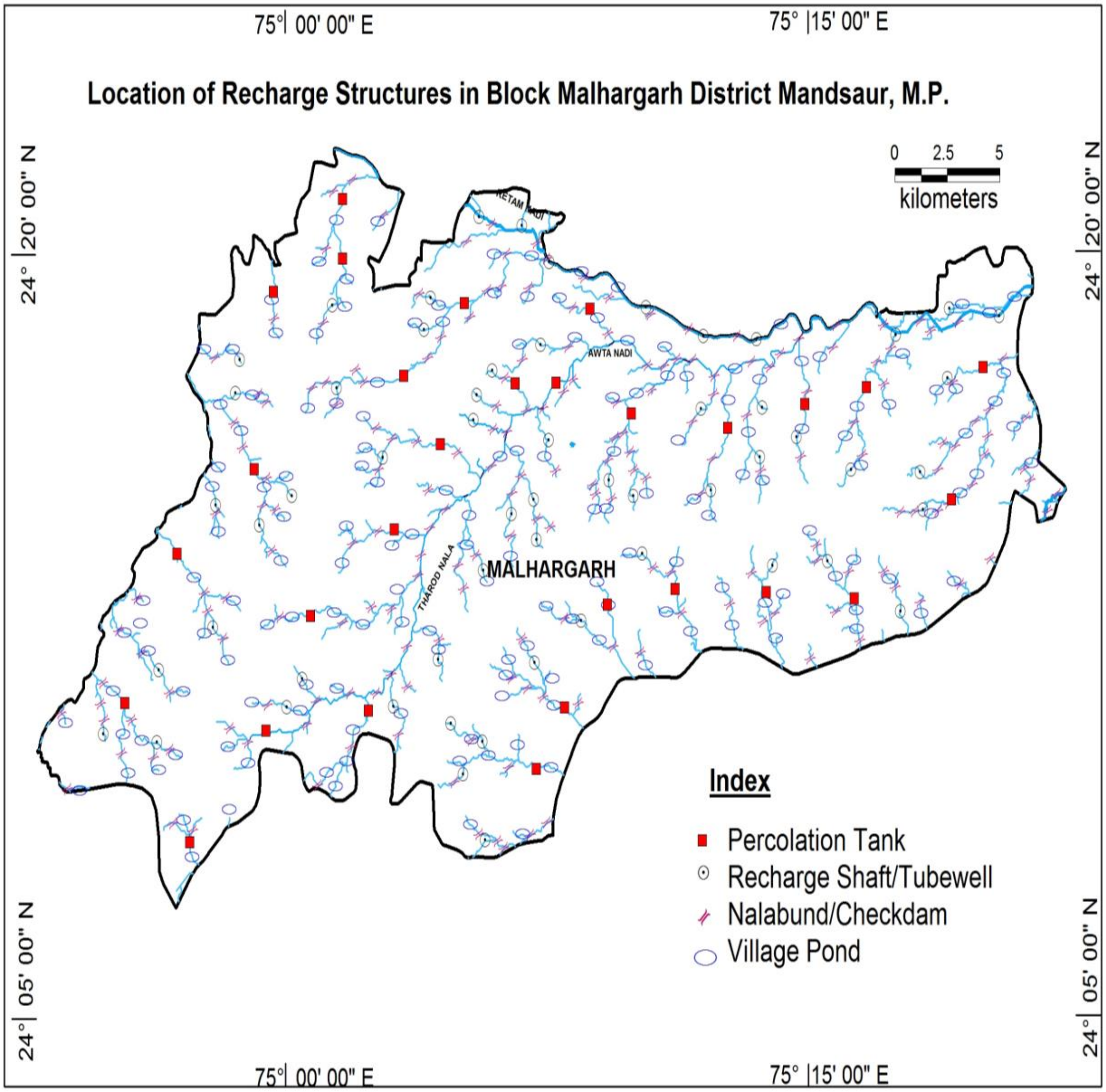

Fig. Possible locations of recharge structures in Malahargarh block

6.6 Management Plan of Mandsaur Block

Area in Sq Km	1266
Rainfall in m	0.783
Area Suitable for Recharge in Sq Km	1266
Average Post Monsoon DTW in mbgl	5.17
Unsaturated Zone in m	2.17
Average Specific Yield in	0.02
Sub Surface Storage Available (MCM)	68.50
Surface Water Required (MCM)	91.11
Runoff Available (MCM)	303.84
Non committed Runoff available (MCM)	91.15

Table 15: Management plan of Mandsaur Block

Items	Statics	Amount in Crore	Total Cost in Crore
No. of Recharge Shaft/ Tube Wells	182	1.82	**88.25**
No. of Percolation tanks	91	18.2	
No. of NB/CD/CP	638	63.77	
No of Village Pond	223	4.46	

