केंद्रीय 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

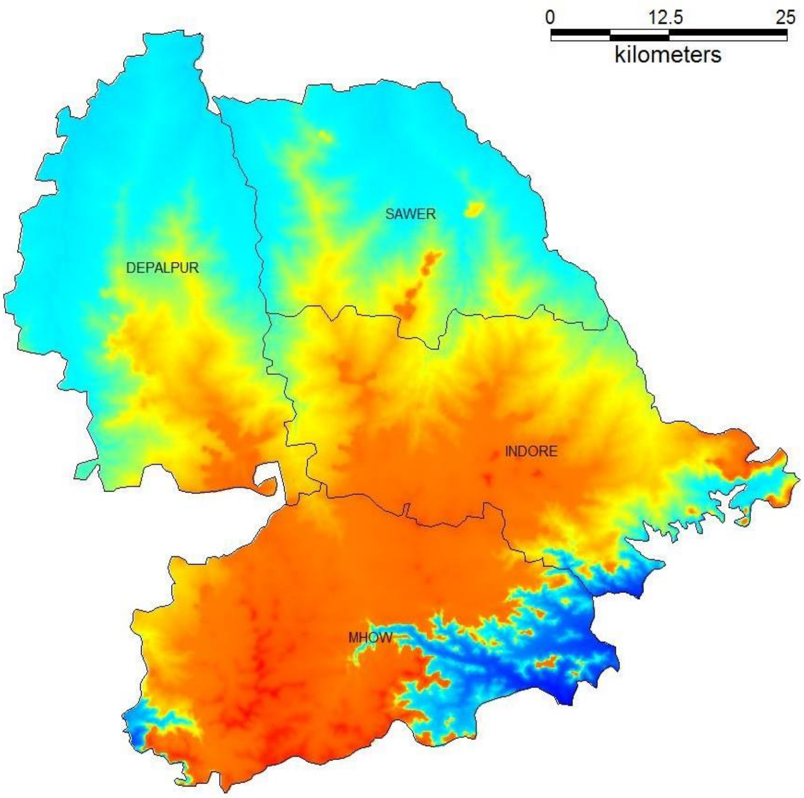
INDORE DISTRICT, MADHYA PRADESH

NORTH CENTRAL REGION
BHOPAL

CENTRAL GROUND WATER BOARD

MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVANATION

AQUIFER MAPPING AND MANAGEMENT PLAN INDORE DISTRICT, MADHYA PRADESH



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CENTRAL GROUND WATER BOARD
NORTH CENTRAL REGION
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PREFACE

Groundwater being a valuable asset and its relatively easy accessibility in comparison to surface water sources is primarily used for irrigation. The district of Indore with a total geographical area of about 3831 sq. km lies in the heart of Malwa Plateau. It is bordered by Ujjain district in the north, by Khargone district in the south by Dewas district in the east and by Dhar district in the west. Ground water is main source of irrigation in the district.

Under the National Aquifer Mapping (NAQUIM) project, multidisciplinary approach has been adopted for preparation of aquifer maps and ground water management plan for Indore district. The report consists of the existing hydrogeological, chemical and geophysical data that were compiled for the preparation of aquifer maps. The collected data was further processed to generate regional hydrogeological maps, thematic maps, water quality maps, cross-sections, 2-D and 3-D aquifer dispositions.

The aquifer management plan for Indore district has been prepared in which the ground water resources can be enhanced by 206.20 MCM through construction of artificial recharge structures viz. 274 percolation tanks, 1920 check dams/nala bunds, 549 recharge shafts and ensuring water use efficiency through maintenance/renovation of 656 existing water bodies/water conservation structures. Adoption of micro-irrigation techniques such as sprinkler irrigation has also been proposed, that will reduce the draft and conserve ground water resources by saving 75.18 MCM of resource from overall irrigation draft. A change in cropping pattern from wheat to gram has also been proposed that would reduce the overall irrigation draft. The interventions suggested in the report will not only have a positive impact on the ground water 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.

Parvinder Singh
(Regional Director)

CONTENTS

1. Introduction

Groundwater is of paramount importance for an agriculture-based country like India. Being a predominant asset the use of groundwater, primarily for irrigation and for various development activities over the years has adversely affected the ground water regime in many parts of the country. This has in turn led to an emergent need for comprehensive and realistic information pertaining to various aspects of groundwater resources available in different hydro-geological settings through a process of systematic data collection, compilation, data generation, analysis and synthesis which together brings in the concept of Aquifer Mapping and Management Plan.

Objectives and scope of the study

The primary objective of the Aquifer Mapping can be specified as "**Know your Aquifer, Manage your Aquifer**"**.** Systematic mapping of an aquifer incorporates activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale.

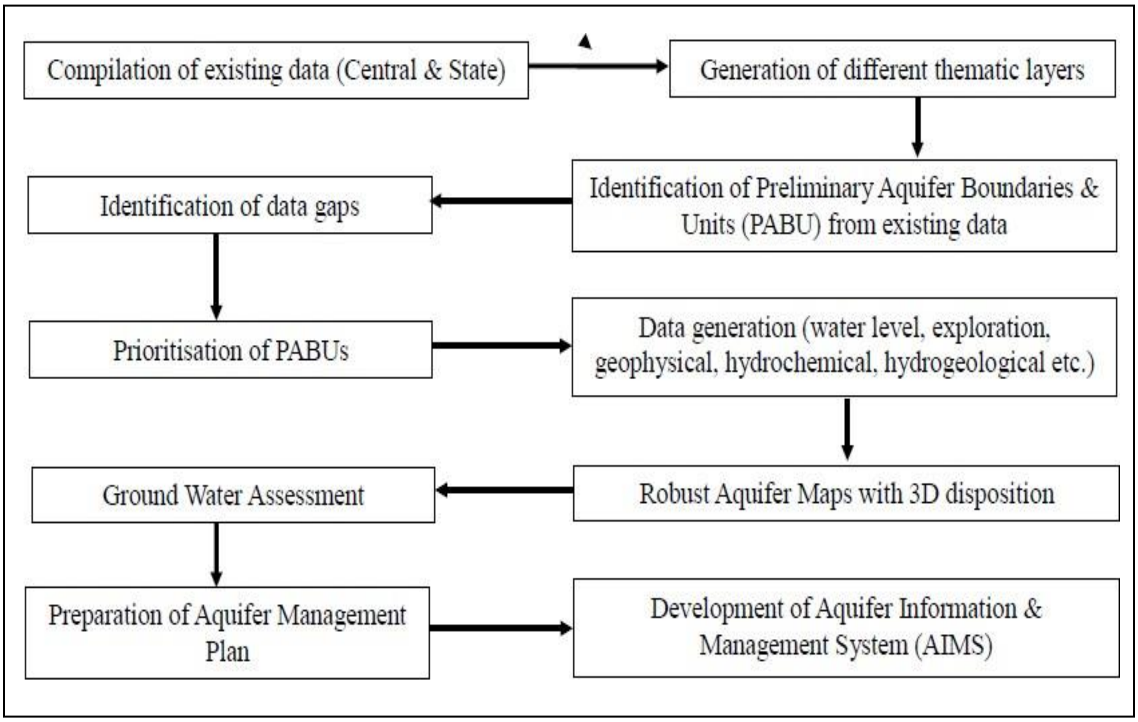
The two major objectives of the aquifer mapping is the delineation of lateral and vertical disposition of aquifers and their characterization on 1: 50,000 scale in general and further detailing up to 1: 10,000 scale in identified priority areas and the quantification of ground water availability and assessment of its quality to formulate aquifer management plans to facilitate sustainable management of ground water resources at appropriate scales through participatory management approach with active involvement of stakeholders.

Approach and Methodology

The aquifer mapping study in this report has been compiled on the basis of existing data that were assembled, analyzed and interpreted from available sources. The collected data was further prepared to generate regional hydrogeological maps, thematic maps, water quality maps, cross-sections, 2-D and 3-D aquifer dispositions and potentiometric maps eventually to define the aquifer geometry, type of aquifers, ground water regime behavior, hydraulic characteristics and geochemistry of multi-layered aquifer systems on 1:50000 scale. To achieve the objectives the following approach and methods have been adopted and stepwise details have been shown in the fig 1.

- Data compilation
- Data gap analysis
- Data generation
- Preparation of block-wise aquifer maps and management plan

Fig 1: Aquifer mapping approach and methodology



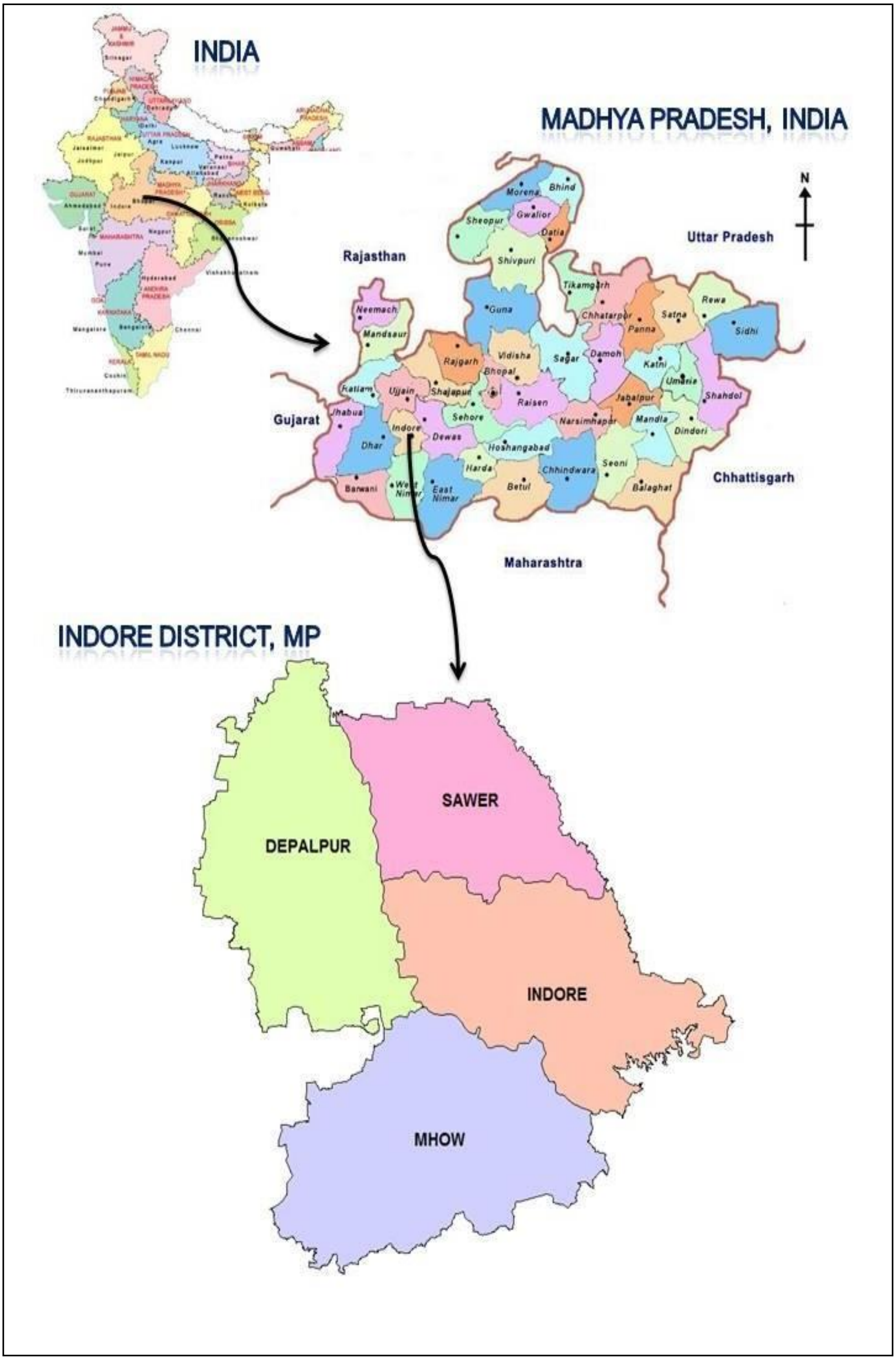
Area Details

The district of Indore with a total geographical area of about 3831 sq. km lies in the heart of Malwa Plateau. It is bordered by Ujjain district in the north, by Khargone district in the south by Dewas district in the east and by Dhar district in the west. The district derived its name from the historical city of Indore, which is, its district headquarters and a commercial & industrial centre of the state. Although the district has, by now seen much industrial development around the urban centers, agriculture is still main stay of the population of the district. The total population of the district is 8,29,327 as per census 2011. For administrative purposes the district has been divided into blocks namely Depalpur, Indore, Sanwer and Mhow. A detailed location map of the study area is shown in the fig 2. The district is bounded by latitude 22 20’ N & 23 05’ N and longitude 75 25’ E and 75 15’ E is presented by the Survey of India toposheet Nos. 46M, 46N and 55B. Detailed administrative divisions of the district are given in Table-1.

Table-1: Administrative Divisions

Block	Area (sq. km)	Villages	Gram Panchayats
Depalpur	1244.89	172	100
Indore	915.52	130	64
Mhow	1027.08	166	73
Sanwer	643.48	142	75
TOTAL	**3830.97**	**610**	**312**

Fig 2: Administrative Map



Data availability, adequacy, data gap analysis and data generation

The basic concept of aquifer mapping stands on these four major pillars. The aquifer mapping and management plan of Indore district is broadly carried out in following steps:

1. Data compilation: The previous studies carried out by Central Ground Water Board and various Government organizations was collected. The Basic data reports of Exploratory wells/Observation wells/Piezometers drilled by CGWB, details of wells drilled by State PHED and district brochures published by CGWB was compiled and integrated for aquifer mapping. The Dynamic ground water resource book (2013) of CGWB and figures from the WRD were used for preparation of management plan.
2. Data adequacy: The data compiled has been collected from the CGWB/State departments. Thus, the adequacy of the data is supposed to be high and reliable for the specific study of aquifer mapping and management plan.
3. Data gap analysis: The identification of data gap was done after the detailed analysis, examination, synthesis and interpretation from available sources. This process incorporated the conversion of analog data in the form of digital data that could be processed readily on GIS platform.
4. Data Generation: The study of Satna district concentrated on the existing data, thus no new data was generated.

Climate and Rainfall

The climate of the Indore district is characterized by hot summer and well distributed rainfall during the south west monsoon. The year may be divided into four seasons. The winter commences from the December and last till the end of February. The period from the month of March to about the first week of the June constitutes the hot weather. May is the hottest month of the year. The south west monsoon starts from the middle of June and continues up to the first week of October. October and November are the post monsoon/retreating monsoon season. There is only one Meteorological observatory in Indore district that is located at Indore. However, there are six rain gauge stations namely Depalpur, Sanwer, Hatod, Gautampura, Mhow and Manpur.

Rainfall

The district receives maximum rainfall during the south west monsoon period. Thus about 91.2% of the total annual rainfall takes place during the south west monsoon period (June to September) alone. The maximum monthly rainfall, more than about 31.1% of the total annual rainfall takes place during the month of July. About 7.2% of the annual rainfall occurs during winter. About 1.7% of the annual rainfall occurs during summer, and about 8.9% of the annual rainfall occurs from October to the first week of June. This meager rainfall between Octobers to the first week of June is hardly sufficient to make up soil moisture and thus it in no ways contributes to the ground water potential of the area. It is only during the monsoon period that surplus water for deep percolation can be available.

The normal annual rainfall of the district is about 920 mm, falling over a period of 35-45 days during the monsoon season. South west monsoon contributes about 90% of annual rainfall and remaining 10% rainfall occurs during the non-monsoon period due to western disturbances and thunderstorms. The normal annual rainfall for the last 30 years (1981-2010) is 920 mm and about 91.28% of the annual rainfall (858.00 mm) falls during the monsoon season and the remaining 81.92 mm occurs during the non-monsoon season extending from October to May. Since major portion of the annual rainfall occurs during June to September so most of the runoff is also generated during these months. There are about 45 rainy days during the monsoon season and it varied between maximum of 65 days to a minimum of 26 days. Table no. 2 shows the decadal variation of annual rainfall from 1951-2010.

Table 2: Decadal variation of annual rainfall (1951-2010)

Year	Monsoon rainfall	Non-Monsoon rainfall	Annual rainfall	% of annual rainfall
1951-1960	887.18	83.76	970.95	91.37
1961-1970	850.28	85.26	935-55	90.88
1971-1980	975.07	84.87	1059.95	91.99
1981-1990	762.87	77.15	840.02	90.81
1991-2000	900.11	84.82	984.93	91.38
2001-2010	858.00	81.92	939.92	91.28

Temperature

The maximum temperature at Indore varies between 36.9°C and 42.5°C whereas the minimum temperature varies between 7.4°C and 11.9°C. The mean monthly temperature at Indore is 24.9°C and varies between 16.3°C and 34.05°C. May and June are the hottest months in the year whereas December and January are the coldest months. Temperature starts rising steadily from March onwards till the onset of monsoon.

Humidity

Relative humidity is not very high at Indore and varies between 53.4% and 65.8% with an average value of 58.9%. The climate is generally dry during most parts of the year. The driest period of the year is the summer season and the maximum humidity occurs during the monsoon season in August.

Droughts

When deficit rainfall occurs over a large area affecting the agriculture growth adversely, it is normally considered as drought. The drought studies have been done for the Manpur and Indore Stations on the basis of long term data. The results are given in the Table no.3.

Table 3: Drought categorization

Name of Station	No. of Year	Drought frequencies as percentage	
		Normal Drought	Severe Drought
Manpur	50	12.2%	2.0%
Indore	50	18.0%	2.0%

It is clear from the Table no. 3 that severe drought occurs at Manpur and Indore stations on an average of 2.0% i.e. once in every fifty years. None of the stations has faced most severe droughts. Normal droughts do occur at 12.2% and 18.0% at Manpur and Indore stations respectively i.e. normal droughts do occur at about 15% occasions i.e. on an average the Indore district may get a normal drought conditions after about every seven years interval.

Physiography/Digital Elevation Model

The Malwa plateau over which the district of Indore is situated is scraped by the Vindhyan hills in the south. The average height of the hills is 579.2 m above mean level. North of Vindhyan ranges lies wide undulating plateau with scattered low flat-topped hills. The plateau ranges in height from 487 to 579.1 meters amsl. The general trend of the terrain is toward north. The southern half of the district is generally rugged and hilly. The denuded Vindhyan hills follows west-south-west and east-north-east trend. Singhgarh (881.18 meters) is the highest point on the Malwa plateau. The Digital Elevation Model (DEM) is shown in the fig. 3.

Geomorphology

The Malwa plateau overlies the major portion of the district. The rest of the area is scraped by the Vindhyan hills in the south. The areas along the rivers are occupied by the alluvial deposits. Geomorphologically the district can be broadly divided into four major divisions viz. Alluvial Palin, Upper Plateau, Plateau Undissected and Denudational hills. The geomorphological map is shown in the fig 4.

Drainage

The district is drained by three major rivers viz. the Gambhir, the Khan and the Kshipra. They are the tributaries of River Ganga. These rivers are generally following south to north courses. Southern fringe of the district south of Vindhyan hills is drained by the river Narmada flowing from east to west. Most of the rivers & streams are seasonal. Flood occurs during rainy seasons, while in the summer the streams maintain a sluggish flow. A detailed drainage map is presented in the fig. 5.

Soil Cover

The district is dominantly covered by fine clayey soil. Clay and loamy soil also occurs in the southern portion of the district. The soil predominantly contains montmorillonite. The soils in vicinity of the major rivers draining in the district are fine in nature. The southern portion of the district consists of loamy soils. Fig. 6 shows broadly classified soil map of Indore district.

