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

Khandwa District
Madhya Pradesh

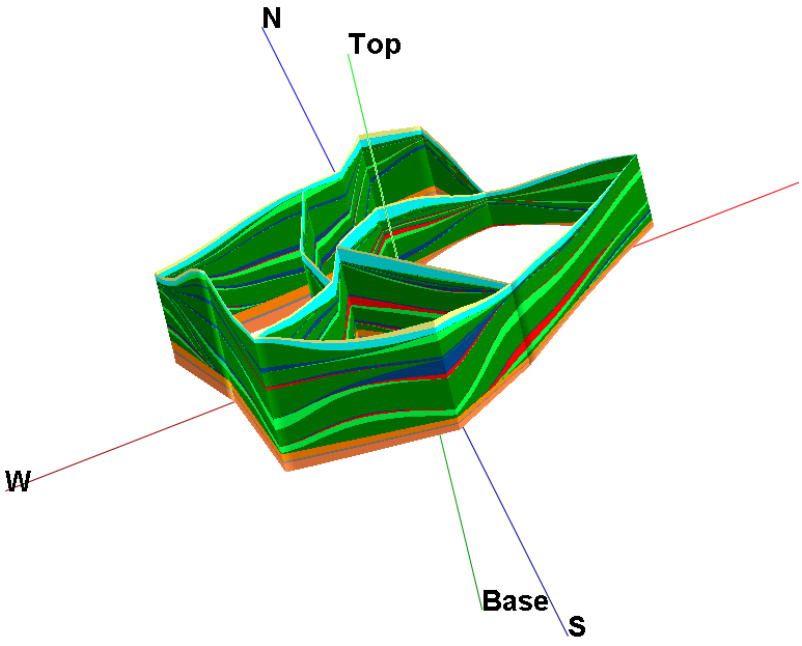
उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

Central Ground Water Board

Department of Water Resources, River Development & Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

Aquifer Mapping and Ground Water Management Plan of Khandwa District, Madhya Pradesh



BY
Dr. K. PARAMASIVAM
Assistant Hydrogeologist

NORTH CENTRAL REGION
BHOPAL
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Content

PREFACE

'Aquifer mapping' is a holistic approach for aquifer-based groundwater management. It may not be construed as aquifer geometry mapping only. In a broader perspective it can be defined as understanding the aquifers, ascertaining and establishing their quantity and quality sustainability through multi-disciplinary scientific approach integrating the techniques of geology, remote sensing, hydrogeology, geophysics, borehole drilling, hydrochemistry, hydrology, hydrometeorology, mathematical modelling, agriculture and soil science, water treatment and remediation, economics and social and environmental sciences.

Under the project on National Aquifer Mapping (NAQUIM to formulate sustainable Aquifer management plan, Central Ground Water Board (CGWB), North Central Region, Bhopal has taken up Khandwa district to prepare the 3-Dimensional Model and 2-Dimensional Aquifer Maps for the entire district and formulate Block-wise Aquifer Management Plan.

The studied area occupies an area of 7524 Sq. Km. It is divided into, four administrative blocks viz Badli, Chhegaon makhan, Harsud, Khalwa, Khandwa, Pandhana and Punasa forming blocks. Khandwa district is underlain by various geological formations, forming different types of aquifers in the area. Main geological; units of the area are Archaean, upper vindhyan, Bagh beds, Deccan traps and alluvium.

The pre-monsoon depth to Water levels ranges from a minimum of 2.7 meters below ground level (mbgl) in Punasa block to a maximum of 15.5 mbgl in Chhegoan Maakkanblock of Kandwah district. The post-monsoon depth to Water levels ranges from a minimum of 1.1 m below ground level in Punasa block to a maximum of 7.6 m bgl Chhegaon Makhan block of Khandwa district.

After the implemented of project interventions in the report, the stage of development is expected to improve by 10 % i.e. from 41 % to 38 % for the Khandwa district and additional area for the irrigation will be 332 Sq.Km.

As per the Management plan prepared under NAQUIM of all the Block of Khandwa District, a total number of 294 Percolation Tanks, 1030 Recharge Shafts/Tube wells and 1177 Nala Bunds/Check Dams and 696 Village pond Cement Plugs have been proposed and these structures can recharge 221 MCM.

Results of these comprehensive studies will contribute significantly to ground water sustainable management tools. It will not only enhance the long-term aquifer monitoring networks and but would also help in building the conceptual and quantitative regional ground-water-flow models for planners, policy makers and other stakeholders. I would like to place on record my appreciation for ***Dr.K.Paramasivam , Assistant Hydrogeologist*** to compile this report. I hope that this report will serve as a valuable guide for sustainable development of ground water in the Khandwa District, Madhya Pradesh

Rana Chatterjee
(Regional Director)

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.

1.1 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: 50,000scale 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.

1.2 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

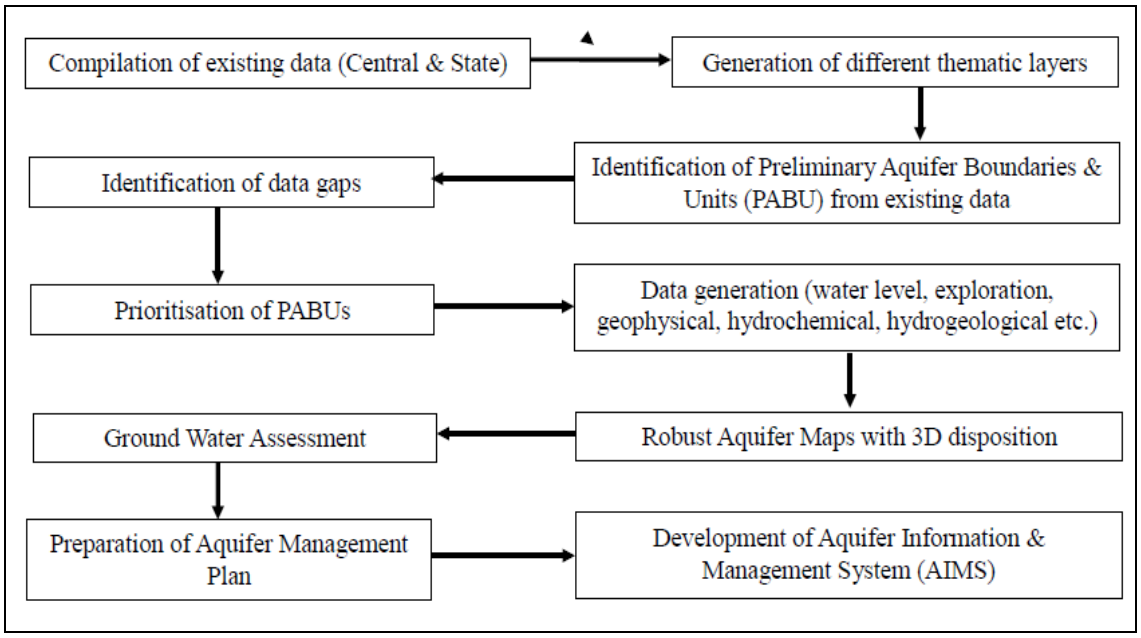


Fig 1: Aquifer mapping approach and methodology

1.3 Study Area

The Khandwa district, formerly known as the East Nimar district, is a district of the Madhya Pradesh state in central India. The city of Khandwa is the administrative headquarters of the district. Other notable towns in the district include Mundi, Harsud, Pandhana, and Omkarshwer. The Indira Sagar Project on Narmada River near Punasa village in Khandwa district is unique project with the largest reservoir on the country. The district lies between north latitude 21° 31’ and east longitude of 75° 57’ 27” and 77° 13” Falling in survey of India toposheet No. 55 B, 55C. E. The total population of the district as per 2011 census is 1309443. The area of the district is 7524.50 sq km and it has been divided into three tehsil and seven blocks. There are 716 villages. A detailed location map of the study area is shown in the Fig 2.

The district has an area of 6206 km², and a population 1,310,061 (2011 census). Khandwa District lies in the Nimar region, which includes the lower valley of the Narmada River, Kherkhali River, Choti Tawa River, and Shiva River. The Narmada forms part of the northern boundary of the district, and the Satpura Range form the southern boundary of the district. Burhanpur District, to the south, lies in the basin of the Tapti River. The pass through the Satpuras connecting Khandwa and Burhanpur is one of the main routes connecting northern and southern India, and the fortress of Asirgarh, which commands the pass, is known as the "Key to the Deccan". Betul and Harda districts lie to the east, Dewas District to the north, and Khargone District to the west.

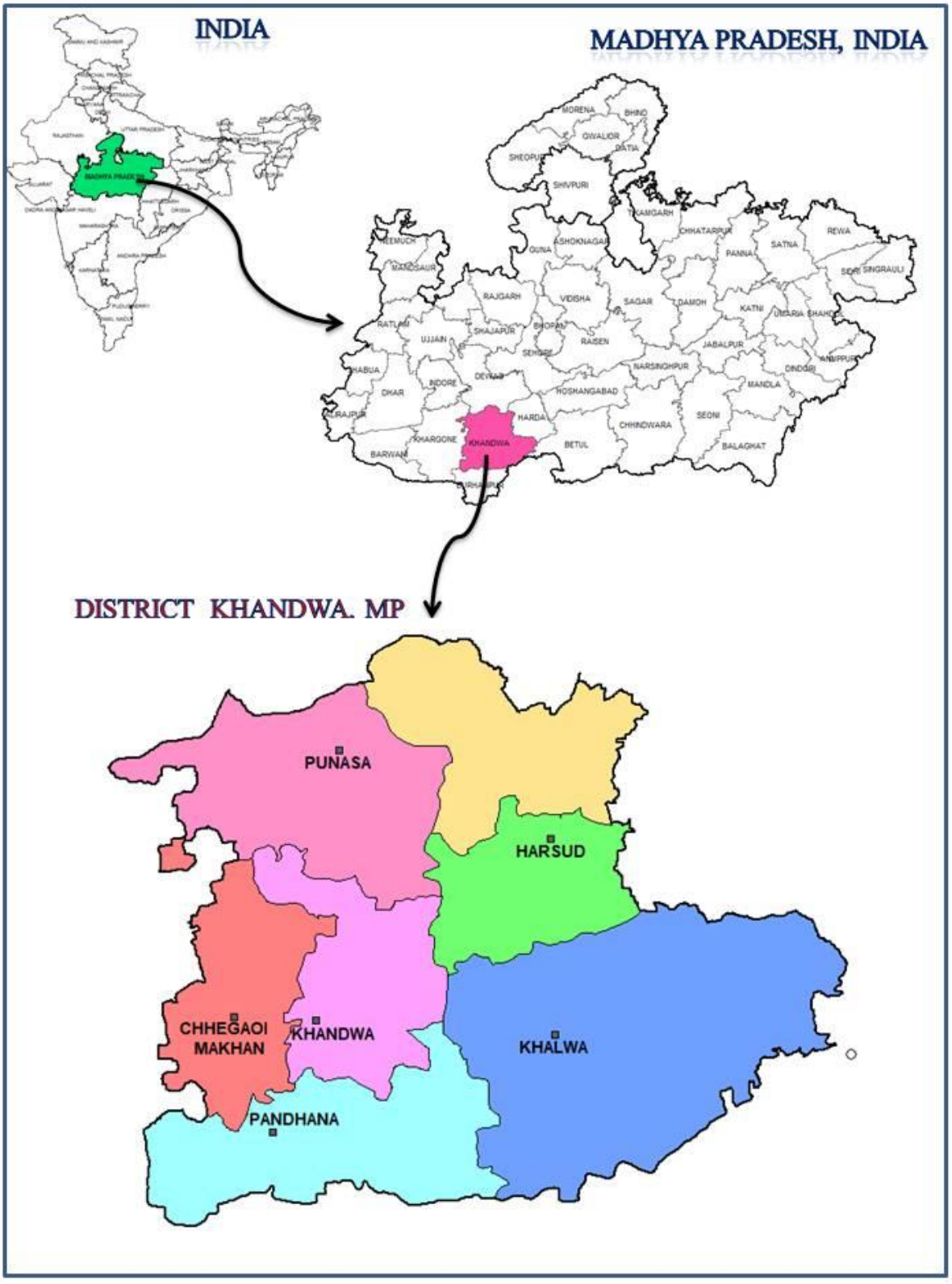


Fig 2: Administrative Map

1.3.1 Administrative Details

The Khandwa district has been divided into 7 Blocks. There are 1816 villages in the district. Total population of the district is1,310,061. Detailed administrative divisions of the district are given in Table-1.

Table-1: Administrative Divisions

Name of Assessment Unit (Block)	Recharge worthy area in Sq.Km	Areal extent (in Sq. Km)			
		Total Geographical Area	Hilly Area	Command Area	Non command
Badli	**545.24**	**1117.00**	**571.76**	**0**	**54524**
Chhegaon makhan	**861.00**	**870.00**	**9.00**	**35.55**	**825.45**
Harsud	**538.47**	**1000.50**	**462.03**	**0**	**538.47**
Khalwa	**970.00**	**1489.00**	**519.00**	**0**	**970.00**
Khandwa	**824.75**	**831.00**	**6.25**	**40.84**	**783.91**
Pandhana	**1170.00**	**1272.00**	**102.00**	**185.01**	**984.99**
Punasa	**905.00**	**945.00**	**40.00**	**664.20**	**240.80**
Dist. Total	**5814.46**	**7524.50**	**1710.04**	**925.60**	**4888.86**

2. 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 Khandwa district is broadly carried out in following steps:

a. **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 Public Health and Engineering Department (PHED) and district brochures published by CGWB was compiled and integrated for aquifer mapping. The Dynamic Ground Water Resource (2020) of CGWB and figures from the Water Resource Department were used for preparation of management plan.

b. **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.

c. **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.

d. **Data Generation:** The study of Khandwa district concentrated on the existing data; thus, no new data was generated The Data gap analysis for 14 Exploratory wells proposed for data generation.

2.1 Climate and Rainfall distribution

The climate of Khandwa district, MP is characterized by hot summer and general dryness except during the south west monsoon season. The year may divide into four seasons. The cold season, December to February is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the south west monsoon season. October and November form the post monsoon or transition period.

The normal annual rainfall of Khandwa District is 777.60 mm. The district receives maximum rainfall during south – west monsoon period i.e. June to September. About 90.5% of the annual rainfall received during monsoon season. Only 9.5% of the annual rainfall takes place between Octobers to May period. Thus surplus water for ground water recharge is available only during the south – west monsoon period.

The normal maximum temperature received during the month of May is 41.8 $^{\circ}$C and minimum during the month of January 11.2 ^{0}C. The normal annual means maximum and minimum temperature of Khandwa district is 34 ^{0}C & 19.5 ^{0}C respectively. During the south- west monsoon season the relative humidity generally exceeds 86% (July/ August month). The rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less than 33%. 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 is 15.6 km / hr. observed during the month of June and minimum 4.0 km/hr during the month of November. The average normal annual wind velocity of Khandwa district is 8.7 km/ hr.

2.2 Physiography/Digital Elevation Model

Khandwa district is endowed with the diverse physiography. The maximum elevation of the district is 570 m above mean sea level (amsl), which is recorded near southern part of the district. The western portion of the region is also highly elevated. The minimum elevation has been recorded in the southern and northern fringes of the district. The major portion of the district lies within an elevation range of about 210 to 380 m amsl. The Digital Elevation Model (DEM) is shown in the Fig. 3.

2.3 Geomorphology

Structural hills of Vindhyans, denudation hills of Deccan traps are predominant in Khandwa district. Apart from these above geomorphic features like flood, plain, alluvial plain, valley fills, intermountain depressions, pediment (Volcanic) are also sees in the district. A detailed Geomorphology map is presented in the Fig.4

Drainage:

Entire Khandwa district falls under the Narmada basin Narmada and its tributaries form the main source of surface water in the area. Narmada flows along the northern boundary of the district main rivers which drains the area of the district which drains the area of the district are Chhoti Tawa, Sukta & Bhim Nadi. A detailed hydrology map is presented in the Fig. 5.

