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

Chhindwara District
Madhya Pradesh

उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

MINISTRY OF JAL SHAKTI
Department of Water Resources
River Department & Ganga Rejuvenation
CENTRAL GROUND WATER BOARD

AQUIFER MAPPING AND MANAGEMENT PLAN OF CHHINDWARA DISTRICT, MADHYA PRADESH

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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.

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 Chhindwara 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 11815Sq. Km. It is divided into, 11 administrative blocks viz Chhindwara, Mohkhed, Tamia, Parasia, Jamai, Amarwara, Harrai, Chourai, Sausar, Bichhua, and Pandhurna forming blocks. Chhindwara district is underlain by various geological formations, forming different types of aquifers in the area. Main geological units of the area are, Granitic Gneiss, Deccan traps, Gondwanas and alluvium.

As per the Management plan prepared under NAQUIM of all the Block of Chhindwara District, a total number of 1150 Percolation Tanks, 9849 Recharge Shafts/Tube wells and 9849 Nala Bunds/Check Dams and 3282 Village pond have been proposed. After the implementation of project interventions in the report, the stage of ground water extraction in Chhindwara district is expected to improve by 5.22% i.e. from 59.80% to 54.58%.

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 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 Shri *S.K. Shrivastava, Sc. D* and *Dr. Rakesh Singh, Sc. D* to compile this report. I hope that this report will serve as a valuable guide for sustainable development of ground water in the Chhindwara District, Madhya Pradesh.

Rana Chatterjee
(Regional Director)

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1.0 INTRODUCTION

Central Ground Water Board has brought out comprehensive regional picture of the Aquifers in terms of their water quality and yield potential. To meet the challenges of growing Groundwater demand and sustainability of the resource, an effective aquifer based Groundwater management in the country, through adequate and precise information on aquifers in time and space is the most imperative and desired. The aquifer-mapping programme demands a multi-disciplinary, innovative and modern approach to arrive at a comprehensive aquifer data base under National Aquifer Mapping Programme.

1.1 Background of Aquifer Mapping

'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 modeling, agriculture and soil science, water treatment and remediation, economics and social and environmental sciences etc. Out of these the hydrogeological technique will help as a strong tool to identify the aquifer geometry precisely.

1.2 Scope of Study

At present a generalized picture of aquifer-disposition and their characteristics are known from the existing hydrogeological and surface geophysical data, the borehole lithological and geophysical logs and the aquifer performance tests conducted by CGWB.. The interpretation of existing data on aquifer disposition has necessitated to carry out systematic mapping of aquifers. Further hydro-geological investigation either by geophysical technique or by exploration is proposed for the aquifer mapping. It is to provide adequate and precise subsurface information in terms of aquifer lithology

and geometry leading to 3-dimensional aquifer dispositions. Also it is to establish the most appropriate technique or combination of techniques for identifying the aquifers in different Hydrogeological terrains.

1.3 Objectives

The objective of applying the hydrogeological techniques is to provide more adequate and more precise information on aquifers – shallow and deep including dry and saturated zones with their geometry at scale (1: 50,000) in the area.

The tentative depth of exploration is 200 m in hard rock area. However, the depth of exploration may vary depending on the geological conditions. Additional exploratory wells shall be drilled for validations of aquifer parameter estimations where borehole data are not available.

The information thus generated through additional drilling of boreholes shall be used for refinement of hydrogeological data base in terms of aquifer characterization, yield capacity, chemical quality, selecting areas for artificial recharge and sustainability under varied future demand scenario leading to preparations of aquifer-management plans and recommendations to mitigate mining of aquifer.

1.4 Approach and Methodology

National Aquifer Mapping Programme basically aims for characterizing the geometry, parameters, behavior of ground water levels and status of ground water extraction in various aquifer systems to facilitate planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps and generation of data for filling data gaps and preparation of aquifer maps. The overall methodology of aquifer mapping is presented once the maps are prepared, plans for sustainable management of ground water resources in the aquifers mapped shall be formulated and implemented through participatory approach involving all stakeholders.

1.5 Study Area

Chhindwara district is located on the southwest region of "Satpura Range of Mountains" in M.P. the district is spread over an area of 11815 sq. km and is located at the southern boundary of the state, laying between North latitudes 21^0 28' and $22^0$50' and East longitude 78^0 15' and 79^0 25 falls in the survey of India topo sheets No. 55J, 55K, 55N and 55O. The district is bounded by Narsingpur and Hoshangabad districts in north, Seoni district in the east, Betul district in the west and Nagpur district of Maharastra state in the south (Fig.2).The GW recharge worthy area of district is **8847** sq.kms.

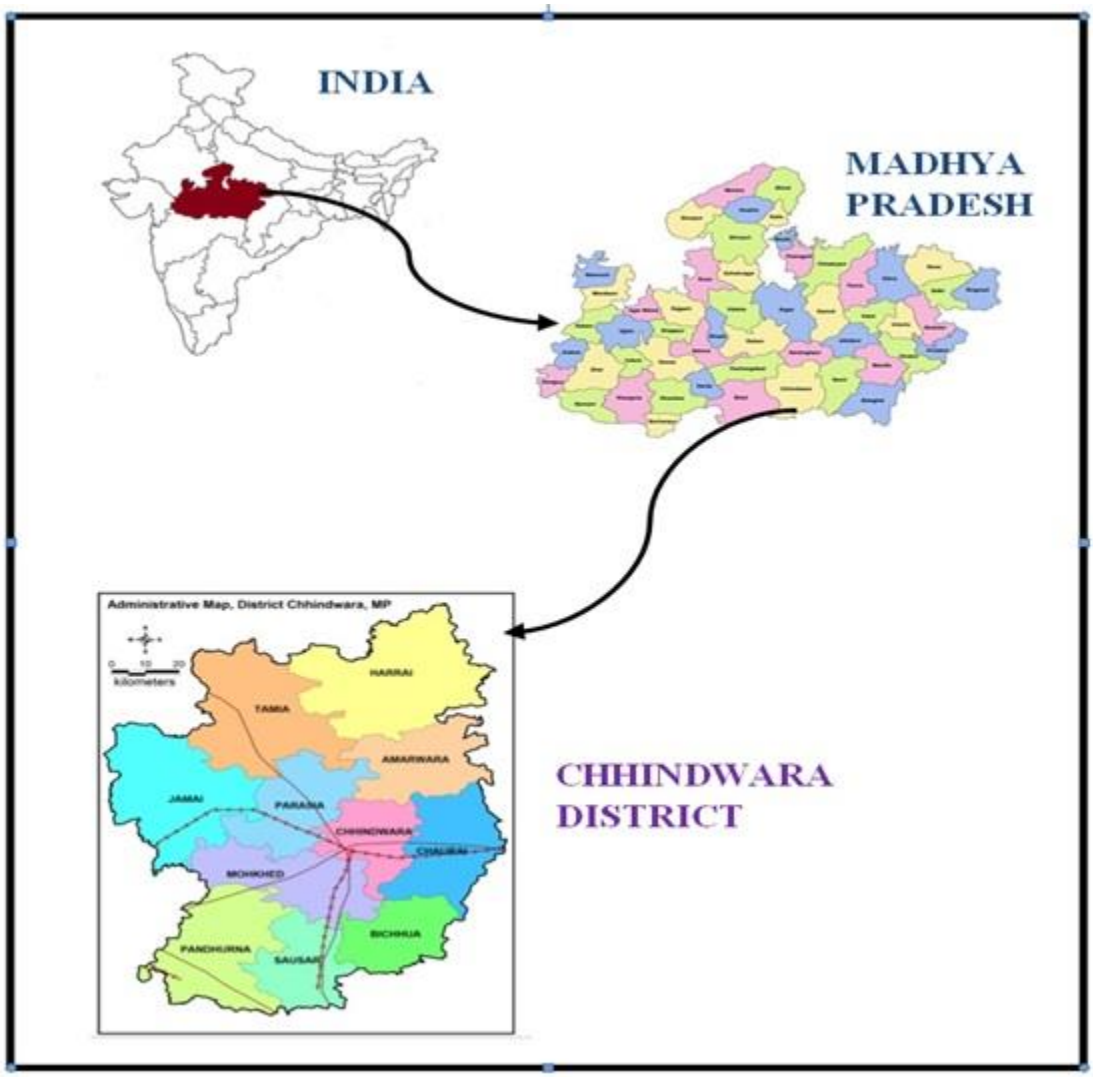

Fig 1: Index Map of Chhindwara District

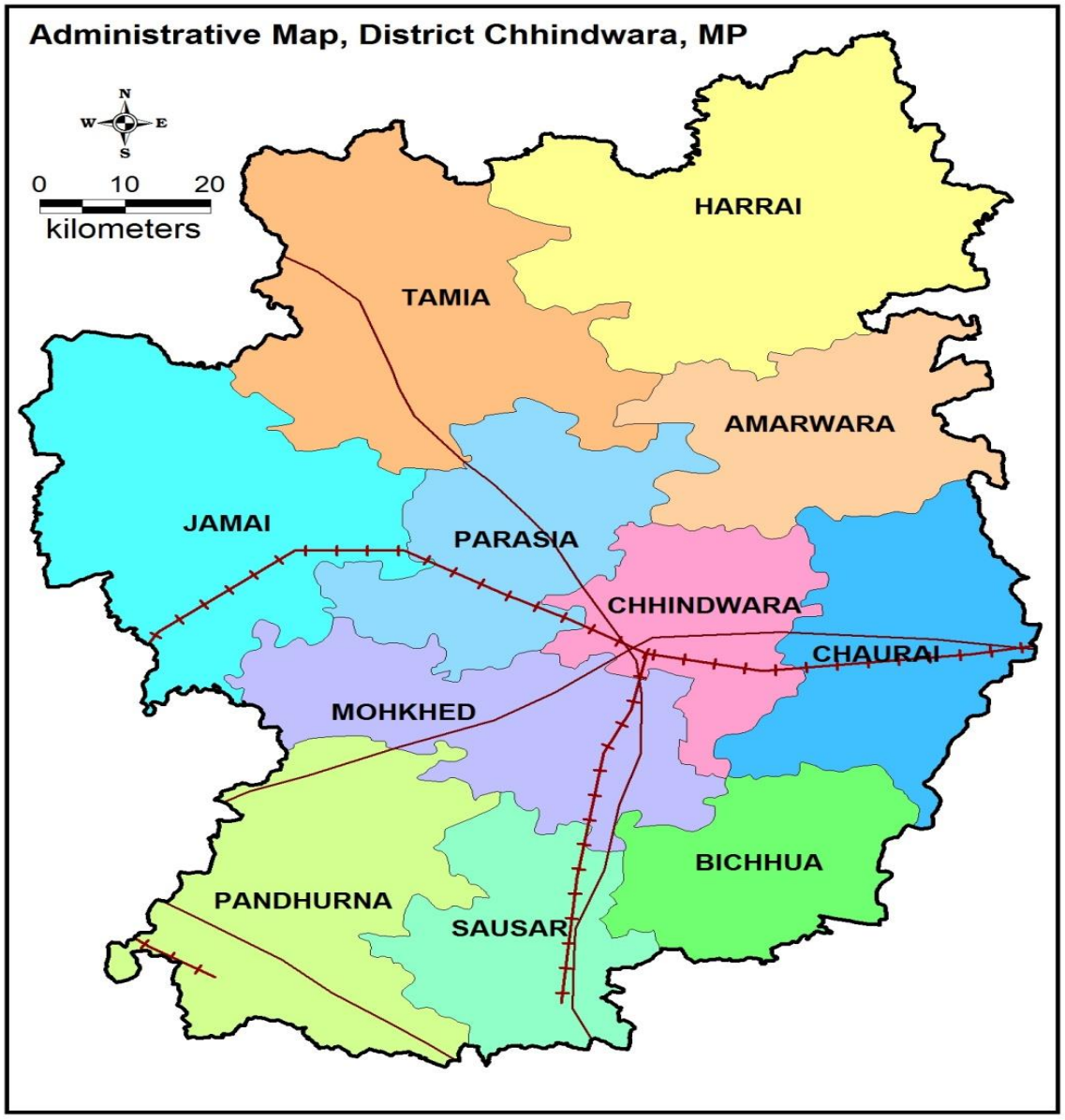

Fig 2: Administrative Map of Chhindwara District

The District is divided into 12 Tahsils namely Chhindwara, Tamia, Parasia, Jamai, Chourai, Amarwara, Sausar, Bichhua Umreth, Mohkhed, Harrai and Pandhurna and 11 Development Blocks namely Chhindwara, Mohkhed, Tamia, Parasia, Jamai, Amarwara, Harrai, Chourai, Sausar, Bichhua, and Pandhurna. There are 1998 villages in the district and 808 nos. panchayats.

As per census **2011**, the total population of the district is 2090306.

Table 1: Details of Administrative Units of Chhindwara district.

Total Blocks	Area (sq km)
Total Geographical Area (sq km)	11815
Recharge worthy Area (sq km)	8847.77
Hilly Area (sq km)	2967.23

S. No.	Block	Total Geographical Area in sq. km.	Recharge worthy Area in sq. km.	Hilly Area
1	Amarwara	1022	939.55	82.45
2	Bichhua	527	413.84	113.16
3	Chhindwara	683	635.16	47.84
4	Chourai	1172	1139.73	32.27
5	Harrai	2107	1272.38	834.62
6	Jamai	1424	966.04	457.96
7	Mohkhed	775	708.86	66.14
8	Pandhurna	972	871.86	100.14
9	Parasia	787	690.20	96.80
10	Sausar	808	693.13	114.87
11	Tamia	1538	517.02	1020.98
Total		**11815**	**8847.77**	**2967.23**

The northern part of the district lies in Narmada basin while the southern part lies in Wainganga sub basin of Godavari basin. The total catchments areas of the Narmada & the Wainganga rivers falling in the district are 3,555 and 8,295 Sq. km respectively. The major tributaries of the Godavari River are Kanhan, Pench and Wardha, while Sakkar, Sitarewa and Dudh are tributaries of Narmada River.

1.6 Rainfall and Climate

Rainfall

A hot summer and general dryness characterize the climate of the area, except during the southwest monsoon season. The year may be divided 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.

Normal Annual Rainfall and Monsoon rainfall (mm)

Monsoon Rainfall	Non Monsoon Rainfall	Annual Rainfall
1019.4	120.0	1139.4

The normal annual rainfall of Chhindwara district is 1139.4 mm. The district receives maximum rainfall during south-west monsoon period i.e. June to September. About 85.7 % of the annual rainfall falls during monsoon season. Only 14.3 % of the annual rainfall takes place between Octobers to May period. Thus, surplus water for ground water recharge is available only during the southwest monsoon period.

The normal maximum temperature noticed during the month of May is 39.40 C and minimum during the month of December 9.80 C. The normal annual mean minimum and maximum temperatures has been worked out as 18.20 C and 30.60 C respectively. During the south-west monsoon season, the relative humidity generally exceeds 87% (August month) and the rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less than 33%. May 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, 9.5 km/hr observed during the month of June and minimum, 3.3 km/hr during the month of November. The average annual wind velocity in is 5.4km/hr.

Temperature

The normal maximum temperature noticed during the month of May is 39.4^0 C and minimum during the month of December 9.8^0 C. The normal annual mean minimum and maximum temperatures has been worked out as 18.2^0 C and 30.6^0 C respectively. During the south-west monsoon season, the relative humidity generally exceeds 87% (August month) and the rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less than 33%. May 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, 9.5 km/hr observed during the month of June and minimum, 3.3 km/hr during the month of November. The average annual wind velocity in is 5.4 km/hr.

Humidity

During the south-west monsoon season, the relative humidity generally exceeds 87% (August month) and the rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less than 33%. May is the driest month of the year.

Wind Velocity

The wind velocity is higher during the pre-monsoon period as compared to post-monsoon period. The maximum wind velocity, 9.5 km/hr observed during the month of June and minimum, 3.3 km/hr during the month of November. The average annual wind velocity in is 5.4 km/hr.

1.7 Hydro-meteorological Study

Chhindwara district received mostly rainfall during south west monsoon season (June to September) and maximum in the month of July that is about 370mm/month followed by August (307mm/month), September (201mm/month) and June (150mm/month). There are large inter-annual variations in rainfall. Inter-annual variations in rainfall for the thirty years period are shown in figure 1. During the last thirty years Chhindwara District received highest rainfall in the year 1999 (1639mm), 2013(1622) and 2019 (1632mm) with a deviation of 34 %, 32% and 33% from normal

rainfall respectively and lowest rainfall in the years 1991(800mm), 2004(768.25mm) and 2017(864.8mm) with a deviation of -34%, -37% and -29% respectively. An increasing rainfall trend of 0.63mm/yr is observed however this is not statistically significant. Decadal pattern in rainfall during monsoon season is shown in figure 2. It has been found that decade 1 received 15% more rainfall during the monsoon season as compared to decade 2 and decade 3 received more rainfall in June, July and august as compared to the corresponding months of decade 1 & 2.

Chhindwara District average maximum temperature varies from 26°C to 40 °C and average minimum temperature from 11 °C to 26 °C within a year (shown in figure3). Chhindwara experiences highest average maximum temperature in April (38°C) and May (40°C) and lowest in December (25°C). During winter season, in December and January average night temperature reaches 11°C. Due to strong warming in April and May maximum evaporation occurs in the same month that is 8.3 mm/day and 8.6mm/day respectively. In the monsoon season due to over cast weather condition lowest evaporation takes place in the district.

Rainfall data source is IMD grid https://indiawris.gov.in and temperature and evapo-transpiration data is downloaded from the indiawaterportal.org. Annual cycle in temperature and evapo-transpiration is calculated by using data from 1901 to 2002.

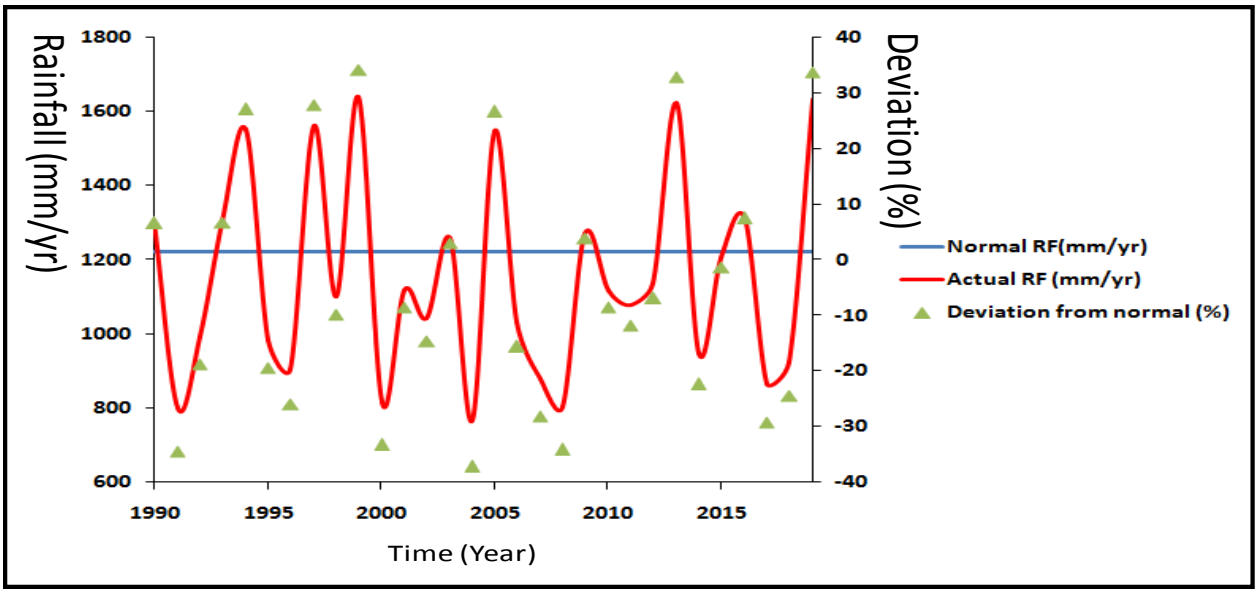

Fig 3: Inter-annual variation of rainfall (mm/yr) and percent deviation from normal rainfall.

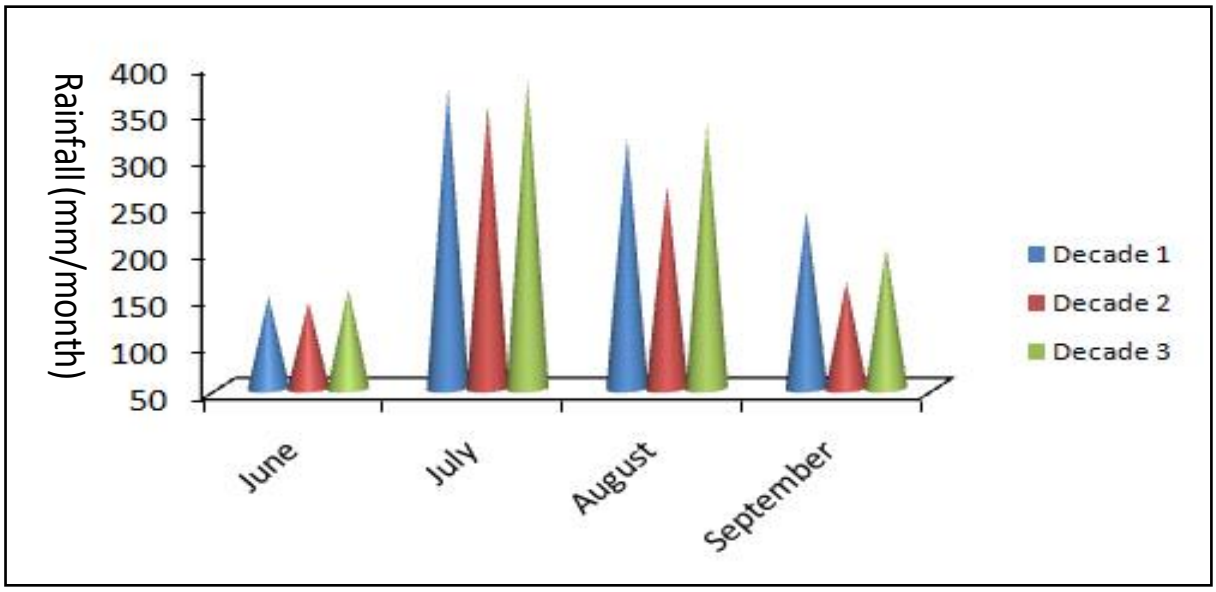

Fig 4: Rainfall (mm/month) during monsoon season in decade 1 (1990-99), decade 2 (2000-09) and decade 3 (2010-19)

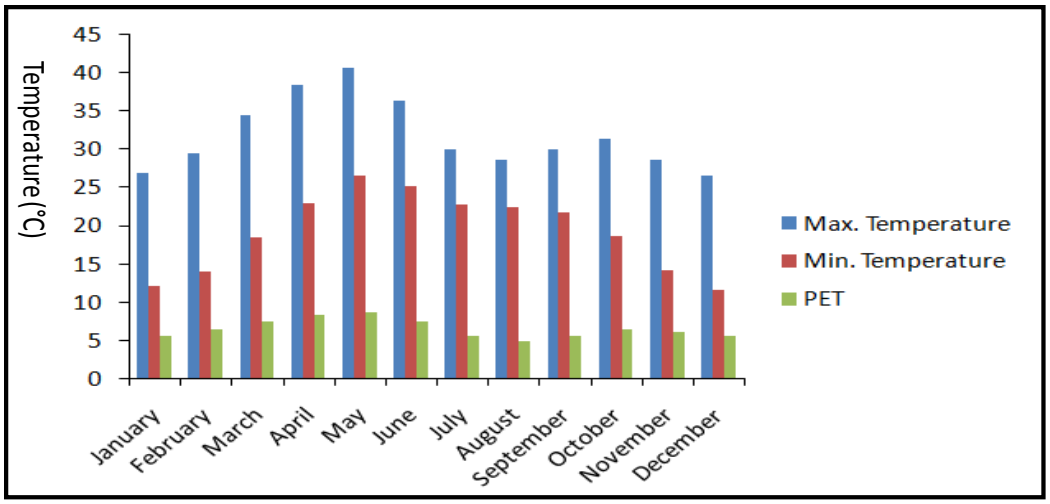

Fig 5: Annual cycle of maximum temperature, minimum temperature and potential evapotranspiration.

1.8 Physiography

Physiographically the Chhindwara ditrict has been divided into two main geomorphic units – one is Satpura plateau and other is Nagpur plateau. The hill ranges lying in the northern part of the district belong to the Mahadeo hill ranges of Satpura mountains stretching nearly east – west. Other hills are Mohtur, Kalapahar and Dulhadeo. The altitude of these hilly areas ranges between 321 and 1204m above M.S.L as shown in Fig. 6. The highest elevation is 1204.2 m above M.S.L. near village Jamundhana in Tamia block which is 58 Kms. From Tamia. While the lowest elevation points is 321 m. above M.S.L. near village Chichkheda in Sausar block.

These hills from the water divide. The northern part is occupied by northerly flowing Denwa, Dudhi, Satwas & Sakkar rivers which are tributaries of Narmada river. The Southern part of the area is drained by Jam Kanhan, Pench rivers which are tributaries of the Wainganga river.

Physiographically the district can be divided in to four parts.

