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

## DINDORI DISTRICT
## MADHYA PRADESH

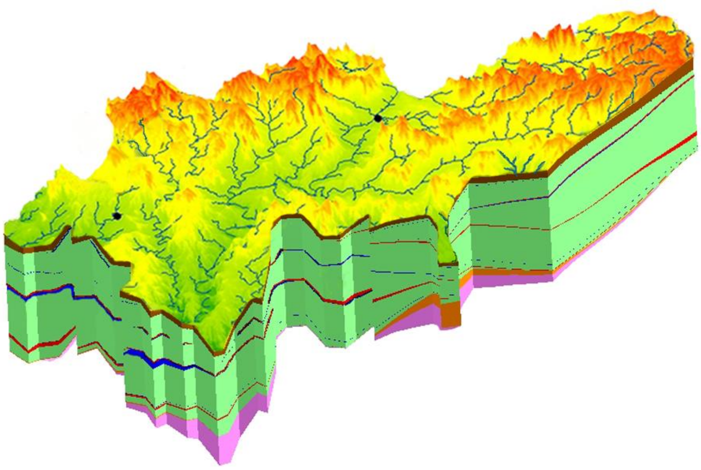
उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

**भारत सरकार**
**GOVERNMENT OF INDIA**
**केन्द्रीय भूमि जल बोर्ड**
**CENTRAL GROUND W ATER BOARD**
**जल शक्ति मंत्रालय**
**MINISTRY OF JAL SHAKTI**

# जलभृत मानचित्रण और भूजल प्रबंधन योजना
# डिंडोरी जिला, मध्य प्रदेश

# AQUIFER MAPPING AND GROUND WATER MANAGEMENT PLAN OF DINDORI DISTRICT, MADHYA PRADESH



वार्षिक कार्य योजना: 2021-22
Annual Action Plan: 2021-22

चित्तरंजन बिश्वाल, वैज्ञानिक-बी
राहुल वी.जे., एसटीए (एचजी)

Chittaranjan Biswal, Scientist-B
Rahul V.J. STA (HG)

**उत्तर मध्य क्षेत्र /NOTRH CENTRAL REGION**
**भोपाल /BHOPAL**

**सितंबर, 2022**
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भारत सरकार
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आज़ादी का अमृत महोत्सव

सत्यमेव जयते

भारत सरकार
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केन्द्रीय भूमिजल बोर्ड, उत्तर मध्य क्षेत्र, भोपाल

Government of India
Ministry of Jal Shakti
Department of Water Resources, R D & G R
Central Ground Water Board, North Central Region

# PREFACE

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

Under the project on National Aquifer Mapping (NAQUIM), Central Ground Water Board (CGWB) North Central Region, Bhopal has taken up Dindori district to prepare the Aquifer Maps for the entire district and formulate Aquifer Management Plan. Dindori district occupies an area of 5725 sq. km out of which the ground water recharge worthy area is 4560 sq. km. and the rest is covered by hilly area. The district is mainly occupied by Laterite, Deccan trap and Banded Gneissic Complex (BGC). As per the Dynamic Ground Water Resource Assessment Report (2022), the annual Ground Water Extractable Resource in the district is 326 mcm and the total ground water extraction for all uses is 41 mcm, resulting the stage of ground water extraction to be 12.68% as a whole for district. The management plan suggested in the report will not only have a positive impact on the ground water regime but would also play a key role in augmenting the net cropping area and would ultimately enhance the agricultural productivity and economy of the district.

I would like to place on record my appreciation of the untiring efforts of **Shri Chittaranjan Biswal, Scientist-B, Shri Rahul VJ, STA (HG)** and **Shri Kamlesh Birla, Young Professional** for preparing the Aquifer maps and Management plan and compiling this informative report. I fondly hope that this report will serve as a valuable guide for sustainable development of Ground Water in the Dindori District, Madhya Pradesh.

**Rana Chatterjee**
**(Regional Director)**

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# C O N T E N T S

# F I G U R E S



# T A B L E S

## A N N E X U R E

# CHAPTER 1

# INTRODUCTION

Aquifer mapping is a multidisciplinary and a holistic scientific approach wherein a combination of geologic, geophysical, hydrologic and chemical analysis is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from "**Ground Water Development**" to "**Ground Water Management**". As large parts of India particularly hard rocks have become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization and changing life style. Therefore, in order to have an accurate and comprehensive micro-level picture of groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through community participation.

## 1.1 OBJECTIVES AND SCOPE OF STUDY

In view of the above challenges, an integrated hydrogeological study was taken up to develop a reliable and comprehensive aquifer map and to suggest suitable Groundwater management plan on 1: 50,000 scale.

The main scope of study is summarized below.

1. Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality with geo-referencing information and identification of principal aquifer units.
2. Periodic long term monitoring of ground water regime (for water levels and water quality) for creation of time series data base and ground water resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on 1:50,000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, information dissemination, education, awareness and training.

**6.** Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

**1.2 STUDY AREA**

Dindori district being spread over an area of 5725 sq.km is lies between north latitude 22°17´-23°22´ and east longitude 80°35´-81°58´, located in the eastern part of Madhya Pradesh bordering Chhattisgarh. It is surrounded by Anuppur district in the east, Mandla in the west, Umaria in the north, and Bilaspur district of the state of Chhattisgarh in the south. The Location Map is prepared and presented in the **Fig.1.1**. It is divided into seven blocks namely Dindori, Shahpura, Mehadwani, Amarpur, Bajag, Karanjiya and Samnapur. According to the 2011 census, Dindori District has a population of 7,04,524, out of which 95% is rural population. In the district there are 3, 51,913 males and 3, 52,611 females respectively.

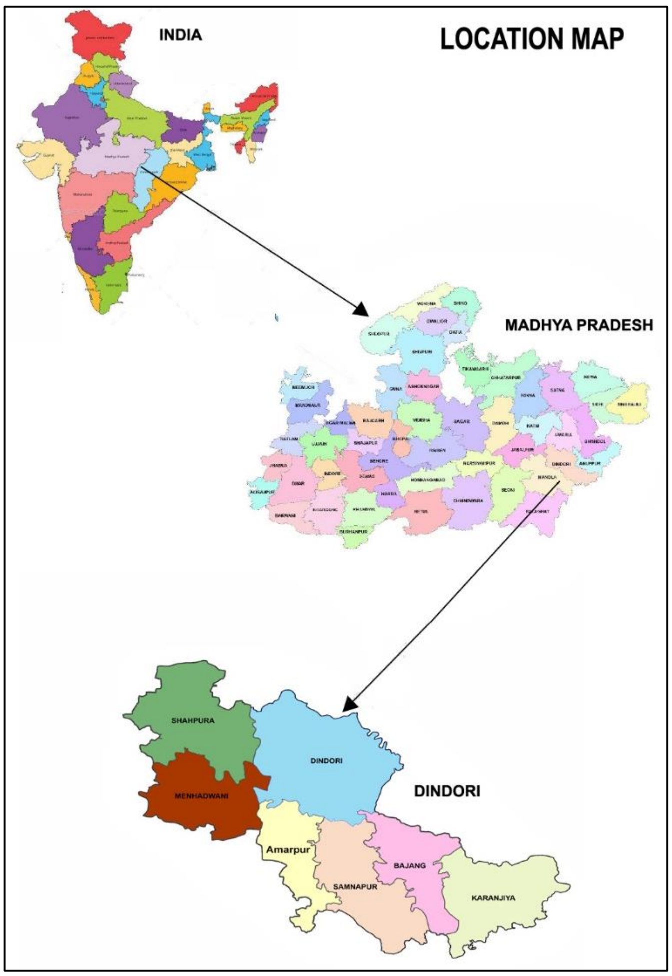


**Fig.1.1: Location Map of Dindori District**

## 1.3 CLIMATE AND RAINFALL

Climate of the district is tropical with moderate winter and severe summers and well distributed rainfall received from southwest monsoon. However due to higher general elevation and abundance of forests, summer temperature does not rise as much as in other areas.

The southwest monsoon starts from middle of June and lasts till end of September. October and middle of November constitute the post monsoon or retreating monsoon season. The normal annual rainfall of Dindori district is 1302 mm. About 90% of annual rainfall is received during monsoon season. Only 10 % of annual rainfall takes place during non-monsoon season. The monsoon, non-monsoon and annual rainfall data of last 5 years is shown in the **Table-1.1**.

**Table. 1.1: Annual rainfall of Dindori District of last 5 years (Source: IMD)**

| YEAR | Monsoon Rainfall (mm) | Non-monsoon Rainfall (mm) | Annual Rainfall (mm) |
|---|---|---|---|
| **2017** | 847.2 | 67.6 | 914.8 |
| **2018** | 1028.4 | 31.4 | 1059.8 |
| **2019** | 1453.4 | 156.7 | 1610.1 |
| **2020** | 1283.9 | 372.6 | 1656.5 |
| **2021** | 1088.5 | 187.6 | 1276.1 |

## 1.4 GEOMORPHOLOGY

Most part of the district is occupied by plateau occurring in nearly 60% area of the district. The pediment pediplain complex covering 36% of the area. The Hills and valleys are present mostly in the norrhern part of the district, occupied very small part of the district around 3% area of the district. plateau is the major landform covering about 3354 km$^2$ (60%) area. The other major landform observed is pediment pediplain complex covering about 1971 km$^2$ (36%). The Geomorphological map is presented in the **Fig.1.2** and Geomorphic landform pie chart is shown in the **Fig.1.3.**

## 1.5 PHYSIOGRAPHY

The elevation of the district is varying from 460 to 1120 meters above Mean Sea Level. The highest elevation observed in the southern side in Karanjiya and Bajang block and in Northern side in Dindori block. The elevation is gradually decreases towards the western side in Menhadwani block and towards northern side in Shahpura block. The Digital Elevation Model Map of Dindori district is prepared and presented in the **Fig.1.4**.

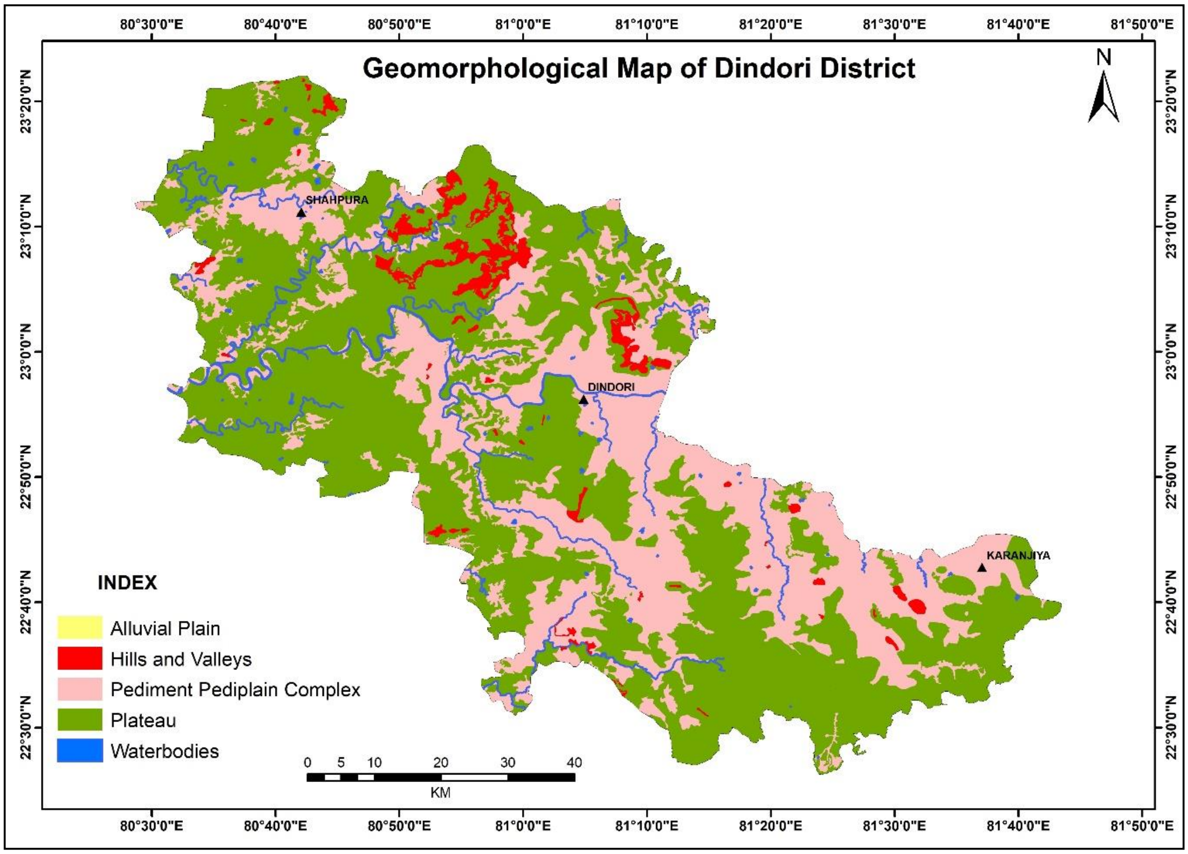


**Fig.1.2: Geomorphology map of Dindori district (Source: Bhukosh - GSI)**

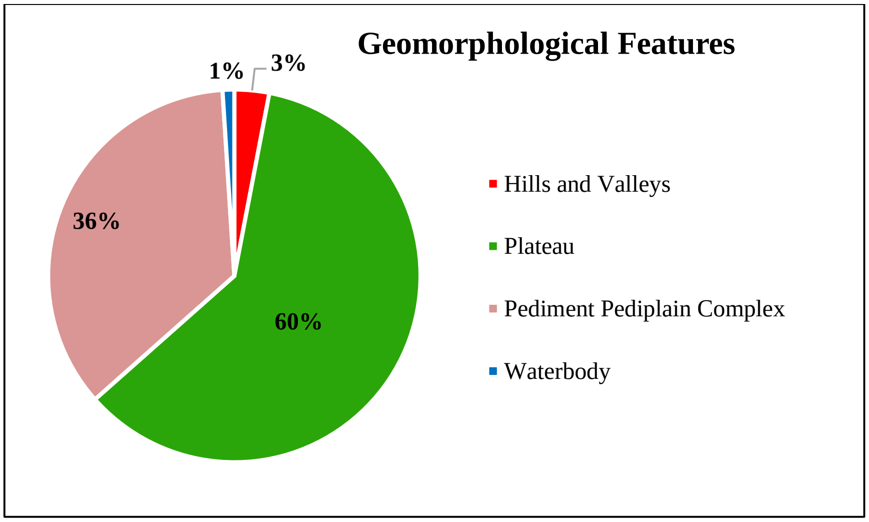


**Fig.1.3: Geomorphology landform Pie chart**

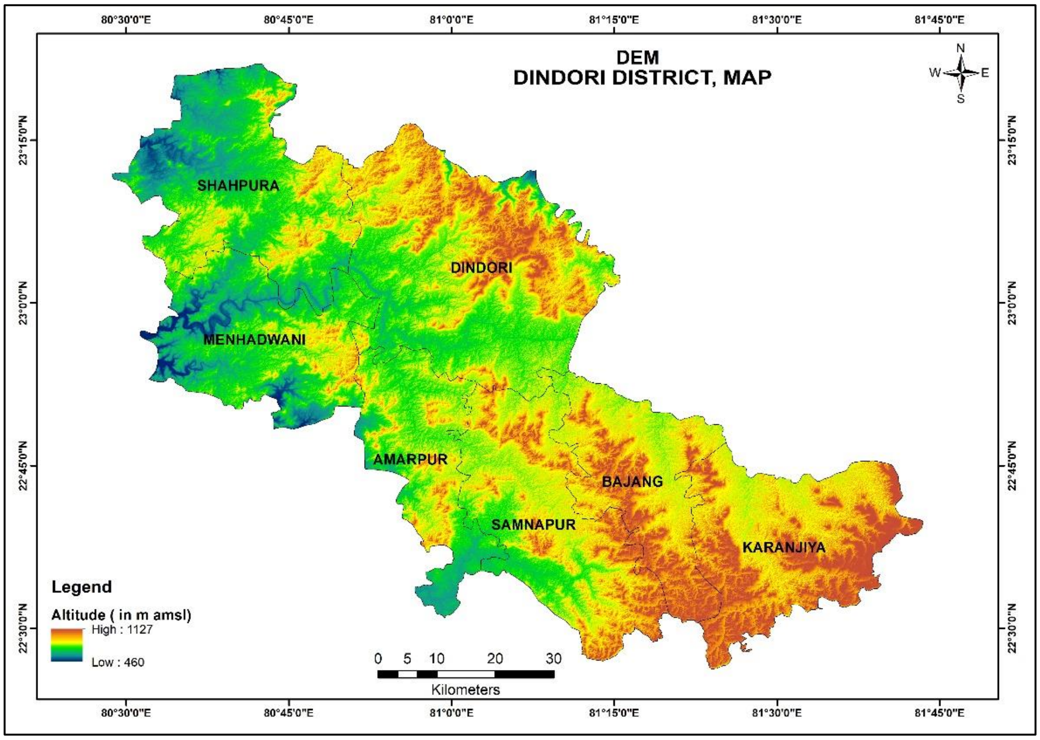


**Fig.1.4: Digital Elevation map of Dindori district**

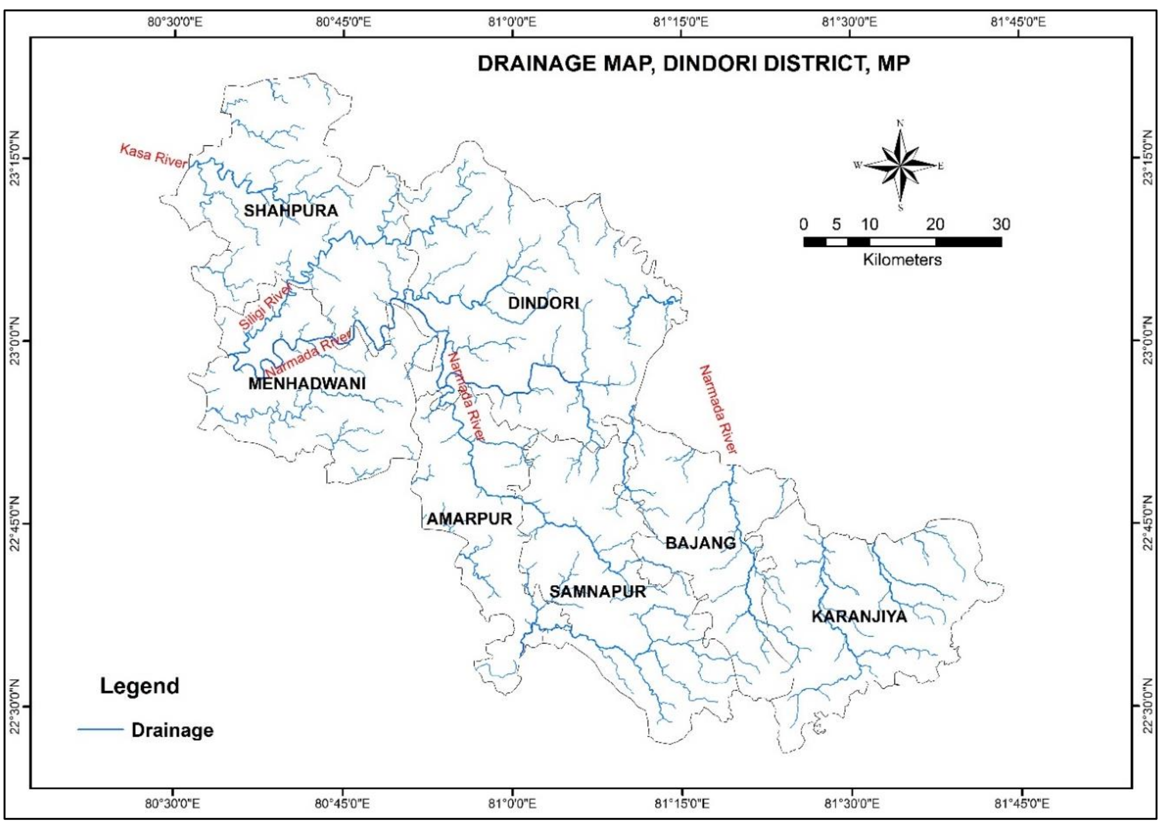


**Fig.1.5: Drainage Map of Dindori district**

## 1.6 DRAINAGE

Dindori district falls under Narmada river basin. The district is mainly drained by river Narmada and its tributaries. Major tributaries are Kasah, Siligi, Johila, Kharmer, Carker, Seoni, Turar rivers. The Drainage map is shown in the **Fig.1.5**.