Block	Annual extractable ground water resource in MCM	GW extraction for Irrigation in MCM	GW extraction for Domestic in MCM	Total extraction in MCM	Stage of extraction (%)	Saving by Sprinkler in MCM	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Extraction after sprinkler	Stage of extraction (%)	Additional area irrigated by GW after intervention
Mandsaur	145.218	147.908	10.793	158.701	109.290	28.280	68.500	213.7180		130.421	61.025	0

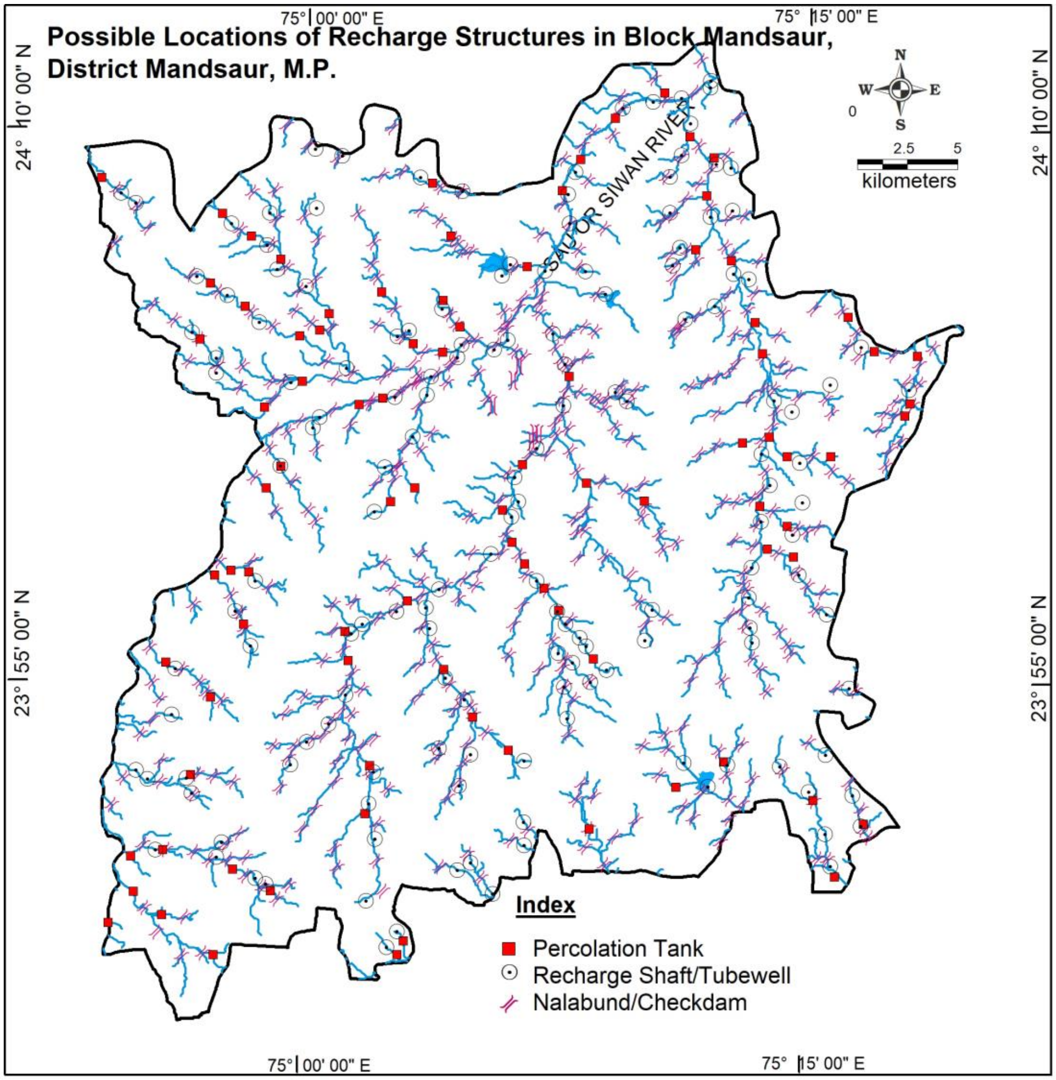

Fig. Possible locations of recharge structures in Mandsaur block

6.7 Management Plan of Sitamau Block

Area in Sq Km	1276
Rainfall in m	1.0865
Area Suitable for Recharge in Sq Km	1276
Average Post Monsoon DTW in mbgl	4.45
Unsaturated Zone in m	1.45
Average Specific Yield	0.02
Sub Surface Storage Available (MCM)	37
Surface Water Required (MCM)	49.22
Runoff Available (MCM)	306.24
Non committed Runoff available (MCM)	91.87

Table 16: Management plan of Sitamau Block

Items	Statics	Amount in Crore	Total Cost in Crore
No. of Recharge Shaft/ Tube Wells	98	0.98	**49.91**
No. of Percolation tanks	49	9.8	
No. of NB/CD/CP	344	34.45	
No of Village Pond	234	4.68	