1. Northern Hilly Region
2. Central High Plateau Region
3. Southern Low grounds

4. Upland Trough of Jam Kanhan rivers.

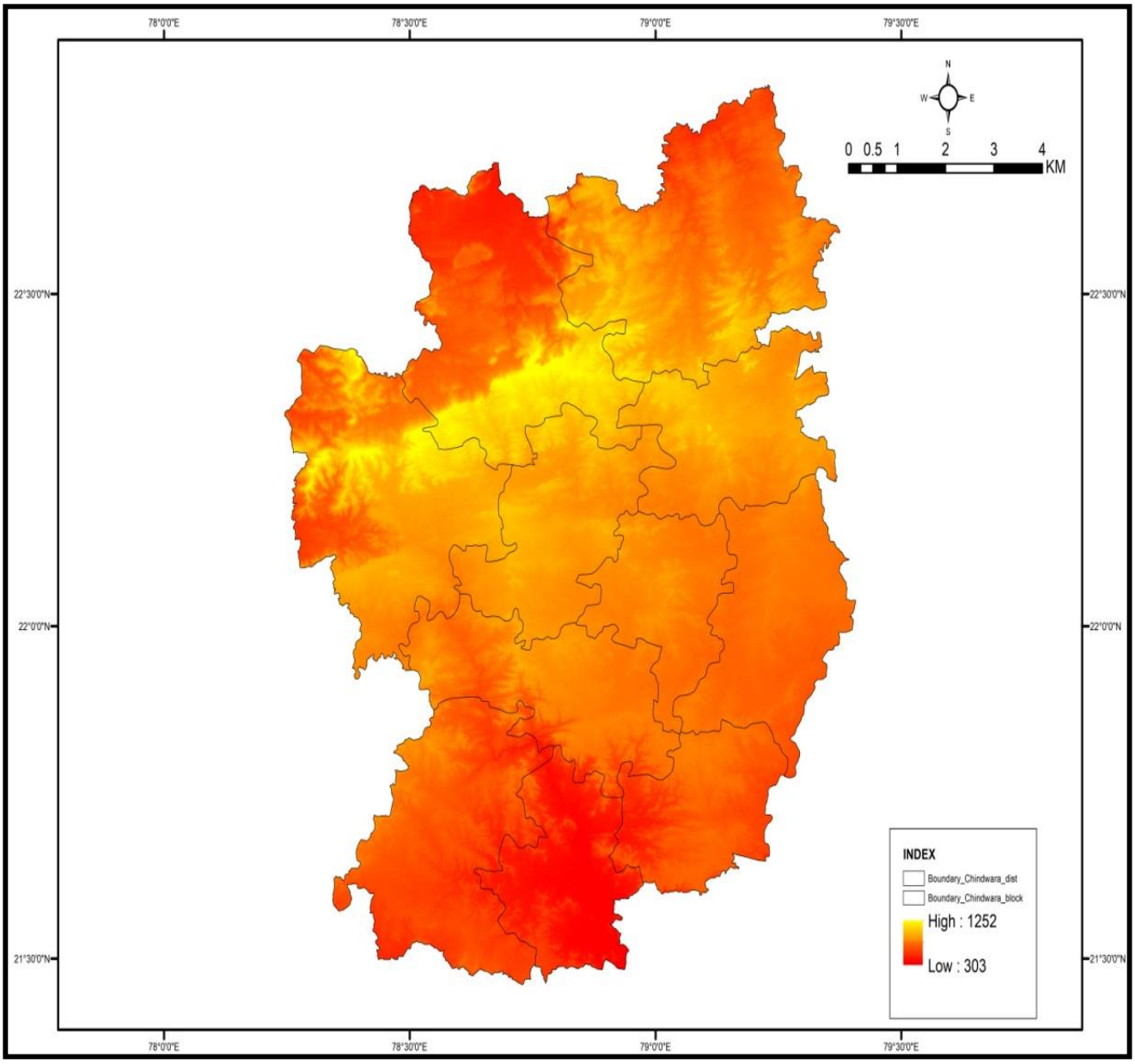

Fig.: 6. Digital Elevation Map

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1.9 Geomorphology

The district exhibits varied geomorphic units which give brief and synoptic idea of general topography of the terrain. Presence of fluvial units showing occurrences of alluvium in the flood plains of all major streams and rivers, buried pediplains showing denudational hills of sand stone as seen in western past of the district. Similarly structural hills of Gondwana in northern part of the district. Denudational hills in southern part and dissected Deccan plateau in eastern and north eastern part of district. (Table-2)

1.10 Drainage

The prominent streams of the district are Kanhan, Pench and wardha of Godavri basin and Shakkar, Sitarewa, Dudhi, Tawa of Narmada basin. Seventy percent of district lies in Godavari basin and thirty percent in Narmada Basin.

The area is traversed by a member of streamlets most of them are seasonal. There are various types of drainage patterns in the district area owing to various lithologies and differential permeabilities. Dendritic pattern is, in general, the most common type in the area (Fig 7). Besides, trellis and radial pattern are also depicted at places.

The streams of dendrirtic pattern are insequent in nature and depicted by all the lithologies granites, sedimentaries and basalts in the north-western, northern, central and north-eastern parts. The trellis pattern shows a marked structural control by joints, faults, fractures or their combination. Trellis pattern is depicted by Gondwana forming elongated ridges parallel to strike direction in the north-western parts. The centrally elevated geological features like domes, volcanic cones, isolated conical hills always show radial type of drainage pattern. This pattern is characteristic of Deccan conical hills i.e. 865 mamsl hill NW of Hatiyagardhana, 799 mamsl hill north of Richhara south-east of Nawegaon are typical examples of this pattern.

Table 2: Hydrogeomorphic Units and Their Characterstics in Chhindwara District.

Map Annotation	Geomorphic Unit	Lithology	Structure	Description	G.W. Occurrence
AP	Alluvial Plain	Constitutes gravel sand silt or clay size unconsolidated material		A level of gently sloping tract or a slightly undulating land surface produced by deposition of alluvium.	Good to Excellent depending upon thickness of soil cover.
VF	Valley Fills	Constitutes boulders, cobbles, pebbles, gravels,sand,silt and clay sized material	The valleys are sometimes fracture controlled	The unconsolidated sediments deposited so as to fill or partly fills a valley some times controlled by fracture forming linear depressions.	Good to Excellent depending upon thickness of material deposited.
DNH(V)	Denudational Hills(volcanic)	Composed of Basltic rocks of Deccan Traps	HIghly jointed and fractured	High relief steep hills and step like terraces composed of basalt.	Poor, Good along lineament and depressions
DPT	Dissected Deccan Plateau	Composed of Basalts of Deccan Traps	Fractured and jointed	Low to moderate relief undulating topography. Normally cultivated	Poor to moderate, good along lineaments
P(SST)	Pediment(Sandstone)	Ferruginous sandstone of Gondwana dominates as underlying lithology.	Criss Cross by fractures etc.	Gently slopping erosional surface covered with detrirus of sandstone and thin veneer of soil	Moderate to good.
SH(GW)	Structural Hills (Gondwana)	Composed of sandstone, clay and coal bearing strata of Gondwana formations.	Associated with folds, faults, fractures and joints	Linear to arcuate hills showing definite trends, red to yellow soil of varrying thickness support dense forest.	Moderate to good, Excellent along faults and lineaments

P(M)	Pediment(Metamorphic)	metamorphic rocks ie. gniess, schist etc of Sausar group	Criss Cross by fractures, joints etc.	Broad gently sloping erosional surface with detritus of metamorphic rock and thin veneer of soil.	Moderate, good along lineaments.
SH(M)	Structural Hills(Metamorphic)	Composed of Quartzites schist and gneiss of Sausar group.	Associated with folds, faults, fractures and joints	Linear to arcuate hills showing definite trend lines.	Poor to moderate, Good along lineaments.
DNH(G)	Denudational Hills(granite)	Mainly composed of granite of Sausar group	Jointed and fractured	Moderate to high relief mostly barren.	Negligible to poor, Moderate along lineaments.
PT	Plateau	Formed over metamorphic rocks of Sausar group.	Criss Cross by fractures, joints etc.	Extensive flat landscape.	Moderate, good at lineaments and their intersections
Lineament	Linear Fracture	Cuts across various litho units	Linear feature	Fault lines, fractures, joints, shear zones, contact zones, other linear features and straight stream courses	Good, Excellent at intersection of lineaments.

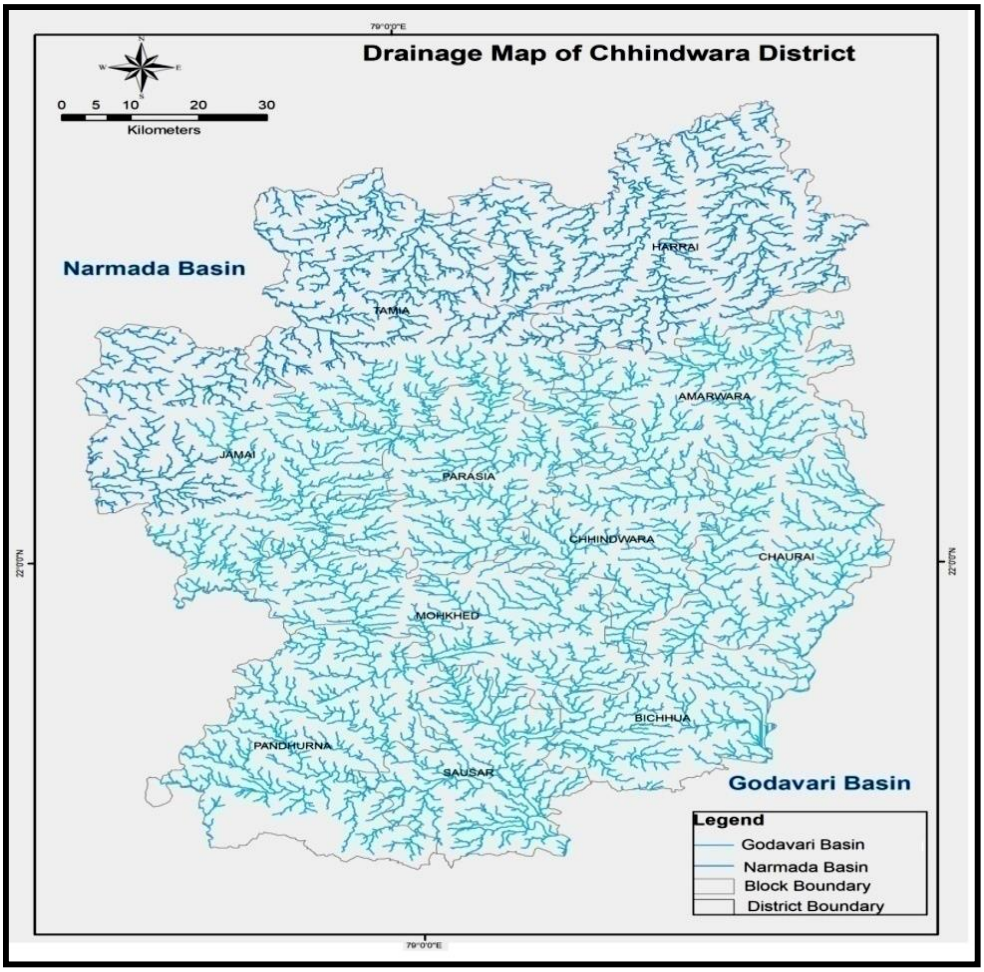


Fig: 7. Drainage Map

1.11 Soils

The soils in the district are generally of three types Viz., black cotton soil, sandy loam soil and clayey loam soils. The black cotton soils occur mainly in Sausar Tahsil while sandy loam soil is found in Chhindwara Tahsil. The clayey loam is predominant in Amarwara Tahsil. The northern hilly region covered by loamy soils, are very shallow, somewhat excessively drained, developed by moderately steep slopes and are marked by severe erosion.

1.12 Geology

General Geology

Geologically the area covered by Chhindwara district is occupied by the rocks belonging to Archaeans, Gondwanas, Deccan Traps and Recent river alluvium.

Table 3: Stratigraphic Sequence

Age	Formation	Rock Types
1	2	3
Recent	Soil River alluvium	Sandy, loamy, black cotton soil clay with intercalation of sandy and gravely layers
Lower Eocene to Cretaceous	Deccan traps with intertrappean beds	Massive, vesicular and zeolitic basalts greenish to dirty yellow coloured clay, green earth red bole beds.
	Infra Trappeans	Lameta sandstones and clays
----------	Unconformity----	----------
Upper Triassic	Upper Gondwana (Denwa Bagra Stage)	Sand stone and Clays
Permocarboniferous	Lower Gondwana	Moture sandstone and clay, Barakar sandstone and shales, Talchir sandstone and clays
----------	Unconformity----	----------
Archaean	Sauser series	Gneisses, schists, marbles, granulites

Alluvium:

The Recent Alluvium is generally restricted to narrow and small belts along the banks of the rivers the Kanhan and the Pench. The thickness of alluvium consists of mainly clayey material intercalcated with thin layers of sand and gravels and sandy silt.

Deccan Traps:

The major portion of Chhindwara district is covered by Deccan traps. These are observed in Amarwada, Pandhurna, Mohkhed blocks and in parts of Chhindwara,

Chourai, Harrai, Bichhua, parasia, Sausar and Tamia blocks. They consist of different lava flows separated by intertrappeans of red bole beds. Each flow, in general, comprises lower massive basalt unit and upper vesicular basalt unit. In some of the flows zeolitic basalts also occur at the base of the flow. In Chhindwara district it is reported that 16 flows have been identified with an average thickness of 21 m. In Sausar and Pandhurna blocks the average thickness for 7 flow have been found to be about 17 m. Some of the individual flows have been found to be extending for distances of 100 Km and more between Chhindwara and Nagpur district.

In Pandhurna – Sausar area it has been observed that each flow consists of (i) intensive fractured zone at the base then (ii) massive (iii) profusely jointed zone with spheroidal weathering and (iv) upper vesicular zone.

Massive basalts are steel grey to grey in color, occasionally brownish in color fine to medium grained hard and compact in nature. At number of places they are jointed and weathered, when weathered they exhibit spheroidal type of weathering.

Vesicular basalts are greenish grey to brownish grey in colour with vesicles. The size shape and distribution of vesicles varies laterally and vertically in different flows. vesicles are rounded to subrounded and irregular in shape and partly filled up by green earths, siliceous zeolitic material locally they are known as 'Urdya'.

Zeolitic basalts are usually purplish grey in colour and contain numerous irregular shaped vesicles filled up by zeolites. In situ, these rocks are very hard and compact but when exposed to atmosphere they crumple into pieces. These are locally known as 'Keet'.

Intratrappeans are mostly greenish or dirty yellowish clayey material. At times they are found as cherts, impure limestone also fossiliferous. At some places the flows are separated by Red bole or bole beds. Red bole beds are red coloured clayey material. While bole beds are light green coloured clayey material. Red bole and bole beds at some places are compact in nature also.

Intratrappeans:

The Intratrappeans in Chhindwara district are constituted of lacustrine deposits i.e. Lametas. They are observed covering a very small patch in Sausar block. The sandstone are fine to coarse grained and white, yellowish white in color. Occasionally they are gritty and with cherty bands. The clays are of variegated colours, viz buff purple, yellow etc.

Lower and Upper Gondwana:

The lower Gondwanas are represented by Talchir, Barakar and Moture sand stones and shales and clays. These rocks are observed in Parasia and Junnaredeo (Jamai) blocks.

The Talchir shales are olive green in colour with typical appearance. Sandstones are dirty yellow to greenish coloured, medium to coarse grained. The Barakar sandstones are generally medium to coarse grained, sometimes gritty in nature, white to fawn in colour. The feldspar of Barakar sandstones are generally Kaolinised forming fine clay matter, they consist of coal seams and often Pyritic. The famous Pench-Kanhan Coal fields exist in Parasia and Junnardeo blocks. In this area, numbers of coal mines are operated by Western Coal Fields Ltd. These sandstones are intercalated with shale and carbonaceous shale bands and clays. The Motures are represented by white sand stones with intercalation of red, yellow and carbonaceous shale. The sandstones are fine to medium grained. Moture clays are greenish to red in color and mottled in nature.

The upper Gondwanas are mainly found in Tamia and parts of Harrai blocks. They are constituted of Denwa and Bagra sandstones and shales. They are supposed to be equivalent to Maleri stage. Sandstones are buff red coloured fine to coarse grained, clays are buff coloured and at places they are ferruginous in nature. Most of the area occupied Denwa and Bagra rocks is hilly.

Archaeans :

The archaeans are represented by Sausar series. The main rock types are gneisses and schists, granulites, marbles and Gondites. The area forms the western part of the famous Balaghat-Nagpur-Chhindwara manganese belt. The sediments

are more calcareous as compared to more argillaceous sediments in Balaghat district. The Manganese horizon generally occurs associated with argillaceous material rather than calcareous material. These rocks are observed in Sausar, Bichua, Chhindwara and Jamai blocks.

Gneisses are generally leucocratic and fine to medium grained in texture. The main minerals are quartz, feldspar and biotite mica with accessory mineral like epidote, hornblend and tourmaline. The gneisses are granite gneisses or biotite gneisses. Schists are in general biotite or muscovite quartz schists, fine grained with foliation. These rocks are intruded by pegmatite dykes and veins and quartz veins. The width ranges from few centimeters to 1.5 m.

Granulites are white to dirty white coloured, hard and compact in nature. They consist of feldspars and quartz with epidote as accessory mineral, when weathered they become friable.

Marbles are grey, pink and flesh coloured, coarse grained, hard and compact and at places show Karstification. At places they are dolomitic. Serpentine marbles are also present in the area near Maligaon (12^0 39', 78^0 51', 55K/14) in Sausar block Serpentine marbles are greenish grey in colour.

Gondites occur in a very small area near Kachhidhana (21^0 43', 78^0 47', 55K/14) in Sausar block. They are leucocratic, Coarse grained with microline feldspar, quartz and manganese minerals, mainly pyrolucite.

1.13 Hydrology and Surface water utilization

Surface water Resources:

Chhindwara district lies in parts of the Narmada basin and the Gondwana basin. The total catchment areas of the Narmada & the Wainganga rivers falling in the district are 355.5 and 829.5 (thousand hectares). The major tributaries of the Godavri river are the Kanhan, The pench and the wardha, while the Sakkar, the Sitarewa, Dudhi and Tawa are tributaries of Narmada river.

The catchment area and their lengths in the district are tabulated below.

Table 4: River Data, Chhindwara District

S.No.	Basin	Tributaries	Catchment area in (000ha)	% of catchment area in district	Lenght of tributaries(Km) in district
1	2	3	4	5	6
1.	Godavari	Kanhan Pench Wardha Total-A	320.00 484.00 25.50 829.50	27% 41.90% 2.10% 70.00	176 184 -
2.	Narmada	Shakkar Sitarewa Dudhi Tawa Direct catchment Total-B	98.6 79.0 60.0 52.0 65.9 355.5	8.30% 7.70% 5.00% 4.30% 6.70% 30.00%	80 52 25 19 - -
		Total-A+B	1185.00	100.00	

The water availability at 75% dependability for above sub-basin in table-5 given below:

Table 5: Water Availability Chhindwara District.

S.No	Sub-basin	Catchment area in district Sq.Km.	Yield per Sq.Km. MCM	Total yield MCM
	Godavari Basin	-	-	-
1.	Kanhan	3200	0.469	1500.80
2.	Pench	4840	0.469	2269.96
3.	Wardha	255	0.239	60.69
	Total-A	8295		3831.45
	Narmada-Basin			
1.	Shakkar	986	0.471	464.41
2.	Sitarewa	790	0.471	372.60
3.	Dudhi	600	0.471	282.60
4.	Tawa	520	0.471	244.90
5.	Direct Catchment	659	0.471	310.39
	Total-B	3555		1674.41
	Total A+B	11850		5505.86

Irrigation Projects:

There was no irrigation facility from Govt. sources available in the district prior to 1951-55, only irrigation from private sources was available. In order to enhance the irrigation potential of district by utilizing surface water, various minor irrigation schemes were taken up since 1960-61.

The Waghya nala tank and Kanhargaon project are the only completed medium schemes in Sausar and Mohkhed blocks respectively. There are 18 No. of minor schemes which are completed and 35 minor schemes are under construction till 1985. The potential created during 1998-99 from 41 Schemes (18 completed and 23 under construction) is 12119 ha and are irrigated in 7492 hectares, the details of which are furnished in Table-15.

The salient features of some of the completed and under constriction schemes are given in table 15 and shown in Plate No. III

The total length of the canals in the district is 188783 m. The total water spread area of the tanks the district in 1471 ha.

1.14 Land Use, Irrigation, and Cropping Pattern

A perusal of the data shows that about 23.45% (2771.61 Sq.km.) percent of the total geographical area is under forest cover. Nearly 42.69 % (5045 Sq km) of the total geographical area is under net area sown. The net irrigated area is 18.28 % (2160.37 Sq km).The major crops are Soyabean, Maize, cotton, Ground nut and Jawar.

The area under various crops in the district is given in Table 9. Wheat is the major Rabi crop. Area under pulse cultivation is also high of gross cultivated area. Oil seed production is also carried out in the area.

Table 6: Land use (Ha)

S.No.	Block	Geographical Area	Forest Area	Agriculture Land	Waste Land	Net Sown Area	Double Crop Area	Land not available for agriculture	Follow Land
1	Chhindwara	62141	1831	75	4344	41897	31985	9522	4472
2	Mohkhed	68989	6712	0	850	51791	34759	6657	2979
3	Tamiya	138739	87123	3445	6648	32344	8556	3744	5435
4	Jamai	110779	44087	9101	6129	37057	12384	6948	7435
5	Parasiya	69293	9796	2367	3774	43216	24631	7031	3109
6	Amarwara	82784	8285	3015	4414	53644	15586	6669	6857
7	Harrai	162348	82916	4542	7060	54054	15667	7452	6324
8	Chourai	92104	3237	1765	2844	66631	48535	9934	7688
9	Sausar	69297	11595	1241	2895	40355	4604	10503	2708
10	Bichhua	45304	11530	337	360	28316	10388	2385	2376
11	Pandhurna	82924	10049	2630	3389	55201	21190	7191	4464
District	**Total**	984702	277161	28518	42707	504506	228285	78036	53847

Table 7: Irrigation Sources

IRRIGATION BY DIFFERENT SOURCES	Areas and Numbers of Structures
Dug wells	96320 Area irrigated= 1553.46 Sq km
Tube wells/ Bore wells	14279 Area irrigated= 503.63 Sq km

Tanks/ ponds	112 Area irrigated= 47.14Sq km
Canals	112 Area irrigated= 254.42 Sq km
Others sources	Area irrigated= 98.08 Sq km

Table 8: Irrigation Area

Block	Tube Well Irrigated Area (Ha)	Dug Well Irrigated Area (Ha)	Ground Water Irrigated Area (Ha)	Canal Irrigated Area (Ha)	Pond Irrigated Area (Ha)	Surface Water Irrigated Area (Ha)	Other sources (Ha)	Total irrigated area (Ha)
Amarwara	3745	11974	15719	3830	395	4225	415	20359
Bichhua	663	9571	10234	90	833	923	112	11269
Chhindwara	7335	23862	31197	2020	778	2798	581	34576
Chourai	9322	26745	36067	10158	516	10674	2347	49088
Harrai	1162	3820	4982	149	210	359	1631	6972
Jamai	6096	5897	11993	0	201	201	608	12802
Mohkhed	4615	29872	34487	1577	1007	2584	80	37151
Sausar	66	8128	8194	1097	0	1097	96	9387
Parasiya	11474	14203	25677	46	284	330	2095	28102
Pandhurna	5868	19806	25674	4927	358	5285	104	31063
TOTAL	**50346**	**153878**	**204224**	**23894**	**4582**	**28476**	**8069**	**240769**

Table 9: Area under Principal Crops (Ha)

	Grain				Pulses			Oilseeds	
Block	**Wheat**	**Peddy**	**Jowar**	**Maise**	**Gram**	**Tuar**	**Urad**	**Groundnut**	**Soyabeen**
Amarwara	15156	1454	983	36342	3950	1506	1168	1432	1768
Bichhua	8036	1044	349	15829	3799	1690	296	577	2881
Chhindwara	28447	267	3	36108	1903	432	106	780	2141
Chourai	35649	1101	12	46773	8299	959	457	1252	8582
Harrai	13447	6980	52	27740	5367	3000	2000	52	303
Jamai	10927	3828	1240	25309	1895	851	252	368	671
Mohkhed	27602	2041	692	34330	2973	674	708	1209	9423
Sausar	2819	14	1439	264	932	6620	38	1902	415
Parasiya	21124	489	345	34880	2764	407	231	667	789
Pandhurna	11119	707	7039	6301	5427	3975	721	6211	7621
Tamiya	4444	3432	219	15406	5142	1421	2350	0	55
TOTAL	**178770**	**21357**	**12373**	**279282**	**42451**	**21535**	**8327**	**14450**	**34649**

2.0 DATA COLLECTION AND GENERATION

2.1 Hydrogeology

The recent alluvium deposits are found at places along the river and major drainage with thickness varying from 5.00 to 30.00 m. Alluvium comprises clayey material with intercalated layers of sand and gravels. The major part of the district is occupied by Deccan Trap, consisting of different lava flows whose thickness ranges between 7 to 21 m. The upper Gondwanas occupy parts of Harrai and Tamia blocks whereas the Coal bearing lower Gondwanas occupies parts of Jamai, Parasia and Jamai blocks. Archaeans are exposed in parts of Sausar, Bichhua, Chhindwara, Jamai and Mohkhed blocks. (Fig. 8)

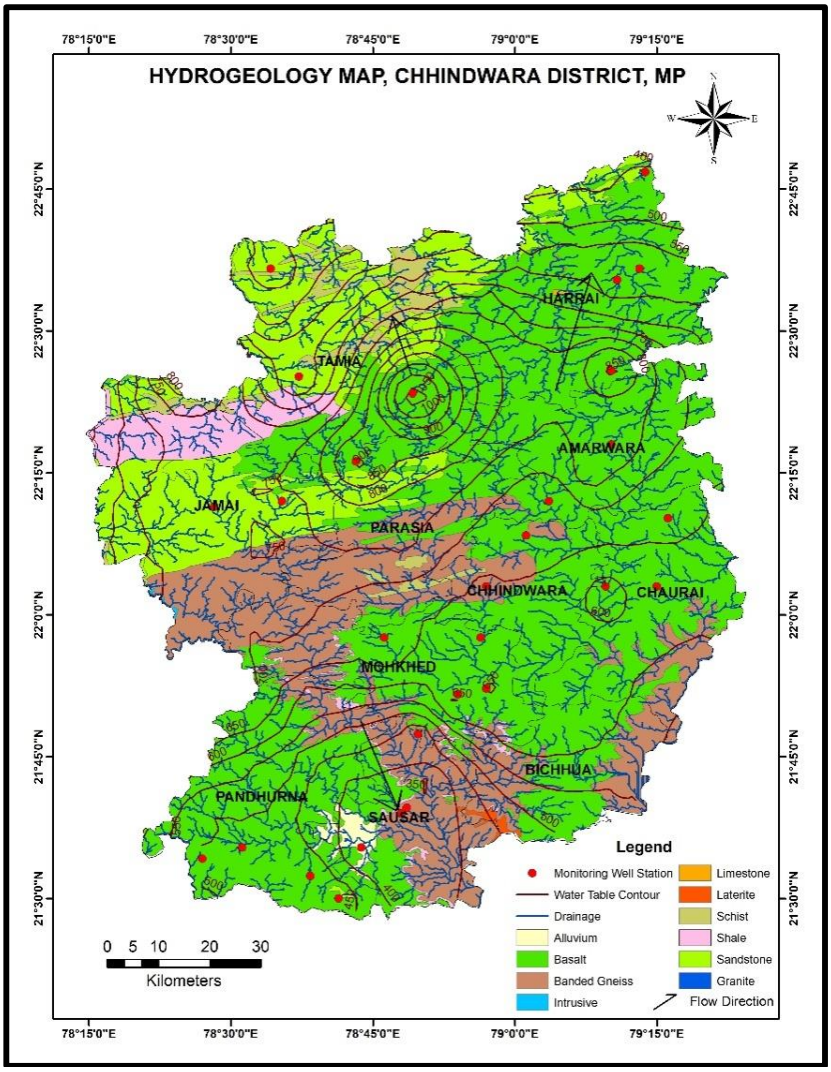


Fig 8: Hydrogelogical Map, Chhindwara District, MP

2.2. Ground Water Scenario

Ground water occurs under unconfined, semi-confined and confined conditions. Alluvium, weathered rocks viz granites/gneisses, sandstones, and basalts form the major aquifer in unconfined condition in shallow depth upto 30 meter.Under semi confined to confined conditions the Gondwana formation semi consolidated ferruginous Barakar sandstones , fractured granites , jointed massive and vesicular basalt, and contact zones of the Basalt and granites are acting as main water-bearing formation at deeper depth upto 200 meter. It is observed that the discharge of dug wells tapping alluvium and vesicular basalt ranges between 80 and 235 m^3/day respectively, while the discharge in jointed massive basalts and weathered gneisses range from 44-177m^3/day and from 61-77m^3/day respectively. Hydrogeological details of some of CGWB exploratory bore wells are given in Table 12. Hydrogeological Map shown in fig no 5.