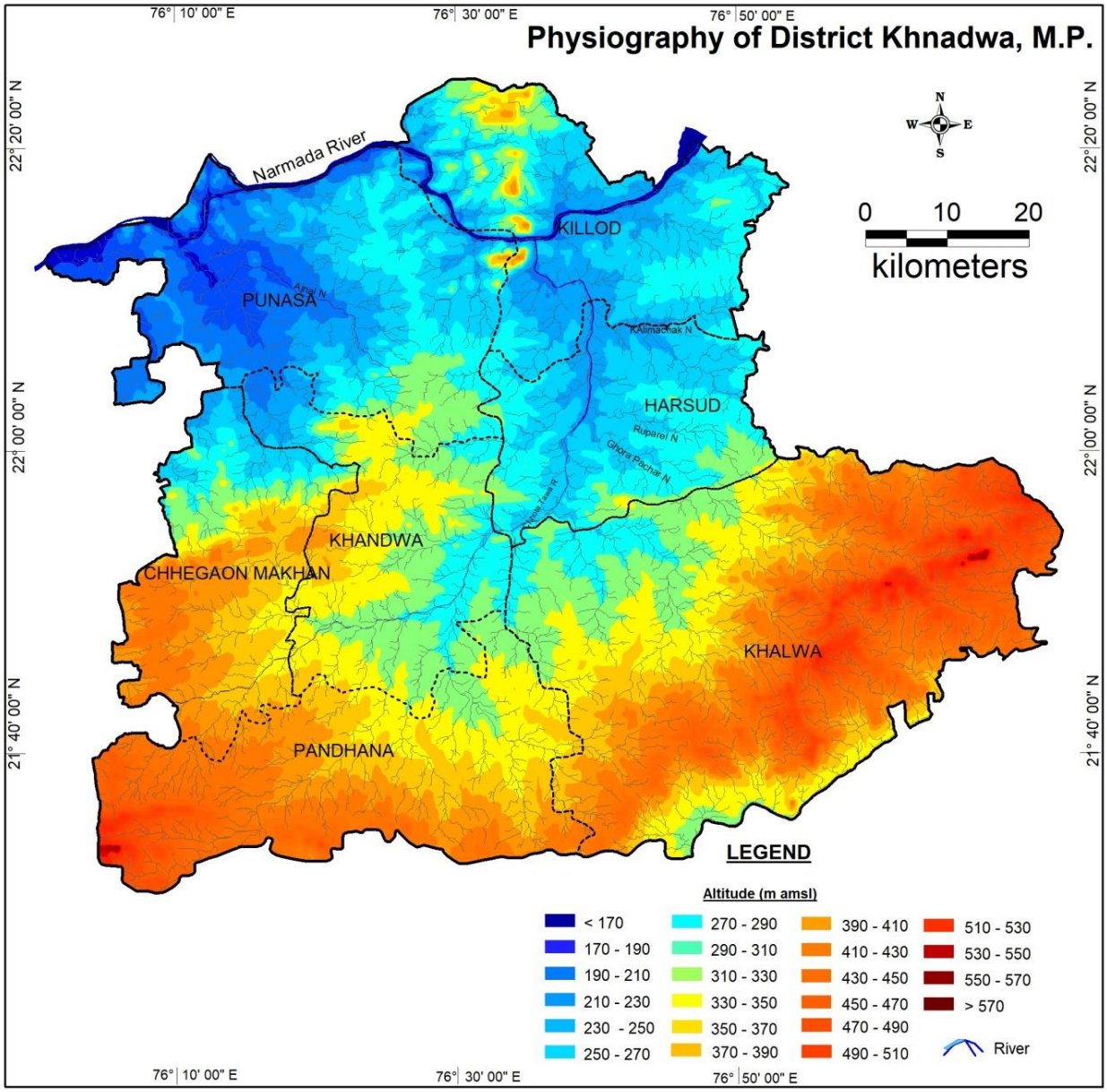


Fig 3: Digital Elevation Model

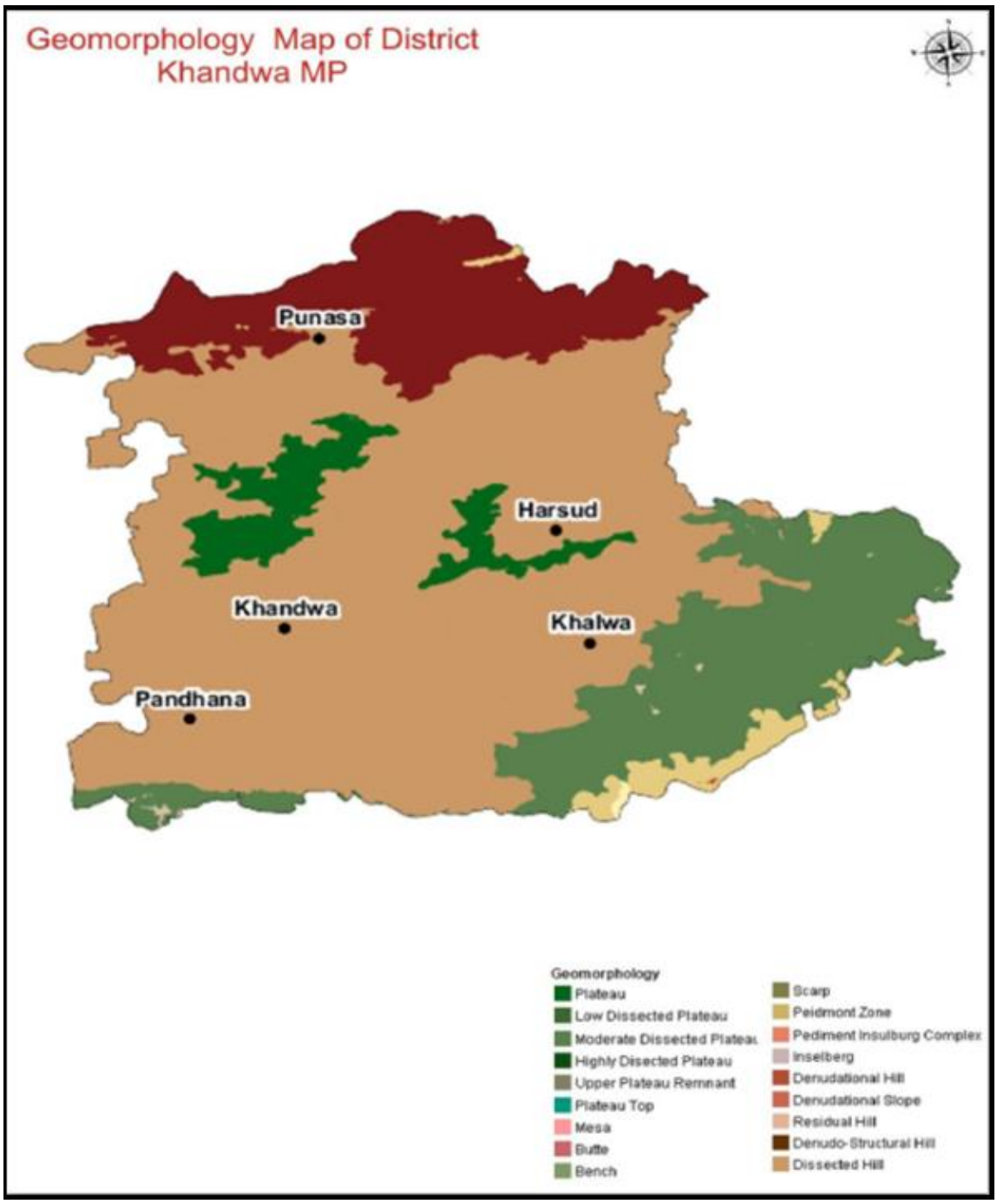


Fig 4: Geomorphological Map

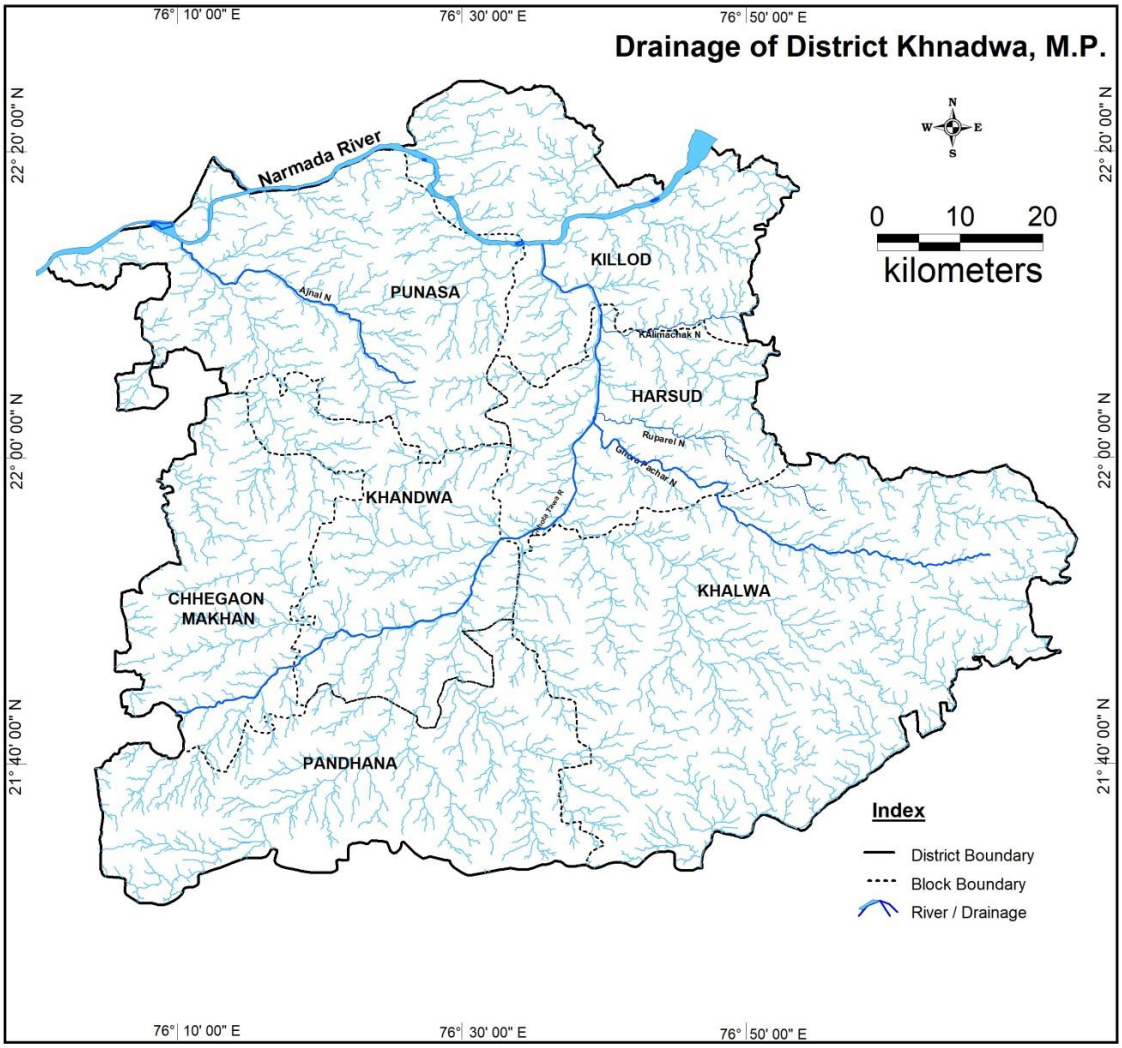


Fig 5: Drainage Map

2.4 Land-use

Khandwa district comprises of 07 development blocks, 5 Tehsils, 422 gram panchayats and 710 villages. Total geographical area of the district is 775616 Hectare, net sown area under agriculture is 303189 and forest area is 283661 ha., In district 185727 ha. area is wasteland and 75890 ha. area under other uses.

The total agricultural land found in Khandwa district area is 303189 hac. and total geographical area of the district 775616 ha. these are the lands primarily used for farming and for production of food, fiber, and other commercial and horticultural crops.

The total forest area is 283661 ha. In Khandwa district among the total geographical area of the district 775616 hac. The highest forest area in 146089 in Khalwa block where is 51.50 % in district. In Khandwa district 185727 ha. Wasteland of the total geographical area of 775616 ha. Wasteland is described as degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized and land which is deteriorating for lack of appropriate water and soil management or an account of natural causes (Fig. 6.).

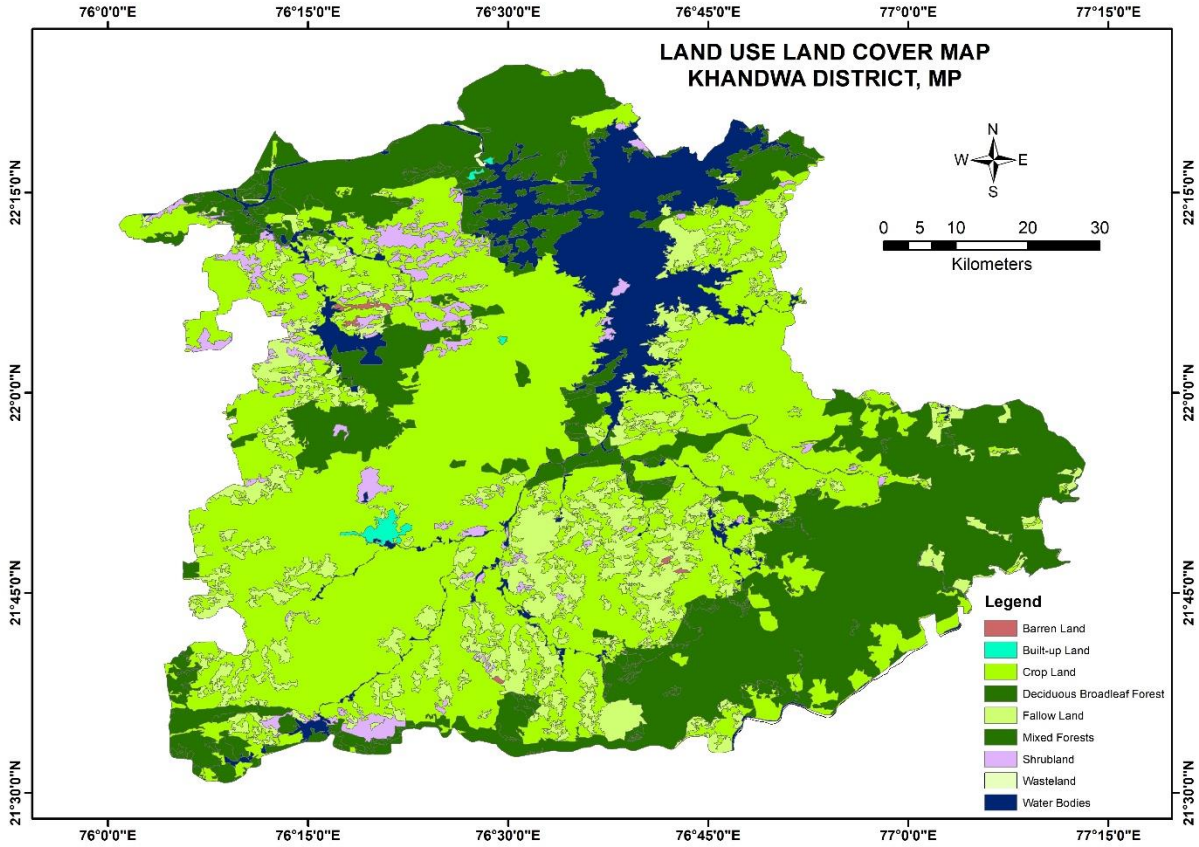


Fig 6: Land Use Land Cover Map

2.5 Soil cover

The nature & Characteristics of soils is dependent primarily on Relief of the area which influences the variation in soil formation. The soils of Khandwa district are classified on medium black soils under the broad classification of soil of India & are low fertility soils. There are alluvial deposits constitute gravel sand; silt or clay sized unconsolidated alluvium found along the narrow strips of rivers. A map showing Soil types is presented in the Fig. 7.

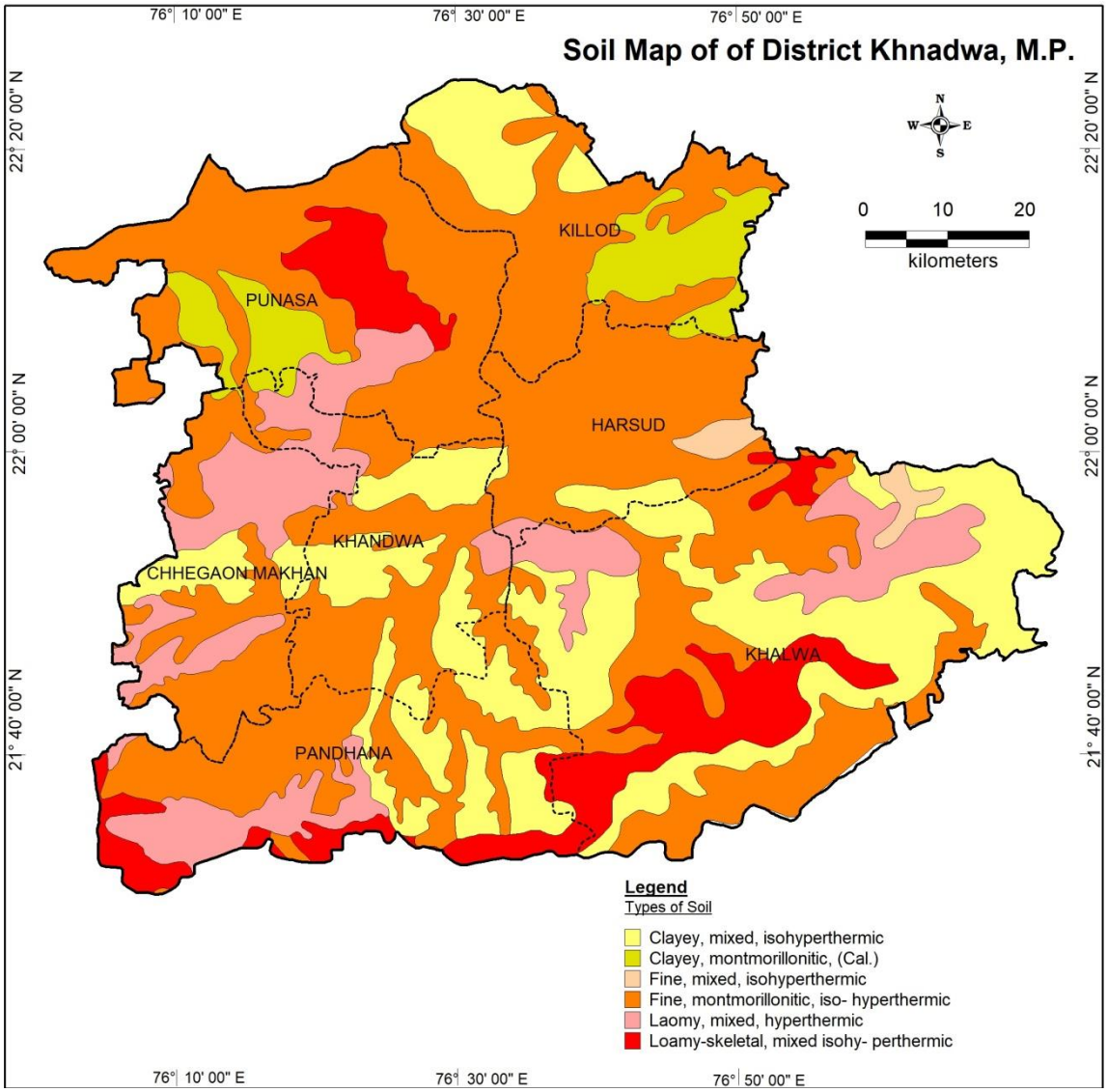


Fig 7: Soil Map

2.6 Agriculture, Irrigation and Cropping patterns

Over a period, geographic pattern of agricultural landuse are the outcome of concurrent interaction between the variable combinations of natural condition and human circumstances. Primarily, these are influenced by natural condition and thereafter affected by human circumstances because of their Colonizing capability. The human circumstances are mainly responsible for dynamism in agriculture landuse or changing cropland occupancy. Therefore, efficient cropland occupancy, say cropping pattern, implies the most successful use of agriculture land, consequent upon development of irrigation facilities and application of modern methods of farm technology. The key to the most important aspect of landuse lies in the relation of population to land. The crux of the review, therefore, refers to the study of the problems in use of land by man. According to R.H. Best, the term land use deals with the spatial aspects of human activities on the land and with the way in which the land surface is adapted or could be adapted, to serve human needs. (Table 2a & 2b).

Table 2 a Land use pattern in Khandwa District

Name of Block	No of Gram Panchayat Covered	Total Geographical Area	Gross Cropped	Net Sown area	Area sown more than once	Cropping Intensity	Area Under forest	Area under Waste	Area under other uses
Khandwa	61	86415	69175	46664	22511	148.24	22914	18476	1639
Pandha	84	105966	103197	72202	30995	142.92	6502	28017	755
Chhegoan Makahan	59	61742	64965	44997	19968	144.37	1526	15801	582
Punasa	71	138060	70722	45730	24992	154.65	67926	31527	7123
Khalwa	85	218626	85754	56487	29267	151.81	146089	17963	1913
Harsud	41	111536	42434	25531	16903	166.2	79395	32423	25813
Baldi	21	53271	19101	11578	7523	164.97	38238	41520	38065
Total	422	775616	455348	303189	152159	1073.16	362590	185727	75890

Table 2 b Crop-wise Irrigation Status in Khandwa

	Kharif (Area in ha)			Rabi (Area in ha)			Summer crop (Area in ha)			Total (Area in ha)			Horticulture & Plantation (Area in Ha0		
Crop type	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**
Cereal	0	38085	38085	115942	0	115942	338	0	338	116280	38085	154365	34408	3720	38128
Coarse Cereals	0	0	0	0	0	0	0	0	0	0	0	0			
Pulses	0	24239	24239	32205	0	32205	2181	0	2181	34386	24239	58625			
Oil seeds	0	183429	183429	128	0	128	58	0	58	186	183429	183615			
Fiber	21000	29236	50236	0	0	0	0	0	0	21000	29236	50236			
Any other crop	0	0	0	485	0	485	0	0	0	485	0	485			
District Total	**21000**	**274989**	**295989**	**148760**	**0**	**148760**	2577	0	2577	172337	274989	447326	34408	3720	38128

3. Data collection and generation

3.1 Hydrogeology

Khandwa district is underlain by various geological formation, forming different types of aquifers in the area. Main geological; units of the area are Archaean, upper vindhyan, Bagh beds, Deccan traps and alluvium. Occurrence and movement ground water in hard rocks is mainly controlled by secondary porosity through joints and fractures. Primary porosity in Bagh sandstone and vesicular basalts in Deccan traps play an important role in ground water occurrence and movement bagh beds may also form potential aquifer made up of relatively loose and friable shale and sand stone (Fig 8). Ground water is general occurs under unconfined to semi confined. The occurrence and movement of ground water in different geological formation is described below:

a) Archaeans -

Weathered portions and fractured zones of granite and gneisses when saturated from moderate aquifers. The yield of wells in the formation, ranges from 1 to 3 lps these rocks are exposed in the north eastern part of the district falling in Baldi block.

b) Bijawars

The Bijawars are exposed in the north eastern part of the district falling in Baldi blocks. Bijawar sandstone and shale breccia occupy and area of 85 sq. km in this block. Generally, yield of wells in this formation in less than 1 lps. But if the formation is consisting of limestone with well development solution opening the yield may be 2 to 5 lps.

c) Vindhyan

The upper vindhyan sandstone shale and are exposed in northern part of the district all along the Narmada River falling in Punasa block. The total area occupied by the vindhyans formations, is about 1115 sq. km which included part of Baldi block in the district. The sandstone and shale of vindhyan formations are compact and having poor permeability. The jointed & fractures and bedding planes in sandstone and shales control the occurrence and movement of ground water in the areas located in favourable geomorphic and topographic conditions. The soil and weathered profile developed in this formation is generally thin and as a result ground water occurs at shallow depth under unconfined condition. The yield of well in formation ranges from 1 to 3 lps. The exploratory well drilled at Bir bad Nimarkheda trapping basalt and vindhyan sandstone has yield 3.28 and 8.16 lps discharge.

d) Bagh Beds-

Bagh beds are exposed in the north central part of the district falling in Punasa block. Bagh beds comprise of sandstone and shales are sedimentary formation but have a limited extent and poor to moderate permeability. The lime stone and calcareous clay when forma productivity aquifers.

e) Deccan Traps-

The Khandwa district is underlain by 13 basaltic flows, which are distinguished by either for presence of red bole, vesicular zone or break in slope. Most of the lava flow are Aa type bad thickness of flows varies from 7 to 35m. These flows are confined between 265 and 698 m amsl. The Deccan trap flow, basic intrusion and the calcite veins at some place constitutes the basaltic terrain ground water generally occurs under phreatic condition in shallow weathered, jointed and fractured horizons. Basalt does not exhibit uniform nature, both vertically and laterally. Physiographic location, thickness of weathered, mantle, degree

of joints, fractures or sheared zones, characteristic of vesicular horizons and their inter connections are important factors, that play a decisive role in the yield capacity of open wells tapping shallow aquifers. The deeper aquifer system appear to be under semi confined conditions. The deeper aquifer mainly governed by secondary porosity. Jointed fractured from of massive unit is creating possibility of their acting as heavy confining bed, consequently resulting into semi confined conditions for water bearing vesicular unit occurring beneath it on other hand is massive unit is compact and have not developed fractured porosity then they may act as a confining bed for water being vesicular horizon, occurring below it and thus leading to confined conditions dug wells in basaltic flows of deccan traps vary in depth from 6 to 15 mbgl. CGWB has drilled number of tube wells in deccan trap in Khandwa District water bearing capacities in deccan traps varies from flow to flow. The ground water in this formation occurs in weathered vesicular and fractured basalt.

f) Alluvium-

Alluvium consists of coarse-grained sand to silty material, gravel and hard brownish soil and clay. The alluvium stretch comprise horizontal to sub horizontal thin horizons. Ground water occurs in the granular zones of sand and gravel the yield of formation depends upon the percentage of band and clay and thickness of alluvium. The yield of well in the formation ranges from 5 to 20 lps.