Block	Annual extractable ground water resource in MCM	GW extraction for Irrigation in MCM	GW extraction for Domestic in MCM	Total extraction in MCM	Stage of extraction (%)	Saving by Sprinkler in MCM	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Extraction after sprinkler	Stage of extraction (%)	Additional area irrigated by GW after intervention
Sitamau	160.051	209.600	6.717	216.317	135.160	24.010	37.000	197.0510		192.307	97.593	0

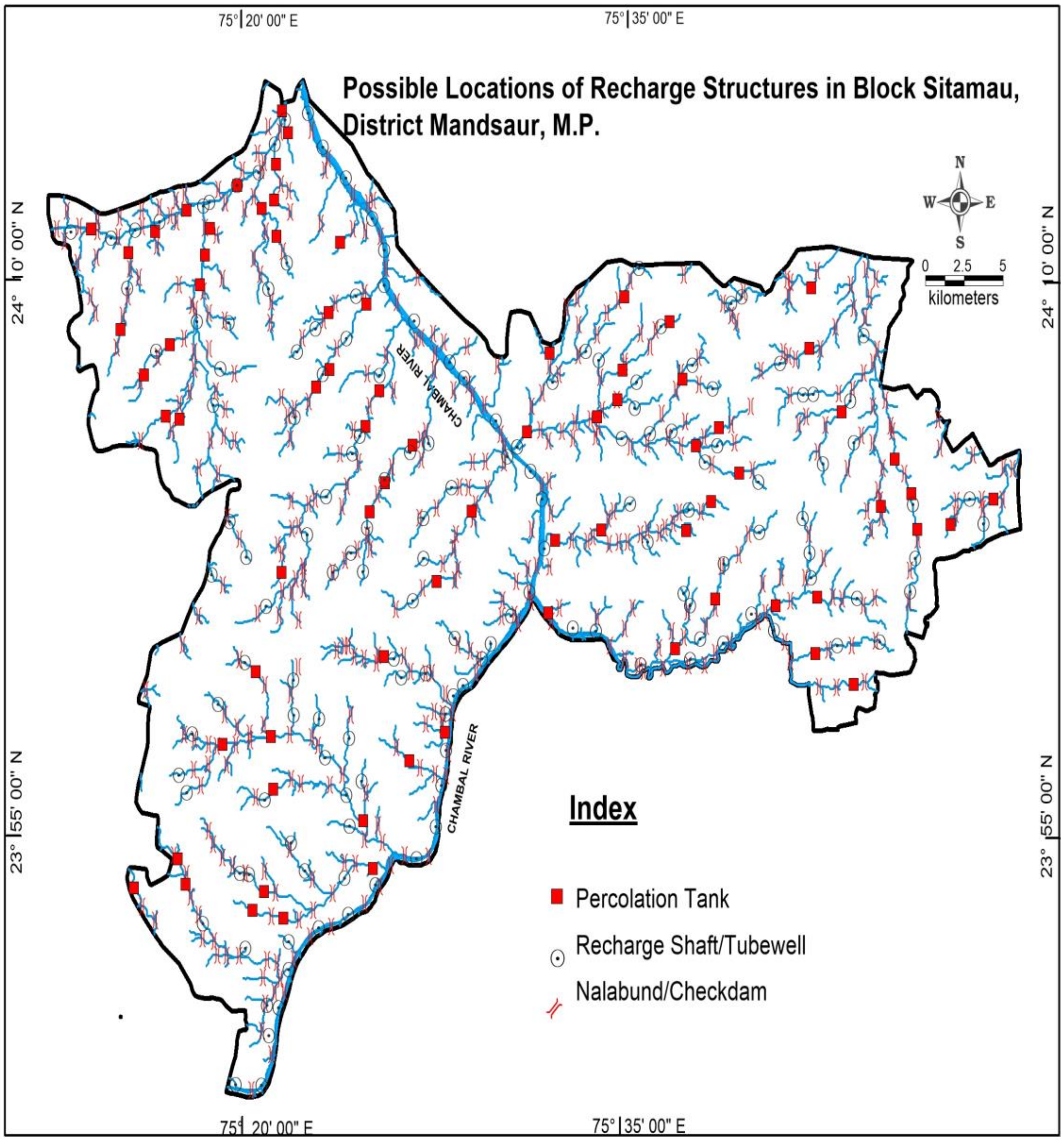

Fig. Possible locations of recharge structures in Sitamau block

Chapter-7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions:

The study was carried out based on data gap analysis, data generated through in-house and outsourcing exploration, data acquired from State Govt. departments and various thematic maps was prepared through GIS platform. All the available data was brought on GIS platform and an integrated approach was adopted for preparation of block wise aquifer maps and aquifer management plans of Mandsaur District.