## 1.7 LAND USE, AGRICULTURE, IRRIGATION AND CROPPING PATTERN

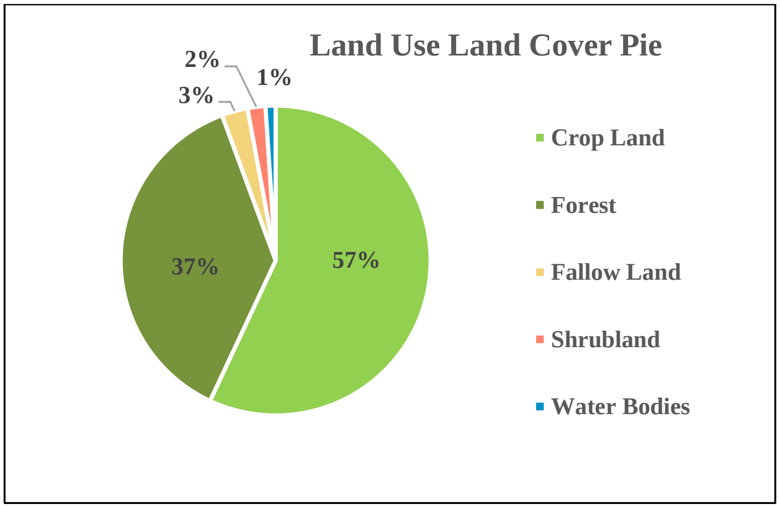


**Fig.1.6: Land use Land Cover Pie**

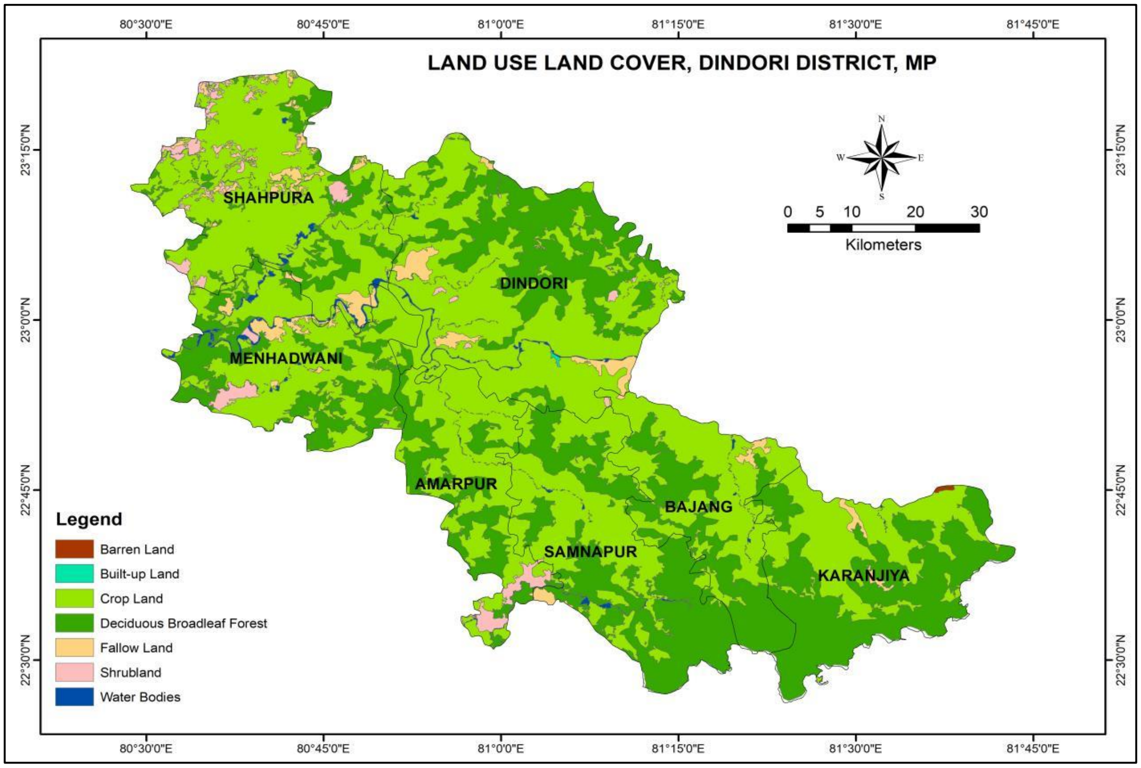


**Fig.1.7:Land use land cover Map**

Agriculture and forest are the prominent land use aspects in Dindori district. Crop land forms 57% and forest area form 37 % of total area followed by Fallow land (3%), Shrub land and water bodies. The land use land cover types are prepared in a pie diagram and shown in the **Fig.1.6.** The spatial distribution of land use is presented in **Fig. 1.7** (as per Land Use Land cover data, NASA, USA).

The much sources of irrigation are Tube well, Dugwells and Ponds. The irrigated area under Tube wells, dug wells, and Ponds, mainly depended on rains.Net sown area of the district during kharif season is 205524 hectare, out of which 21990 hectare is irrigated and 183536 hectare area is unirrigated. The Block wise details during kharif season is shown in the **Table.1.2** and **Fig.1.8.** During Rabi season total sown area of the district is 137300 hectare, out of which 12900 hectare is irrigated and 124400 hectare area is unirrigated. The Block wise details during kharif season is shown in the **Table.1.3** and **Fig.1.10**

**Table.1.2: Block wise irrigated and Un-irrigated area in Kharif Season (Source: DIP, PMKSY)**

| S.N. | Block | Total Sown Area (Ha) | Irrigated Area (Ha) | | Unirrigated Area (Ha) | |
|---|---|---|---|---|---|---|
| | | | Area | % | Area | % |
| 1 | Dindori | 42245 | 2978 | 7.05 | 39267 | 92.95 |
| 2 | Amarpur | 24036 | 3280 | 13.65 | 20756 | 86.35 |
| 3 | Samnapur | 23209 | 3450 | 14.87 | 19759 | 85.13 |
| 4 | Bajag | 24275 | 3300 | 13.6 | 20975 | 86.4 |
| 5 | Karanjiya | 26841 | 3210 | 11.96 | 23631 | 88.04 |
| 6 | Sahpura | 28180 | 2972 | 10.55 | 25208 | 89.45 |
| 7 | Mehadwani | 36738 | 2800 | 7.67 | 33940 | 92.33 |
| | **District** | **205524** | **21990** | **10.7** | **183536** | **89.3** |

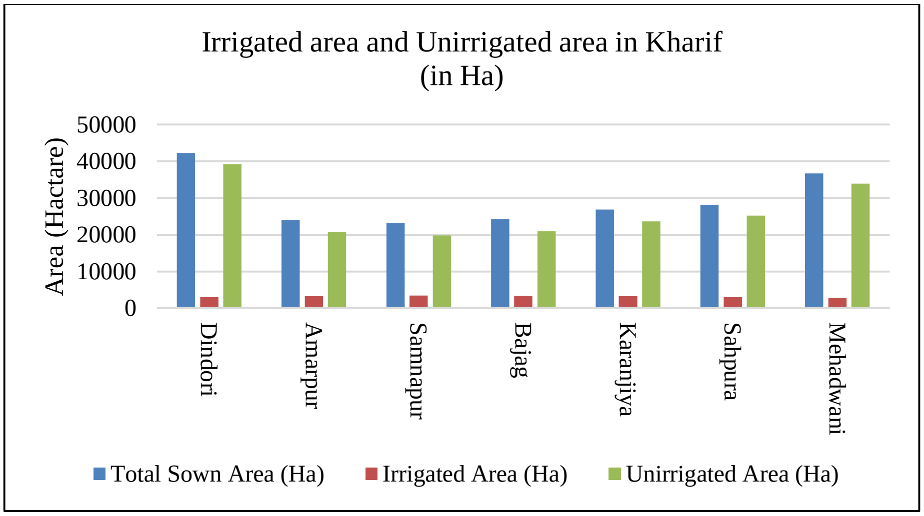


**Fig.1.8: Irrigated area and Un-irrigated area in Kharif season**

**Table.1.3: Block wise irrigated and Un-irrigated area in Rabi Season (Source: DIP, PMKSY)**

| S.N. | Block | Total Sown Area (Ha) | Irrigated Area (Ha) | | Unirrigated Area (Ha) | |
|---|---|---|---|---|---|---|
| | | | Area | % | Area | % |
| 1 | Dindori | 23120 | 2000 | 8.6 | 21120 | 91.4 |
| 2 | Amarpur | 15700 | 2300 | 14.65 | 13400 | 85.35 |
| 3 | Samnapur | 16000 | 2200 | 13.75 | 13800 | 86.25 |
| 4 | Bajag | 19810 | 1600 | 8.03 | 18210 | 91.92 |
| 5 | Karanjiya | 25740 | 1500 | 5.82 | 24240 | 94.18 |
| 6 | Sahpura | 21080 | 2300 | 10.91 | 18780 | 89.08 |
| 7 | Mahedwani | 15850 | 1000 | 6.3 | 14850 | 93.7 |
| | **District** | **137300** | **12900** | **9.4** | **124400** | **90.6** |

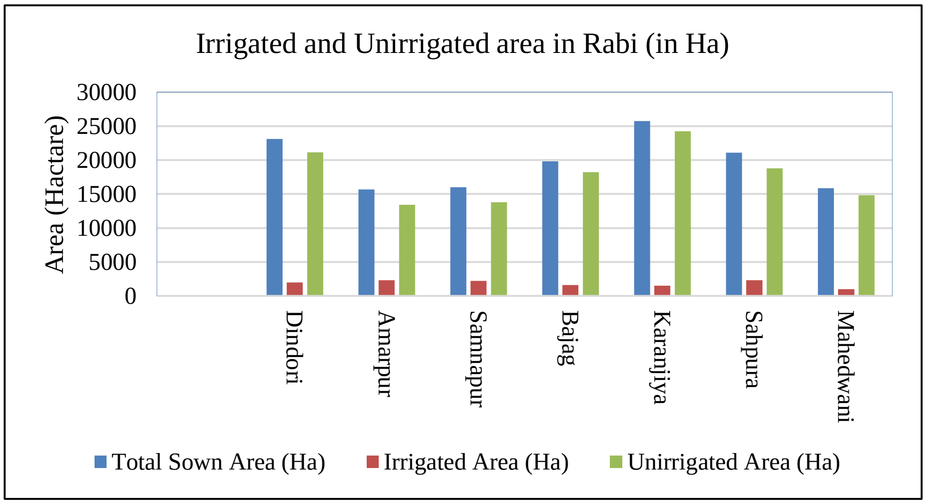


**Fig.1.9: Irrigated area and Un-irrigated area in Rabi season**

The main crops grown in Dindori District are Cereals 113189 ha (56%), followed by Coarse Cereals 35048 ha (17%), Oil seeds 34510 ha (17%), Pulses 17563 ha (9%) during Kharif season and Pulses 56800 ha (40%), Cereals 42000 ha (30%), Oil seeds 38500 ha (27%) and other crops 3400 ha (3%) during Rabi season respectively. During summer season only Pulses grown in 618 ha. Season wise cropping pattern is given in **Table.1.4** and **Fig.1.10.**

**Table.1.4: Season wise Cropping Pattern (Source: DIP, PMKSY)**

| Crop | Kharif (ha) | Rabi (ha) | Summer crop (ha) | Total (ha) |
|---|---|---|---|---|
| Cereals | 113189 | 42000 | 0 | 155189 |
| Coarse Cereals | 35048 | 0 | 0 | 35048 |
| Pulses | 17563 | 56800 | 618 | 74981 |
| Oil Seeds | 34510 | 38500 | 0 | 72952 |
| Fibre | 0 | 0 | 0 | 0 |
| Any other crops | 2200 | 3400 | 700 | 6300 |
| **Total** | **202510** | **140700** | **1318** | **344470** |

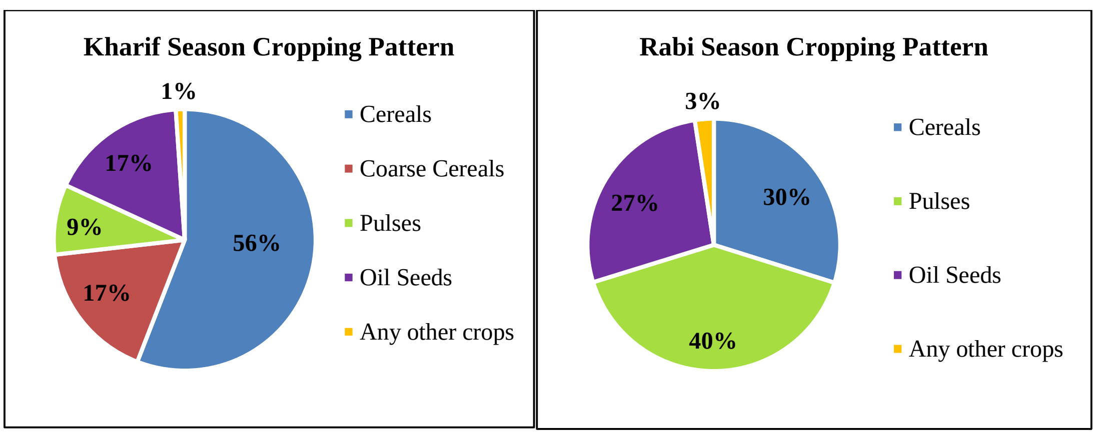


**Fig.1.10: Cropping Pattern**

## 1.8 GEOLOGY

The study area exposes the rocks of Laterite, Deccan trap and Banded Gneissic Complex (BGC). The sequence of rock formation is shown in the **Table. 1.5** and the Geological Map is Shown in the **Fig.1.11**. The whole district covered with Deccan trap basalt, the Banded Gneissic Complex exposed in a very small part in the southern tip of Amarpur block. The laterites are occur as a cap rock above the deccan trap basalt and are scattered throughout the district.