3.2 Depth to Water levels

Pre-monsoon water level (May 2019)

The pre-monsoon depth to Water levels ranges from a minimum of 2.7 meters below ground level (mbgl) in Punasa block to a maximum of 15.5 m bgl in Chhegoan Maakkan block of Khandwa district. About 10% very shallow water levels up to 3-6m bgl have been recorded in a small patch in Northern and central part of district. About 60 % of monitoring wells recorded water level in the range of 6-9 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 15% of monitoring wells recorded water level in the depth range of 9-12 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging 12-15 m bgl constituting only about 15% of wells in this category have been observed only in small pocket in the northern and south-western part of Khandwa district. Ground water levels of more than 15.5 m bgl have been recorded in the eastern part of the area. The pre-monsoon Depth to Water Level map has been shown in the Fig. 9.

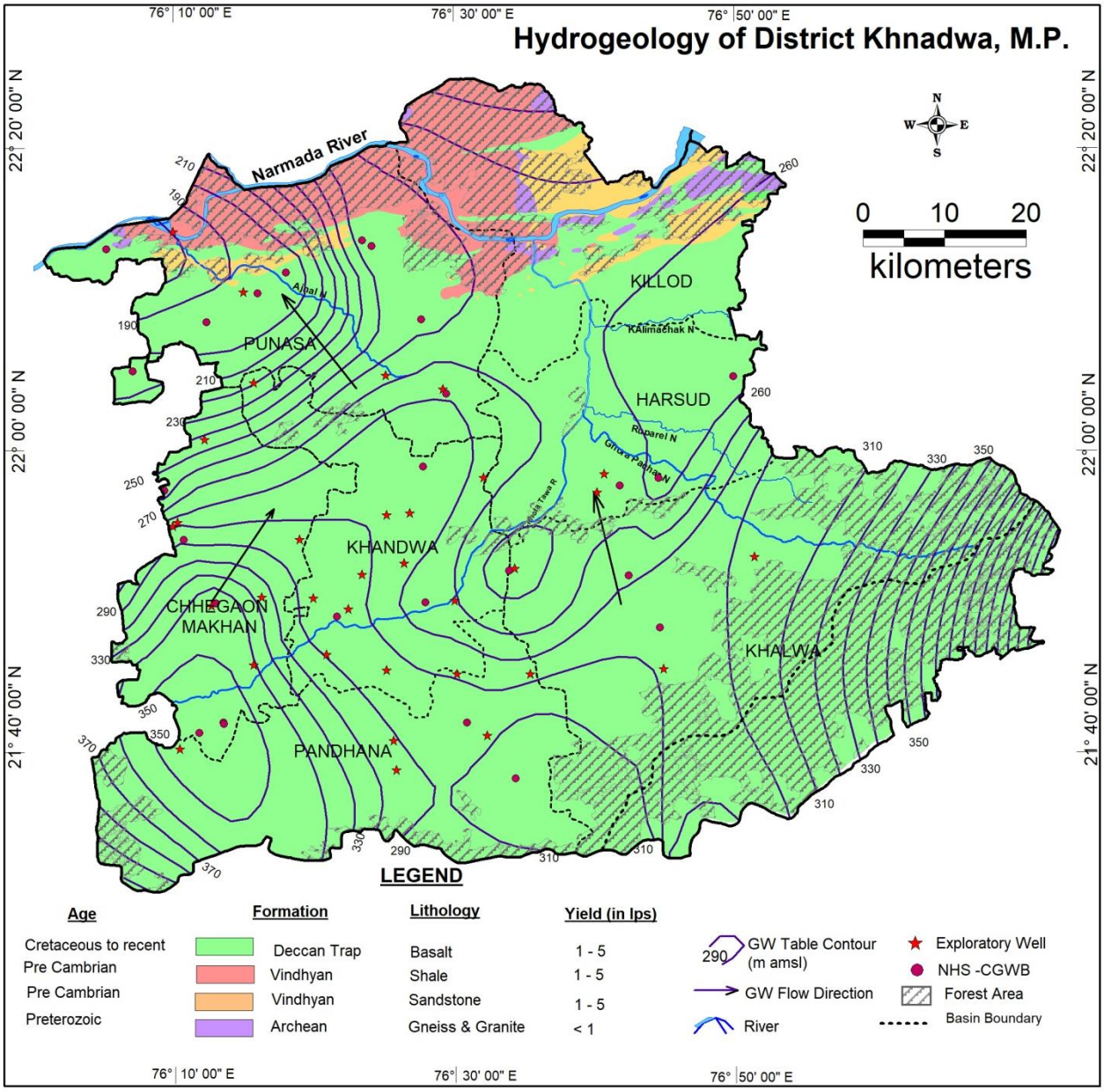


Fig 8: Hydrogeology of Khandwa District, M.P.

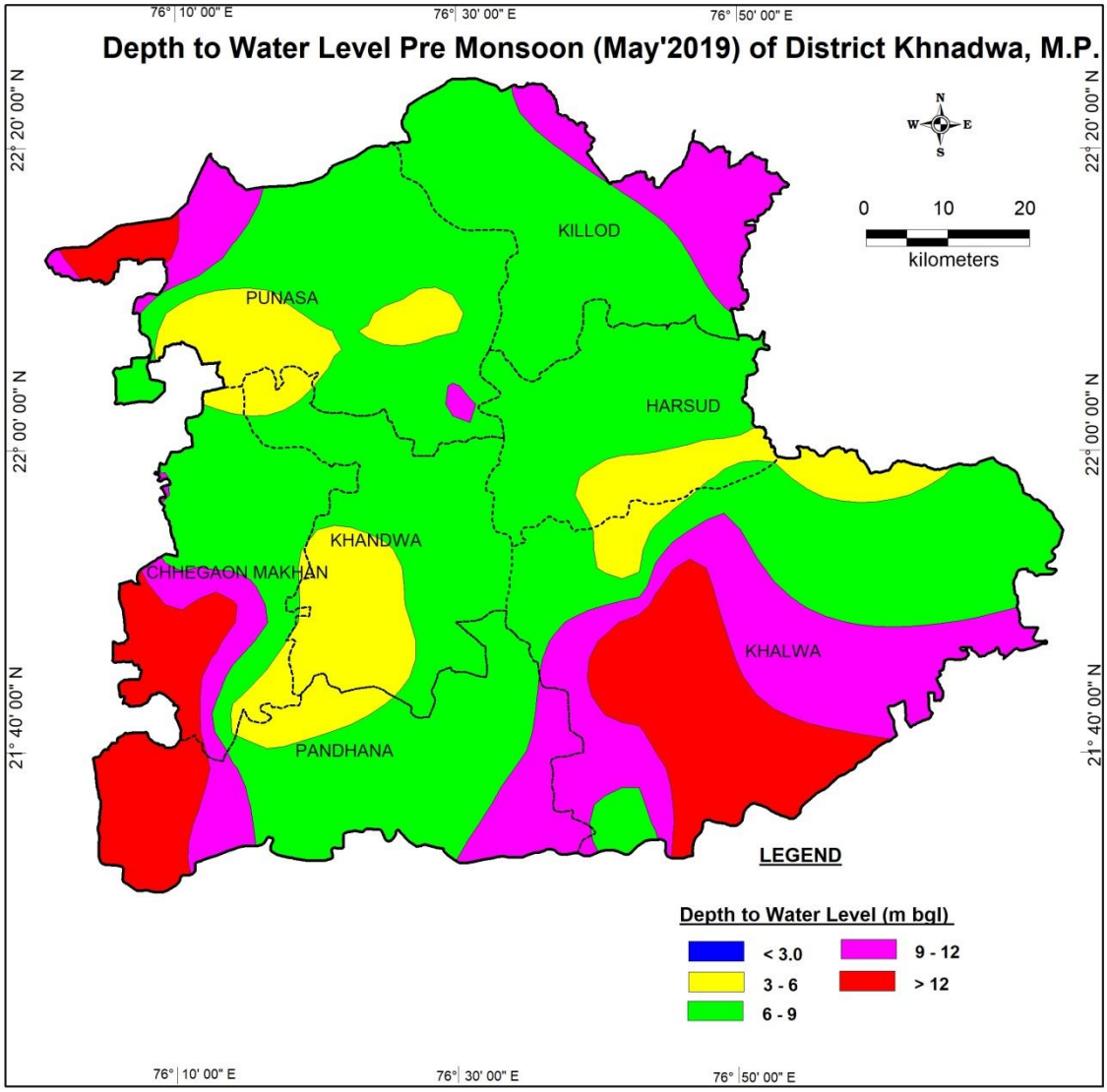


Fig 9: Depth to Water Level Map (2019)

Post-monsoon water level (Nov 2019)

The post-monsoon depth to Water levels ranges from a minimum of 1.1 m below ground level in Punasa block to a maximum of 7.6 m bgl Chhegaon Makhan block of Khandwa district. Very shallow water levels up to 3 m bgl have been recorded in patches scattered all over the district contributing to about 41.46% of total monitoring wells in Khandwa district.

About 40% of monitoring wells recorded water level in the range of less than 3 mbgl category, majorly occupying the central portion and patches in the north-eastern, and southern part of area. About 50% of monitoring wells recorded water level in the depth range of 3-6 m bgl occurring in pockets all over the region. About 10% Depth to water levels ranging 6-9 m bgl has been noticed predominantly in northern and western part of the district. Ground water levels of more than 9 m bgl have not been recorded in Khandwa district. The post-monsoon Depth to Water Level map has been shown in the Fig. 10.

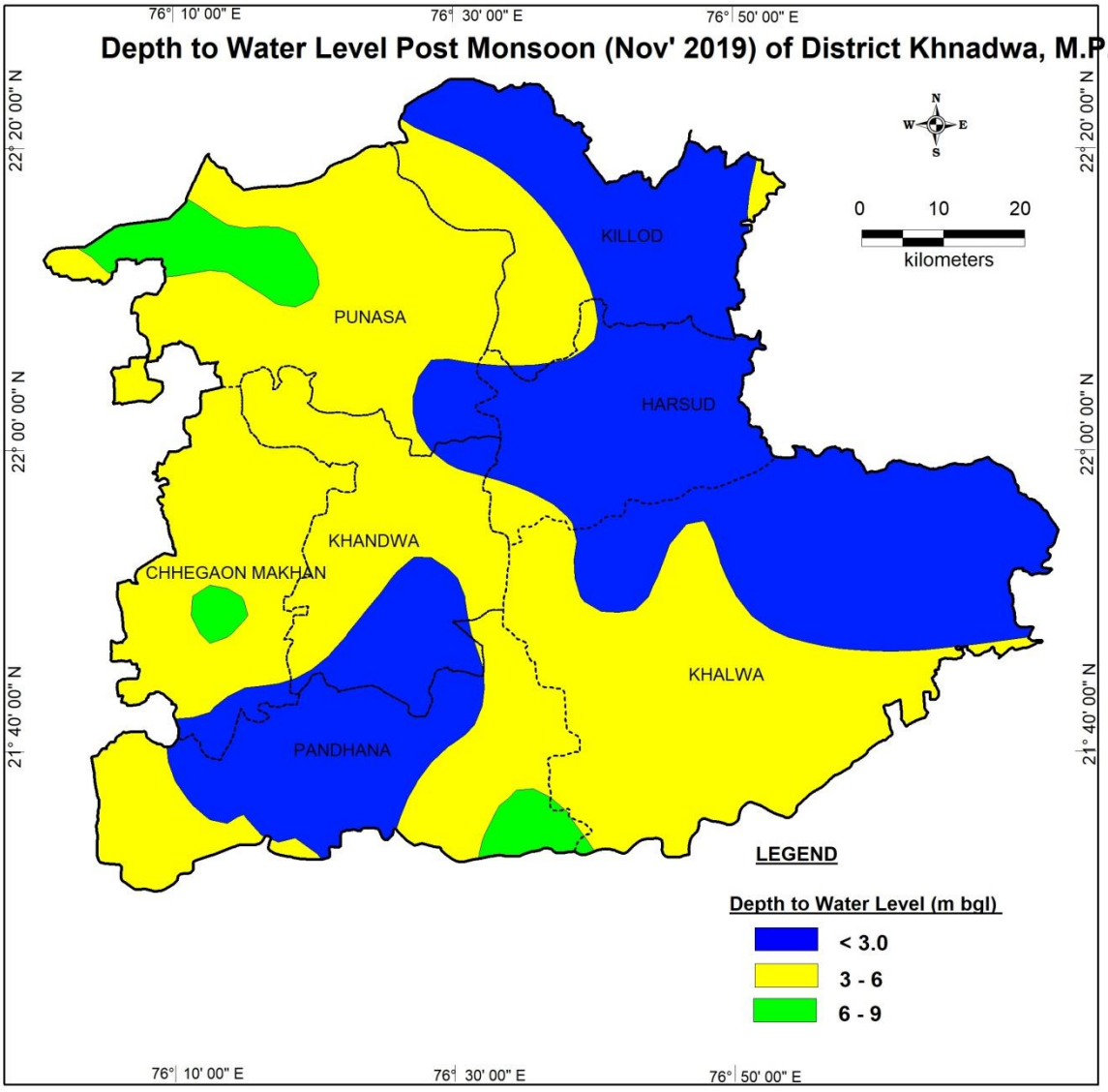


Fig 10: Depth to Water Level Map (2019)

3.3 Exploratory drilling

CGWB under its exploration program drilled 36 borewells (Fig. 11). On the basis of samples collected during exploration, lithologs have been prepared. The aquifer parameters are calculated on the basis of pumping tests. The salient details of the some of the drilled bore wells and piezometers is given in Table No 3

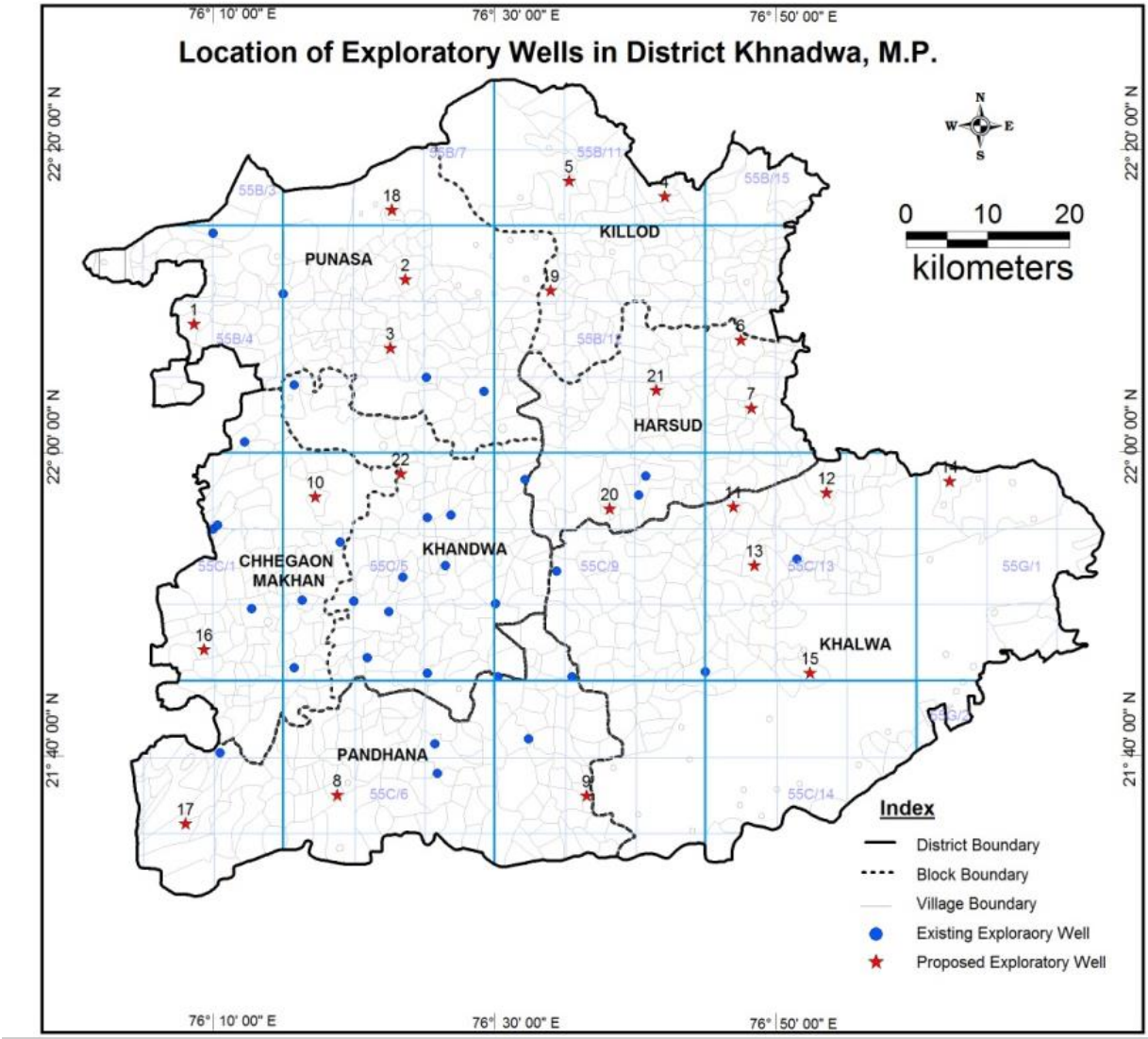


Fig 11: Map showing locations of Exploratory Wells

Table 3: Salient Hydrogeological Details of Exploratory Wells of Khandwa district.