Fig 3: Digital Elevation Model

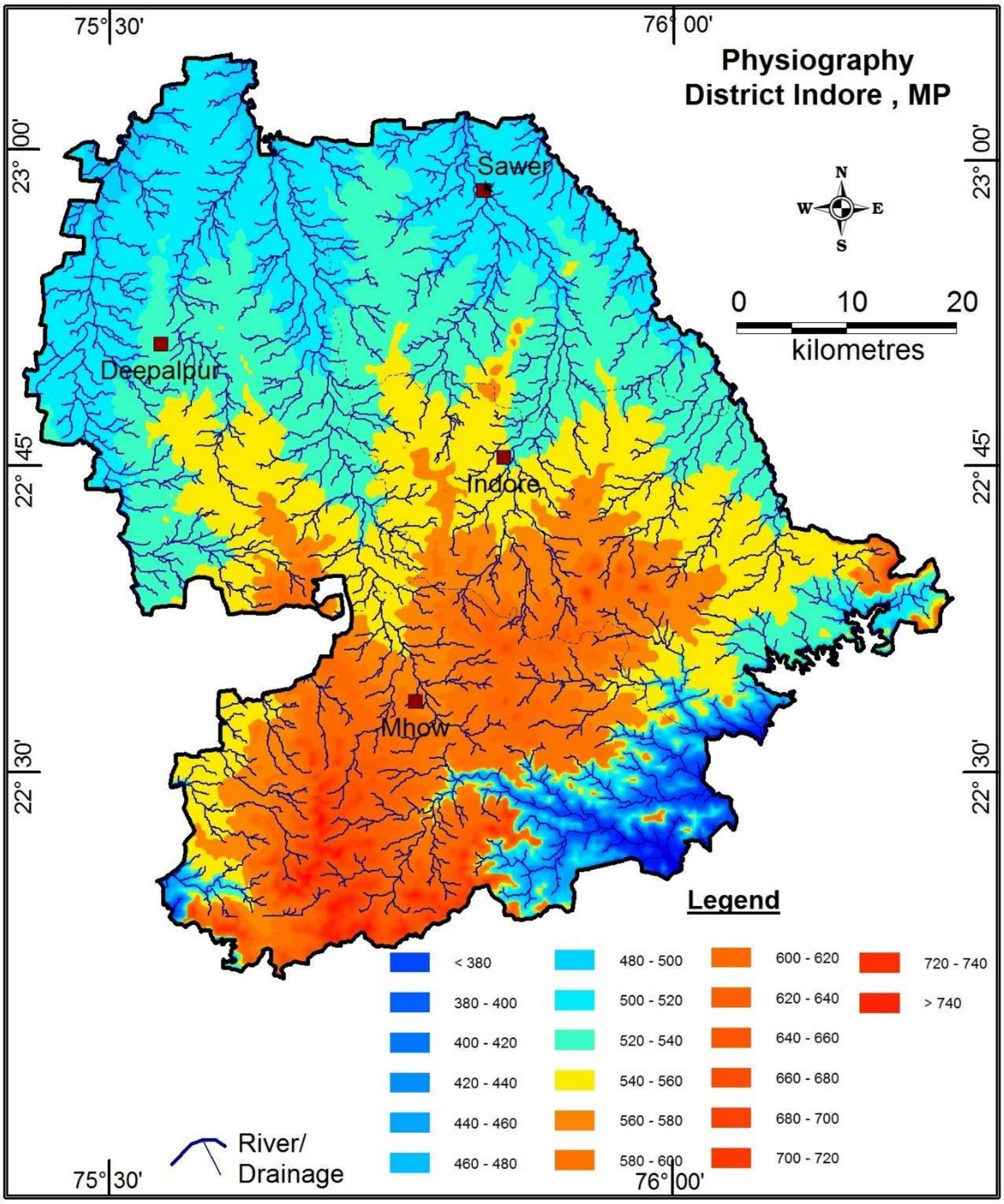


Fig 4: Geomorphological Map

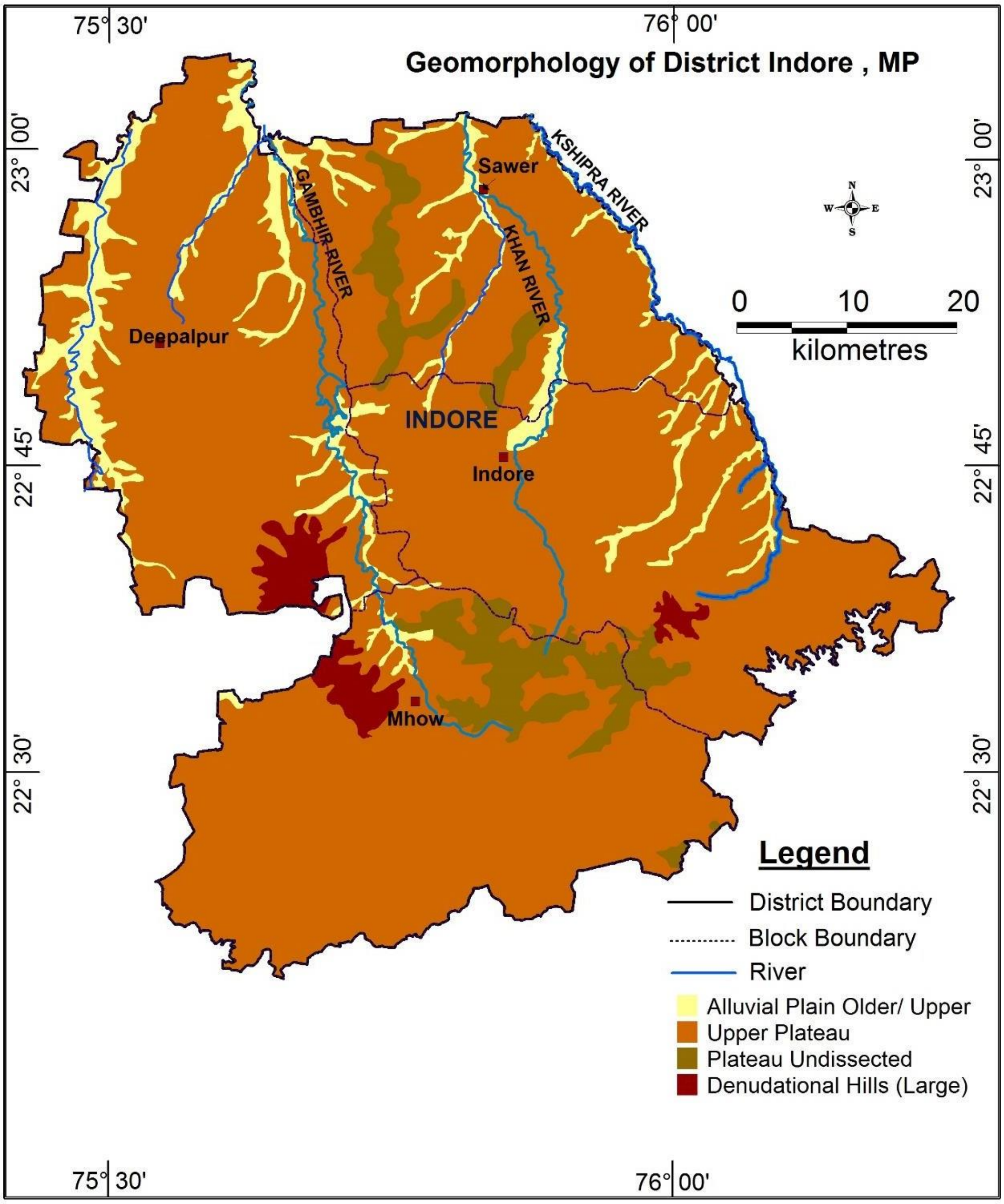


Fig 5: Drainage Map

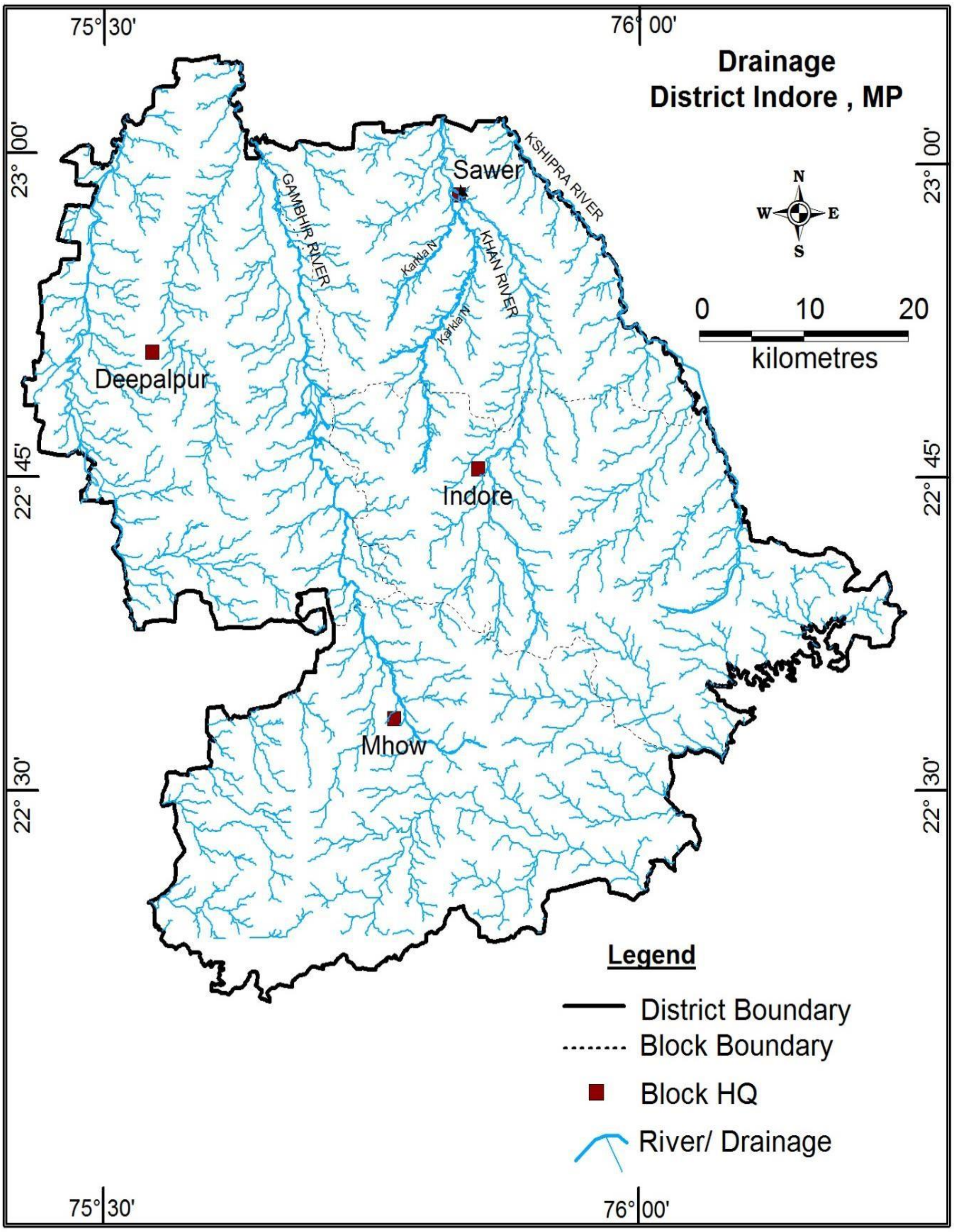
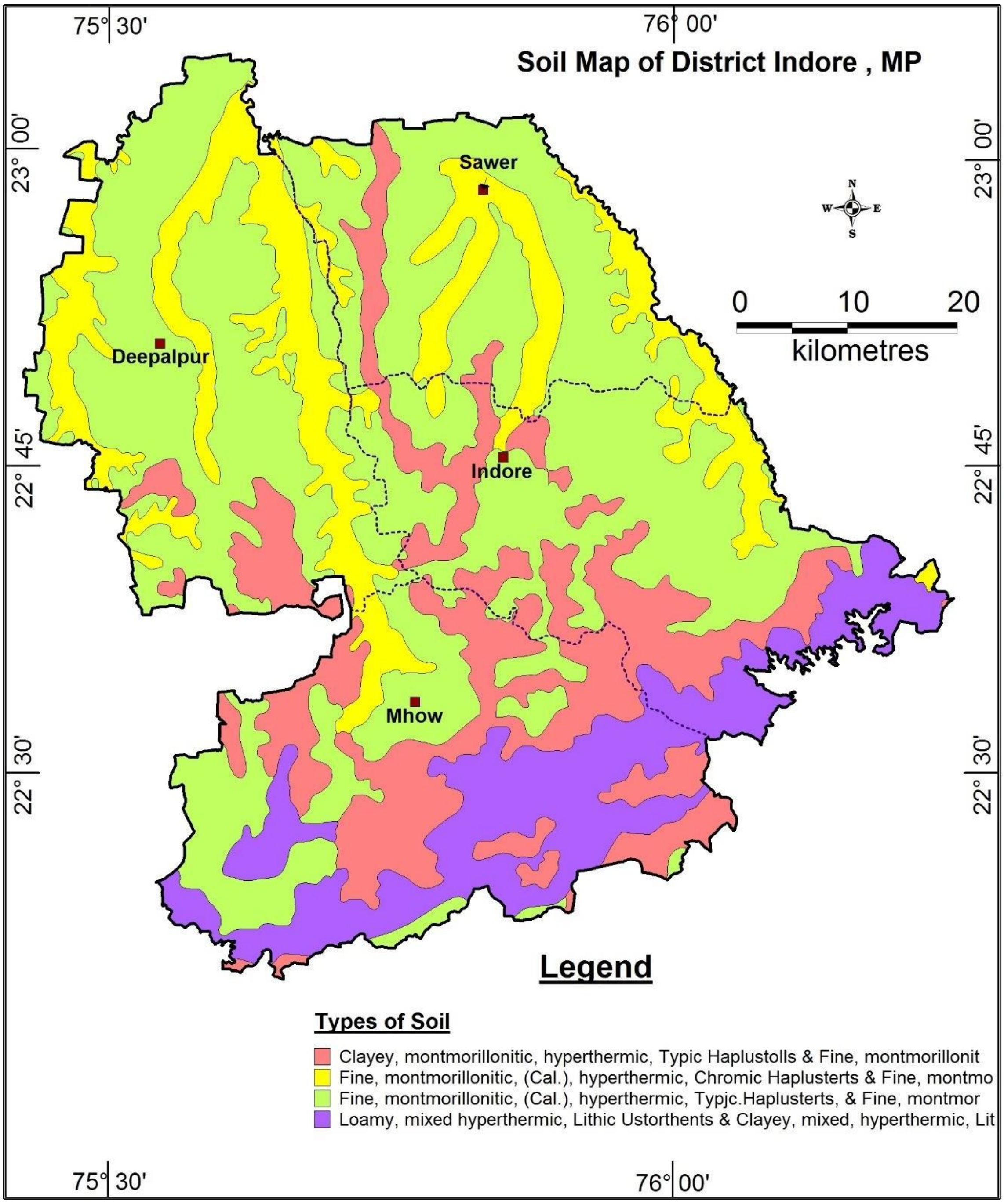


Fig 6: Soil Map



Agriculture, Irrigation and Cropping patterns

Ground water is main source of irrigation in the district. Out of total 206471 Ha irrigated area, 200190 Ha is irrigated from ground water sources, which is about 97% of total irrigation. About 54278 tube wells and 4538 dug wells in the district were used for irrigation during year 2016. An area of about 6362 Ha is irrigated through ponds and canals which accounts for only 3% of total irrigation of the district (Table-4).

Table-3: Area irrigated by different sources (*as per census 2016*)

Tehsil	Area irrigated by Ground water (Ha)			Area irrigated by surface water (Ha)		
	Dugwell	Tube well	Total	Ponds	Canals	Total
Depalpur	456	72331	72787	1290	784	2074
Indore	2445	46821	49266	1049	0	1049
Mhow	9248	14761	24009	1530	1538	3068
Sanwer	19	54028	54047	171	0	171
TOTAL	12168	187941	200109	4040	2322	6362

Prevailing water conservation/recharge practices

Water conservation is also equally important technique to prevent runoff from flowing out of area. In ancient times many surface water bodies like Bilaoli, Yashwant Sagar, Sirpur etc were created to conserve surface runoff and to meet water supply of the city. During study it was noticed that water body like Bilaoli Talab is located on weathered/ vesicular horizon which is directly recharging to ground water body apart from surface water storage. Surface water conserved in local ponds can be used for recharging of ground water by dugwell/ tubewells. In Choithram hospital compound, located in south-west part of the city having an area of 16.20 hectares land , gabion structures for soil and water conservation and one pond has been created for storage of surface runoff and same is being used for artificial recharge through tubewells. Suggestion for creation of small water body in hard rock area of Kasturbagram trust in Khandwa road and to use this water for artificial recharge through dugwell tapping porous vesicular basalt, has been given earlier by the Central Ground Water Board.

In Indore city Roof Top rainwater harvesting technique for artificial recharge has been adopted by various Govt./Private Agencies. Agencies like GS Institute of a Technology & Science, Kasturba Gandhi Trust, Choithram Hospital, Gautam Ashram (Sundama Nagar), Nagar Nigam have adopted roof water harvesting techniques for artificial recharge of ground water at various places.

2. Data collection and generation

Hydrogeological

The area is mainly occupied by the lava flows belonging to the Deccan Trap locally known as Malwa traps. Isolated patches of alluvium also occur along the Kshipra and Khan rivers and along the Katkiya Nala. The general Geological succession in the area is as follows:

Alluvium (Clays, Silt, Sand and Gravels)--------------------------------Recent Age

Deccan Traps Basalt (Lava Flows) -----------------------------Cretaceous to Eocene Age

Hydrogeology of the area

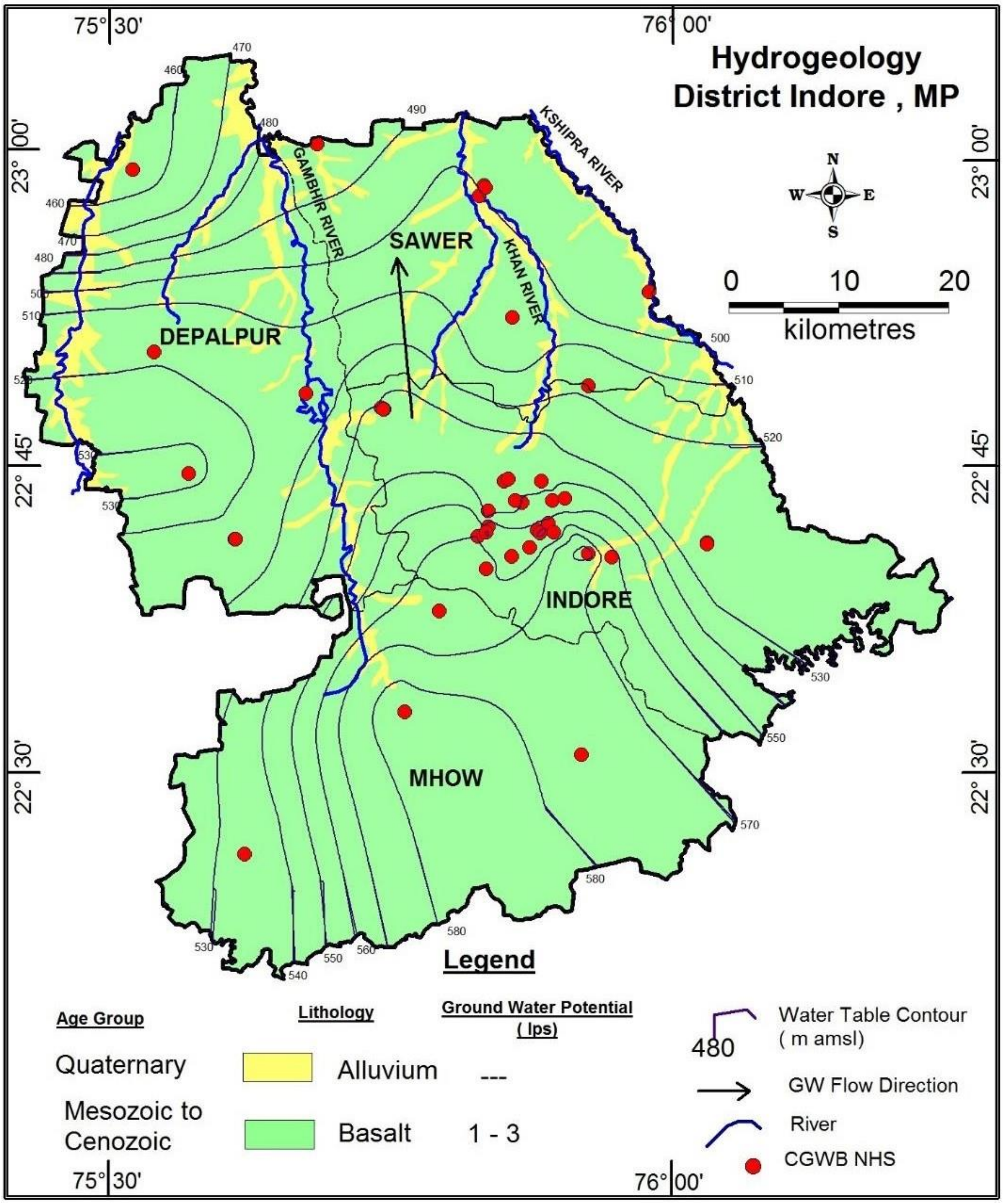
The interesting feature of the Deccan traps, the prevalent rock type of the district is the contrast in the nature of the water bearing properties of the different units constituting them. The massive traps with their weathered zones and fractures proposition and vesicular traps with their minutely interconnected and partially filled vesicles plays and decisive role in determining the occurrence movement of ground water in the main water bearing horizons and invariably form the potential aquifers. The zeolitic basalt in the weathered state also forms productive water bearing horizons. The red bole itself is non-productive but it is an indicator of the presence of the productive vesicular and zeolitic horizons underneath it. The well jointed massive basalts also form potential aquifers at places. In the alluvial areas, the occurrence of ground water is governed by sand/clays ratio. The sand and kankars layer forms fairly good water bearing horizons. But these are restricted and erratic in natures.