Water Level

Water level data, including historical data, are essential for not only to know the present ground water conditions but also for forecasting future trends in response to ground water reservoir operations. Using the water level data of 38 monitoring wells (32 are Dugwells and 6 are Piezometers) of Chhindwara district, Pre and Post monsoon depth to water level maps are reproduced.

Pre- monsoon (May 2020)

Depth to water level of shallow aquifer in Pre monsoon in the year 2020 ranges from 1.1 to 18.9 mbgl. Shallow water levels (<5.00m) occur in northern part of the district. Water level varies between 6.0 – 10.0 m noticed in major part of the area and water levels between more than 10 mbgl is observed Eastern & Southern part, where intense agricultural activities are noticed. Pre-monsoon water level map of shallow aquifer shown in figure 9.

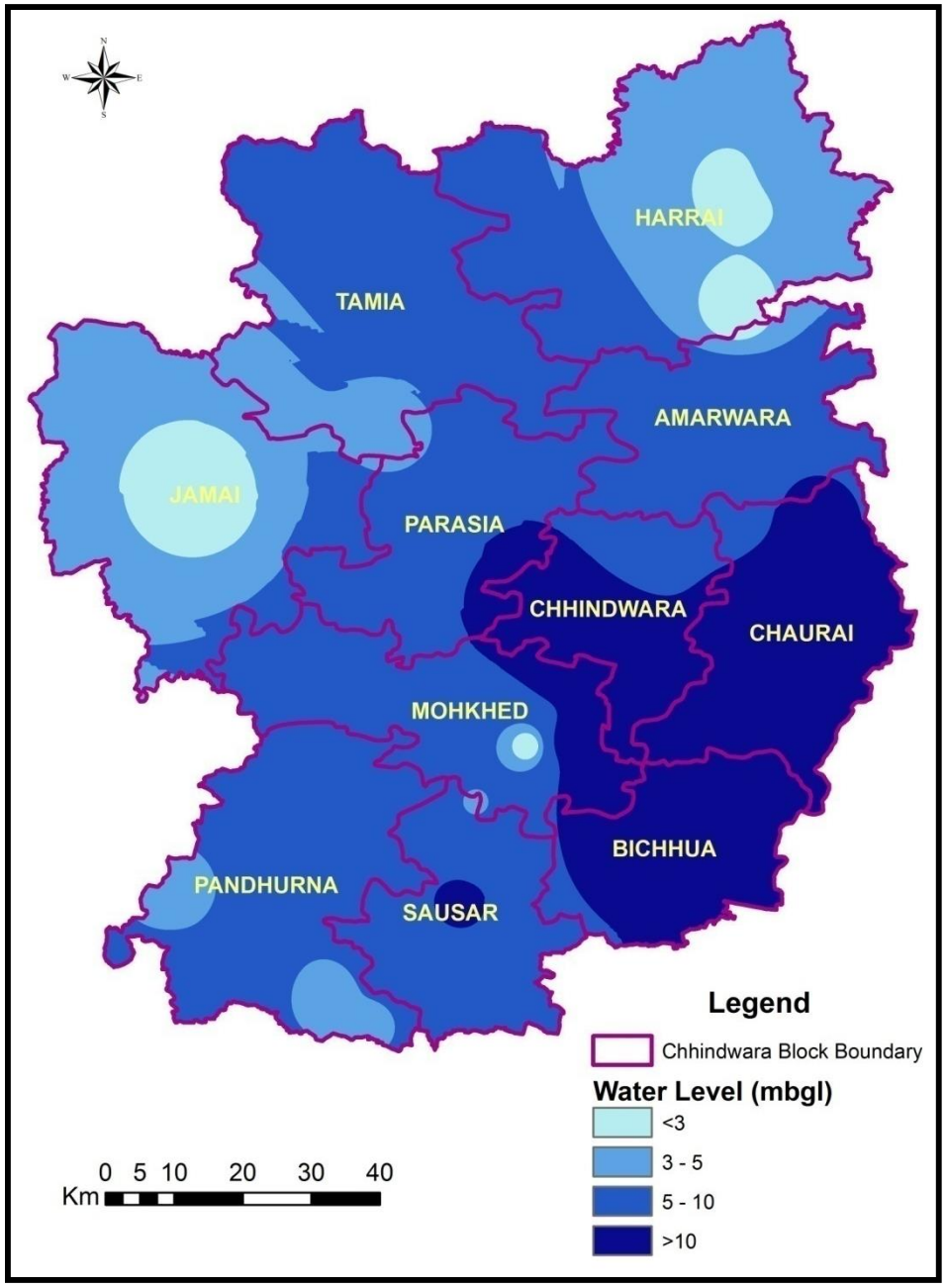


Fig:9 Depth to Water level Map Pre Monsoon (May 2020)

Post- monsoon (November 2020)

During post monsoon period, in shallow aquifer water level ranges from 0.81 to 9.43 mbgl. Shallow water level (<1.00 m) occurs in north, while deep water levels (>11) observed in southern parts. Post-monsoon water level map of shallow aquifer is shown in figure 10.

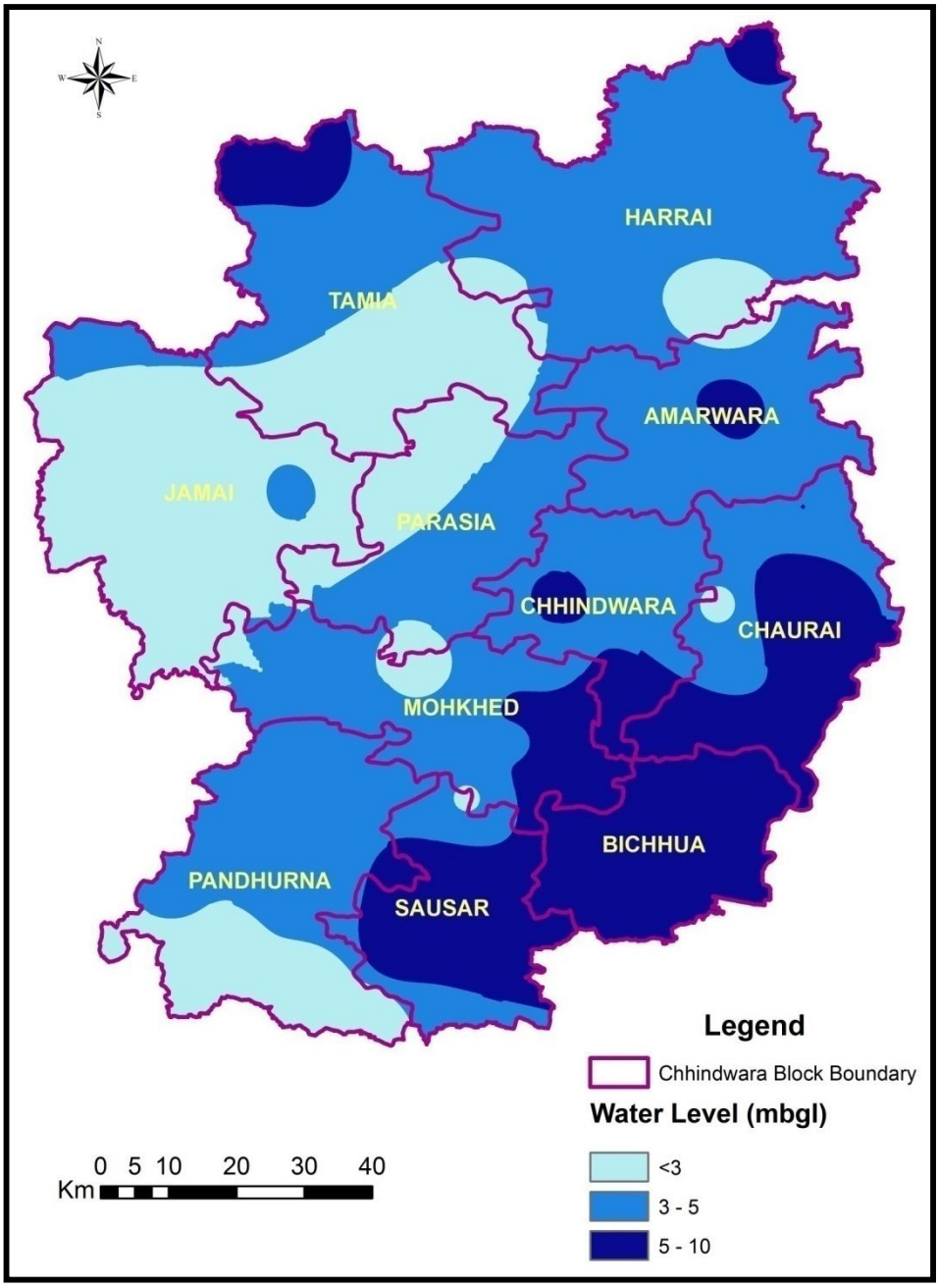


Fig:10 Depth to Water Level Map Post Monsoon (November 2020)

The water level measured during pre and post monsoon period (2020) was used to compute the seasonal fluctuation. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Surla (0.3m) while maximum water level fluctuation was observed at Pandhurna (22.43 m). The water level

fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed.

Table 10: Water Level Fluctuations categories

S. no	Category	Fluctuation in m	% of wells
1	Less WL Fluctuation	0 to 3	40
2	Moderate WL Fluctuation	3 - 6	29
3	High Fluctuation	> 6	31

The analysis indicates that majority of the wells (31%) are falling in high fluctuation range indicating aquifer storage is not good and not suitable for recharge, whereas moderate water level fluctuation are observed in 29 % wells and low water level fluctuation were observed in 40 % wells. The seasonal fluctuation map is presented as **Fig. 11** the perusal of map indicates that fluctuation of greater than 5 m is observed in major part of the area, whereas lower fluctuation of less than 3 m is observed in the north east, North West and southern part of the district.

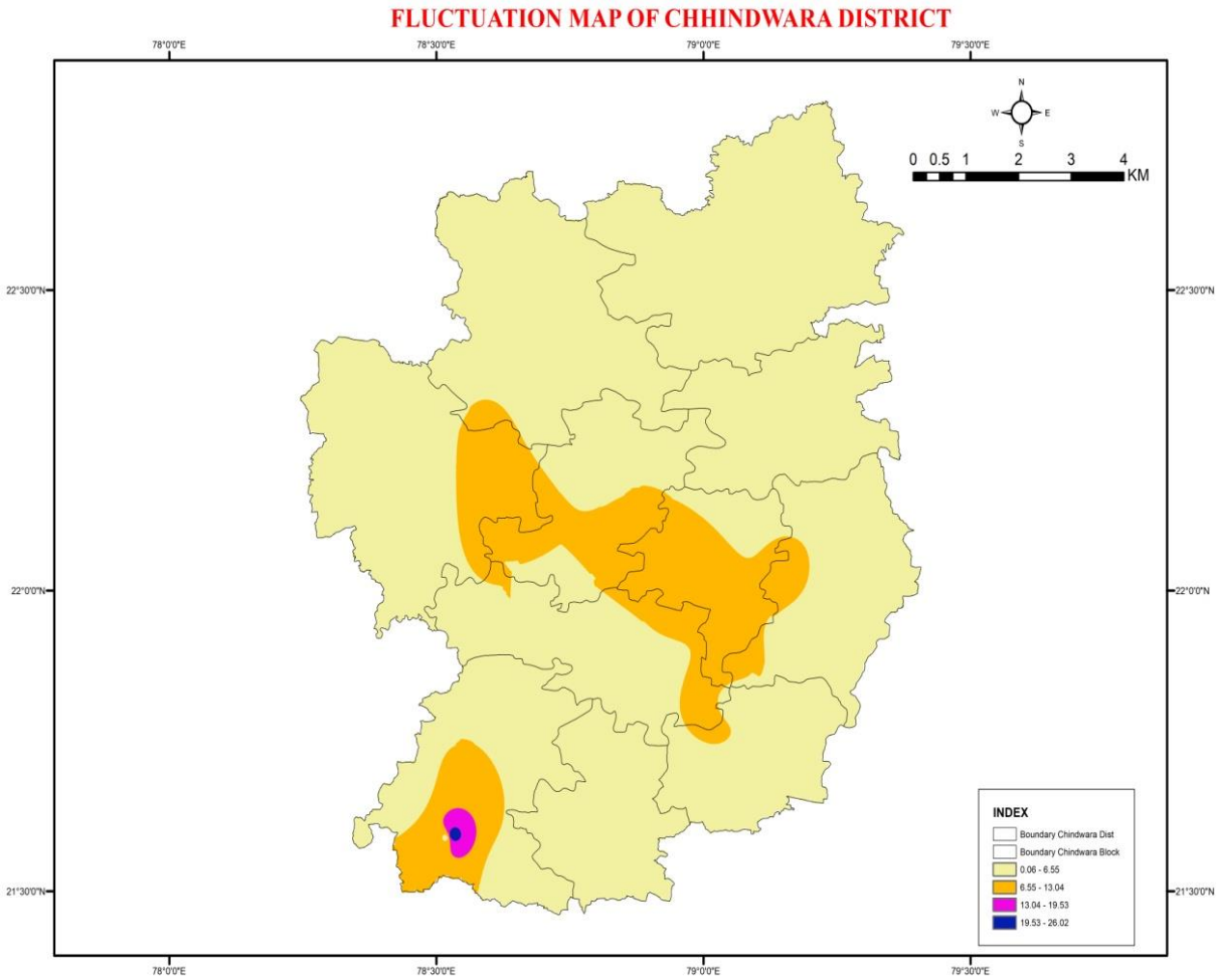


Fig 11: Water Level Fluctuation map of Pre-Monsoon and Post-Monsoon 2020

Ground Water Level Trend:

The decadal pre-monsoon water level trend analysis (**Fig 12**) indicates that during pre-monsoon period, the northeast, northwest and southern part of the district are showing falling trend in 9 wells ranging between 0.6074 and 0.00749 m/yr. Rest part of the district is showing rising trend.

The decadal post-monsoon water level trend analysis (**Fig 12**) indicates that about 95% of the area is showing declining trend. Maximum falling trend is ranged between 0.0124 to 1.34 m/yr. Only a small Southern & central part of the district and small part of Pandhurna and Parasia block are showing rising trend in water levels.