- Mandsaur district is located on northwest part of Madhya Pradesh extends between the parallels of latitude 24°4'36.6096" North and between the meridians of longitude 75°4'9.4728" East, and it is falling in the Survey of India Topo Sheet No. 45P and 46M. The total geographical area of the district is 5535 Sq.Km, with a population of 1340411 according to census 2011. The district is divided into 8 tehsils and 5 blocks.
- Major parts of the district having gently sloping topography ranging the elevation between 445 m and 518 m above mean sea level and falls under Chambal river sub-basin.
- Geologically major parts of the Mandsaur district is occupied by Deccan Trap basalts except narrow patch of alluvium and sedimentary rocks of Vindhyans super group in isolated patches, which are forming different type of aquifer in the area. Occurrence and movement of groundwater in hard rock is mainly controlled by secondary porosity through joints and fractures. Presences of vesicle in basaltic lava flow of Deccan Traps play an important role in groundwater movement. Groundwater in general occurs under unconfined to semi-confined conditions.
- Depth to water level ranges from 4.3m bgl to 22.8 (mbgl) during pre-monsoon 2020 and 0.4 m bgl to 8.9 m bgl during post-monsoon 2019. The ground water of the study area can be assessed as neutral to slightly alkaline.It is observed that 38% samples have Nitrate concentration more than the acceptable limit.
- The Annual Extractable ground water resource for Mandsaur district has been assessed as 60359.85 ham. Total extraction of the entire district for 2020 has been estimated as 64748.93 ham. Agriculture sector remained the predominant consumer of ground water resources. Total annual ground water extraction i.e. 61437.69 ham is for irrigation use.

Only 3311.25 ham is for Domestic use. An analysis of ground water extraction figure indicates **107.27%** stage of ground water extraction.

- As a part of Supply side Management, a total of 234 percolation tanks, 496 recharge shafts, 1643 Nalla bunds/Check dams and 906 village ponds were proposed for water conservation.
- As a part of Demand side Management, micro-irrigation techniques are to be adopted and it is proposed if 50 % of total irrigated area (127491 ha) is irrigated by using sprinkle 101.99 MCM of groundwater can be saved and in turn can bring down the Stage of Ground Water Development to 73.56%.

7.2 Recommendations:

- Awareness program to educate about conservation of precious ground water resources and trainings on rainwater harvesting will be beneficial for managing and proper utilization of available groundwater resources.
- Ground water development in over-exploited, critical and semi-critical area should not be encouraged.
- Micro irrigation technologies such as drip and sprinkler systems to be promoted as technological solutions for achieving water conservation.
- Modern agricultural management techniques have to be adopted for effective and optimum utilization of the water resources. This can be achieved by maintaining irrigation through minimum pumping hours as per minimum requirement of water by the crop and also selecting most suitable cost effective crop pattern.
- High water requirement crops to be discouraged. Proper agriculture extension services should be provided to the farmers so that they can go for alternate low water requirement economical crops.
- Roof top Rain water harvesting can be adopted to meet the day to day requirements which will reduce ground water withdrawal. Implementation of artificial recharge structures in such areas through outside surface water sources or floodwater during excess rainy years be promoted.
- The Impact assessment study is to be conducted about the change in Ground water scenario in quantitative & qualitative aspects, which can be done by monitoring of Dugwells & piezometres for water level measurements and water samples collection & chemical analysis periodically, after construction of suitable recharge structures.

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ANEXURE-I

LOCATION DETAILS OF EXPLORATION BORE WELLS

Bore wells	Easting	Northing	Elevation	Total Depth
Barkeda dev	501784.2	2690652.6	445.4	200
Aakli Shivdas	563606	2680359.8	446	158.85
Area	558314.4	2695755.3	409	200
Bhetikhedi	530983.6	2671974.7	411	161.6
Bhatana	525080.3	2658366.2	450.2	200
Bhawanipura	566844	2714864.6	413	200
Borekhedi	576092.3	2653760.3	482.7	164.2
Borkhedi Jagir	546678	2667083.1	412.5	200
Chikniya	574987.2	2688304.7	440.7	200
Damma Khedi	534102.4	2653990.3	465.7	200
Dhukiya	550553.7	2657852	434.3	200
Gadriya	538588.2	2677307.8	409	200
Garrawad	517462.3	2680476.9	446.4	87.6
Gudbheli	540474.6	2648686.3	435.8	200
Jetpura	495995.3	2679445.7	475.2	200
Kajuri	497626.9	2655711.9	447.1	170.05
Kaktiya	520328.6	2642646.5	492.2	200
Kheroda	523181.3	2610452.5	457	200
Kunta Khedi	527247.8	2663006.1	445	200
Kuravan	554864.7	2669943.1	424.6	200
Labdadi	514024.5	2666257.1	430.7	139.7
Lakhamkhedi	540889.2	2685784.4	411.9	97.6
Lasudiya	533395.3	2637984.9	439.3	152.5
Navli	574091.8	2723290.6	474.8	200
Pardikeda	567570.1	2666797.8	475.9	150.2
Pithyakhedi	547811.8	2652165.8	421	200
Ralayati	549020.5	2685201.2	424.2	200
Rinchha	508528.7	2679472.3	443.7	200
Sameli	589174.5	2707433.2	358	158.85
Sandhara	587795.9	2717169.1	360.9	200
Semli	491092.9	2674755.9	468.2	200
Vishniya	577886.4	2677801.3	397	200