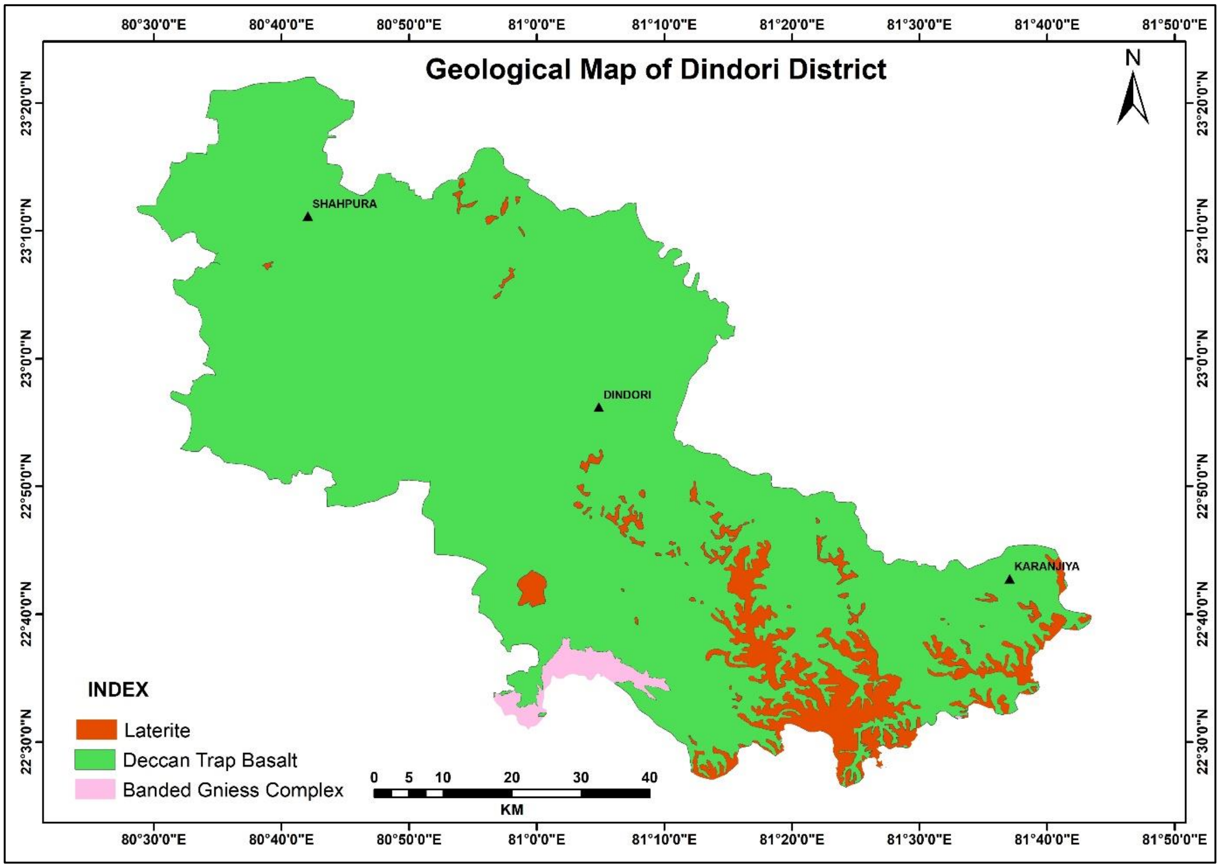


**Fig.1.11: Geological Map of Dindori district**

**Table.1.5: Sequence of Geological Formation**

| Age | Formation | Litho- characteristic |
|---|---|---|
| Pleistocene | Laterite | Compact, ferruginous and weathered product of Deccan trap |
| Cretaceous to Eocene | Deccan trap | Basaltic lava flows |
| Unconformity | | |
| Precambrian | Banded Gneissic Complex | Granite and Gneiss |

## 1.9 SOIL TYPES

In the district mostly two types of soil are present namely, Clayey and loamy soil. The Loamy soil further divided in to loamy skeletal soil. The the distribution of soil in the district is shown in the **Fig.1.12**.

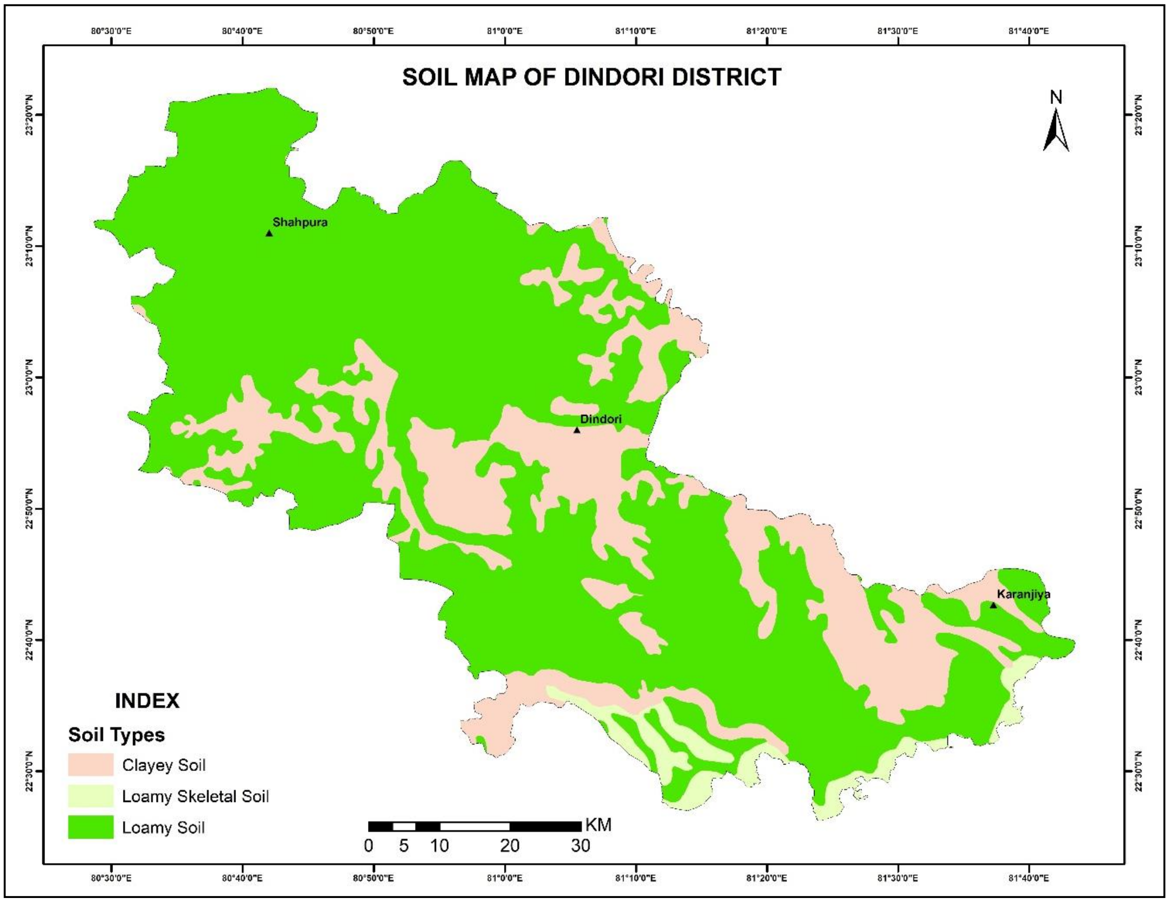


**Fig.1.12: Soil map of Dindori district**

# CHAPTER 2

# DATA COLLECTION AND GENERATION

## 2.1 DATA COLLECTION AND COMPILATION

The data collection and compilation for various components was carried out as given below.

**Hydrogeological Data**:

- Current and historical water levels along with water level trend data of 14 Dug wells of Central Ground Water Board Viz. National Hydrograph Stations representing Shallow aquifer (Aquifer-I).
- The weathered zone thickness (Aquifer-I), lithological details of deeper aquifers (Aquifer-II) of 23 exploratory wells were also collected and compiled.

**Hydro chemical Data**:

- Ground water quality data of 14 monitoring wells of Central Ground Water Board representing shallow aquifer are collected and compiled.

**Exploratory Drilling**:

- Ground water exploration data of 23 exploratory wells drilled by Central Ground Water Board are collected and compiled.

**Geological Data:**

- Geological Data from Geological Survey of India.

**Hydro meteorological Data**:

- 5-years rainfall data for the whole district from Indian Meteorological Department and Water Resource Department, Govt of Madhya Pradesh are collected.

. **Water Conservation Structures**:

- Numbers, type of water conservation structures prevailing in the district from MGNREGA.

**Statistical Data**

- Demography data of Dindori district from Dept. of Statistics, Economics and Planning, M.P.
- Geomorphological Data from Geological Survey of India (bhukosh.gsi.gov.in).
- Data of prevailing land use pattern, Dindori district from NASA, USA.

- Data of prevailing cropping pattern, Irrigation details from District Irrigation Plan, Dindori district.
- Data of existing surface water irrigation structures from District Irrigation Plan, Dindori district.

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities **(Table-2.1)**.

**Table.2.1: Brief activities showing data compilation and generations.**

| S. No. | Activity | Sub-activity | Task |
|---|---|---|---|
| 1 | **Compilation of existing data/**<br><br>**Identification of Principal Aquifer Units and Data Gap** | Compilation of Existing data on groundwater | Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc. |
| | | Identification of Data Gap | Data gap in thematic layers, sub-surface information and aquifer parameters, information on geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc. |
| 2. | **Generation of Data** | Generation of geological layers (1:50,000) | Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern. |
| | | Preparation of Hydrogeological map (1:50, 000 scale) | Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections. |
| | | Generation of additional water quality parameters | Analysis of groundwater for general parameters. |
| 3. | **Aquifer Map Preparation**<br><br>**(1:50,000 scale)** | Analysis of data and preparation of GIS layers and preparation of aquifer maps | Integration of Hydrogeological, Geological and Hydro-chemical data. |

| S. No. | Activity | Sub-activity | Task |
|---|---|---|---|
| **4.** | **Aquifer Management Plan** | Preparation of aquifer management plan | Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain. |

# CHAPTER 3

# DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

## 3.1 HYDROGEOLOGY

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. Main geological units of the district are Laterite, Deccan trap basalt and Banded Gneissic complex. The principal aquifers in the area are Basalt and Granite. The hydrogeological map of area is prepared and presented in **Fig.3.1**.

The water table elevation map was also prepared (**Fig.3.1**) to understand the ground water flow directions. The groundwater movement in the district is towards the Northern sidein the northern part of district and in the central part towards the western side, which follows the drainage and topography of the area.

### 3.1.1 Deccan Trap Basalt

Almost the entire district is covered by Deccan trap Basalt. Ground water occurs in the weathered, jointed and fractured basalts under Unconfined and semi-confined to confined conditions. These form the most important aquifers in the region. The weathered, fractured, jointed and vesicular units of basalts form moderate to good aquifers. Discharge is upto 5 lps. Transmissivity is upto 250 $m^2$/day and Secific Yield is up to 3%. The Deccan Traps formations can be tapped by dug well, dug-cum-bore and bore wells.

### 3.1.2 Archaeans

The Archaean rocks generally Granitoids are generally occur in a very small part in the western side in Samnapur block. Archaeans comprise granites and gneisses. They are hard and compact formations with low primary permeability, forming poor aquifers. Ground water occurs in these only in the weathered mantle and underlying fractured zone. Groundwater mostly occurs under under unconfined to semi confined conditions. Transmisivity is found upto 100 m2/day., Discharge is up to 2 lps and Specific yield is up to 2%.

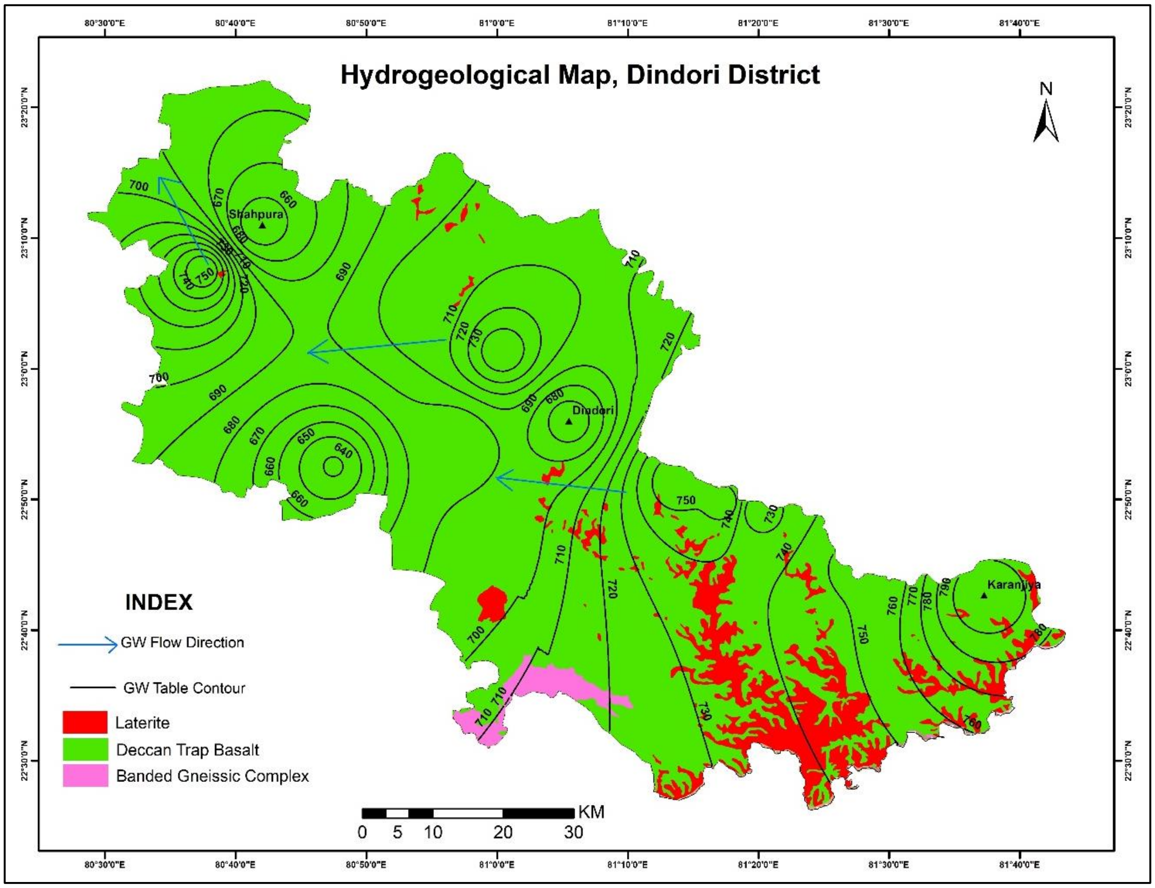


**Fig. 3.1: Hydrogeology map of Dindori district**

## 3.2 GROUNDWATER EXPLORATION

Central Ground Water Board drilled 23 exploratory wells to delineate the aquifers vertically as well as laterally and to determine the aquifer parameters. The wells were plotted the **Fig.3.2.** The lithology of the well are given in the **Annexure. I.**

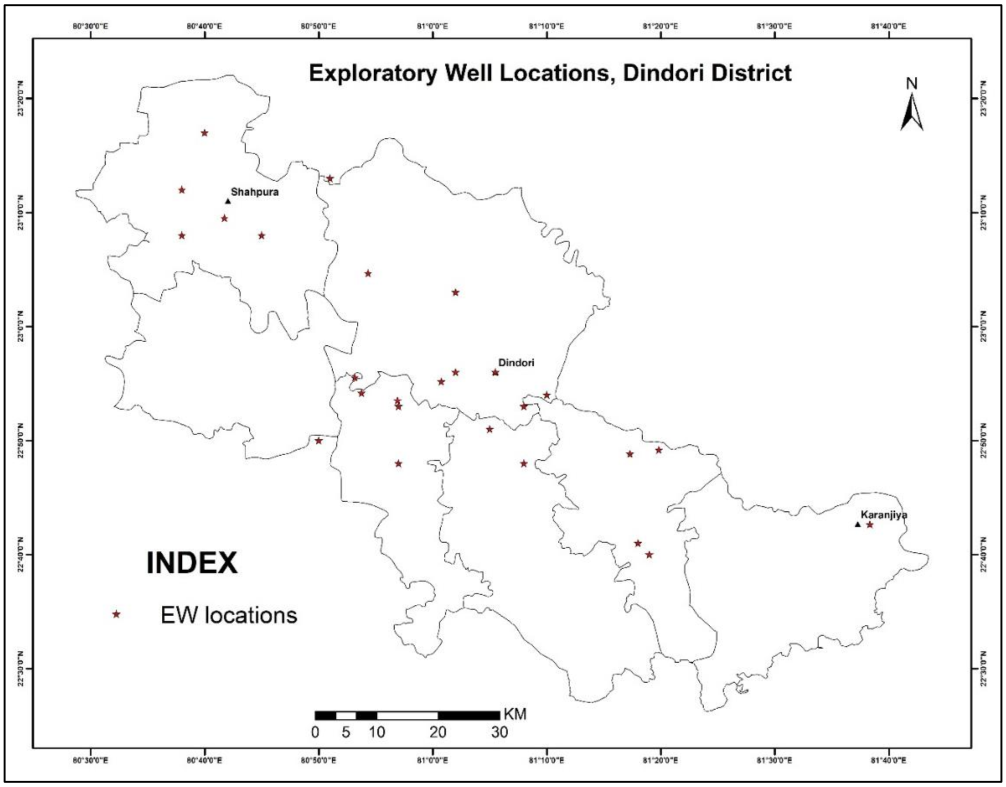


**Fig. 3.2: Exploratory Well Locations in Dindori district**

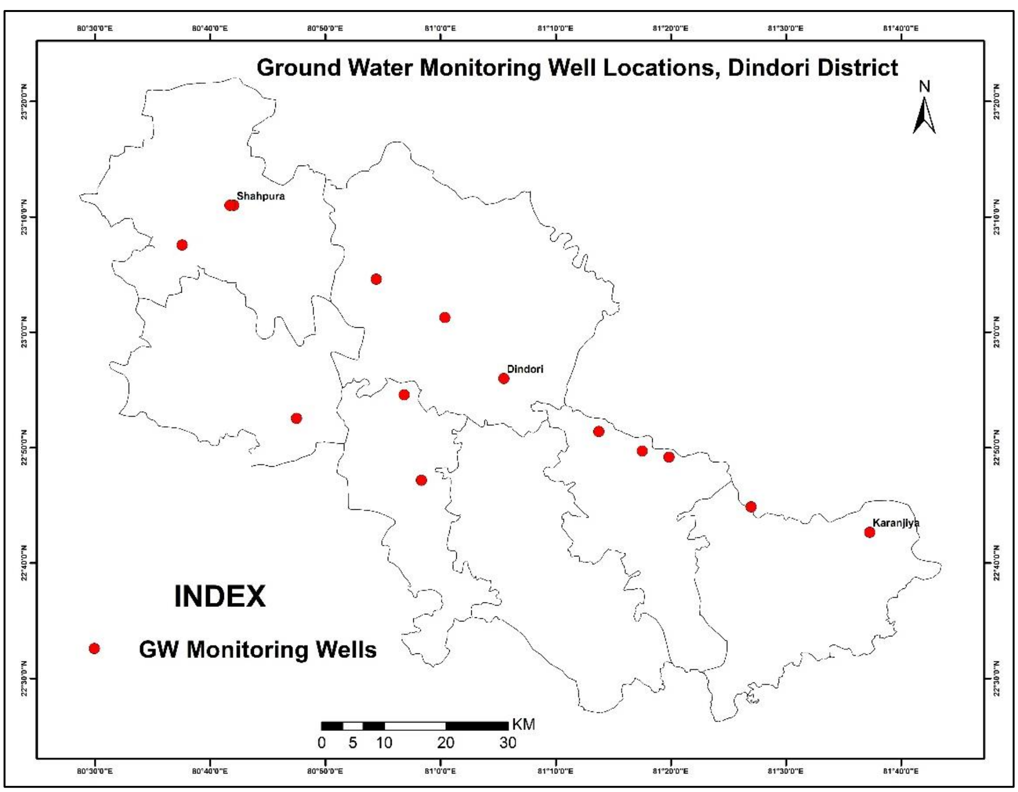


**Fig.3.3: Ground water Monitoring well locations**

## 3.3 GROUND WATER LEVEL SCENARIO

Ground water levels form a very important parameter of the ground water system, as these are its physical reflection. Central Ground Water Board monitored the water level of 14 dug wells four times (January, May, August and November) in every year. The monitored dug wells locations are plotted in the **Fig.3.3**. The present depth to water level scenario of shallow aquifer were generated by utilizing water level data of 14 monitoring wells representing shallow aquifer.

