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

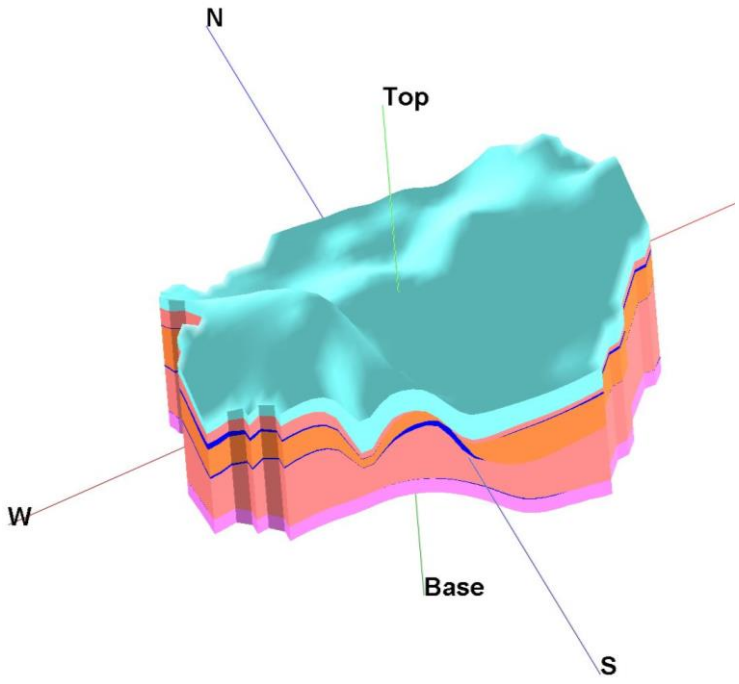
Gwalior District
Madhya Pradesh

उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

Central Ground Water Board
Department of Water Resources, RD& GR
Ministry of Jal Shakti
Government of India

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



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NORTH CENTRAL REGION
BHOPAL
2021-22

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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 integrating the techniques of geology, remote sensing, hydrogeology, geophysics, borehole drilling, hydrochemistry, hydrology, hydrometeorology, mathematical modelling, agriculture and soil science, water treatment and remediation, economics and social and environmental sciences.

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

Gwalior district occupies an area of 4564sq km out of which the ground water recharge worthy area is 4282 sq. km. and the rest is covered by hilly and forest area. The major rivers flowing through the area includes the Sindh, ken. The major part of the district is covered by the Bundelkhand Granite Gwalior Sandstone and Shale, Vindhayan sandstones and Alluvium. On the basis of the 21 exploratory borewells drilled by CGWB, NCR under its Exploratory program, it has been observed that the yield varies from 1 to 10 lps. There are three aquifer zone demarcated in the Gwalior District.

The ground water occurs under unconfined condition and semi confined to confined condition. The pre monsoon water level in the year 2021 north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range of 9-12 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging 12-15 m bgl constituting only about 15% of wells in this category have been observed only in small pocket in the northern and eastern part of Gwalior district Long term water level trend show declining in Ghatigoan, Morar, Dabra, and Bhitarwar.

As per the Management plan prepared under NAQUIM of all the Block of Gwalior District, a total number of 198 Percolation Tanks, 1688 Recharge Shafts/Tube wells and 1688 Nala Bunds/Check Dams and 563 Village pond Cement Plugs have been proposed and these structures can recharge 112 MCM.

Results of these comprehensive studies will contribute significantly to ground water sustainable management tools. It will not only enhance the long-term aquifer monitoring networks and but would also help in building the conceptual and quantitative regional ground-water-flow models for planners, policy makers and other stakeholders.

I would like to place on record my appreciation for ***Dr.K.Paramasivam , Assistant Hydrogeologist*** to compile this report . I fondly hope that this report will serve as a valuable guide for sustainable development of ground water in the Gwalior District, Madhya Pradesh.

Rana Chatterjee
(Regional Director)

1. Introduction

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

1.1 Objectives and scope of the study

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

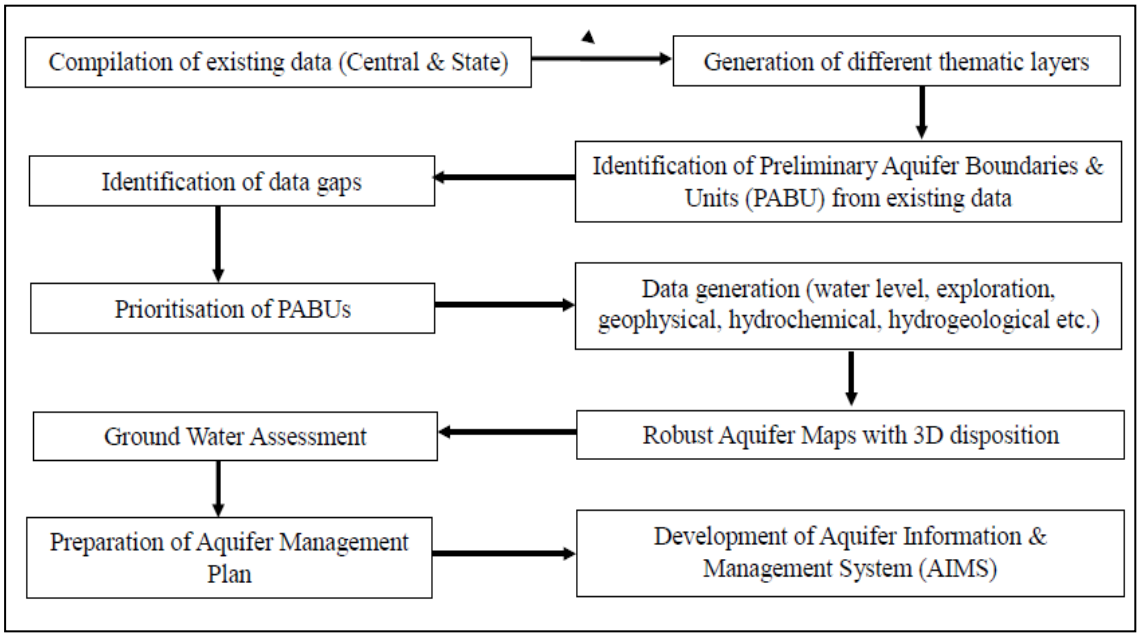
The two major objectives of the aquifer mapping is the delineation of lateral and vertical disposition of aquifers and their characterization on 1: 50,000scale in general and further detailing up to 1: 10,000 scale in identified priority areas and the quantification of ground water availability and assessment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

1.2 Approach and Methodology

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

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

Fig 1: Aquifer mapping approach and methodology



1.3 Study Area

Gwalior District lies between North latitude 25°43′ and 26°21′ and East longitude 77°40′ and 78°39′ of Madhya Pradesh. The district is bounded by Bhind and Morena in the North, Datia in the East and Shivpuri in the southern direction . There are 5 Tehsils and 4 Blocks in the district. The block headquarters are Ghatigaon, Morar, Dabra and Bhitarwar and the total population of the district is 2032036 (As per census 2011) (Fig-2). Gwalior district falls under Ganga basin, Yamuna Sub Basin, Sind and Kunwari Minor basin. The entire area of Gwalior district falls in Sindh & Kunwari sub basin of Yamuna basin. The major tributaries of river Sindh are Parbati, Baisali and Pahuj. The tributaries of Kunwari are Sank and Asan. Sank & Asan are the other major drainages of Kunwari river in the district.

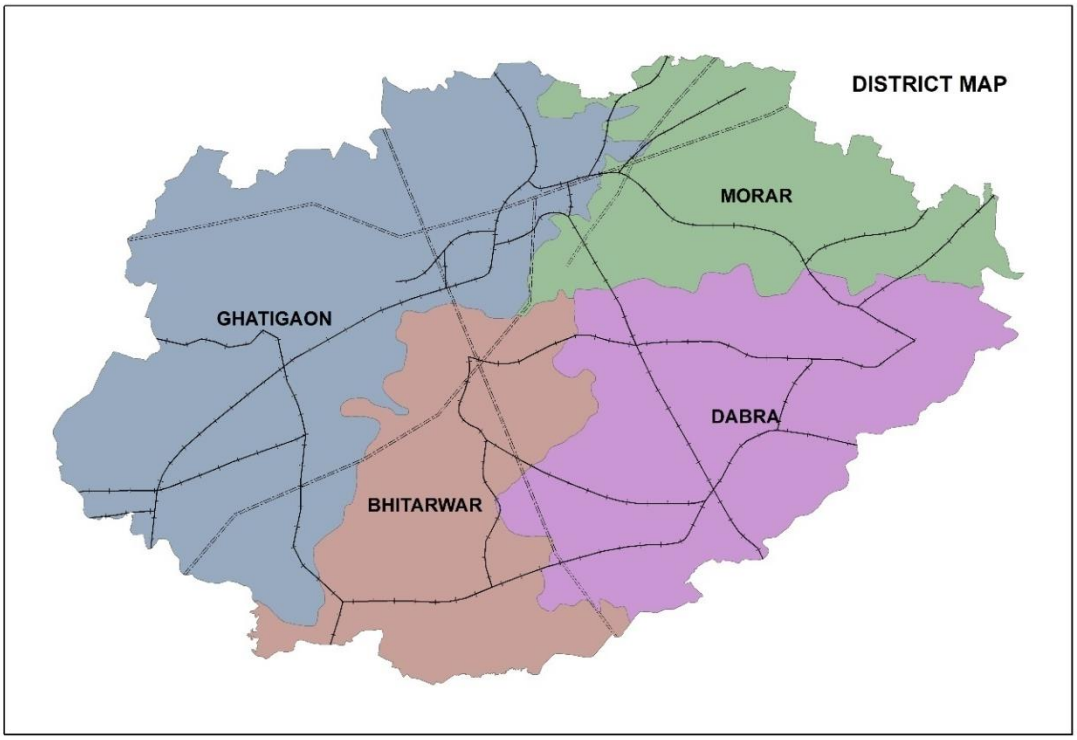


Fig 2: Administrative Map

1.3.1 Administrative Details

The Gwalior district has been divided into 4 Blocks and 1 Urban Assessment unit. There are 618 villages in the district. Total population of the district is 2032036 as on census 2011. Detailed administrative divisions of the district are given in Table-1.

Name of Assessment Unit (Block)	Recharge worthy area of formation in (Sq.Km)	Total Geographical Area(Sq.Km)	Hilly Area(Sq.Km)	Command area(Sq.Km)	Non-command area(Sq.Km)
Bhitarwar	839	900	61	531.33	307.67
Dabra	913	974	61	601	312
Ghatigaon	1309.9	1468.9	159	179	1130.9
Gwalior_Urban	423.35	423.35	0	0	423.35
Morar	797.75	797.75	0	0	797.75
Total	4283	4564	281	1311.33	2971.67

Table-1: Administrative Divisions

Data availability, adequacy, data gap analysis and data generation

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

1. Data compilation: The previous studies carried out by Central Ground Water Board and various Government organizations were collected. The Basic data reports of Exploratory wells/Observation wells/Piezometers drilled by CGWB, details of wells drilled by State PHED and district brochures published by CGWB was compiled and integrated for aquifer mapping. The Dynamic ground water resource book (2020) of CGWB and figures from the WRD were used for preparation of management plan.
2. Data adequacy: The data compiled has been collected from the CGWB/State departments. Thus, the adequacy of the data is supposed to be high and reliable for the specific study of aquifer mapping and management plan.
3. Data gap analysis: The identification of data gap was done after the detailed analysis, examination, synthesis and interpretation from available sources. This process incorporated the conversion of analog data in the form of digital data that could be processed readily on GIS platform.
4. Data Generation: The study of Gwalior district concentrated on the existing data; thus no new data was generated.10 EW wells has been proposed as per the data gap.