The occurrence and movement of ground water in different lithological units is majorly controlled by following formations and is shown in the fig. 7:

Deccan Traps Basalt

The basaltic lava flows of the Cretaceous to Eocene age are the major rock formation of the area and are known as Malwa Traps. Geological mapping of the area has brought a light a succession of five basaltic lava flows in an approximate vertical column of 120 m above mean sea level. Red bole beds which are predominantly the ferruginous clays characterized for their litho logical and textural characteristics serve as the marker horizons in distinguishing the two different lava flows. Individual lava flows differ in thickness from 15 to 30 m. Litho logically the different type of trappean flows can be grouped as massive and vesicular basalts. The massive basalts are generally hard and compact in nature varying in colour from green to dark grey. In most of the cases they are weathered down to a depth of 3 to 5 meters. In the case of vesicular basalt the rocks are angular to sub angular which are filled with secondary fillings. Zeolite, Silica and Calcite are the common secondary minerals fillings in these vesicles. Structurally the trappean units are mostly horizontally disposed and do not exhibits any evidence of deformation. Vesicular units however, in individual flows within a group of flows do not appear to occur uniformly which indicates vide variation in thickness within a short distance. The trappean rocks are often (Highly) jointed but there is

Fig 7: Hydrogeological Map



no uniformity in the distribution of joints and fractures. At places the columnar joints are conspicuous in massive basalts. Spheroidal weathering is also very commonly seen. The weathered product of basalt is clays and loamy in nature and is kwon as black cotton soil, which has a vide areal extent and a variable thickness of 1.0 to 6.0 meter. Groundwater in the Deccan trap basalt occurs under water table conditions within a depth range of 15 meter below ground level. The nature of topography, extent and depth of weathering, distribution of joints and fractures and occurrence of vesicular units govern the movement of groundwater. Further the alternating nature of the impervious massive and productive vesicular basalts results in groundwater occurring under confined condition at depth. In case of confined conditions also, occurrence and movement of groundwater governed by the hydro geological settings, which shows vide variations laterally within short distances.

Alluvium

The alluvium deposits occurs in narrows patches and are restricted mainly banks of Chambal Gambhir and Kshipra rivers. Its, comprises clays, silts, gravel and sand. The sand and gravels are restricted to rivers channels while the finer fractions are confined to river banks. These deposits attain a maximum thickness of 15 meters but are very irregular in nature. In alluvial materials groundwater occurs under water table conditions.

Water levels

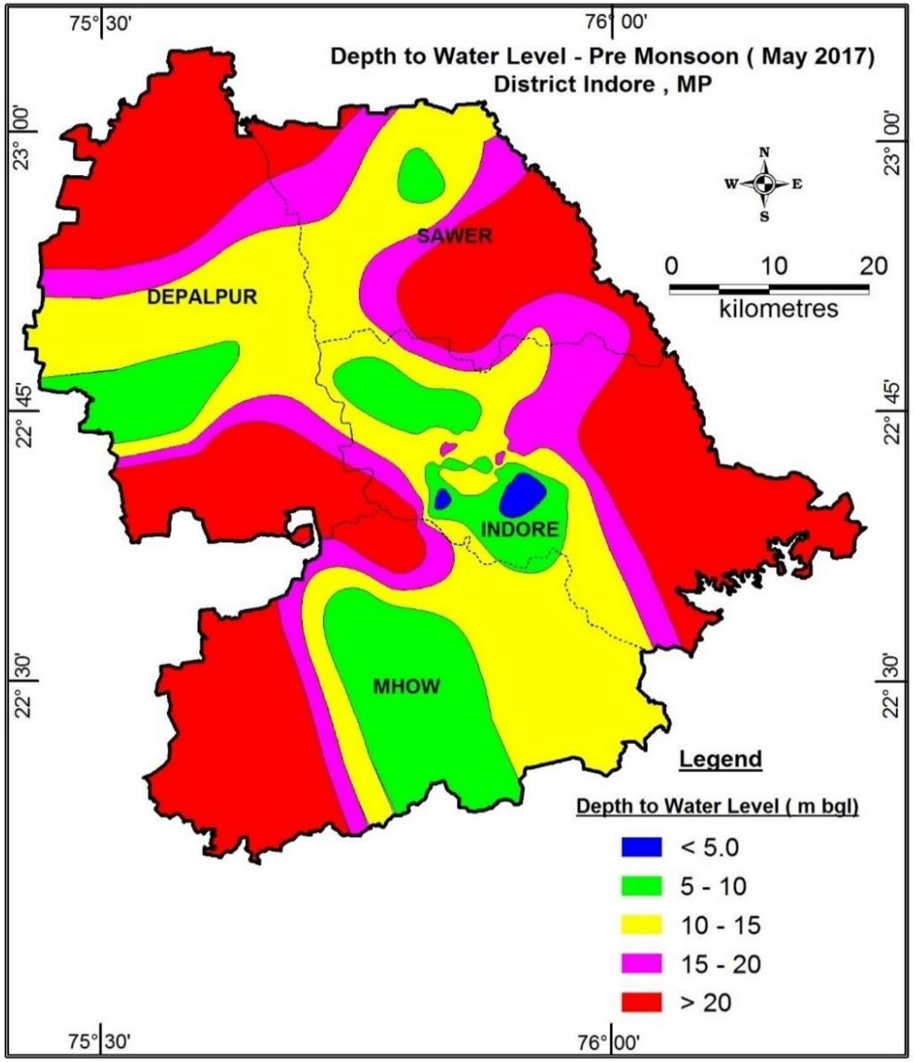
Pre-monsoon water level (May 2017)

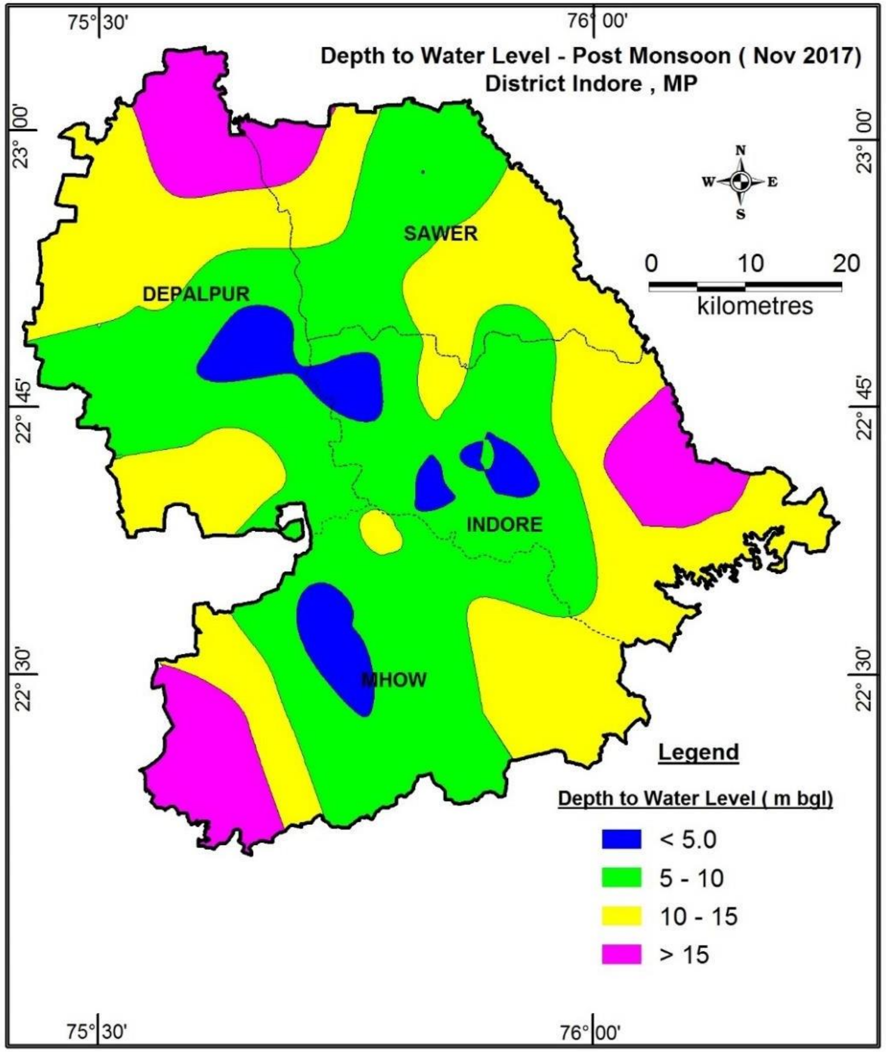
Depth to water level during pre-monsoon, 2017 ranged between 0.9 m bgl at Deoguradia to 43.57 m bgl at Gautampura piezometer in Indore district. Shallow ground water level in the depth range of 5 to 10 m bgl occurs in small pockets in the Indore, Mhow and Depalpur blocks. Water levels in range of 10 to 15 m bgl are most dominant in the almost entire district. Deeper water level of more than 15 m bgl are seen in the piezometer of Indore and Depalpur Blocks. Deeper ground water level is due to high ground water development in the district. The average depth to ground water level of the district is 14.95 m bgl. Depth to water level during pre-monsoon, 2017 has been depicted in Fig- 8.

Post-monsoon water level (Nov 2017)

Depth to water level during post-monsoon, 2017, the depth to water levels ranges 1.24 m bgl at Deoguradia IMC to 16.94 m bgl at Manpur peizometer in Mhow block. Shallow water level below 5 m bgl is seen in and around Indore city and in parts of Mhow block. Shallow water level in depth range of 5 to 10 m bgl is prominent and seen in most part of the district. Deep depth to water level in the range of 10 to 15 m bgl is seen in patches in Depalpur, Indore and Sanwer blocks. The average depth to water of the district Indore during the post monsoon 2015 is 8.37 m bgl. Depth to water level during post monsoon, 2017 has been depicted in Fig- 8.

Fig 8: Depth to water level maps (Pre & Post Monsoon 2017)





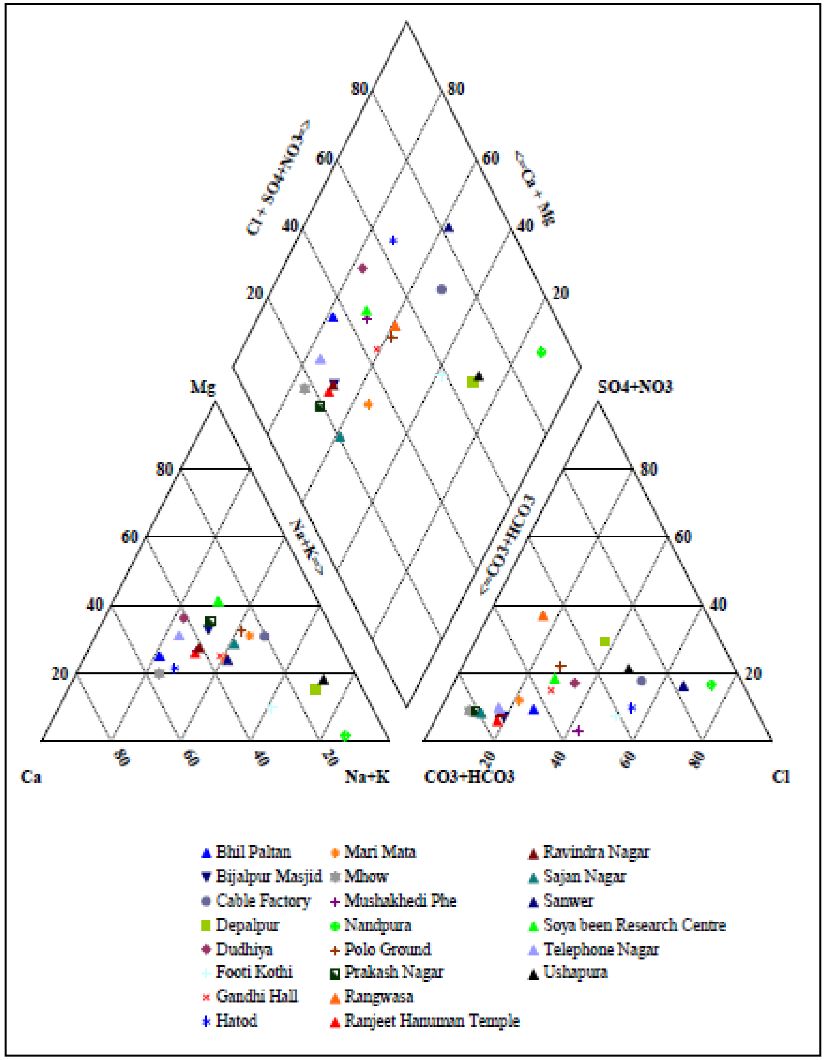
Hydrochemical

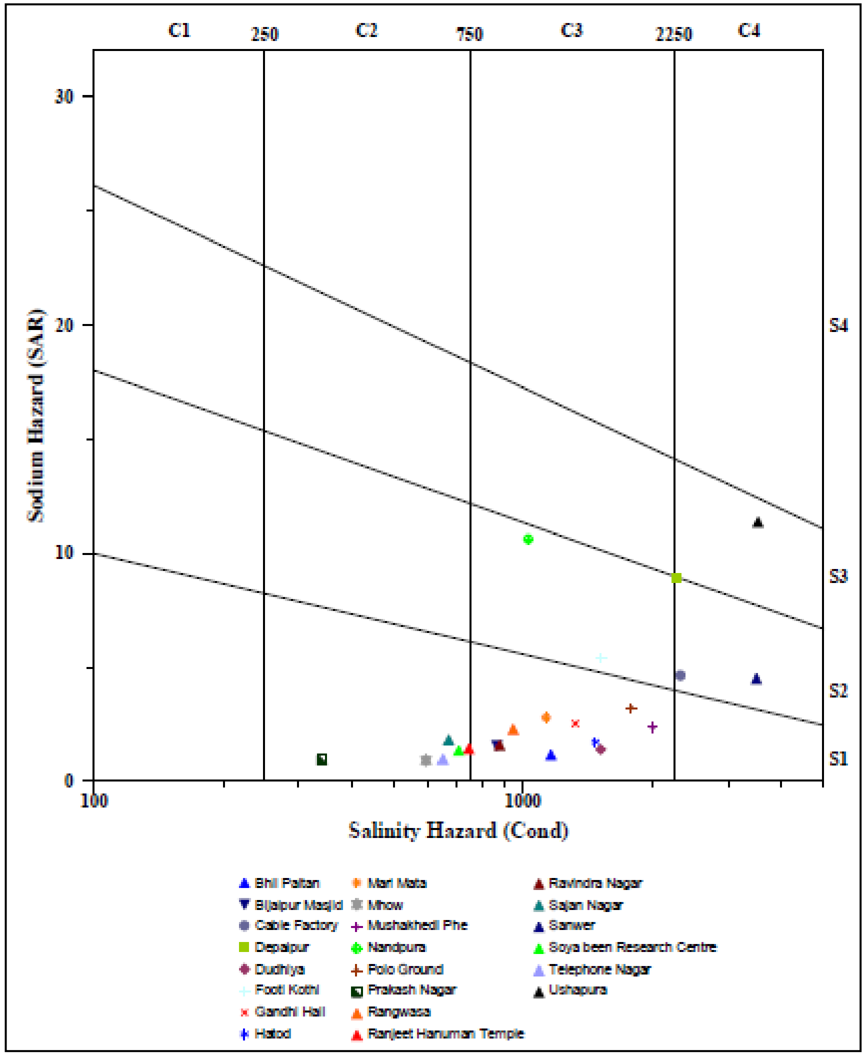
The water samples were collected from National Hydrograph Stations in clean double-stopped poly ethylene bottles from 22 different locations of Indore district during May 2017. The pH of ground water of Indore district ranged in between 7.05 to 7.85. As per BIS recommendation, all water samples recorded within the permissible limit of 6.5 to 8.5. The ground water of the study area can be assessed as neutral to slightly alkaline in nature. The electrical conductivity of ground water in Indore district ranged between 340 to 3522 µS/cm at25°C. The electrical conductivity more than 3000 µS/cm at25°C has been observed in the dug well of Sanwer 3492 µS/cm at25°C) and Ushapura (3522 µS/cm at25°C) villages. The electrical conductivity shows that the ground water in Indore district is good to slightly saline in nature.

The fluoride concentration in Indore district ranged in between 0.20 to 1.93 mg/l. As per BIS permissible limit, the concentration of fluoride more than 1.50 mg/l has been detected in ground water of Nandpura (1.93 mg/l). In the district, nitrate concentration in ground water ranged in between 2 to 135 mg/l. The 77% ground water samples recorded nitrate concentration within the BIS acceptable limit of 45 mg/l and 23% water samples recorded more than 45 mg/l as BIS recommendation. The concentration of nitrate more than 100 mg/l has been detected in ground water of Rangwasa (107 mg/l), Sanwer (121 mg/l), Ushapura (126 mg/l), and Depalpur (135 mg/l) dug wells. High nitrate in ground water appears may be due to anthropogenic activities or excessive use of fertilizers etc.

Total hardness of ground water in the study area ranged in between 69 to 1015 mg/l. The concentration of total hardness more than 600 mg/l has been observed in the dug well of Mushakhedi (683 mg/l) and Sanwer (1015 mg/l) villages. In the district water are $CaHCO_3$, mixed CaMgCl and NaCl types of water. The $CaHCO_3$ type of water shows temporary hardness whereas mixed CaMgCl and NaCl types shows permanent hardness type of water. The US Salinity Diagram (fig. 9) of Indore district shows the ground water is low to high salinity classes i.e. C_2S_1, C_3S_2, C_4S_2 and C_4S_3 classes. C_3 and C_4 classes of water should not be used for irrigation purpose unless proper soil management.