ANEXURE-II

LITHOLOG DETAILS OF EXPLORATORY BORE WELLS

Bore wells	Depth1	Depth2	Stratigraphy
Barkeda dev	0	3	Top Soil
Barkeda dev	3	10	Weathered Basalt
Barkeda dev	10	30	Massive Basalt
Barkeda dev	30	116	Sandstone
Barkeda dev	116	200	Shale
Aakli Shivdas	0	3	Top Soil
Aakli Shivdas	3	10	Weathered Basalt
Aakli Shivdas	10	79	Massive Basalt
Aakli Shivdas	79	90	Fractured Basalt/Vesicular Basalt
Aakli Shivdas	90	90	Red Ball
Aakli Shivdas	90	130	Massive Basalt
Aakli Shivdas	130	148	Fractured Basalt/Vesicular Basalt
Aakli Shivdas	148	155	Red Ball
Bhetikhedi	0	2	Top Soil
Bhetikhedi	2	11	Weathered Basalt
Bhetikhedi	11	35	Massive Basalt
Bhetikhedi	35	41	Fractured Basalt/Vesicular Basalt
Bhetikhedi	41	160	Sandstone
Bhetikhedi	160	162	Shale
Borekhedi	0	5	Top Soil
Borekhedi	5	29	Weathered Basalt
Borekhedi	29	70	Massive Basalt
Borekhedi	70	87	Fractured Basalt/Vesicular Basalt
Borekhedi	87	92	Red Ball
Borekhedi	92	140	Massive Basalt
Borekhedi	140	145	Fractured Basalt/Vesicular Basalt
Borkhedi Jagir	0	3	Top Soil
Borkhedi Jagir	3	10	Weathered Basalt
Borkhedi Jagir	10	40	Massive Basalt
Borkhedi Jagir	40	52	Fractured Basalt/Vesicular Basalt
Borkhedi Jagir	52	56	Red Ball
Borkhedi Jagir	56	98	Massive Basalt
Borkhedi Jagir	98	128	Fractured Basalt/Vesicular Basalt
Borkhedi Jagir	128	128	Red Ball
Borkhedi Jagir	128	200	Sandstone
Chikniya	0	3	Top Soil

Bore wells	Depth1	Depth2	Stratigraphy
Chikniya	3	12	Weathered Basalt
Chikniya	12	58	Massive Basalt
Chikniya	58	65	Fractured Basalt/Vesicular Basalt
Chikniya	70	140	Massive Basalt
Chikniya	140	158	Fractured Basalt/Vesicular Basalt
Damma Khedi	0	5	Top Soil
Damma Khedi	5	13	Weathered Basalt
Damma Khedi	13	55	Massive Basalt
Damma Khedi	55	62	Fractured Basalt/Vesicular Basalt
Damma Khedi	62	200	Sandstone
Dhukiya	0	5	Top Soil
Dhukiya	5	12	Weathered Basalt
Dhukiya	12	73	Massive Basalt
Dhukiya	73	78	Fractured Basalt/Vesicular Basalt
Dhukiya	78	138	Massive Basalt
Dhukiya	138	145	Fractured Basalt/Vesicular Basalt
Dhukiya	145	200	Sandstone
Gadriya	0	5	Top Soil
Gadriya	5	28	Weathered Basalt
Gadriya	28	60	Massive Basalt
Gadriya	60	85	Fractured Basalt/Vesicular Basalt
Gadriya	85	90	Red Ball
Gadriya	90	114	Massive Basalt
Gadriya	114	127	Fractured Basalt/Vesicular Basalt
Gadriya	127	200	Sandstone
Garrawad	0	2	Top Soil
Garrawad	2	5	Weathered Basalt
Garrawad	5	70	Massive Basalt
Garrawad	70	83	Fractured Basalt/Vesicular Basalt
Garrawad	83	88	Red Ball
Gudbheli	0	5	Top Soil
Gudbheli	5	18	Massive Basalt
Gudbheli	18	30	Fractured Basalt/Vesicular Basalt
Gudbheli	30	79	Red Ball
Gudbheli	79	146	Massive Basalt
Gudbheli	146	152	Fractured Basalt/Vesicular Basalt
Gudbheli	152	200	Sandstone
Kaktiya	0	5	Top Soil
Kaktiya	5	13	Weathered Basalt
Kaktiya	13	68	Massive Basalt
Kaktiya	68	93	Fractured Basalt/Vesicular Basalt