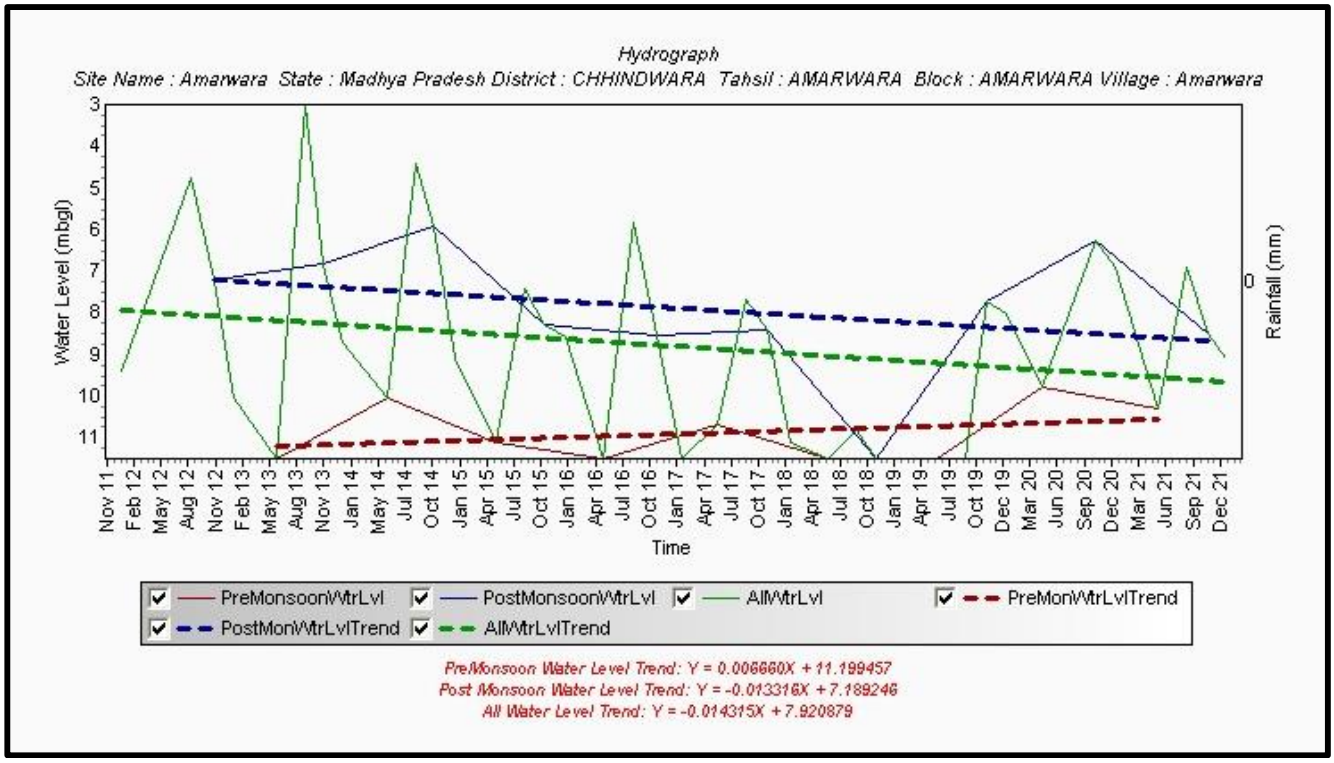


Fig 12(a): Hydrograph Amarwara

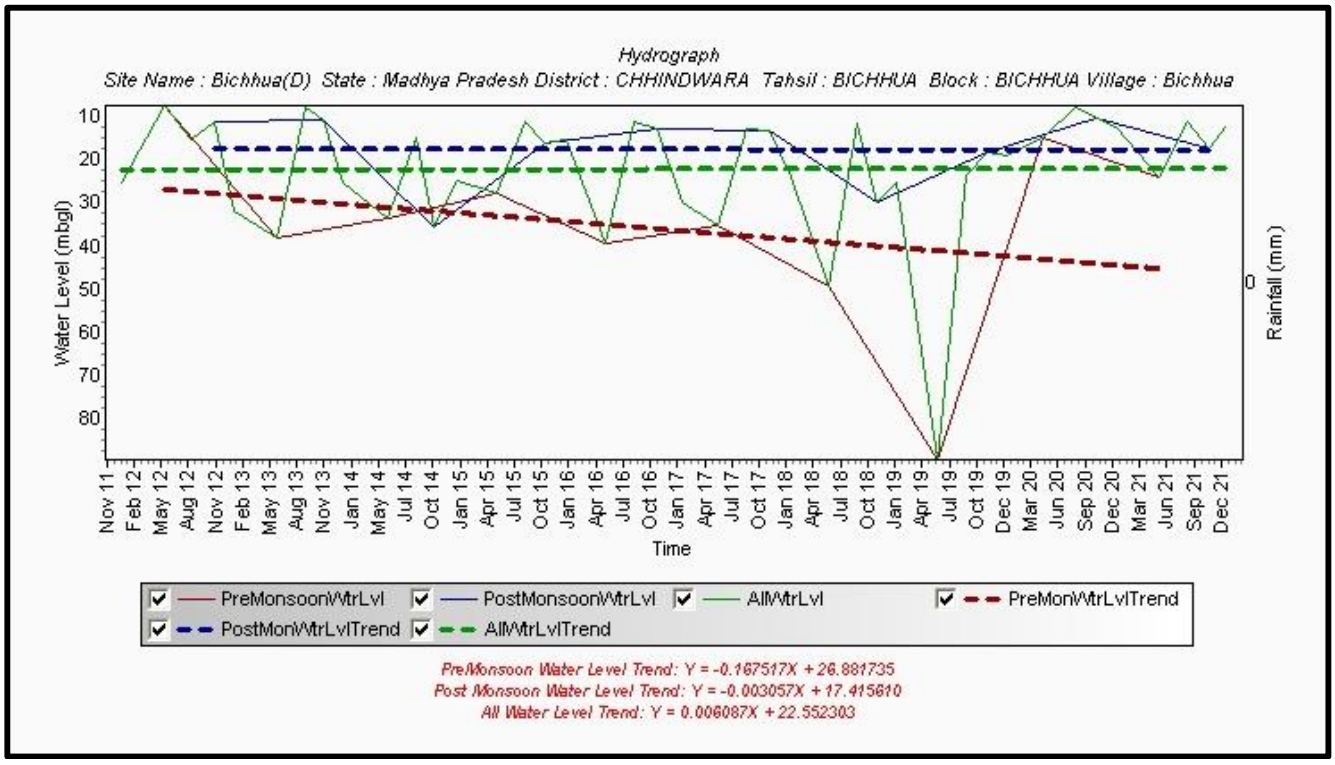


Fig 12(b): Hydrograph Bichhua

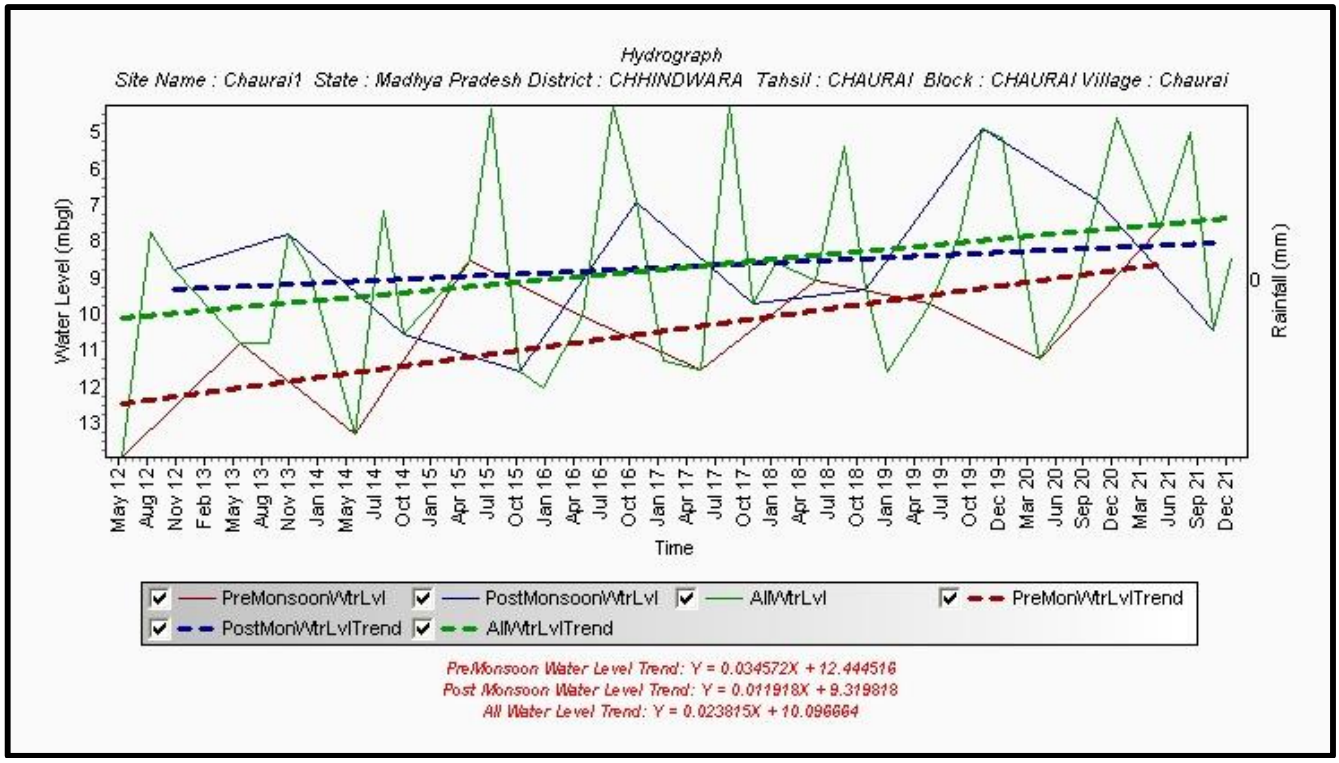


Fig 12(c): Hydrograph Chaurai

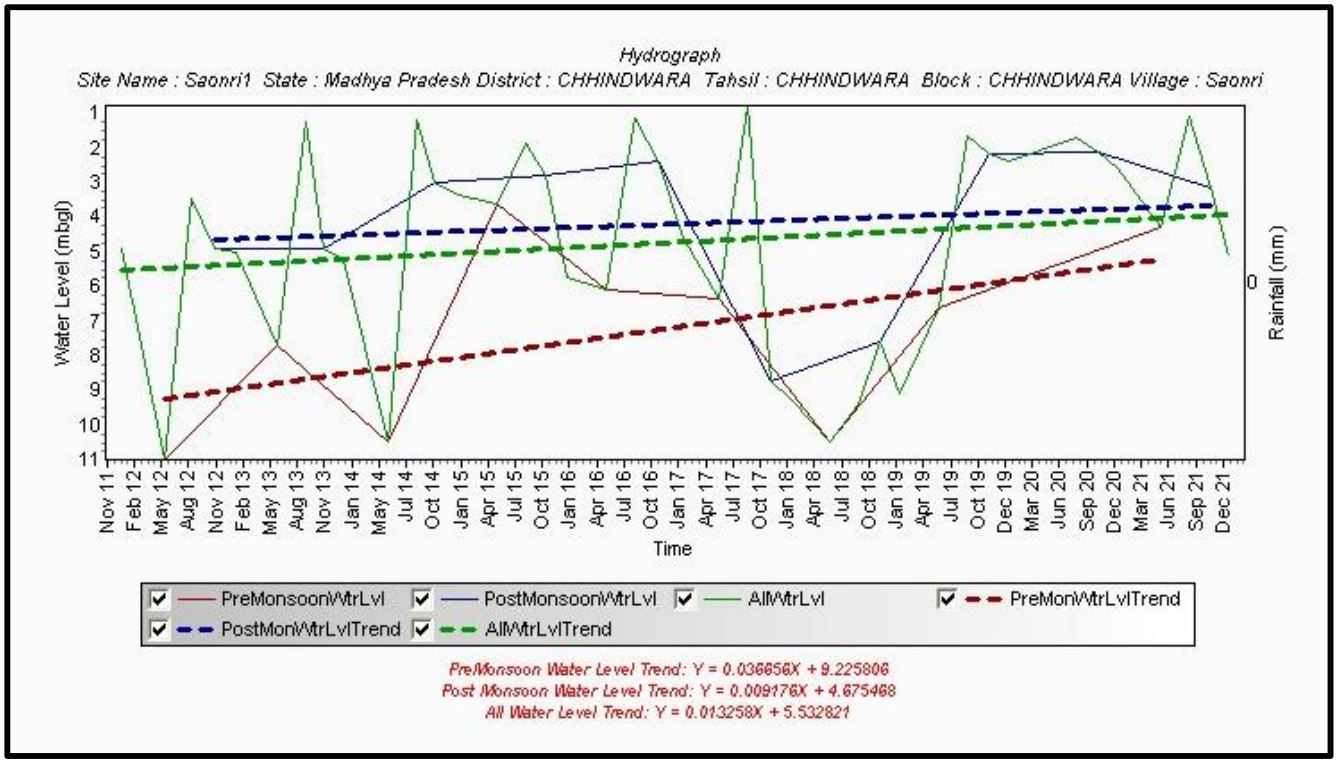


Fig 12(d): Hydrograph Saonri

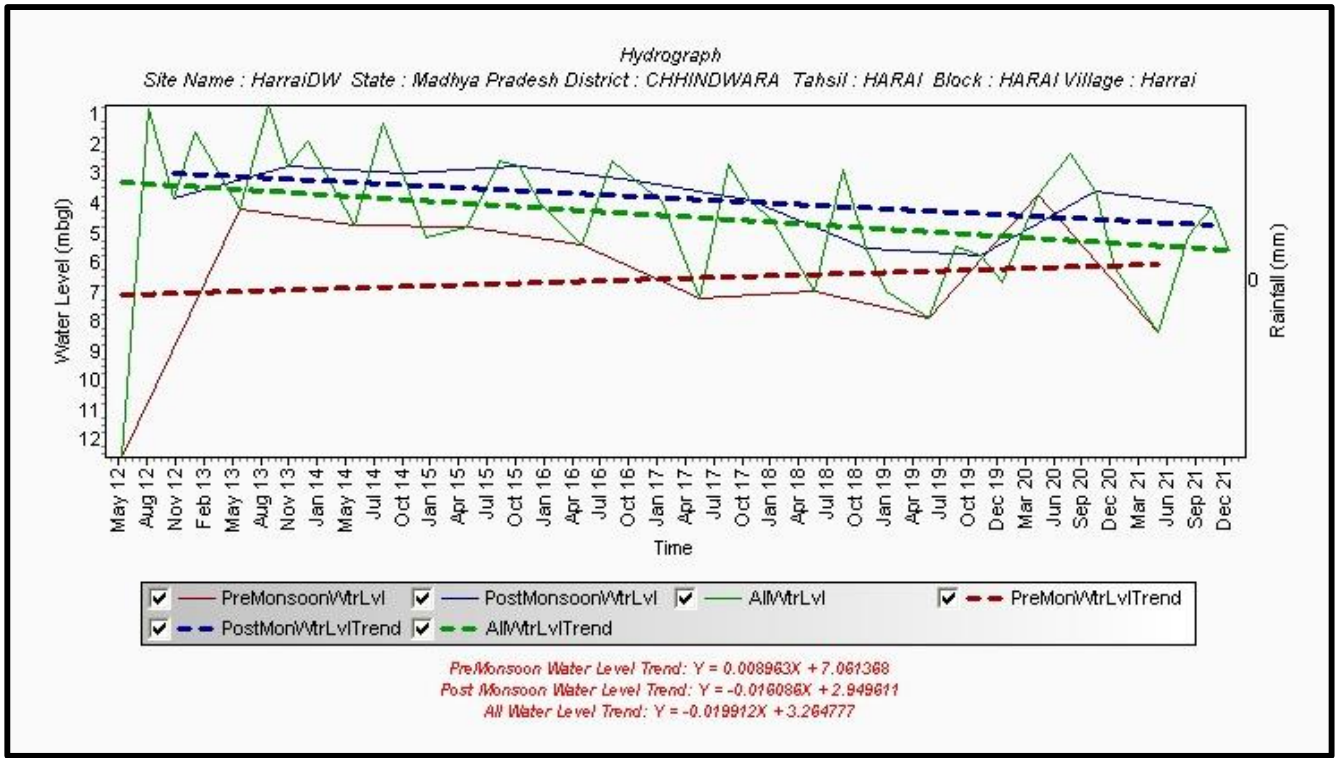


Fig 12(e): Hydrograph Harrai

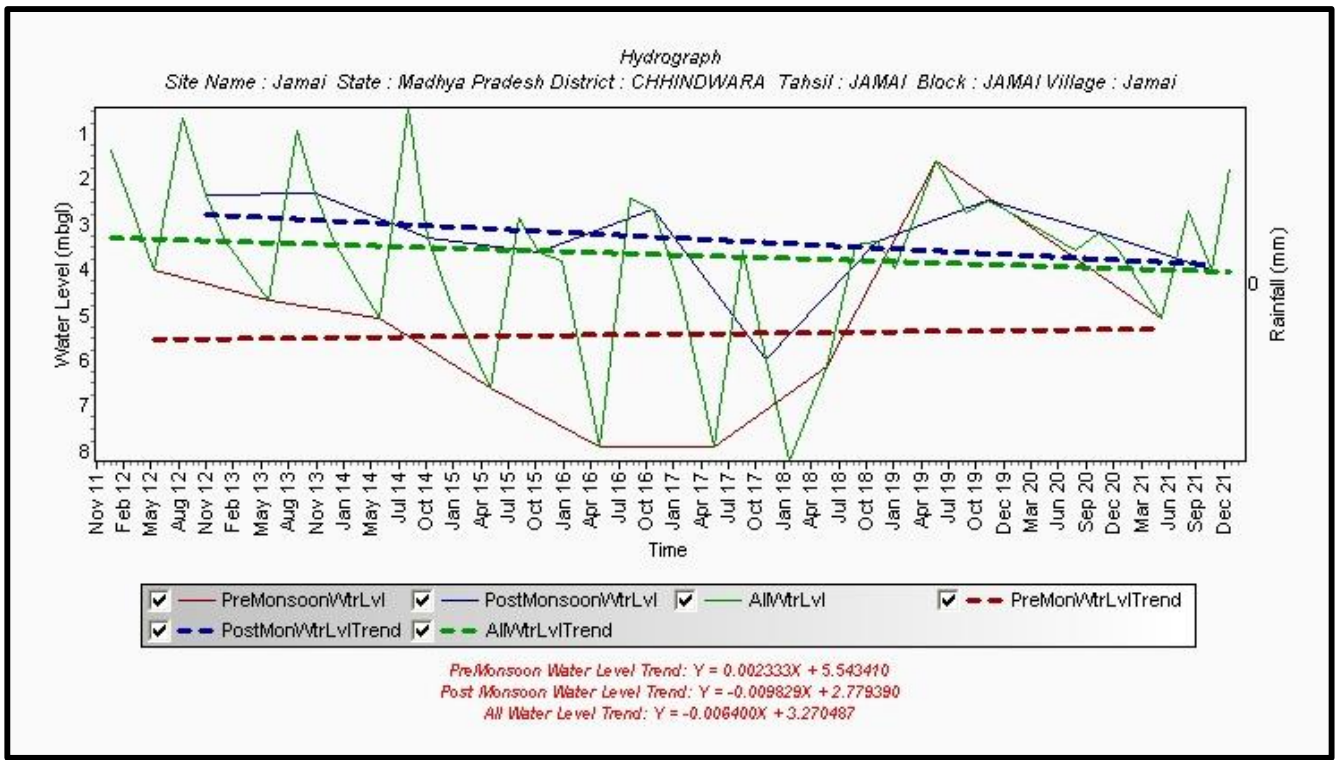


Fig 12(f): Hydrograph Jamai

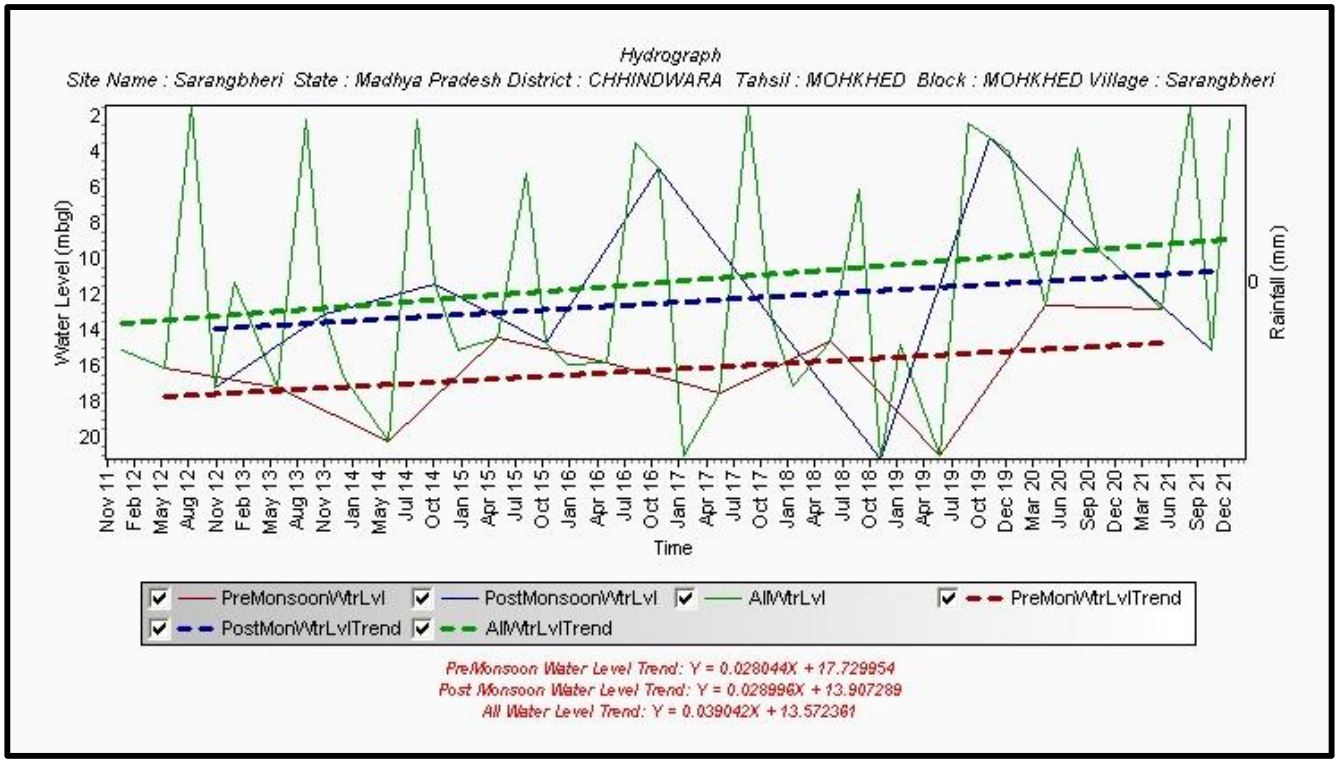


Fig 12(g): Hydrograph Sarangbheri

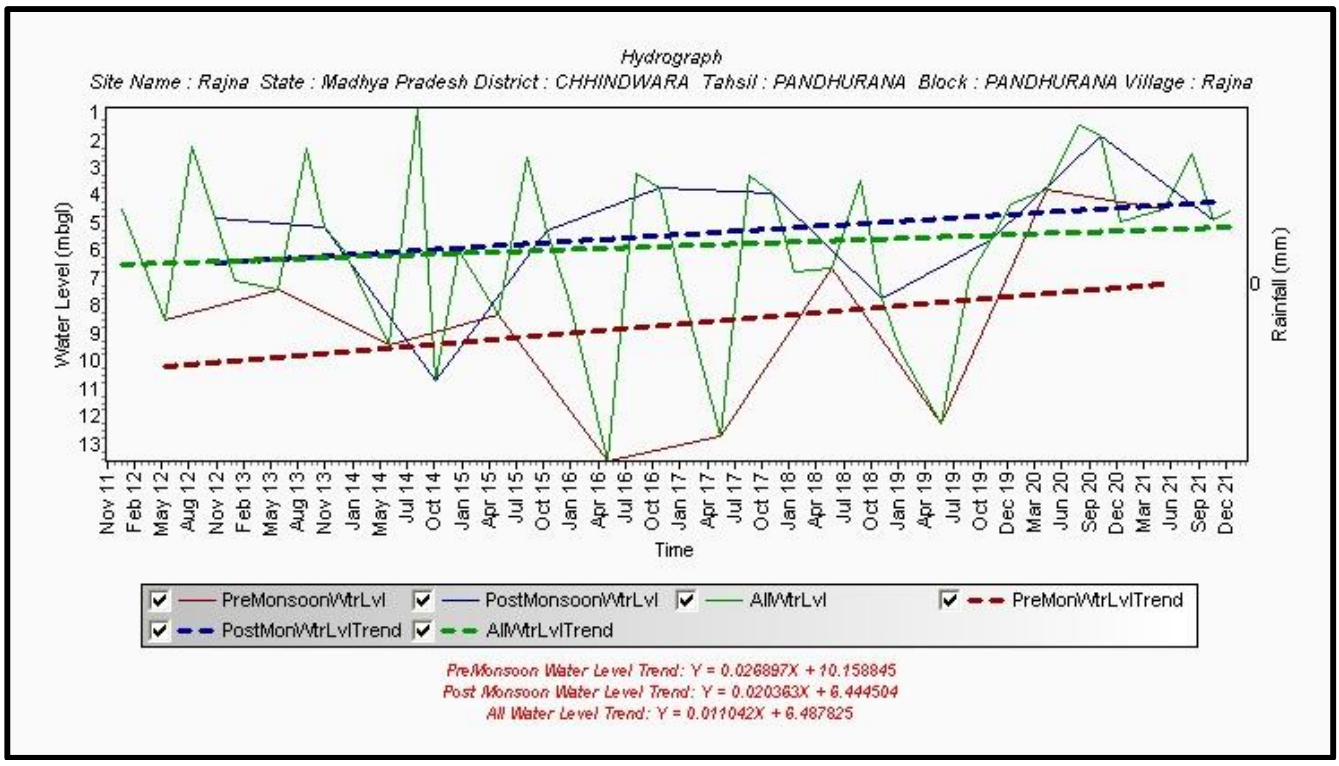


Fig 12(h): Hydrograph Rajna

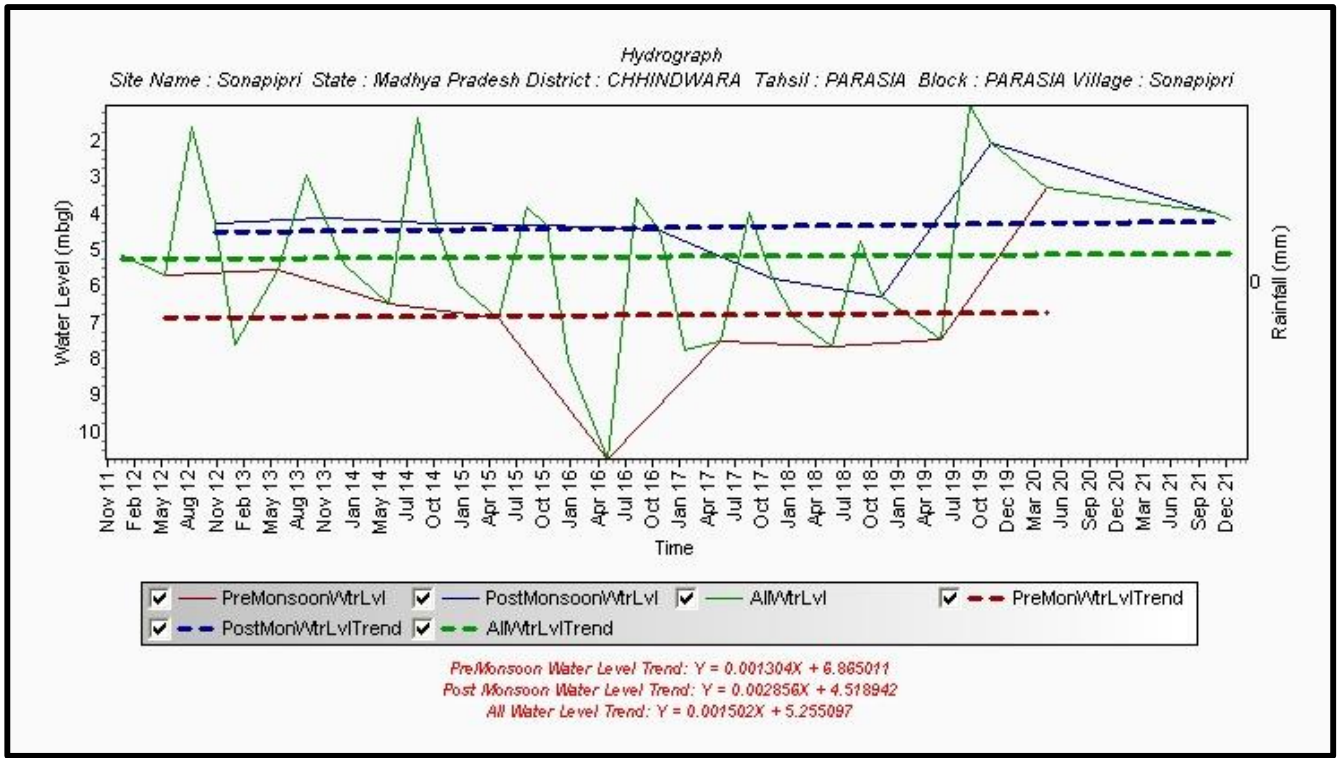


Fig 12(i): Hydrograph Sonapipri

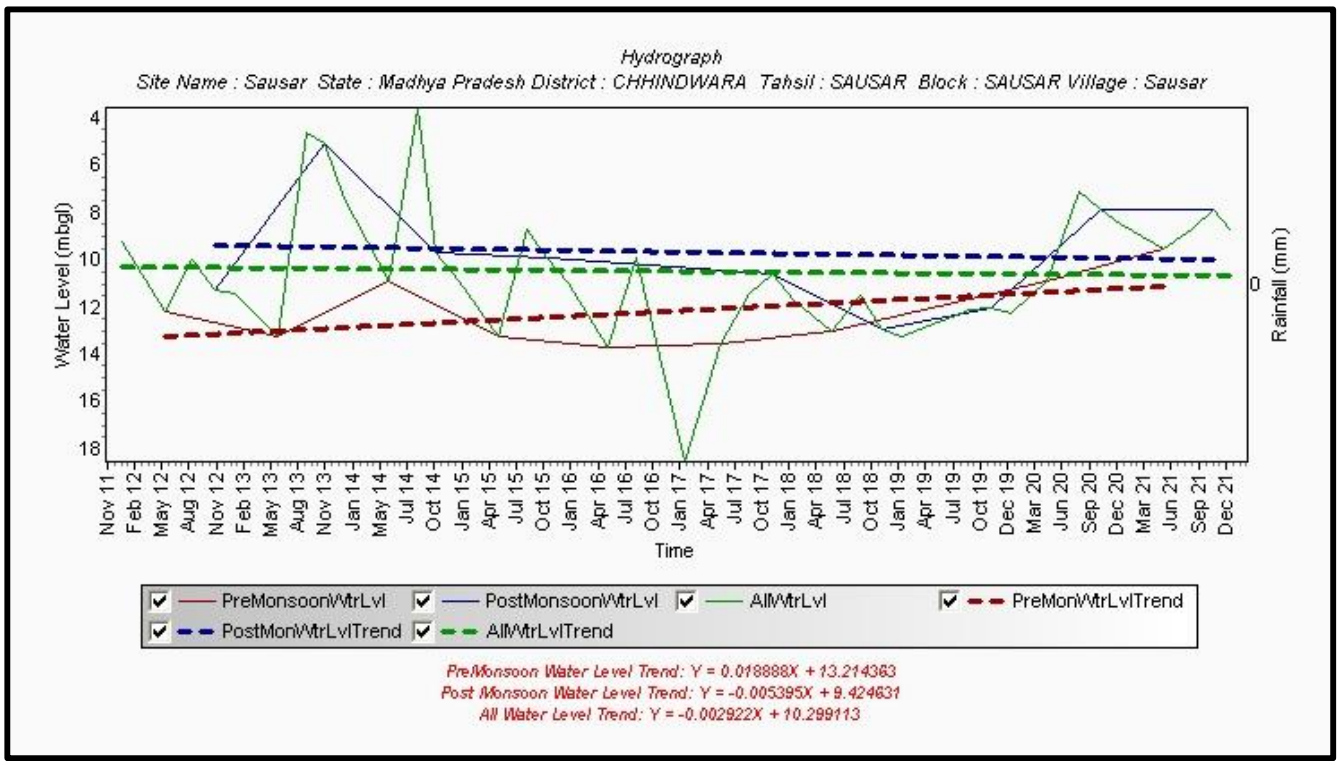


Fig 12(j): Hydrograph Sausar

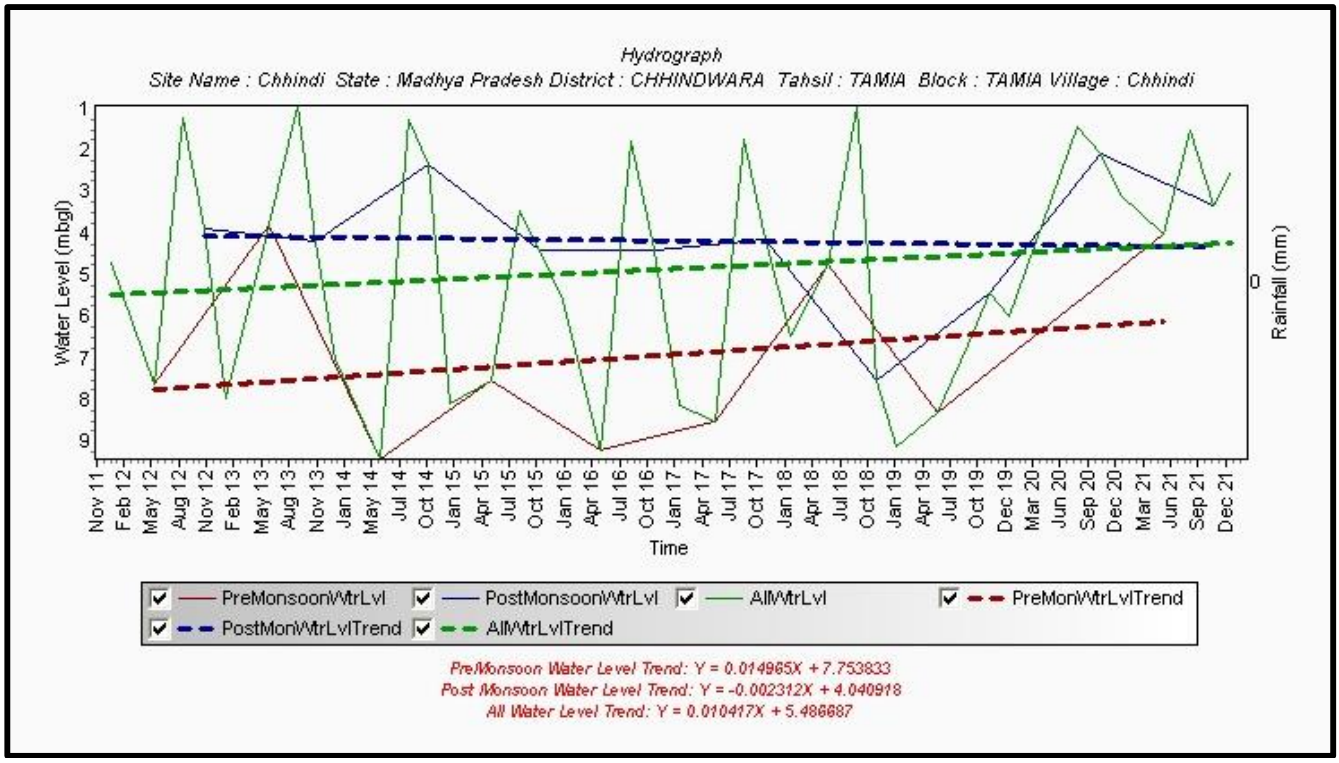


Fig 12(k): Hydrograph Chhindi

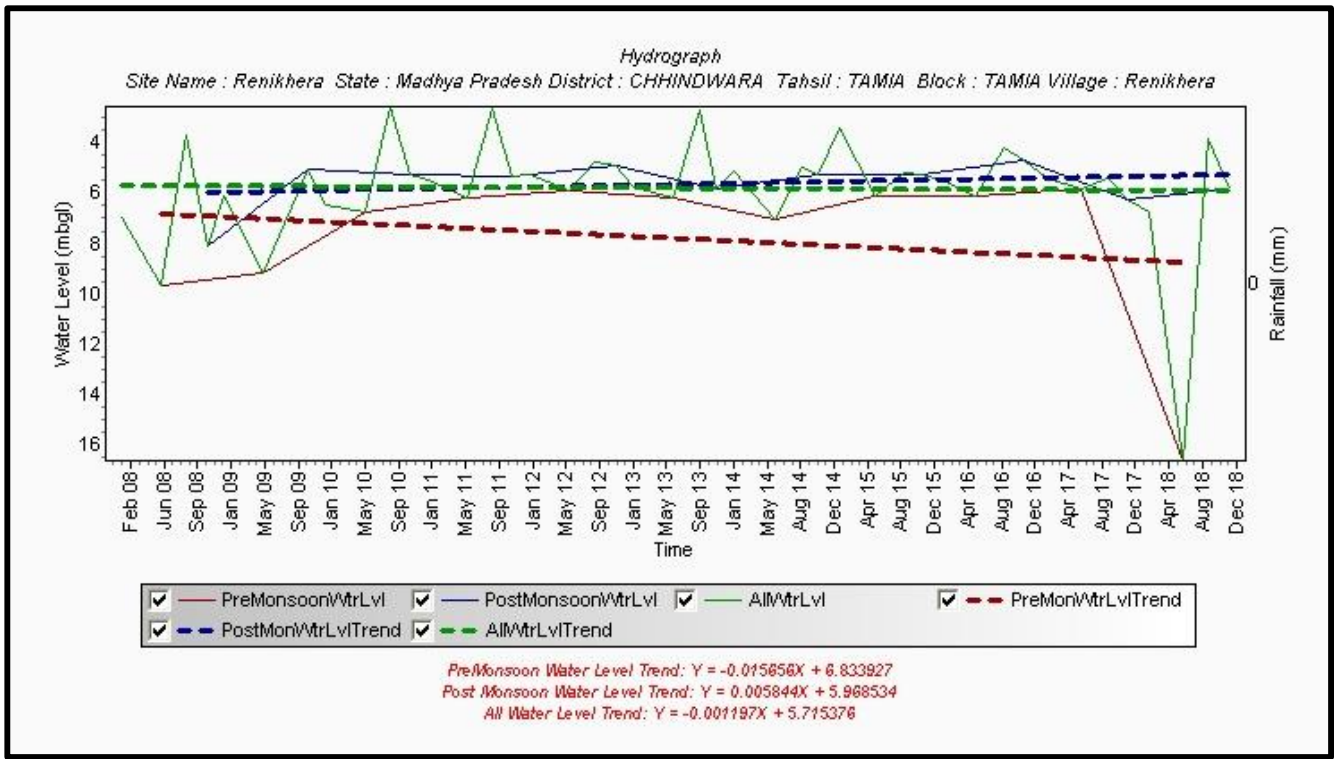


Fig 12(l): Hydrograph Renikhera

Table 11: Summerised Details of Water Leval Trend (2012-2021)