1.4 Climate and Rainfall distribution

The normal annual rainfall of Gwalior district is 764.4 mm. Gwalior District receives maximum rainfall during southwest monsoon period i.e. June to September. About 89.1% of the annual rainfall received during monsoon period and only 10.9% takes place during non- monsoon period between October to May. The surplus water for ground water recharge is available only during the monsoon period. The maximum rainfall received at Gwalior is 895.9 mm and minimum at Dabra is 693.1 mm. The climate of Gwalior district is characterized by hot summer and dryness except during southwest monsoon season. The year can be divided into four seasons. The winter season commences from December to February followed by the hot season from March to middle of June. The period from middle of June to September is the monsoon season; October and November form the post monsoon or transition period. The normal maximum temperature recorded during the month of May is 42.1° C and minimum during the month of January is 7.1°C. The relative humidity generally exceeds 83% and the wind velocity is higher during pre-monsoon period as compared to post-monsoon period.

1.5 Physiography/Digital Elevation Model

Physiographically Granite rocks of Gwalior formation and Vindhyan system forms the Hillocks and Alluvial plain forming the flat terrain. The maximum elevation is 440 mamsl near Laxmanpura village and minimum elevation is 166.46 m near Baisora village. In Gwalior district 8 groups of geomorphic units have been classified on the basis of differential erosion and deposition of rock material.Fig.3.

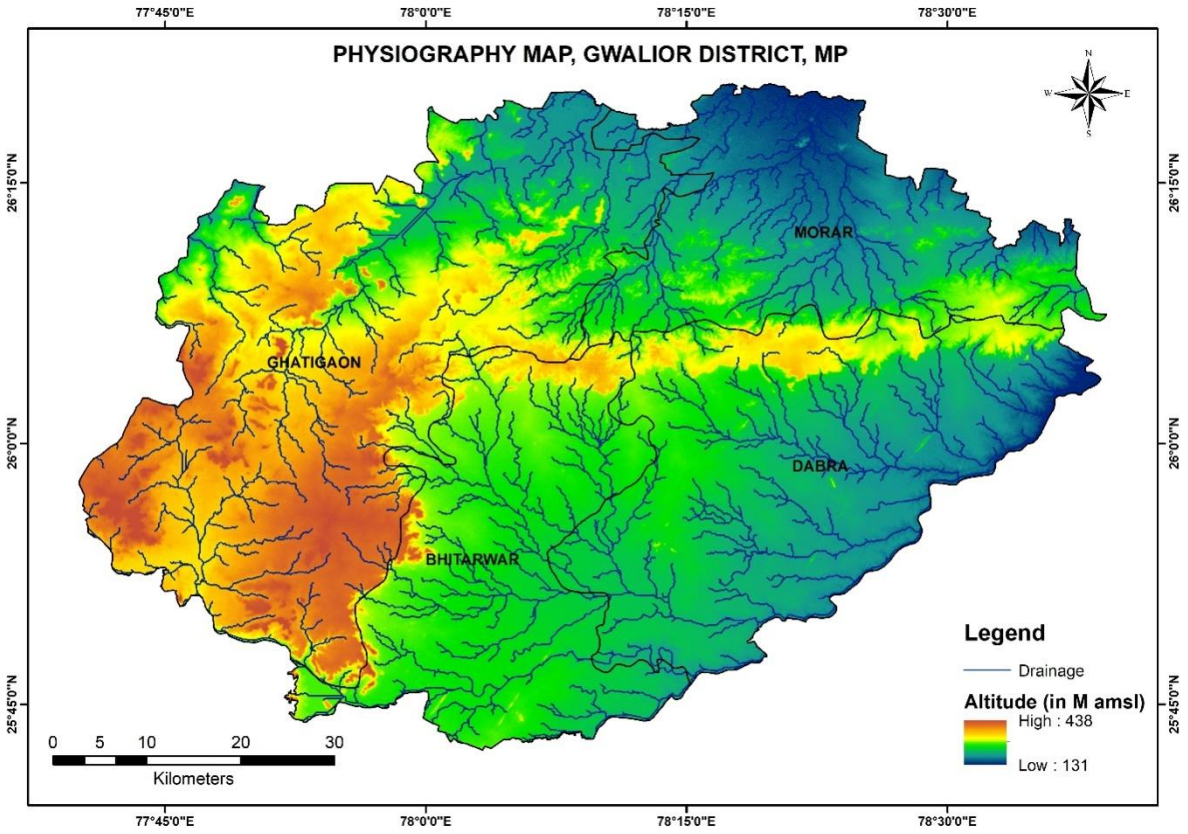


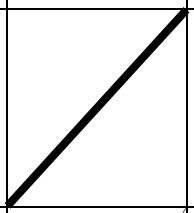
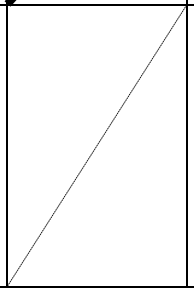
Fig 3: Digital Elevation Model

1.6 Geomorphology

Landforms:

The district exhibits varied geomorphic units which give (Fig.4) 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 sandstone of Gwalior series as seen in central part of the area in district. Table-2.

Table: 2- Hydro geomorphic Units and their Characteristics in Gwalior District.

S. No	Map Annotation	Geomorphic unit	Lithology	Structure	Description
1	YAP	Younger Alluvial Plain	Gravel sand silt or clay size unconsolidated material	-Flat undulating land	Alluvial of recent origin undulating terrain
2	OYP	Older Alluvial Plain	Gravel sand silt or clay size unconsolidated material	Flat undulating land	Alluvial of recent origin undulating terrain
3	R(S)	Ridge sedimentary	Consists of sandstone and shale	Fractured and jointed	High relief, steep slope. Area of runoff
4	R(G)	Pediment granites	Granite as underlying lithology	Fractured and jointed	Broad gently sloping ,Erosional surface
5	DNH (VC)	Denudational hills (Gwalior series and Vindhyans)	Consists of sandstone and shale	Fractured and jointed	High relief, no soil cover normally barren ,moderate to steep slope
6		Dyke	Intrusive of quartz		Discordant. Quartz intrusive that cut across the county as ground water barrier
7		Lineament	Cuts across various litho units	Linear feature	Fault lines, fractures, joints, Shear zones, contact zones, other linear features and straight stream courses

1.6.1 Drainage:

The area is mainly drained by Sind River and its tributaries (Fig. 5). The Sind river flows north easterly direction along the eastern boundary of the Gwalior district for a considerable distance. The main tributaries of Sind river are Parvati flowing easterly, Non and Chachunder flowing south easterly while Morar and Vaisali flows northerly direction. All streams are ephemeral in nature and have dendritic pattern. The major surface divides runs east – west. The entire drainage system has been divided into six watersheds. Details are given below Table.3.

Table – 3 Watersheds in the area

Sl. No.	Basin	Sub-basin	Watershed	Code	Area of watershed	Area falling in the blocks	% of area falling in the blocks	Sharing districts
1	GANGA	SIND	Parbati	SI - 31	220	Bhitarwar	50	Shivpuri – upstream
2	GANGA	SIND	Non	SI – 32	633	Bhitarwar	100	-
3	GANGA	SIND	Chhachunder	SI – 33	960	Dabra	100	-
4	GANGA	SIND	Morar	SI – 34	245	Morar	75	Bhind – downstream
5	GANGA	SIND	Vaisali	SI – 35	425	Morar	80	Bhind – downstream
6	GANGA	SIND	Besuri	SI – 36	190	Morar	20	Bhind – downstream