### 3.3.1 Shallow Aquifer

#### 3.3.1.1 Pre-Monsoon (May 2021)

The pre-monsoon depth to water levels during May 2021 ranged between 3.5 (Gadasarai, Bajrang block) to 9.85 mbgl (Karanjiya, Karanjiya block). The depth to water level map of pre-monsoon is given in **Fig.3.4.** The water levels between 5 to 10 mbgl are observed in major part of the district and the water levels between 2 to 5 mbgl are observed in the northern most corner in the Shahpura block and in the central part in Dindori block.

#### 3.3.1.2 Post-Monsoon (November, 2021)

The post-monsoon depth to water levels during November 2021 ranged between 0.5 (Vikrampur, Dindori block) to 9.35 mbgl (Karanjiya, Karanjiya block). The depth to water level map is given in **Fig.3.5.** The water levels between 2 to 5 mbgl are observed in major part of the district, Water level between 0 to 2 mbgl are observed in the Dindori block and 5 to 10 mbgl are observed in the Karanjiya block

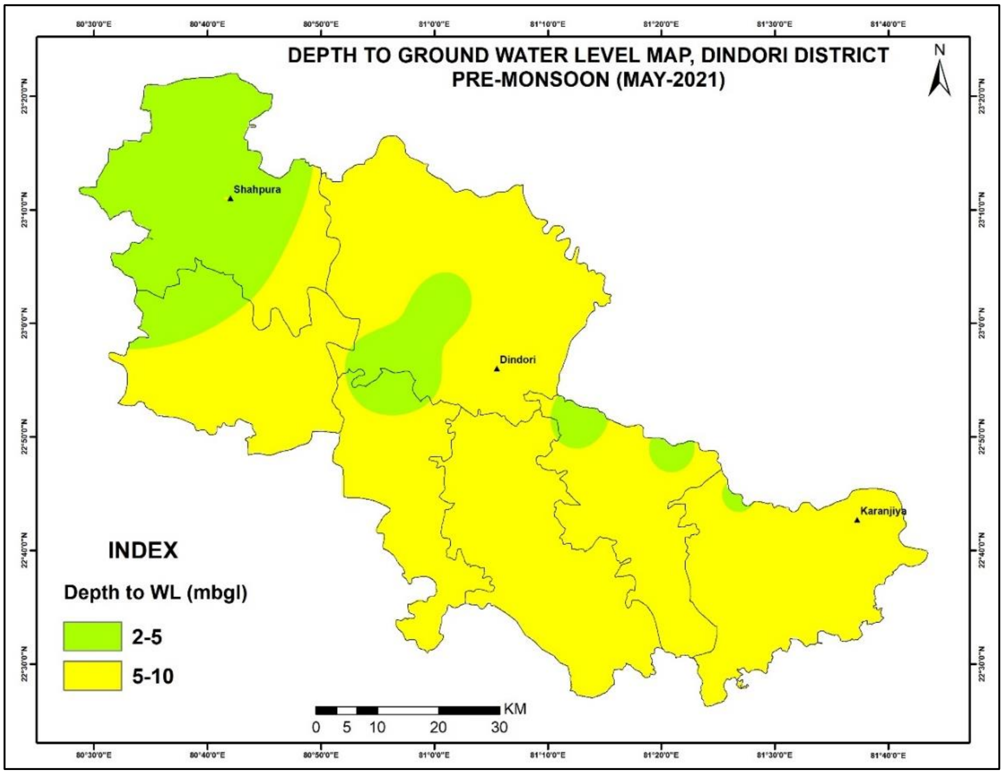


**Fig.3.4:Pre-monsoon (May 2021) Depth to Water Level of Shallow Aquifer**

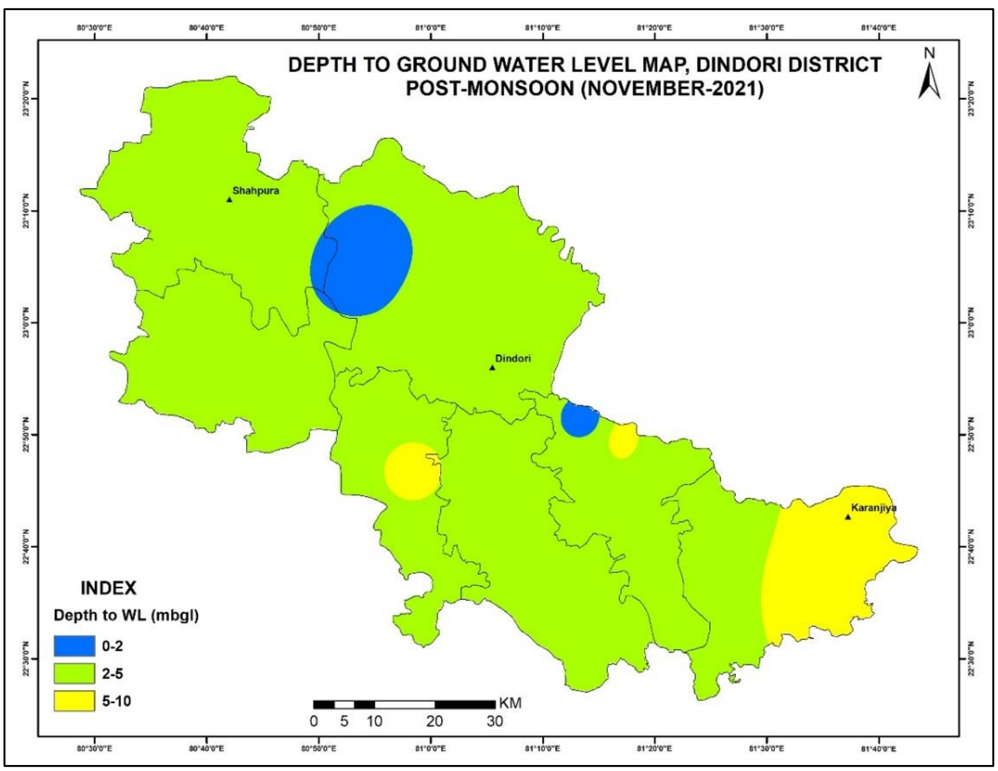


**Fig.3.5:Post-monsoon (Nov 2021) Depth to Water Level of Shallow Aquifer**

### 3.3.1.3 Seasonal Water Level Fluctuation

The water level measured during pre-monsoon (May 2021) and post monsoon (Nov 2021) period was used to compute the seasonal fluctuation. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Karanjiya, Karanjiya block (0.5 m) while maximum water level fluctuation was observed at Vikrampur monitoring well of Dindori block (11.6 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the percentage of wells in each category was analysed. The analysis is described in **Table.3.6**.

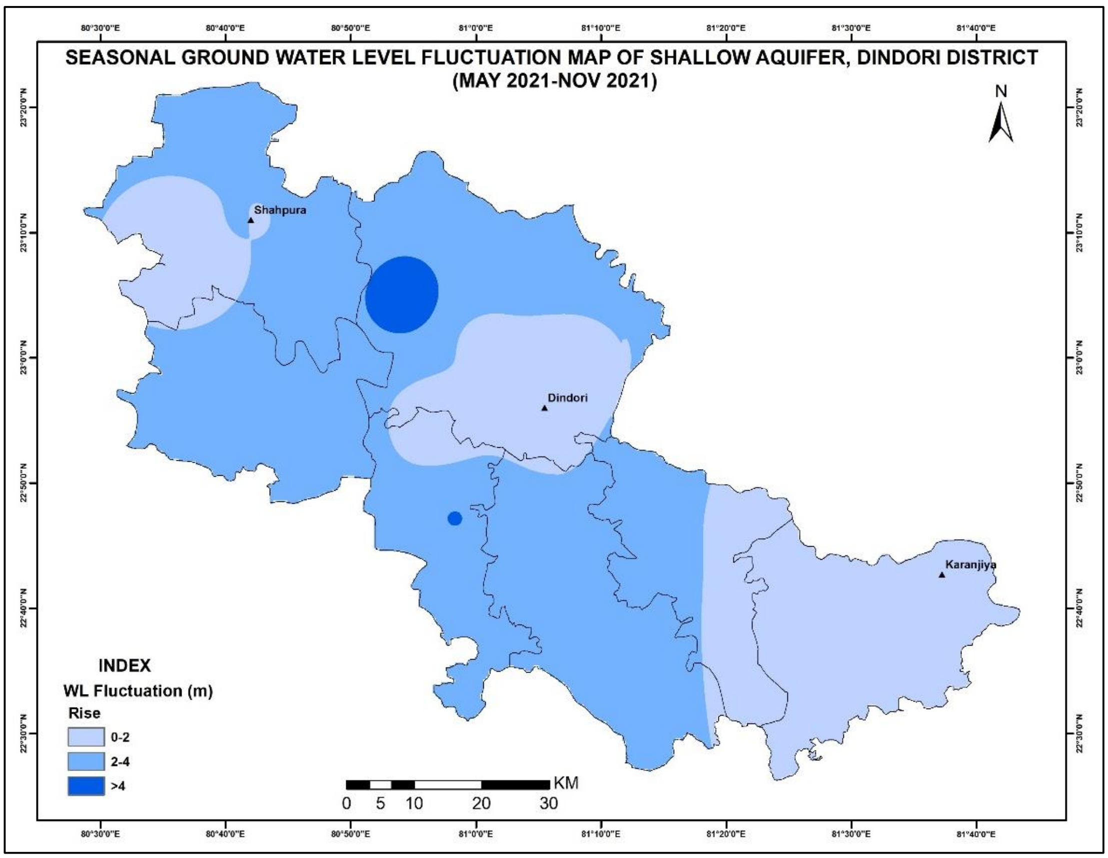


**Fig.3.6: Seasonal Fluctuation of Water Level, Shallow Aquifer**

**Table.3.2: Analysis of Water Level Fluctuation.**

| S N | Category | Fluctuation Range | % of Wells |
|---|---|---|---|
| 1. | Less water level fluctuation | 0 to 2 m | 57% |
| 2. | Moderate water level fluctuation | 2 to 5 m | 36% |
| 3. | High water level fluctuation | >5 m | 7% |

The analysis indicates that of 57% the wells are falling in low fluctuation indicating aquifer storage is good, whereas moderate water level fluctuation is observed in 36 % wells and high water level fluctuation were observed only in 7 % wells. The seasonal fluctuation map is presented as **Fig.3.6**; the perusal of map indicates that fluctuation between 2 to 4 meter is observed in major part of the district.

The pre-monsoon, post monsoon water level and seasonal fluctuation for the year 2021 of shallow aquifer is shown in the **Annexure. II**.

**3.3.1.4 Long Water Level Trend (2012-21)**

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data for the period 2012-21 have been computed and analyzed.

The decadal pre-monsoon water level trend is presented in the **Fig.3.7,** which indicates that during pre-monsoon period, more than 90 % of the area showing rising trend. Declining trend only observed in southern part of the district. The rising trend more than 0.4 mm/year is observed in most part of the district. The falling trend between more than 0.4 mm/year is observed in southern part of the district.

Similarly, the decadal post-monsoon water level trend is presented in the **Fig.3.8,** which indicates that almost the whole district is showing declining trend. Maximum falling trend is more than 0.4 m/yr. The rising trend observed in patches.

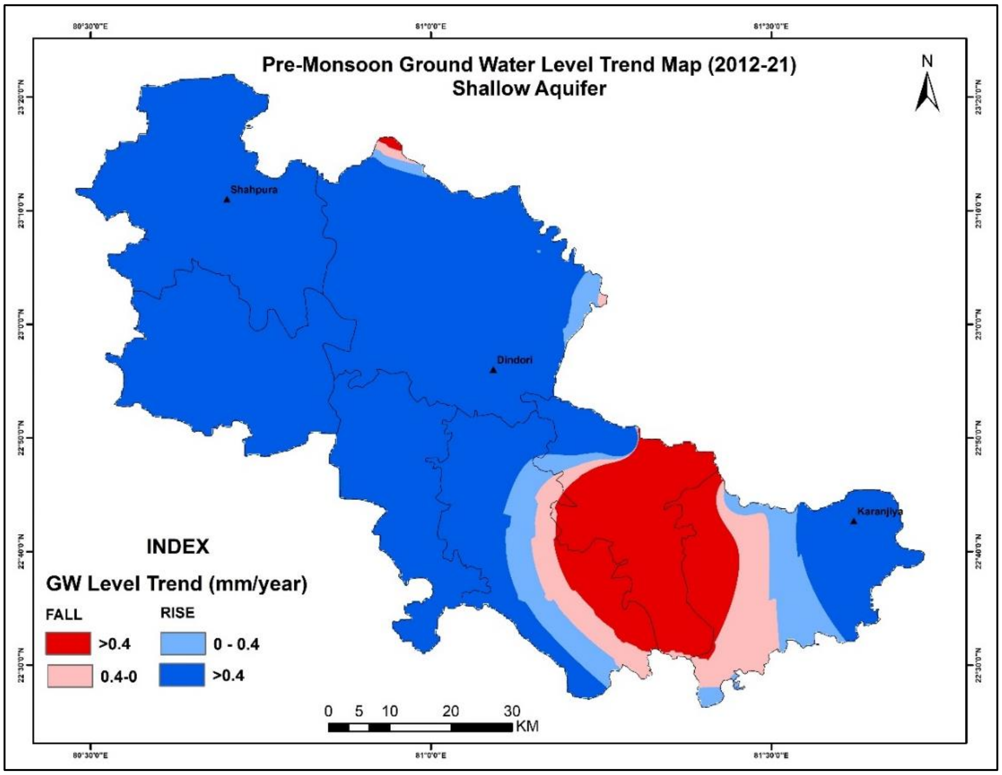


**Fig.3.7:Pre-monsoon Water Level Trend (May 2012-21) of Shallow Aquifer**

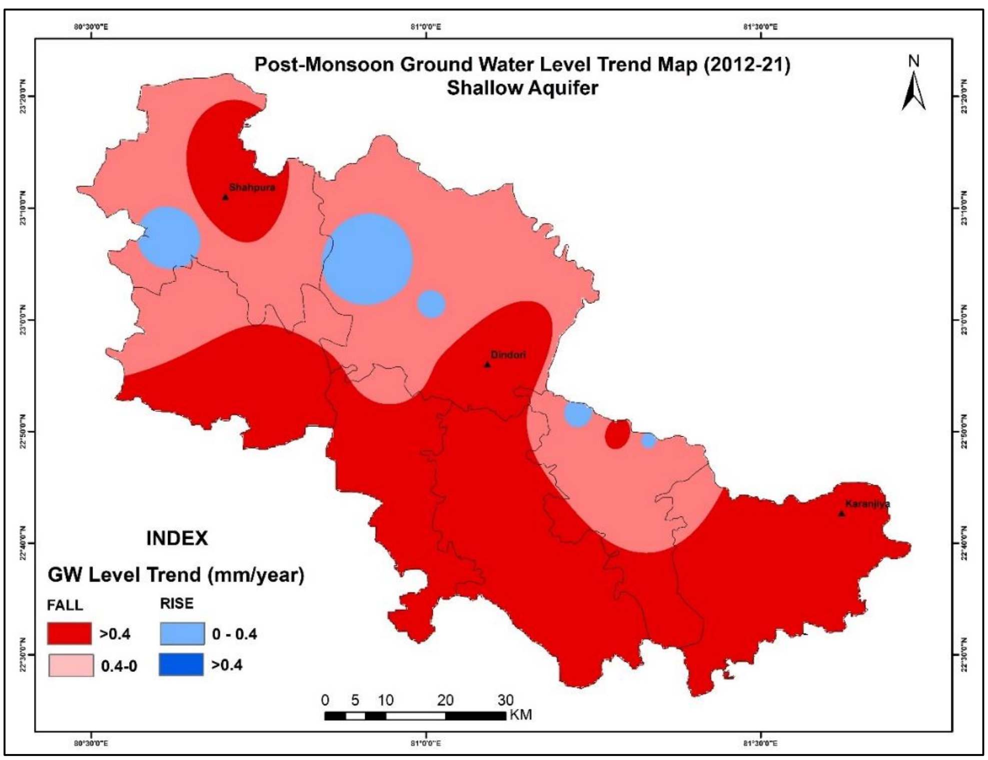


**Fig.3.8:Post-monsoon Water Level Trend (Nov 2012-21) of Shallow Aquifer**

## 3.4 HYDRO CHEMICAL STUDIES

### 3.4.1 Shallow Aquifer

Water samples were collected from 14 Ground Water Monitoring Wells during May 2021 and monitored for chemical quality of ground water (phreatic aquifer) and their location is given in **Figure.3.3**. Detailed analysis of the chemical samples was carried out parameters namely: pH, Electrical Conductivity (EC), Carbonate, Bi-carbonate, Chloride, Fluoride, Nitrate, Sulphate, Phosphate, Total hardness, Calcium, Magnesium, Sodium and Potassium. The results of chemical data observed are given in **Annexure III**.