Fig 9: Hill Piper Diagram and US Salinity diagram representing classification of water samples collected from National Hydrograph Stations





Exploratory drilling

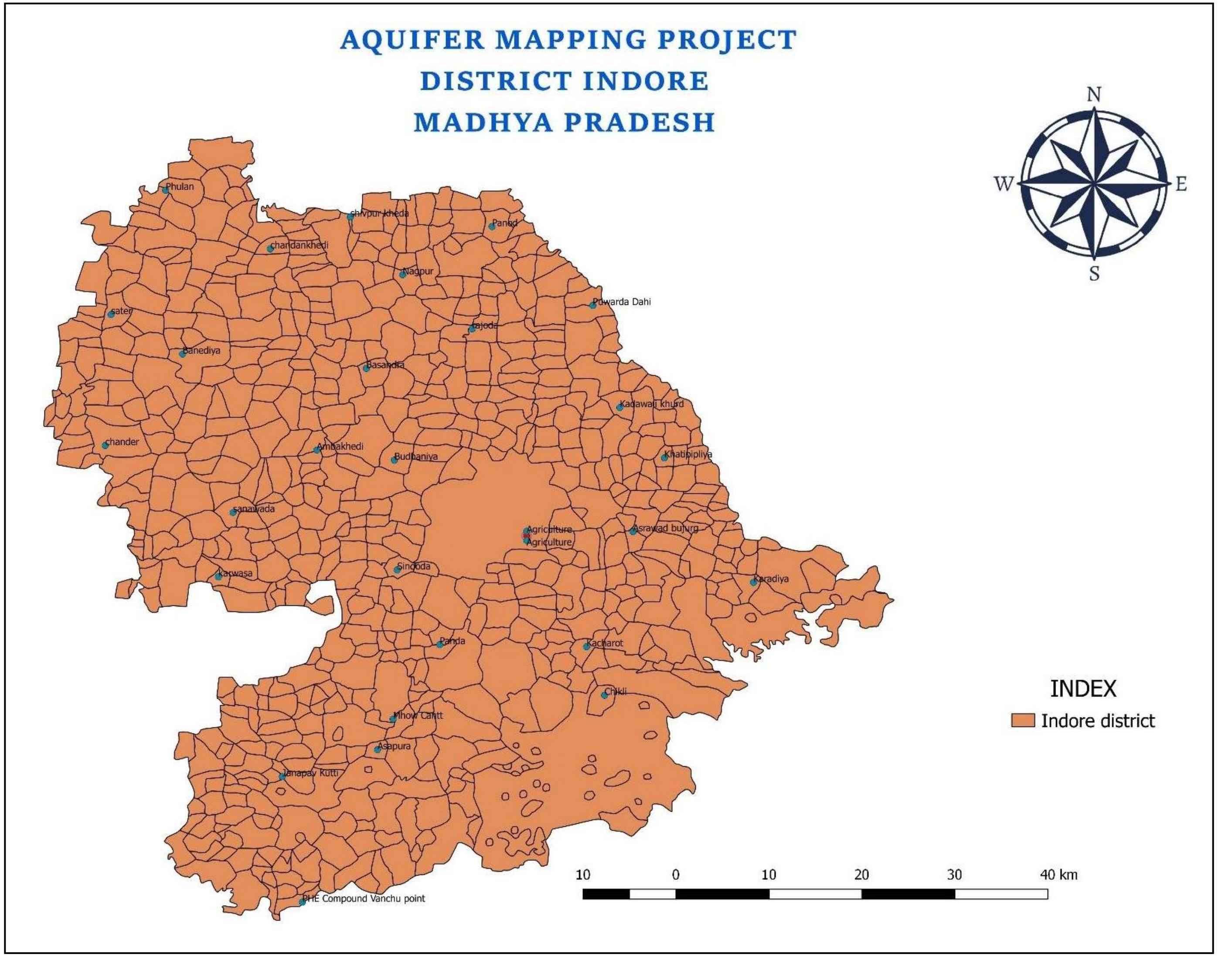
Central Ground Water Board has drilled wells in the Indore district under the National Aquifer Mapping program. The salient details of the some of the drilled bore wells is given in Table No 5.

Table 5: Salient details of the Exploratory borewells drilled by CGWB

Sl.No.	District	Location	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Aquifer zones tapped (mbgl)	Discharge (lps)	Drawdown (m)	Specific capacity (lpm/m) of dd
1	Indore	Harsola	22.5803	75.8167	88.9	Deccan Trap	15.00 - 21.12	11.02	6.33	1.43
2	Indore	Nirdi Panth	22.6881	75.7681	104.35	Deccan Trap	20.00 - 33.04 44.35 - 47.40	1.95	1.25	13.33
3	Indore	Dhannar	22.3833	75.7500	165.3	Deccan Trap		1.48		
4	Indore	Gangle	22.7194	75.7500	229.35	Deccan Trap		4.29	0.50	
5	Indore	Boria	22.7194	75.6889	85	Deccan Trap	10.73 - 33.98	5.1	4.20	
6	Indore	Sonway	22.6194	75.7722	82.68	Deccan Trap	23.97 - 30.07	12.47	1.80	10.88
7	Indore	Rojri	22.7750	75.7250	238.5	Deccan Trap	16.80- 20.90	7.53	3.36	2.84
8	Indore	Suptha	22.9208	75.7072	120.15	Deccan Trap				
9	Indore	Kanchahia	22.8564	75.6561	82.52	Deccan Trap		5.67	4.30	13.23

CGWB, under contractual drilling program WAPCOPS has drilled 29 Exploratory wells in the district in the year 2018. Two wells at Indore of 200 mbgl depth are high yielding with the discharge of about 6-10 lps. The wells drilled in the north of the district are having moderate discharge of about 2-3 lps. The wells drilled in south of the district are dry but aquifer material is there hence, these sites are feasible for recharging. The location and lithological details of the wells is given in the Annexures I & II. The location of the exploratory wells is shown in the fig. 10

Fig 10: Map showing locations of Exploratory Wells (Out-sourcing)



3. Data Interpretation, Integration and Aquifer Mapping

The lithological data collected from CGWB Borewells, Piezometers and State Ground Water Piezometers were studied, compiled and integrated to prepare 2-Dimensional Cross section and Fence diagrams. The sub-surface lithology of the Indore district as inferred from the 2-D Section and Fence diagram is presented below.

2-D Cross Sections

A 2-D cross section was prepared for Indore district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB and State department as well as the exploration data obtained from the outsourcing drilling. Three sections have been attempted to ascertain the sub-surface picture and in order to cover the maximum portion of the district (fig. 11). The section A-A’ passes in the NNW-SSE direction and covers the sites Sater, Banediya, Ambakhedi, Budhaniya, Agriculture, Asrawad Buzurg & Karadia. The section lines X-X’ and Y-Y’ follows the NNE-SSW directions. X-X’ covers Karwasa, Ambakhedi, Basandra & Panod villages. Y-Y’ passes through Vinchu Point, Ashapura, Panda, Agriculture & Khadawali villages.

Fig 11: Outlay map for borewells section lines

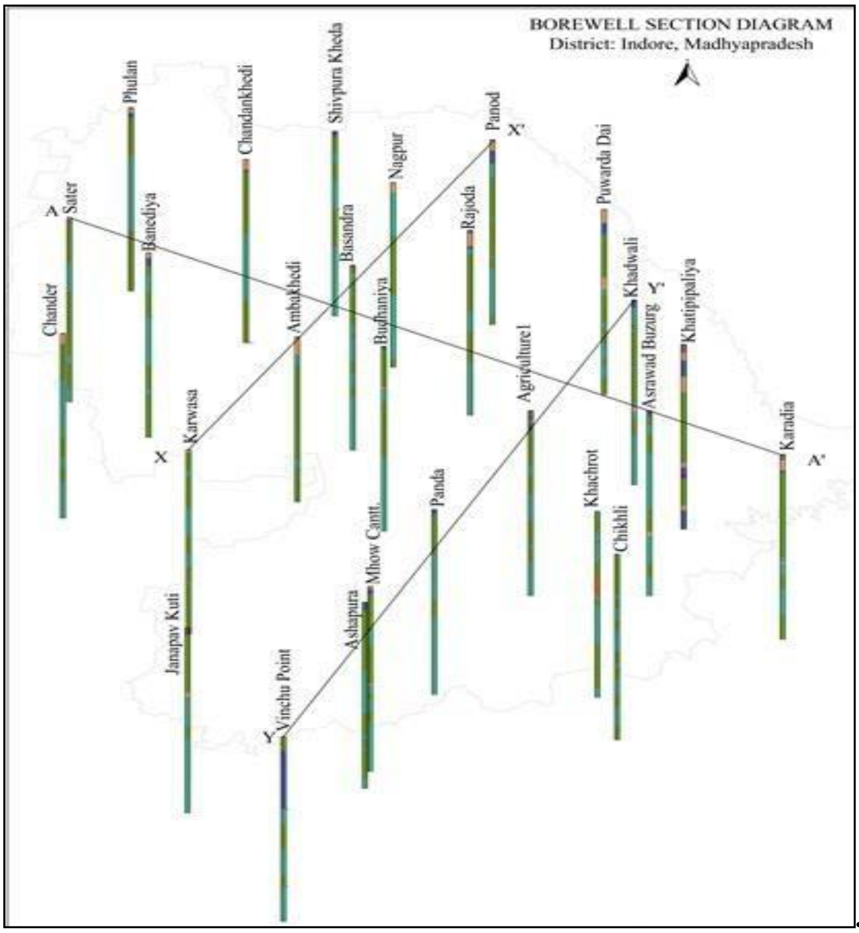


Fig 12: 2-D Hydrogeological Cross section A-A'

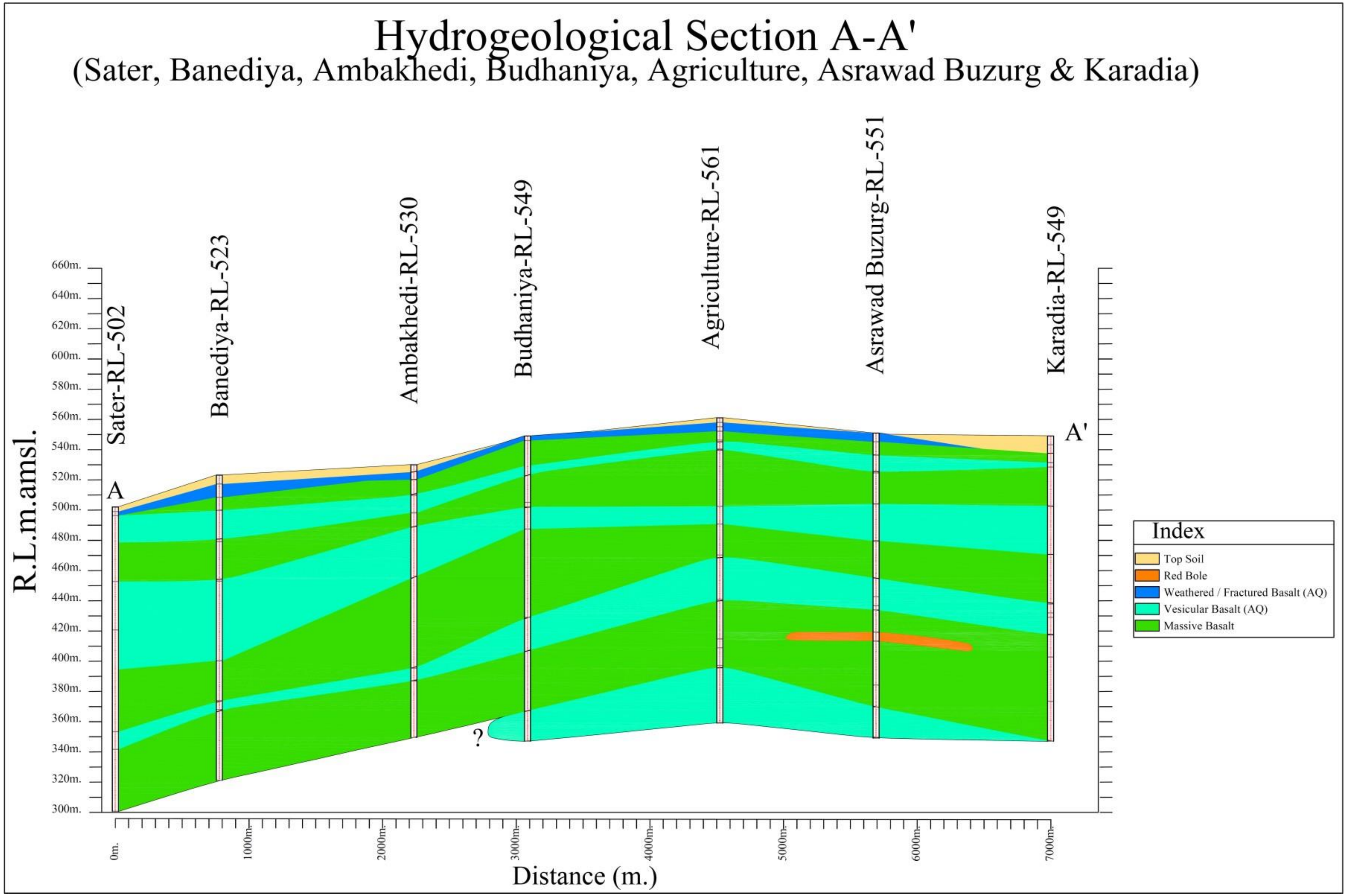


Fig 13: 2-D Hydrogeological Cross section X-X’

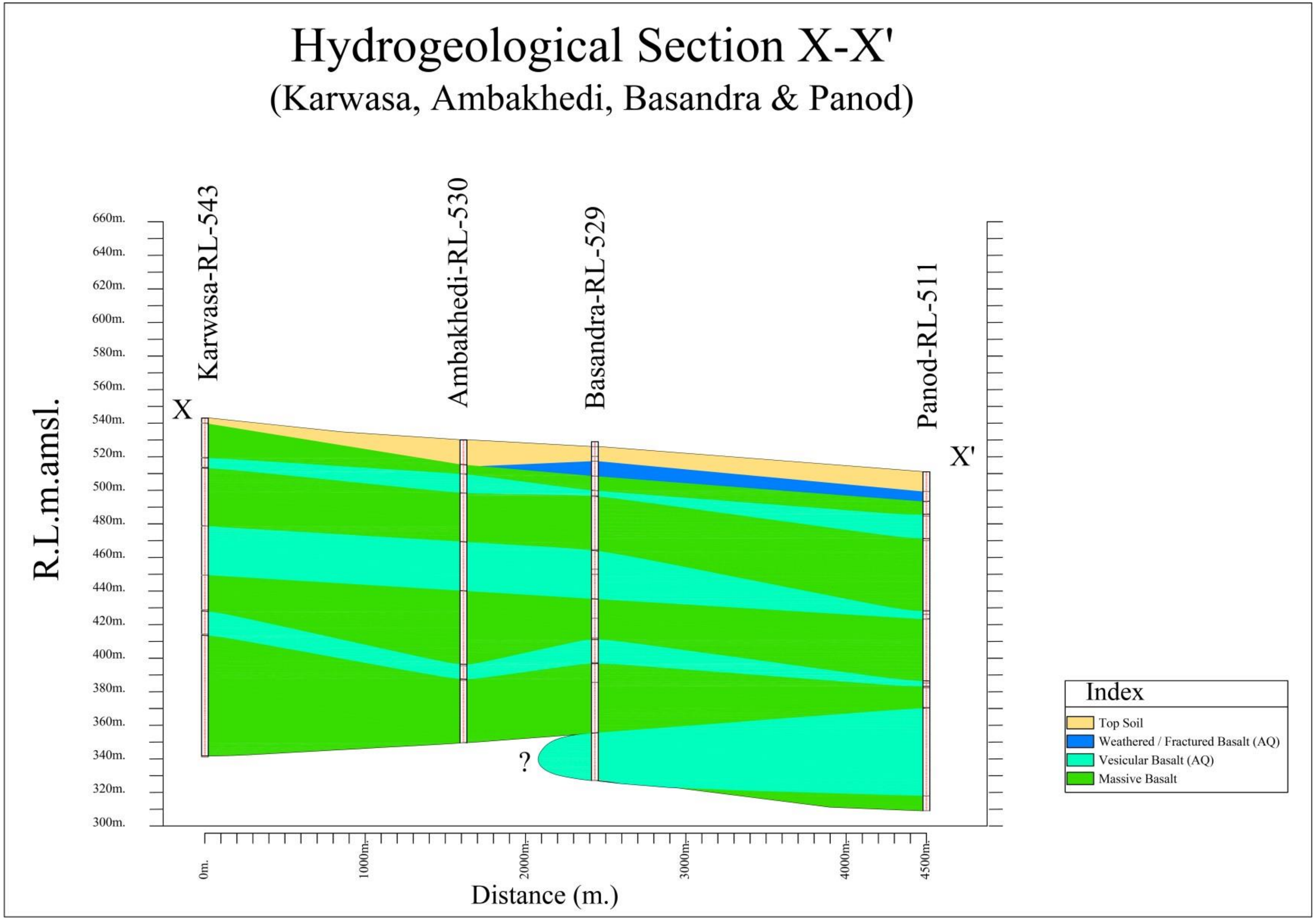
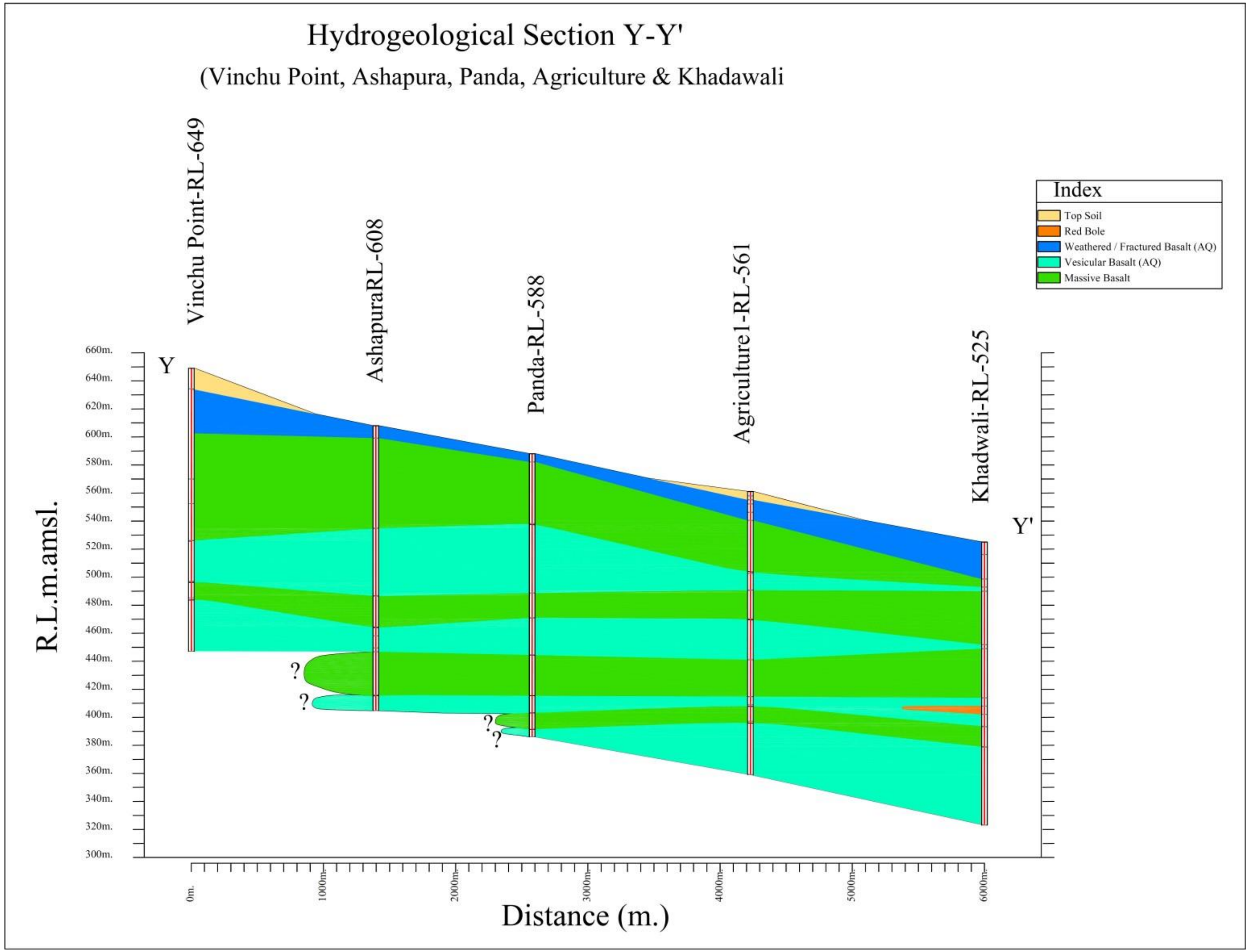