Block	Station Name	Pre Monsoon Trend m/year	Post Monsoon Trend m/year
AMARWARA	Surla	0.23134	-0.1091
CHAURAI	Chaurai1	0.40886	0.02202
CHAURAI	Marka Handi	-0.12313	-0.3031
CHAURAI	Ramgarh	0.2637	-0.2196
CHAURAI	Thanvari Kunda	-0.42612	-0.3842
CHHINDWARA	Chhindwara	-0.18038	-0.4625
CHHINDWARA	Jamunia Ner	0.06222	0.33467
CHHINDWARA	Saonri1	0.43357	-1.3437
HARAI	HarraiDW	0.10602	-0.1903
HARAI	Kundali	-0.00749	-0.3502
HARAI	Sathiya	0.9204	-0.031
JAMAI	Damua	-0.08507	0.15316
JAMAI	Jamai	0.0276	-0.1163
MOHKHED	Goni	0.09762	0.31262
MOHKHED	Linga rly.stn.	0.30634	-0.0812
MOHKHED	Sarangbheri	0.33172	0.343
MOHKHED	*Silwani1	-0.06299	-0.8355
MOHKHED	Tansara Mal	1.01251	-0.3235
PANDHURANA	Bangaon1	0.13955	-0.1569
PANDHURANA	Borgaon1	-0.19843	-0.8861
PANDHURANA	Chinchkheda	0.35513	-0.0124
PANDHURANA	Chincholiwad	0.04051	0.04715
PANDHURANA	Mohi	0.05754	-0.1732
PANDHURANA	Pandurna	0.14515	0.73273
PANDHURANA	Piplanarayanwar	0.08285	-0.1854
PANDHURANA	Rajna	0.31814	0.24085
PARASIA	Lahgudna	0.07922	0.20941
PARASIA	Sonapipri	0.01546	0.03379
SAUSAR	Sausar	0.22339	-0.0638
SAUSAR	Silwanighati	0.065	0.0197
TAMIA	Chhindi	0.17699	-0.0273
TAMIA	Delakhari	-0.31877	-0.031
TAMIA	Mahaljhir	0.46361	-0.6548
TAMIA	Renikhera	-0.6074	0.07507

2.3 Ground Water Exploration

The district is mainly occupied by Archaeans, Deccan Traps and upper Gondwanas. By looking into the characteristics of rock formations, it is felt the suitable rig for the area is combination rig having Rotary cum DTH arrangements. In the basaltic and basaltic/granitic contact zone bore wells constructed are mostly unsuccessful due to improper well construction designing as collapsible formation (Intratrappeans clay and unconformity or loose material of contact zone) occurring at various intervening depths. Aquifers are not properly tapped and target depth of drilling are not achieved due to this collapsible formation. In this condition suitable well design with part assembly should be lowered with reverse socket. Also gravel/hard drill cutting should be shrouded in annular space between assembly pipe and borehole to prevent collapsible formation (Red Bole) which is occurring at intervening depth range 45-90m and 145 – 210 m.

In Gondwana formation bore holes can be left naked below the surface pipe/casing but in some cases full assembly pipes may be required to prevent semi Consolidated barakar sandstone of collapsible in nature.

In the Archaean basement is not evenly distributed in the area explored. At palatwara (Parasia) it occurs at 5.50 m at Kakra, Chennari at 53 m, Jhilmili at 36m, and at Bulaikheri more than 183 m. The high fluoride content reported in many borewells constucted within the weathered and fractured granite and also at the contact of basalt and granite formations. The Location of Exploratory Wells drilled in Chhindwara District is show in Fig. 13.

Table 12: Hydrogeological details of CGWB exploratory bore wells

S. No.	Location	Depth Drilled (m bgl)	Depth of Well constructed (m bgl)	Zones tapped (m bgl)	Aquifer material	Static water level (m bgl)	Discharge (lps)	Draw down (m)	Remarks/Fluoride
1	Jhiilmili	127.10	127.10	82-90; 115-126	Fractured granite	58.90	4.07	8.72	2.5
2	Rajakhodhana	103.70	103.70	88.5-103.7	Fractured granite	20.98	10.0	38.45	20.00
3	Khakra chaurai	137.20	137.20	82-84; 122-137	Fractured granite	19.22	5.04	67.45	15.00
4	Panjara	138.30	138.30	82-92.5; 135.5-138.3	Fractured granite	52.88	3.41	-	
5	Loniamaru	167.70	167.70	71-82;97.5-107;140-146	Fractured granite	48.48	4.07	13.16	10.00
6	Khedi Bhutai	183.00	183.00	-	Basalt	80.00	Meager	-	
7	Atarwara	134.20	130.00-133.00	130-134	Fractured granite	71.72	4.5	26.28	9.00
8	Sarra	183.00	43.00	9-15.5; 18.00-27.00; 30.50-36.50	Fractured granite	6.50	1.1	22.37	1.95
9	Sahapura	183.00		Abandoned	Fractured granite	9.84	0.40	67.06	0.49
10	Ubhegaon	152.50	152.50	-	Basalt & Fractured granite				Well construction issues
11	Datla	183.00	183.00	30-45 (basalt)	Basalt & Fractured granite	27.30	1.0	-	Well construction issues
12	Bichhbi	201.30		115.90 – 128.10	Basalt & Fractured				Well construction

					granite				issues
13	Bisapur	183.00	183.00		Basalt & Fractured granite				Well construction issues
14	Datla	183.00	183.00	30.00 – 45.00	Basalt & Fractured granite	27.30	1.00	-	
15	Gangiwara	183.00			Fractured granite	15.81	0.84	-	
16	Goreghat	183.00	-	-	Basalt & Fractured granite	9.58	-	-	Well construction issues
17	Jatama	173.80	-	-	Fractured granite	88.55	1.00	-	9.00
18	Khunajhir Khurd	113.90	113.90	14.00 – 20.00	Basalt & Fractured granite	17.30	1.85		8.50
19	Lawagogri	183.00	-	-	Fractured granite	3.25	Poor		Well construction issues
20	Rajara	125.00	125.00	-	Basalt & Fractured granite	80.93	3.38	-	
21	Ridhora Mal	183.00	183.00	-	Fractured granite	72.50	1.60	-	1.75
22	Salimeta	201.30	-	39.00 – 42.00	Basalt & Fractured granite	Dry	-	-	Well construction issues
23	Umret	183.00	-		Fractured granite	25.28	3.00	72.27	1.30
24	Chhinda	118.90	-	18.00 – 70.00	Basalt	-	-	-	Well construction issues

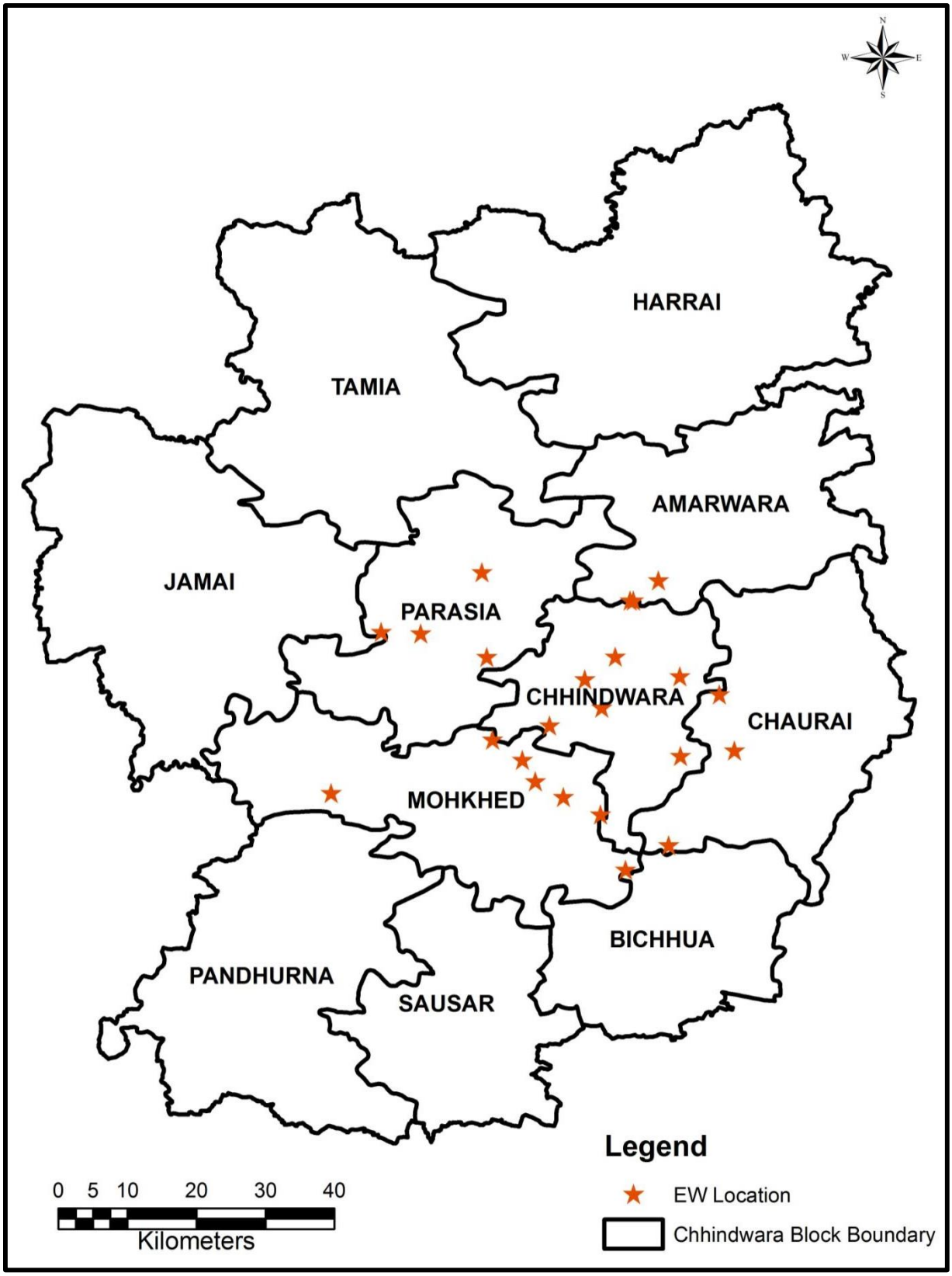


Fig 13: Well Location Map of Chhindwara District

2.4 Geophysical Studies

Geophysical Survey:

Geophysical survey has been conducted in YEAR 2020 in parts of Chindwara district. In this study, surface geophysical method comprised of Vertical Electrical Sounding (VES). Electrical resistivity is one of the most sensitive geophysical methods for monitoring changes of electrical properties in the subsurface. It is very effective in determining depth to water saturated zone.

Resistivity Sounding

Resistivity sounding is a process by which the depth investigation is made. In this, the center of configuration is kept fixed and the measurements are made by successively increasing the electrode spacing. The apparent resistivity values obtained with increasing values of electrode separations are used to estimate the thickness and resistivities of the subsurface formations. In Schlumberger sounding arrangement all the four electrodes are kept in a line symmetrically over a point `0; with inner (Potential) electrodes kept closer. For increasing the depth of investigation the current electrodes A and B are moved apart symmetrically about the center point `0' keeping the potential electrodes fixed. The separation between the Potential Electrodes is changed only when the potential between them drops to allow value during the course of sounding. The apparent resistivity for each electrode separation is calculated by multiplying the resistance `R' by Schlumberger configuration factor.

The main purpose of applying geophysical method for ground water exploration is to help and assess the unknown sub-surface hydrogeological conditions economically, adequately and speedily. Generally the prime task is to compliment the exploratory drilling programme. Mostly it is employed to narrow down the target zone to pin point the probable borehole site for drilling and its proper design.

In accordance with the drilling programme, geophysical surveys were carried out in the hydrogeologically suitable areas of some villages, in order to decipher potential aquifers and to guide drilling operations. The main objective of geophysical survey was to know the sub-surface hydrogeological conditions as well as the demarcation of litho

boundaries so as to guide the drilling programme accordingly by giving suitable recommendations.

The present report covers the finding of the results of the resistivity survey conducted around village Titori, Nonia Maru, and Bhotai Kheri of Chhindwara district, M.P.

The surveyed area lies between latitudes $21^0$45'00" & $22^0$15'00" and longitudes $79^0$00'00" & $79^0$30'00" .The locations are shown in Plate-I (Survey of India Toposheet No.55 O/1& 55 N/4 0n 1" to 1mile scale)

Geophysical Survey was organised by the Central Ground Water Board, North Central Region, Bhopal. In all, ten Vertical Electrical Soundings were conducted. Wherever the spread/pace length was available, attempts of conducting two VES at the same point in cross fashion were done. The type of the array used was SCHLUMBERGER Resistivity meter GGA-30 (Germany made) was deployed for measurements. The investigations were carried out in between 8.1.2000 and 13.1.2000.

Geo-Electrical Investigations

The method is based upon the principle of measurement of conductivity contrast of different formations. It is used to determine the lateral & vertical variations in conductivity within the formation. In favorable conditions, the variation in conductivity provides information about the actual depth of occurrence, thickness and aerial extent of the aquifer.

The well known curve matching techniques between the field sounding curves and master curves have been used for interpretation of VES curves. The interpreted layer parameters have been modeled with computer software 'SCHLUM'.

In Deccan traps, the Expanding Schlumberger Array (ESA) is mainly employed because it is preferred to Wenner Configuration due to less time consuming operations and reduced background noise levels.

In total 10 number of ESA data were conducted in the area and in first instance interpretation of data was done by curve matching techniques using two and three layer

master curves (Orellans and Moorey). The data could be interpreted in terms of three and four layers but reliably correlation with Deccan trap lithology could not be observed because of the limitations with the resistivity methods in detecting thin beds at depth with a large resistivity contrast. The auxiliary curve matching techniques for cases of more than four layers is particularly unreliable and such interpretation has been checked by the computer modelling.

Discussion of Results

Titri: VES-1 is located about 20m west of primary school

Field curve is of "HKH' type i.e.ρ1>ρ2<ρ3>ρ4<ρ5, the top layer which correspond to the soil is having an electrical resistivity of 45 ohms-m and thickness of about0.40 m. The second geo-electrical layer having a thickness of 4.60 m and resistivity of 27 ohm-m is indicative of weathered basalt. The third geo-electrical resistivity (80 ohm-m) and thickness of 15 may correspond to semi-weathered basalt. The fourth geo-electrical layer continuing down to a depth of 80 m from ground level and has electrical resistivity of 14 ohm-m which may correspond to fractured product of basalt/weathered basalt. The last geo-electrical layer shows a very high electrical resistivity (3168 ohm-m). This is indicative of granite.

Titri : VES 2 Conducted 50 m East Of Primary School

The field curve is of "KH" type i.e. ρ1<ρ2>ρ3<ρ4. Here there is no soil cover. Weathered basalt starts from the surface. This layer has an electrical resistivity of 15 ohms-m & thickness of 0.2 m. The next layer having the thickness of 11.40 m & resistivity of 200 ohms-m is indicative of massive basalt. The layer below it continues down to a depth of 52m from the ground surface and shows a resistivity of 13 ohm-m is indicative of weathered /fractured product of basalt. The last geo-electrical layer below 52 m which shows an electrical resistivity of 690 ohm-m clearly indicates presence of major compact granite with top weathered portion of granite.

Bhotai Kheri :**VES-3 (CGWB Exp. drilling site)**

Two soundings (NW-SE & NE-SW) were conducted at the initially proposed site. Later on due to unavailability of space for the rig placement, the drilling site has been shifted to a new location. However the interpretation of the previous site has been given below:

The top soil having the resistivity of 60 ohm-m is quite thick and continues down to a depth of 7.9 m. The second geo-electrical layer which may correspond to weathered basalt shows an electrical resistivity of 20 ohm-m and thickness of 15.6 m. The third geo-electrical layer having resistivity of 146 ohm-m and thickness of 26.5 m may reflect semi-weathered to massive basalt. The fourth layer continues down to a depth of 73.5 m from ground surface and bears an electrical resistivity of about 17 ohm-m may correspond to weathered /fractured product of basalt. The last geo-electric layer below this depth having very high electrical resistivity (4738 ohm-m) is indicative of massive compact granite.

Nonia Maru: The VES –4 conducted about 250 m N of existing PHE tube well 7 (CGWB expl. drilling site.

The field curves are of HKH type ($\rho1>\rho2<\rho3>\rho4<\rho5$).The top layer which correspond to soil is having an electrical conductivity of 83 ohm-m and thickness of 2.1m. The second geo-electrical layer having a thickness of 6.1m and resistivity of 2 ohm-m is indicative of weathered basalt. The third geo-electrical layer resistivity 51 ohm-m and thickness of 30.2 m may correspond to massive basalt. The fourth geo-electrical layer continuing down to a depth of 78.6 m from ground level have electrical resistivity of about 10 ohm-m represents weathered product of basalt. The last geo-electrical layer which shows an electrical resistivity of 1696 ohm-m is indicative of highly compact granite.

Two soundings were conducted at this site of Nonia Maru. On the recommendation of geophysical survey results, the drilling for exploratory well has been carried out by CGWB, NCR at VES-4 (Nonia Maru). The litholog encountered during drilling is summarised below:

Depth range in mbgl	Lithology
0.00 – 10.50	Loose soil & weathered basalt (Dry)
9.50 - 34.50	Massive Basalt
34.50 – 36.50	Red-bole
36.50 – 65.00	Weathered product of basalt
65.00 – 68.00	Weathered Granite
68.00 – 140.00	Compact granite

By comparison , it shows that the fourth geo- electrical layer having a thickness of 40m & resistivity of 10 ohm-m has incorporated mainly three geo-electrical layers viz. Red bole , vesicular basalt and weathered granite. Basically three geological layers have resistivity value very close to each other. Hence these three layers have not been distinguished by surface resistivity method. But the electrical resistivity contained with the compact granite is so high that it has been reflected clearly. (Plate –II d).

A relative comparison shows that the electrical resistivity values between 10 – 17 ohms-m is indicative of fractured / weathered product of basalt which acts as an aquifer. The sub surface zone with appreciable thickness of fractured basalt and weathered granite may not have good yielding capacity but still may act as an aquifer. The point where this type of zone is encountered is, therefore, to be properly explored.

Nonia- Maru :**(VES-5) Near existing PHE bore well:**

Two cross soundings (N-S and E-W) were conducted at this site. Field curve is of "AKH" type ($\rho1<\rho2<\rho3>\rho4<\rho5$). The top soil has electrical resistivity of 10 ohm-m and thickness of 0.5 m. The second geo-electrical layer continues down to a depth of 8.5 m have a resistivity order of 40 ohm-m. This may correspond to weathered basalt. The third layer having the resistivity of 600 ohm-m and thickness of 8.90 m is indicative of massive basalt. The next geo-electrical layer is quite thick (82.6 m) and has a resistivity

of 15 ohm-m. It may include more than one geological horizon like the previous case. The last geo-electrical layer having the resistivity of 800 ohm-m is indicative of compact granite.

Nonia- Maru :**VES-6 400 m south of existing PHE bore well as cross sounding (N-S and E-W).**

Field curve is of "KH" type ($\rho1<\rho2>\rho3<\rho4$). The top soil has an electrical resistivity of 10 ohm –m and thickness of 0.70 m. The next layer having a thickness of 1.5 m and resistivity of 150 ohm-m may correspond to semi weathered to massive basalt. The layer below this continues down to a depth of 45.3 m and shows a resistivity of 10 ohm-m may correspond to weathered, collapsible strata of basalt. The last geo-electrical layer, which shows an electrical resistivity of 600 ohm-m reflects compact granite at this depth.

Results of Geo-physical Logging :

The data of geophysical logs (SP, SPR, 16"/64" NR & natural gamma) of exploratory bore hole in the area under the present investigation was of considerable use in confirming to the results of present findings.

The geo-physical data at Nonia-Maru (Plate –III) reflected by high resistivity order ranging from 200 – 1200 ohm-m indicate massive basalt at 14m up to 34m depth below surface and occurence of red bole may be seen from 34.5 to 36.5 m (resistivity 10 ohm-m) and below this depth weathered /fractured product of basalt exists upto a depth of about 65 m. The weathered granite is determined by resistivity range of 20-50 ohm-m & high natural gamma activity about 300 CPS between 65 & 68 m from ground level.

The compact granite encountered at 68m & continues downwards upto the logged depth (i.e. 72m) but drill cutting examination confirmed this sequence exist upto drilled depth 140 m.

Conclusions and recommendations of geophysical studies conducted -

Based upon the results of resistivity survey and other available information, the following conclusions are drawn:

i) The resistivity of top soil layer varies a lot. Actually it depends upon the nature of the soil viz. lateritic, cultivable.

ii) In all the areas layer of weathered basalt is present where resistivity varies from 10-40 ohm-m. depending on the degree of weathering. Below this there is a massive basalt layer which is generally having resistivity value ranges between 80 & 600 ohm-m. The next layer is a low resistivity layer in the order of 10 –16 ohm-m. This may include number of geological horizons like red bole, weathered product of basalt & weathered granite. Fine distinction between them is a limitation of surface electrical resistivity survey. There is a compact granite layer below this which has a resistivity of more than 600 ohm-m to very high value (>4500 ohm-m).

iii) The contrast of resistivity value between layer IV (low resistivity) and layer V (high resistivity, compact granite) is so high that it has been picked up in all the investigated sites. The depth of the compact granite from ground surface varies from 45 m to 100 m.

iv) On the basis of surface geophysical surveys, VES-2, VES-3 & VES-4 were found to be better sites for exploration in the area under investigation.

Table 13: Interpretated results of Vertical Electrical Soundings in parts of Chhindwara District, M.P.