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	Aquifer zones tapped (mbgl)	SWL (mbgl) / Date	Discharge (lps)	Draw down (m)	T (m^2/ day)	S
1	Surgaon	21.141667	76.016667	1982-83	100.8		Deccan trap basalt			Dry			
2	Nagchun	21.8375	76.333333	1990-91	205.02		Deccan trap basalt		26.25	Negligible			
3	Badgaon Gujar	21.754167	76.504167	1990-91	221	85.5	Deccan trap basalt	57.00-69.00 72.00-84.00	7	1.22	2.3		
4	Rangaon	21.929167	76.420833	1990-91	274	270	Deccan trap basalt	41.50-57.50 260.00-270.00	9.45	5.00	26.14	65.87	
5	Kalmukhi	22.075	76.2625	1990-91	220.37		Deccan trap basalt	53.00-77.00	8.6	2.33	39.87	11.44	
6	Nimarkhedi	24.108333	76.145833	1990-91	236.02		Deccan trap basalt	200.00-220.00					
7	Deshgaon	21.916667	76.166667	1990-91	266.42		Deccan trap basalt			Negligible			
8	Kusumbia	21.670833	76.175	1990-91	192.32		Deccan trap basalt	76.00-83.00 190.00-192.00	7.17	5.80	16.72	18	1.10×10^{-1}
9	Badiyasakna	21.679167	76.088889	1990-91	228.6		Deccan trap basalt		9.03	6.69	35.8		
10	Sirran	21.920833	76.172222	1990-91	128		Deccan Trap basalt	49.00-61.00 118.00-126.00	10.2	1.67	6.11		
11	Kaudigol	22.083333	76.419444	1991-92	170.3		Deccan trap basalt			Negligible			
12	Mundi	22.068056	76.4875	1991-92	251.27		Deccan trap basalt		7.44	Negligible			
13	Amalpura	21.834722	76.501389	1991-92	251.22		Deccan trap basalt		16.55	Negligible			
14	Khedighat	22.175	76.25	1991-92	165.62		Deccan trap basalt	84.00-129.00	12.35	10.00	36.2	34	1.10×10^{-2}
15	Onkareshwar	22.241667	76.166667	1991-92	61.37		Deccan trap basalt	13.00-15.00	5.9	0.40			
16	Kharkalan	21.754167	76.591667	1991-92	175.07		Deccan trap basalt	174.2-175.0	21.32	12.50	20.07	112	1.10×10^{-2}
17	Debaldi	21.954167	76.670833	1991-92	198.07		Deccan trap basalt	5.00-13.00	3.06	17.40	30.55	12	
18	Sadiyapani Sarkar	21.975	76.679167	1991-92	213.3		Deccan trap basalt		6.28	Negligible			
19	Itwah	21.686111	76.540278	1991-92	228.5		Deccan trap basalt	160-162	43	0.25			
20	Savulikheda	21.759722	76.75	1991-92	205		Deccan trap basalt	130.0-145.0	17.87	5.40			

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	Aquifer zones tapped (mbgl)	SWL (mbgl) / Date	Discharge (lps)	Draw down (m)	T (m^2/ day)	S
21	Khedi	21.870278	76.573333	1991-92	201.05		Deccan trap basalt	140-143	14.7	0.50			
22	Sunderdeo	21.883333	76.858333	1991-92	243.62		Deccan trap basalt		10.67	Negligible			
23	Chhegaon Makhan	21.829167	76.2125	1991-92	201.75		Deccan trap basalt	32-32.5	17.3	Negligible			
24	Sihada	21.758333	76.420833	1991-92	236		Deccan trap basalt			Dry			
25	Singot	21.680556	76.429167	1991-92	220.7		Deccan trap basalt	176.0-188.0 193.6-199.0	13.88	10.80	16.42		
26	Chhegaon Devi	21.763889	76.2625	1991-92	135.66		Deccan trap basalt	86.0-92.0 98.0-104.0	40.3	12.23	2		
27	Badiyan	21.758333	76.420833	1991-92	121.92		Deccan trap basalt	87.5-102.5	18.2	14.53	14.6		
28	Gaul	21.775278	76.349167		209.66	209.66	Deccan trap basalt		4.71	5.78	19.89	119	0.11×10^{-3}
29	Sirpur	21.775278	76.349167	1992-93	188.8		Deccan trap basalt	99-101	6.24	0.77			
30	Khandwa	21.825556	76.375	1992-93	199.9		Deccan trap basalt	110-135	50	1.90			
31	Satwada	21.876111	76.441667	1992-93	203.1		Deccan trap basalt	160-162		Negligible			
32	Padaliya	21.648056	76.432222	1992-93	243.52		Deccan trap basalt		16.41	Negligible			
33	Sahejla	21.970833	76.536111	1992-93	243.24		Deccan trap basalt			Dry & Abondened			
34	Bhakroda	22.920833	76.370833	1992-93	202.8		Deccan trap basalt		25.6	0.40			
35	Talwadia Attar	22.0125	76.204167	1993-94	243.2		Deccan trap basalt	29-38	7.3	0.20	50		
36	Talwadia Jawar	22.458333	76.085833	1994-95	251.32		Deccan trap basalt	11.7-19.32	5.25	0.25	>50		

4. Data Interpretation, Integration and Aquifer Mapping

The lithological data collected from CGWB Borewells, Piezometers and State Ground Water Piezometers were studied, compiled and integrated as per Rockworks software format to prepare the 3-Dimensional Stratigraphic model, 2-Dimensional Cross section and Fence diagrams. The sub-surface lithology of the Khandwa district as inferred from the 3-D Model, 2-D Section and Fence diagram is presented below.

4.1 3-D Lithological model

A 3-Dimensional lithological model was prepared for the Khandwa district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB (Fig 12). A comprehensive analysis was made as per lithology and stratigraphy of the area. The location details with RL values and their corresponding stratigraphic details as per the Rockworks format is provided in the Annexures- I and II.

The 3-D Model results showed that the region is dominantly occupied by Basalt, Sandstone Shale and Alluvium respectively. The sub-surface lithology has been broadly classified into Top soil/Unsaturated zone, underlain by Weathered Basalt and which has been considered as shallow aquifer (upto a depth of 30 mts). Massive Basalt was encountered in few bore wells mainly occupying the southern region of Kandawa. This overlies the Fractured Basalt Sandstone that forms the deeper aquifer (from 30-200 mts). The fractured aquifer lies between Vesicular Baslt and predominantly Masive Baslt.

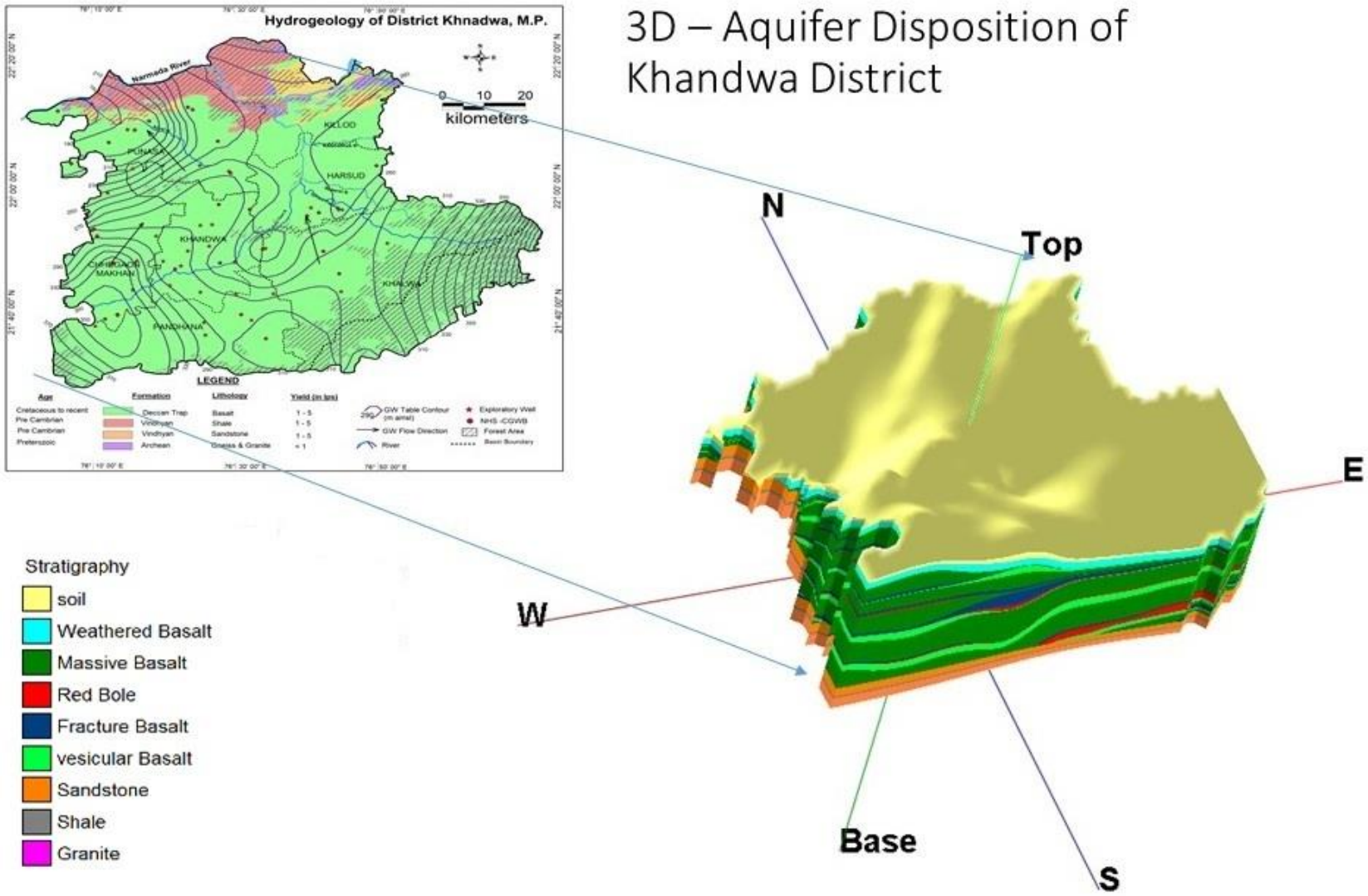


Fig 12: 3-D Lithological Model of Khandwa District, Madhya Pradesh

4.2 Fence Diagram

The Fence diagram was also prepared using the Rockworks software (Fig. 13). 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 3-D stratigraphic model. It has also been interpreted from the diagram that the shallow and deeper aquifers are not in connection to each other.

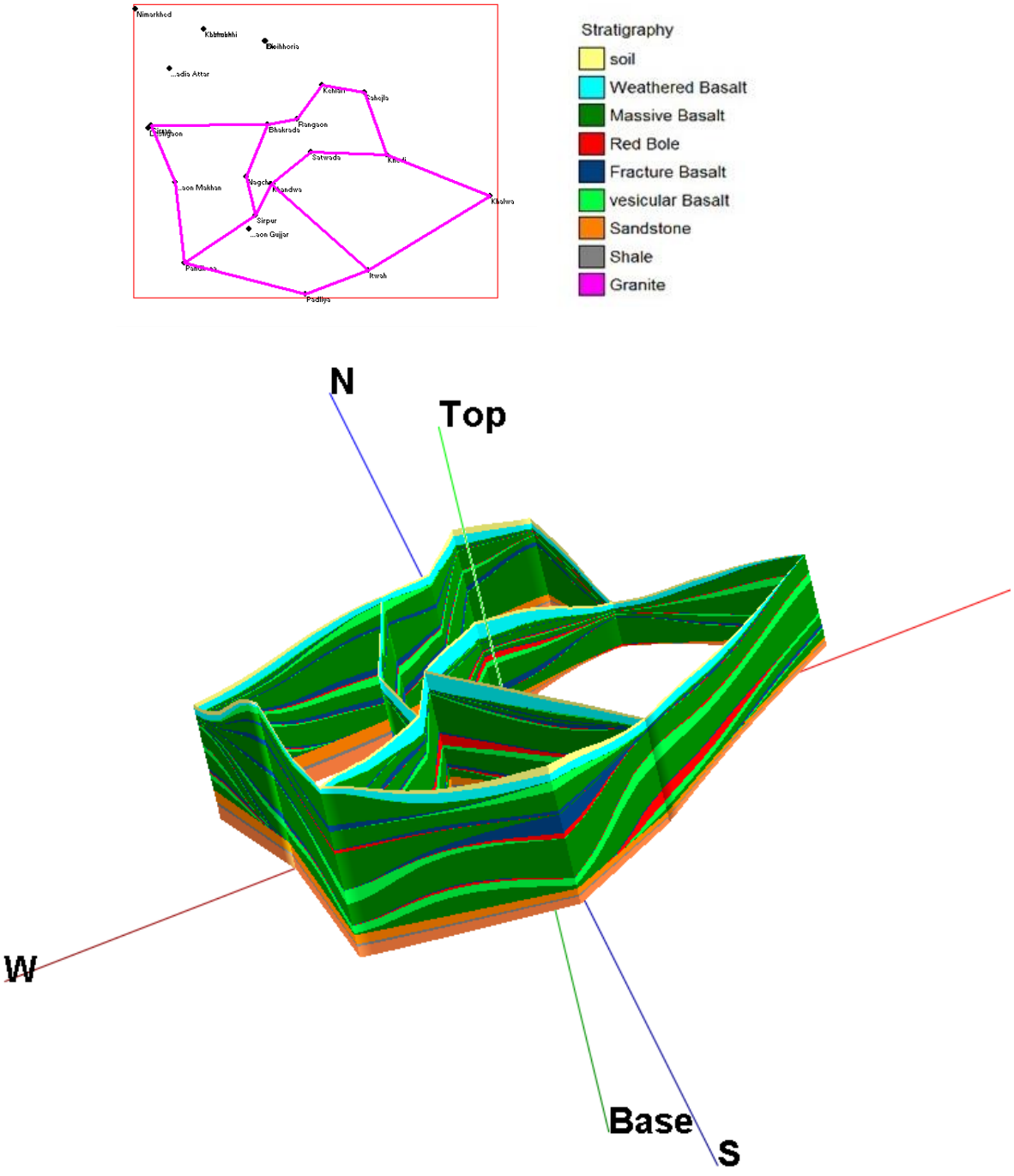
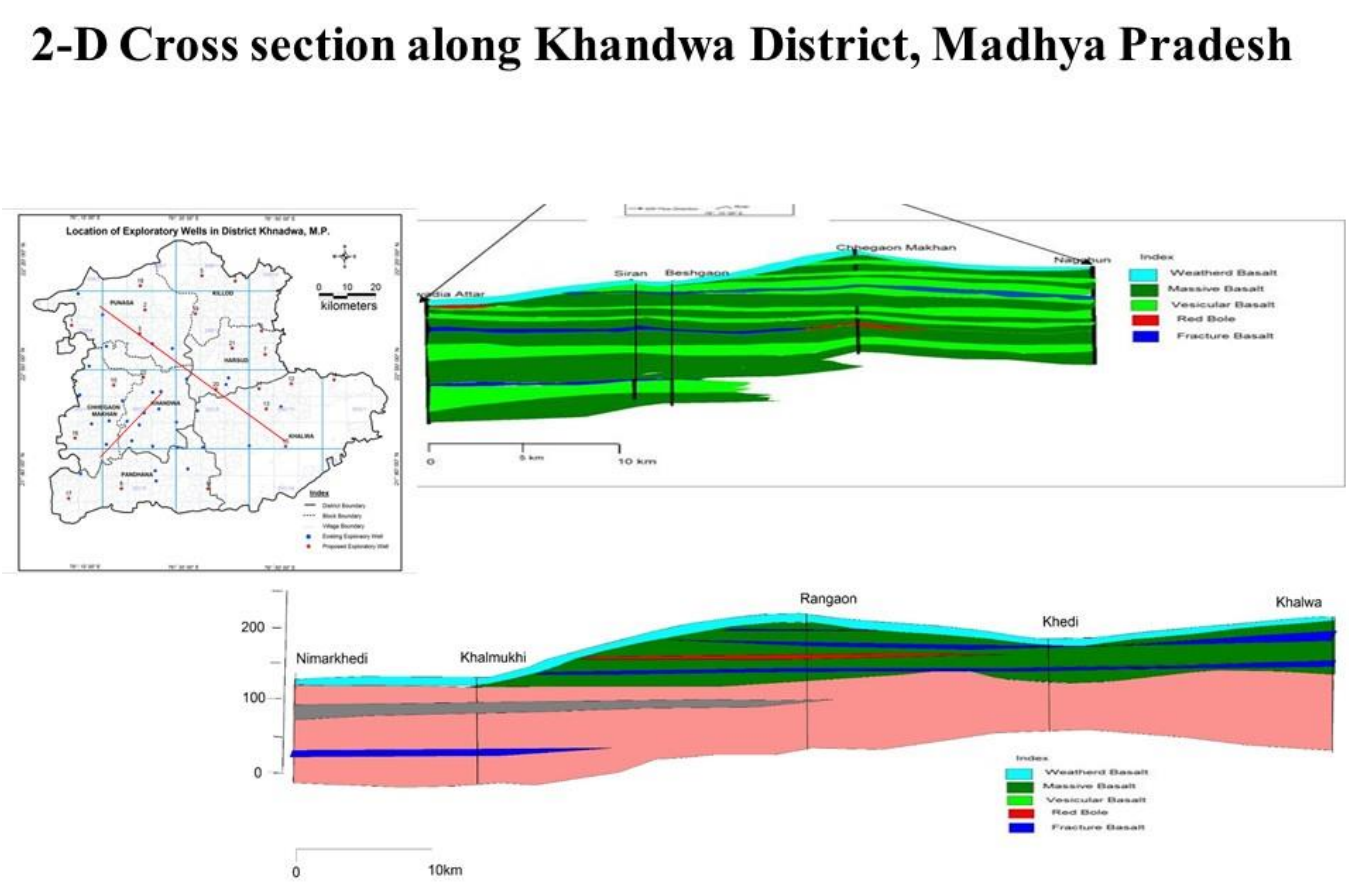


Fig 13: Fence Diagram, Khandwa District, Madhya Pradesh

4.3 2-D Cross Section

2-Dimensional cross-section along the section line A-A' (SW-NE), covering the wells Talwada Atar,Siran,r, Beshgoan, Chhegoan Makkan, and Neguwan has been prepared using Rockworks and later refined in AutoCAD (Fig. 14). The cross-section shows that the shallow aquifer is not continuing for the whole region and occurs as narrow pinches in the western portion of Khandwa. The deeper aquifers whereas, occurs throughout the section line and can be encountered at depth where fractures are present.

Fig 14: 2-D Cross section along A-A' (SW-NE), B-B'Khandwa District, Madhya Pradesh



5.Ground Water Resources

5.1 Dynamic Ground Water Resource (2020)

Khandwa district is underlain by Vindhyan Shale and Sandstone Deccan trap and Alluvium. Dynamic ground water resources of the district have been estimated on block-wise basis. Out of 6404.50 sq. km of geographical area, 5269.22 sq. km (82.27%) is ground water recharge worthy area and 1138.28 sq. km is hilly area (17.73%). There are seven assessment units (block) in the district out of which three blocks fall under non-command category whereas Badli, Harsud and Khalwa, four blocks falls under both command as well as non-command category Chhegaonmakhan, Khandwa,Pandhuna and Punasa. One block of the district is categorized as semi-critical namely Chhegaonmakhan, (non-command) and rest as safe. The highest stage of ground water development is computed as 80.73 % in non-command area of Chhegaonmakhan block. The net ground water availability in the district is 1009.84 mcm and ground water draft for all uses is415.19mcm, making stage of ground water development to 41.12% as a whole for district (Table 4).