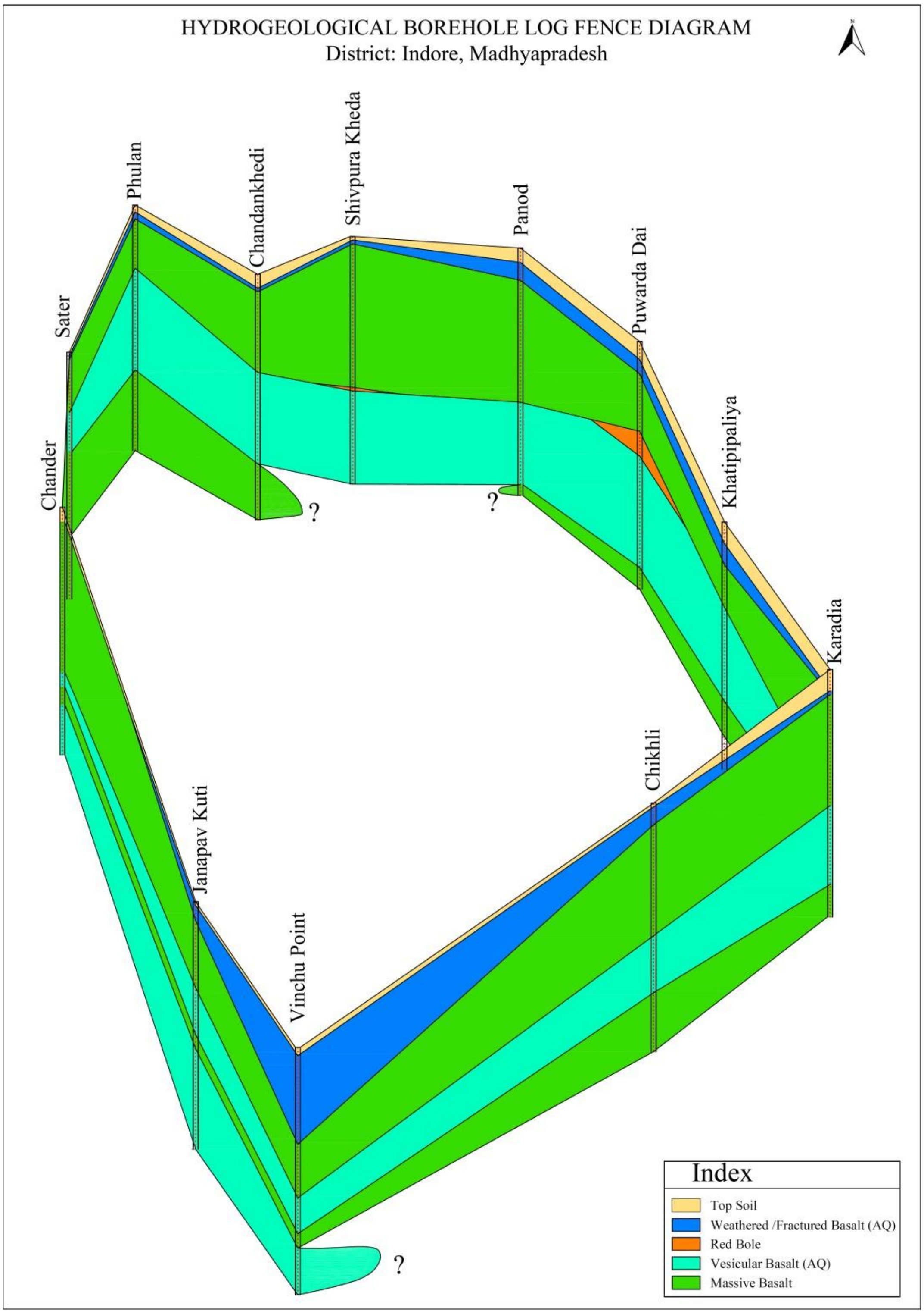
Fig 14: 2-D Hydrogeological Cross-section Y-Y'



Fence Diagram

The Fence diagram was also prepared (fig. 15). The pattern for the Fence was chosen as such to cover the maximum portion of the region to represent the enhanced picture of the sub-surface as deciphered from the 2-D cross sections

Fig 15: 2-D Hydrogeological Fence Diagram



4. Ground Water Resources

Dynamic Ground Water Resource (2013)

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 Committee. The base year of computation of the Ground Water Resources is 2013. The dynamic ground water resources are also known as Annual Replenishable Ground Water Resources since it gets replenished/ recharged every year.

The Annual Replenishable Ground Water Resource for the Indore District has been assessed as 61813.85 Ham. The major source of ground water recharge is the monsoon rainfall. Block -wise Ground Water Resources of Indore District as on March, 2013 is given in Table No 8 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. is 27.9% of total annual recharge in Indore district.

The assessment of ground water draft 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 Draft of the entire district for 2013 has been estimated as 68885.53 Ham. Agriculture sector remained the predominant consumer of ground water resources. About 94.6 % of total annual ground water draft i.e. 65164.51 Ham is for irrigation use. Only 3721 Ham is for Domestic & Industrial use which is about 5.4% of the total draft. An analysis of ground water draft figures indicates that the district is over exploited with 117.31% stage of ground water development.

The status of ground water development is very high in the three blocks i.e. Depalpur, Indore and Sanwer where the Stage of Ground Water Development is more than 100%, which implies that in these blocks the annual ground water consumption is more than annual ground water recharge. In Mhow block the stage of ground water development is below 70%. The ground water development activities have increased generally in the areas where future scope for ground water development existed. This has resulted increase in stage of ground water development. List of categorizations of Blocks is given in Table No 6.

Table 6: Dynamic Ground Water Resource (Zone of Fluctuation) as on March' 2013

District	Assessment Unit / District	Command / Non Command	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham (11+12)	Allocation For Domestic & Industrial Water Supply in Ham	Net Ground Water Availability for Future Irrigation Development in Ham (10-11-14)	Stage of Ground Water Development in % {(13/10)*100}
Indore	Depalpur	Command	452.77	235.87	11.51	247.38	27.00	189.90	54.64
		Non Command	15740.07	18238.02	741.52	19024.54	741.52	-3284.47	120.87
		Block Total	**16192.84**	**18518.89**	**753.03**	**19271.92**	**786.52**	**-3094.57**	**119.02**
	Indore	Non Command	18684.79	26942.39	1383.21	28325.60	1383.21	-9640.81	151.60
		Block Total	**18684.79**	**26942.39**	**1383.21**	**28325.60**	**1383.21**	**-9640.81**	**151.60**
	Mhow	Command	661.70	174.94	47.39	222.33	80.00	406.76	33.60
		Non Command	14074.35	8728.30	1072.35	9800.65	1805.00	3541.05	69.63
		Block Total	**14736.05**	**8903.24**	**1119.74**	**10022.98**	**1885.00**	**3947.81**	**68.02**
	Sanwer	Non Command	9109.40	10799.99	465.04	11265.03	465.04	-2155.63	123.66
		Block Total	9109.40	10799.99	465.04	11265.03	465.04	-2155.63	123.66
		District	**58723.08**	**65164.51**	**3721.02**	**68885.53**	**4501.77**	**-10943.20**	**117.31**

Ground Water Resources- (Outcome of NAQUIM)

The Ground Water Resource for Indore district has been calculated block-wise as per the lithology and the aquifer parameters. The In-storage resource for the shallow aquifer below zone of fluctuation (upto 30 mbgl) is computed to be around 186.01 MCM. The static resource for the deeper aquifer (30-200 mbgl) is computed as 525.53 MCM. The total resource available accounts to about 1298.75 MCM. The block-wise details of ground water resources as an outcome of NAQUIM is presented in the Table no 7.

Table 7: Ground Water Resources (Outcome of NAQUIM)

Block	Shallow Aquifer (0-30mts)		Deeper Aquifer (30-200 mts)	Total Resources (Dynamic + In-storage + Static) (MCM)
	Dynamic (MCM)	In-storage (MCM)	Static (MCM)	
Depalpur	161.92	32.26	89.45	283.63
Indore	186.85	53.83	183.02	423.70
Mhow	147.36	51.91	91.88	291.16
Sanwer	91.09	48.01	161.17	300.27
District	**587.22**	**186.01**	**525.53**	**1298.75**

5. Ground Water Related Issues

Ground Water Depletion

Over-Exploitation of Ground Water Resources is the main ground water related issue in Indore district. Indore District as a whole is Over-Exploited (117.3%). Out of 4 Blocks, 3 blocks are Over-Exploited. The Indore Municipal Corporation Area has been notified for ground water abstraction under Central Ground Water Authority. The declining Ground Water Levels is another big issue in the district. The water levels went below 18 m bgl during pre-monsoon season in the year 2017. The annual declining ground water level trend observed for a period of 10 years from 2008-2017 is in the range of -0.049 m/year to -0.897 m/year. The area under irrigation is hugely dependent on ground water. About 80% of irrigation requirement is met through Ground Water. Table no. 8 provides the detailed water level trend for 2008-17.

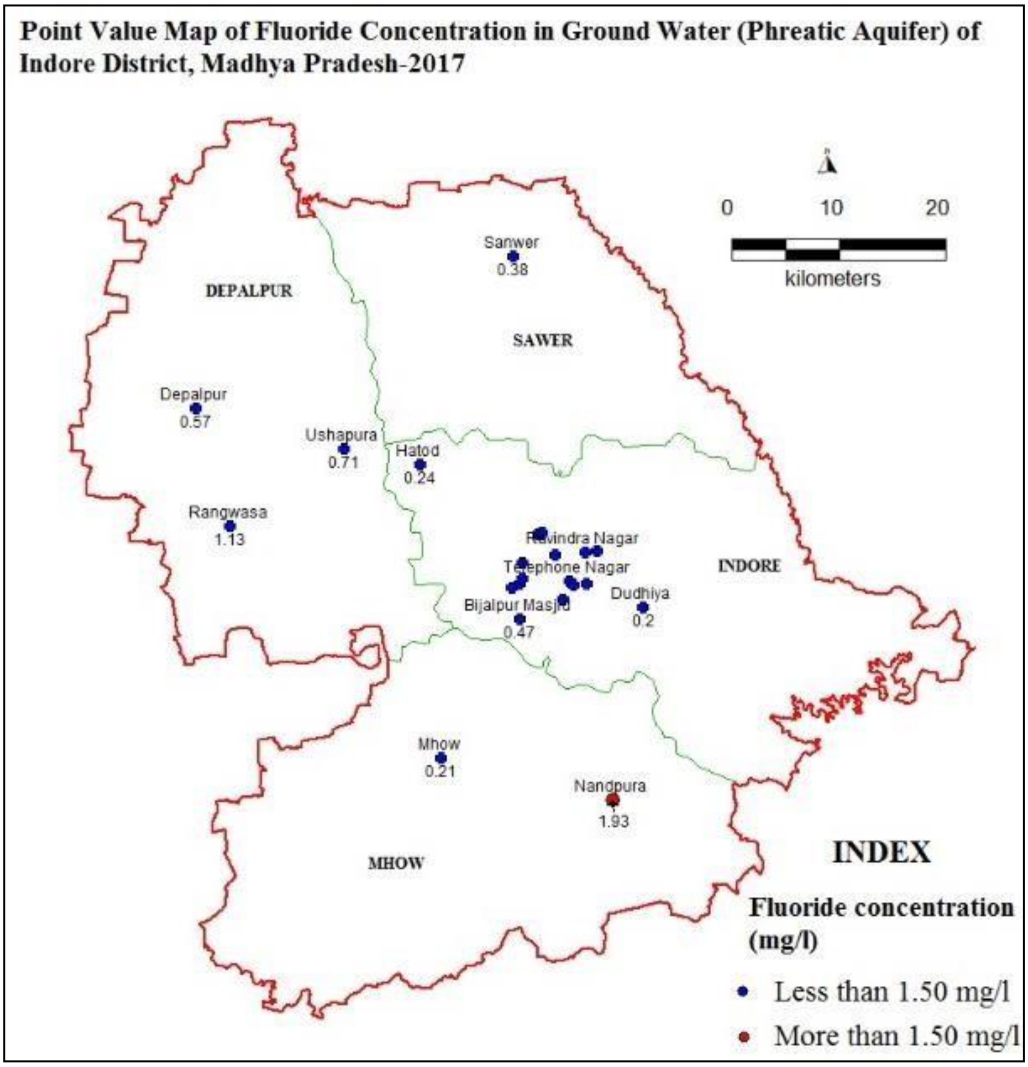
Table 8: Decadal Ground Water level trend (2008-2017)

S. No.	Location	Pre-monsoon		Post-monsoon		Annual	
		Rise (m/yr)	Fall (m/yr)	Rise (m/yr)	Fall (m/yr)	Rise (m/yr)	Fall (m/yr)
1	Manpur(D)		0.5874		0.2238	0.0106	
2	Choral		0.5073				
3	Nandpura	0.1882		0.05		0.1447	
4	Mhow Dbiss			0.7715			
5	Mhow	0.0499			0.0007	0.0518	
6	Rau IIM		1.7961	0.129			
7	Dudhiya	0.4158		0.2604		0.5337	
8	Indore Pipliyapala		1.0116				
9	Deoguradia IMC	0.3799					
10	Khudel(D)		0.1927			0.4879	
11	Khudel New Pz	0.1503					0.8972
12	Betma(S)		0.012		0.3235	0.0982	
13	Betma(D)	0.1247				0.397	
14	Indore(D)	1.7372		1.2145		1.383	
15	Indore(S)	0.2359				0.5801	
16	Indore IMC Office	1.205					
17	Musakhedi(S)	0.3198				0.1726	
18	Rangwasa	0.119		0.058			0.0493
19	Hatod	0.5628		0.5122		0.6015	
20	Hatod(D)				0.2325		
21	Hatod(S)	0.4668		0.9199		0.7844	
22	Hatod PWD New	1.3716					
23	Ushapura	0.5459		1.0999		0.6357	
24	Mangliya(D)	0.2413		0.5591		0.6676	
25	Depalpur	0.4678		0.1405		0.5488	
26	Dharampuri(D)	0.582			0.5911	0.9219	
27	Khsipra Budhi Barlai	1.1768					
28	Sanwer	0.1155		0.0659		0.0688	
29	Sanwer(S)	0.8503		0.0776		0.42	
30	Gautampura(S)	0.2124					
31	Sanwer Block	0.7421					0.1944
32	Chandrawatiganj	1.1617					

Ground water quality

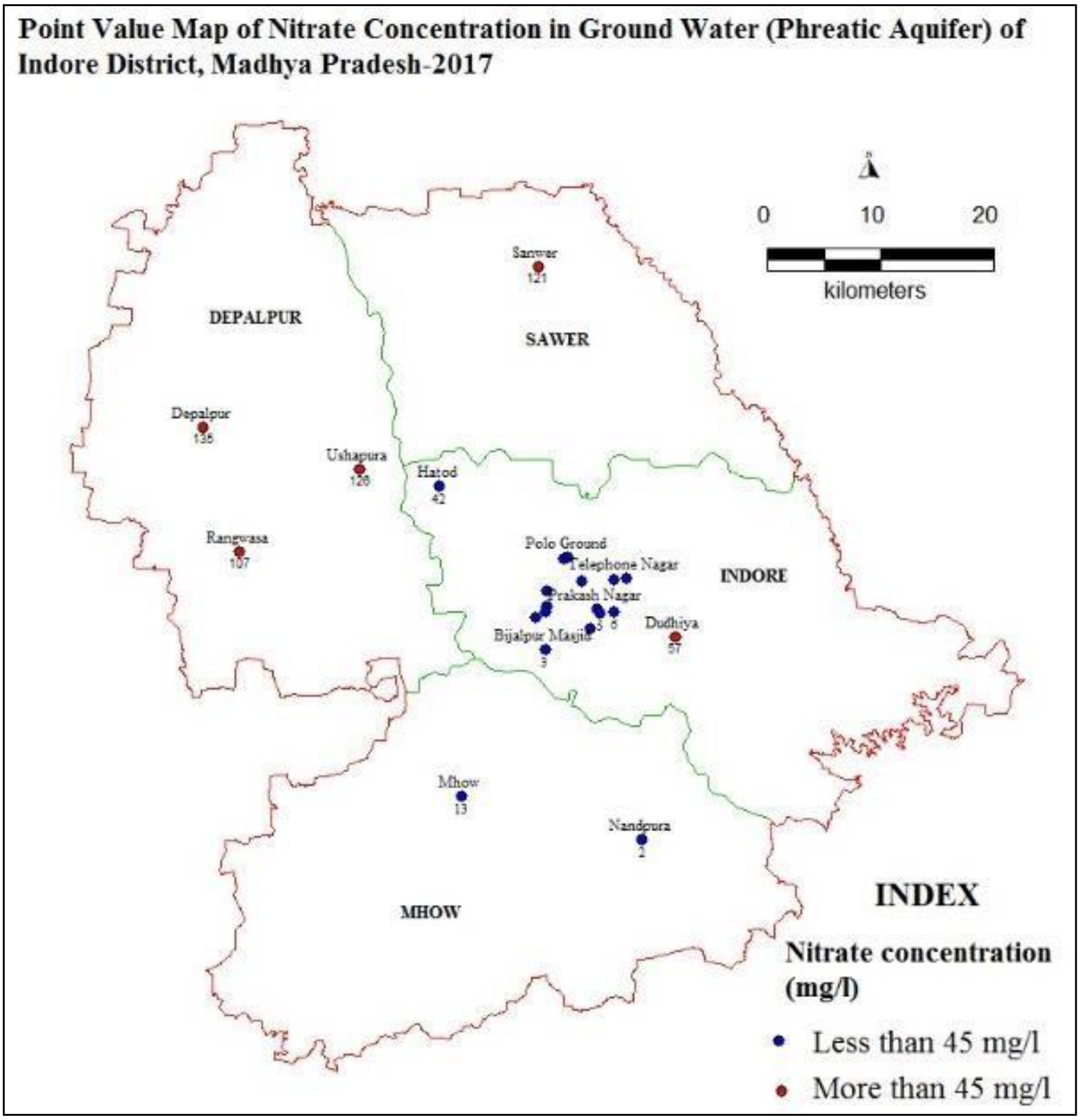
The fluoride concentration in Indore district ranged in between 0.20 to 1.93 mg/l. As per BIS permissible limit, the concentration of fluoride more than 1.50 mg/l has been detected in ground water of Nandpura (1.93 mg/l). The distribution of Fluoride concentration in Ground Water is shown in the fig 16.

Fig 16: Map showing distribution of Fluoride concentration in Ground Water



In the district, nitrate concentration in ground water ranged in between 2 to 135 mg/l. The 77% ground water samples recorded nitrate concentration within the BIS acceptable limit of 45 mg/l and 23% water samples recorded more than 45 mg/l as BIS recommendation. The concentration of nitrate more than 100 mg/l has been detected in ground water of Rangwasa (107 mg/l), Sanwer (121 mg/l), Ushapura (126 mg/l), and Depalpur (135 mg/l) dug wells and is shown in the fig. 18. High nitrate in ground water appears due to anthropogenic activities or excessive use of fertilizers etc. The distribution of Fluoride concentration in Ground Water is shown in the fig 17.