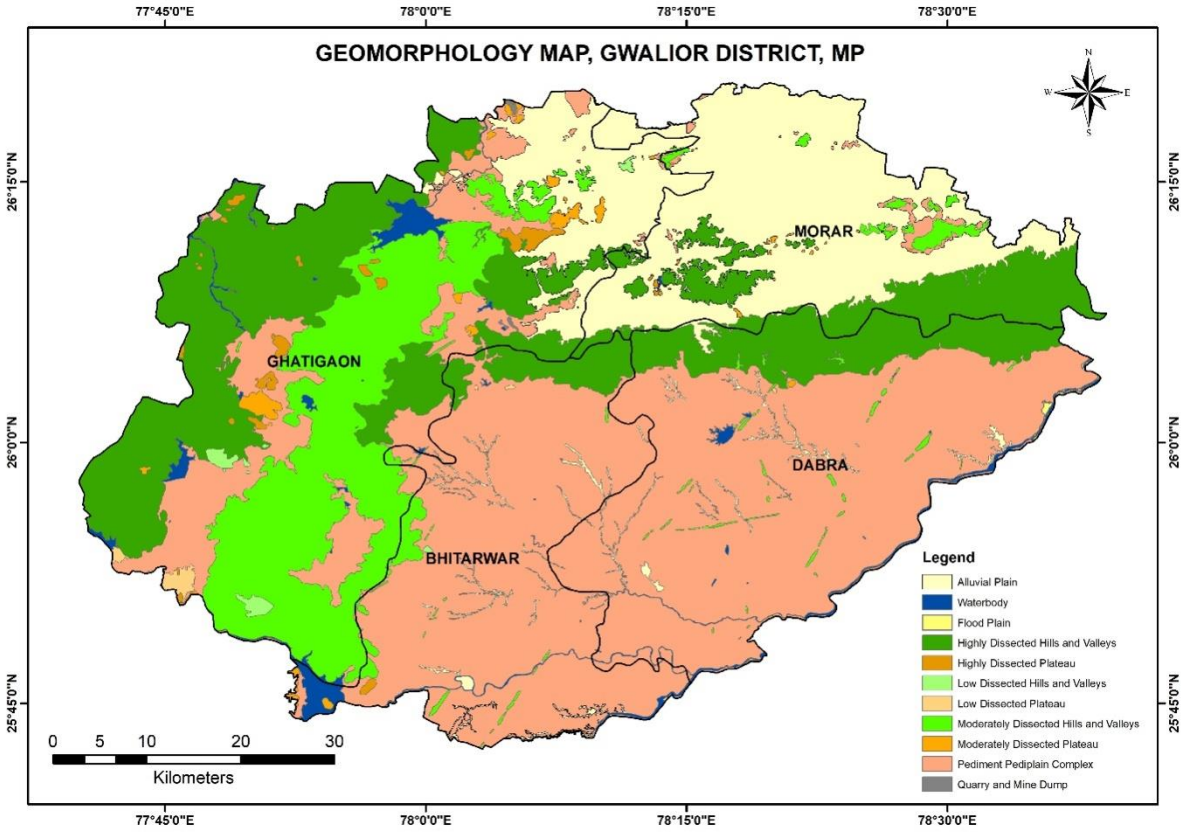


Fig 4: Geomorphological Map

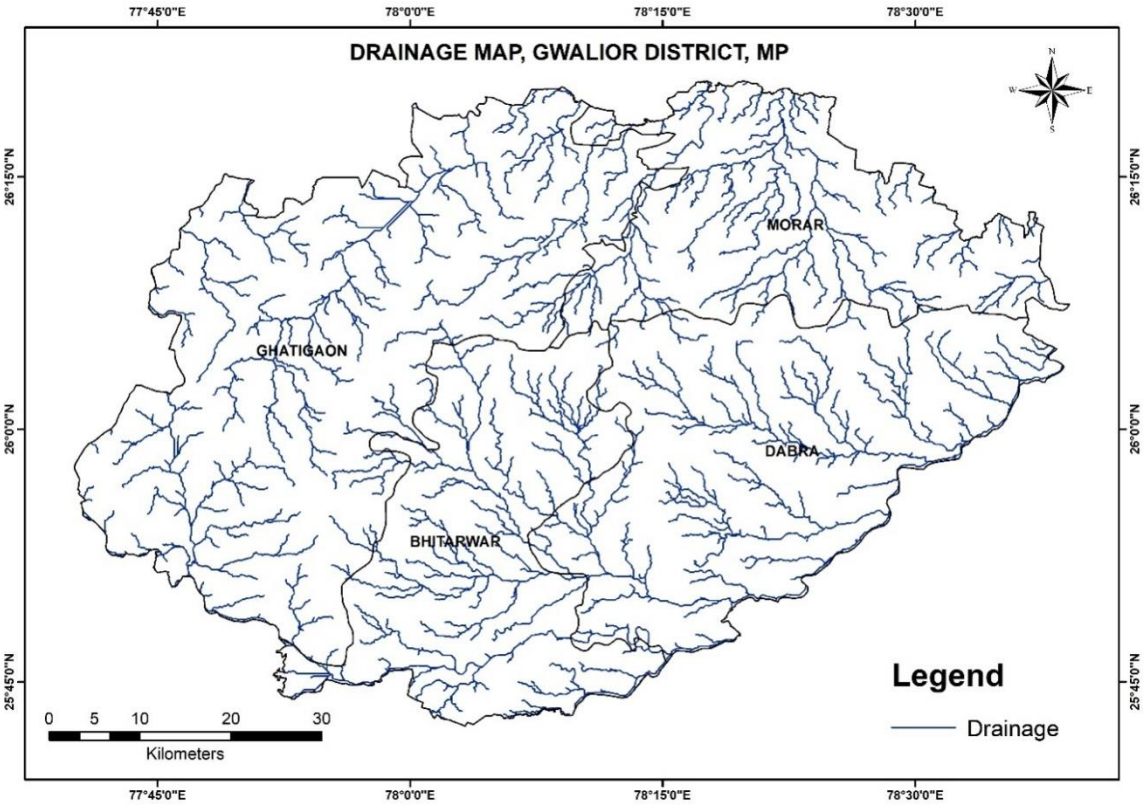


Fig 5: Drainage Map

1.7 Land-use

Gwalior district comprises of 04 development blocks, 05 Tehsil, 299 Panchayat and 618 village. Total geographical area of the district is 446500 Hectare, of which the gross cropped area is 352634 Hectare, of which the net sown area is 273360 Hectare and more than once crop area is 187001 Hectare. Average crop intensity of whole district is 129 of which Gwalior, Morar, Dabra, Ghatigaon and Bhitarwar blocks has more than 129 crop intensity resulting in irrigation facility of more than 129. PMKSY-DIP 14 GWALIOR The Gwalior region comes under dry deciduous task forests. The other species found are Kher, Babool, Rewaja and Neem, Seesam which cover 111.048 Sq. km. area of the district. There are 05 river major rivers, (Sindh, Parvati, Sank, Noon, Vaishali) Fig 6.

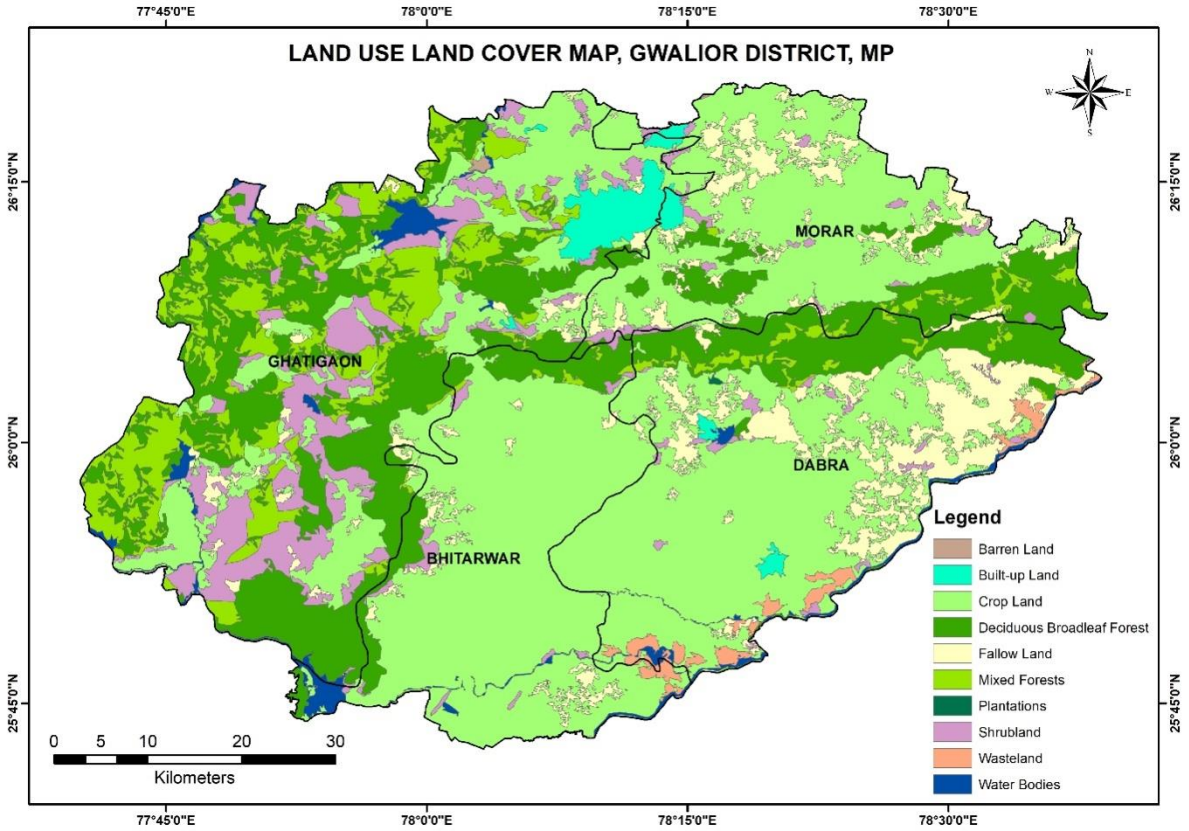


Fig 6: Land Use Land Cover Map

1.8 Soil cover

Soils are the most valuable life supporting natural resource as they produce food, fiber and fodder which are the basic to our very existence. For its sustained utilization, it is imperative to know the nature, characteristics, and extent of distribution of different soils, their qualities, productive capacity and suitability for alternative land uses. In order to assess the potential and problem of different soils and to develop rational land use for optimizing agriculture production, there is a need to have consistent and comparable information about the soils.

Soils of the area are classified as below :

i **Fine loamy & silty mixed hypothermic type Ustrochepts**--Black, Deep, Well drained, Calcareous/Clays, Soils on moderately slopes ravines land (slightly dissected) with very severe erosion, associates with deeper, well drained calcareous clayey soil on steeply slopes with very severe to moderates erosion.

ii **Fine loamy kaolin tic Ustrothents** – Reddish, very shallow, well drained, loamy soils on gently slopes, undulating upland (Slightly dissected) with severe erosion associated with moderately deep well drained, clayed soils, on very quietly sloping with moderate erosion.

iii **Fine loamy silty calcareous Ustrofluents**- Pale yellow, deep somewhat of excessive drained calcium, loamy soils, on moderately sloping river land (slightly dissected), with severe erosion. associated with deep, extensively drained calcium, loamy soil on moderately steep soil with severe erosion.

iv **Fine loamy calcareous Hypothermic Ustrochepts**-- Black, very shallow, well drained loamy soils on moderately sloping residual , calcareous with severe erosion, shallow, well drained loamy soil on slightly sloping with some erosion and slight sloping.

1.9 Agriculture, Irrigation and Cropping patterns

Over a period, geographic pattern of agricultural landuse are the outcome of concurrent interaction between the variable combinations of natural condition and human circumstances. Primarily, these are influenced by natural condition and thereafter affected by human circumstances because of their colonizing capability. The human circumstances are mainly responsible for dynamism in agriculture landuse or changing cropland occupancy. Therefore, efficient cropland occupancy, say cropping pattern, implies the most successful use of agriculture land, consequent upon development of irrigation facilities and application of modern methods of farm technology. The key to the most important aspect of landuse lies in the relation of population to land. The crux of the review, therefore, refers to the study of the problems in use of land by man. According to R.H. Best, the term land use deals with the spatial aspects of human activities on the land and with the way in which the land surface is adapted or could be adapted, to serve human needs. The details of land use pattern and Crop-wise Irrigation Status is given in Table 4 a,b.

Table 4 a Landuse pattern in Gwalior District

Area in ha									
S.No.	Name of Block	Number of the Villages Covered	Total Geographical Area	Area under Agriculture			Area under Forest	Area under Waste land	Area under other uses
				irrigated	Rainfed	Total			
1	2	3	4	5	6	7	8	9	10
1	Morar	170	85800	23716	33125	56841	15527	2153	3591
2	Dabra	151	101800	65233	23304	88537	9178	10457	2859
3	Ghatigaon	139	168900	11939	16156	28095	86343	6766	5192
4	Bhitarwawr	158	90000	86113	13774	99887	0	1105	2368
Total		**618**	**446500**	**187001**	**86359**	**273360**	**111048**	**20481**	**14010**

Table 4b Crop-wise Irrigation Status in Gwalior

Crop	Kharif (Area in ha)			Rabi (Area in ha)			Summer crop (Area in ha)			Total (Area in ha)		
Type	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
1	2	3	4	5	6	7	8	9	10	11	12	13
A) Cereals	52316	1521	53837	105285	0	105285	0	0	0	157601	1521	159122
B) Coarse Cereals	0	15351	15351	0	0	0	0	0	0	0	15351	15351
C) Pulses	0	5551	5551	6510	13533	20043	276	0	276	6786	19084	25870
D) Oilseeds	3271	20671	23942	11340	21415	32755	0	0	0	14611	42086	56697
E) Fibre	0	0	0	0	0	0	0	0	0	0	0	0
F) Any other crops	1101	6276	7377	6853	2041	8894	49	0	49	8003	8317	16320
Total	**56688**	**49370**	**106058**	**129988**	**36989**	**166977**	**325**	**0**	**325**	**187001**	**86359**	**273360**

Source: DAP, Agriculture Statistics

1.10 GEOLOGY

1.10.1 General Geology

The main geological formations exposed in the district are the Bundelkhand granites, Gwalior and alluvium. The sequence of rock formations is shown below in order of increasing antiquity. (Fig-7) and details are given in the table 5.