Table 4: Dynamic Ground Water Resources (2020)

Assessment Unit / District	Command / NonCommand	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	Allocation For Domestic & Industrial Water Supply in Ham	Net Ground Water Availability for Future Irrigation Development in Ham	Stage of Ground Water Extraction in %
Badli	Non Command	5717.39	3108.84	108.43	3217.27	109.54	2499.01	56.27
	Block Total	5717.39	3108.84	108.43	3217.27	109.54	2499.01	56.27
Chhegaonmakhan	Command	460.82	104.54	35.92	140.46	46.25	310.03	30.48
	Non Command	12147.7	9466.76	340.13	9806.89	416.26	2264.68	80.73
	Block Total	12608.52	9571.3	376.05	9947.35	462.51	2574.71	78.89
Harsud	Non Command	4557.3	2760.05	220.31	2980.36	224.86	1572.39	65.4
	Block Total	4557.3	2760.05	220.31	2980.36	224.86	1572.39	65.4
Khalwa	Non Command	9999.97	5681.43	582.38	6263.81	773.04	3545.5	62.64
	Block Total	9999.97	5681.43	582.38	6263.81	773.04	3545.5	62.64
Khandwa	Command	524.17	185.11	31.07	216.18	28.93	310.13	41.24
	Non Command	9262.08	5910.41	370.58	6280.99	218.44	3133.23	67.81
	Block Total	9786.25	6095.52	401.65	6497.17	247.37	3443.36	66.39
Pandhana	Command	3967.74	254.42	93.65	348.07	112.14	3601.18	8.77
	Non Command	11297.88	7024.02	504.27	7528.29	597.04	3676.82	66.63
	Block Total	15265.62	7278.44	597.92	7876.36	709.18	7278	51.6
Punasa	Command	40711.51	2936.15	334.33	3270.48	530.89	37244.47	8.03
	Non Command	2331.86	1333.76	132.76	1466.52	191.62	806.48	62.89
	Block Total	43043.37	4269.91	467.09	4737	722.51	38050.95	11.01
	DISTRICT TOTAL	**100978.4**	**38765.49**	**2753.83**	**41519.32**	**3249.01**	**58963.92**	**41.12**

5.2 Ground Water Resource & Draft (Outcome of NAQUIM)

The Ground Water Resource of Khandwa district has been calculated block-wise considering the variable lithology and their associated aquifer parameters like specific yield. The In-storage resource for the shallow aquifer below zone of fluctuation (upto 30 mbgl) is computed to be around 430.07mcm. The static resource for the deeper aquifer (30-200 mbgl) is computed as 120.98mcm. The block-wise details of ground water resources and draft as an outcome of NAQUIM is presented in the Table no 5.

Table 5 : Ground Water Resources (Outcome of NAQUIM)

Block	**Badli**	**Chhegaon Makhan**	**Harsud**	**KHANDWA**	**Khandwa**	Pandhana	Punasa	**Total**
Shallow Aquifer								
Dynamic Resources (MCM)	57.17	126.09	45.57	100.00	97.86	152.65	430.43	1009.78
Instorage Resources (MCM)	57.27	24.59	19.26	35.45	39.52	73.77	66.00	430.07
Total Resources (MCM)	**114.44**	**150.68**	**64.83**	**135.45**	**137.38**	**226.42**	**496.43**	**1325.64**
Irrigation	31.08	95.71	27.60	56.81	60.95	72.78	42.96	705.98
Domestic+Industries	1.08	3.76	2.20	5.82	1.01	5.97	4.67	30.14
Deeper Aquifer								
Static Resources (MCM)	10.06	15.27	11.28	9.94	7.90	7.26	6.46	120.98
GW Draft (MCM	6.53	35.41	14.96	**3.89**	4.91	48.80	3.95	159.74
Total GW Resources (MCM)	124.50	165.96	76.11	145.40	145.28	233.68	502.90	1446.62
Gross Ground Water Draft (MCM)	32.16	99.47	29.80	62.63	61.96	78.75	47.63	736.11
Stage of Ground Water Development (%)	56.27	78.89	65.4	62.64	66.39	51.6	11.01	41.12
Category	**Safe**	**Semi critical**	**Safe**	**Safe**	**Safe**	**Safe**	**Safe**	**Safe**

6. Ground Water Related Issues

6.1 Declining of water level

The long-term water level trend analysis indicates mixed results. During pre-monsoon season, out of 18 Hydrograph Stations, 13 are showing declining trend (Fig. 15). Similarly, during post-monsoon season, out of 18 stations 8 stations are showing falling trend in the district and all stations of Khandwa blocks are showing depletion of water levels in the area. Ground Water Resource Estimation also reveals that out of 7 Blocks of the district 1 Block (Chhegaonmakhan) have crossed 70% stage of ground water development

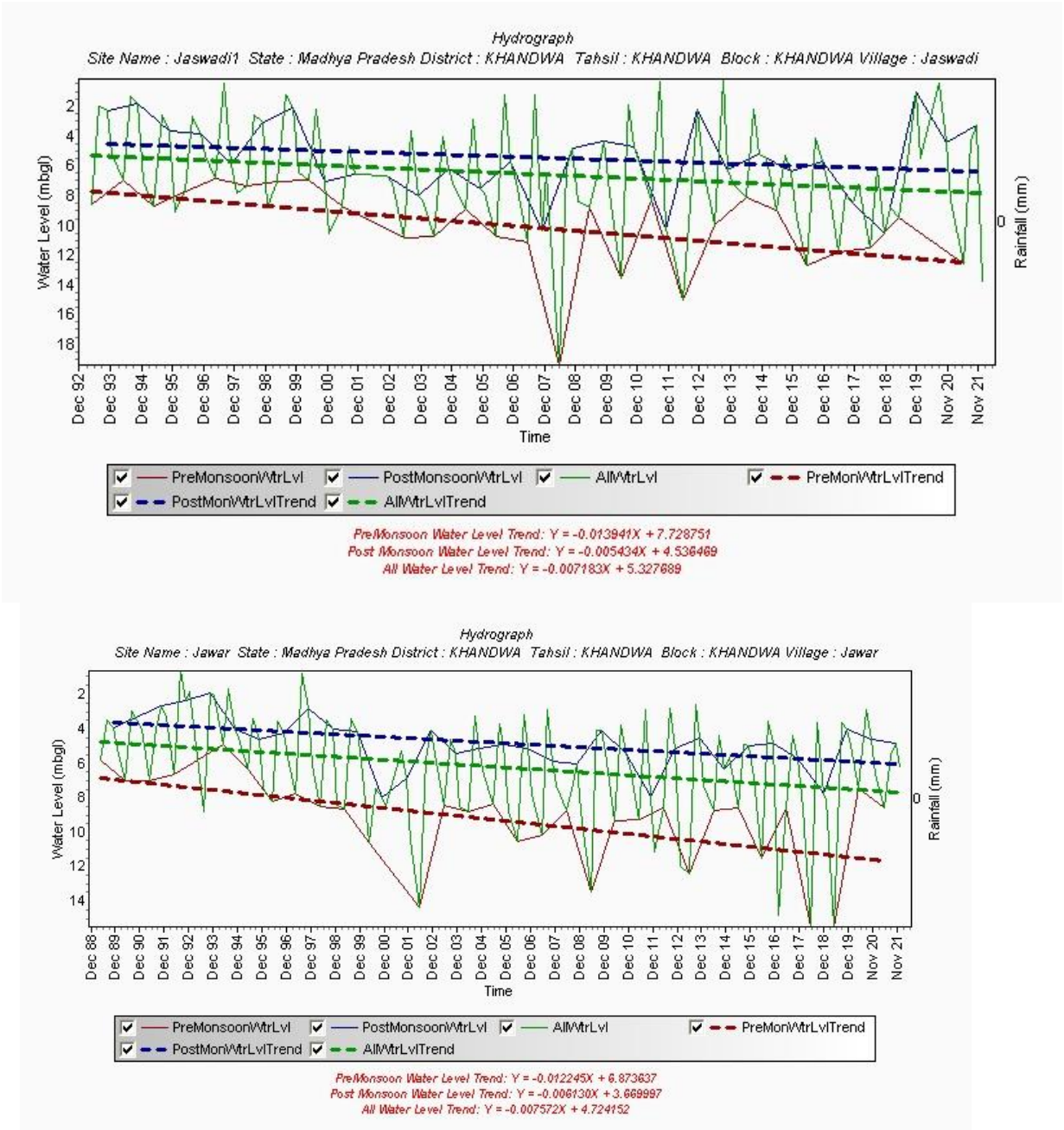


Fig 15: Hydrographs showing declining water level trend during Pre-monsoon and Post-Monsoon at sites Jaswadi and Jawar, Khandwa District, Madhya Pradesh

6.2 Ground Water Quality of Khandwa District

The water samples were collected from National Hydrograph Stations in clean double stopper poly ethylene bottles from 24 different locations of Khandwa district during May 2020.

Quality of Ground Water for Drinking Purpose:

The ground water samples from Khandwa district have varied range of pH from 7.24 to 8.22. 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 Gujar Khedi (8.22). The ground water of the study area can be assessed as neutral to slightly alkaline. The electrical conductivity of ground water samples in Khandwa district varies from 333 to 1700 µS/cm at 25°C. In the 14 nos. of water samples shows electrical conductivity less than 1000µS/cm; in 8 nos. of samples EC in between 1000 to 1500 µS/cm and remaining 2 samples is more than 1500 µS/cm. So, overall ground water quality in Khandwa district is good. The maximum electrical conductivity has been observed in the water sample of Pandhan village i.e. 1700 µS/cm at 25 °C.

The fluoride concentration in Khandwa district lies in between 1.00 to 1.55 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) except Gujar Khedi village i.e. 1.55 mg/l. Nitrate in ground water samples of Khandwa district fall within limits of 5 to 194 mg/l. It is observed that 45.8% samples have Nitrate concentration more than the acceptable limit i.e. 45 mg/l, while rest 54.2% samples have concentration less than acceptable limit. Highest nitrate is reported in the water sample of Gurhi (194mg/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 74 to 727 mg/l. In all locations, total hardness concentrations are within the permissible limit of 600 mg/l except the village of Gurhi (693 mg/l) and Pandhan (727 mg/l) village. The maximum concentration of total hardness observed in the village of Pandhan (727 mg/l).

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. The piper diagram of Khandwa district shows the ground water samples are Calcium-Bicarbonate type, hence show temporary hardness; Calcium Chloride type (permanent hardness); Mixed type and Sodium Chloride (saline) types.

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 Khandwa district is plotted on U.S. Salinity Laboratory diagram.

It is clear that approx. 41.7% samples shows that the ground water are C_2-S_1 Class (Medium Salinity & Low Sodium); 50% samples of study area are observed under C_3-S_1 Class (High Salinity & Low Sodium) and 8.3% samples of study area are observed under C_3-S_2 Class (High Salinity & Medium Sodium) which means that these waters can be used for

irrigation purpose for most of the crops, Water from these areas can be used for irrigation, considering the salinity content of the ground water.

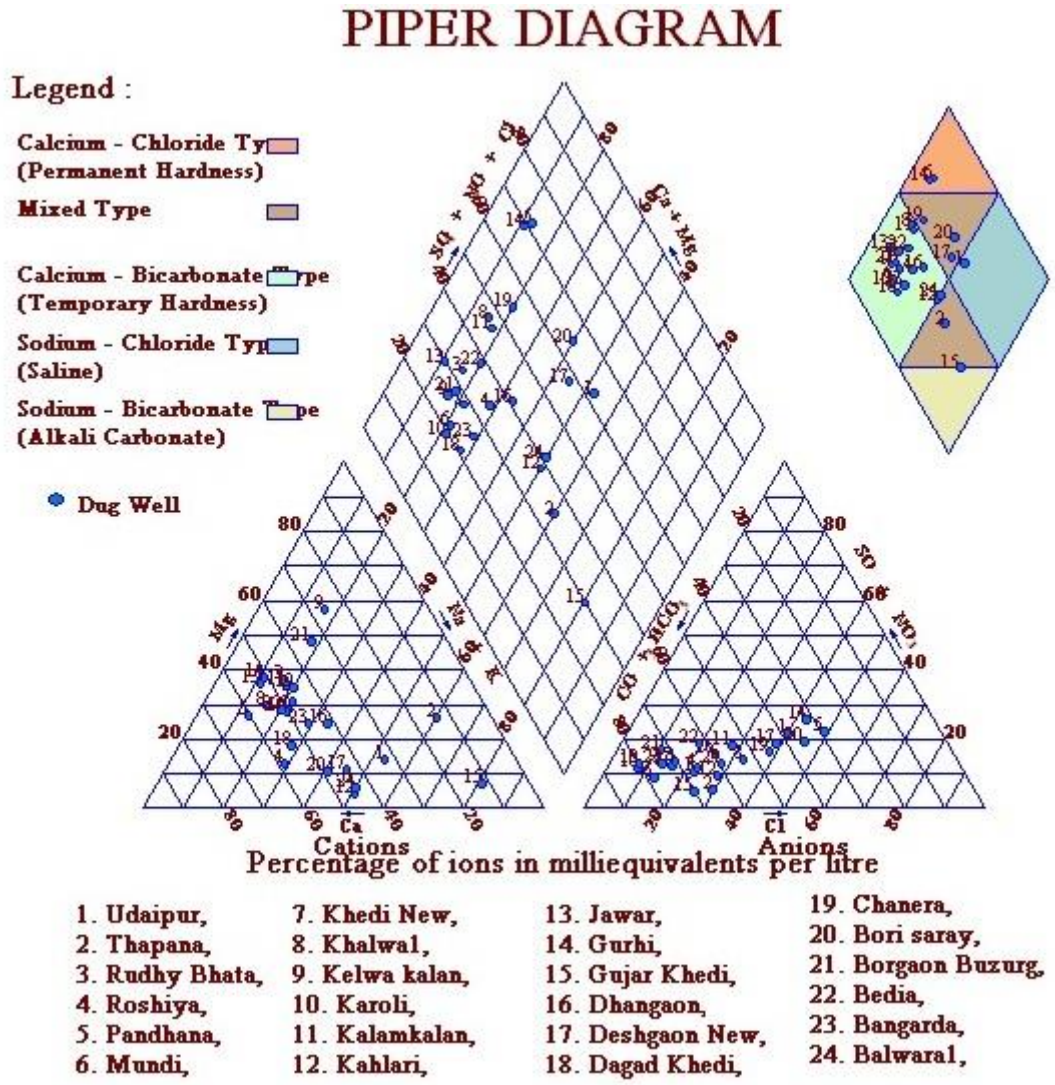


Fig 16: Hill Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Khandwa District, Madhya Pradesh

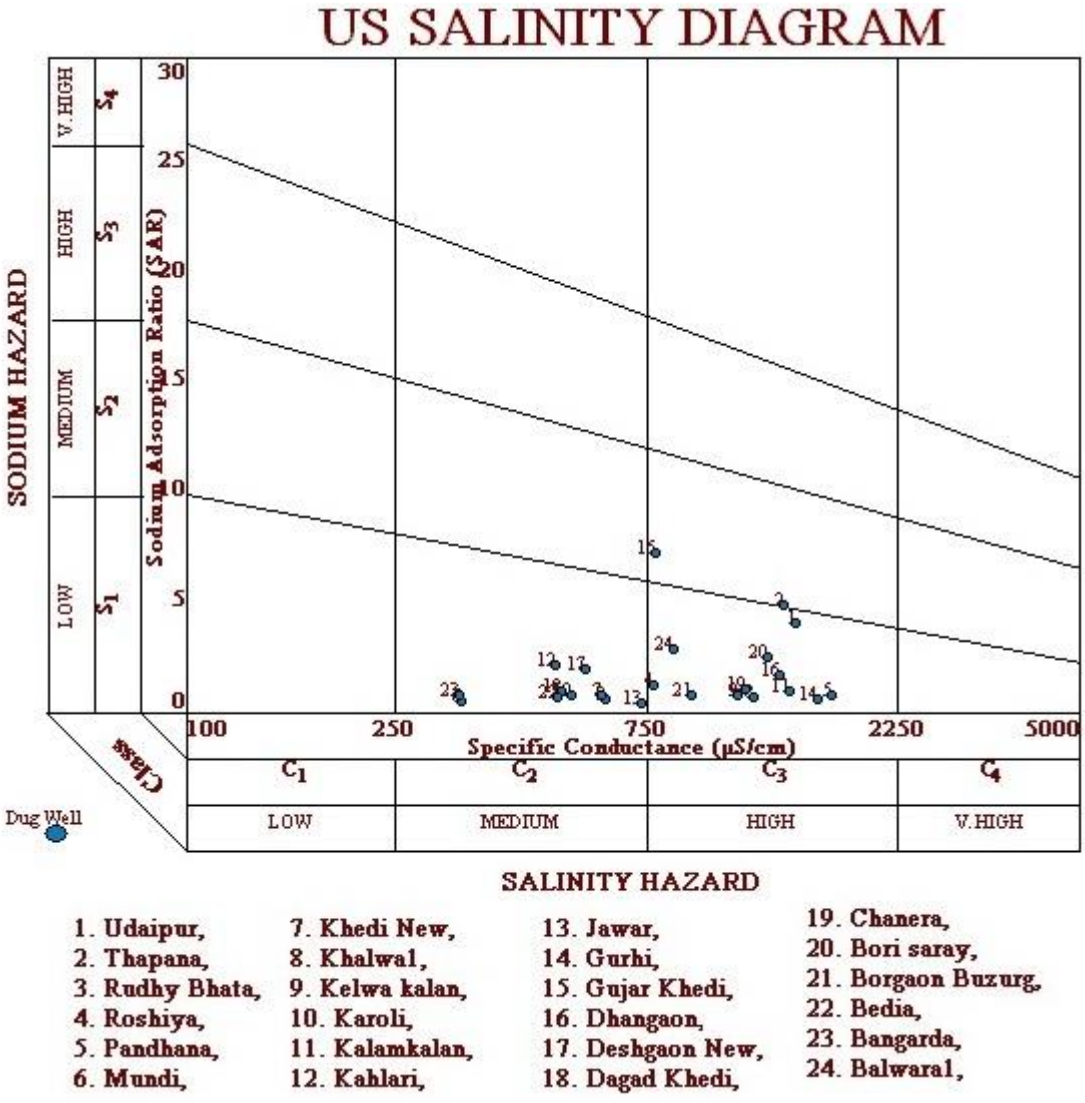


Fig 17: US Salinity Diagram for water samples collected from National Hydrograph Stations of Khandwa District, Madhya Pradesh

7. Ground Water Management Strategies

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.

7.1. District Ground Water Management Plan (Outcome of NAQUIM)

Khandwa district has been facing problems of ground water exploitation which in turn are depleting the ground water resources in the non-command area. This has led to evolve sustainable water conservation and management practices through an integrated approach. The ground water management plan for Khandwa 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.

7.1.1. Supply Side Management

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 artificial recharge techniques simultaneously rejuvenate the depleted ground water storage, reduces the ground water quality problems and also improves the sustainability of wells in the affected areas.

The supply side management plan for Khandwa 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 (considering the variable lithology) 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 Khandwa 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%, 35% and 20% 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. 6.

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. 241.82 Crores to successfully implement the supply side management strategy. Table no. 7 represents the complete financial outlay plan for the district.

7.1.2. 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.

Adoption of Sprinkler irrigation techniques in 50% of the area irrigated by ground water has been suggested for the Khandwa district Also, the 60% of additional recharge created by construction of artificial recharge structures can be utilized to increase the total cropping area, thereby enhancing the productivity and economy of the district.

Table 6: Ground Water Management– Supply Side, Khandwa District, Madhya Pradesh

Block	Area (Sq.Km)	Area suitable for recharge (Non-command) (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
Baldi	**1117.00**	545.24	0.78	5.84	2.84	0.020	30.97	41.19
Chhegaon	**870.00**	861	0.78	4.300714	1.30	0.020	22.40	29.79
Harsud	**1000.50**	538.47	0.78	4.49875	1.50	0.020	16.14	21.47
Khalwa	**1489.00**	970	0.78	4.028333	1.03	0.020	19.95	26.53
Pandhana	**831.00**	824.75	0.78	4.49	1.49	0.020	24.58	32.69
Punasa	**1272.00**	1170	0.78	5.942222	2.94	0.020	68.85	91.57
Khandwa	**945.00**	905	0.78	5.117	2.12	0.020	38.32	50.96
District Total	**7524.50**	**5814.46**	**0.78**	**4.89**	**1.65**	**0.02**	**221**	**294**

Table 7: Financial Outlay Plan- Supply Side Management, Khandwa District, Madhya Pradesh

Block	Area Suitable for AR	Volume of Surface Water available for AR (MCM)	Volume of Water required for recharge (MCM)	Percolation Tanks		NB/ CP		CP/Recharge shaft		Renovation of Village Ponds		Total Cost of ARS in crores
				structure	cost	structure	cost	structure	cost	structure	cost	
				Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	
Baldi	545.24	136.31	41.19	41	8.20	165	16.50	144	7.20	45	0.90	32.80
Chhegaon	861	433.19	29.79	30	5.96	119	11.90	104	5.20	85	1.70	24.76
Harsud	538.47	134.62	21.47	21	4.29	86	8.60	75	3.75	69	1.38	18.02
Khalwa	970	242.50	26.53	27	5.31	106	10.60	93	4.65	146	2.92	23.48
Pandhana	824.75	252.71	32.69	33	6.54	131	13.10	114	5.70	96	1.92	27.26
Punasa	1170	292.50	91.57	92	18.31	366	36.60	320	16.00	121	2.42	73.33
Khandwa	905	226.25	50.96	51	10.19	204	20.40	178	8.90	134	2.68	42.17
TOTAL	**5814.46**	**1718.072**	**294**	**294**	**58.80**	**1177**	**117.70**	**1030**	**51.40**	**696**	**13.92**	**241.82**

7.2. Post-Intervention Impact

The expected outcome of the proposed interventions from both supply side and demand side has been described in Table no 8. It can been revised that the Stage of groundwater development for the entire Khandwa district, would reduce to 41.21% as compared to the present stage of ground water development of 38.12% after implying and successful implementation of proposed interventions.