Fig 17: Map showing distribution of Nitrate concentration in Ground Water



6. Ground Water Management Plan

Groundwater has been contributing more to agricultural wealth than surface irrigation since ages. Tube wells are now the largest source of irrigation in the country. Since this sector has almost no dependence on the government, it is growing at a rapid rate and it is estimated that one million wells are added every year (Shah and Deb, 2004). Being an individually managed source, ground water irrigation is also a more efficient form of irrigation, with crop yields per cubic meter of water being 1.2 to 3 times higher than surface irrigation. However, since this sector has grown through investment by individual farmers, with little state involvement compared to canal irrigation, government support for understanding this sector and improving its performance is negligible. The major issues for the future growth of groundwater irrigation is declining resource base, demand driven growth, and a lack of policy and regulatory framework. Since groundwater extraction is primarily driven by the needs of the population and the density of farmer population and not the quality of resource, groundwater irrigation is scaling up even in such hard rock areas causing irreversible depletion of the resource base (Shah and Deb, 2004). To warrant the current situation effective groundwater management strategies needs to be evolved.

Ground Water Management Strategies

Indore district has been facing problems of ground water exploitation which in turn are depleting the ground water resources in the area. This has led to evolve sustainable water conservation and management practices through an integrated approach. The block-wise ground water management plan for Indore district has been made keeping in view the area specific details and includes the strategies like enhancing the ground water resources through construction of artificial recharge structures such as percolation tanks, check dams/nala bunds, recharge shafts, etc. and ensuring water use efficiency through maintenance/ renovation of existing water bodies/water conservation structures. Also, adoption of micro-irrigation techniques such as sprinkler irrigation has been proposed, that would not only conserve ground water resources by reducing the draft but would also increase the net cropping area thereby augmenting the agricultural economy of the district.

Supply side Management Plan

The supply side management plan for Indore district has been formulated using the basic concepts of hydrogeology. Sub-surface storage is calculated by multiplying the total area with the respective specific yield and the unsaturated zone thickness obtained by subtracting 3 mts from the post-monsoon water level. The volume of ground water recharge generated through pre-existing rain water harvesting/water conservation structures is subtracted from the sub-surface storage to assess the available storage potential. Thus, the surface water requirement to completely saturate the sub-surface storage is obtained by multiplying a factor of 1.33 to available storage potential. A runoff coefficient factor of 0.23 has been considered for Indore district to calculate the total surface water runoff, 30% of which accounts to the non-committed runoff which is available to sustain the proposed artificial recharge structures. Further, the number of structures has been calculated by allotting 35%, 20% and 35% of non-committed runoff to Percolation tanks, Recharge shafts/Tube wells and Nala bunds/Check dams/Cement Plugs respectively. The remaining 10% runoff is considered to restore the pre-existing village tanks, ponds and water conservation structures. A detailed calculation of the proposed artificial recharge structures is presented in the Table no. 9.

A financial outlay plan has also been chalked out, assuming the cost for the artificial recharge structures to be Rs. 20 lakhs each for percolation tanks, Rs. 10 lakhs each for Nala bunds/Check Dams/Cement Plugs, Rs. 5 lakhs each for Recharge shafts/Tube wells and Rs. 2 lakhs each for renovation of Village tanks/ponds/WCS. This accounts to a total of Rs. 287.37 Crores to successfully implement the supply side management strategy. Table no. 10 represents the complete financial outlay plan for the district.

Demand Side Management

Micro irrigation technologies such as drip and sprinkler systems are being increasingly promoted as technological solutions for achieving water conservation. micro-irrigation comprises two technologies—drip and sprinkler irrigation. Both saves conveyance losses and improve water application efficiency by applying water near the root-zone of the plant Some benefits of the micro-irrigation have been listed below:

1. The increase in yield for different crops ranges from 27 per cent to 88 per cent and water saving ranges from 36 per cent to 68 per cent vis-à-vis conventional flow irrigation systems (Phansalker and Verma, 2005).
2. It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.
3. It saves costs of hired labour and other inputs like fertilizer.
4. It reduces the energy needs for pumping, thus reducing energy per ha of irrigation because of its reduced water needs. However, overall energy needs of the agriculture sector may not get reduced because most farmers use the increased water efficiency to bring more area under irrigation.

Sprinkler Irrigation

Adoption of Sprinkler irrigation techniques in 50% of the area irrigated by ground water has been suggested for the Indore district. About 1879.39 sq.km area is irrigated by Tube wells . About 75.17 MCM water can be saved by applying sprinkler irrigation technique in 50% of this area i.e. 939.70 sq.km.

Change in cropping pattern

The total irrigated area in Indore district is 2064.71 sq.km and area under wheat cultivation is 1189.13 sq.km. Wheat requires minimum four watering and whereas Gram requires only two watering. Therefore, it is proposed that if 50% of this area under wheat cultivation is changed to gram cultivation then approximately 59.46 MCM of water can be saved. A summarized table for the demand side management is given in the Table no. 15. A summarized table for the demand side management is given in the Table no. 11.

Table 9: Ground Water Management Plan- Supply side

Station	Area (Sq Km)	Area suitable for recharge (Sq Km)	Rainfall (m)	Average post-monsoon water level (m)	Unsaturated zone (m)	Average SP Yield (%)	Sub-surface storage (MCM)	GW Recharge through RWH Structures Constructed (MCM)
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Depalpur	1042	1009.59	0.94376	5.42	2.42	0.02	48.86	1.19
Indore	1040	1028.21	0.94376	5.81	2.81	0.02	57.79	4.93
Mhow	1047	1020.92	0.94376	5.88	2.88	0.02	58.80	4.17
Sanwer	769	760.25	0.94376	6.58	3.58	0.02	54.43	3.40
TOTAL	**3898**	**3818.97**		**5.9225**	**2.9225**		**219.89**	**13.69**

Station	Available Storage Potential (MCM)	Surface water required (mcm)	Surface water (Run-off) available (mcm)	Non-committed Run-off (mcm)	Percolation tank	Recharge shaft/ Tube well	NB/ CD/ CP	No of Village tank, pond and WCS
	9	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Depalpur	47.67	63.41	239.66	71.90	63.00	127.000	444.00	148.00
Indore	52.86	70.30	239.20	71.76	70.00	141.000	492.00	212.00
Mhow	54.63	72.66	240.81	72.24	73.00	145.000	509.00	170.00
Sanwer	51.03	67.88	176.87	53.06	68.00	136.000	475.00	126.00
TOTAL	**206.20**	**274.24**	**896.54**	**268.96**	**274.00**	**549.00**	**1920.00**	**656.00**

Table 10: Financial Outlay Plan

Block	Area Suitable for AR	Available Storage Potential (MCM)	Surface water required (mcm)	Percolation Tanks		NB/ CD/ CP		Recharge shaft/ Tube well		Renovation of Village Ponds		Total Cost of RS in crores
				structure Nos	cost (crores)	structure Nos	cost (crores)	structure Nos	cost (crores)	structure Nos	cost (crores)	
Depalpur	1009.59	41.21278	54.813	63	12.6	444	44.4	127	6.35	148	2.96	66.31
Indore	1028.21	32.90813	43.76781	70	14	492	49.2	141	7.05	212	4.24	74.49
Mhow	1020.92	33.80822	44.96494	73	14.6	509	50.9	145	7.25	170	3.4	76.15
Sanwer	760.25	36.4371	48.46134	68	13.6	475	47.5	136	6.8	126	2.52	70.42
Total	**3818.97**	**144.37**	**192.01**	**274**	**54.8**	**1920**	**192**	**549**	**27.45**	**656**	**13.12**	**287.37**

Table 11: Groundwater Management Plan- Demand Side

Block	Area Irrigated by Tube Well (Sq.Km)	50% Area Irrigated by Tube Well (Sq.Km)	Groundwater draft saved by Sprinkler Irrigation @0.08 m (MCM)
Depalpur	723.31	361.66	28.93
Indore	468.21	234.11	18.73
Mhow	147.61	73.81	5.90
Sanwer	540.26	270.13	21.61
Total	**1879.39**	**939.70**	**75.18**

Block	Area under Wheat Cultivation (Sq.Km)	50% Area under wheat proposed for Gram cultivation (Sq.Km)	Groundwater saved by change in cropping pattern @ 0.1m (MCM)
Depalpur	440.63	220.32	22.03
Indore	291.56	145.78	14.58
Mhow	122.25	61.13	6.11
Sanwer	334.69	167.35	16.73
Total	**1189.13**	**594.57**	**59.46**

Post-Intervention Impact

The expected outcome of the proposed interventions from both supply side and demand side has been described in Table no 12. It can be envisaged that the Stage of ground water development for the entire district, would reduce to 74.81% as compared to the present stage of ground water development of 115.57% after adoption and successful implementation of proposed interventions.

Table 12: Post-Intervention Impact

Assessment Unit / District	Net Ground Water Availability (MCM)	Additional recharge created by AR (MCM)	Net GW availability after interven-tion (MCM)	Existing Gross Ground Water Draft for All Uses (MCM)	GW saved by Sprinkler irrigation (MCM)	Total draft after interven-tions (MCM)	Stage of GW Develop-ment before interven-tions %	Stage of GW Develop-ment after interven-tions %
Depalpur	161.93	47.67	**209.60**	192.72	28.93	**163.79**	119.02	78.14
Indore	186.85	52.86	**239.70**	283.26	18.73	**264.53**	151.60	110.36
Mhow	147.36	54.63	**202.00**	100.23	5.90	**94.33**	68.02	46.70
Sanwer	91.09	51.03	**142.13**	112.65	21.61	**91.04**	123.66	64.05
Total	**587.23**	**206.20**	**793.43**	**688.86**	**75.18**	**613.68**	**115.57**	**74.81**

Block-wise Ground Water Management Plan (Outcome of NAQUIM)

As per directions of Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, Aquifer Management Plan for Satna district has been prepared block-wise. The plan for each block discusses the broad framework of ground water situation in the block, status of water availability (both surface and ground water), feasibility of artificial recharge and other water conservation structures and their numbers and cost estimates. A tentative list of artificial recharge structures block-wise is given with each management plan.

1. Block Depalpur

Salient features:

Area (Sq Km)	**1042**
Area Suitable for Recharge-NC (Sq.Km)	**1009.59**
Rainfall (m)	**0.94376**
Average Post Monsoon DTW in (mbgl)	**5.42**
Unsaturated Zone (m)	**2.42**
Average Specific Yield	**0.02**
Sub Surface Storage Available (MCM)	**48.86**
Recharge through RWH structures (MCM)	**1.19**
Available Storage Potential (MCM)	**47.67**
Surface Water Required (MCM)	**63.41**
Runoff Available (MCM)	**239.66**
Non-committed Runoff available (MCM)	**71.90**

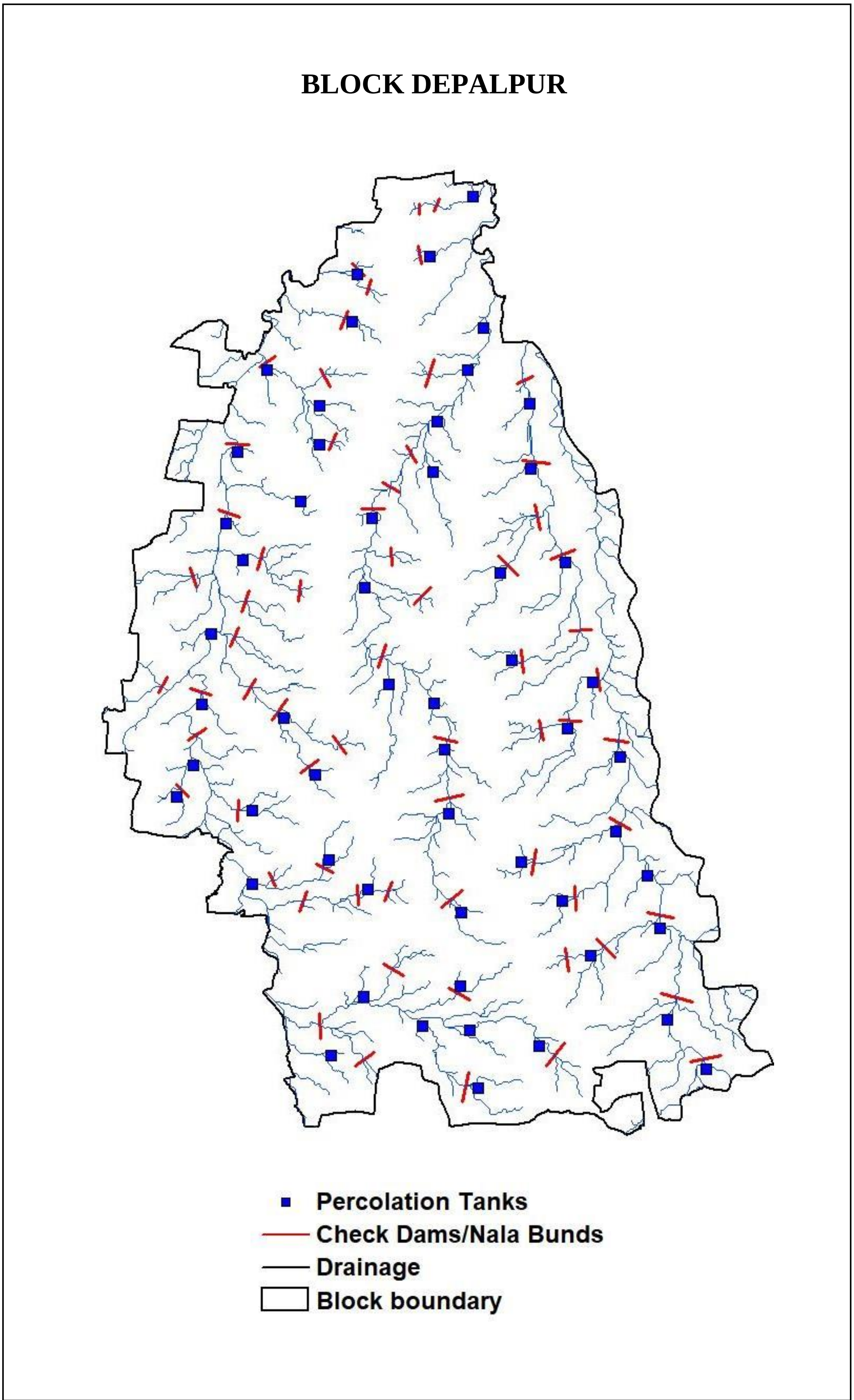
Resources:

- ✓ **First Aquifer**
  - ➢ **Dynamic Resources (MCM) : 161.92**
  - ➢ **Static Resources (MCM) : 32.26**
  - ➢ **Total Resources (MCM) : 194.18**
  - ➢ **Second Aquifer**
  - ➢ **Static Resources (MCM) : 89.45**
  - ➢ **Total GW Resources (MCM) : 283.63**
  - ➢ **Gross Ground Water Draft (MCM) : 192.72**
  - ➢ **Stage of Ground Water Development: 119.02**
  - ➢ **Category : Over Exploited**
- ✓ **Issues: Over Exploitation, Declining Water Levels**

Financial Outlay Plan:

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	**63**	12.6 (Rs 20 Lakh Per Structure)
NB/CD/CP	**127**	6.35 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	**444**	44.4 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	**148**	2.96 (Rs 02 Lakh Per Structure)
Total Cost		**66.31 Crores**

Proposed locations of Artificial Recharge structures



Tentative locations of Artificial Recharge structures

PERCOLATION TANKS	LATITUDE	LONGITUDE
PT1	75.5564	23.0374
PT2	75.5538	23.0150
PT3	75.5366	22.9744
PT4	75.5366	22.9556
PT5	75.4938	22.9523
PT6	75.5982	22.9670
PT7	75.6309	22.8941
PT8	75.6653	22.8992
PT9	75.4971	22.9004
PT10	75.5181	22.8246
PT11	75.5603	22.8870
PT12	75.4711	22.8019
PT13	75.6935	22.8058
PT14	75.6633	22.7368
PT15	75.6196	22.6468
PT16	75.5596	22.6904
PT17	75.6782	22.7102
PT18	75.7181	22.6794
PT19	75.6108	22.7308
PT20	75.5418	22.7565
PT21	75.7081	22.7487
PT22	75.6663	22.8193
PT23	75.6371	22.8524
PT24	75.6043	22.7783
PT25	75.4805	22.8650
PT26	75.6471	22.9441
PT27	75.6222	23.0120
PT28	75.5645	22.9204
PT29	75.5347	22.7971
PT30	75.4755	22.8309
PT31	75.6151	22.6746
PT32	75.7145	22.7233
PT33	75.5015	22.7445
PT34	75.6912	22.7698
PT35	75.6101	22.6957
PT36	75.6019	22.8095
PT37	75.5967	22.8316
PT38	75.5733	22.8407
PT39	75.6792	22.8415
PT40	75.5960	22.9424
PT41	75.6144	22.9918
PT42	75.5097	22.9914
PT43	75.6466	22.9757
PT44	75.6167	23.0750
PT45	75.5946	23.0465
PT46	75.4878	22.9181
PT47	75.5015	22.7802
PT48	75.4621	22.7864
PT49	75.6422	22.7553
PT50	75.7385	22.6560
PT51	75.5431	22.6625
PT52	75.5618	22.7419
PT53	75.6514	22.6671
PT54	75.5272	22.9288
PT55	75.5906	22.6766

CHECK DAM/NALA BUNDS	LATITUDE	LONGITUDE
CD1	75.5889	23.0692
CD2	75.5981	23.0709
CD3	75.5571	23.0400
CD4	75.5627	23.0315
CD5	75.5893	23.0469
CD6	75.5498	23.0158
CD7	75.5943	22.9902
CD8	75.5438	22.9575
CD9	75.5400	22.9878
CD10	75.6442	22.9870
CD11	75.5744	22.9021
CD12	75.5740	22.9354
CD13	75.5848	22.9512
CD14	75.5265	22.8857
CD15	75.4981	22.8806
CD16	75.4945	22.7798
CD17	75.5121	22.7469
CD18	75.5727	22.7410
CD19	75.5568	22.7394
CD20	75.5395	22.7522
CD21	75.5284	22.7362
CD22	75.4652	22.7896
CD23	75.5318	22.8012
CD24	75.4729	22.8166
CD25	75.4751	22.8370
CD26	75.5006	22.8384
CD27	75.5158	22.8284
CD28	75.5473	22.8116
CD29	75.4551	22.8404
CD30	75.4712	22.8918
CD31	75.4924	22.8633
CD32	75.4896	22.9226
CD33	75.5062	22.9011
CD34	75.5647	22.9249
CD35	75.4941	22.9560
CD36	75.5097	22.9956
CD37	75.5694	22.8541
CD38	75.6028	22.8141
CD39	75.6524	22.8188
CD40	75.6674	22.8233
CD41	75.6825	22.8428
CD42	75.6426	22.8518
CD43	75.6732	22.8667
CD44	75.6043	22.7862
CD45	75.6488	22.7553
CD46	75.6057	22.7375
CD47	75.6705	22.7379
CD48	75.6659	22.7082
CD49	75.6863	22.7138
CD50	75.5754	22.7035
CD51	75.6097	22.6918
CD52	75.5372	22.6763
CD53	75.6600	22.6628
CD54	75.6130	22.6472
CD55	75.7383	22.6608
CD56	75.7232	22.6901
CD57	75.5603	22.6604
CD58	75.7147	22.7297

2. Block Sanwer

Salient features:

Area (Sq Km)	**769**
Area Suitable for Recharge-NC (Sq.Km)	**760.25**
Rainfall (m)	**0.94376**
Average Post Monsoon DTW in (mbgl)	**6.58**
Unsaturated Zone (m)	**3.58**
Average Specific Yield	**0.02**
Sub Surface Storage Available (MCM)	**54.43**
Recharge through RWH structures (MCM)	**3.40**
Available Storage Potential (MCM)	**51.03**
Surface Water Required (MCM)	**67.88**
Runoff Available (MCM)	**176.87**
Non-committed Runoff available (MCM)	**53.06**