Bore wells	Depth1	Depth2	Stratigraphy
Kaktiya	93	160	Massive Basalt
Kaktiya	160	176	Fractured Basalt/Vesicular Basalt
Kheroda	0	5	Top Soil
Kheroda	5	12	Weathered Basalt
Kheroda	12	66	Massive Basalt
Kheroda	66	84	Fractured Basalt/Vesicular Basalt
Kheroda	84	152	Massive Basalt
Kheroda	152	170	Fractured Basalt/Vesicular Basalt
Kheroda	170	200	Sandstone
Kunta Khedi	0	3	Top Soil
Kunta Khedi	3	5	Weathered Basalt
Kunta Khedi	5	32	Massive Basalt
Kunta Khedi	32	38	Fractured Basalt/Vesicular Basalt
Kunta Khedi	38	85	Sandstone
Kunta Khedi	85	200	Shale
Kuravan	0	3	Top Soil
Kuravan	3	10	Weathered Basalt
Kuravan	10	78	Massive Basalt
Kuravan	78	83	Fractured Basalt/Vesicular Basalt
Kuravan	83	168	Massive Basalt
Kuravan	168	173	Fractured Basalt/Vesicular Basalt
Kuravan	173	200	Sandstone
Labdadi	0	1	Top Soil
Labdadi	1	140	Sandstone
Lakhamkhedi	0	1	Top Soil
Lakhamkhedi	1	5	Weathered Basalt
Lakhamkhedi	5	94	Massive Basalt
Lakhamkhedi	94	97.6	Red Ball
Lasudiya	0	1	Top Soil
Lasudiya	1	5	Weathered Basalt
Lasudiya	5	68	Massive Basalt
Lasudiya	68	73	Fractured Basalt/Vesicular Basalt
Lasudiya	73	138	Massive Basalt
Lasudiya	138	143	Fractured Basalt/Vesicular Basalt
Lasudiya	143	153	Red Ball
Ralayati	0	1	Top Soil
Ralayati	1	5	Weathered Basalt
Ralayati	5	38	Massive Basalt
Ralayati	38	43	Fractured Basalt/Vesicular Basalt
Ralayati	43	46	Red Ball
Ralayati	46	127	Massive Basalt

Bore wells	Depth1	Depth2	Stratigraphy
Ralayati	127	139	Fractured Basalt/Vesicular Basalt
Ralayati	139	200	Sandstone
Semli	0	3	Top Soil
Semli	3	5	Weathered Basalt
Semli	5	52	Massive Basalt
Semli	52	200	Shale
Vishniya	0	3	Top Soil
Vishniya	3	10	Weathered Basalt
Vishniya	10	58	Massive Basalt
Vishniya	58	65	Fractured Basalt/Vesicular Basalt
Vishniya	65	109	Massive Basalt
Vishniya	109	115	Fractured Basalt/Vesicular Basalt
Vishniya	115	200	Sandstone

Annexure-III

Resistivity characteristics of weathered zone, Mandsaur district

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
68					120-130(?)
69	49-24	24	132	24-42	Vindhyan Sandstone
					12-15, 25-35, 50-55, 65-75(?), 95-110,
					150-170
70	7-21	22			30-45, 70-75, 80-85, 120-130(?), 150
					160
71	9	5	67	5-17	30-50, 60-70, 80-85, 100-120, 160
					170, 180-190
			180	17-179	
72			55	6-11	20-40, 60-65, 95-100, 120-140,
			193	11-83	
73	26	18			
74			51	8-39	60-70, 100-110
75	14	12	72	12-113	30-55, 65-75, 160-200
76	49	25	180	25-54	Vindhyan Sandstone
					20-25, 55-60, 90-100(?),

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
77	12-27	38	21	102-182	12-15, 35-40(?), 45-55, 75-85, 90-100,
					150-160, 180-190
78	< 2	33			20-45, 80-85, 90-95
79	7	5	85	41-166	30-35, 80-85, 160-170
80	12	5	82	5-99	120-130(?)
81			17	27-107	20-25, 30-35
82			76	3-106	100-130, 150-160
83			88	1-104	
			36	104	
84	21	5	210	5-180	12-15, 35-40, 55-65, 100-120, 190-200
85	32	7	42	7-51	15-20, 35-40, 70-90, 120-130(?), 170
					180(?),
86	31	3			40-45, 110-120, 160-180
87			14	8-33	45-50, 80-90, 110-120(?)
88	5	6	36	49	35-45, 160-180
89	6	4	176	4-111	35-45, 50-55, 160-180(?)
90			27	47	

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
91			117	50-101	12-15, 20-25, 150-160
92	9	6	29	54-168	65-70, 95-110, 160-170
93	16	6	118	18-125	45-50, 100-120, 160-180
94					Vindhyan Sandstone 15-35, 50-55, 65-70, 100-110(?), 120 130, 150-160(?)
210	2	15			Vindhyan Sandstone 75-90
211	16	8	83	8-62	40-45, 70-75, 80-85, 130-160
212	14	6	53	11-31	15-20, 70-75, 90-95, 100-140, 170 180(?)