Table 5- Sequence of Geological Formations

Age	**Geological formation**	**Lithology**
Recent	Alluvium (Older)	clay ,silt with red medium to coarse grained quartz felspathic sand and Ferruginous nodules. Grey, brown, soft unconsolidated sediments
Unconformity		
Purana	Gwalior System	**Morar Series-** Shale with limestone bands, jaspilite, Ferruginous chert, with iron ore **Par Series-** Orthoquarzite and Sandstones, Flaggy, gritty Sandstones with alternation of Shale
Unconformity		
Achaean	Bundelkhand	Granites and granite gneisses with associated schist's, pegmatite veins, basic dykes and quartz reefs

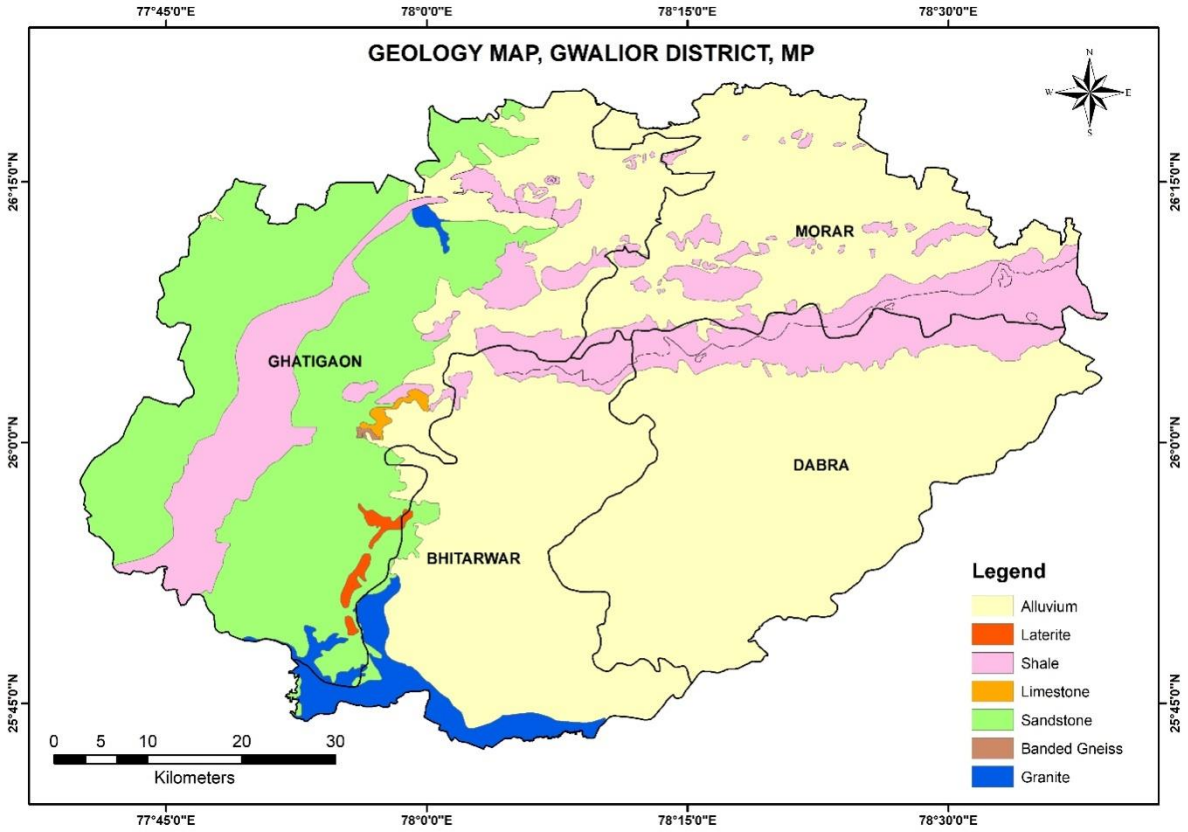


Fig 7: Geology Map of Gwalior District

The Bundelkhand granite –

The Bundelkhand granite is regarded as a relic of old sea floor on which Dharwar sediments were laid down, in trough, in part, it may include reconstituted portions of the Dharwarian sediments. This tract has been protected in some way from the excessive metamorphism to which the Achaeans of other areas were subjected. It is sharply bounded by scarps several hindered metres in height, of Vindhyan rocks which, though ancient, are younger than the granites. North of the main tract the granite projects through the alluvium as inliers.

1.10.2 Structures

The chief characteristic features of these granites are their massive structure, obscurely developed foliation and scarcity of accessory minerals. It is a medium-to-coarse grained rock chiefly consisting of orthoclase quartz and biotite. Pink feldspar is more common in the porphyritic granite that crops out in the Sind river. The bulk of the granite exposed in the southern tract of the district and central part of the area or an inliers in the alluvium, shows pink &grey appearance. The prominent feldspars in these rocks are microcline and microcline micro perthite. Plagioclase is present in subordinate quantity. Quartz rarely occur in large quantity. A dark colored hornblende is often present but is never abundant.

When discernible, the planes of foliation are more or less vertical and generally strike E.N.E.- W.S.W. with local variations to N.E. to S.W. and E.S.E., to W.N.W. There are two major systems of joints, striking between N.W-S.E, and S.W. – N.E. The rock weathers concentrically to large spheroidal masses.

Various forms of schistose bands are also observed within the granite, the most prominent being a hornblendic rock consisting of an even mosaic of quartz and feldspar with hornblende and biotite. Sometimes other ferromagnesian minerals are also present as accessories. The chief difference between the pegmatite veins and schistose bands is the absence of Ferro-magnesium constituents in the case of the former.

The long narrow separated ridges of quartz reefs interrupt the uniformity of the granite tract. The vary in thickness from 5 m. to 150 m. and in length from 15m. to 2,000 m. In general the large reefs are discontinuous and ventricular. They have a predominant. N.E.-S.W., trend, although a few trend N.N. E.-S. W.N.-S and N.W.-S.E. The trend of the quartz reefs is parallel to the prominent joints in the granite. They are invariably sheared, brecciated and highly silicified. Secondary silicification veins traverse these sheared quartz reefs. These veins occur along fracture and joint planes which are parallel to and at an angel of 450 to the general trend of the reefs. They vary in thickness from a few centimeters to over one metre. Cavities filled with white, pink and amethyste quartz are present at places in the thicker veins. Sulphide mineralisation consisting of galena, pyrite, chalcopyrite, etc., are associated with some of these quartz veins. The reefs are almost entirely made up of quartz, though a little serpentine is also present at places. Under microscope the rock reveals porphyroclastes of quartz showing extinction in a matrix of line granulated quartz shows in mortar texture. Cracks in the porphyroclastes are filled with serpentine.

The granite is extensively traversed by basic dykes, which are more numerous than the reefs. Their predominant trend is N. 35° W., making an angel of about 70°with the trend of the reefs. Common type of dyke rocks is a dolerite which under microscope reveals ophitic penetration of plagioclase with ferromagnesian minerals, mostly augite. Intersection of the dykes and the quartz reefs are rare.

Gwalior System

The Gwalior rocks were deposited on the irregular denuded surface of the granite. The age of these rocks is still in doubt. According to M.K. Roy Chowdhury the relative age of these rocks to the Bijawars to which they bear some resemblance is as yet uncertain. According to V.S. Dubey the age of the trap that forms the upper portion of the Gwalior series is 500 million years. They constitute the plateau ranges extending from east to west along the northern fringe of narrow belt of Bundelkhand gneiss at and near the Gwalior. The outcrops of these rocks occupy an area of 80 km. Long and 25 to 30 km wide. The dip of the rocks is towards north, north- west, and north- east with magnitude of 3° to 8°.

A twofold sub-division of the Gwalior System, has been divided into lower Par series up to 60m thick and upper Morar series which is 600m thick.

Par Series-

The Orthoquarzite Sandstone is a hard compact rock and breaks with conchoidal fracture. Sometimes Sandstones are flaggy and gritty Sandstones with alternation. The colour varies from pale grey to various shades of pink white to reddish, gyerish white. Usually the rock shows fine to medium grained texture with semi vitreous luster. Under microscope the rock shows an inter-licking mosaic of quartz with a few feldspar and little chloritic cement. Towards the base the quartzite shows unaffected mechanical texture as well as current bedding and ripple mark. A few centimeter of the base is conglomerate, formed of small rounded pebbles in a ferruginous matrix. Thin intercalations of shale in the quartzite are noticed in the lower horizon. The quartzite is intruded by numerous veins of quartz and intrusive of basics rocks.

Morar Series -

It is represented by thin flaggy siliceous or ferruginous Shale copiously inter bedded with Chert and Limestone and bright red Jasper, both finely bedded and concretionary.

The colour varies from green, brown, dark grey, black and jet black. Siliceous concretions occur as flattened ellipsoids, usually 4 cm, along the shorter and 6 cm. along the diameter, the latter being parallel to the bedding of the shales. Though foldings are quite common and the exposures, as a whole, exhibit a slight roll.

Alluvium-

Nearly sixty five percent of the area of is covered by alluvium consisting of clay, silt with red medium to coarse grained Quartz Feldspathic sand and ferruginous nodules.

At places it appears as grey, brown unconsolidated sediments. Along the bank rivers section the thickness of the alluvium often exceeds 20m and its thickness seldom reaches up to 40m. The nalas and ravines are often thickly covered with kankar (calcareous concretions). The material is used locally for lime burning.

1.10.3 Sub - Surface Geology

To have an insight of subsurface geology, the district area has to be explored thoroughly through drilling operations. In annual action plan 2000-2001, only four exploratory wells were drilled down to a maximum depth of 200 mbgl which is inadequate to comment on sub surface geology. However, to have a rough idea regarding underlying geological formation, litho logical logs of bore wells drilled by C.G.W.B. for drinking water purpose were collected and their details are given in Table-9.

2. Data collection and generation

2.1 Hydrogeology

Hydrogeological of Gwalior district with a view to study the change in ground water regime causes by ground water development, and to assess present hydrogeological scenario for better management Fig 8.

Aquifer systems

The district is underlain by alluvium, granite, sandstone and shale terrains and occurrence of ground water in different formation varies with the rock type. About 75% of area is occupied by alluvium the extending from Bhitarwar to Chinnaur (North to South –54K/1) in Bhitarwar block, Kachhua-Dabra to Chandpur (East to West- 54K/1&5) in Dabra block and Manpur to Parsain block (North to south 54jJ/7&8) The thickness of alluvium varies between 10-30 m. It is the most extensive aquifer system in the district. Only one aquifer i.e. phreatic comprising of fine to medium to coarse-grained sand often with clay are encountered. This phreatic aquifer ranges in thickness of 2 to 3 m and encounter between 4 to 30 mbgl. The phreatic aquifer mostly comprises of clay, and fine sand with silt and at places medium grained sand.. The contact of alluvium with granite or shale or sand stone form productive in all three blocks yielding 2-20 lps.

Ground water in granite occurs in joints, fractured planes and mostly in weathered zone under water table condition. The occurrence of ground water is controlled by degree of weathering, size and interconnectivity of joints, which varies from place to place. This hydrogeological environment is found in southern and western part of Bhitarwar block and north & north-western part of Dabra block. Dug wells and tube wells sustain discharge of 1-5 lps depending on degree of weathering and fracturing.

Shale and sandstone of Gwalior system with extending generally east- west and isolated patches in northern part of Morar block. of the district are hard with thin bedding plane. Ground water occurs mostly in unconfined condition, but at places semi confined conditions. The yield potential in this formation ranges between 1 to 8 lps.

Aquifer parameters-

During the course of reappraisal survey in the area three pumping tests have been carried out on the dug wells and tube wells. The transmissivity in the granite area is found to be10 m^2/day and 150 m^2/day.

Well Design

Four exploratory wells, under contractual drilling programme of CGWB, were drilled by down to the hammer method in granitic and shale terrain.

The tube wells in alluvial may have diameter of 152-200 mm assembly with within portion having 3.17 mm width slots. A slotted portion of about 10 mm would be sufficient to get yield of 2-10 lps.

In granitic terrain, bore wells can be constructed tapping the weathered portion and deeper jointed and fractured, should have 152 mm die assembly. The upper portion may be cased to prevent collapsing of wells while the deeper part may be uncased. Slotted pipes having width of 3.17mm be required in weathered portion only. In general combination rig using rotary method at the top and followed by down to the hammer method is very much suitable in the entire area.