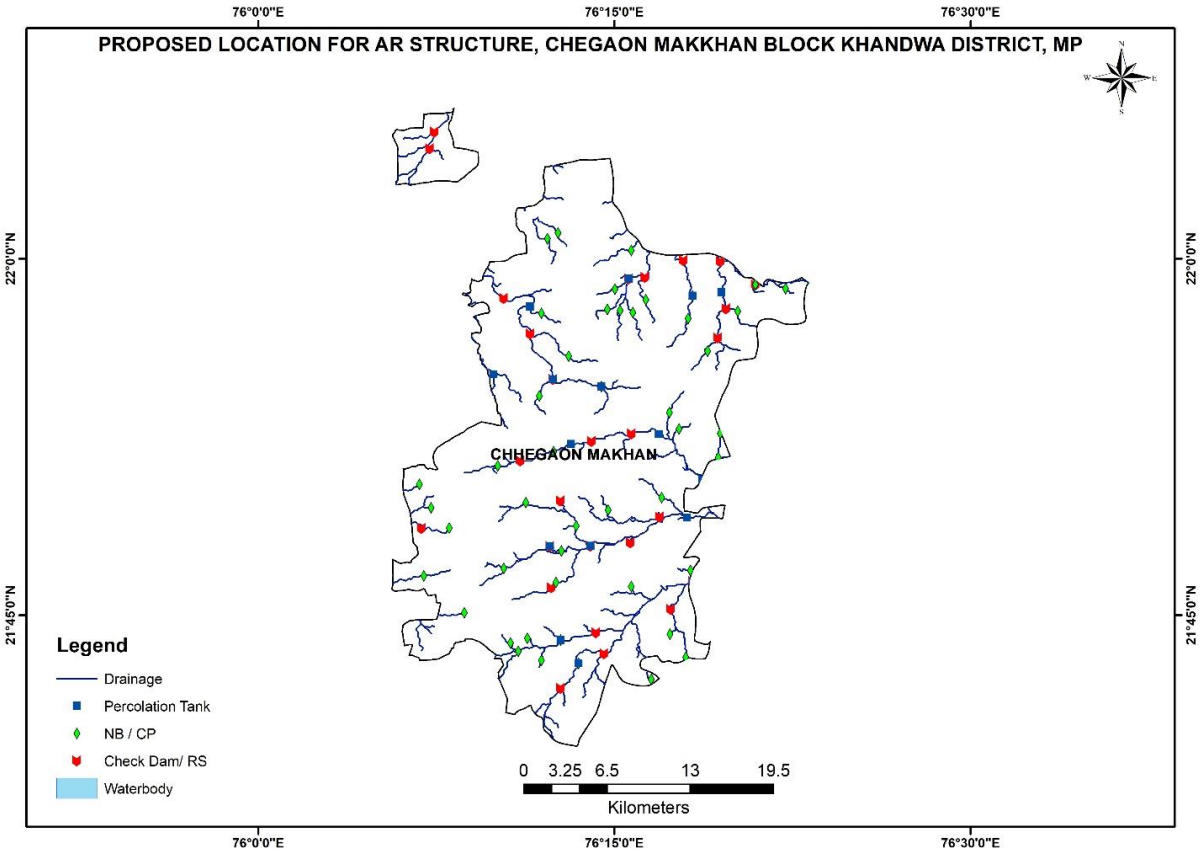
Table 8: Post-Intervention Impact, Khandwa District, Madhya Pradesh (in MCM)

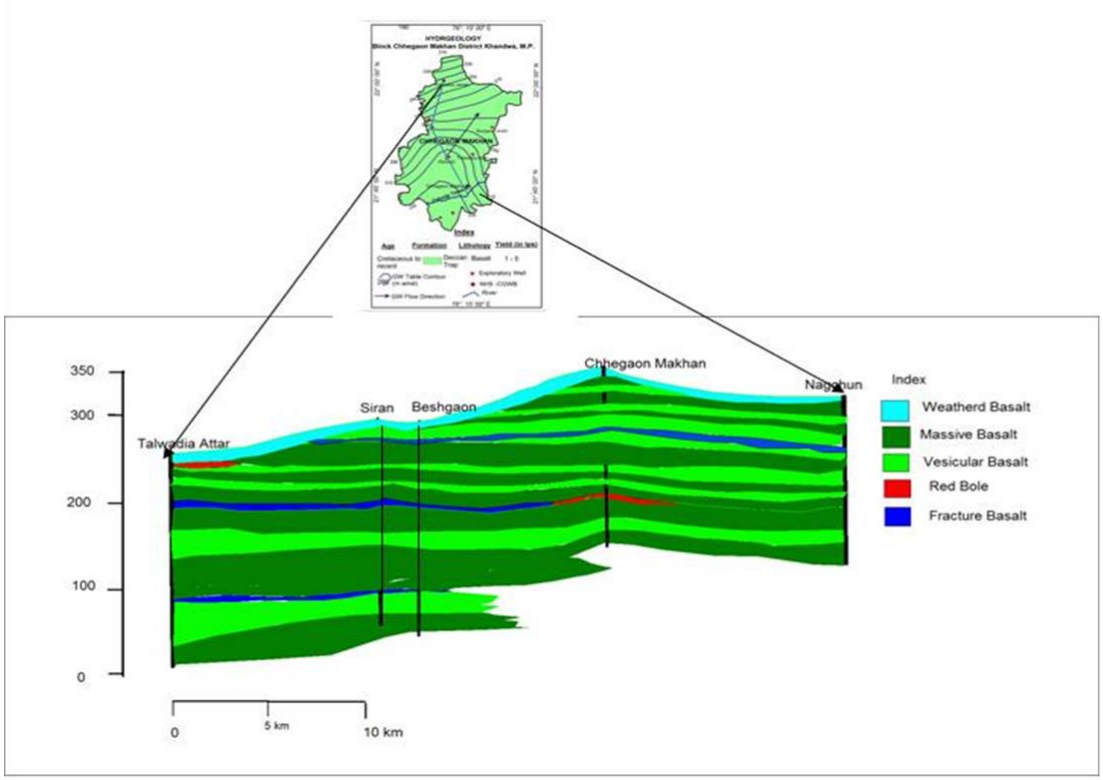
Block	Net GW Availability	GW Draft for Irrigation	GW Draft for Domestic & Industrial	Gross Draft	Stage of Development (%)	Saving by Sprinklar	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Draft after sprinkler & additional area created for agriculture	Stage of Development W/O GW use for additional Area Irrigation	Additional area irrigated by GW after intervention
Badli	57.17	31.08	1.08	32.17	**56.27**	6.22	30.97	88.1435	18.581	44.54	**50.53**	464.5
Chhegaon Makhan	126.08	95.71	3.76	99.47	**78.89**	19.14	22.40	148.48	13.43	93.77	**63.15**	33.60
Harsud	45.573	27.60	2.20	29.80	**65.40**	5.52	16.14	61.71	9.684	33.97	**55.04**	24.21
Khalwa	99.99	56.81	5.82	62.63	**62.64**	11.36	19.95	119.94	11.969	63.25	**52.73**	29.92
Khandwa	97.86	60.95	4.01	64.97	**66.39**	12.19	24.58	122.44	14.746	67.53	**55.15**	36.87
Pandhana	152.65	72.78	5.97	78.76	**51.60**	14.56	68.85	221.50	41.308	105.52	**47.64**	103.27
Punasa	430.43	42.69	4.67	47.37	**11.01**	8.54	38.32	468.75	22.990	61.82	**13.19**	57.48
Total	**1009.78**	**387.65**	**27.53**	**415.19**	**41.12**	**77.53**	**221.20**	**1230.985**	**132.72**	**470.38**	**38.21**	**331.80**

7.3. Block-Wise Mapping and Management Plan

1. Block Chegoan Makkkan

Geographical area	**870.00**Sq. km (NAQUIM Recharge worthy area **861.00**Sq. Km)
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Weathered/Fractured Basalt
Normal Annual Rainfall	777mm
Aquifer Disposition	Two Types of Aquifer System Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt. Deeper Aquifer System (Aquifer-II): Depth range from 30-170m, Fractured Basalt Shale /sandstone.
Status of GW Exploration	Exploratory wells :6 Observation Well : 1 Piezometer well: 1
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):12 DTWL (m bgl): 3-14 Yield (lps): 1 to 4.5 Specific yield :0.02 Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.5 to 6 DTWL (m bgl): 11 - 28 Yield (lps): Meager to 12 T (m^2/day), Specific yield :0.010
Ground water Monitoring Status	NHS:5DW, Piezometer well: 1
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 12608.52GW Draft 9947.35 ham Stage of GW Development 78.89%
Existing and Future water Demand	Present Demand for All usage 9947.35ham Future Demand for Domestic and Industrial Use 462.51ham.


PROPOSED LOCATION FOR AR STRUCTURE, CHEGAON MAKKHAN BLOCK KHANDWA DISTRICT, MP
76°0'0"E
76°15'0"E
76°30'0"E
22°0'0"N
21°45'0"N
CHHEGAON MAKHAN
Legend
Drainage
Percolation Tank
NB / CP
Check Dam/ RS
Waterbody
0 3.25 6.5 13 19.5
Kilometers


350
300
200
100
0
Talwadia Attar
Siran
Beshgaon
Chhegaon Makhan
Nagzhun
Index
Weatherd Basalt
Massive Basalt
Vesicular Basalt
Red Bole
Fracture Basalt
0
5 km
10 km

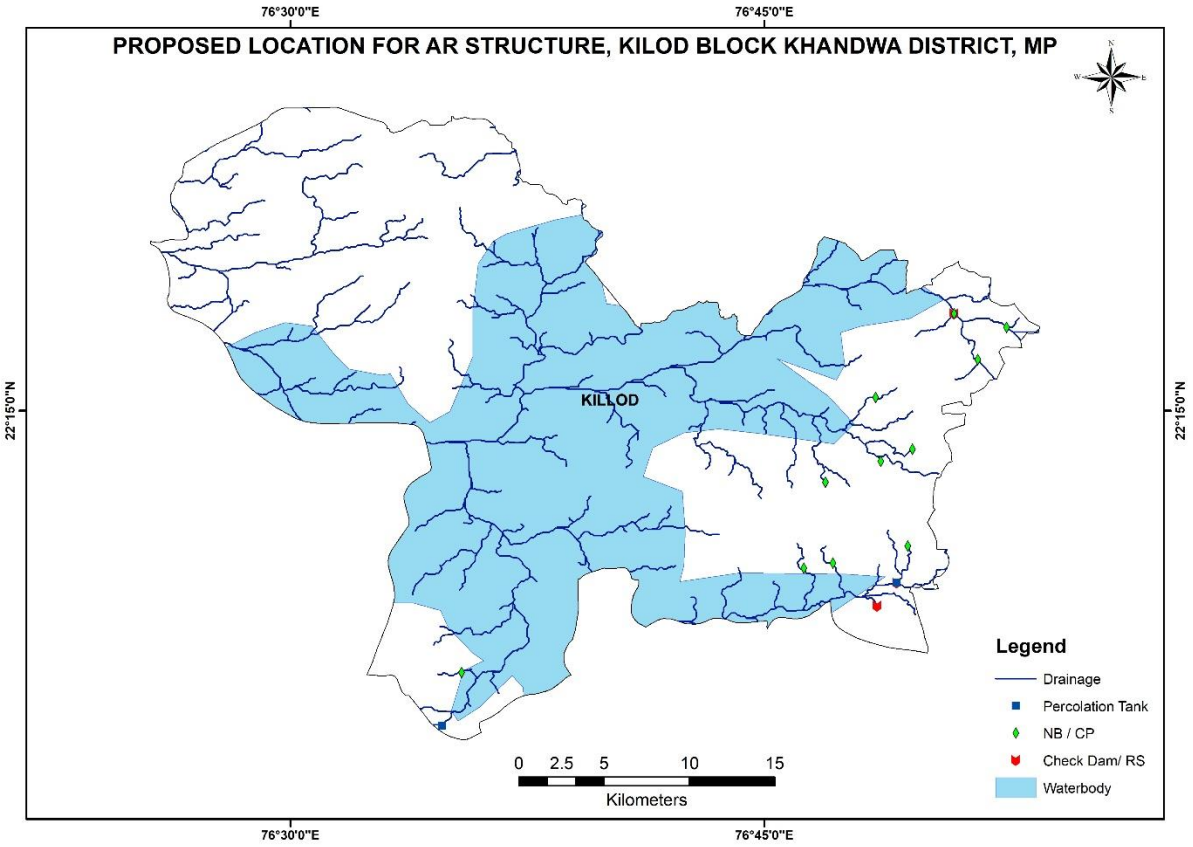
Salient Features

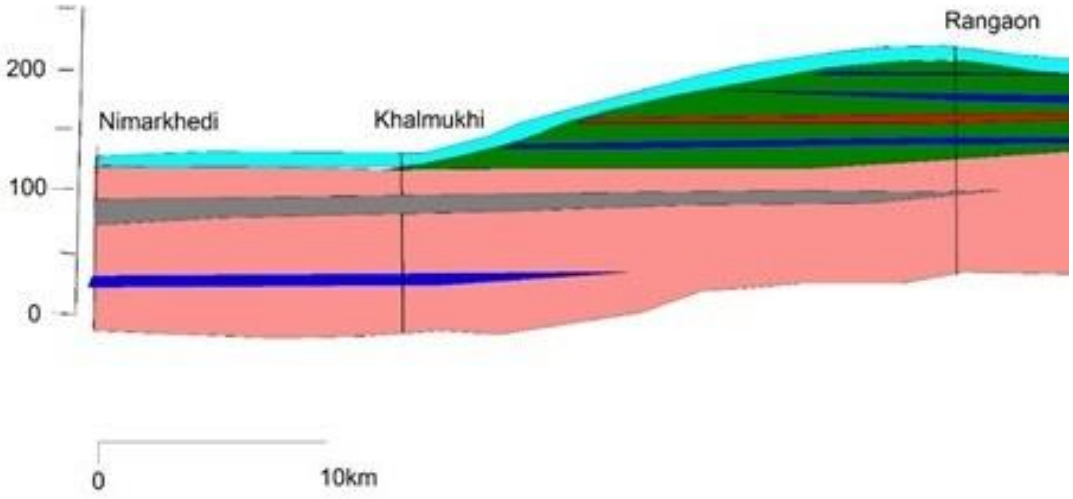
Block	**Chhegaon Makhan**
Shallow Aquifer	
Dynamic Resources (MCM)	126.09
Instorage Resources (MCM)	24.59
Total Resources (MCM)	**150.68**
Irrigation	95.71
Domestic+Industries	3.76
Deeper Aquifer	
Static Resources (MCM)	15.27
GW Draft (MCM	35.41
Total GW Resources (MCM)	165.96
Gross Ground Water Draft (MCM)	99.47
Stage of Ground Water Development (%)	78.89
Category	**Semi critical**

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	30	5.96 (Rs 20 Lakh Per Structure)
NB /CP	119	11.90 (Rs 10 Lakh Per Structure)
CD /Recharge Shaft	104	5.20 (Rs05 Lakh Per Structure)
Renovation of Village Ponds	85	1.70 (Rs02 Lakh Per Structure)
Total Cost		24.76 **Crores**

2. Block Baldi

Geographical area	**1117.00** Sq. km (NAQUIM Recharge worthy area **545.24.00**Sq. Km)
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Weathered/Fractured Basalt
Normal Annual Rainfall	777mm
Aquifer Disposition	Two Types of Aquifer System Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt. Deeper Aquifer System (Aquifer-II): Depth range from 30-170m, Fractured Basalt Shale /sandstone.
Status of GW Exploration	Exploratory wells :3 Observation Well :1 Piezometer well:
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):12 DTWL (m bgl): 3-14 Yield (lps): 1 to 4.5 Specific yield :0.02 Aquifer I : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.5 to 6 DTWL (m bgl): 11 - 28 Yield (lps): Meager to 12 T (m^2/day), Specific yield :0.010
Ground water Monitoring Status	NHS:5DW, Piezometer well: 1
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 5717.39GW Draft 3217.27 ham Stage of GW Development 56.27%
Existing and Future water Demand	Present Demand for All usage 3217.27 ham Future Demand for Domestic and Industrial Use 462.51ham.





Stratigraphy

- soil
- Weathered Basalt
- Massive Basalt
- Red Bole
- Fracture Basalt
- vesicular Basalt
- Sandstone
- Shale
- Granite

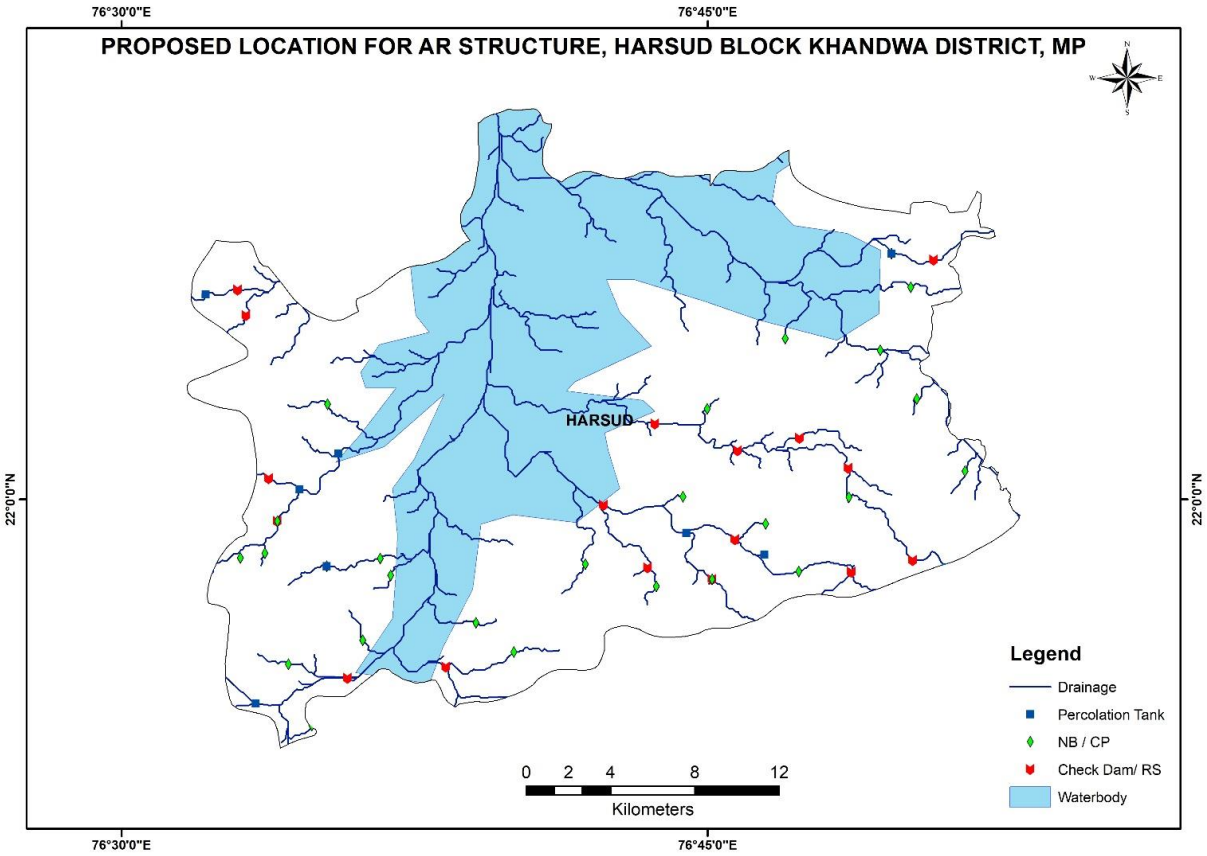
Salient Features

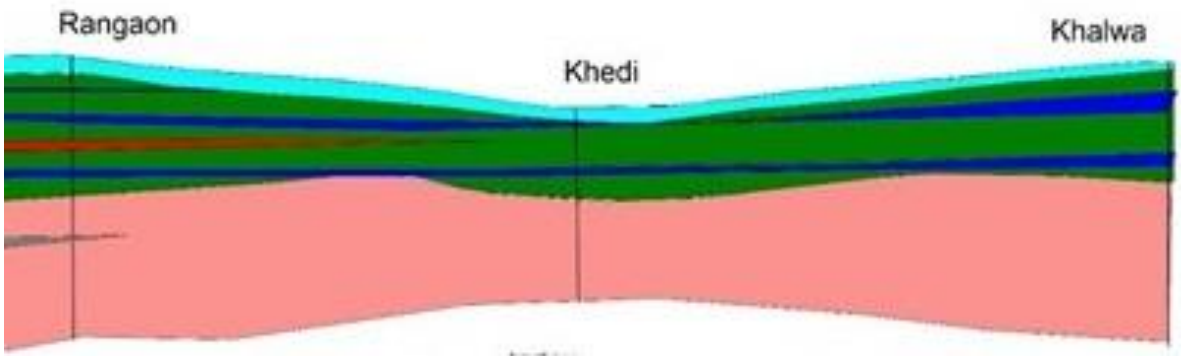
Block	**Badli**
Shallow Aquifer	
Dynamic Resources (MCM)	57.17
Instorage Resources (MCM)	57.27
Total Resources (MCM)	**114.44**
Irrigation	31.08
Domestic+Industries	1.08
Deeper Aquifer	
Static Resources (MCM)	10.06
GW Draft (MCM	6.53
Total GW Resources (MCM)	124.50
Gross Ground Water Draft (MCM)	32.16
Stage of Ground Water Development (%)	56.27
Category	**Safe**