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
213	10	8	34	8-30	25-30, 45-50, 100-110, 130-140, 150
					160
214	7-9	27	15	55-118	25-40, 45-55, 70-75, 85-95, 130-140,
					160-170
215	13	3			30-35,45-55, 65-70, 100-110
216	Exmpl of v/m bslt repititio n	VES curve can be given as an example and discuss limitation in interpretation	82	2-15	45-50, 55-60, 95-120, 170-180
			124	15-146	
553					Vindhyan Sandstone
					25-30, 55-60(?),100-130
554	12	9	29	9-81	25-30, 55-60, 85-90(?), 100-110, 140
					150

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
555	17	10			Vindhyan Sandstone
					10-12, 40-45, 60-70, 100-120,
556	< 2	18			Vindhyan Sandstone
					12-15, 75-95(?), 160-170
557	28	7-20	77	20-88	100-120, 180-190
558	21	13	50	13-32	15-25, 35-50, 80-85(?), 140-150, 190
					200
			75	65-142	
559	5	1-8			Vindhyan Sandstone
	20	8-18			40-55, 70-75, 80-85, 100-110, 120
					130,
	54	18-48			

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
560	19	14	32	14-49	12-20, 35-40, 45-50, 65-70, 75-80, 90-
					95, 130-160
561	13	5	129	5-13	35-40, 50-55, 60-70, 130-140
	Example of vesicular fractured basalt limits				
562					
563			69	21-62	12-15, 120-150
564	Another example		55	4-10	15-20, 25-30, 140-150, 160-170
			97	10-180	
565	18	4	14	24-96	180-190
566	24	2-6			40-45, 70-75, 180-190
	3	6-45			
567	2	15			Vindhyan Sandstone
					75-80, 90-95,
568	5-2	2-32			45-50, 80-85, 95-100
569	8	4	67	4-109	10-12, 140-150, 160-170
			143	109	

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
570			13	24-121	140-150
571			31	38-165	15-25
572	12	7	87	7-164	20-35, 130-140, 160-170
573			20	30-147	15-20, 180-190
574					
575			115	18	15-20(?), 110-120(?), 180-190(?)
576	14	8	94	8-169	20-35, 140-150
577			77	45-145	130-150, 160-170
578	36	6	48	6-40	Vindhyan Sandstone, Basalt contact 12-30(?), 40-55, 70-75, 130-160
579	11	11	2	11-41	45-55,
580	10	10			50-55, 60-65, 95-100, 120-130, 160
					180
581	17	7	275	7-130	10-12, 40-45(?), 100-130, 150-160

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		**Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)**		
	Resistivity (ohm.m)	**Depth to the Bottom (m)**	**Resistivity (ohm.m)**	**Depth to the top & Bottom (m)**	
					Interpretation problem example and to utilize fractured zone in interpretation
582	11	6	18	24-73	10-12, 160-170(?)
583	4	23			25-30, 65-70, 85-100, 150-170
584	10	4-37			35-45, 50-55, 60-65, 75-80, 85-95(?),
					160-170(?)
585			12	38-150	
586			36	33-126	15-20, 170-180
587	3	3			30-40(?), 120-130, 160-170
588			46	17-93	160-170
589			18	15-84	15-20, 80-85, 100-120, 150-160, `170
					180
590			35	14-38	75-80, 120-130, 140-150(?), 170-180
			103	38-125	

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
591			147	1-49	50-55(?), 80-85, 120-140, 170-180(?)
592			166	2-44	15-20, 120-130, 190-200
593	7	11	55	11-90	30-35, 40-45, 50-55, 95-130, 180-190
594			173	3-126	15-20, 95-100, 120-130, 150-160(?)
595					
596	15-3	13	5	13-92	20-25, 30-35, 40-45, 70-80, 90-100,
					110-120, 150-160(?), 170-180(?).
597	4	8	45	8-77	20-25, 30-55(?), 65-70, 75-80, 85-90,
					130-150(?)
598	3-12	21			15-25, 40-50, 70-80, 95-110, 140-150,
					160-170(?)

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
599	28	3	39	7-40	12-15, 55-60, 80-85, 140-160(?), 180
					190
600			45	12-141	12-15, 160-170, 190-200
601	17	11	82	11-131	20-25, 35-40, 100-110, 140-150(?)
602			78	1-34	20-25, 60-65, 80-85, 100-110, 130
					140, 170-180
603	21	13			25-30, 45-50, 90-100, 130-140,
	7	13-34			
604	46	4	132	4-58	15-20, 60-70(?), 110-120, 140-150
605	9	4			12-15, 25-30, 55-60, 75-80, 100-110,
					120-130, 140-150, 180-190(?)
	35	4-40			
607	5	4			

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
608			30	10-45	75-80, 90-110, 130-140(?)
609			35	7-37	55-60, 85-95(?), 140-160
			121	37-74	
610	43	10	24	43-92	12-15, 25-30, 45-50, 60-65(?), 70-75,
					170-190
611	27	8			40-55, 70-75(?)
	7	8-38			
612			83	3-40	30-35, 50-55, 140-150(?),
613			40	3-50	45-55, 95-110, 120-130(?), 170-190
614	13	3-20			20-25, 40-45, 55-65, 85-90, 100-110,
					160-170
615			73	2-23	30-35, 50-55, 60-70(?), 100-110, 120
					130,
616	42	4			
617			103	2-20	30-40, 65-70(?), 100-110(?), 150