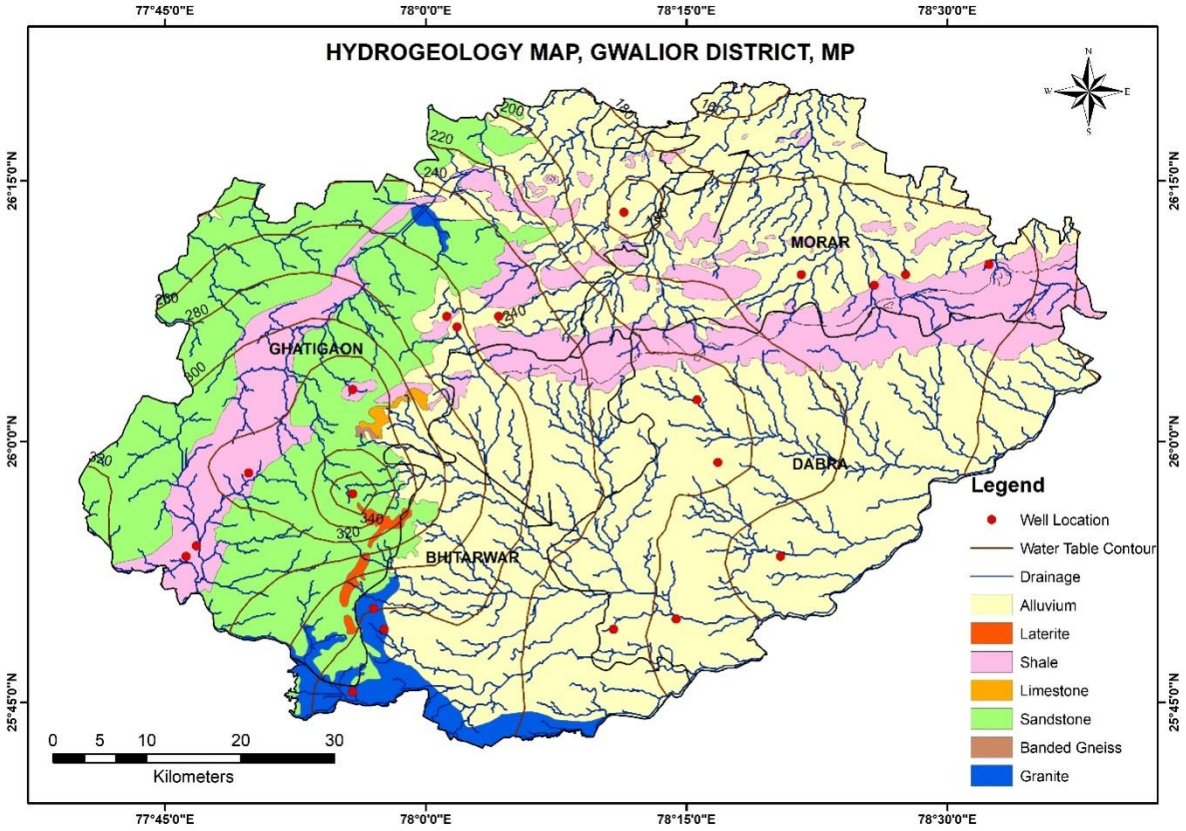


Fig. 8 Hydrogeological Map of Gwalior district.

2.1.2 Depth to Water levels

Pre-monsoon water level (May 2021)

The pre-monsoon depth to Water levels ranges from a minimum of 1.8 meters below ground level (mbgl) in Ghatigoan block to a maximum of 22.3 m bgl in Ghatigoan block of Gwalior district. About 15% very shallow water levels up to 3-6m bgl have been recorded in a small patch in western and central part of district. About 40% of monitoring wells recorded

water level in the range of 6-9 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range of 9-12 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging 12-15 m bgl constituting only about 15% of wells in this category have been observed only in small pocket in the northern and eastern part of Gwalior district. Ground water levels of more than 15m bgl have been recorded in the eastern part of the area. The premonsoon Depth to Water Level map has been shown in the Fig. 9.

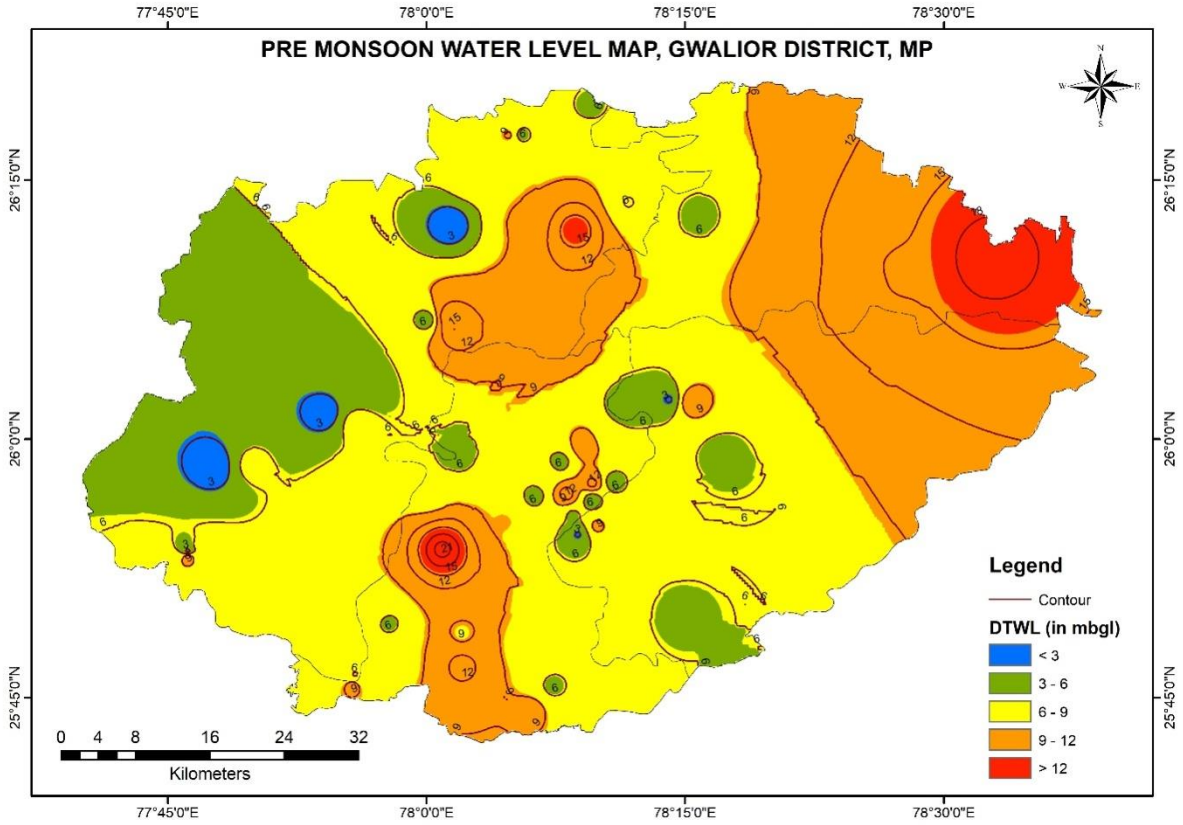


Fig 9: Depth to Water Level Map (2021)

Post-monsoon water level (Nov 2021)

The post-monsoon depth to Water levels ranges from a minimum of 0.5 m below ground level in Ghatigoan block to a maximum of 18.6 m bgl Ghatigoan block of Gwalior district. Very shallow water levels up to 3 m bgl have been recorded in patches scattered all over the district contributing to about 10 % of total monitoring wells in Gwalior district.

About 10 % of monitoring wells recorded water level in the range of less than 3 mbgl category, majorly occupying the central portion and patches in the north-eastern, and southern part of area. About 60% of monitoring wells recorded water level in the depth range of 3-6 m bgl occurring in pockets all over the region. About 15% Depth to water levels ranging 6-9 m bgl has been noticed predominantly in northern and western part of the district. About 15% Ground water levels of more than 9 m bgl have not been recorded in Gwalior district. The post-monsoon Depth to Water Level map has been shown in the Fig. 10.

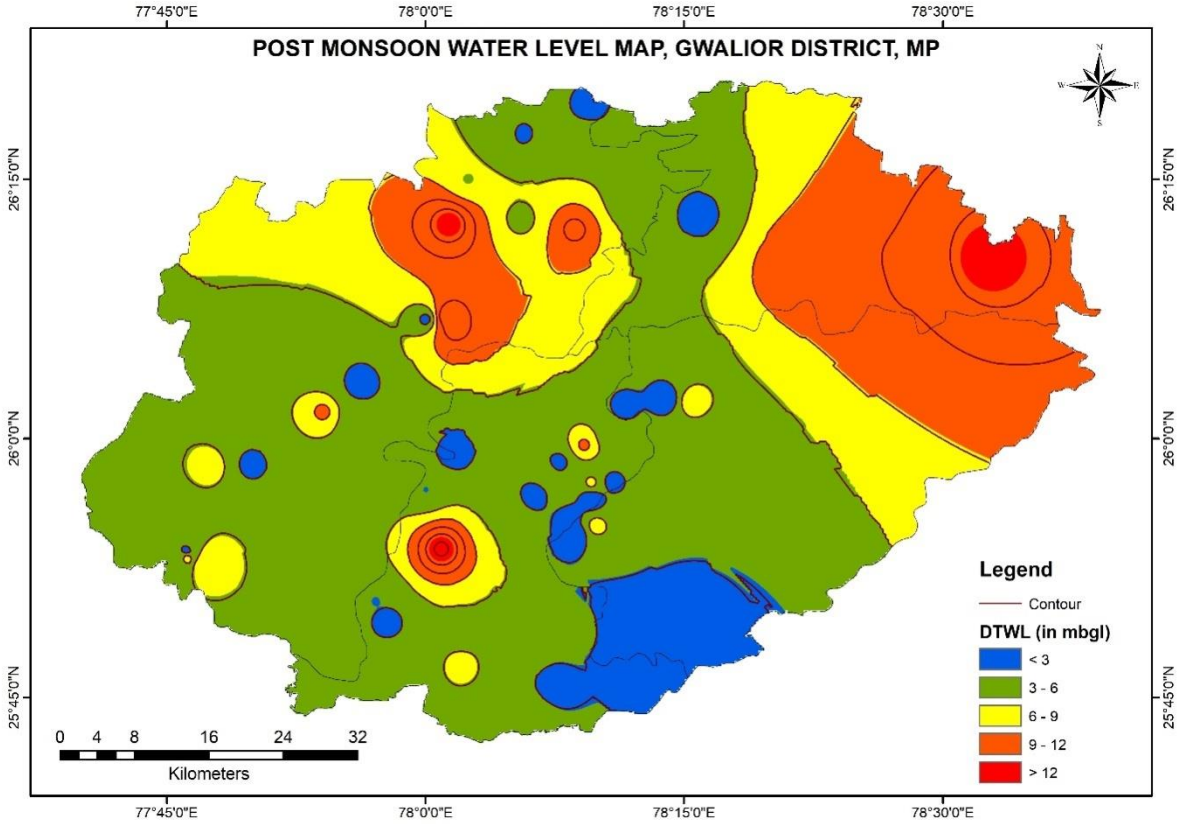


Fig 10: Depth to Water Level Map (2021)

2.2 Exploratory drilling

CGWB under its exploration program drilled 21 borewells (Fig. 11). On the basis of samples collected during exploration, lithologs have been prepared. The aquifer parameters are calculated on the basis of pumping tests. The salient details of the some of the drilled bore wells and piezometers is given in Table No.6