Topo sheet No	VES No	Approximate location	Geo-electric parameter	Resistivity of Geo-electric Layers (Ohm-m)					Thickness of Geo-electric layers (m)					
				I	II	III	IV	V	I	II	III	IV	V	
55 O/1	1	Titri: 20m W of Primary School	ρ/h	45.0	27.3	80	13.7	3169	0.35	4.7	14.8	60	-	From top to bottom basalt followed by granite
55 O/1	2	Titri: 50m E of Primary School	ρ/h	14.9	200	13	690		0.2	11.4	40.4			From top to bottom basalt followed by granite
55 N/4	3	Bhotai Kheri	ρ/h	59.9	19.9	146.3	16.6	4737	7.9	15.6	26.5	23.3		From top to bottom basalt followed by granite
55 N/4	4	Nonia Maru: 250m N of existing PHE B/H	ρ/h	82.6	20.8	151	9.9	1696	2.1	6.1	30.2	40.3		From top to bottom basalt followed by granite
55 N/4	5	Nonia Maru: Near existing PHE B/H	ρ/h	9.9	40	600	15	800	0.5	7.9	8.9	82.6		From top to bottom basalt followed by granite
55 N/4	6	Nonia Maru: 400m S of existing PHE B/H	ρ/h		10	150	10	600		0.7	1.5	43.1		From top to bottom basalt followed by granite

*p =True electrical resistivity value of layer (Ohm-m)

*h =Thickness of individual layers in metres

2.5 Ground Water Quality of Chhindwara District

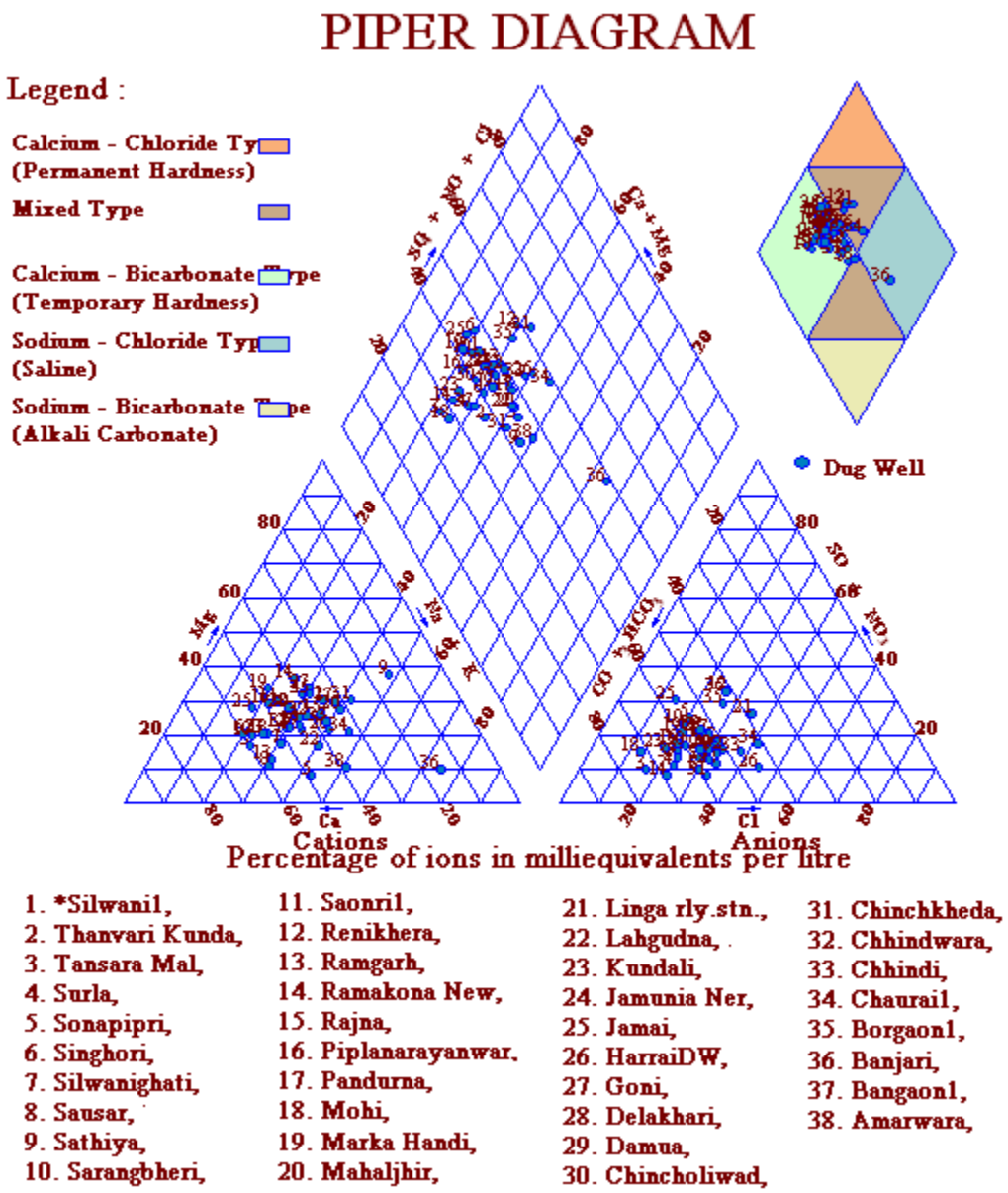
The water samples were collected from National Hydrograph Stations in clean double stopped poly ethylene bottles from 38 different locations of Chhindwara district during May 2019.

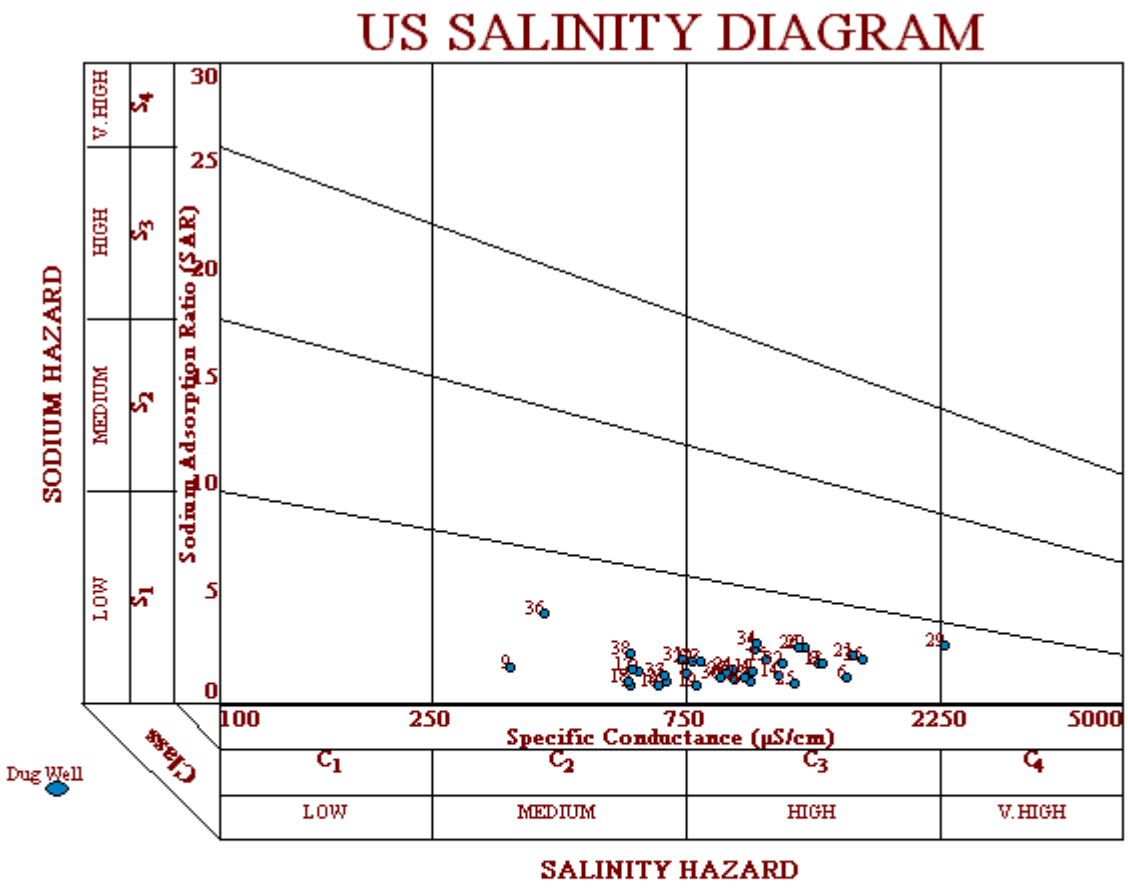
The pH of ground water of Chhindwara district ranged in between 7.09 to 7.97 shows the ground water of the district is netural to slightly alkaline in nature; the highest value of pH (7.97) has been observed in Sarangbheri dugwell. The electrical conductivity of ground water in Chhindwara district ranged between 354 to 2318 µS/cm at 25°C and the maximum EC value at Damua (2318 µS/cm at 25°C). The electrical conductivity shows that the ground water in Chhindwara district is good to moderately saline in nature.

The fluoride concentration in Chhindwara district ranged in between 0.22 to 1.97 mg/l. In the district, maximum concentration of fluoride has been recorded in the dug well of Ramakona i.e. 1.97 mg/l. In the district, fluoride concentration more than 1.50 mg/l have been observed in ground water of Chaurai (1.68 mg/l), Boragaon (1.78 mg/l), Sonapipri (1.89 mg/l) and Ramakona (1.97 mg/l). In the district, nitrate concentration in ground water ranged in between 8 to 189 mg/l. The 65.8% ground water samples recorded nitrate concentration within the acceptable limit of 45 mg/l whereas 34.2% water samples recorded more than 45 mg/l as per BIS recommendation. The nitrate concentration has been recorded more than 100 mg/l in ground water of Linga Railway Station (112 mg/l), Sonapipri (125 mg/l), Renikhera (152 mg/l) and Boragaon (189 mg/l). Total hardness of ground water in the study area ranged in between 51 to 773 mg/l. The maximum concentration have been observed in the dug well of Singhori (601 mg/l) and Damua (773 mg/l).

As per the piper diagram of district, water samples are Calcium Bi-carbonate (temporary hardness), Mixed Type (Calcium Magnesium Chloride and Calcium Sodium Bi-carbonate type) and Sodium Chloride types of water. The US Salinity Diagram of Chhindwara district shows the ground water is low to high salinity classes i.e. C_2S_1,

C_3S_1 and C_4S_1 classes and C_3S_1 and C_4S_1 class of water should not be used for irrigation purpose unless proper soil management.





1. *Silwani1,
2. Thanvari Kunda,
3. Tansara Mal,
4. Surla,
5. Sonapipri,
6. Singhori,
7. Silwanighati,
8. Sausar,
9. Sathiya,
10. Sarangbheri,
11. Saonri1,
12. Renikhera,
13. Ramgarh,
14. Ramakona New,
15. Rajna,
16. Piplanarayanwar,
17. Pandurna,
18. Mohi,
19. Marka Handi,
20. Mahaljhir,
21. Linga rly.stn.,
22. Lahgudna,
23. Kundali,
24. Jamunia Ner,
25. Jamai,
26. HarraiDW,
27. Goni,
28. Delakhari,
29. Damua,
30. Chincholiwad,
31. Chinchkheda,
32. Chhindwara,
33. Chhindi,
34. Chaurai1,
35. Borgaon1,
36. Banjari,
37. Bangaon1,
38. Amarwara,

Table 14: Water Quality of samples collected from National Hydrograph Stations

S. No.	Block	Location	Long.	Lat.	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K
						µS/cm at 25°C	mg/l												
1	Amarwara	Amarwara	79.171	22.301	7.47	594	0	178	50	48	11	0.65	0.11	26	141	44	7	65	1.9
2	Amarwara	Banjari	79.132	22.26	7.79	410	0	98	37	42	26	0.89	BDL	22	51	12	5	70	1.6
3	Amarwara	Singhori	79.062	22.201	7.34	1516	0	461	172	73	38	0.73	0.1	32	601	176	39	69	0.7
4	Chaurai	Chaurai1	79.251	22.054	7.54	1029	0	240	145	52	39	1.68	BDL	22	268	65	26	106	2.7
5	Chaurai	Marka Handi	79.164	22.045	7.55	794	0	264	57	48	35	0.4	0.24	56	313	73	32	35	0.8
6	Chaurai	Ramgarh	79.272	22.175	7.74	1365	0	400	145	83	39	0.69	0.1	18	465	152	21	95	1.7
7	Chaurai	Thanvari Kunda	79.267	22.176	7.58	615	0	221	47	32	13	0.44	0.09	26	197	42	22	48	2.5
8	Chhindwara	Chhindwara	78.949	22.053	7.39	1147	0	338	132	54	40	0.87	BDL	32	379	93	36	85	2.3
9	Chhindwara	Jamunia Ner	79.023	22.137	7.36	924	0	289	97	36	41	0.82	0.14	27	313	79	28	66	1.7
10	Harrai	Harraidw	79.221	22.613	7.38	1230	0	314	192	22	49	0.78	0.22	39	359	91	32	115	1.1
11	Harrai	Kundali	79.227	22.776	7.11	696	0	264	45	29	30	0.47	BDL	25	258	75	17	38	2.2
12	Harrai	Sathiya	79.179	22.59	7.62	354	0	117	35	16	8	0.22	BDL	33	91	10	16	38	0.9
13	Harrai	Surla	79.172	22.433	7.3	997	0	375	80	36	21	0.25	0.23	34	348	77	38	65	1.1
14	Jamai	Damua	78.469	22.194	7.69	2318	0	750	222	118	65	1.02	BDL	46	773	204	64	173	1.4
15	Jamai	Jamai	78.595	22.196	7.11	1204	0	381	60	98	90	0.59	0.11	28	485	127	41	49	3.2
16	Mohkhed	Goni	79.013	21.821	7.09	901	0	277	80	41	60	0.69	0.36	33	313	65	37	59	2.9
17	Mohkhed	Linga Rly.Stn.	78.938	21.963	7.88	1552	0	338	192	98	112	1.04	BDL	22	510	137	41	119	1.7

18	Mohkhed	Saonri1	78.77	21.965	7.31	929	0	295	80	42	62	0.57	0.1	19	348	85	33	50	1.5
19	Mohkhed	Sarangbheri	78.953	21.867	7.97	669	0	215	45	31	52	0.87	BDL	24	253	75	16	33	1.7
20	Mohkhed	Silwani1	78.836	21.823	7.39	758	0	234	67	27	53	0.65	BDL	26	258	77	16	52	1.7
21	Mohkhed	Tansara Mal	78.898	21.862	7.48	596	0	252	35	14	18	0.41	BDL	23	227	71	12	30	1.5
22	Pandhurna	Bangaon1	78.447	21.573	7.36	687	0	252	55	32	13	1.45	BDL	33	232	63	18	47	1.4
23	Pandhurna	Chinchkheda	78.479	21.64	7.28	743	0	252	85	20	10	0.47	BDL	21	212	40	27	70	1.9
24	Pandhurna	Chincholiwad	78.693	21.5	7.35	876	0	301	70	26	55	0.71	BDL	33	313	77	29	53	2.7
25	Pandhurna	Mohi	78.441	21.658	7.42	590	0	246	27	22	25	0.79	0.11	51	217	63	15	35	1.3
26	Pandhurna	Pandurna	78.518	21.589	7.87	598	0	178	57	43	17	1.09	0.21	37	182	38	21	51	1.7
27	Pandhurna	Rajna	78.639	21.54	7.19	1071	0	320	115	58	32	0.98	0.1	29	338	79	34	86	1.4
28	Parasia	Sonapipri	78.803	22.143	7.62	1012	0	320	72	22	125	1.89	BDL	26	283	97	10	100	1.4
29	Sausar	Borgaon1	78.816	21.559	7.55	1614	0	406	147	67	189	1.78	0.14	40	551	119	61	112	2.1
30	Sausar	Piplanarayanwar	78.731	21.588	7.49	997	0	350	72	42	49	0.74	BDL	20	379	95	34	49	2.8
31	Sausar	Ramakona New	78.843	21.702	7.43	1132	0	455	92	34	15	1.97	BDL	24	424	87	50	62	2.8
32	Sausar	Sausar	78.806	21.655	7.42	1337	0	461	142	42	24	0.42	0.18	44	444	149	17	98	2.2
33	Sausar	Silwanighati	78.831	21.788	7.25	986	0	424	52	18	41	0.89	0.15	29	359	95	29	59	0.9
34	Tamia	Chhindi	78.824	22.388	7.95	804	0	215	105	40	21	1.14	0.15	29	242	59	23	71	1.9
35	Tamia	Delakhari	78.618	22.421	7.14	977	0	314	107	39	25	0.87	BDL	22	348	85	33	55	10.7
36	Tamia	Lahgudna	78.724	22.272	7.29	778	0	240	90	32	13	1.1	BDL	34	227	65	16	70	1.9
37	Tamia	Mahaljhir	78.574	22.609	7.85	1264	0	394	132	62	43	1.25	0.32	48	369	79	42	118	1.3
38	Tamia	Renikhera	78.573	22.544	7.14	1008	0	240	90	38	152	1.12	BDL	22	348	95	27	67	3.1

Ground Water Quality of Deep wells in Chhindwara District.-

In the year 2000-01the Central Ground Water Board has collected as many as 38 ground water samples during the Ground water exploration programme from deep exploratory wells and tested for chemical quality of ground water.

The analysis of finding has indicated presence of fluoride in excessive quantities in 24 bore wells. Granites/granotides and basalts are thought to be the main sources of Fluoride in the ground water in many parts of Chhindwara District. Generally fluoride traced in contact of basalt and granitic formation or in deeper aquifer in granite formation. The ranges of fluoride concentration between 0.2 mg/l and 24mg/l in Chhindwara district maximum concentration of fluoride in Rajakhoh Dhana and minimum in Chhind of Parasia Block. The details of the location and depth of fluoride content are given below in **Table 15**

Table 15: Water Quality of samples collected from Deep Wells in Chhindwara District

S. No.	Block	Village	Type/Source	pH	EC micro S/cm at 25^{0}C	TH as $Caco_3$, mg/l	F mg/l	Co_3 mg/l	HCo_3 mg/l	Cl mg/l	Ca mg/l	Mg mg/l	NA	K	Remarks
1.	Chaurai	Jhilmili	OW-1 depth 30.50 mbgl	7.33	1020	205	1.0	Nil	232	138	60	13			
2.	Chaurai	Jhilmili	OW-1 depth 109.08 mbgl	7.83	777	105	5.5	Nil	183	85	24	11			Fluoride Effected
3.	Chaurai	Jhilmili	Ow-2 depth 130.00 mbgl	7.76	732	80	4.0	Nil	232	89	8	10			
4.	Chaurai	Jhilmili	OW-2 depth 140.00 mbgl	7.83	794	90	3.7	Nil	220	103	16	12			
5.	Chaurai	Jhilmili	EW-3 depth 127.10	7.27	690	70	2.3	Nil	268	-	22	4			
6.	Chaurai	Jhilmili	EW-3 SDT	7.25	800	175	3.43	Nil	299	74	48	13			
7.	Chaurai	Jhilmili	EW-3 APT	8.06	828	155	3.36	Nil	287	82	48	9			
8	Chaurai	Jhilmili	Dugwell	7.47	388	0.40	Nil	180	25	145	20	23			
9	Chaurai	Jhilmili	Pench River	7.63	1140	5	Nil	360	135	305	84	23			
10	Chaurai	Jhilmili	Shallow tubewell	7.60	722	3.8	Nil	207	92	45	12	4			
11	Chaurai	Jhilmili	Deep tubewell	7.83	788	5.4	Nil	183	106	80	24	5			
12	Chhindwara	Noniamaru	EW depth 90.00 mbgl	7.71	493	14.5	Nil	134	32	20	6	1			
13	Chhindwara	Noniamaru	EW depth105.00 mbgl	7.97	467	14.9	Nil	153	11	20	4	2			
14	Chhindwara	Noniamaru	EW depth 151.00 mbgl	8.05	506	14.2	Nil	153	28	25	6	2			
15	Chhindwara	Noniamaru	EW depth167.70 mbgl	7.62	488	15.2	Nil	134	32	10	2	1			
16	Chhindwara	Noniamaru	EW depth depth167.70 mbgl	7.70	466	14.7	Nil	122	28	15	4	1			
17	Chhindwara	Rajakhoh Dhana	OW-1 depth 48.80mbgl	7.66	512	1.10	Nil	281	25	85	30	2.4			
18	Chhindwara	Rajakhoh Dhana	OW-2 depth: 86.80 mbgl	8.02	462	9.71	Nil	171	35	45	14	2			
19	Chhindwara	Rajakhoh Dhana	EW-3 depth 92.00 mbgl	7.40	760	3.25	Nil	470	21	215	48	23			
20	Chhindwara	Rajakhoh Dhana	EW-3 depth 103.7 mbgl	8.14	451	20.00	Nil	128	50	30	6	3.6			
21	Chhindwara	Rajakhoh	EW-3 during SDT	8.90	429	14.84	24	55	46	20	4	2			Fluoride

S. No.	Block	Village	Type/Source	pH	EC micro S/cm at 25^{0}C	TH as $Caco_3$, mg/l	F mg/l	Co_3 mg/l	HCo_3 mg/l	Cl mg/l	Ca mg/l	Mg mg/l	NA	K	Remarks
		Dhana													Effected
22	Chhindwara	Rajakhoh Dhana	EW-3 during APT	8.75	430		18	61	46	20	4	2			Fluoride Effected
23	Chaurai	Panjara	EW-1 depth 91.50 m	7.97	1060	5.62	Nil	104	121	180	64	05			
24	Chaurai	Panjara	EW-2 depth138.30 mbgl	8.40	633	9.07	12	159	53	65	24	01			
25	Amarwara	Khakra Chaurai	EW-65.00 mbgl	7.36	547	18.5	Nil	140	67	55	10	7.3			
26	Amarwara	Khakra Chaurai	EW- depth 97.60 mbgl	7.67	415	18.75	Nil	122	39	25	4	3.6			
27	Amarwara	Khakra Chaurai	EW-depth 127.10 mbgl	8.10	408	17.5	Nil	110	50	15	2	2.4			
28	Amarwara	Khakra Chaurai	EW-depth 137 mbgl	8.07	400	17.5	Nil	110	46	20	2	2.4			
29	Parasia	Umreth	EW -180 mbgl	7.27	577	235	nil	225	235	43	60	21	16	1.5	
30	Chhindwara	Goreghat	EW- depth 183 mbgl	7.67	454	160	0.84	Nil	195	18	30	21		1.8	
31	Chhindwara	Salimata	EW depth 201 mbgl	7.71	565	186	0.84	Nil	197	18	36	21		1.8	
32	Parasia	Chhinda	EW depth 140 mbgl	7.1	15.59	530	0.2		323	110	194	11	122	1.1	
33	Bichua	Bichhvi	EW depth 201 mbgl	7.1	15.59	530	0.2		323	110	78	11	122	1.1	
34	Sausar	Nimni	EW depth 61m bgl	7.36	864		0.84					360			
35	Sausar	Nimni	EW- depth 146	7.52	892		0.97								
36	Sausar	Nimni	EW- during PYT	7.31	922		0.93		403	32		40	43		
37	Sausar	Lodhikheda	EW – depth 79 mbgl	7.31	763	305	0.81		323		52	42	20	11	
38	Sausar	Lodhikheda	EW –depth 150 mbgl	7.06	1601	325	0.75		214		70	36	210	11	

High concentration of fluoride is found at Rajakhoh Dhana(EW), ranges between 18 and 24 mg/l. The concentration of fluoride at Panjara (EW) site in ground water sample is 12mg/l. In Jhilmil village concentration of fluoride ranges between 2.3mg/l to 5.5 mg/l.

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The lithological data collected from 24 CGWB Exploratory Borewells and deep borewells constructed by PHE were studied, compiled and integrated to prepare the 2-Dimensional Cross section. From the 2-D Section is presented in the figures it has been interpreted that the major water bearing zones has been encountered in weathered/fractured basalts and fractured sandstone (Gondwana) and Granite formations.

2-Dimensional Lithological & Stratigraphic sections prepared for the Chhindwara district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB. A comprehensive analysis was made as per lithology and stratigraphy of the area.

3.1 HYDROGEOLOGICAL 3D MODEL

As the area is covered with hard rocks, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 30m. The fractured /jointed basalt and Granitic gneiss, Gondwana sandstones form the deeper aquifer. 3-D representation is presented in **Fig. 14**. The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the 3D diagram.

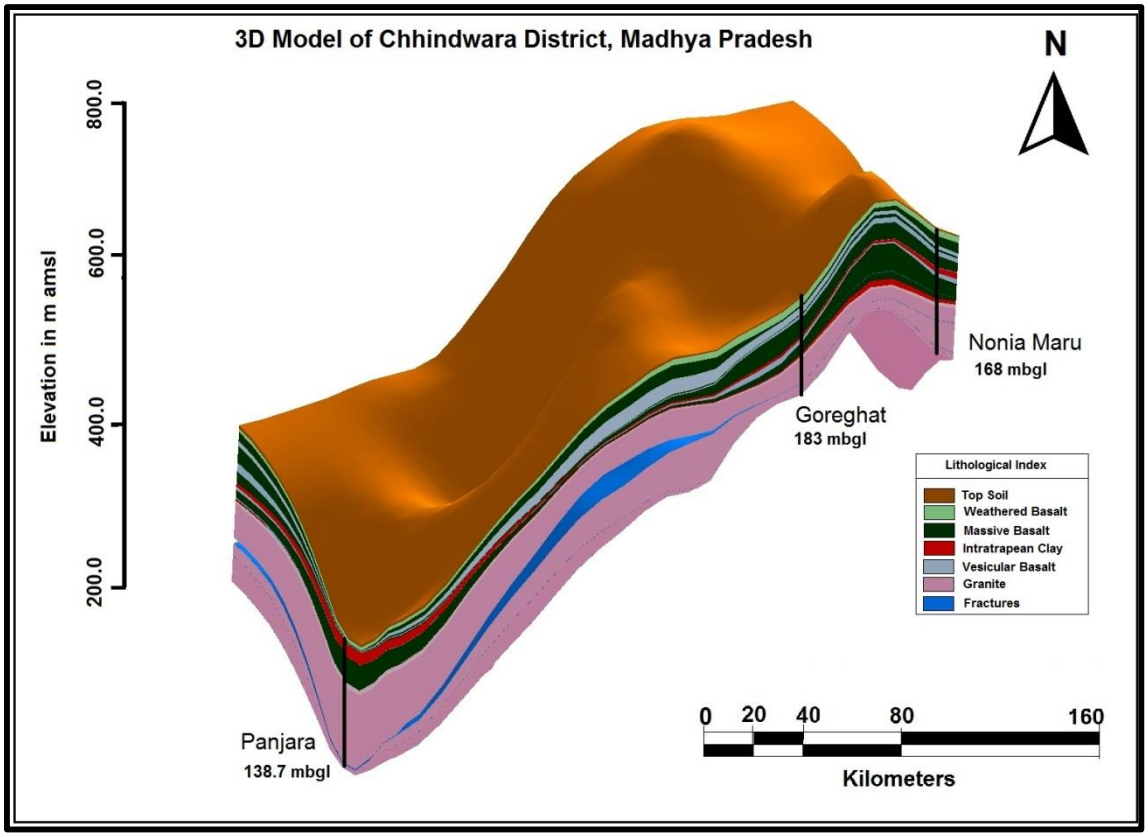


Fig 14: 3D Model of the Chhindwara District.