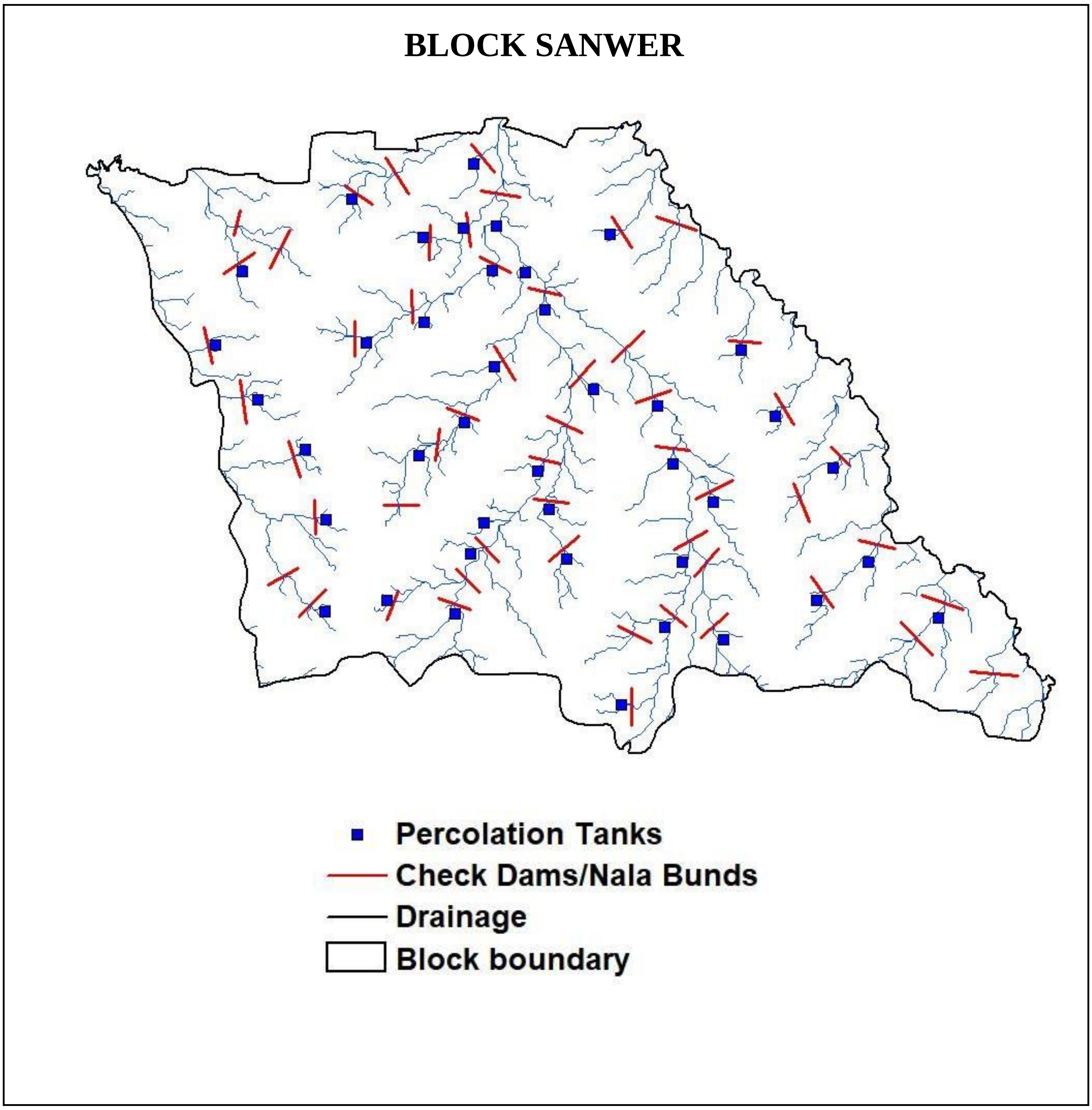
Ground Water resources:

- ✓ **First Aquifer**
  - ➢ **Dynamic Resources (MCM) : 91.09**
  - ➢ **Static Resources (MCM) : 48.01**
  - ➢ **Total Resources (MCM) : 139.10**
  - ➢ **Second Aquifer**
  - ➢ **Static Resources (MCM) : 161.17**
  - ➢ **Total GW Resources (MCM) : 300.27**
  - ➢ **Gross Ground Water Draft (MCM) : 112.65**
  - ➢ **Stage of Ground Water Development: 123.66**
  - ➢ **Category : Over Exploited**
- ✓ **Issues: Over Exploitation, Declining Water Levels**

Financial Outlay Plan:

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	**68**	13.6 (Rs 20 Lakh Per Structure)
NB/CD/CP	**475**	47.5 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	**136**	6.8 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	**126**	2.52 (Rs 02 Lakh Per Structure)
Total Cost		**70.42 Crores**

Proposed locations of Artificial Recharge structures



Tentative locations of Artificial Recharge structures

PERCOLATION TANKS	LATITUDE	LONGITUDE
PT1	75.7505	23.0065
PT2	75.7814	22.991
PT3	75.7987	22.9949
PT4	75.8132	22.9958
PT5	75.8111	22.9779
PT6	75.7816	22.9575
PT7	75.8119	22.9398
PT8	75.7992	22.9176
PT9	75.8256	22.9771
PT10	75.8357	22.8828
PT11	75.7391	22.8787
PT12	75.9067	22.886
PT13	75.8857	22.8361
PT14	75.8933	22.862
PT15	75.8018	22.8654
PT16	75.9115	22.8311
PT17	75.8895	22.9009
PT18	75.9739	22.8618
PT19	75.9336	22.9199
PT20	75.8435	22.8631
PT21	75.8076	22.8778
PT22	75.7655	22.8469
PT23	75.831	22.8981
PT24	75.8827	22.9242
PT25	75.8549	22.9307
PT26	75.867	22.8052
PT27	76.0043	22.8397
PT28	75.9189	22.9463
PT29	75.8621	22.9923
PT30	75.7032	22.9777
PT31	75.6914	22.9483
PT32	75.8031	23.0203
PT33	75.7566	22.9491
PT34	75.9587	22.8994
PT35	75.7794	22.9045
PT36	75.7951	22.8415
PT37	75.9513	22.8469
PT38	75.7389	22.8423
PT39	75.8342	22.9624
PT40	75.7302	22.9069
PT41	75.7098	22.9265

CHECK DAM/NALA BUNDS	LATITUDE	LONGITUDE
CD1	75.7019	22.9808
CD2	75.7520	22.9507
CD3	75.6883	22.9481
CD4	75.7841	22.9892
CD5	75.8125	22.9803
CD6	75.7768	22.9636
CD7	75.7257	22.9028
CD8	75.7348	22.8800
CD9	75.8422	22.8672
CD10	75.8008	22.8546
CD11	75.7682	22.8446
CD12	75.7950	22.8454
CD13	75.8339	22.9024
CD14	75.8090	22.8668
CD15	75.7721	22.8847
CD16	75.7336	22.8457
CD17	75.7209	22.8564
CD18	75.8897	22.8406
CD19	75.9074	22.8366
CD20	75.9039	22.8619
CD21	75.9541	22.8500
CD22	75.8969	22.8707
CD23	75.9074	22.8909
CD24	75.9618	22.9042
CD25	75.9777	22.8689
CD26	75.9377	22.9230
CD27	75.8368	22.8863
CD28	75.8425	22.9167
CD29	75.8892	22.9072
CD30	75.8808	22.9278
CD31	75.8700	22.9478
CD32	75.8503	22.9369
CD33	75.8165	22.9411
CD34	75.7877	22.9087
CD35	75.7985	22.9208
CD36	75.8340	22.9695
CD37	75.8674	22.9931
CD38	75.8071	23.0226
CD39	75.8010	22.9942
CD40	75.9204	22.9495
CD41	76.0059	22.8460
CD42	75.8728	22.8333
CD43	75.8714	22.8045
CD44	75.8908	22.9969
CD45	75.7536	23.0080
CD46	75.7011	22.9969
CD47	75.7037	22.9258
CD48	75.7194	22.9864
CD49	75.7701	23.0157
CD50	75.9449	22.8857
CD51	76.0283	22.8176

3. Block Indore

Salient features:

Area (Sq Km)	**1040**
Area Suitable for Recharge-NC (Sq.Km)	**1028.21**
Rainfall (m)	**0.94376**
Average Post Monsoon DTW in (mbgl)	**5.81**
Unsaturated Zone (m)	**2.81**
Average Specific Yield	**0.02**
Sub Surface Storage Available (MCM)	**57.79**
Recharge through RWH structures (MCM)	**4.93**
Available Storage Potential (MCM)	**52.86**
Surface Water Required (MCM)	**70.30**
Runoff Available (MCM)	**239.20**
Non-committed Runoff available (MCM)	**71.76**

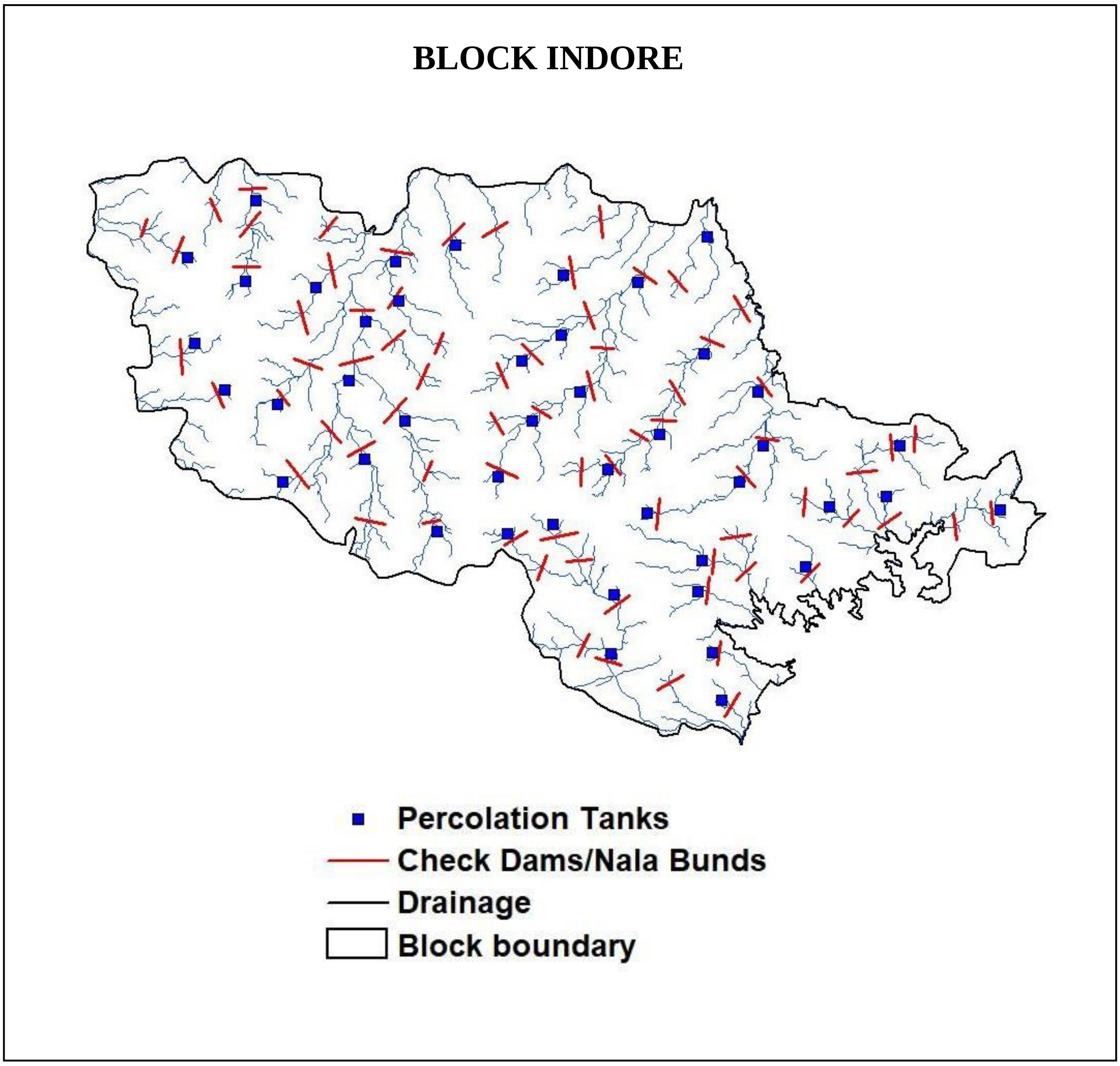
Ground Water resources:

- ✓ **First Aquifer**
  - ➢ **Dynamic Resources (MCM) : 186.85**
  - ➢ **Static Resources (MCM) : 53.83**
  - ➢ **Total Resources (MCM) : 240.68**
  - ➢ **Second Aquifer**
  - ➢ **Static Resources (MCM) : 183.02**
  - ➢ **Total GW Resources (MCM) : 423.70**
  - ➢ **Gross Ground Water Draft (MCM) : 283.26**
  - ➢ **Stage of Ground Water Development: 151.60**
  - ➢ **Category : Over Exploited**
- ✓ **Issues: Over Exploitation, Declining Water Levels and Water Quality**

Financial Outlay Plan:

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	**70**	14 (Rs 20 Lakh Per Structure)
NB/CD/CP	**492**	49.2 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	**141**	7.05 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	**212**	4.24 (Rs 02 Lakh Per Structure)
Total Cost		**74.49 Crores**

Proposed locations of Artificial Recharge structures



Tentative locations of Artificial Recharge structures

PERCOLATION TANKS	LATITUDE	LONGITUDE
PT1	75.8376	22.7586
PT2	75.8844	22.7515
PT3	75.9862	22.7041
PT4	75.8651	22.6693
PT5	75.816	22.698
PT6	75.9708	22.6354
PT7	76.0893	22.6764
PT8	75.977	22.765
PT9	75.8879	22.6892
PT10	75.9055	22.6317
PT11	76.0016	22.6642
PT12	75.9403	22.6605
PT13	75.9756	22.7339
PT14	75.8042	22.8036
PT15	76.031	22.6825
PT16	75.7698	22.7295
PT17	76.0548	22.6171
PT18	76.1264	22.6449
PT19	76.0053	22.5992
PT20	76.0034	22.5684
PT21	76.0526	22.6006
PT22	76.1583	22.65
PT23	76.1128	22.6138
PT24	75.9455	22.6307
PT25	75.9594	22.6892
PT26	76.0185	22.7613
PT27	76.086	22.7045
PT28	76.0559	22.7241
PT29	76.2225	22.6432
PT30	76.166	22.6767
PT31	76.0658	22.5444
PT32	75.9165	22.7807
PT33	75.9536	22.7205
PT34	76.0574	22.7847
PT35	75.7984	22.7621
PT36	75.7654	22.7739
PT37	75.8563	22.7103
PT38	75.8659	22.7408
PT39	75.8189	22.6579
PT40	76.024	22.6417
PT41	75.8827	22.772
PT42	75.7866	22.7053
PT43	76.0757	22.6579
PT44	76.0607	22.5692

CHECK DAM/NALA BUNDS	LATITUDE	LONGITUDE
CD1	75.7604	22.7782
CD2	75.8194	22.7016
CD3	75.8275	22.6617
CD4	75.8822	22.6949
CD5	75.7622	22.7226
CD6	75.8978	22.7125
CD7	75.8815	22.7311
CD8	75.9425	22.6634
CD9	75.9922	22.7078
CD10	75.8305	22.7431
CD11	75.9746	22.6295
CD12	75.8470	22.7673
CD13	76.0300	22.6411
CD14	75.9914	22.7442
CD15	75.8024	22.8098
CD16	75.7989	22.7693
CD17	75.7828	22.7028
CD18	75.8633	22.6748
CD19	75.8683	22.6372
CD20	75.9005	22.6634
CD21	75.9025	22.6371
CD22	75.9503	22.6283
CD23	75.9882	22.5728
CD24	76.0070	22.5940
CD25	76.0580	22.6015
CD26	76.0645	22.5689
CD27	76.0021	22.5644
CD28	76.0611	22.6164
CD29	76.1154	22.6102
CD30	76.0796	22.6602
CD31	76.1612	22.6757
CD32	76.2176	22.6418
CD33	76.1385	22.6389
CD34	76.0899	22.7070
CD35	76.0914	22.6798
CD36	76.0048	22.6667
CD37	76.0331	22.6894
CD38	75.9594	22.7242
CD39	75.9646	22.6939
CD40	76.0606	22.7302
CD41	76.0226	22.7648
CD42	75.8823	22.7534
CD43	75.8637	22.7467
CD44	75.8335	22.7188
CD45	75.8605	22.7204
CD46	75.9150	22.7862
CD47	75.9817	22.7662
CD48	75.8830	22.7773
CD49	75.9424	22.7128
CD50	75.9978	22.7926
CD51	76.0410	22.7619
CD52	75.8464	22.6838
CD53	76.0370	22.5537
CD54	75.9396	22.6880
CD55	76.0410	22.7040
CD56	75.9868	22.6628

4. Block Mhow

Salient features:

Area (Sq Km)	**1047**
Area Suitable for Recharge-NC (Sq.Km)	**1020.92**
Rainfall (m)	**0.94376**
Average Post Monsoon DTW in (mbgl)	**5.88**
Unsaturated Zone (m)	**2.88**
Average Specific Yield	**0.02**
Sub Surface Storage Available (MCM)	**58.80**
Recharge through RWH structures (MCM)	**4.17**
Available Storage Potential (MCM)	**54.63**
Surface Water Required (MCM)	**72.66**
Runoff Available (MCM)	**240.81**
Non-committed Runoff available (MCM)	**72.24**

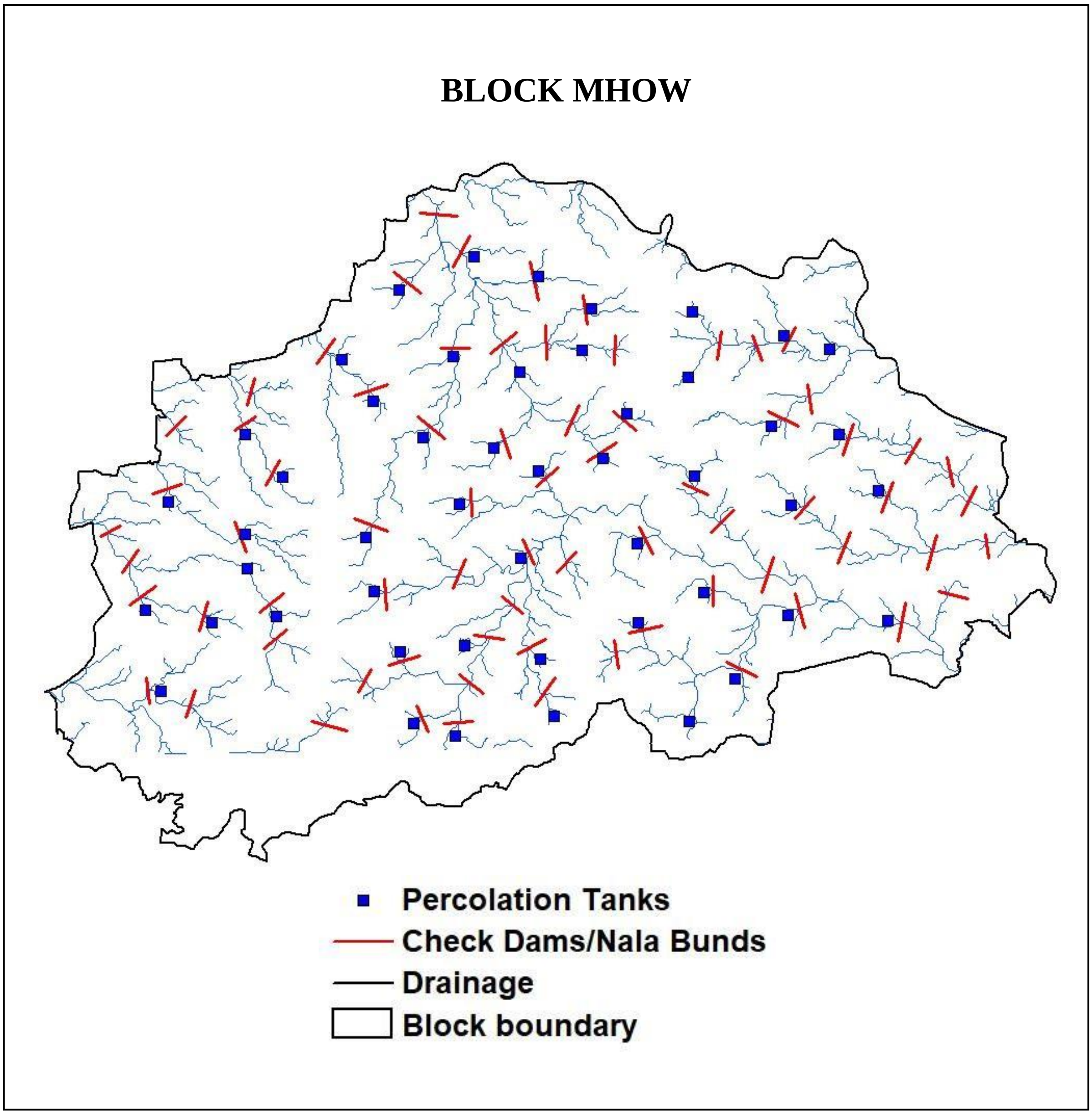
Ground Water resources:

- ✓ **First Aquifer**
  - ➢ **Dynamic Resources (MCM) : 147.36**
  - ➢ **Static Resources (MCM) : 51.91**
  - ➢ **Total Resources (MCM) : 199.27**
- ➢ **Second Aquifer**
  - ➢ **Static Resources (MCM) : 91.88**
- ➢ **Total GW Resources (MCM) : 291.16**
- ➢ **Gross Ground Water Draft (MCM) : 100.23**
- ➢ **Stage of Ground Water Development: 68.02**
- ➢ **Category : Semi-Critical**

Financial Outlay Plan:

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	**73**	14.6 (Rs 20 Lakh Per Structure)
NB/CD/CP	**509**	50.9 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	**145**	7.25 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	**170**	3.4 (Rs 02 Lakh Per Structure)
Total Cost		**76.15 Crores**

Proposed locations of Artificial Recharge structures



Tentative locations of Artificial Recharge structures

PERCOLATION TANKS	LATITUDE	LONGITUDE
PT1	75.7214	22.5985
PT2	75.7922	22.6051
PT3	75.8192	22.5898
PT4	75.8146	22.5703
PT5	75.7489	22.5673
PT6	75.7825	22.5601
PT7	75.7692	22.5246
PT8	75.8371	22.5407
PT9	75.825	22.5196
PT10	75.7043	22.4823
PT11	75.7521	22.4978
PT12	75.8716	22.5114
PT13	75.7286	22.395
PT14	75.8429	22.442
PT15	75.6258	22.442
PT16	75.6586	22.4451
PT17	75.5999	22.4101
PT18	75.662	22.5107
PT19	75.7337	22.5293
PT20	75.9208	22.4975
PT21	75.7501	22.389
PT22	75.7218	22.4284
PT23	75.8692	22.3959
PT24	75.7924	22.5136
PT25	75.7084	22.4571
PT26	75.8426	22.4795
PT27	75.8764	22.4565
PT28	75.9651	22.5044
PT29	75.945	22.5309
PT30	75.604	22.4991
PT31	75.8003	22.3984
PT32	75.7832	22.4726
PT33	75.7549	22.4316
PT34	75.6441	22.4678
PT35	75.5924	22.4483
PT36	75.6427	22.4839
PT37	75.6429	22.5306
PT38	75.8704	22.5886
PT39	75.8682	22.5576
PT40	75.7596	22.6145
PT41	75.9402	22.571
PT42	75.917	22.5773
PT43	75.9699	22.443
PT44	75.9194	22.4455
PT45	75.8921	22.4159
PT46	75.7081	22.5462
PT47	75.6924	22.5657
PT48	75.9105	22.5348
PT49	75.7933	22.4249

CHECK DAM/NALA BUNDS	LATITUDE	LONGITUDE
CD1	75.7496	22.5715
CD2	75.8159	22.5893
CD3	75.7069	22.5515
CD4	75.7377	22.5338
CD5	75.7743	22.574
CD6	75.7255	22.6024
CD7	75.753	22.6169
CD8	75.7415	22.6341
CD9	75.7903	22.6029
CD10	75.796	22.574
CD11	75.836	22.5373
CD12	75.8245	22.5224
CD13	75.8094	22.5374
CD14	75.9171	22.5381
CD15	75.8842	22.5726
CD16	75.9197	22.5755
CD17	75.9498	22.5282
CD18	75.8309	22.5704
CD19	75.7967	22.5108
CD20	75.7754	22.5264
CD21	75.8472	22.4809
CD22	75.8721	22.5052
CD23	75.886	22.4899
CD24	75.9697	22.5012
CD25	75.8812	22.4573
CD26	75.8467	22.439
CD27	75.8955	22.4202
CD28	75.9255	22.4477
CD29	75.9773	22.4423
CD30	75.9088	22.4646
CD31	75.9276	22.4963
CD32	75.9479	22.4773
CD33	75.9925	22.4751
CD34	75.9826	22.5228
CD35	76.0113	22.4995
CD36	76.0019	22.5131
CD37	75.8318	22.4272
CD38	75.7241	22.4243
CD39	75.7957	22.4097
CD40	75.7887	22.431
CD41	75.7144	22.4554
CD42	75.707	22.4882
CD43	75.7521	22.4653
CD44	75.7788	22.4505
CD45	75.8066	22.4706
CD46	75.7579	22.4989
CD47	75.787	22.4755
CD48	75.6428	22.536
CD49	75.657	22.5127
CD50	75.6407	22.4825
CD51	75.6032	22.5051
CD52	75.6562	22.4515
CD53	75.6218	22.4451
CD54	75.5907	22.455
CD55	75.5936	22.4101

Annexure-I

Location details of Exploratory Borewells

Bore	Long	Lat	Total Depth	Elevation
Agriculture	75.8930	22.7061	201.9	561
Panda	75.8090	22.5982	201.9	588
Khatipipliya	76.0261	22.7786	201.9	532
Khadwali	75.9831	22.8272	201.9	525
Karadia	76.1123	22.6584	201.9	549
Chikli	75.9683	22.5493	202.73	561
Asrawad Buzurg	75.9964	22.7060	201.9	551
Puwarda dai	75.9569	22.9258	201.9	510
Khachrot	75.9509	22.5962	203.15	580
Ashapura	75.7489	22.4967	203.15	608
Janapav Kuti	75.5945	22.4689	201.9	552
Mhow cantt	75.7534	22.5141	201.9	596
Vinchu point	75.6779	22.3501	201.9	649
Budhaniya	75.7652	22.7764	201.9	549
Rajoda	75.8403	22.9032	201.9	517
Basandra	75.7381	22.8650	201.9	529
Nagpur	75.7733	22.9556	201.9	518
Shivpura Kheda	75.7226	23.0113	201.9	525
Panod	75.8596	23.0021	201.9	511
Chander	75.4858	22.7906	201.9	515
Karwasa	75.5951	22.6637	201.9	543
Banediya	75.5605	22.8789	201.9	523
Sater	75.4914	22.9171	201.9	502
Phulan	75.5451	23.0372	200.27	499
Chandankhedi	75.6452	22.9806	200.27	500
Amba Khedi	75.6899	22.7869	177.51	530

Annexure-II

Lithological details of Exploratory Borewells

Bore	Depth1	Depth2	Stratigraphy
Agriculture	0.00	3.00	Top Soil
Agriculture	3.00	5.85	Massive Basalt
Agriculture	5.85	8.85	Weathered Basalt
Agriculture	8.85	14.70	Massive Basalt
Agriculture	14.70	20.55	Weathered Basalt
Agriculture	20.55	58.50	Massive Basalt
Agriculture	58.50	70.20	Vesicular Basalt
Agriculture	70.20	90.75	Massive Basalt
Agriculture	90.75	120.00	Vesicular Basalt
Agriculture	120.00	146.25	Massive Basalt
Agriculture	146.25	152.10	Vesicular Basalt
Agriculture	152.10	163.80	Massive Basalt
Agriculture	163.80	201.90	Vesicular Basalt
Panda	0.00	5.85	Weathered Basalt
Panda	5.85	49.80	Massive Basalt
Panda	49.80	99.45	Vesicular Basalt
Panda	99.45	117.00	Massive Basalt
Panda	117.00	201.90	Vesicular Basalt
Khatipipliya	0	8.85	Top Soil
Khatipipliya	8.85	17.55	Clay
Khatipipliya	17.55	35.10	Weathered Basalt
Khatipipliya	35.10	52.65	Clay
Khatipipliya	52.65	128.70	Massive Basalt
Khatipipliya	128.70	134.55	Clay
Khatipipliya	134.55	140.40	Weathered Basalt
Khatipipliya	140.40	146.25	Fractured Basalt
Khatipipliya	146.25	175.50	Massive Basalt
Khatipipliya	175.50	181.35	Clay
Khatipipliya	181.35	201.90	Weathered Basalt
Khadwali	0.00	8.85	Top soil
Khadwali	8.85	26.40	Vesicular basalt
Khadwali	26.40	32.10	Massive basalt
Khadwali	32.10	35.10	Vesicular basalt
Khadwali	35.10	73.20	Massive basalt
Khadwali	73.20	76.05	Vesicular basalt
Khadwali	76.05	111.15	Massive basalt
Khadwali	111.15	117.00	Vesicular basalt
Khadwali	117.00	122.85	Clay

Khadwali	122.85	131.70	Vesicular basalt
Khadwali	131.70	146.25	Massive basalt
Khadwali	146.25	201.90	Vesicular basalt
Karadia	0.00	5.85	Top soil
Karadia	5.85	17.55	Clay
Karadia	17.55	20.55	Weathered basalt
Karadia	20.55	111.15	Massive basalt
Karadia	111.15	117.00	Vesicular basalt
Karadia	117.00	120.00	Clay
Karadia	120.00	131.70	Vesicular basalt
Karadia	131.70	146.25	Massive basalt
Karadia	146.25	175.50	Vesicular basalt
Karadia	175.50	201.90	Massive basalt
Chikli	0	3.00	Vesicular basalt
Chikli	3.00	43.95	Massive basalt
Chikli	43.95	49.80	Vesicular basalt
Chikli	49.80	58.50	Massive basalt
Chikli	58.50	73.20	Vesicular basalt
Chikli	73.20	81.90	Massive basalt
Chikli	81.90	107.40	Vesicular basalt
Chikli	107.40	118.72	Massive basalt
Chikli	118.72	124.27	Vesicular basalt
Chikli	124.27	135.51	Massive basalt
Chikli	135.51	154.66	Vesicular basalt
Chikli	154.66	165.81	Massive basalt
Chikli	165.81	188.46	Vesicular basalt
Chikli	188.46	202.73	Massive basalt
Asrawad Buzurg	0.00	5.85	Weathered basalt
Asrawad Buzurg	5.85	14.70	Massive basalt
Asrawad Buzurg	14.70	26.40	Vesicular basalt
Asrawad Buzurg	26.40	46.80	Massive basalt
Asrawad Buzurg	46.80	108.30	Vesicular basalt
Asrawad Buzurg	108.30	114.15	Massive basalt
Asrawad Buzurg	114.15	117.00	Vesicular basalt
Asrawad Buzurg	117.00	131.70	Massive basalt
Asrawad Buzurg	131.70	137.55	Clay
Asrawad Buzurg	137.55	166.80	Vesicular basalt
Asrawad Buzurg	166.80	181.35	Massive basalt
Asrawad Buzurg	181.35	201.90	Vesicular basalt
Puwarda dai	0.00	14.70	Yellow Clay
Puwarda dai	14.70	26.40	Weathered Basalt
Puwarda dai	26.40	73.20	Massive basalt

Puwarda dai	73.20	87.75	Clay
Puwarda dai	87.75	93.60	Vesicular basalt
Puwarda dai	93.60	122.85	Massive basalt
Puwarda dai	122.85	128.70	Vesicular basalt
Puwarda dai	128.70	146.25	Massive basalt
Puwarda dai	146.25	163.80	Vesicular basalt
Puwarda dai	163.80	169.65	Massive basalt
Puwarda dai	169.65	184.35	Vesicular basalt
Puwarda dai	184.35	201.90	Massive basalt
Khachrot	0.00	3.00	Vesicular basalt
Khachrot	3.00	23.40	Massive basalt
Khachrot	23.40	32.25	Vesicular basalt
Khachrot	32.25	35.10	Massive basalt
Khachrot	35.10	55.65	Vesicular basalt
Khachrot	55.65	73.20	Massive basalt
Khachrot	73.20	90.75	Red boll
Khachrot	90.75	96.40	Vesicular basalt
Khachrot	96.40	102.05	Massive basalt
Khachrot	102.05	144.25	Vesicular basalt
Khachrot	144.25	192.15	Massive basalt
Khachrot	192.15	203.15	Vesicular basalt
Ashapura	0.00	8.85	Weathered basalt
Ashapura	8.85	73.20	Massive basalt
Ashapura	73.20	121.65	Vesicular basalt
Ashapura	121.65	144.25	Massive basalt
Ashapura	144.25	149.90	Vesicular basalt
Ashapura	149.90	158.55	Clay
Ashapura	158.55	161.20	Vesicular basalt
Ashapura	161.20	192.15	Massive basalt
Ashapura	192.15	203.15	Vesicular basalt
Janapav Kuti	0.00	3.00	Top soil
Janapav Kuti	3.00	8.85	Weathered basalt
Janapav Kuti	8.85	70.20	Massive basalt
Janapav Kuti	70.20	76.05	Clay
Janapav Kuti	76.05	108.30	Vesicular basalt
Janapav Kuti	108.30	120.00	Massive basalt
Janapav Kuti	120.00	201.90	Vesicular basalt
Mhow cantt	0.00	3.00	Clay
Mhow cantt	3.00	8.85	Weathered basalt
Mhow cantt	8.85	49.80	Massive basalt
Mhow cantt	49.80	64.35	Vesicular basalt
Mhow cantt	64.35	105.30	Massive basalt

Mhow cantt	105.30	108.30	Clay
Mhow cantt	108.30	117.00	Vesicular basalt
Mhow cantt	117.00	122.85	Massive basalt
Mhow cantt	122.85	137.55	Vesicular basalt
Mhow cantt	137.55	146.25	Massive basalt
Mhow cantt	146.25	201.90	Vesicular basalt
Vinchu point	0.00	14.70	Weathered basalt
Vinchu point	14.70	79.05	Massive basalt
Vinchu point	79.05	96.60	Vesicular basalt
Vinchu point	96.60	122.85	Massive basalt
Vinchu point	122.85	152.10	Vesicular basalt
Vinchu point	152.10	163.80	Massive basalt
Vinchu point	163.80	201.90	Vesicular basalt
Budhaniya	0.00	3.00	Weathered basalt
Budhaniya	3.00	43.95	Massive basalt
Budhaniya	43.95	46.80	Clay
Budhaniya	46.80	61.50	Vesicular basalt
Budhaniya	61.50	120.00	Massive basalt
Budhaniya	120.00	201.90	Vesicular basalt
Rajoda	0.00	3.00	Top soil
Rajoda	3.00	17.55	Clay
Rajoda	17.55	20.55	Weathered basalt
Rajoda	20.55	26.40	Vesicular basalt
Rajoda	26.40	87.75	Massive basalt
Rajoda	87.75	111.15	Vesicular basalt
Rajoda	111.15	143.40	Massive basalt
Rajoda	143.40	201.90	Vesicular basalt
Basandra	0.00	3.00	Top soil
Basandra	3.00	8.85	Massive basalt
Basandra	8.85	11.70	Clay
Basandra	11.70	20.55	Vesicular basalt
Basandra	20.55	29.25	Massive basalt
Basandra	29.25	32.25	Vesicular basalt
Basandra	32.25	64.35	Massive basalt
Basandra	64.35	76.05	Vesicular basalt
Basandra	76.05	79.05	Massive basalt
Basandra	79.05	105.30	Vesicular basalt
Basandra	105.30	117.00	Massive basalt
Basandra	117.00	131.70	Vesicular basalt
Basandra	131.70	143.40	Massive basalt
Basandra	143.40	201.90	Vesicular basalt
Nagpur	0.00	11.70	Clay

Nagpur	11.70	20.55	Weathered basalt
Nagpur	20.55	58.50	Vesicular basalt
Nagpur	58.50	122.85	Massive basalt
Nagpur	122.85	193.05	Vesicular basalt
Nagpur	193.05	201.90	Massive basalt
Shivpura Kheda	0.00	5.85	Weathered basalt
Shivpura Kheda	5.85	23.40	Massive basalt
Shivpura Kheda	23.40	35.10	Vesicular basalt
Shivpura Kheda	35.10	52.65	Massive basalt
Shivpura Kheda	52.65	84.90	Vesicular basalt
Shivpura Kheda	84.90	122.85	Massive basalt
Shivpura Kheda	122.85	125.85	Red boll
Shivpura Kheda	125.85	201.90	Vesicular basalt
Panod	0	11.7	Clay
Panod	11.7	26.4	Weathered/massive basalt
Panod	26.40	40.95	Vesicular basalt
Panod	40.95	84.9	Massive basalt
Panod	84.9	87.75	Vesicular basalt
Panod	87.75	125.85	Massive basalt
Panod	125.85	128.7	Vesicular basalt
Panod	128.7	140.4	Massive basalt
Panod	140.4	193.05	Vesicular basalt
Panod	193.05	201.9	Massive basalt
Chander	0	11.70	Clay
Chander	11.70	49.8	Massive basalt
Chander	49.8	114.15	Vesicular basalt
Chander	114.15	134.55	Massive basalt
Chander	134.55	146.25	Vesicular basalt
Chander	146.25	160.95	Massive basalt
Chander	160.95	201.9	Vesicular basalt
Karwasa	0	3	Clay
Karwasa	3	23.4	Massive basalt
Karwasa	23.4	29.25	Vesicular basalt
Karwasa	29.25	64.35	Massive basalt
Karwasa	64.35	93.6	Vesicular basalt
Karwasa	93.6	114.15	Massive basalt
Karwasa	114.15	128.7	Vesicular basalt
Karwasa	128.7	201.9	Massive basalt
Banediya	0	5.85	Clay
Banediya	5.85	14.7	Weathered basalt
Banediya	14.7	23.4	Massive basalt
Banediya	23.4	43.95	Vesicular basalt

Banediya	43.95	70.2	Massive basalt
Banediya	70.2	122.85	Vesicular basalt
Banediya	122.85	149.25	Massive basalt
Banediya	149.25	155.1	Vesicular basalt
Banediya	155.1	201.9	Massive basalt
Sater	0	3	Clay
Sater	3	5.69	Weathered basalt
Sater	5.69	49.32	Massive basalt
Sater	49.32	81.32	Vesicular basalt
Sater	81.32	148.67	Massive basalt
Sater	148.67	160.37	Vesicular basalt
Sater	160.37	201.32	Massive basalt
Phulan	0	5.69	Clay
Phulan	5.69	11.38	Weathered basalt
Phulan	11.38	51.53	Massive basalt
Phulan	51.53	134.67	Vesicular basalt
Phulan	134.67	200.27	Massive basalt
Chandankhedi	0	11.38	Clay
Chandankhedi	11.38	14.38	Weathered basalt
Chandankhedi	14.38	80.14	Massive basalt
Chandankhedi	80.14	154.59	Vesicular basalt
Chandankhedi	154.59	200.27	Massive basalt
Amba Khedi	0	20.23	Clay
Amba Khedi	20.23	31.77	Vesicular basalt
Amba Khedi	31.77	134.67	Massive basalt
Amba Khedi	134.67	143.21	Vesicular basalt
Amba Khedi	143.21	180.51	Massive basalt