Fig 11: Map showing locations of Exploratory Wells

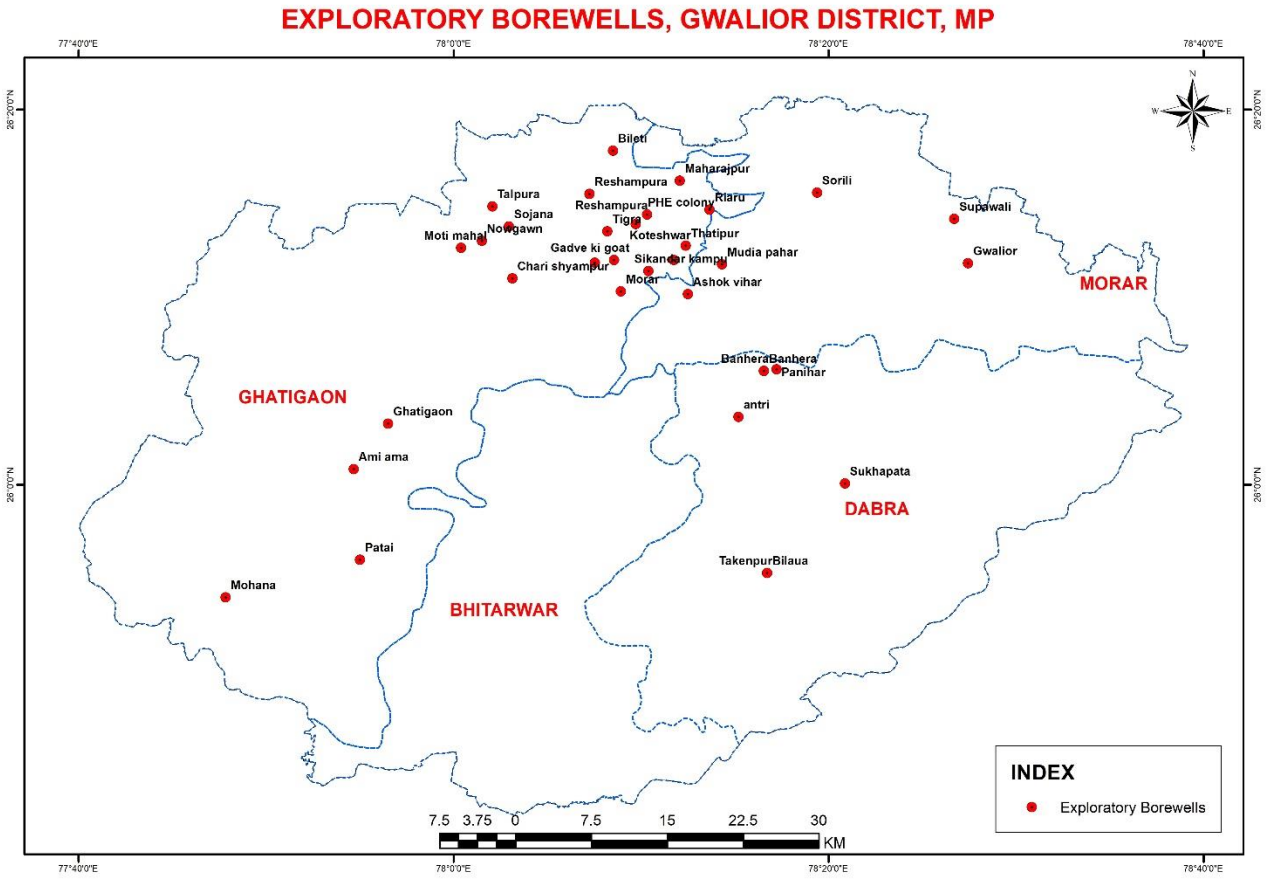


Table 6: Salient Hydrogeological Details of Exploratory Wells

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	SWL (mbgl) / Date	Discharge (lps)	Drawdown (m)	Specific capacity (lpm/m) of dd	T (m^2 / day)	S
1	Ashok vihar	26.169444	78.208333	2002	300	300	Morar shale	33-39 105-200	18	26.00	5.14		
2	Sikandar kampu	26.189722	78.173056	2002	190.25	190.25	Alluvium shale	3-42, 48-52	17.1	55.00	1.55		
3	Reshampura	26.258333	78.120833	2002	51.2	51.2	Weathered Sst.	18-35	15.65	19.00	4.77		
4	Reshampura	26.258333	78.120833	2002	79.36		Weathered Sst.	Abandoned		2.00			
5	Mudia Pahar	26.195833	78.238611	2002	201.3		Morar shale	29-35, 45.5-51.5 120-128.5 190-192	25.9	11.60	7.3		
6	Maharajpur	26.27	78.201111	2003	250.8		Alluvium / Morar Shale	13.5-19.5 47-52 151-154 180.7-183.7	9.3	3.67	4.52	30	
7	Moti Mahal	26.210556	78.006667	2003	280.6		Alluvium / Morar Shale	37-43 44.8-50.8 155-158	16.87	8.80	18.28		
8	PHE Colony, Sharma Farm	26.24	78.171944	2003	281.9		Alluvium,Dolerite	42.5-50.5 58-60 242-245	10.72	20.00	3.17	1581	3.5×10^{-3}

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	SWL (mbgl) / Date	Discharge (lps)	Drawdown (m)	Specific capacity (lpm/m) of dd	T (m^2 / day)	S
9	Thatipur	26.2125	78.206389	2003	298.9		Alluvium / Morar Shale	30-42 274-283	14.55	20.00	1.07		
10	Jeewaji University	26.199722	78.195833	2004	305		Morar shale	30-42 281-296	21.97	12.20	4.95	321.47	9.5×10^{-4}
11	Raja Gas Godown	26.197222	78.125556	2004	305		Morar shale	26-30 42-51 87-90 158-164.7	28.7	16.50	1.67	3219	
12	Sojana	26.229444	78.049167	2004-05	305				Dry	Dry			
13	Gadwe Ki goti	26.199722	78.1425	2004-05	305		Alluvium & Morar shale	27-39 49-51 137-151	28	43.20	4.41		
14	Sorili	26.259444	78.323056	2004-05	193		Alluvium & Morar shale	12-18 34-40 88-94	19.89	6.30	26.33		
15	Bilaua	25.921667	78.278611	2004-05	250.1		Alluvium & Morar shale		7.2	1.26			
16	Koteshwar	26.231667	78.161944	2004-05	274	274	Alluvium & Morar shale	39-48.6 100-104 205-213	12.85	13.18	13.97	65	3.5×10^{-3}

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	SWL (mbgl) / Date	Discharge (lps)	Drawdown (m)	Specific capacity (lpm/m) of dd	T (m^2 / day)	S
17	Takenpur	25.921667	78.278611	2004-05	274	274	Weathered Sst.	9-12 23.4-24	3.9	7.20			
18	Antri	26.060278	78.253056	2004-05	305		Weathered & Fractured granite	26-35 271-274	23.7	7.20			
19	Panihar	26.1025	78.286944	2004-05	274.5		Morar shale	74.7-82	45.2	14.40			
20	Banhera	26.101111	78.275833	2004-05	7			Abandoned					
21	Banhera	26.101111	78.275833	2004-05	300		Par Quarzite	161-167	41.5	7.20			

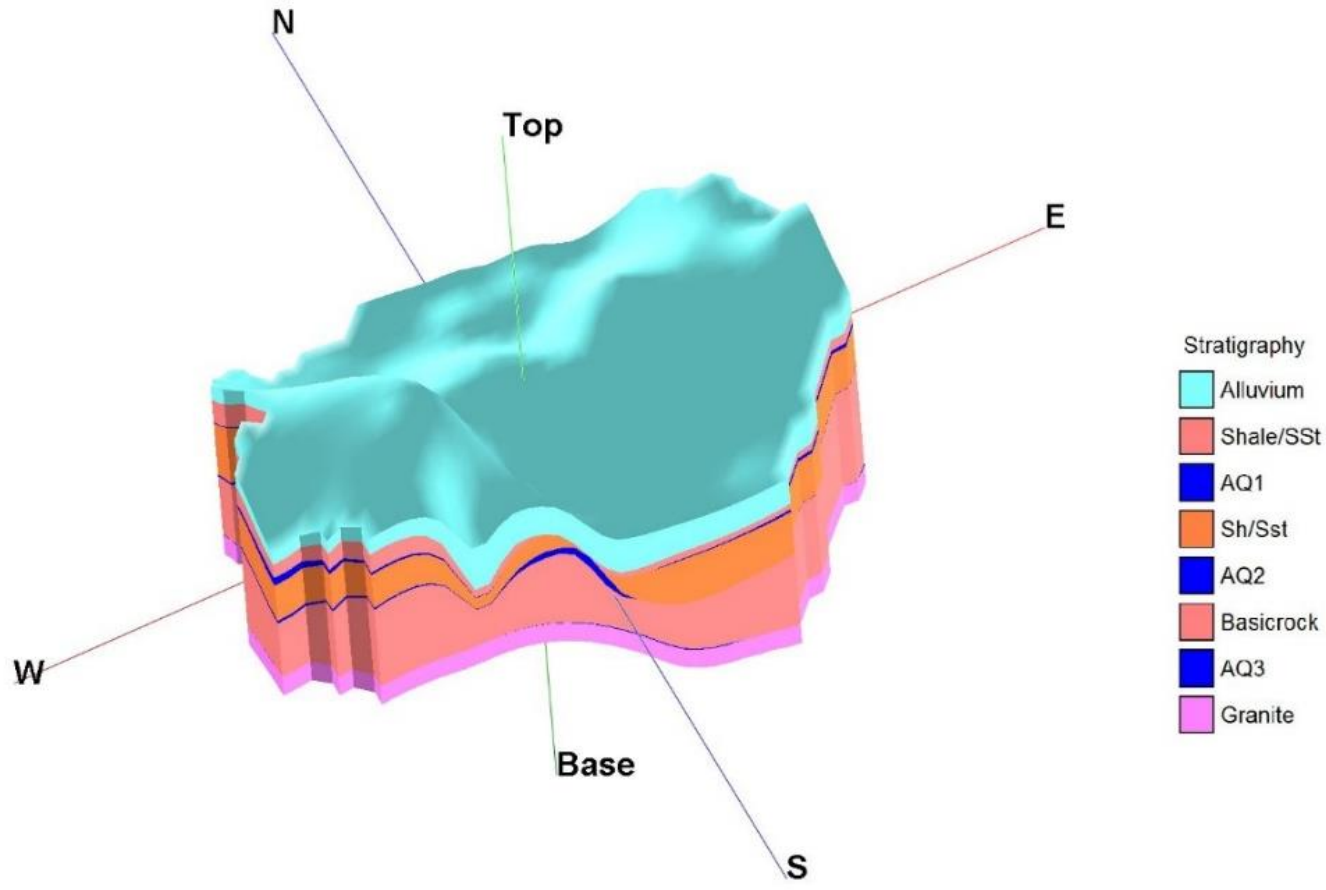
3. Data Interpretation, Integration and Aquifer Mapping

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

3.1 3-D Lithological model

A 3-Dimensional lithological model was prepared for the Gwalior district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB (Fig 12) and field well inventory data. A comprehensive analysis was made as per lithology and stratigraphy of the area.

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



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

3.2 Fence Diagram

The Fence diagram was also prepared using the Rockworks software (Fig. 13). The pattern for the Fence was chosen as such to cover the maximum portion of the region to represent the enhanced picture of the sub-surface as deciphered from the 3-D stratigraphic model. It has also been interpreted from the diagram that the shallow and deeper aquifers are not in connection to each other.