3.2 HYDROGEOLOGICAL CROSS-SECTIONS

The 2-D section shows that the region is dominantly occupied by Basalt and Granite. The sub-surface lithology has been broadly classified into Top soil underlain by Weathered Basalt/Granite and Massive Basalt/ Granite which has been considered as shallow aquifer (upto a depth of 30 mts) and Deeper Aquifer (30-200) m.

3.2.1 Hydrogeological cross section-1

Hydrogeological cross section (**Fig.15)** represents data of 3 exploratory wells i.e., Rajakhoh Dhana, Panjara Chau to Bichhvi been utilized. into Top soil underlain by Weathered Basalt/Granite and Massive Basalt/ Granite which has been considered as shallow aquifer (upto a depth of 30 mts) and Deeper Aquifers are aquifer are mainly in fractured gneiss (30-200) m.

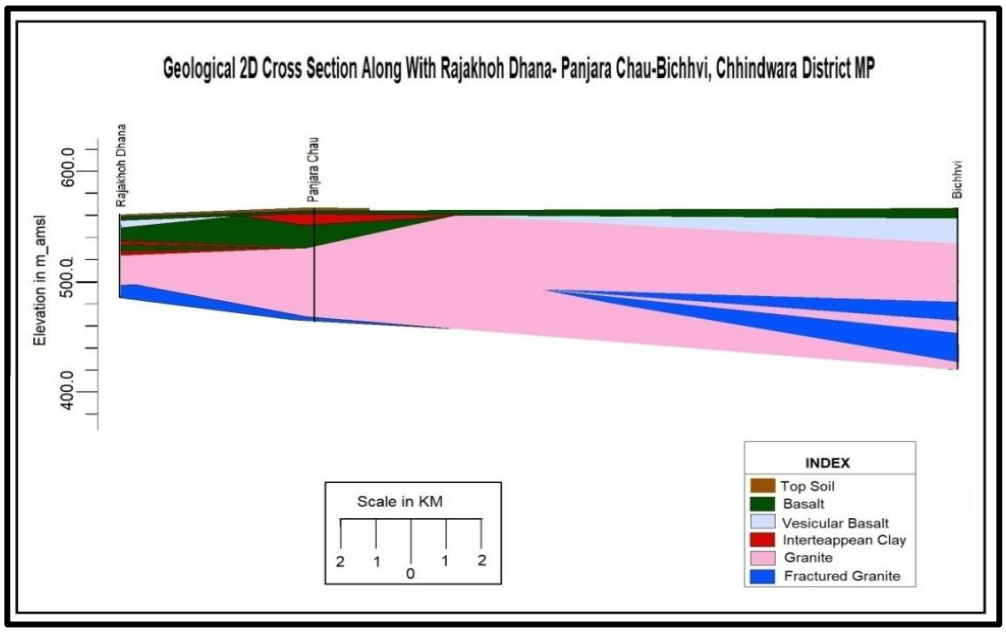


Fig 15: 2-D Lithological Section (1)

3.2.2 Hydrogeological cross section-2

Hydrogeological cross section (**Fig.16)** represents data of 4 exploratory wells i.e., Khakrachaurai, Noniamaru, Rajakhohdhana and Panjara been utilized. Top soil underlain by Weathered Basalt/Granite and Massive Basalt/ Granite which has been considered as shallow aquifer (upto a depth of 30 mts) and Deeper Aquifers are aquifer are mainly at contact zone of basalt and granite and fractured granitic gneiss (30-200) m.

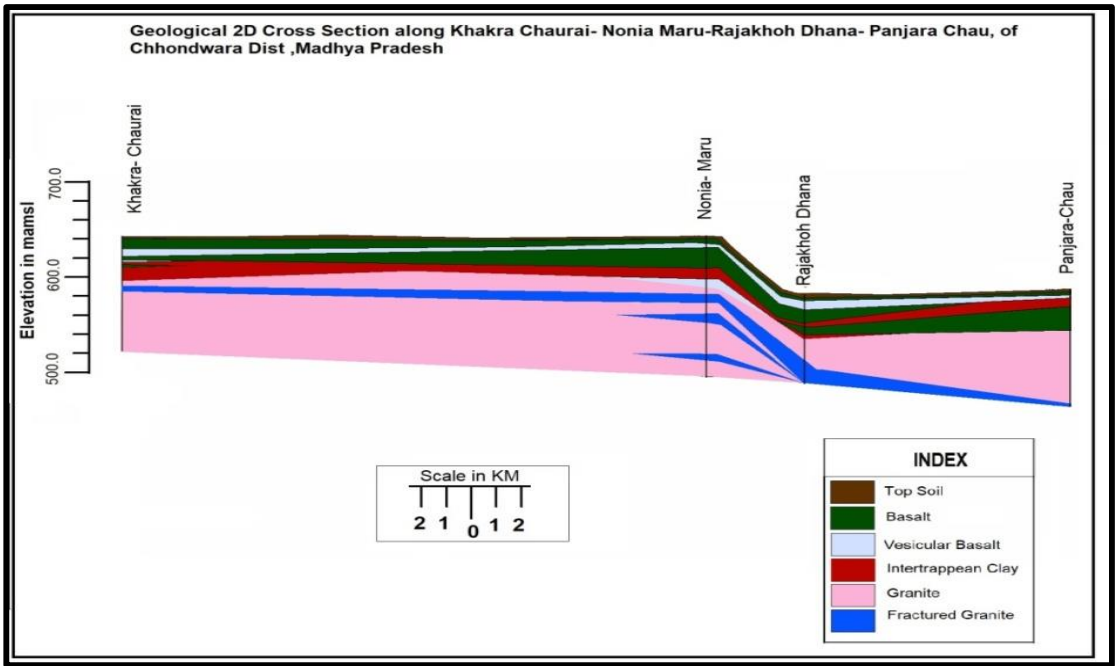


Fig 16: 2-D Lithological Section (2)

3.2.3 Hydrogeological cross section-3

Hydrogeological cross section (**Fig.17)** represents data of 3 exploratory wells i.e., Salimata, Goreghat and Panjarachau been utilized. Top soil underlain by Weathered Basalt/Granite and Massive Basalt/ Granite which has been considered as shallow aquifer (upto a depth of 30 mts) and Deeper Aquifers are aquifer are encounterd only at Goreghat at contact zone of vesicular basalt/granite gneiss (30-200) m.

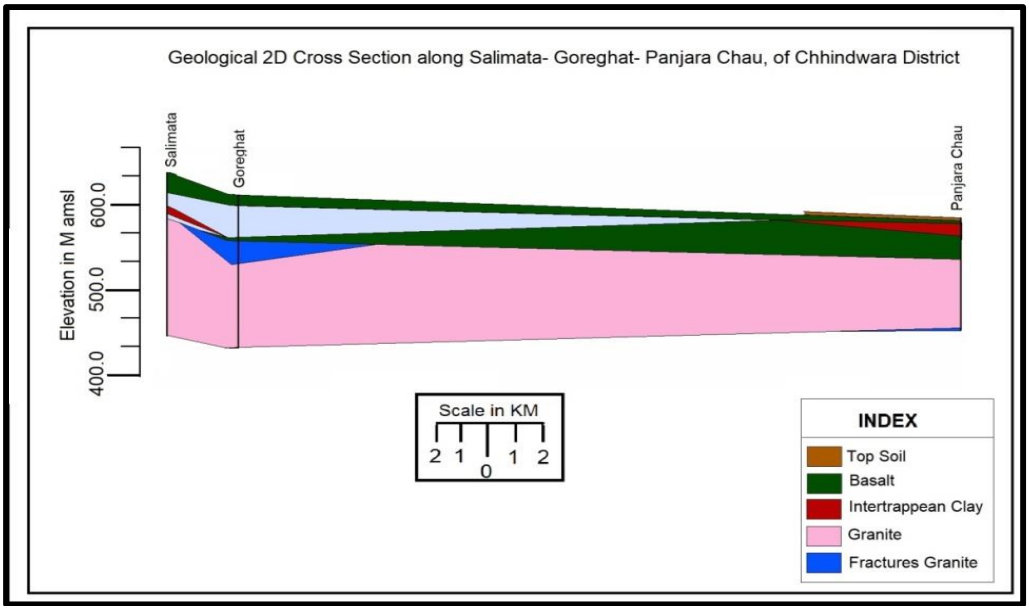


Fig 17: 2-D Lithological Section (3)

3.2.4 Hydrogeological cross section-4

Hydrogeological cross section (**Fig.18)** represents data of 3 exploratory wells i.e.,Bichhvi, Goreghat and Ridhomal been utilized. Top soil underlain by Weathered Basalt/Granite and Massive Basalt/ Granite which has been considered as shallow aquifer (upto a depth of 30 mts) and Deeper Aquifers are aquifer are mainly at contact zone of basalt and granite and fractured granitic gneiss (30-200) m.

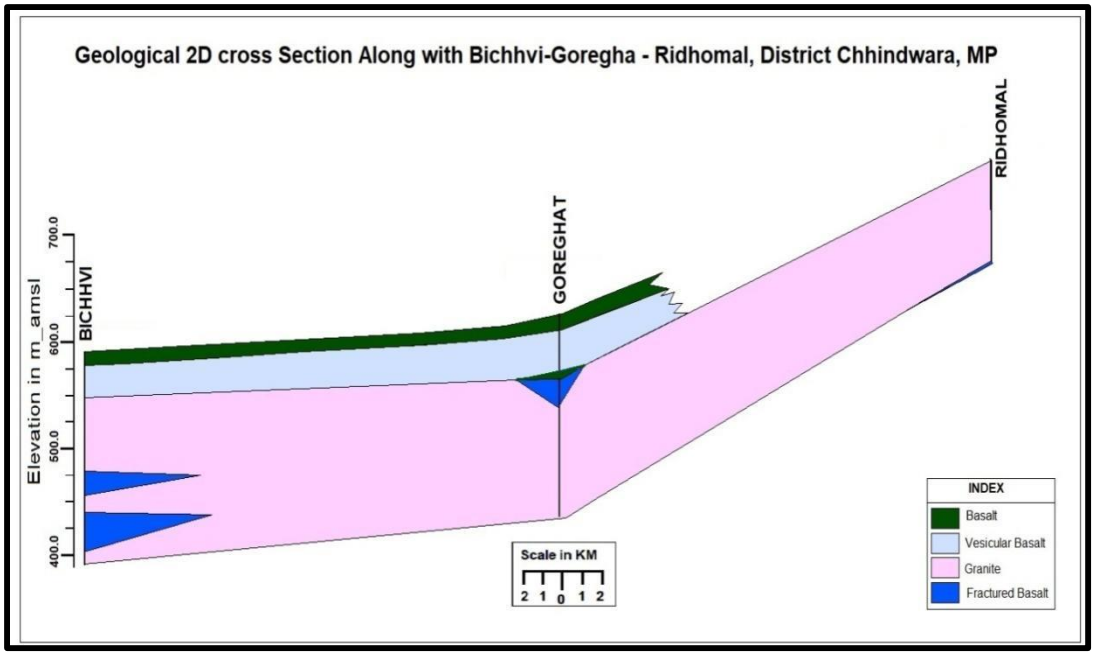
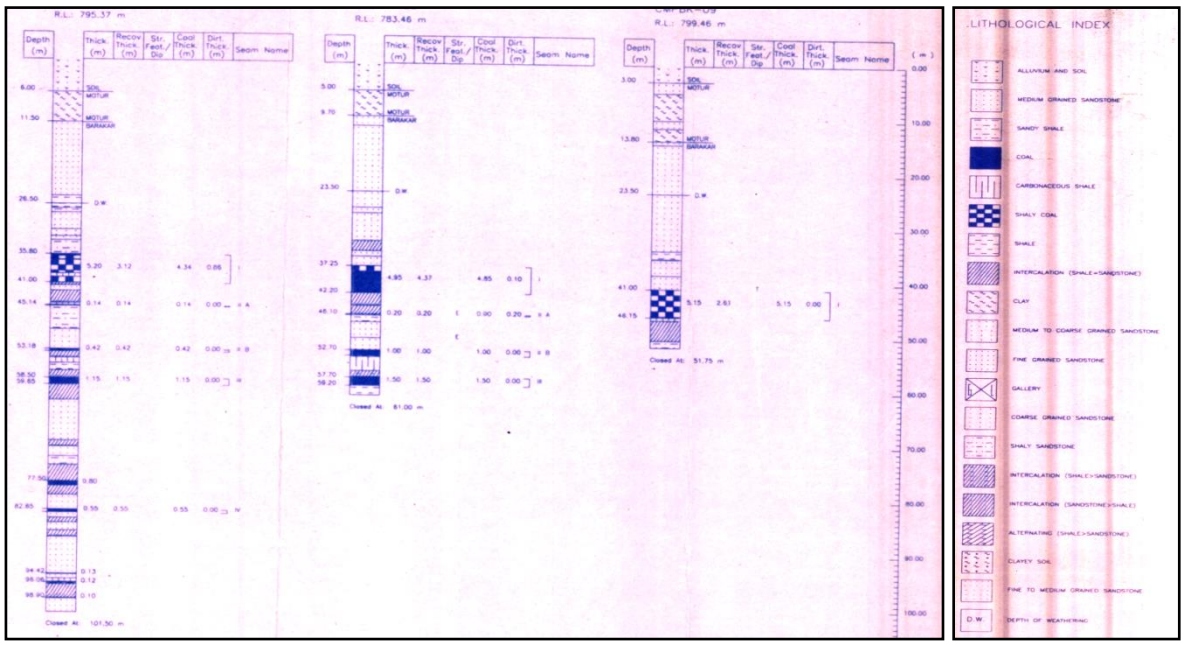


Fig 18: 2-D Lithological Section (4)

3.2.5 Core log section- 5

Hydrogeological cross section (**Fig.19)** represents data of 3 Core wells in Gondwana, WCL, Chhindwara.



Reference: Barkui Mines, (Western Coal Limited) Core log report of Chhindwara District.

Fig 19: Core log Section of Barkui Village Mining area, Parasia Block District, Chhindwara, MP

Correlating the core logs of underground coal mining blocks of WCL Coal fields and the PHE department tubewells in the buffer area of mines of Parasia and Jamui block, the major aquifers observed are at varying depth. In weathered sand stones/ basalt at depth 6-12 meters, in vesicular and fractured basalt at depth of 45-57 meters and in Barakar semi consolidated fractured sandstone encountered at depth of 90-112 meter respectively. While extracting the coal seams the aquifers above the seams are exploited due to heavy dewatering. Dug wells and tube well are affected and are losing their potential in terms of quality as well as quantity. Yield of wells particularly in deeper aquifer are gradually diminishing in term of quantity as well as quality.

4.0 GROUND WATER RESOURCES

Chhindwara district is underlain by Deccan trap basalt, Achaeans granite-gneisses and Gondwanas sandstone-clays. Dynamic ground water resources of the district have been estimated for base year - 2019-20 on block-wise basis. Out of 1176024 ha of geographical area, 879301 ha (75%) is ground water recharge worthy area and 296723 ha (25%) is hilly area. There are eleven number of assessment units (blocks) in the district which fall under non-command (99 %) and command (1 % Mohkhed and Sauser) sub units. Amarwara, Bichhua, Chourai, Harrai, Jamai, Sausar, Parasia and Tamia blocks of the district are categorized as safe blocks, Mohkhed and Pandhurna are **Semi Critical** and Chhindwara is categorized as **Critical**. Highest stage of ground water extraction is computed as 96.55% for Chhindwara block. The annual extractable ground water resource in the district is 98786.94 Ham and ground water extarction for all uses is 59076.21 Ham, making stage of ground water extraction 59.80% as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 39353.93 ham.

Table16: Assessment Unit Wise Area Details(2020)

Assessment Unit	Type of Rock Formation	Recharge Worthy area of formation (in Ha)	Areal extent (in Ha)			
			Total Geographical Area	Hilly Area	Ground Water Recharge Worthy Area	
					Command Area	Non-Command Area
AMARWARA	Deccan trap basalt	93955	102200	8245	0	93955
BICHHUA	Deccan trap basalt	41384	52700	11316	0	41384
CHHINDWARA	Archaen granite, Deccan trap basalt	63516	68300	4784	0	63516
CHOURAI	Deccan trap basalt	113973	117200	3227	0	113973
HARRAI	Deccan trap basalt	127238	210700	83462	0	127238
JAMAI	Gondwana Formation & Deccan trap basalt	96604	142400	45796	0	96604
MOHKHED	Archaean granite, Deccan trap basalt	70886	77500	6614	6238	64648
PANDHURNA	Deccan trap basalt	87186	97200	10014	0	87186
PARASIA	Gondwana Sandstone, Archaean Granite	69020	78700	9680	0	69020
SAUSAR	Archaean Granite, Gondwana Sandstone	69313	80800	11487	6238	63075
TAMIA	Gondwana Formation & Deccan trap basalt	51702	153800	102098	0	51702
DISTRICT TOTAL		884777	1181500	296723	12476	872301

Table 17: Assessment Unit Wise Recharge (2020)

Assessment Unit Name	Recharge Worthy Area(Ha)	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources-Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources-Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
AMARWARA	93955	8881.26	309.85	72.98	1096.95	10361.04	518.06	9842.98
BICHHUA	35908	4111.56	155.56	27.89	569.35	4864.36	243.22	4621.14
CHHINDWARA	63516	7985.99	545.37	47.06	1727.95	10306.37	515.32	9791.05
CHOURAI	113973	12167.26	365.89	88.53	1408.4	14030.08	701.51	13328.57
HARRAI	127238	8361.08	159.82	53.22	557.78	9131.9	456.6	8675.3
JAMAI	96604	10415.19	164.46	71.86	687.01	11338.52	566.92	10771.6
MOHKHED	70886	8132.91	736.34	52.96	2210.46	11132.67	556.63	10576.04
PANDHURNA	87186	9347.6	664.75	67.72	1797.26	11877.33	593.87	11283.46
PARASIA	69020	7499.09	240.18	41.24	788.32	8568.83	856.89	7711.94
SAUSAR	69313	6090.33	447.85	37.19	1402.27	7977.64	398.88	7578.76
TAMIA	51702	4810.8	76.31	39.68	191.1	5117.89	511.79	4606.1
DISTRICT TOTAL	879301	87803.07	3866.38	600.33	12436.85	104706.6	5919.69	98786.94

Table 18: Assessment Unit Wise Extraction (2020)

Assessment Unit Name	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Category
AMARWARA	9842.98	5235.87	0	399.1363	5635	438.23	4168.89	57.25	safe
BICHHUA	4621.14	2540.32	0	214.6857	2755	231.48	1849.35	59.62	safe
CHHINDWARA	9791.05	8485.074	0	967.7342	9452.8	967.73	338.25	96.55	critical
CHOURAI	13328.57	6945.25	0	456.6895	7401.93	487.04	5896.29	55.53	safe
HARRAI	8675.3	2646.17	0	352.8178	2998.98	399.49	5629.65	34.57	safe
JAMAI	10771.6	3186.82	0	584.6402	3771.46	627.12	6957.66	35.01	safe
MOHKHED	10576.04	7078.75	0	411.7988	7490.55	443.76	3053.53	70.83	semi_critical
PANDHURNA	11283.46	9076.392	0	948.5	10024.89	948.5	1258.57	88.85	semi_critical
PARASIA	7711.94	3946.6	0	720.1881	4666.78	794.97	2970.38	60.51	safe
SAUSAR	7578.76	3489.61	0	423.6884	3913.3	441.96	3647.19	51.64	safe
TAMIA	4606.1	652.69	0	312.8327	965.52	369.24	3584.17	20.96	safe
DISTRICT TOTAL	98786.94	53283.55	0	5792.712	59076.21	6149.52	39353.93	59.80	safe

5.0 GROUND WATER RELATED ISSUES

5.1 Declining Of Water Level

The long-term water level trend (2012-2021) analysis indicates that during pre-monsoon period the blocks of Bichhua, Jamai, Parasia and Tamia are showing declining trend Similarly, during post-monsoon period all the blocks are showing falling trend except Mohkhed, Pandhurna and Sausar .The overall water level trend shows that except the blocks Chhindwara, Harrai and Mohkhed all the blocks having declining trend ranging from 0.01 m/yr to 1.03 m/yr.

The Ground Water Resource Estimation 2020 reveals that out of 11 Blocks of the district only 3 blocks namely Chhindwara Mohkhed and Pandhurna have crossed 70% stage of ground water extraction. Mohkhed & Pandhurna is in category of semi critical and Chhindwara in Critical category. Over all stage of ground water extraction of the district is computed as 59.80%.

5.2 Cropping Patterns

High intensive crops particularly Grapes and Oranges are grown in Pandhurna block in which heavy withdrawal of ground water done mostly from Dugwells and Very deep borewells about 300 mbgl. Water level in the area going down and stage of ground water extraction of the block is 88 % and block fall in semi critical category.

Cropping patterns of the area should be on the basis of availability of ground water and suitable for artificial ground water recharge.

5.3 Ground Water Quality

The fluoride concentration in Chhindwara district ranged in between 0.22 to 1.97 mg/l.in shallow/ phreatic aquifers and 0.2 to 24 mg/l in deeper aquifer In the district, maximum concentration of fluoride has been recorded in the dug well of Ramakona i.e. 1.97 mg/land Exploratory well in Rajakhoh Dhana is 24 mg/l. In the district, fluoride concentration more than 1.50 mg/l have been observed in ground water of Chaurai (1.68 mg/l), Boragaon (1.78 mg/l), Sonapipri (1.89 mg/l) and Ramakona (1.97 mg/l) as per shallow groundwater chemical analysis but the on the basis of deeper aquifer

ground water analysis this is observe that the fluoride ranges between 0.2 to 24 mg/l in mainly granitic and basalt with granite formation. In the district, nitrate concentration in ground water ranged in between 8 to 189 mg/l. The 65.8% ground water samples recorded nitrate concentration within the acceptable limit of 45 mg/l whereas 34.2% water samples recorded more than 45 mg/l as per BIS recommendation. The nitrate concentration has been recorded more than 100 mg/l in ground water of Linga Railway Station (112 mg/l), Sonapipri (125 mg/l), Renikhera (152 mg/l) and Boragaon (189 mg/l).

5.4 Heavy Dewatering Of Ground Water In Mining Areas

The major mining activities by underground coal mining is going on in the Parasia, Jamunia and in some part of Tamia down to depth of about 300 m in which are heavy dewatering of ground water is being done. It is also pumped out from the major aquifers of fractured vesicular basalt and ferruginous Barakar sandstone The dewatered water from various mines are pumping about 10000 KL/day which is having high iron content and it is discharged in Pench and Kanhan rivers . Buffer zone aquifers adjoining to mining area are showing depleting ground water levels and many spring are also getting dry and its flow is gradually diminishing. Also ground water qualities in Buffer zone are deteriorating having high iron content, which may be due to pumping of ground water from Barakar sandstone of ferruginous nature. Column pipe of PHED handpump observed to be frequently corroded and are damaged due to high content iron in ground water.

Table 19: High Iron contents in coal mining buffer area PHED hand pumpsof Parasia block.

S.No	Village	Location	Desirable limits mg/l	Iron mg/l
1	Ambada	Jhiriya Mohalla Bad tree	0.15	2.1
2	Ambada	Amabada	0.15	1.7
3	Ambada	Road Side ambada	0.15	2.3
4	Ambada	Near WCL Bungalow		2.3
5	Sheeladehi	Dinesh House	0.15	2.07
6	Sheeladehi	Radheshyam	0.15	1.5

S.No	Village	Location	Desirable limits mg/l	Iron mg/l
		Vishvakarma House		
7	Sheeladehi	Near Anganwadi	0.15	1.79
8	Sheeladehi	Infront of Sarpanch house	0.15	2.14
9	Sheeladehi	Near Nag mandir	0.15	1.32

(Source: PHED Sub division , Parasia, Chhindwara)

5.5 Well Construction Design

Large numbers of deep tube wells constructed in the basaltic rock formation even though having sufficient yield observed during well construction, are found to be abandoned or unused due to faulty well construction design in which part assembly are not generally placed/lowered properly against the collapsible formation (intertrappean clay) encountered at various intervening depth . These Intertrappean clays of thickness 2 to 9 meter generally occurring at variable depth 30-45, 70-90, 130-145 and 170-190 are non cohesive and non collapsible under unsaturated condition when well is dry but when sufficient yield observed in well then these over lying clays start collapsing rapidly under saturated condition.

The recommended well design in the area is as is given in Fig. 12

5.6 Very Deep Water Level

The very deep water level more than 100 meter is due to cavities and Handpumps becomes inoperative in the wells having water level more than 45 meters. Borewells having this deep water level should be studied scientifically for utilising this cavity as a subsurface storage/recharge in which surplus monsoon/ high intensity rain runoff can be utilised effectively .