#### 3.4.1.1 Quality of Ground Water for Drinking Purpose

The ground samples that are collected are analysed, compared with Bureau of Indian Standard set for drinking water quality and ranges of different chemical constituents present in ground water are given in **Table 3.3**.

**Table.3.3: Ranges of chemical constituents in Shallow aquifer**

| Constituents | Acceptable Limit | Permissible limit in the absence of alternate source | Aquifer – I (Shallow aquifer) | | |
|---|---|---|---|---|---|
| | | | Min. | Max. | No. of samples above PL |
| pH | 6.5 | 8.5 | 7.11 | 7.96 | Nil |
| EC | - | - | 308 | 1154 | - |
| TH | 200 | 600 | 130 | 395 | Nil |
| Calcium | 75 | 200 | 28 | 102 | Nil |
| Magnesium | 30 | 100 | 13 | 39 | Nil |
| Potassium | - | - | 1.4 | 9.8 | - |
| Sodium | - | - | 9 | 95 | - |
| Carbonate | - | - | 0 | 0 | - |
| Bi-carbonate | 200 | 600 | 122 | 415 | Nil |
| Chloride | 250 | 1000 | 12 | 140 | Nil |
| Nitrate | - | 45 | 3 | 38 | Nil |
| Fluoride | 1 | 1.5 | 0.02 | 0.32 | Nil |

The ground water samples from Dindori district have varied range of pH from 7.11 to 7.96. As per BIS (IS 10500 2012) recommendation, all the water samples have pH recorded within the permissible limits of 6.5 to 8.5, the maximum pH recorded in the water sample of Vikrampur (7.96). The pH of ground water can be assessed as neutral to slightly alkaline in nature.

The electrical conductivity of ground water samples in Dindori district varies from 308 to 1154 µS/cm at 25°C. The electrical conductivity of ground water of Dindori district is good. The electrical conductivity shows that the ground water is good. The EC contour map is shown in the **Fig.3.9**.

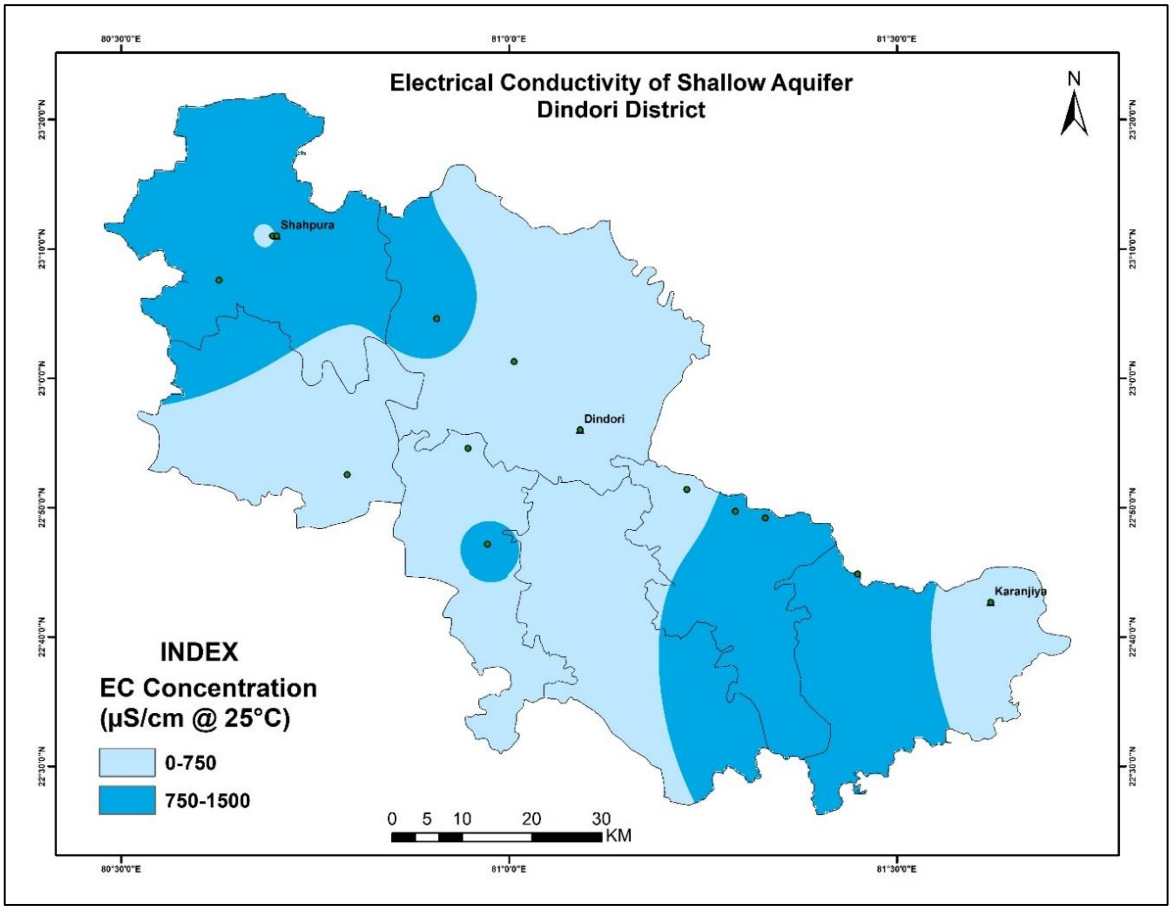


**Fig.3.9: Electrical Conductivity in Shallow aquifer**

The fluoride concentration in Dindori district lies in between 0.02 to 0.32 mg/l, which represent that all the samples are within the permissible limit of 1.5 mg/l as per BIS (IS 10500: 2012). The maximum concentration of fluoride has been observed in the village of Salaiya village i.e. 0.32 mg/l. The distribution of fluoride concentration is shown in the **Fig.3.10**. In the assessment of ground water resources estimation, PHED has reported high Fluoride concentration in ground water in two blocks, viz. Amarpur and Dindori.

Nitrate concentration in ground water samples of Dindori district fall in between 3 to 38 mg/l. It shows that the all samples within the acceptable limit of 45 mg/l and the maximum concentration has been observed in the village of Sagar Tola (38 mg/l). The distribution of nitrate concentration is shown in the **Fig.3.11**.

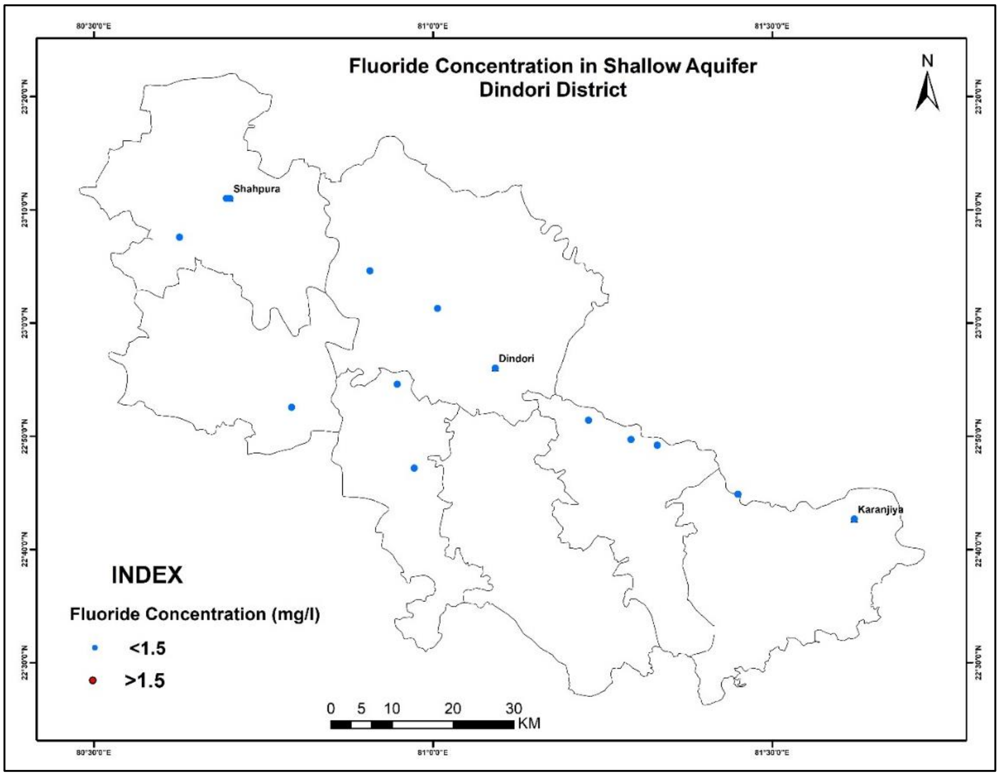


**Fig.3.10: Distribution of Fluoride Concentration in Shallow aquifer**

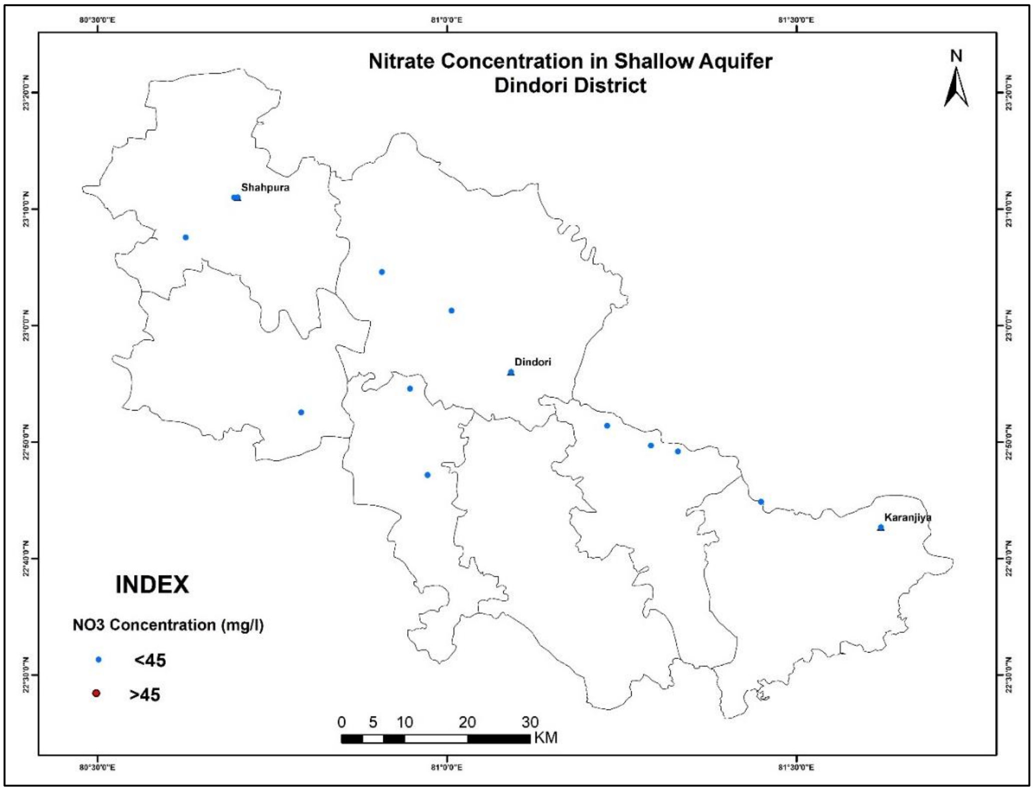


**Fig.3.31: Distribution of Nitrate Concentration in Shallow aquifer**

The range of Total Hardness (as $CaCO_3$) concentration in ground water samples is 130 to 395 mg/l. The maximum concentration of Total hardness has been observed in the village of Shahpura (395 mg/l).

The Piper diagram for the shallow aquifer is prepared and given in the **Fig.3.12** Piper diagram has three parts: a Cation triangle, an Anion triangle, and a Central diamond-shaped field. In Cation triangle, the relative percentages of the major cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$) are plotted. In Anion triangle the major anions ($HCO_3^{-}$+$CO_3^{2-}$, $SO_4^{2-}$, $Cl^{-}$) are plotted. These points are then projected to the central diamond shaped field. In the district; piper diagram shows that the ground water samples are Calcium-Bicarbonate type and mixed type of water, hence show temporary hardness.

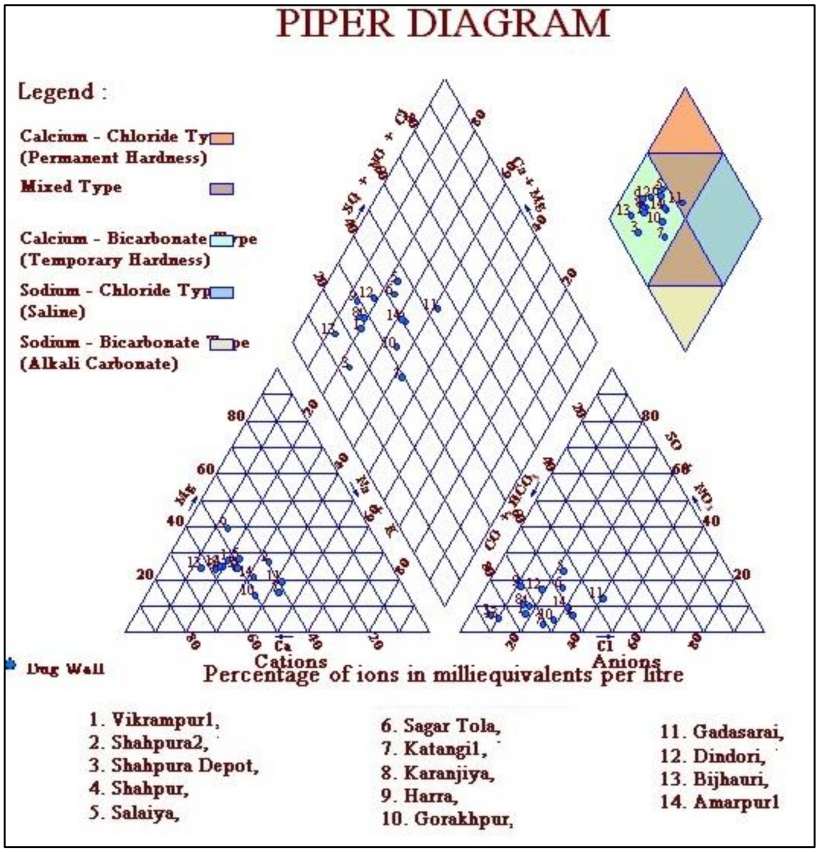


**Fig.3.12: Hill Piper Diagram representing classification of water samples, Shallow Aquifer**

### 3.4.1.2 Quality of Ground Water for Irrigation Purpose

In classification of water for irrigation purpose, it is assumed that the water will be used for irrigation purpose based upon its soil texture, infiltration rate, drainage and climate. Suitability of ground water for irrigation can be assesses using the indices for salinity, chlorinity and sodicity. Various indices such as SAR (**Sodium Absorption Ratio**), SSP (**Soluble Sodium Percentage**) %Na, KI (**Kelly's Index**), PI (**Permeability Index**), RSC (**Residual Sodium Carbonate**) are used for quality criteria for irrigation water. The ground samples that are collected are analysed, compared with the standard values of different indices and ranges of indices and its suitability for irrigation are given in **Table 3.15**. The formula for different indices and calculation of all the indices are given in **Annexure-IV.**

The chemical data of all the water samples from Dindori district is plotted on U.S. Salinity Laboratory diagram shown in the Fig.3.13 In the district USSL diagram shows that the 80% wells of study area are observed under C2-S1 Class (Medium Salinity & Low Sodium) which means that these waters can be used for irrigation purpose for most of the crops, 10% of ground water samples fall under C3-S1 class (High Salinity & Low Sodium). The water from C2-S1 and C3-S1 classes may be used for irrigation purpose under proper soil management

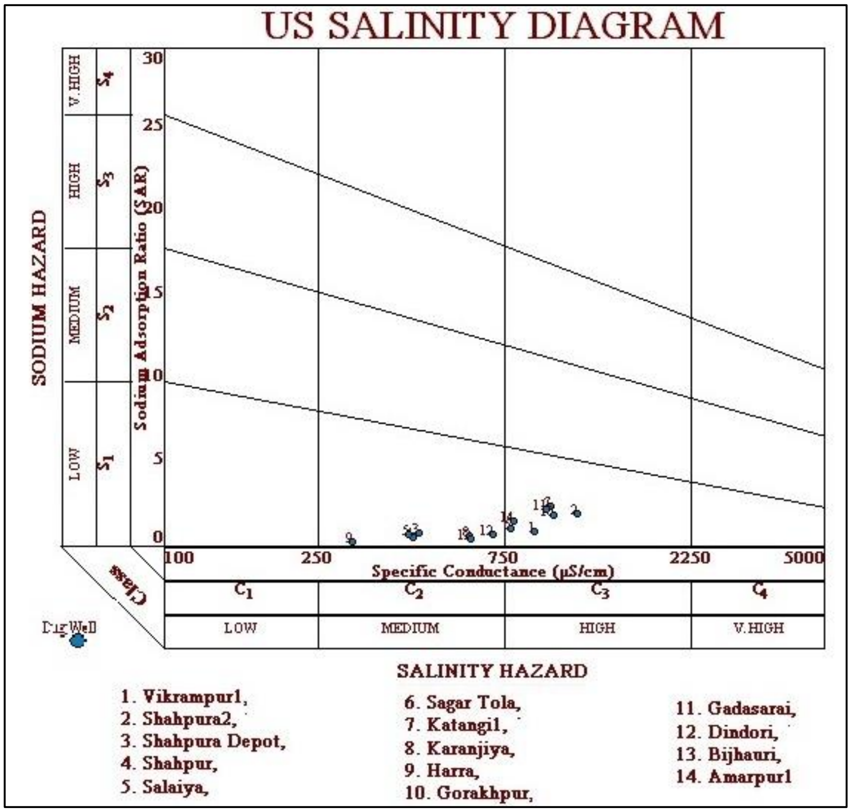


**Fig.3.13: US Salinity Diagram, Shallow Aquifer**

**Table.3.4: Ranges of Indices and Suitability of Ground Water for irrigation**

| | Standards for Irrigation | Aquifer – I (Shallow aquifer) | | |
|---|---|---|---|---|
| | | Min. | Max. | No. of samples above PL |
| **Salinity (EC)** | 3000 | 308 | 1154 | Nil |
| **Soluble Sodium Percentage** | 50 | 12.14 | 42.53 | Nil |
| **Sodium Absorption Ratio** | 10 | 0.34 | 2.47 | Nil |
| **%Na** | 40-60 | 13.14 | 43.32 | Nil |
| **Residual Sodium Carbonate** | 1.25-2.50 | -1.79 | 1.22 | Nil |
| **Kelly's Index** | 1 | 0.32 | 1.36 | Nil |
| **Mg2+ Ratio** | 50 | 0.14 | 0.74 | Nil |
| **Permeability Index** | 75 | 47.13 | 69.39 | Nil |

### 3.4.1.3 Quality of Ground Water for Industrial Purpose

Ground water quality needs to be assessed with reference to its usefulness for industrial purposes as majority of the industries consume huge quantities of water in various processes, water with in specific quality is a must to protect the necessary machinery from scaling or corrosion effects. The Corrosivity ratio (CR) is calculated for all the samples collected during pre-monsoon. The CR value of water with less than or equal to 1 is considered good whereas more than 1 indicates corrosive nature and is not fit for transportation through metal pipes (Ryner 1944; Raman 1985) and it is not suitable for industrial or domestic purposes. The CR values for all the samples is calculated and values are less than 1, so the Ground water of shallow aquifer in Dindori district is suitable for industrial purpose. The calculation of Corrosivity ratio (CR) are given in **Annexure-V.**

## 3.5 3-D AND 2-D AQUIFER DISPOSITION

The data generated from ground water monitoring wells, exploratory and observation wells, various thematic layers was utilized to decipher the aquifer disposition of the area. This particularly includes the information on geometry of aquifers and hydrogeological information of these aquifers. In the area the two aquifer systems have been deciphered as listed below:

a. **Aquifer –I (Shallow Aquifer)**
b. **Aquifer – II (Deeper Aquifer)**

### 3.5.1 Fence Diagram and 3D model

A 3-Dimensional lithological model and fence diagram was prepared for the Dindori district after detailed analysis of the pre-existing and available bore-log data from the exploratory and observation well. A comprehensive analysis was made as per lithology and stratigraphy of the area.