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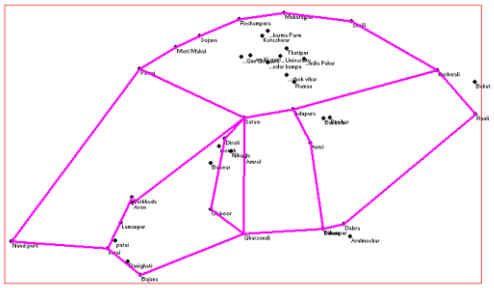
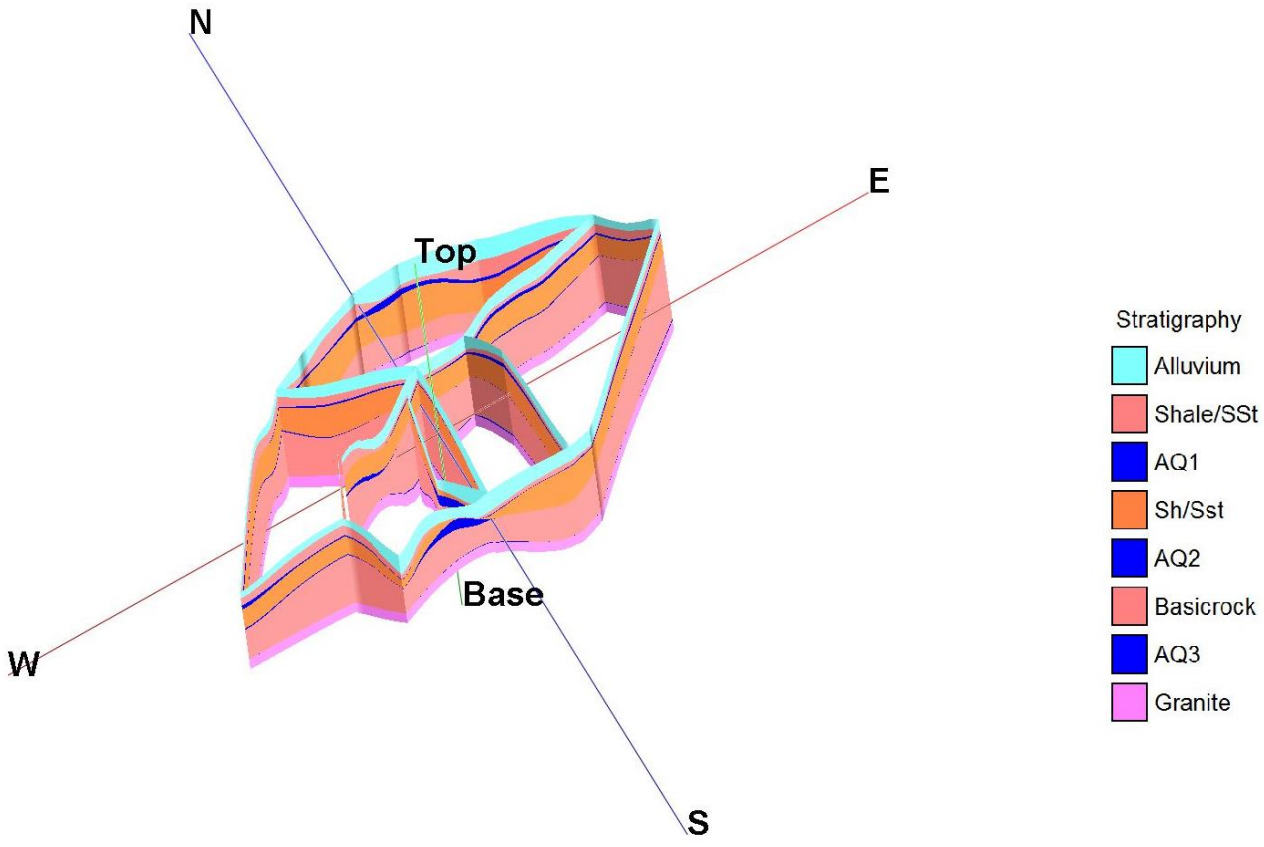
Fig 13: Fence Diagram,Gwalior District, Madhya Pradesh





3.3 2-D Cross Section

2-Dimensional cross-section along the section line A-A' (SW-NE), covering the wells morar and Dabra Blockhas been prepared using Rockworks(Fig. 14 and 14.a). The cross-section shows that the shallow aquifer is not continuing for the whole region and occurs as narrow pinches in the western portion of Khandwa. The deeper aquifers whereas, occurs throughout the section line and can be encountered at depth where fractures are present.

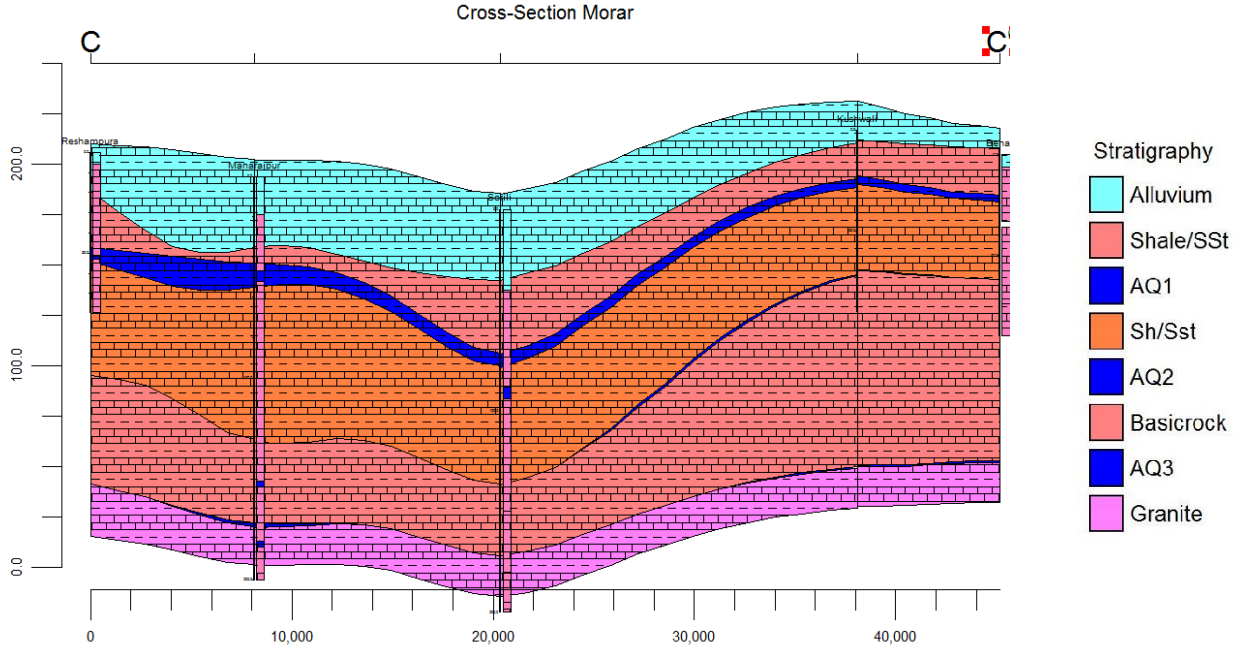


Fig 14: 2-D Cross section along CC' (W-E), Gwalior District, Madhya Pradesh

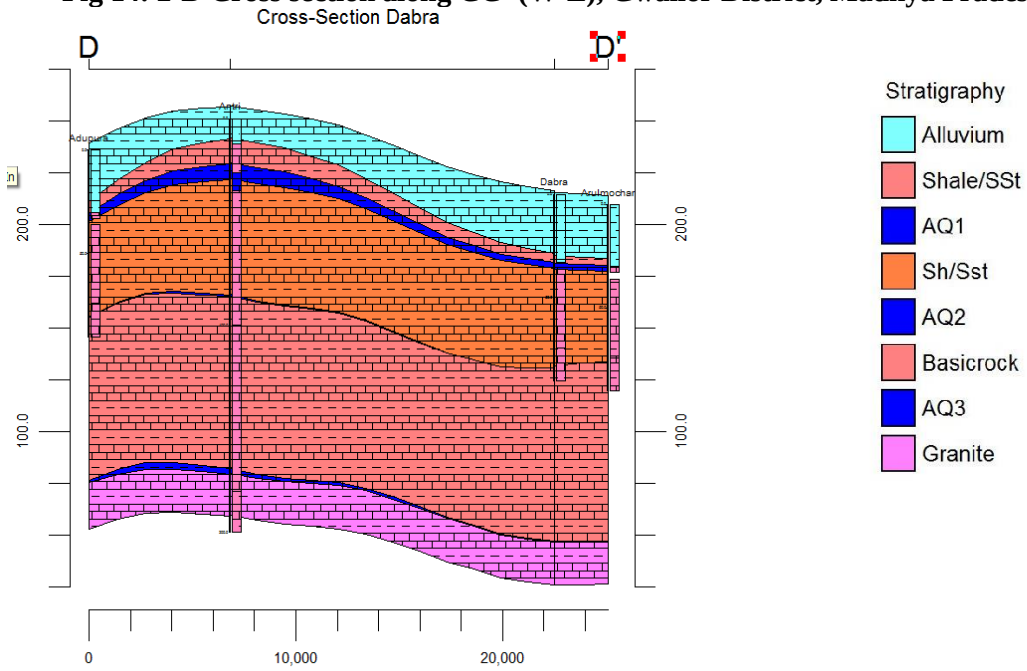


Fig 14a: 2-D Cross section along CC' (N-S), Gwalior District, Madhya Pradesh

4. Ground Water Resources

4.1 Dynamic Ground Water Resource (2020)

Gwalior district is underlain by Bundel khand Granite and Gwalior sandstone and Shale Vindhyan Shale and Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated on block-wise basis. Out of 4564 sq. km of geographical area, 4254 sq. km(93.21%) is ground water recharge worthy area and 310 sq. km is hilly area(6.79 %). There are five assessment units (4 blocks and1 Urban) in the district out of which one block Morar fall under non-command category whereas Bhitarwar, Dabra and Ghatigoan, four blocks falls under both command as well as non-command category, One block of the district are categorized as semi-critical namely Gwalior Urban,(non-command) and rest as safe. The highest stage of ground water development is computed as 80.73 % in non-command area of Gwalior Urban. The net ground water availability in the district is 736.89 mcm and ground water draft for all uses is 217.12 mcm, making stage of ground water development to 29.47 % as a whole for district (Table 7).

Table 7: Dynamic Ground Water Resources of Gwalior district (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 Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization
BHITARWAR	21915.39	4366	0	228.54	4594.53	299.16	17250.24	20.96	safe
GWALIOR_URBAN	2468.46	0	0	2109.78	2109.79	2482.56	358.67	85.47	semi_critical
MORAR	13340.71	6764.82	0	447.39	7212.21	503.79	6072.10	54.06	safe
GHATIGAON	15015.59	3021.134	0	560.17	3581.31	674.03	11320.42	23.85	safe
DABRA	20948.95	3803.87	0	410.81	4214.68	416.97	16728.11	20.12	safe
DISTRICT TOTAL	73689.1	17955.82	0	3756.70	21712.52	4376.51	51729.54	29.47	

4.2 Ground Water Resource & Draft- (Outcome of NAQUIM)

The Ground Water Resource of Gwalior district has been calculated block-wise considering the variable lithology and their associated aquifer parameters like specific yield. The In-storage resource for the shallow aquifer below zone of fluctuation (upto 30 mbgl) is computed to be around 809.5 mcm. The static resource for the deeper aquifer (30-200 mbgl) is computed as 765.2 mcm. The block-wise details of ground water resources and draft as an outcome of NAQUIM are presented in the Table no 8.