Well Design

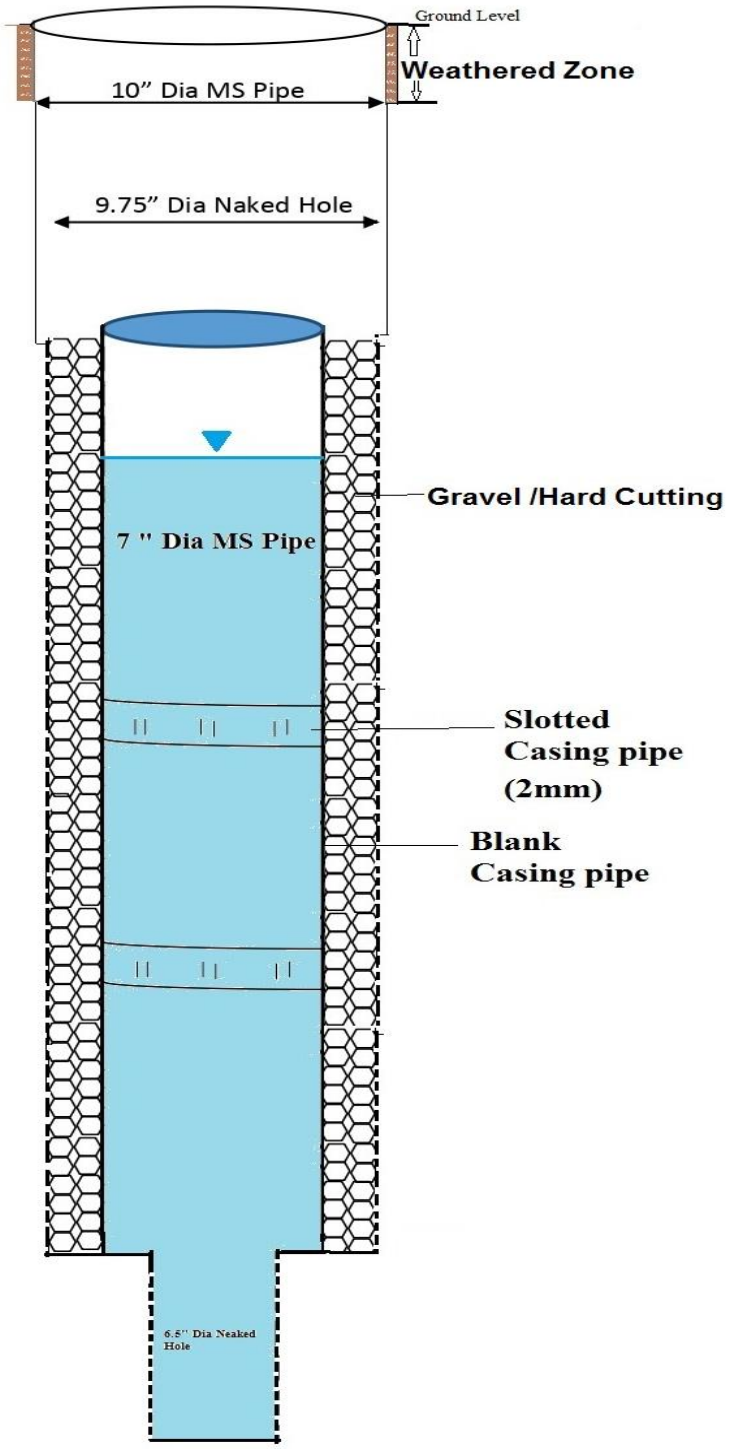


Fig12: Recommended Well Design

6.0 GROUND WATER MANAGEMENT STRATEGIES

As discussed in previous chapter, there are many groundwater related issues owing to many socio-economic and hydrogeological reasons. The groundwater management plan for Chhindwara district has been made keeping in view the area specific details and includes the strategies like enhancing the ground water resources through the 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 technique such as sprinkler/drip 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.

6.1 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 increase 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 Chhindwara 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 Chhindwara 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 ana as per master plan. The remaining 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 20 and Fig. 17

Table 20: Detailed calculation of the proposed artificial recharge structures in Chhindwara district, Madhya Pradesh

	Units	
Total Area	Sq Km	11815.0
Area suitable for recharge		8847.77
Sub-surface storage	MCM	371.18
Surface water required		493.67
Surface water (Run-off) available		3379.09
Non-committed Run-off		1013.73
Percolation tank	No's	1150
Check Dam		9849
Village Pond		3282
Nala Bund/ CP		9849

Structures	**Number**	**Cost in Crores**
Percolation Tanks	1150	207
Check Dam	9849	393.96
Nala Bund/ CP	9849	98.49
Renovation of Village Ponds	3282	82.05
Total Cost		**781.5**

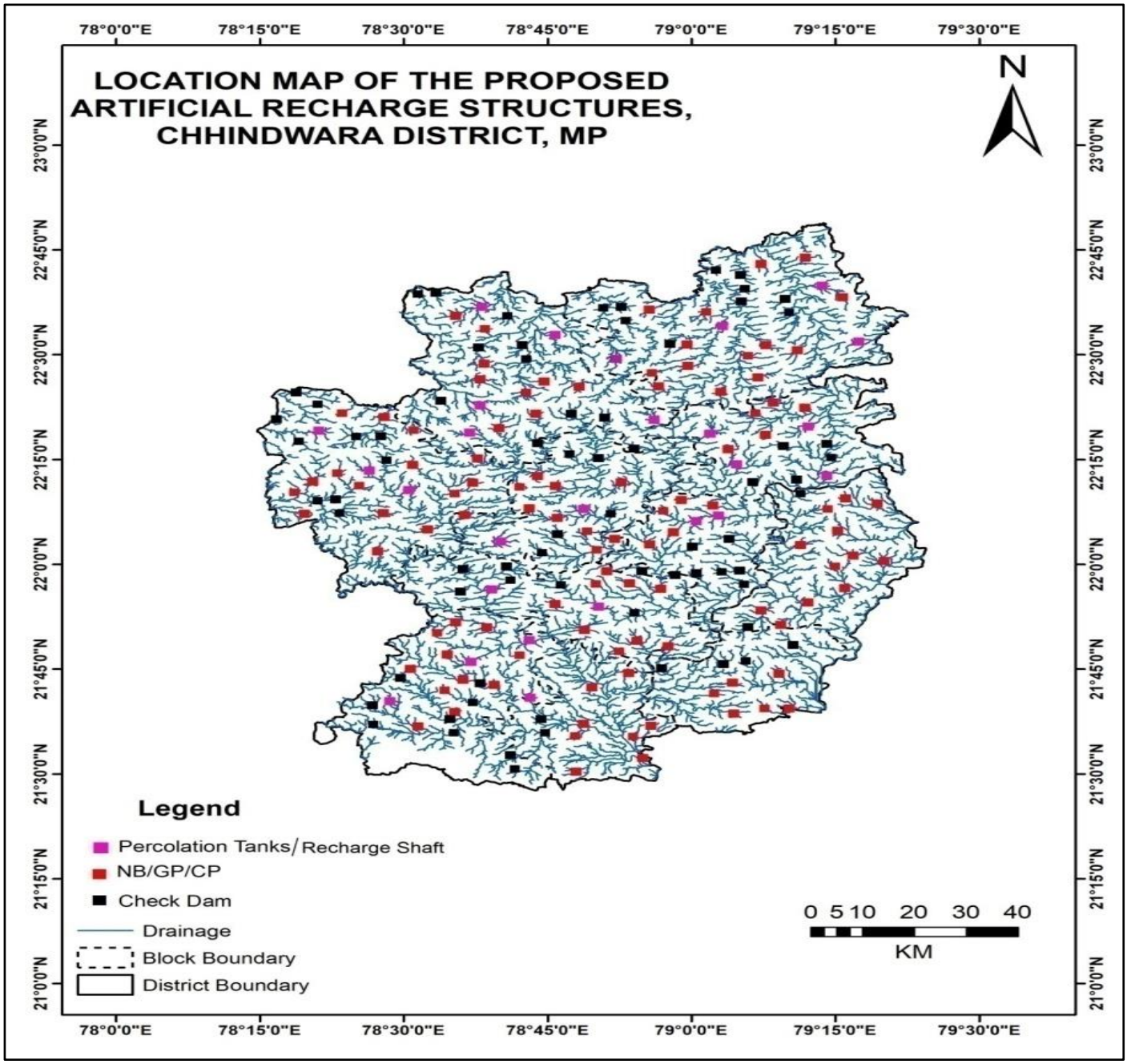


Fig 21: Location map of the Tentative Artificial recharge structure

6.2 Demand Side Management

However, considering the low storage potential of hard rock aquifer in the area the above ground water development plan should also be coupled with ground water

augmentation plan, so that there is no stress on ground water regime of the area. 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:

- 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).
- It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.

- It saves costs of hired labour and other inputs like fertilizer.

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

Table 21: Block Wise Ground Water Management– Supply Side, Chhindwara District, Madhya Pradesh

Block	Rain fall (mm)	Area (Sq Km)	Area suitable for recharge (Sq Km)	Average post-monsoon water level (m)	Unsaturated zone (m)	Average SP Yield (%)	Sub-surface storage (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 Villages
Amarwara	1039	1022	939.55	4.49	1.49	0.02	28.00	37.24	292.29	87.69	87	743	743	248
Bichhua	1039	527	413.84	6.95	3.95	0.02	32.69	43.48	150.72	45.22	101	867	867	289
Chhindwara	1039	683	635.16	4.37	1.37	0.02	17.40	23.15	195.34	58.60	54	462	462	154
Chourai	1039	1172	1139.73	4.08	1.08	0.02	24.62	32.74	335.19	100.56	76	653	653	218
Harrai	1039	2107	1272.38	2.9	0	0.02	25.45	33.85	602.60	180.78	79	675	675	225
Jamai	1039	1424	966.04	5.23	2.23	0.02	43.09	57.30	407.26	122.18	133	1143	1143	381
Mohkhed	1039	775	708.86	6.00	3	0.02	42.53	56.57	221.65	66.50	132	1129	1129	376
Pandhurna	1039	972	871.86	9.39	6.39	0.02	40.98	54.50	277.99	83.40	127	1087	1087	362
Parasia	1039	787	690.2	9.62	6.62	0.02	91.38	121.54	225.08	67.52	283	2425	2425	808
Sausar	1039	808	693.13	7.31	4.31	0.02	22.87	30.42	231.09	69.33	71	607	607	202
Tamia	1039	1538	517.02	3.21	0.21	0.02	2.17	2.89	439.87	131.96	7	58	58	19
DISTRICT TOTAL		**11815**	**8847.77**	**5.17**	**2.27**	**0.02**	371.18	493.67	3379.09	1013.73	1150	9849	9849	3282

Table 22: Proposed demand Side Interventions

Net GW Availability	MCM	987.87
Gross Draft		590.76
Stage of Development	%	59.80
Saving by Sprinkler in MCM	MCM	106.57
Additional recharge created by AR		1013.73
After intervention of AR Structure Net GW AvL.		2001.60
After intervention of AR Structure & utilisation of 60% of additional GW created.		608.24
Draft after sprinkler & additional area created for agriculture		1092.43
Stage of Development W/O GW use for additional Area Irrigation		54.58
Additional area irrigated by GW after intervention (Sq.Km)		1520.6

6.3 Post-Intervention Impact

The expected outcome of the proposed interventions from both supply side and demand side has been described in Table no 23. It can be envisaged that the Stage of ground water development for the entire Chhindwara district, would reduce to 54.58 % as compared to the present stage of ground water development of 59.80 % after implying and successful implementation of proposed interventions.

6.4 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 Chhindwara 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.

Table 23: Block Wise Post-Intervention Impact, Chhindwara District, Madhya Pradesh

Block	Net GW Availability (MCM)	GW Draft for Irrigation (MCM)	GW Draft for Domestic & Industrial (MCM)	Gross Draft (MCM)	Stage of Development (%)	Saving by Sprinkler in (MCM)	Additional recharge created by AR (MCM)	After intervention of AR Structure Net GW AvL. (MCM)	After intervention of AR Structure & utilisation of 60% of additional GW created. (MCM)	Draft after sprinkler & additional area created for agriculture (MCM)	Stage of Development W/O GW use for addidtional Area Irrigation (%)	Additional area irrigated by GW after intervention (ha)
AMARWARA	98.43	52.36	3.99	56.35	**57.25**	10.47	87.69	186.12	52.6126	98.49	**52.92**	13153
BICHHUA	46.21	25.40	2.15	27.55	**59.62**	5.08	45.22	91.43	27.1300	49.60	**54.25**	6782
CHHINDWARA	97.91	84.85	9.68	94.53	**96.55**	16.97	58.60	156.51	35.1608	112.72	**72.02**	8790
CHOURAI	133.29	69.45	4.57	74.02	**55.53**	13.89	100.56	233.84	60.3346	120.46	**51.51**	15084
HARRAI	86.75	26.46	3.53	29.99	**34.57**	5.29	180.78	267.53	108.4684	133.17	**49.78**	27117
JAMAI	107.72	31.87	5.85	37.72	**35.01**	6.37	122.18	229.90	73.3075	104.65	**45.52**	18327
MOHKHED	105.76	70.79	4.12	74.91	**70.83**	14.16	66.50	172.26	39.8970	100.64	**58.43**	9974
PANDHURNA	112.83	90.76	9.49	100.23	**88.85**	18.15	83.40	196.23	50.0386	132.13	**67.34**	12510
PARASIA	77.12	39.47	7.20	46.67	**60.51**	7.89	67.52	144.64	40.5148	79.29	**54.82**	10129
SAUSAR	75.79	34.90	4.24	39.13	**51.64**	6.98	69.33	145.11	41.5958	73.75	**50.82**	10399
TAMIA	46.06	6.53	3.13	9.66	**20.96**	1.31	131.96	178.02	79.1762	87.53	**49.17**	19794
District Total	987.87	532.84	57.93	590.76	**59.80**	106.57	1013.73	2001.60	608.24	1092.43	**54.58**	152059

The stage of ground water extraction of the district is 59.80% (GW resource 2020) and about 42.82 % area is irrigated of total area of the district. The northern part of the district covering blocks of **Tamia, Jamai** and **Harrai** are identified for central sector/state schemes like **PMKSY** as these areas having water level less than 15 mbgl during pre-monsoon 2021, normal annual rainfall is more than 750 mm. (GW Resource 2020) and stage of GW extraction is less than 60% (criteria for Pradhan mantra krishi sichai yojna). Presently about 50% area of the total area of these blocks are irrigated through all sources. The suitable ground water abstraction structure recommended for the area is shallow Borewells and Dugwells. It is also estimated that a Borewell of 2.5 lps discharge can irrigate approximately 2-3 hec. of land. As per the PMKSY report available in the GoI website, the non irrigated area in Chhindwara district is 288463 hectare. Assuming that a borewell in the area can irrigated on an average 2.5 hectare, the total number feasible borewells and dugwells for irrigation is around 115283. Harrai and Tamia area suitable for construction of dugwells and Jamai is suitable for borewells.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Chhindwara district occupies an area of 11815 sq km out of which the ground water recharge worthy area is 8847 sq. km. and the rest is covered by hilly and forest area. The northern part of the district lies in Narmada basin while the southern part lies in Wainganga sub basin of Godavari basin. The total catchments areas of the Narmada & the Wainganga rivers falling in the district are 3,555 and 8,295 Sq. km respectively. The major tributaries of the Godavari River are Kanhan, Pench and Wardha, while Sakkar, Sitarewa and Dudh are tributaries of Narmada River.Seventy percent of district lies in Godavari basin and thirty percent in Narmada Basin.

- The major part of the district is covered by the Deccan trap lava flows in eastern part, Gondwanas in north western part and by Archeans in west-central part.
- Chhindwara district comprises of eleven blocks, namely Amarwara, Bichhua, Chhindwara, Chourai, Harrai, Jamai, Mohkhed, Pandhurna, Parasia, Sausar, Tamia.
- The phreatic aquifer is recharged during monsoon and sustains for 5 to 6 months.
- More stress on Groundwater, 83 % of irrigation carried out by Ground water and 17% of irrigation by surface water.
- The overall water level trend shows that except the blocks Chhindwara, Harrai and Mokhed all the blocks having declining trend ranging from 0.01 m/yr to 1.03 m/yr.
- The fluoride concentration in Chhindwara district ranged in between 0.22 to 1.97 mg/l. in shallow aquifer where basalt and Gondwana formation in the Chhindwara districts but in deeper aquifer ranges between 0.2 mg/l and 24 mg/l. Some of the locations have high flouride concentration, higher than permissible limit set by BIS.
- Today there are many techniques to obtain fluoride-free water, but waste materials created from chemical-rich techniques will carry the risk of further contamination. So, Rainwater recharge potential area has to identify in the strategic locations. in which thick aquifer zone like Colluviums, Alluvium and weathered section of granitic are

where thickness ranges from 15 to 20 m in which percolation tanks, sub surface check dam and stop dams along the first and second order streams. This will naturally recharge the upper layer of unconfined aquifer with fluoride within the safe limit.

- If the fluoride is found in the contact zone of basalt and granite zone, the contact zone can be sealed during well construction through cementing and further drilling may be carried out for tracing the fresh water bearing aquifer zone.

- In the district, nitrate concentration in ground water ranged in between 8 to 189 mg/l. The 66% ground water samples recorded nitrate concentration within the acceptable limit of 45 mg/l whereas 34% water samples recorded more than 45 mg/l as per BIS recommendation.

- The heavy dewatered water having high iron contents in mining areas should not be discharge into natural steams without treatment of water and also resulting in depletion of ground water levels and high content of iron in ground water in buffer area. These problems must be addressed by the regulatory authorities.

- The abandoned/unused borewells having very deep water levels should be identified for recharge well/shaft in that area

- High Intensive crops which is OCS blocks should be discouraged and need to change the crop pattern as per the availability of water resources.

- Large numbers of abandoned wells should be identified for recharge wells.

- The yield of borewells observed in groundwater exploration varies from 0.4-10 lps in Granitic gneiss while in Basalt it varies from meagre to 1.85 lps and 2.0-5.0 lps in Gondwana formation.

- As per the Dynamic Ground Water Resource Assessment Report (2020), the net ground water availability in the district is 987.87 MCM and ground water extraction

for all uses is 590.76 MCM, resulting the stage of ground water extraction is 59.80% as a whole for district.

- There are eleven number of assessment units (blocks) in the district which fall under non-command and command (Morkhed and Sauser) sub units. Amarwara, Bichhua, Chourai, Harrai, Jamai, Sausar, Parasia and Tamia blocks of the district are categorized as safe blocks, **Chindwara** is **critical** with highest stage of ground water extraction is computed as 96.54% and **Pandhurna** and Mohkhad is fall under **semi critical** category.

- After the implementation of project interventions suggested in the report, the stage of extraction is expected to improve by 8% i.e. from 59.8 % to 48.49% for the district and additional area for the irrigation will be created 78951Ha.

- As per the Management plan prepared in all the Block of Chhindwara District, a total number of 1774 Percolation Tanks, and 15206 Check Dams 15206 Nala Bunds/Cement Plugs and 1963 Village ponds have been proposed.

- It is also recommended that implementation of intervention would be two phase the first phase should be in above 70 % stage of Ground water extraction of the blocks. In second phase, safe blocks may be taken.

Acknowledgement

The author is grateful to Sh. P.K Jain Ex Regional Director and Sh. Rana Chatterjee Regional Director Central Ground Water Board, North Central Region, Bhopal for NAQUIM Study, findings of which were incorporated in the report, and providing full back up support. Thanks are due to Ms. Rose Anita Kujur Scientist 'E' for scrutiny of this report.

The author expresses his thanks to all the Scientist of NCR Bhopal providing full technical support guidance.

The author also thanks to Mr. Tej Singh ACH, CGWB, NCR Bhopal for their support.

Thanks are also extended to Sh. Kamlesh Birla Sh. Vishal Wagh and Sh. Vishesh Seth (Young professionals) for preparation of maps and data compilation of this report.

Annexure-1 Pre-Monsoon Water Level-2020

BLOCK_NAME	SITE_NAME	LATITUDE	LONGITUDE	SITE_TYPE	DEPTH	WTR_LEVEL
AMARWARA	Amarwara	22.3014	79.1708	Dug Well	11.9	9.78
AMARWARA	Banjari	22.2597	79.1319	Dug Well	8.3	6.91
AMARWARA	Singhori	22.2011	79.0617	Dug Well	11.5	5.19
AMARWARA	Surla	22.4333	79.1722	Dug Well	11	1.1
BICHHUA	Bichhua(D)	21.8178	79.0361	Bore Well	90	15.1
CHAURAI	Chaurai(D)	22.0500	79.2636	Bore Well	80.35	8.45
CHAURAI	Chaurai1	22.0536	79.2508	Dug Well	13.93	11.25
CHAURAI	Marka Handi	22.0453	79.1644	Dug Well	17.5	10.5
CHAURAI	Ramgarh	22.1747	79.2717	Dug Well	14.5	10.8
CHHINDWARA	Chhindwara	22.0531	78.9494	Dug Well	17.29	16.61
CHHINDWARA	Jamunia Ner	22.1369	79.0233	Dug Well	17	7.05
HARAI	HarraiDW	22.6125	79.2208	Dug Well	12.6	3.7
HARAI	Sathiya	22.5903	79.1792	Dug Well	13	1.8
JAMAI	Damua	22.1936	78.4694	Dug Well	19.58	1.58
JAMAI	Jamuai(D)	22.1944	78.6017	Bore Well	64	20.5
MOHKHED	Goni	21.8214	79.0131	Dug Well	22.63	18.9
MOHKHED	Linga rly.stn.	21.9625	78.9378	Dug Well	17.2	11.5
MOHKHED	Sarangbheri	21.8669	78.9528	Dug Well	21.3	12.55
MOHKHED	Tansara Mal	21.8622	78.8981	Dug Well	11	1.32
PANDHURANA	Borgaon1	21.5594	78.8161	Dug Well	8.95	5.92
PANDHURANA	Chincholiwad	21.5000	78.6931	Dug Well	12	4.39
PANDHURANA	Mohi	21.6581	78.4408	Dug Well	13	4.1

BLOCK_NAME	SITE_NAME	LATITUDE	LONGITUDE	SITE_TYPE	DEPTH	WTR_LEVEL
PANDHURANA	Pandhurna(D)	21.5931	78.5297	Bore Well	120	30.33
PANDHURANA	Pandurna	21.5894	78.5183	Dug Well	9.4	6.4
PANDHURANA	Piplanarayanwar	21.5878	78.7314	Dug Well	18.4	8.8
PANDHURANA	Rajna	21.5403	78.6389	Dug Well	18.75	3.75
PARASIA	Lahgudna	22.2722	78.7242	Dug Well	10.5	4.4
PARASIA	Sonapipri	22.1428	78.8025	Dug Well	11	3.25
SAUSAR	Ramakona New	21.7019	78.8425	Dug Well	12.9	11.3
SAUSAR	Sausar	21.6553	78.8056	Dug Well	18.75	10.88
SAUSAR	Sausar(D)	21.6519	78.8028	Bore Well	90	8.99
SAUSAR	Sausar(S)	21.6519	78.8028	Bore Well	30	10.64
SAUSAR	Silwanighati	21.7881	78.8306	Dug Well	10.9	4.7
TAMIA	Delakhari	22.4211	78.6175	Dug Well	10.65	4.4

Annexure-2 Post-Monsoon Water Level-2020

BLOCK_NAME	SITE_NAME	LATITUDE	LONGITUDE	SITE_TYPE	DEPTH	WLS_WTR_LEVEL
AMARWARA	Amarwara	22.3014	79.1708	Dug Well	11.9	6.27
AMARWARA	Banjari	22.2597	79.1319	Dug Well	8.3	3.72
AMARWARA	Singhori	22.2011	79.0617	Dug Well	11.5	4.02
AMARWARA	Surla	22.4333	79.1722	Dug Well	11	1.28
BICHHUA	Bichhua(D)	21.8178	79.0361	Bore Well	90	10.52
CHAURAI	Chaurai(D)	22.0500	79.2636	Bore Well	80.35	3.37
CHAURAI	Chaurai1	22.0536	79.2508	Dug Well	13.93	6.87
CHAURAI	Marka Handi	22.0453	79.1644	Dug Well	17.5	2.46
CHAURAI	Ramgarh	22.1747	79.2717	Dug Well	14.5	5.52
CHAURAI	Thanvari Kunda	22.1761	79.2669	Dug Well	15.4	3.23
CHHINDWARA	Chhindwara	22.0531	78.9494	Dug Well	17.29	5.32
CHHINDWARA	Jamunia Ner	22.1369	79.0233	Dug Well	17	4.22
CHHINDWARA	Saonri(D)	21.9631	78.7756	Bore Well	95	49.24
CHHINDWARA	Saonri1	21.9647	78.7703	Dug Well	11	2.12
HARAI	HarraiDW	22.6125	79.2208	Dug Well	12.6	3.56
HARAI	Kundali	22.7761	79.2272	Dug Well	10.5	5.36
HARAI	Sathiya	22.5903	79.1792	Dug Well	13	4.27
JAMAI	Damua	22.1936	78.4694	Dug Well	19.58	1.52
JAMAI	Jamai	22.1956	78.5947	Dug Well	16	3.18
JAMAI	Jamuai(D)	22.1944	78.6017	Bore Well	64	7.52
MOHKHED	Goni	21.8214	79.0131	Dug Well	22.63	7.92
MOHKHED	Linga rly.stn.	21.9625	78.9378	Dug Well	17.2	3.97

BLOCK_NAME	SITE_NAME	LATITUDE	LONGITUDE	SITE_TYPE	DEPTH	WLS_WTR_LEVEL
MOHKHED	Sarangbheri	21.8669	78.9528	Dug Well	21.3	9.43
MOHKHED	Tansara Mal	21.8622	78.8981	Dug Well	11	4.42
PANDHURANA	Bangaon1	21.5725	78.4472	Dug Well	11.5	1.57
PANDHURANA	Chincholiwad	21.5000	78.6931	Dug Well	12	0.83
PANDHURANA	Mohi	21.6581	78.4408	Dug Well	13	3.35
PANDHURANA	Pandhurna(D)	21.5931	78.5297	Bore Well	120	4.08
PANDHURANA	Pandurna	21.5894	78.5183	Dug Well	9.4	2.92
PANDHURANA	Piplanarayanwar	21.5878	78.7314	Dug Well	18.4	7
PANDHURANA	Rajna	21.5403	78.6389	Dug Well	18.75	1.86
PARASIA	Lahgudna	22.2722	78.7242	Dug Well	10.5	0.81
SAUSAR	Sausar	21.6553	78.8056	Dug Well	18.75	7.9
SAUSAR	Sausar(D)	21.6519	78.8028	Bore Well	90	7.88
SAUSAR	Silwanighati	21.7881	78.8306	Dug Well	10.9	2.72
TAMIA	Chhindi	22.3875	78.8239	Dug Well	11	2.06
TAMIA	Mahaljhir	22.6094	78.5744	Dug Well	19.5	7.02
TAMIA	Renikhera	22.5444	78.5725	Dug Well	17	3.76