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	41	8.2 (Rs 20 Lakh Per Structure)
NB /CP	165	16.5 (Rs 10 Lakh Per Structure)
CD /Recharge Shaft	144	7.2 (Rs05 Lakh Per Structure)
Renovation of Village Ponds	45	0.90 (Rs02 Lakh Per Structure)
Total Cost		24.76 **Crores**

3. Block Harsud

Geographical area	**1000.50** Sq. km (NAQUIM Recharge worthy area **538.47.00**Sq. Km)
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Weathered/Fractured Basalt
Normal Annual Rainfall	777mm
Aquifer Disposition	Two Types of Aquifer System Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt. Deeper Aquifer System (Aquifer-II): Depth range from 30-170m, Fractured Basalt, Shale /sandstone.
Status of GW Exploration	Exploratory wells :2 Observation Well : Piezometer well:
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):12 DTWL (m bgl): 3-14 Yield (lps): 1 to 4.5 Specific yield :0.02 Aquifer I : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.5 to 6 DTWL (m bgl): 11 - 28 Yield (lps): Meager to 12 T (m^2/day), Specific yield :0.010
Ground water Monitoring Status	NHS:5DW, Piezometer well: 1
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 4557.3GW Draft 2980.36 ham Stage of GW Development 65.4%
Existing and Future water Demand	Present Demand for All usage 2980.36 ham Future Demand for Domestic and Industrial Use 462.51ham.





Stratigraphy

- soil
- Weathered Basalt
- Massive Basalt
- Red Bole
- Fracture Basalt
- vesicular Basalt
- Sandstone
- Shale
- Granite

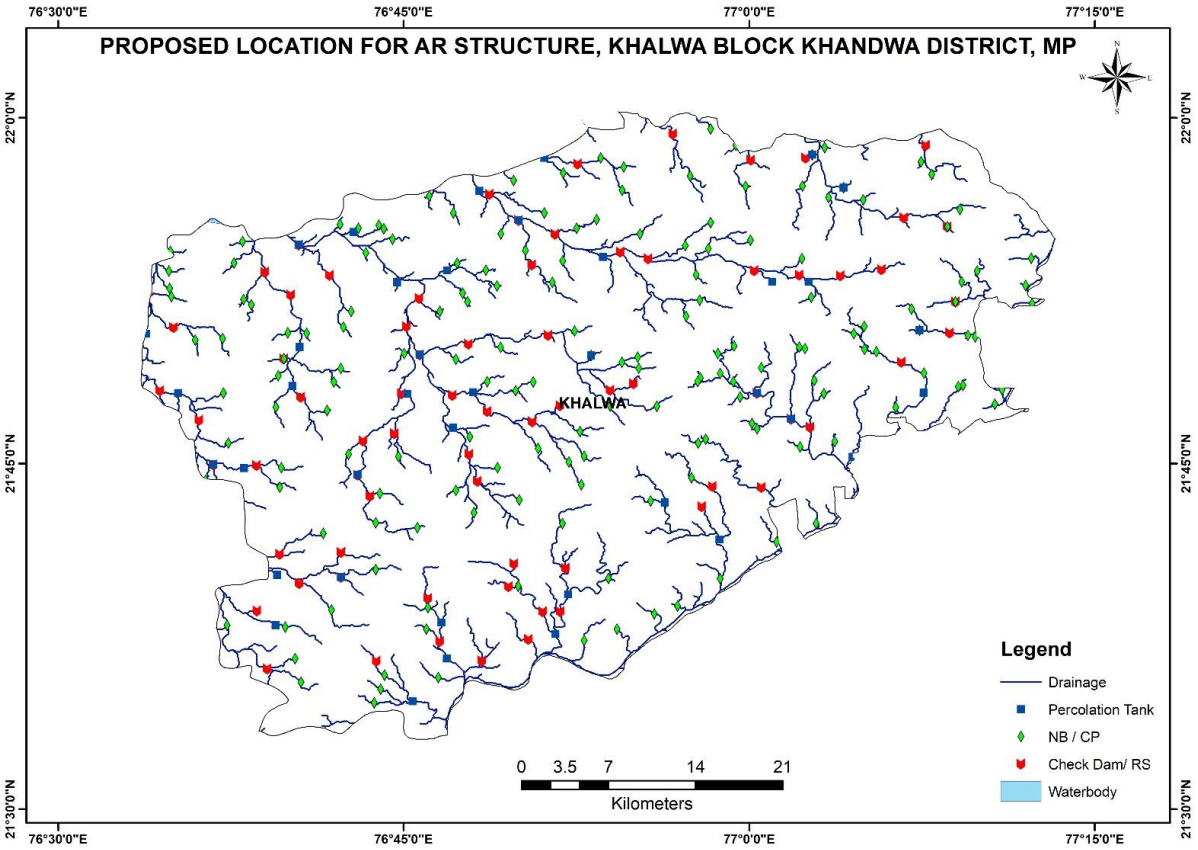
Salient Features

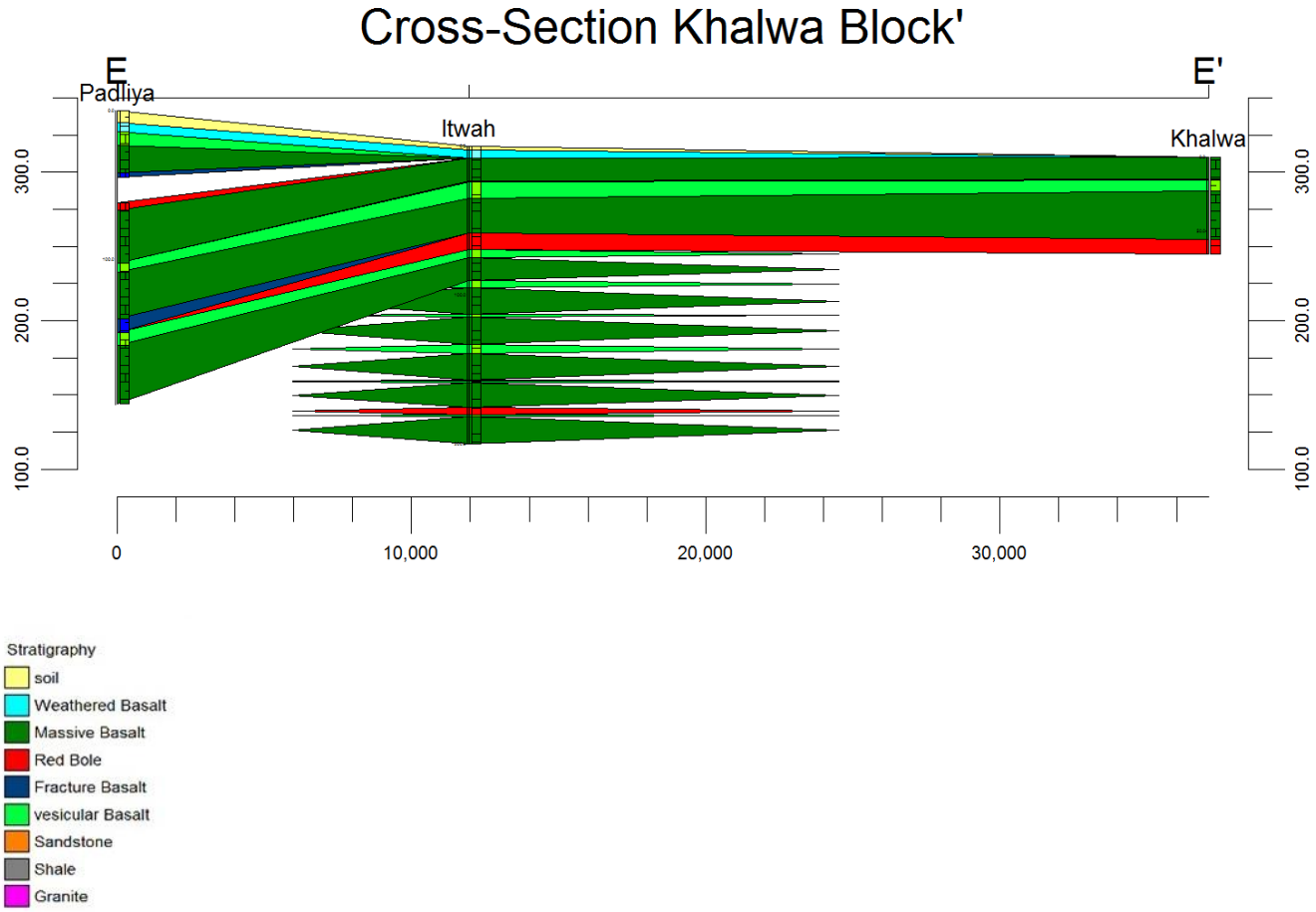
Block	Harsud
Shallow Aquifer	
Dynamic Resources (MCM)	**45.57**
***Instorage* Resources (MCM)**	**19.26**
Total Resources (MCM)	**64.83**
Irrigation	**27.60**
Domestic+Industries	**2.20**
Deeper Aquifer	
Static Resources (MCM)	**11.28**
Total GW Resources (MCM)	**76.11**
Gross Ground Water Draft (MCM)	**29.80**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	21	4.29 (Rs 20 Lakh Per Structure)
NB /CP	86	8.60 (Rs 10 Lakh Per Structure)
CD /Recharge Shaft	75	3.75 (Rs05 Lakh Per Structure)
Renovation of Village Ponds	69	1.38 (Rs02 Lakh Per Structure)
Total Cost		18.02 **Crores**

4. Block Khalwa

Geographical area	**1489.00** Sq. km (NAQUIM Recharge worthy area **970.00**Sq. Km)
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Weathered/Fractured Basalt
Normal Annual Rainfall	777mm
Aquifer Disposition	Two Types of Aquifer System Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt. Deeper Aquifer System (Aquifer-II): Depth range from 30-170m, Fractured Basalt Shale /sandstone.
Status of GW Exploration	Exploratory wells :3 Observation Well: Piezometer well:
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):12 DTWL (m bgl): 3-14 Yield (lps): 1 to 4.5 Specific yield :0.02 Aquifer I : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.5 to 6 DTWL (m bgl): 11 - 28 Yield (lps): Meager to 12 T (m^2/day), Specific yield :0.010
Ground water Monitoring Status	NHS:5DW, Piezometer well: 1
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 9999.97GW Draft 6263.81 ham Stage of GW Development 62.64%
Existing and Future water Demand	Present Demand for All usage 6263.81 ham Future Demand for Domestic and Industrial Use 462.51ham.


PROPOSED LOCATION FOR AR STRUCTURE, KHALWA BLOCK KHANDWA DISTRICT, MP
76°30'0"E
76°45'0"E
77°0'0"E
77°15'0"E
22°0'0"N
21°45'0"N
21°30'0"N
KHALWA
0 3.5 7 14 21
Kilometers
Legend
Drainage
Percolation Tank
NB / CP
Check Dam/ RS
Waterbody


Cross-Section Khalwa Block'
E
E'
Padliya
Itwah
Khalwa
300.0
200.0
100.0
0
10,000
20,000
30,000
Stratigraphy
soil
Weathered Basalt
Massive Basalt
Red Bole
Fracture Basalt
vesicular Basalt
Sandstone
Shale
Granite

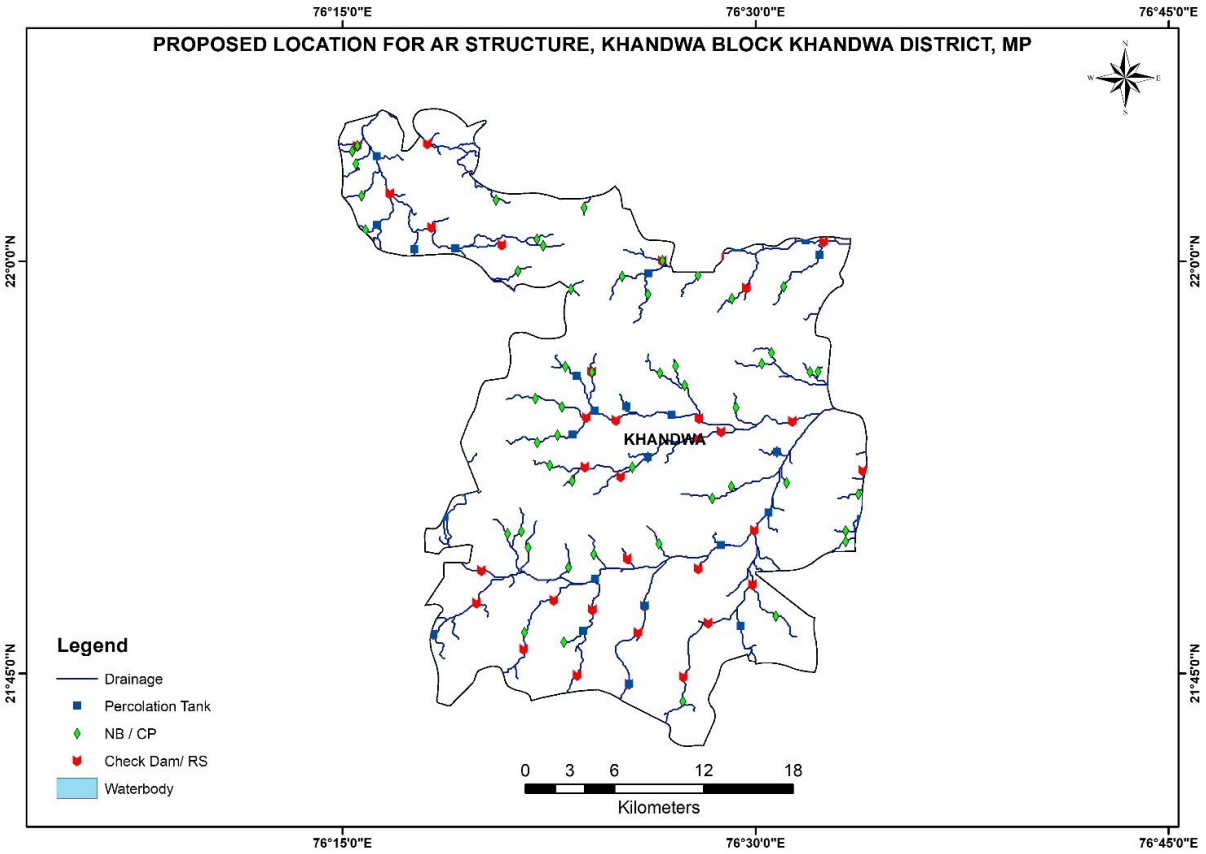
Salient Features

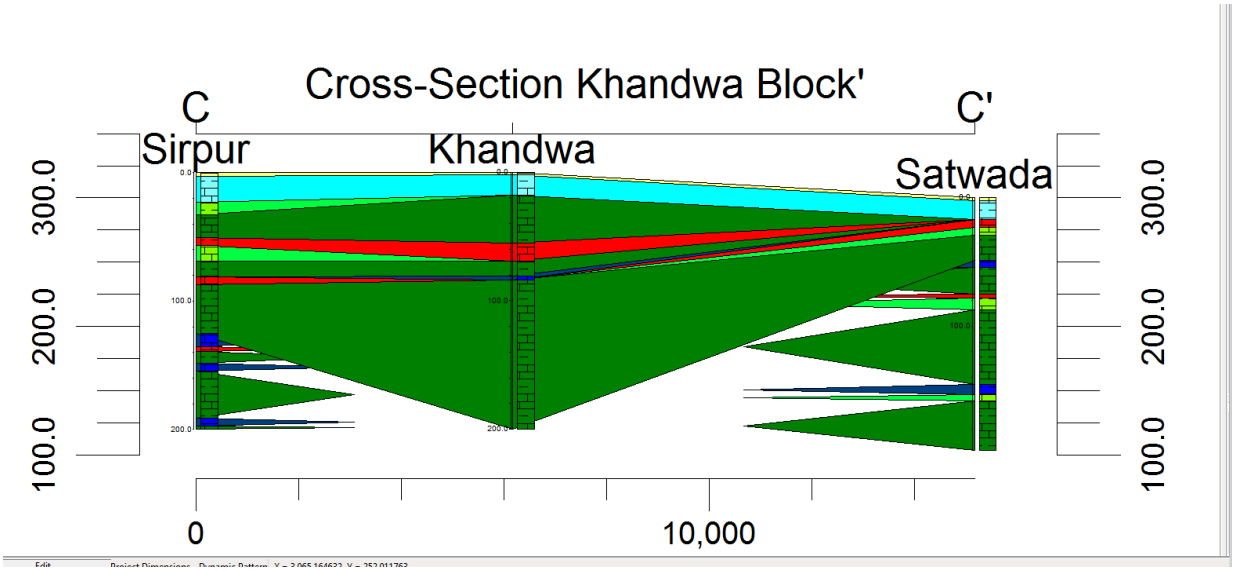
Block	Khalwa
Shallow Aquifer	
Dynamic Resources (MCM)	**100.00**
***Instorage* Resources (MCM)**	**35.45**
Total Resources (MCM)	**135.45**
Irrigation	**5.82**
Domestic+Industries	**70.58**
Deeper Aquifer	
Static Resources (MCM)	**9.94**
Total GW Resources (MCM)	**145.40**
Gross Ground Water Draft (MCM)	**62.63**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	27	5.31 (Rs 20 Lakh Per Structure)
NB /CP	106	10.60 (Rs 10 Lakh Per Structure)
CD /Recharge Shaft	93	4.65 (Rs05 Lakh Per Structure)
Renovation of Village Ponds	146	2.92 (Rs02 Lakh Per Structure)
Total Cost		24.76 **Crores**

5. Block Khandwa

Geographical area	**831.00** Sq. km (NAQUIM Recharge worthy area **824.75**Sq. Km)
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Weathered/Fractured Basalt
Normal Annual Rainfall	777mm
Aquifer Disposition	Two Types of Aquifer System Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt. Deeper Aquifer System (Aquifer-II): Depth range from 30-170m, Fractured Basalt Shale /sandstone.
Status of GW Exploration	Exploratory wells :10 Observation Well: Piezometer well:
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):12 DTWL (m bgl): 3-14 Yield (lps): 1 to 4.5 Specific yield :0.02 Aquifer I : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.5 to 6 DTWL (m bgl): 11 - 28 Yield (lps): Meager to 12 T (m^2/day), Specific yield :0.010
Ground water Monitoring Status	NHS:5DW, Piezometer well: 1
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 9786.25 GW Draft 6497.17 ham Stage of GW Development 66.39%
Existing and Future water Demand	Present Demand for All usage 6497.17 ham Future Demand for Domestic and Industrial Use 462.51ham.