The 3-D Model and fence diagram results concluded that the region is dominantly occupied by Deccan trap Basalt. The sub-surface lithology has been broadly classified into Top soil/Unsaturated zone, weathered Basalt which has been considered as shallow aquifer (up to a depth of 30meter). The Fractured and jointed Basalt that forms the deeper aquifer (from 30-200 meters).

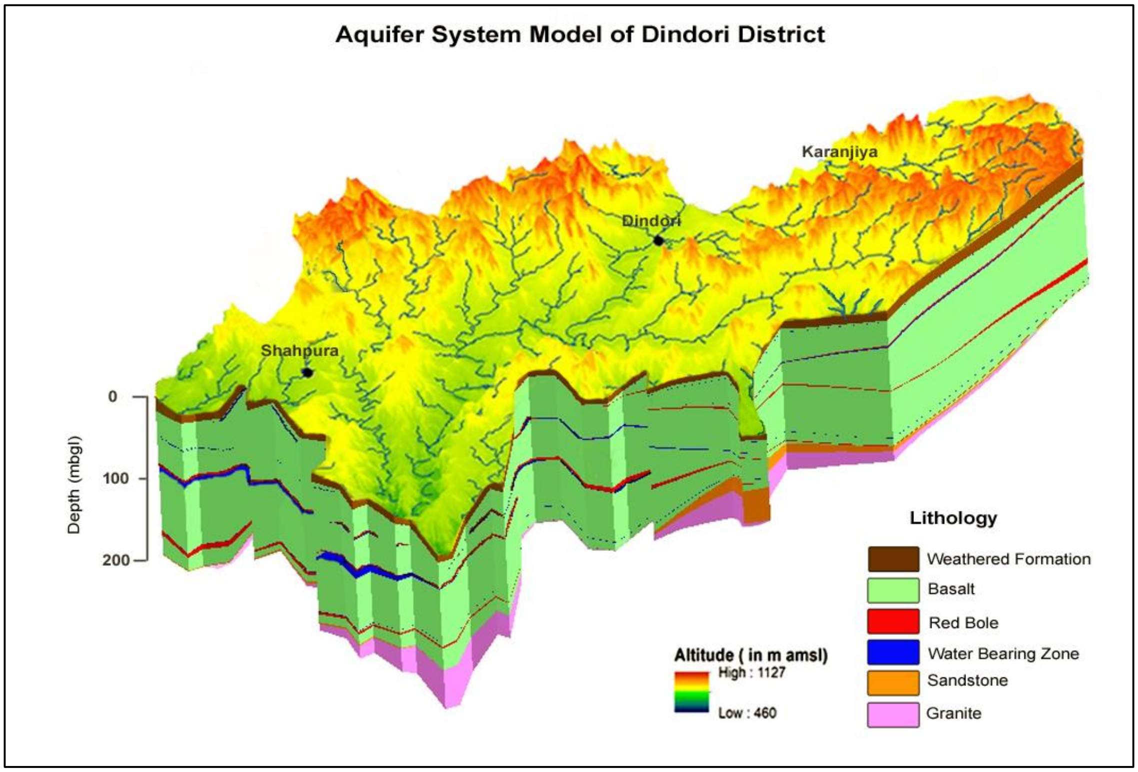


**Fig.3.14: 3D Representation of Aquifers, Dindori District**

# CHAPTER 4
# GROUND WATER RESOURCES

In Dindori district the Ground Water Resources are estimated considering entire area as a single aquifer system. Block wise Dynamic Ground Water Resources are computed as per the guidelines laid down in GEC methodology 2015.

## 4.1 DYNAMIC GROUND WATER RESOURCES

The Dynamic Ground Water Resources assessment has been carried out for Dindori district in the year 2022 and the salient features of the resources are described below**.**

As per the Dynamic Ground Water Resource 2022, the overall contribution of rainfall (both monsoon and non-monsoon) recharge to District's total annual ground water recharge is 98 % and the share of recharge from 'Other sources' viz., return flow from Ground Water irrigation, recharge from tanks, ponds and water conservation structures taken together is 2%. The Ground Water Recharge Scenario is shown in the **Fig.4.1**.

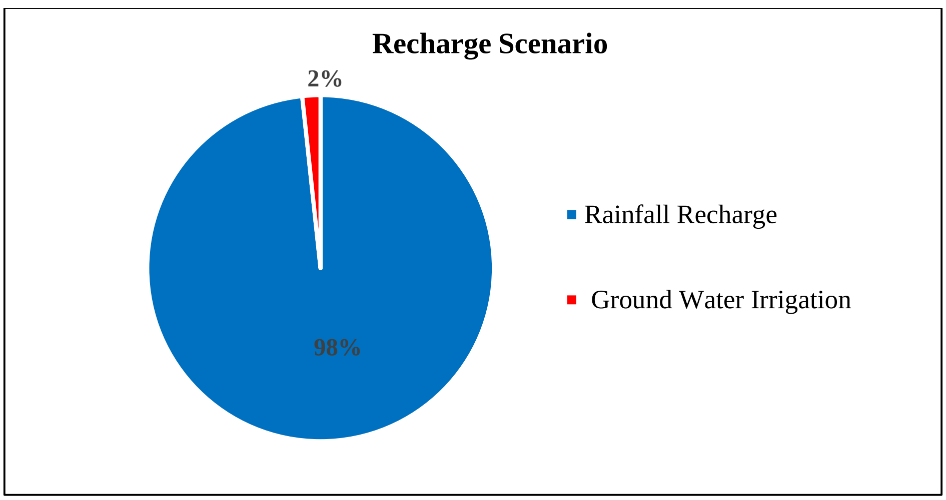


**Fig.4.1:Ground Water Recharge Scenario**

Total annual Ground Water recharge from all sources in the district is of the order of 343 mcm. Total unaccounted natural discharge in the district is of the order of 17 mcm. The total natural discharge is about 5% of the total annual Groundwater recharge. The Annual Extractable Ground Water Resource is 44 mcm, which is 95% of the total annual Groundwater recharge.

Total extraction of ground water for all uses in district is calculated as 41 mcm. From the **Table.4.2**, it is seen that extraction for irrigation accounts for more than 56 % of total ground water extraction, whereas extraction for domestic supply accounts for 44% of the total ground water extraction in the district. The Ground Water Extraction Scenario is shown in the **Fig.4.2.**

**Table.4.1: Ground Water Recharge**

| Assessment Unit | Rainfall Recharge (in Ham) | Recharge from Ground Water Irrigation (in Ham) | Recharge due to Water Conservation Structures (in Ham) |
|---|---|---|---|
| Amarpur | 3400.44 | 40.43 | 4.14 |
| Bajang | 3330.14 | 31.01 | 7.8 |
| Dindori | 6652.77 | 81.24 | 3.84 |
| Karanjiya | 4537.48 | 61.78 | 5.22 |
| Menhadwani | 4367.18 | 55.9 | 5.22 |
| Samnapur | 3983.3 | 84.67 | 9.3 |
| Shahpura | 7425 | 223.99 | 11.52 |
| **District Total** | **33696.3** | **579.02** | **47.04** |

**Table.4.2: Ground Water Resources**

| Assessment Unit | Total Annual Ground Water Recharge (Ham) | Total Natural Discharges (Ham) | Annual Extractable Ground Water Resource (Ham) |
|---|---|---|---|
| Amarpur | 3445.01 | 172.25 | 3272.76 |
| Bajang | 3368.95 | 168.45 | 3200.5 |
| Dindori | 6737.85 | 336.89 | 6400.96 |
| Karanjiya | 4604.48 | 230.22 | 4374.26 |
| Menhadwani | 4428.3 | 221.41 | 4206.89 |
| Samnapur | 4077.27 | 203.86 | 3873.41 |
| Shahpura | 7660.51 | 383.03 | 7277.48 |
| **District Total** | **34322.37** | **1716.11** | **32606.26** |

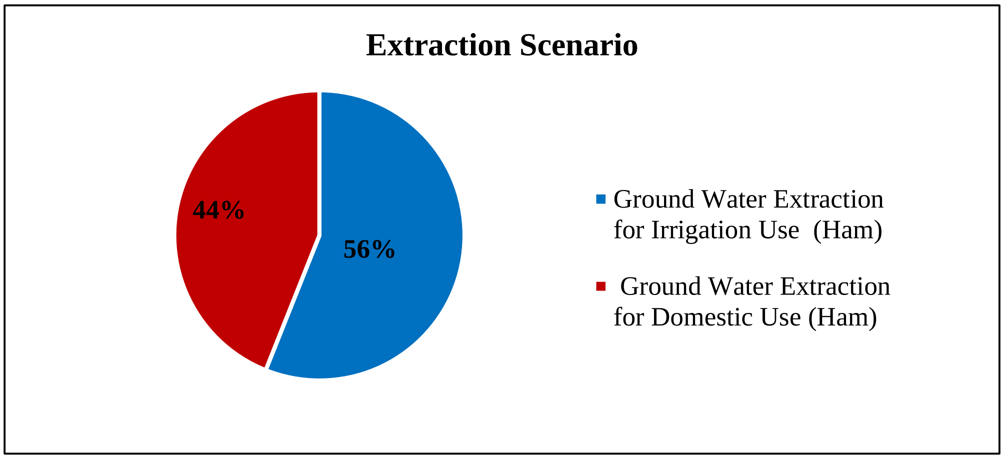


**Fig.4.2: Ground Water Extraction Scenario**

**Table.4.3: Ground Water Extraction**

| Assessment Unit | Ground Water Extraction for Irrigation Use (Ham) | Ground Water Extraction for Domestic Use (Ham) | Total Extraction (Ham) | Stage of Ground Water Extraction (%) | Categorization |
|---|---|---|---|---|---|
| Amarpur | 161.7 | 200.68 | 362.38 | 11.07 | safe |
| Bajang | 124.03 | 231.42 | 355.44 | 11.11 | safe |
| Dindori | 325 | 359.32 | 684.32 | 10.69 | safe |
| Karanjiya | 247.15 | 234.64 | 481.79 | 11.01 | safe |
| Menhadwani | 223.6 | 223.42 | 447.01 | 10.63 | safe |
| Samnapur | 338.7 | 234.03 | 572.73 | 14.79 | safe |
| Shahpura | 896 | 333.56 | 1229.56 | 16.9 | safe |
| **District Total** | **2316.18** | **1817.05** | **4133.23** | **12.68** | |

The overall stage of groundwater extraction in the district is **12.68 %.** The block wise stage of Ground water extraction is given in the **Table.4.3**. All the blocks are categorised as '**Safe**'.

# CHAPTER 5

## GROUND WATER RELATED ISSUES

### 5.1 LIMITED AQUIFER THICKNESS

The district is covered mostly with hard rock i.e. Deccan trap basalt and Achaean Granitoids. These hard rocks don't have primary porosity and are impermeable. So they can form aquifers only when they are weathered, fractured and jointed. So the depth of weathering in shallow aquifer and aquifer thickness in deeper aquifers are limited.

### 5.2 SUSTAINABILITY/ LOW GROUND WATER POTENTIAL

The major part of the district is occupied by basaltic rock formation that inherently consist of limited extent of porous and pervious zone; predominance of secondary porosity that has evolved from prevailing erratic joint pattern and also absence of primary porosity and also, low rainfall results in poor sustainability of the aquifers. However, the erratic nature of existing joints/fractures pattern results in highly varying yield capacities of the aquifers in the area. In the area, depth of potential aquifers is generally restricted up to 30 m. The potential of the fracture zones reduces substantially below 100 m depth. This causes reduction in the well yield drastically during the summers. The entire district is having low yield potential.

# CHAPTER 6

# GROUND WATER MANAGEMENT STRATEGIES

As discussed in previous chapter, there are many groundwater related issues owing to many socio-economic and hydrogeological reasons. As surface water resources in the Dindori district are in-adequate, the dependability on ground water resources has increased substantially. This has resulted in rapid exploitation of ground water resources vis a vis depletion of ground water levels in various parts of the District. The groundwater management plan for Dindori district are described as follow.

## 6.1 MICRO IRRIGATION TECHNOLOGIES:

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

## 6.2 PROPER WELL DESIGN IN BASALTIC FORMATIONS

Alternative flows are generally found within basaltic formations and between flows a clay, sticky collapsible formation present which is known as Red bole or Grey Bole. This formation creates problem during the construction of Borewell in Basaltic formation and also sometimes this formation is acts as a barrier to the aquifers, so a proper well design should be adopted during the construction of borewell in the district. A schematic diagram of a well design for basaltic formation is shown in **fig 6.1**.

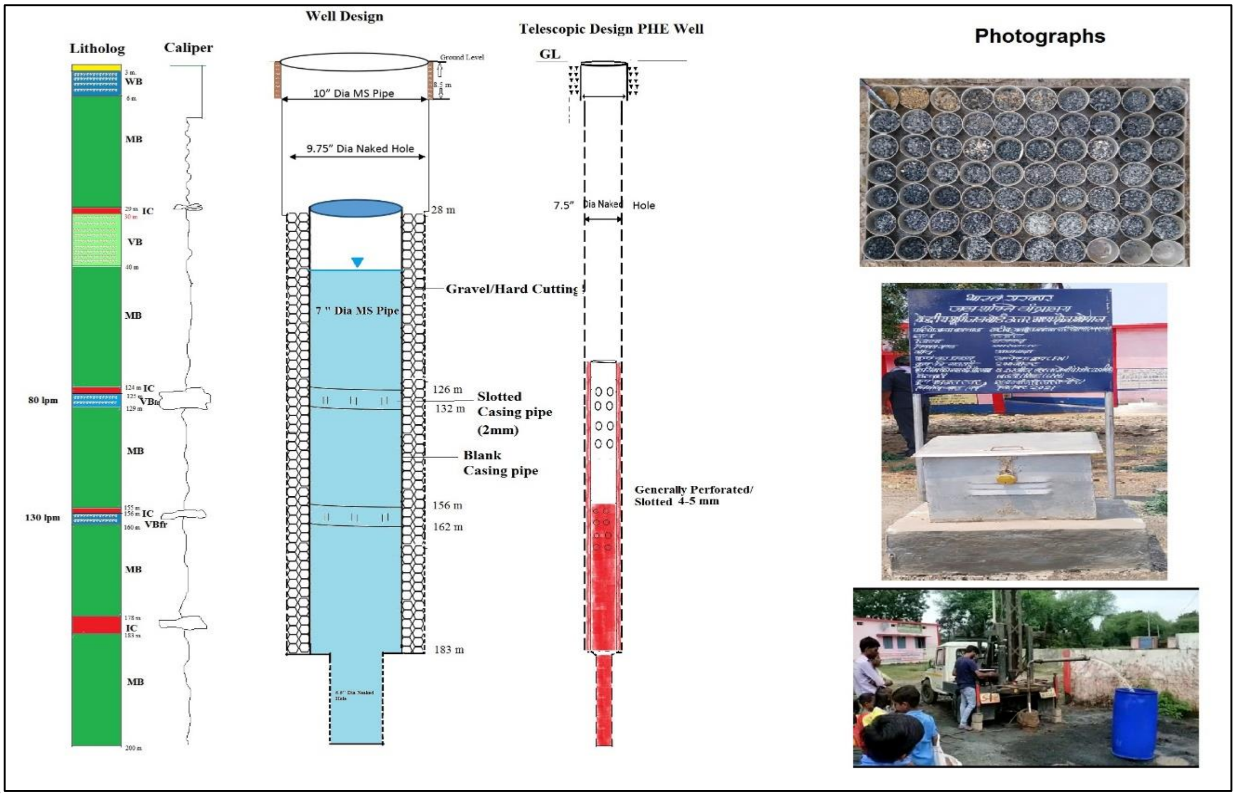


**Fig. 6.1: Typical Well Construction Design in Basaltic Formations**

The drilling in these areas should be done in telescopic manner. The deeper collapsible formations should have cased with blank pipe and slotted pipe given to the aquifer found in between. Gavel or cuttings should be given in the annular space between the deeper casing pipe and the borewell wall.