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
					160(?)
618			40	4-31	12-15, 25-30, 40-50(?), 70-75,
619	39	4	104	4-27	30-40, 70-75, 140-150, 170-180
620	5	3			30-35, 60-65, 100-120
621	16	11	71	11-35	15-20, 45-50, 55-60, 70-75, 90-95,
					100-110,150-160, 180-190
			120	35-130	
622					
623			48	1-45	60-70(?), 100-120
624	48	0-14			30-35, 45-55, 90-100, 110-130
	18	14-38			
625	15	5	129	16-156	25-30, 110-120,
626	9	5	143	5-168	50-55, 140-150, 170-180
627	17	7	30	12-21	10-15, 30-35, 60-65, 100-130(?)
			94	52-204	

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive-Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
628					50-55, 65-70, 100-120(?), 130-140,
					180-190(?)
629	An ex to show how to use fractured zone in modf lyr interp		15	10-44	55-60(?), 70-95(?), 100-110, 130-150,
					160-170
			62	44-181	
630	51	4			12-15, 100-130, 150-160
631	35	3	114	3-26	12-20(?), 25-30, 45-55, 75-90, 120-130
632	7	5			40-55(?), 65-70, 120-130
633			120	2-51	12-15(?), 110-120, 130-140(?), 180
					190
634	20	6			100-120, 140-160

Annexure-IV

VES sites where weathered zone aquifer can be tapped and depth to the bottom of weathered zone is >10 min which groundwater salinity problem has inferred

VES No.	Geology	Resistivity Characteristics	
		Weathered Zone Aquifer	
		Resistivity (ohm.m)	Depth to the Bottom (m)
69	Vindhyan Sandstone	49-24	24
70	Deccan Trap Basalt	7-21	22
73	Deccan Trap Basalt	26	18
75	Deccan Trap Basalt	14	12
76	Vindhyan Sandstone	49	25
77		12-27	38
555	Vindhyan Sandstone	17	10
557		28	7-20
558	Vindhyan Sandstone	21	13
559	Vindhyan Sandstone	5	1-8
		20	8-18
		54	18-48
560	Deccan Trap Basalt	19	14
579	Deccan Trap Basalt	11	11
580	Deccan Trap Basalt	10	10
584	Deccan Trap Basalt	10	4-37
596	Deccan Trap Basalt	15-3	13
598	Deccan Trap Basalt	3-12	21
601	Deccan Trap Basalt	17	11
603	Deccan Trap Basalt	21	13
		7	13-34
605	Deccan Trap Basalt	9	4

VES No.	Geology	Resistivity Characteristics	
		Weathered Zone Aquifer	
		Resistivity (ohm.m)	Depth to the Bottom (m)
		35	4-40
610	Binota Shale	43	10
611	Deccan Trap Basalt	27	8
		7	8-38
614	Deccan Trap Basalt	13	3-20
621	Deccan Trap Basalt	16	11
624	Deccan Trap Basalt	48	0-14
		18	14-38

Annexure-V

VES sites where fractured zone aquifers are expected to occur

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
77	12-27	38	21	102-182	12-15, 35-40(?), 45-55, 75-85, 90-100, 150-160, 180-190
85	32	7	42	7-51	15-20, 35-40, 70-90, 120-130(?), 170-180(?),
90			27	47	
92	9	6	29	54-168	65-70, 95-110, 160-170
214	7-9	27	15	55-118	25-40, 45-55, 70-75, 85-95, 130-140, 160-170
554	12	9	29	9-81	25-30, 55-60, 85-90(?), 100-110, 140-150
560	19	14	32	14-49	12-20, 35-40, 45-50, 65-70, 75-80, 90-95, 130-160
565	18	4	14	24-96	180-190
570			13	24-121	140-150
573			20	30-147	15-20, 180-190
582	11	6	18	24-73	10-12, 160-170(?)
585			12	38-150	
588			46	17-93	160-170
589			18	15-84	15-20, 80-85, 100-120, 150-160, `170-180
590			35 103	14-38 38-125	75-80, 120-130, 140-150(?), 170-180

VES	Resistivity Characteristics				Possible presence of thin fractured zone aquifer in the depth range (m)
	Weathered Zone Aquifer		Aquifer in Massive Vesicular Basalt Sequence (in basalt area)		
	Resistivity (ohm.m)	Depth to the Bottom (m)	Resistivity (ohm.m)	Depth to the top & Bottom (m)	
596	15-3	13	5	13-92	20-25, 30-35, 40-45, 70-80, 90-100, 110-120, 150-160(?), 170-180(?).
599	28	3	39	7-40	12-15, 55-60, 80-85, 140-160(?), 180-190