Stratigraphy
- soil
- Weathered Basalt
- Massive Basalt
- Red Bole
- Fracture Basalt
- vesicular Basalt
- Sandstone
- Shale
- Granite

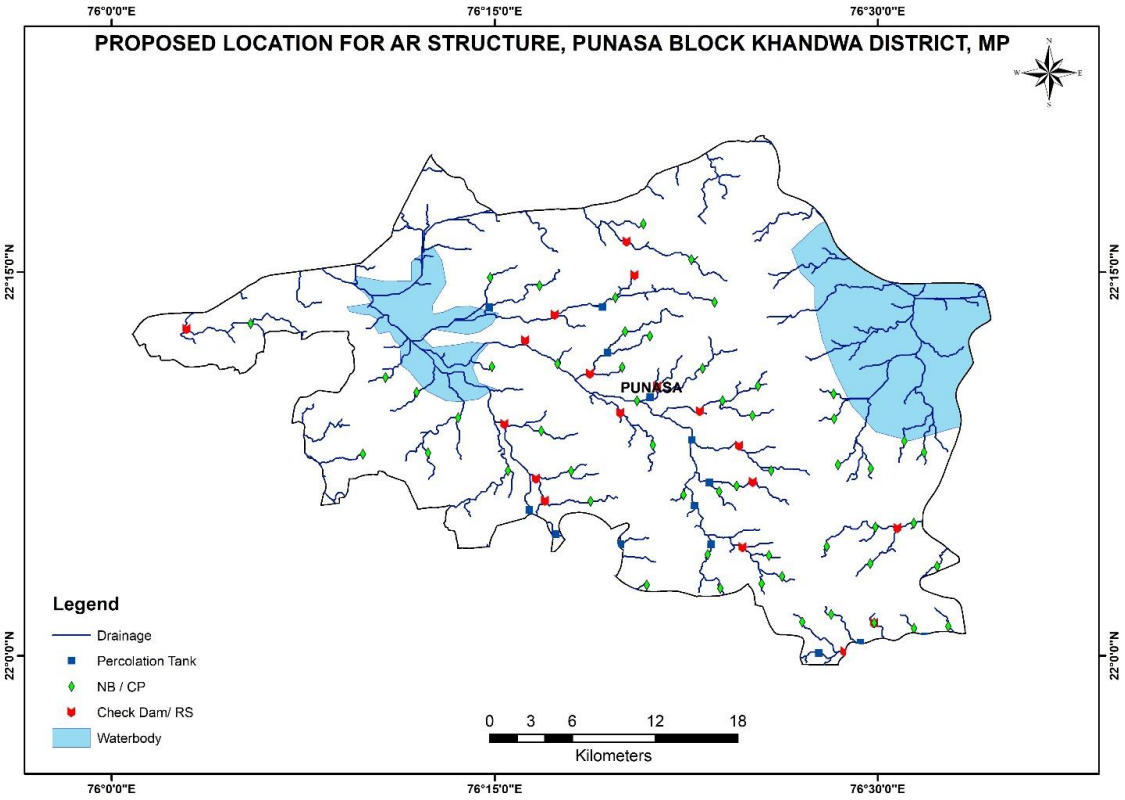
Salient Features

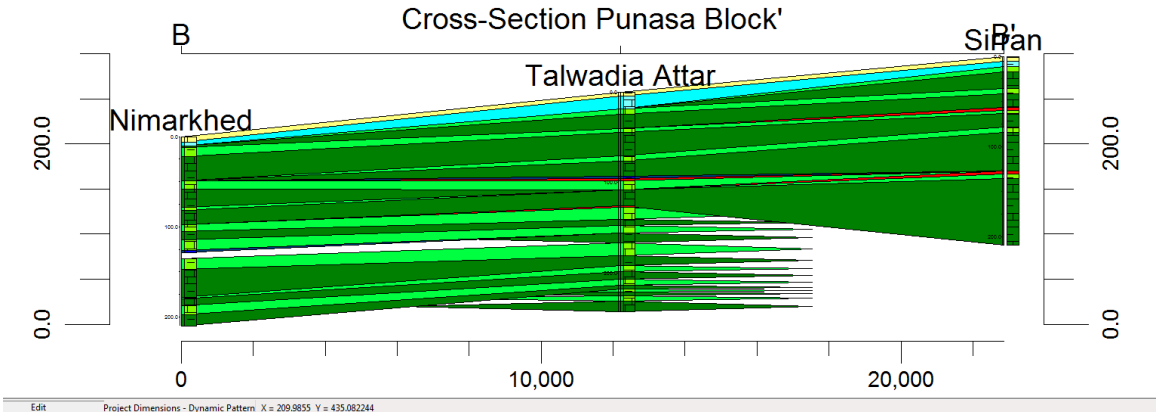
Block	Khandwa
Shallow Aquifer	
Dynamic Resources (MCM)	**97.86**
***Instorage* Resources (MCM)**	**39.52**
Total Resources (MCM)	**137.38**
Irrigation	**60.95**
Domestic+Industries	**1.01**
Deeper Aquifer	
Static Resources (MCM)	**7.90**
Total GW Resources (MCM)	**145.28**
Gross Ground Water Draft (MCM)	**61.96**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	51	10.19 (Rs 20 Lakh Per Structure)
NB /CP	204	20.40 (Rs 10 Lakh Per Structure)
CD /Recharge Shaft	178	8.90 (Rs05 Lakh Per Structure)
Renovation of Village Ponds	134	2.68 (Rs02 Lakh Per Structure)
Total Cost		42.17 **Crores**

6 .Block Punasa

Geographical area	**945.00** Sq. km (NAQUIM Recharge worthy area **905.0**Sq. Km)
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Weathered/Fractured Basalt
Normal Annual Rainfall	777mm
Aquifer Disposition	Two Types of Aquifer System Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt. Deeper Aquifer System (Aquifer-II): Depth range from 30-170m, Fractured Basalt Shale /sandstone.
Status of GW Exploration	Exploratory wells :4 Observation Well: Piezometer well:
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):12 DTWL (m bgl): 3-14 Yield (lps): 1 to 4.5 Specific yield :0.02 Aquifer I : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.5 to 6 DTWL (m bgl): 11 - 28 Yield (lps): Meager to 12 T (m^2/day), Specific yield :0.010
Ground water Monitoring Status	NHS:5DW, Piezometer well: 1
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 43043.37 GW Draft 4737 ham Stage of GW Development 11.01%
Existing and Future water Demand	Present Demand for All usage 4737 ham Future Demand for Domestic and Industrial Use 462.51ham.





Stratigraphy
- soil
- Weathered Basalt
- Massive Basalt
- Red Bole
- Fracture Basalt
- vesicular Basalt
- Sandstone
- Shale
- Granite

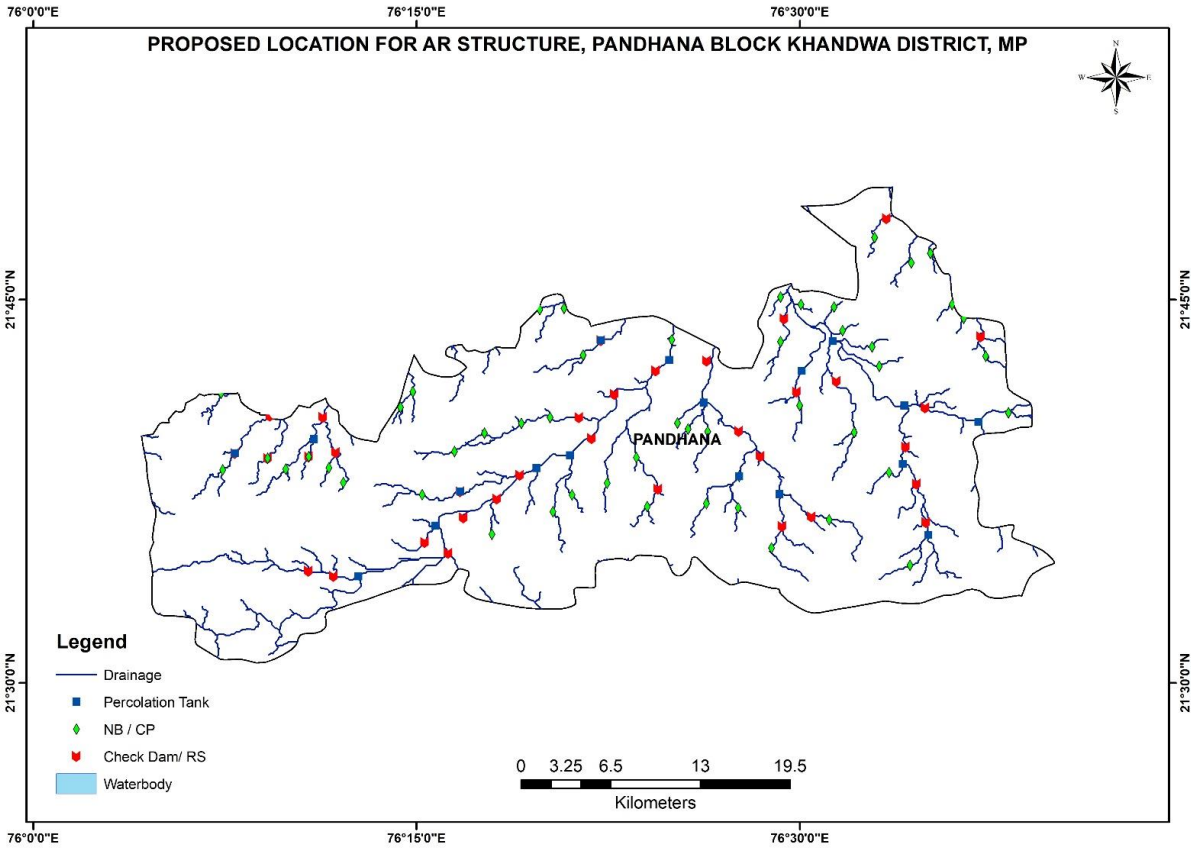
Salient Features

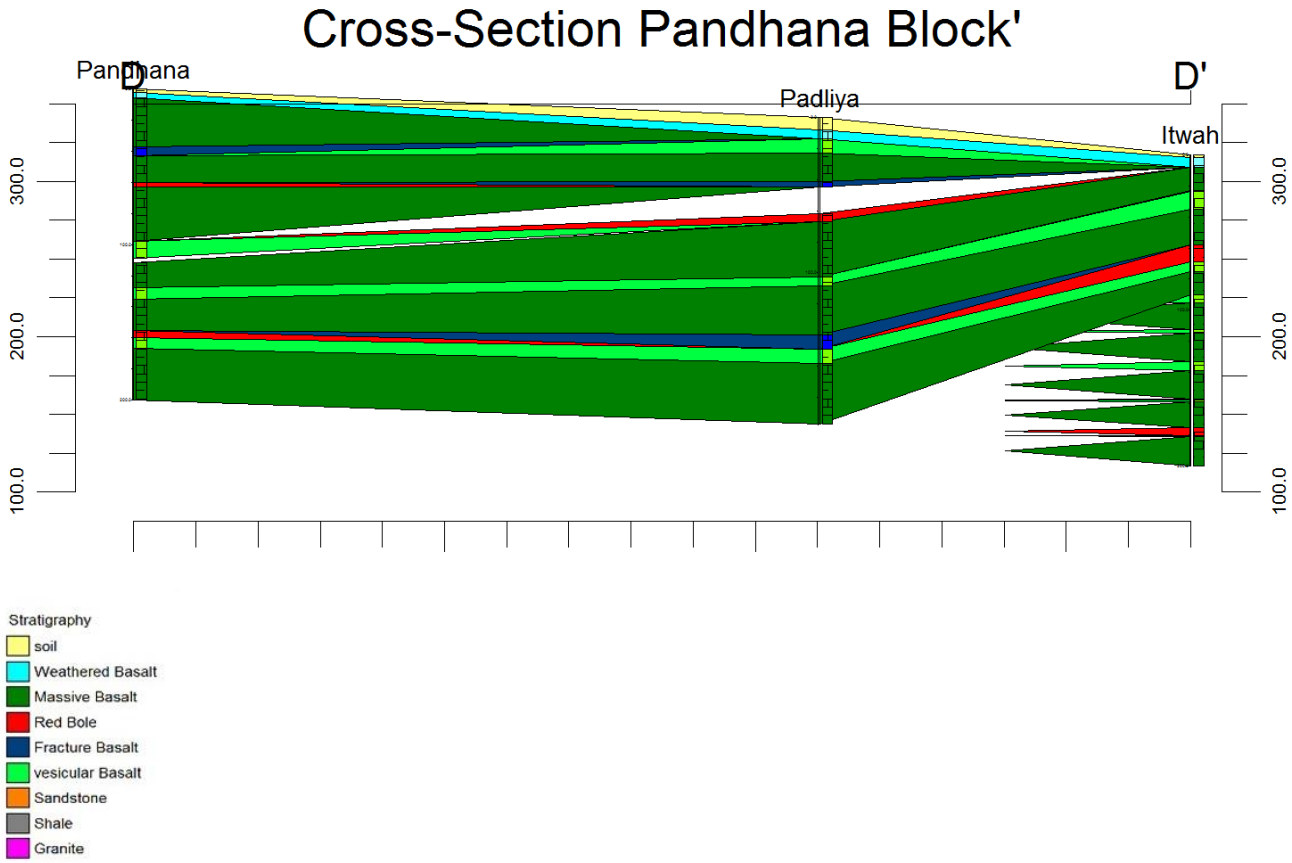
Block	**Punasa**
Shallow Aquifer	
Dynamic Resources (MCM)	**430.43**
***Instorage* Resources (MCM)**	**66.00**
Total Resources (MCM)	**496.43**
Irrigation	**42.96**
Domestic+Industries	**4.67**
Deeper Aquifer	
Static Resources (MCM)	**6.46**
Total GW Resources (MCM)	**502.90**
Gross Ground Water Draft (MCM)	**47.63**

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	92	18.31 (Rs 20 Lakh Per Structure)
NB /CP	366	36.60 (Rs 10 Lakh Per Structure)
CD /Recharge Shaft	320	16.00 (Rs05 Lakh Per Structure)
Renovation of Village Ponds	121	2.42 (Rs02 Lakh Per Structure)
Total Cost		73.33 **Crores**

7. Block Pandhana

Geographical area	**1272.00** Sq. km (NAQUIM Recharge worthy area **1170.0**Sq. Km)
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Weathered/Fractured Basalt
Normal Annual Rainfall	777mm
Aquifer Disposition	Two Types of Aquifer System Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt. Deeper Aquifer System (Aquifer-II): Depth range from 30-147m, Fractured Basalt Shale /sandstone.
Status of GW Exploration	Exploratory wells :6 Observation Well: 1 Piezometer well: 1
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):12 DTWL (m bgl): 3-14 Yield (lps): 1 to 4.5 Specific yield :0.02 Aquifer I : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.5 to 6 DTWL (m bgl): 11 - 28 Yield (lps): Meager to 12 T (m^2/day), Specific yield :0.010
Ground water Monitoring Status	NHS:5DW, Piezometer well: 1
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 15265.62 GW Draft 7876.36 ham Stage of GW Development 51.6%
Existing and Future water Demand	Present Demand for All usage 7876.36 ham Future Demand for Domestic and Industrial Use 462.51ham.


PROPOSED LOCATION FOR AR STRUCTURE, PANDHANA BLOCK KHANDWA DISTRICT, MP
76°0'0"E
76°15'0"E
76°30'0"E
21°45'0"N
21°30'0"N
PANDHANA
Legend
Drainage
Percolation Tank
NB / CP
Check Dam/ RS
Waterbody
0 3.25 6.5 13 19.5
Kilometers


Cross-Section Pandhana Block'
Pandhana
D
Padliya
D'
Itwah
300.0
200.0
100.0
Stratigraphy
soil
Weathered Basalt
Massive Basalt
Red Bole
Fracture Basalt
vesicular Basalt
Sandstone
Shale
Granite

Block	Pandhana
Shallow Aquifer	
Dynamic Resources (MCM)	**152.65**
***Instorage* Resources (MCM)**	**73.77**
Total Resources (MCM)	**226.42**
Irrigation	**72.78**
Domestic+Industries	**5.97**
Deeper Aquifer	
Static Resources (MCM)	**7.26**
Total GW Resources (MCM)	**233.68**
Gross Ground Water Draft (MCM)	**78.75**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	33	6.54 (Rs 20 Lakh Per Structure)
NB /CP	131	13.10 (Rs 10 Lakh Per Structure)
CD /Recharge Shaft	114	5.70 (Rs05 Lakh Per Structure)
Renovation of Village Ponds	96	1.92 (Rs02 Lakh Per Structure)
Total Cost		27.26 **Crores**

8. Conclusions and Recommendations

On the basis of NAQUIM studied in the area, the following conclusions are drawn.

The studied area occupies an area of 7524 Sq. Km. It is divided into, four administrative blocks viz Badli, Chhegaon makhan, Harsud, Khalwa, Khandwa, Pandhana and Punasa forming blocks.

The maximum elevation is 570 m amsl in Bhitarwar Block and minimum elevation is 170 m amsl in Khalwa Block . The minimum elevation has been recorded in the southern and northern fringes of the district. The major portion of the district lies within an elevation range of about 210 to 380 m amsl.

Entire Khandwa district falls under the Narmada basin Narmada and its tributaries form the main source of surface water in the area. Narmada flows along the northern boundary of the district main rivers which drains the area of the district which drains the area of the district are ChhotaTawa, Sukta & BhimNadi

Khandwa district is underlain by various geological formation, forming different types of aquifers in the area. Main geological; units of the area are Archaean, upper Vindhyan, Bagh beds, Deccan traps and alluvium.

The pre-monsoon depth to Water levels ranges from a minimum of 2.7 meters below ground level (mbgl) in Punasa block to a maximum of 15.5 m bgl in Chhegoan Maakkanblock of Kandwah district. About 10% very shallow water levels up to 3-6m bgl have been recorded in a small patch in Northern and central part of district. About 60 % of monitoring wells recorded water level in the range of 6-9 m bgl category.

The post-monsoon depth to Water levels ranges from a minimum of 1.1 m below ground level in Punasa block to a maximum of 7.6 m bgl Chhegaon Makhan block of Khandwa district. Very shallow water levels up to 3 m bgl have been recorded in patches scattered all over the district contributing to about 41.46% of total monitoring wells in Khandwa district

There are seven assessment units (block) in the district out of which three blocks fall under non-command category whereas Badli, Harsud and Khalwa, four blocks falls under both command as well as non-command category Chhegon makhan, Khandwa, Pandhuna and Punasa. One block of the district are categorized as semi-critical namely Chhegaon makhan, (non-command) and rest as

safe. The highest stage of ground water development is computed as 80.73 % in non-command area of Chhegaon makhan block.

Long term water level trend show declining in Chhegaon makan block

Under the prevailing hydrogeological conditions, Aquifer Mapping and Characterization, the following recommendations are made for the development & management of ground water.

- As per the Management plan prepared under NAQUIM of all the Block of Khandwa District, a total number of 294 Percolation Tanks, 1030 Recharge Shafts/Tube wells and 1177 Nala Bunds/Check Dams and 696 Village pond Cement Plugs have been proposed and these structures can recharge 221 MCM.

- Financial expenditure is expected to be Rs 242 Crores in Khandwa District for sustainable development and management of ground water resources.

- The number of artificial recharge structure and financial estimation has been proposed based on the CGWB Master plan 2020. It may be differ from the field condition as well as changes in dynamic Ground water resources.

- After the implemented of project interventions in the report, the stage of ground water development is expected to improve by 10 % i.e. from 41 % to 38.21 % for the Khandwa district and additional area for the irrigation will be 332 Sq.Km.

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