## 6.3 WATER CONSERVATION

The growing population puts tremendous pressure on the Ground water resources and the Ground Water resource available in the district is also limited. The normal annual rainfall of the district is 1300 mm, So Several management techniques should be adopted to increase rainfall use efficiency. As Ground Water Level in the district is shallow, the rainwater should be stored by making Farm pond. for collection of excess rainfall flowing from the farm area. Farm ponds would help the farmers for on farm water management by using stored water for tackling the dry spells. Farm Pond is a dug out structure with definite shape and size having proper inlet and outlet structures for collecting the surface runoff flowing from the farm area. It is one of the most important rain water harvesting structures constructed at the lowest portion of the farm area.

- Depending on the source of water and their location, farm ponds are grouped into four types: **(Source: Farm Ponds: A Climate Resilient Technology for Rainfed Agriculture, Central Research Institute for Dryland Agriculture, Hyderabad**)

1) Excavated or Dug out ponds
2) Surface ponds
3) Spring or creek fed ponds and
4) Off stream storage ponds.

**Selection of site**

Selection of the site for farm pond depends on local soil condition, topography of area, drainage capacity, infiltration, rainfall pattern and distribution. Selecting the suitable site is considered as one of the most important steps in planning for farm ponds. The following points may be considered for site selection within farm area:

**1. Dugout ponds**

- Observe the average slope direction in the farm area in which farm pond is to be planned for construction
- If the slope is towards left bottom corner of the field (Fig.6.2a), a farm pond must be constructed in the left corner of the plot.
- If the slope is towards bottom right corner of the field (Fig.6.2b), a farm pond must be constructed in the right hand corner
- If the slope is towards the bottom of the field (Fig.6.2c), a farm pond must be constructed to the corner of either side with proper field channel at the bottom of the field connecting to the inlet of the structure.
- If the farm area has multiple slopes in different directions (Fig.6.2d), a farm pond must be located in a portion of area in which water is drained into the structure, may be at centre of the field or near to it.

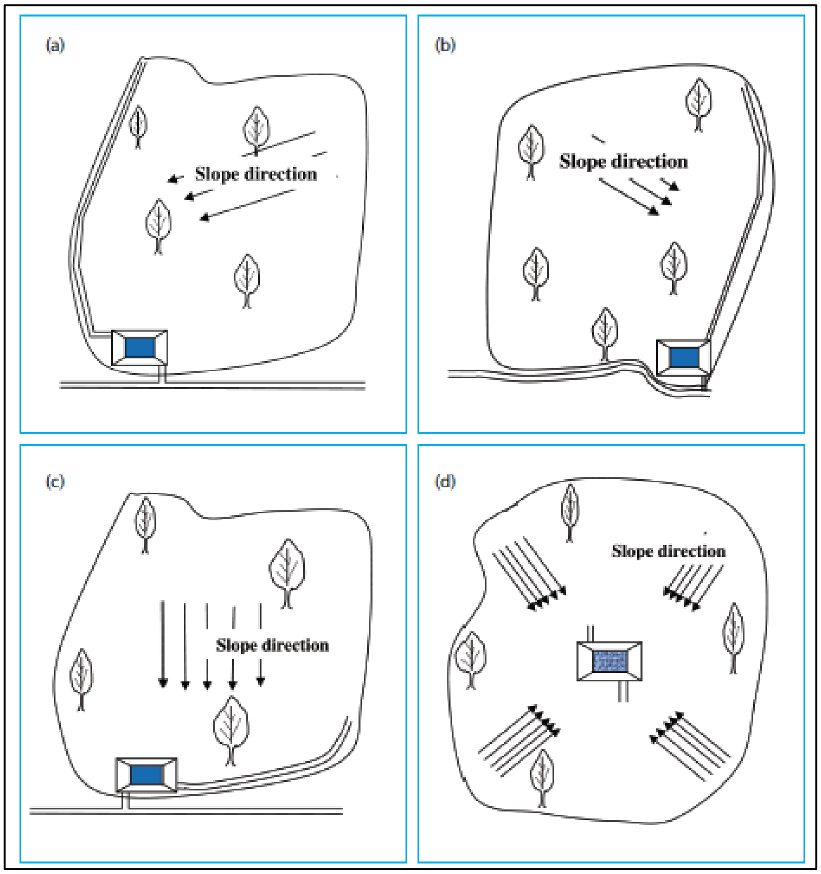


**Fig.6.2: Planning and selection of site for farm pond location in farm catchment areas with different slopes**

**2. Surface Pond**

Surface ponds are considered to collect surface runoff from farm area into a local depression or the lowest portion of the farm so that the excavation is minimum except to construct the earthen bund surrounding the water body (Fig.6.3a). These are possible in highly eroded farm areas with undulating topography. Such farm ponds do not require inlet provision but it should have outlet provision in the earthen bund to remove the excess flow.

**3.Spring or Creek Fed Ponds**

In the ridge portions of the farm area, particularly hilly catchments, after saturation of the soil, there will be a flow from the subsurface layers drawing water into the pond (Fig.6.3b). The sub surface flow is called base flow. It may be a perennial source for water within a farm.

**4.Off stream storage ponds**

The streams are seasonal from which water is drawn into the farm pond by diversion (Fig.6.3c). When the stream flows are the source of storage, the farm ponds shouldnever be constructed across the streams and the structure must be located off the stream with proper diversion of water through pipe or channel.

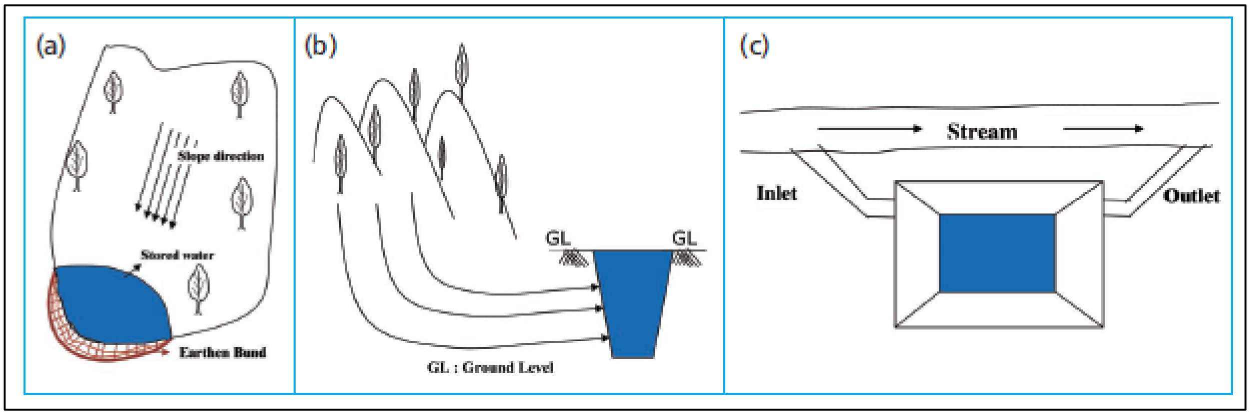


**Fig.6.3: Different types of farm ponds: surface (a), spring (b) and offstream (c) and their location in the catchment**

# CHAPTER 7

# CONCLUSION AND RECOMMENDATIONS

- Dindori District occupies an area of 5725 Sq.Km and recharge worthy area is 4560 sq. km, and the rest is covered by hilly areas.
- About 90% of annual rainfall is received during monsoon season. Only 10 % of annual rainfall takes place during non-monsoon season.
- Dindori district falls under Narmada river basin. The district is mainly drained by river Narmada and its tributaries. Major tributaries are Kasah, Siligi, Johila, Kharmer, Carker, Seoni, Turar rivers.
- Agriculture and forest are the prominent land use aspects in Dindori district. Crop land forms 57% and forest area form 37 % of total area followed by Fallow land (3%), Shrub land and water bodies.
- Major Socio–economy of the District is dependent on Agriculture. The livelihood of rural population of district is dependent on Agriculture.
- The elevation of the district is varying from 460 to 1120 meters above Mean Sea Level.
- Net sown area of the district during kharif season is 205524 hectare, out of which 21990 hectare is irrigated and 183536 hectare area is unirrigated. During Rabi season total sown area of the district is 137300 hectare, out of which 12900 hectare is irrigated and 124400 hectare area is unirrigated.
- In the district mostly two types of soil are present namely, Clayey and loamy soil.
- Main geological units of the district are Laterite, Deccan trap and Banded Gneissic Complex (BGC).
- The principal aquifers in the area are Basalt and Granite.
- The groundwater movement in the district is towards the Northern sidein the northern part of district and in the central part towards the western side, which follows the drainage and topography of the area.
- In the shallow aquifer water levels between 5 to 10 mbgl in pre-monsoon and between 2 to 5 mbgl in the post-monsoon are observed in major parts of the district. The decadal pre-monsoon water level trend analysis indicates that during pre-monsoon period, more more than 90 % of the area showing rising trend. Similarly, the decadal post-monsoon water level trend analysis indicates that almost the whole district is showing declining trend.

- For Shallow aquifers the electrical conductivity of ground water in Neemuch district ranged between 308 to 1154 µS/cm at 25°C, pH ranged in between 7.11 to 7.96, fluoride concentration was ranged in between 0.02 to 0.32 mg/l, nitrate concentration ranged in between 3 to 38 mg/l. Total hardness ranged in between 130 to 395 mg/l. In the assessment of ground water resources estimation, PHED has reported high Fluoride concentration in ground water in two blocks, viz. Amarpur and Dindori.
- The sub-surface lithology has been broadly classified into Top soil/Unsaturated zone, weathered Basalt which has been considered as shallow aquifer (up to a depth of 30meter). The Fractured and jointed Basalt that forms the deeper aquifer (from 30-200 meters).
- In Basaltic formations the Discharge is upto 5 lps. Transmissivity is upto 250 m2/day and Secific Yield is up to 3%. The Deccan Traps formations can be tapped by dug well, dug-cum-bore and bore wells. Ground water occurs in the weathered, jointed and fractured basalts under Unconfined and semi-confined to confined conditions.
- In Archaean formations Groundwater mostly occurs under under unconfined to semi confined conditions. Transmisivity is found upto 100 m2/day., Discharge is up to 2 lps and Specific yield is up to 2%.

- As per the Dynamic Ground Water Resources Estimation (2020), the annual recharge from rainfall contributes maximum component (337 mcm) and recharge from other sources is 6 mcm. The Annual Extractable Ground Water Resource is 326 mcm, which is 95% of the total annual Groundwater recharge. Total extraction of ground water for all uses in district is calculated as 41 mcm. The overall stage of groundwater extraction in the district is 12.68 %.
- All the blocks are categorised as ‘Safe’.
- In the district, the main ground water issues are Limited Ground Water Potential, Limited Aquifer Thickness, Sustainability of hard rocks, Decline in the water level both in shallow and deep aquifers in some areas.

# ANNEXURES

**Annexure-I: Ground Water Exploration Lithologs**

| Location | Depth1 | Depth2 | Lithology |
|---|---|---|---|
| Amachua | 0 | 2 | Top Soil |
| Amachua | 2 | 14 | Weathered |
| Amachua | 14 | 15 | Fractured1 |
| Amachua | 15 | 93 | Massive Basalt |
| Amachua | 39 | 111 | Massive Basalt |
| Amadongri | 0 | 1.5 | Top Soil |
| Amadongri | 1.5 | 6 | Weathered |
| Amadongri | 6 | 8 | Massive Basalt |
| Amadongri | 8 | 29 | Red Bole |
| Amadongri | 29 | 31 | Fractured1 |
| Amadongri | 31 | 63 | Massive Basalt |
| Amarpura | 0 | 2 | Top Soil |
| Amarpura | 2 | 9 | Weathered |
| Amarpura | 9 | 30 | Massive Basalt |
| Amarpura | 30 | 32 | Fractured1 |
| Amarpura | 32 | 109 | Massive Basalt |
| Amarpura | 109 | 118 | Red Bole |
| Amarpura | 118 | 131 | Massive Basalt |
| Bahera | 0 | 7 | Top Soil |
| Bahera | 7 | 10 | Vesicular Basalt |
| Bahera | 10 | 30 | Massive Basalt1 |
| Bahera | 30 | 31 | Fractured1 |
| Bahera | 31 | 40 | Massive Basalt2 |
| Bahera | 40 | 41 | Fractured2 |
| Bahera | 41 | 70 | Massive Basalt3 |
| Bahera | 70 | 73 | Vesicular Basalt |
| Bahera | 73 | 81 | Massive Basalt4 |
| Bargaon | 0 | 1 | Top Soil |
| Bargaon | 1 | 7 | Weathered |
| Bargaon | 7 | 20 | Vesicular Basalt |
| Bargaon | 20 | 50 | Massive Basalt |
| Bargaon | 50 | 52 | Fractured1 |
| Bargaon | 52 | 78 | Massive Basalt |
| Bargaon | 78 | 126 | Vesicular Basalt |
| Bargaon | 126 | 181 | Massive Compact |
| Bargaon | 181 | 182 | Fractured 2 |
| Bargaon | 182 | 188 | Massive Basalt |

| Location | Depth1 | Depth2 | Lithology |
|---|---|---|---|
| Batondra | 0 | 2 | Top Soil |
| Batondra | 2 | 12 | Weathered |
| Batondra | 12 | 42 | Vesicular Basalt |
| Batondra | 42 | 101 | Massive Basaly |
| Batondra | 101 | 109 | Red Bole |
| Chargoan | 0 | 5 | Weathered |
| Chargoan | 5 | 26 | Massive Basalt |
| Chargoan | 26 | 33 | Limestone |
| Chargoan | 32 | 35 | Fractured Basalt |
| Chargoan | 35 | 40 | Vesicular Basalt |
| Chargoan | 40 | 44 | Fractured Basalt |
| Chargoan | 44 | 100 | Vesicular Basalt |
| Chargoan | 100 | 133 | Massive Basalt |
| Chargoan | 133 | 175 | Vesicular Basalt |
| Chargoan | 175 | 176 | Red Bole |
| Chargoan | 176 | 183 | Vesicular Basalt |
| Chargoan | 183 | 184 | Red Bole |
| Chargoan | 184 | 200 | Vesicular Basalt |
| Dhanwasi | 0 | 9 | Weathered |
| Dhanwasi | 9 | 67 | Vesicular Basalt |
| Dhanwasi | 67 | 70 | Fractured |
| Dhanwasi | 70 | 91 | Red Bole |
| Dhanwasi | 91 | 100 | Vesicular Basalt |
| Dhanwasi | 100 | 105 | Fractured |
| Dhanwasi | 105 | 124 | Vesicular Basalt |
| Gadasarai | 0 | 3 | Top Soil |
| Gadasarai | 3 | 9 | Weathered |
| Gadasarai | 9 | 30 | Vesicular Basalt |
| Gadasarai | 30 | 35 | Fractured |
| Gadasarai | 35 | 45 | Vesicular Basalt |
| Gadasarai | 45 | 61 | Red Bole |
| Gutalwah | 0 | 17 | Weathered |
| Gutalwah | 17 | 20 | Fractured |
| Gutalwah | 20 | 93 | Massive Basalt |
| Gutalwah | 93 | 118 | Sand |
| Gutalwah | 118 | 139 | Massive Basalt |
| Gutalwah | 139 | 200 | Clay |
| Karanjiya | 0 | 6 | Weathered |

| Location | Depth1 | Depth2 | Lithology |
|---|---|---|---|
| Karanjiya | 6 | 30 | Red Bole |
| Karanjiya | 30 | 40 | Massive Basalt |
| Karanjiya | 40 | 68 | Clay |
| Kevlari | 0 | 1 | Top Soil |
| Kevlari | 1 | 7 | Weathered |
| Kevlari | 7 | 11 | Vesicular Basalt |
| Kevlari | 11 | 24 | Massive Basalt |
| Kevlari | 24 | 31 | Red Bole |
| Kevlari | 31 | 40 | Vesicular Basalt |
| Kevlari | 40 | 98 | Massive Basalt |
| Khairda | 0 | 1 | Top Soil |
| Khairda | 1 | 7 | Weathered |
| Khairda | 7 | 35 | Massive Basalt |
| Khairda | 35 | 38 | Red Bole |
| Khairda | 38 | 50 | Vesicular Basalt |
| Khairda | 50 | 111 | Massive Basalt |
| Khairda | 111 | 116 | Clay |
| Khairda | 116 | 130 | Vesicular Basalt |
| Khairda | 130 | 140 | Clay |
| Khairda | 140 | 165 | Vesicular Basalt |
| Khairda | 165 | 200 | Massive Basalt |
| Kuhani Devari | 0 | 8 | Weathered |
| Kuhani Devari | 8 | 57 | Massive Basalt |
| Kuhani Devari | 57 | 60 | Fractured |
| Kuhani Devari | 60 | 145 | Massive Basalti |
| Kuhani Devari | 145 | 160 | Red Bole |
| Kuhani Devari | 160 | 203 | Massive Basalt |
| Majhiakhar | 0 | 6 | Weathered |
| Majhiakhar | 6 | 18 | Vesicular Basalt |
| Majhiakhar | 18 | 73 | Massive Basalt |
| Majhiakhar | 73 | 76 | Fractured |
| Majhiakhar | 76 | 88 | Vesicular Basalt |
| Rahungi | 0 | 5 | Weathered |
| Rahungi | 5 | 26 | Vesicular Basalt |
| Rahungi | 26 | 38 | Red Bole |
| Rahungi | 38 | 63 | Vesicular Basalt |
| Rahungi | 63 | 124 | Massive Basalt |
| Rai | 0 | 17 | Weathered |

| Location | Depth1 | Depth2 | Lithology |
|---|---|---|---|
| Rai | 17 | 27 | Vesicular Basalt |
| Rai | 27 | 97 | Massive Basalt |
| Rai | 97 | 100 | Red Bole |
| Rai | 100 | 112 | Vesicular Basalt |
| Rai | 112 | 200 | Massive Basalt |
| Raipura | 0 | 4 | Top Soil |
| Raipura | 4 | 7 | Weathered |
| Raipura | 7 | 30 | Vesicular Basalt |
| Raipura | 30 | 50 | Massive Basalt |
| Raipura | 50 | 55 | Vesicular Basalt |
| Raipura | 55 | 62 | Massive Basalt |
| Raipura | 62 | 65 | Red Bole |
| Raipura | 65 | 72 | Vesicular Basalt |
| Raipura | 72 | 99 | Massive basalt |
| Raipura | 99 | 117 | Vesicular Basalt |
| Raipura | 117 | 150 | Massive Basalt |
| Rehpura | 0 | 25 | Weathered |
| Rehpura | 25 | 72 | Massive Basalt |
| Rehpura | 72 | 75 | Red Bole |
| Rehpura | 75 | 100 | Vesicular Basalt |
| Rehpura | 100 | 142 | Massive Basalt |
| Rehpura | 142 | 148 | Clay |
| Rehpura | 148 | 200 | Massive Basatl |
| Sarhari | 0 | 5 | Top Soil |
| Sarhari | 5 | 15 | Weathered |
| Sarhari | 15 | 17 | Fractured |
| Sarhari | 17 | 90 | Massive Basalt |
| Sarhari | 90 | 93 | Fractured |
| Sarhari | 93 | 128 | Vesicular Basalt |
| Shahpur | 0 | 11 | Weathered |
| Shahpur | 11 | 38 | Red Bole |
| Shahpur | 38 | 63 | Vesicular Basalt |
| Shahpur | 63 | 66 | Red Bole |
| Shahpur | 66 | 200 | Vesicular Basalt |
| Shakka | 0 | 1 | Top Soil |
| Shakka | 1 | 7 | Weathered |
| Shakka | 7 | 25 | Massive Basalt |
| Shakka | 25 | 27 | Red Bole |

| Location | Depth1 | Depth2 | Lithology |
|---|---|---|---|
| Shakka | 27 | 34 | Vesicular Basalt |
| Shakka | 34 | 50 | Massive Basalt |
| Shakka | 50 | 74 | Vesicular Basalt |
| Shakka | 74 | 120 | Massive Basalt |
| Shakka | 120 | 151 | Vesicular Basalt |
| Shakka | 151 | 153 | Fractured |
| Shakka | 153 | 200 | Massive Basalt |
| Tikaniya | 0 | 11 | Weathered |
| Tikaniya | 11 | 36 | Massive Basalt |
| Tikaniya | 36 | 38 | Fractured |
| Tikaniya | 38 | 72 | Massive Basalt |
| Tikaniya | 72 | 93 | Vesicular Basalt |
| Tikaniya | 93 | 124 | Massive Basalt |
| Vikrampur | 0 | 1 | Top Soil |
| Vikrampur | 1 | 24 | Weathered |
| Vikrampur | 24 | 31 | Red Bole |
| Vikrampur | 31 | 40 | Vesicular Basalt |
| Vikrampur | 40 | 73 | Massive Basalt |
| Vikrampur | 73 | 102 | Vesicular Basalt |
| Vikrampur | 102 | 130 | Massive Basalt |
| Vikrampur | 130 | 180 | Vesicular Basalt |
| Vikrampur | 180 | 200 | Massive Basalt |
| Dindori | 0 | 1.3 | Top Soil |
| Dindori | 1.3 | 11 | Weathered |
| Dindori | 11 | 22 | Massive Basalt |
| Dindori | 22 | 23 | Fractured |
| Dindori | 23 | 51 | Massive Basalt |

**Annexure-II: Ground Water Level Scenario of Shallow Aquifer**

| Block | Village | Latitude | Longitude | Pre_WL _21 | Post_WL_21 | Fluctuation |
|---|---|---|---|---|---|---|
| Amarpur | Amarpur | 22.7861 | 80.9722 | 9.74 | 5.7 | 4.04 |
| Bajag | Bijhauri | 22.8567 | 81.2292 | 3.64 | 1 | 2.64 |
| Bajag | Gadasarai | 22.8197 | 81.3306 | 3.47 | 2.21 | 1.26 |
| Bajag | Sagar Tola | 22.8283 | 81.2919 | 9.5 | 6.8 | 2.7 |
| Dindori | Dindori | 22.9333 | 81.0917 | 5.78 | 4.88 | 0.9 |
| Dindori | Salaiya | 22.9097 | 80.9472 | 3.52 | 2.8 | 0.72 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Dindori | Shahpur | 23.0214 | 81.0064 | 4.7 | 3 | 1.7 |
| Dindori | Vikrampur | 23.0767 | 80.9069 | 5.7 | 0.5 | 5.2 |
| Karanjiya | Gorakhpur | 22.7478 | 81.4494 | 4.86 | 3.16 | 1.7 |
| Karanjiya | Karanjiya | 22.7111 | 81.6211 | 9.85 | 9.35 | 0.5 |
| Mehadwani | Harra | 22.8756 | 80.7914 | 5.4 | 2 | 3.4 |
| Shahpura | Katangi | 23.1261 | 80.6261 | 4.25 | 2.7 | 1.55 |
| Shahpura | Shahpura | 23.1833 | 80.7006 | 4.5 | 2.6 | 1.9 |
| Shahpura | Shahpura Depot | 23.1833 | 80.6953 | 5.1 | 3 | 2.1 |
| | | | **Minimum** | **3.47** | **0.5** | **0.5** |
| | | | **Maximum** | **9.85** | **9.35** | **5.2** |
| | | | **Average** | **5.715** | **3.55** | **2.165** |

## Annexure-III: Chemical Quality Data of Shallow Aquifer

| Block | Location | Lat. | Long. | pH | EC | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | F | $PO_4$ | $SiO_2$ | TH | Ca | Mg | Na | K | TDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | @ 25°C | µS/cm @ 25°C | mg/liter | | | | | | | | | | | | | |
| Amarpur | Amarpur | 22.7861 | 80.9722 | 7.88 | 795 | 0 | 268 | 85 | 22 | 14 | 0.02 | 0.05 | 24 | 275 | 76 | 21 | 59 | 2 | 517 |
| Bajag | Bijhauri | 22.8567 | 81.2292 | 7.94 | 620 | 0 | 311 | 23 | 12 | 5 | 0.22 | 0.08 | 29 | 285 | 82 | 19 | 18 | 2.9 | 403 |
| Dindori | Dindori | 22.9333 | 81.0917 | 7.9 | 705 | 0 | 256 | 45 | 26 | 32 | 0.06 | 0.1 | 27 | 290 | 80 | 22 | 30 | 2.3 | 458 |
| Bajag | Gadasarai | 22.8197 | 81.3306 | 7.83 | 960 | 0 | 250 | 132 | 32 | 30 | 0.16 | 0.05 | 16 | 285 | 76 | 23 | 89 | 9.8 | 624 |
| Karanjiya | Gorakhpur | 22.7478 | 81.4494 | 7.94 | 1010 | 0 | 384 | 97 | 9 | 18 | 0.31 | 0.08 | 39 | 325 | 102 | 17 | 79 | 7.5 | 657 |
| Mehadwani | Harra | 22.8756 | 80.7914 | 7.11 | 308 | 0 | 122 | 12 | 14 | 13 | 0.09 | 0.12 | 20 | 130 | 28 | 15 | 9 | 1.4 | 200 |
| Karanjiya | Karanjiya | 22.7111 | 81.6211 | 7.84 | 612 | 0 | 268 | 35 | 19 | 16 | 0.21 | 0.06 | 23 | 255 | 72 | 18 | 25 | 1.4 | 398 |
| Shahpura | Katangi | 23.1261 | 80.6261 | 7.76 | 987 | 0 | 415 | 90 | 7 | 11 | 0.31 | 0.09 | 31 | 280 | 82 | 18 | 95 | 5.3 | 642 |
| Bajag | Sagar Tola | 22.8283 | 81.2919 | 7.73 | 780 | 0 | 244 | 65 | 27 | 38 | 0.05 | 0.13 | 35 | 290 | 78 | 23 | 43 | 2.1 | 507 |
| Dindori | Salaiya | 22.9097 | 80.9472 | 7.41 | 429 | 0 | 128 | 32 | 24 | 26 | 0.32 | 0.14 | 17 | 165 | 40 | 16 | 22 | 2.6 | 279 |
| Dindori | Shahpur | 23.0214 | 81.0064 | 7.72 | 440 | 0 | 183 | 27 | 16 | 6 | 0.19 | 0.08 | 21 | 175 | 48 | 13 | 18 | 2.7 | 286 |
| Shahpura | Shahpura Depot | 23.1833 | 80.6953 | 7.89 | 455 | 0 | 226 | 12 | 11 | 3 | 0.28 | 0.09 | 34 | 170 | 46 | 13 | 24 | 1.4 | 296 |
| Shahpura | Shahpura | 23.1833 | 80.7006 | 7.83 | 1154 | 0 | 409 | 140 | 12 | 32 | 0.03 | 0.1 | 25 | 395 | 94 | 39 | 91 | 2.7 | 750 |
| Dindori | Vikrampur | 23.0767 | 80.9069 | 7.96 | 900 | 0 | 397 | 57 | 17 | 16 | 0.19 | 0.14 | 39 | 365 | 96 | 30 | 41 | 3.9 | 585 |

| | pH | EC | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | F | $PO_4$ | $SiO_2$ | TH | Ca | Mg | Na | K | TDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Min** | 7.11 | 308. | 0.00 | 122 | 12 | 7 | 3 | 0.02 | 0.05 | 16 | 130 | 28 | 13 | 9 | 1.40 | 200.00 |
| **Max** | 7.96 | 1154 | 0.00 | 415 | 140 | 32 | 38 | 0.32 | 0.14 | 39 | 395 | 102 | 39 | 95 | 9.80 | 750.00 |
| **Avg** | 7.77 | 725 | 0.00 | 275 | 60 | 17 | 18 | 0.17 | 0.09 | 27 | 263 | 71 | 20 | 45 | 3.43 | 471.57 |

**Annexure-IV: Ground Water Quality Calculation for Irrigation, Shallow aquifer**

| | | S S P% | SAR | %Na | RSC | K I | Mg2+ Ratio |
|---|---|---|---|---|---|---|---|
| | | Na*100/ Ca+Mg+Na | Na / √ (Ca+Mg) / 2 | ((Na+K) / (Ca+Mg+Na+K))*100 | (HCO3 + CO3) – (Ca + Mg) | Na/Ca+Mg | (Mg) / (Ca+Mg)*100 |
| | | | | | | | |
| Amarpur | Amarpur | 31.70 | 1.54 | 32.12 | -1.13 | 0.46 | 31.26 |
| Bajag | Bijhauri | 12.14 | 0.47 | 13.14 | -0.57 | 0.14 | 27.61 |
| Dindori | Dindori | 18.33 | 0.77 | 19.00 | -1.61 | 0.22 | 31.16 |
| Bajag | Gadasarai | 40.47 | 2.29 | 41.99 | -1.59 | 0.68 | 33.25 |
| Karanjiya | Gorakhpur | 34.58 | 1.91 | 35.82 | -0.20 | 0.53 | 21.53 |
| Mehadwani | Harra | 12.93 | 0.34 | 13.95 | -0.63 | 0.15 | 46.86 |
| Karanjiya | Karanjiya | 17.62 | 0.68 | 18.10 | -0.69 | 0.21 | 29.15 |
| Shahpura | Katangi | 42.53 | 2.47 | 43.32 | 1.22 | 0.74 | 26.54 |
| Bajag | Sagar Tola | 24.40 | 1.10 | 24.93 | -1.79 | 0.32 | 32.67 |
| Dindori | Salaiya | 22.38 | 0.74 | 23.57 | -1.22 | 0.29 | 39.70 |
| Dindori | Shahpur | 18.40 | 0.59 | 19.71 | -0.47 | 0.23 | 30.83 |
| Shahpura | Shahpura Depot | 23.64 | 0.80 | 24.26 | 0.34 | 0.31 | 31.75 |
| Shahpura | Shahpura | 33.34 | 1.99 | 33.73 | -1.20 | 0.50 | 40.58 |
| Dindori | Vikrampur | 19.69 | 0.94 | 20.57 | -0.76 | 0.25 | 33.96 |
| | Minumum | **12.14** | **0.34** | **13.14** | **-1.79** | **0.14** | **21.53** |
| | Maximum | **42.53** | **2.47** | **43.32** | **1.22** | **0.74** | **46.86** |
| | Average | 25.15 | 1.19 | 26.01 | -0.74 | 0.36 | 32.63 |

**Formulae: -**

Soluble Sodium Percentage (S S P%)= Na*100/ Ca+Mg+Na
Sodium Absorption Ratio (SAR)= Na / √ (Ca+Mg) / 2
%Na=((Na+K) / (Ca+Mg+Na+K)) *100
Residual Sodium Carbonate (RSC) = (HCO3 + CO3) – (Ca + Mg)
Kelley's Index (K I) = Na/Ca+Mg\
Mg2+ Ratio =(Mg) / (Ca+Mg)*100
Permeability Index (P I) = ((Na+ (√HCO3) / (Ca+Mg+Na))*100

**Annexure-V: Ground Water Quality Calculation for Industrial use, Shallow aquifer**

| Block | Location | $CO_3^{2-}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | Cl/35.50 | $2(SO_4/96)$ | $((Cl/35.50+2(SO_4/96))$ | $2(HCO_3+CO_3/100)$ | $((Cl/35.50+2(SO_4/96))/2(HCO_3+CO_3/100)$ | $((Cl/35.50+2(SO_4/96))/2(HCO_3+CO_3/100)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amarpur | Amarpur | 0 | 268 | 85.00 | 22 | 2.39 | 0.46 | 2.85 | 536 | 0.005322201 | 0.0053 |
| Bajag | Bijhauri | 0 | 311 | 23.00 | 12 | 0.65 | 0.25 | 0.90 | 622 | 0.001443549 | 0.0014 |
| Dindori | Dindori | 0 | 256 | 45.00 | 26 | 1.27 | 0.54 | 1.81 | 512 | 0.003533735 | 0.0035 |
| Bajag | Gadasarai | 0 | 250 | 132.00 | 32 | 3.72 | 0.67 | 4.38 | 500 | 0.008769953 | 0.0088 |
| Karanjiya | Gorakhpur | 0 | 384 | 97.00 | 9 | 2.73 | 0.19 | 2.92 | 768 | 0.003801946 | 0.0038 |
| Mehadwani | Harra | 0 | 122 | 12.00 | 14 | 0.34 | 0.29 | 0.63 | 244 | 0.002580717 | 0.0026 |
| Karanjiya | Karanjiya | 0 | 268 | 35.00 | 19 | 0.99 | 0.40 | 1.38 | 536 | 0.00257789 | 0.0026 |
| Shahpura | Katangi | 0 | 415 | 90.00 | 7 | 2.54 | 0.15 | 2.68 | 830 | 0.003230174 | 0.0032 |
| Bajag | Sagar Tola | 0 | 244 | 65.00 | 27 | 1.83 | 0.56 | 2.39 | 488 | 0.004904684 | 0.0049 |
| Dindori | Salaiya | 0 | 128.00 | 32.00 | 24.00 | 0.90 | 0.50 | 1.40 | 256.00 | 0.005474252 | 0.005474252 |
| Dindori | Shahpur | 0 | 183.00 | 27.00 | 16.00 | 0.76 | 0.33 | 1.09 | 366.00 | 0.002988789 | 0.002988789 |
| Shahpura | Shahpura Depot | 0 | 226.00 | 12.00 | 11.00 | 0.34 | 0.23 | 0.57 | 452.00 | 0.001254856 | 0.001254856 |
| Shahpura | Shahpura | 0 | 409 | 140 | 12 | 3.94 | 0.25 | 4.19 | 818.00 | 0.005126726 | 0.005126726 |
| Dindori | Vikrampur | 0 | 397 | 57 | 17 | 1.61 | 0.35 | 1.96 | 794.00 | 0.002468263 | 0.002468263 |

**Formulae: -**

**Corrosivity Ratio (CR)** = $((Cl/35.50 + 2(SO_4/96)) / 2(HCO_3 + CO_3/100)$

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# ABBREVIATION

µS: Microsiemens

$^0$C: Degree Centigrade

2-D: 2-Dimensional

3-D: 3-Dimensional

AR: Artificial Recharge

bcm: Billion Cubic Meter

BGC: Bande Gneissic Complex

BIS: bureau of Indian Standards

CD: Check Dam

CGWB: Central Ground Water Board

cm: Centimeter

CR: Corrosivity Ratio

DEM: Digital Elevation Model

DIP: District Irrigation Plan

E: East

EC: Electrical Conductivity

EFC: Expenditure Finance Committee

ERT: Electrical Resistivity Tomography are collected and compiled

EW: Exploratory Well

GEC: Groundwater Estimation Committee

GRP: Gradient Resistivity Profiling

GSI: Geological Survey of India

GW: Ground Water

Ha: hectare

Ham: Hectare meter

IMD: India Meteorological Department

KI: Kelly's Index

Km: Kilometer

l: litre

lps: Litre Per Second

M.P.: Madhya Pradesh

m: Meter

Max: Maximum

mbgl: Meter below Ground Level

mcm: Million Cubic Meter

mg: Milligram

MGNREGA: Mahatma Gandhi National Rural Employment Guarantee Act 2005

Min: Minimum

N: North

NAQUIM: National Aquifer Mapping

NB: Nala Bund

NCR: North Central Region

Nov: November

OW: Observation Well

PI: Permeability Index

PL: Permissible Limit

PMKSY: Pradhan Mantri Krishi Sinchayee Yojana

PT: Percolation Tank

PHED: Public Health Engineering Department

RS: Recharge Structure

RSC: Residual Sodium Carbonate

S: South

SAR: Sodium Absorption Ratio

Sq: Square

SSP: Soluble Sodium Percentage

TEM: Transient Electromagnetic

TH: Total Hardness

USSL: U.S. Salinity Laboratory

VES: Vertical Electrical Sounding

VP: Village Pond

W: West

WL: Water Level

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**CENTRAL GROUND WATER BOARD**

**North Central Region, Bhopal**

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