Table 8: Ground Water Resources of Shallow & Deeper Aquifers (Outcome of NAQUIM)

	BHITARWAR	DABRA	GHATIGAON	GWALIOR_URBAN	MORAR	**DISTRICT TOTAL**
Shallow Aquifer						
Dynamic Resources (MCM)	219.15	209.48	150.15	24.68	133.4	736.89
In Storage Resources (MCM)	206.629	123.438	56.588	84.678	150.559	809.590
Total Resources (MCM)	425.78	332.92	206.74	109.36	283.96	1358.752
GW Irrigation Draft	22.2	17.6505	7.12	0	29.14	76.103
Deeper Aquifer						
Static Resources (MCM)	236.60	129.24	92.71	255.64	51.09	765.273
GW Draft (MCM	21.46	20	23	15	39	118.221
Domestic+Industries	2.28	4.10	5.60	21.09	4.47	37.540
Total GW Resources (MCM)	662.38	462.15	299.45	365.00	335.05	2124.025
Gross Ground Water Draft (MCM)	45.94	42.13	35.82	35.86	72.12	231.864

5. Geophysical Studies

Surface Geophysical Surveys –

The Surface Geophysical methods have been used for many years to support the groundwater exploration programme. The electrical resistivity methods are commonly being used for this purposed. The surface resistivity method comprising vertical Electrical Sounding (VES) and Gradient Resistivity profiling (GRP) were conducted to pin point the suitable borehole sites for augmenting the water supply to MES. Cantonment area of Morar and Maharajpur Air force based station in Gwalior district.

Surface resistivity measurements have been made with help of DDR – 4 Resistivity Meter. It is digital sensitive intimated consisting of transmitting and receiver in two separate units. It gives the direct resistance as well as resistivity values.

In total 12 VES were conducted with maximum current electrode separation of 300 to 500m (AB) in Main Gate, Chetak Pump, Golf Course, PPLQ and B Flight area of Maharajpur Air Force Based station Gwalior. The VES curves had been plotted on double log paper against half current electrode separation. The VES are had been interpreted by conventional curve matching methods using two layers master curve auxiliary point chart.

The VES were conducted in hydro geologically suitable area wherever the open space was available. The interpreted layers parameter (resistivity and thickness of each geoelectrical layers) of all interpretable VES is given in Table 9. This indicates the presence of in homogenous formation at surface as well in subsurface. It may be due to land fillings of the undulating topography for making plains industrial area.

All the VES observed in the Maharajpur area are 'H' type ($\rho 1 > \rho 2 < \rho 3$), which clearly indicate the presence of 3-geoclaternal layers system within the depth of range of 60 m bgl. It is observed that the geo electrical layers hence wide range of resistivity (6 – 800 ohm m) variation. The nature of VES curve suggest the presence of sub surface Alluvium/Morar shales varies from 0 – 30 mbgl.

In total 11 VES were conducted with maximum current electrode separation of 300 to 500 m (AB) in Hathikhana, MES IBand Mohanpur of Cantonment area of Morar, distt. Gwalior. The VES curves had been plotted on double log paper against half current electrode separation. The VES are had been interpreted by conventional curve matching methods using two layers master curve auxiliary point chart.

The VES were conducted in hydro geologically suitable area wherever the open space was available. The interpreted layers parameter (resistivity and thickness of each geo electrical layers) of all interpretable VES is given in Table 9. This indicates the

presence of inhomogeneous formation at surface as well in subsurface. It may be due to land fillings of the undulating topography for making plains industrial area.

In order to observe the variation in resistivity in horizontal direction G.P.R. was conducted in Mohanpur area. All the VES observed in the Cantonment area of Morar are 'H' type ($\rho 1 > \rho 2 < \rho 3$), which clearly indicate the presence of 3-geoclaternal layers system within the depth of range of 60 m bgl. It is observed that the geo electrical layers hence wide range of resistivity (6 – 800 ohm m) variation. The nature of VES curve suggest the presence of sub surface Alluvium/Morar shale varies from 25 – 56 mbgl.

Table-9 Interpreted Results of VES conducted in Maharajpur Air Force Based station & Cantonment area of Morar, Gwalior District.

S.no.	Location	VES No.	Interpreted layer Parameters							Total Thickness (m)
			Layer Resistivity (ohm-m)				Layer Thickness (m)			
			ρ1	ρ 2	ρ 3	ρ 4	H-1	H-2	H-3	
Maharajpur Air Force station										
1	Main Gate	1-7	70	35	1600	-	3.0	8.4	-	11.4
2	Chetak Pump	8	95	19	400		1.1	27.5		28.4
3	Golf Course	9	13	7.8	400		6.0	7.8		13.8
4	C-Ak	10	33	165	55	2720	0.9	3.4	13.2	17.5
5	PPLQ	11	21	6.3	3000		3.0	7.8		10.8
6	B Flight	12	20	6	288		0.9	3.8		4.7
	Cantonment area- Morar									
1	Hathikhana	1-3	15	6	240		3.0	24.6		27.6
2	Mohanpur	4	38	19	800		0.9	15.0		16.0
3	MESIB	5	54	11	440		2.0	50.0		52.0
4	Resistivity	6-11	74	22	240		4.6	55.2		58.8

6. Ground Water Quality of Gwalior District

The water samples were collected from National Hydrograph Stations in clean double stoppered poly ethylene bottles from 18 different locations of Gwalior district during May 2020 (Table 10).

Quality of Ground Water for Drinking Purpose:

The ground water samples from Gwalior district have varied range of pH from 7.29 to 7.95. 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 Ghatigaon (7.95). The pH of ground water can be assessed as neutral to slightly alkaline in nature. The electrical conductivity of ground water samples in Gwalior district varies from 265 to 2415 µS/cm at 25°C. In the district, 11 locations of sample shows EC less than 1000 µS/cm; 4 locations of sample shows EC in between 1000 to 1500 µS/cm and 3 locations of sample shows EC more than 1500 µS/cm from Mohna (2112), Tekanpur (2168) and Dongarpur (2415 µS/cm) villages. So, overall ground water quality of Gwalior district is good to saline in nature in few pockets.

The fluoride concentration in Gwalior district lies in between 0.05 to 0.95 mg/l, which represent that all the samples are within the permissible limit i.e. 1.5 mg/l of BIS standard. The maximum concentration of fluoride has been observed in the dug well of Masoorpur village i.e. 0.95mg/l. The nitrate concentration in the Gwalior districts ranges in between 3 to 285 mg/l. In the district, 27.8% samples have nitrate concentration more than the acceptable limit i.e. 45 mg/l, while rest 72.2% samples have concentration less than acceptable limit. Highest nitrate have been recorded in the villages of Aarauli (160 mg/l) and Dongarpur (285 mg/l).

The total hardness in the ground water of the districts ranges between 94 to 861 mg/l. In the district, all the ground water samples recorded less than BIS permissible limit i.e. 600 mg/l except the ground water of Dongarpur (861 mg/l) i.e. maximum concentration of total hardness.

Piper diagram (Fig 15) 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 (Ca2+, Mg2+, Na+, K+) are plotted. In Anion triangle the major anions (HCO3-+CO32-, SO42-, Cl-) are plotted. These points are then projected to the central diamond shaped field.

In the district; piper diagram shows that the samples are Calcium-Bicarbonate type (temporary hardness); Mixed type and Sodium chloride type (saline) types of water.

Quality of Ground Water for Irrigation Purpose:

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

The USSL diagram (Fig 16) shows that the districts falls under C2-S1 Class (Medium Salinity & Low Sodium); C3-S1 Class (High Salinity & Low Sodium), C3-S2 Class (High

Salinity & Medium Sodium) and C4-S1 class (Very High Salinity & Low Sodium). The ground water of C3-S2 and C4-S1 classes of the district may be used for irrigation with proper soil management.

Fig. 15 Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Gwalior District, Madhya Pradesh

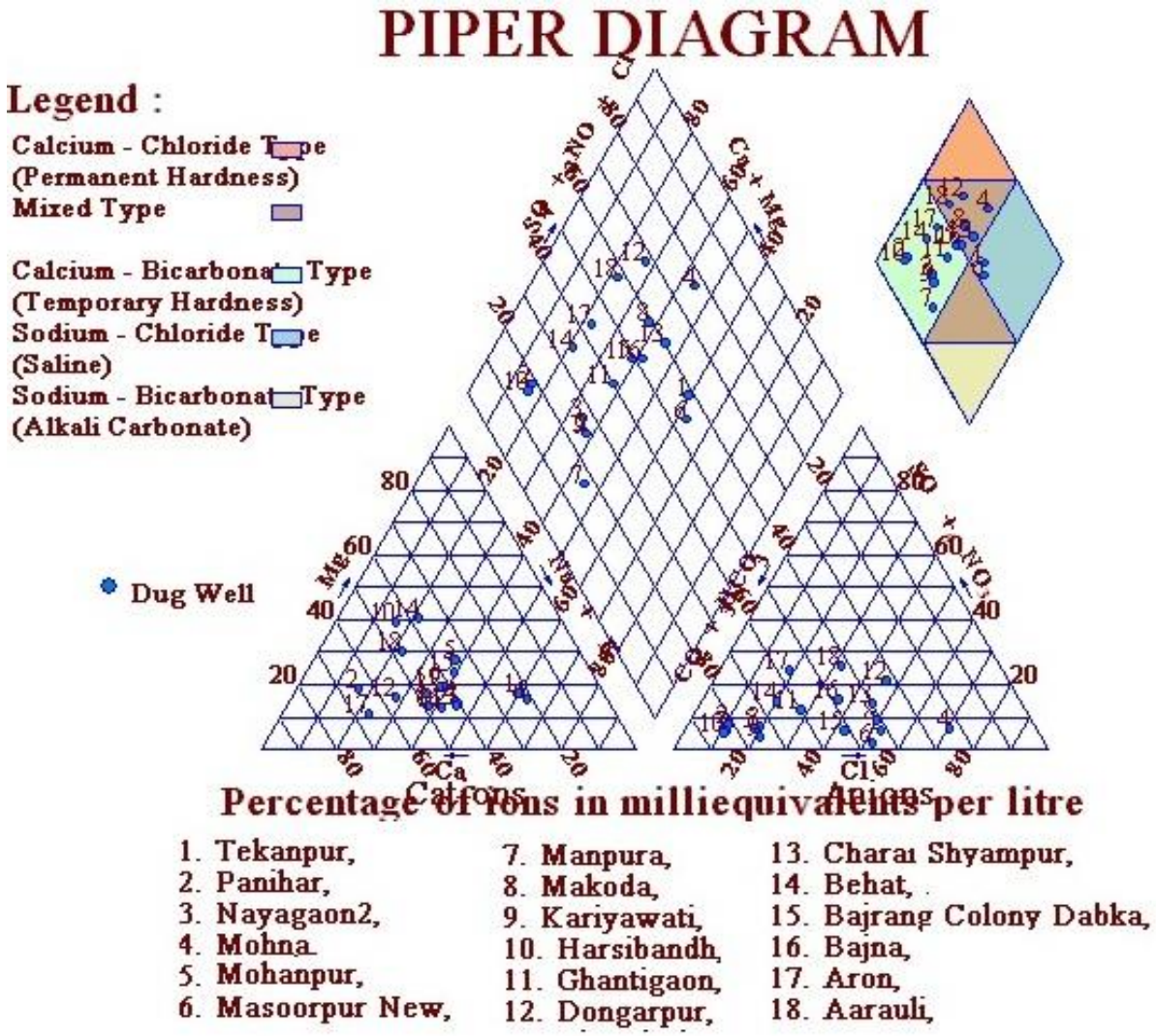


Fig. 16 US Salinity Diagram for water samples collected from National Hydrograph Stations of Gwalior District, Madhya Pradesh

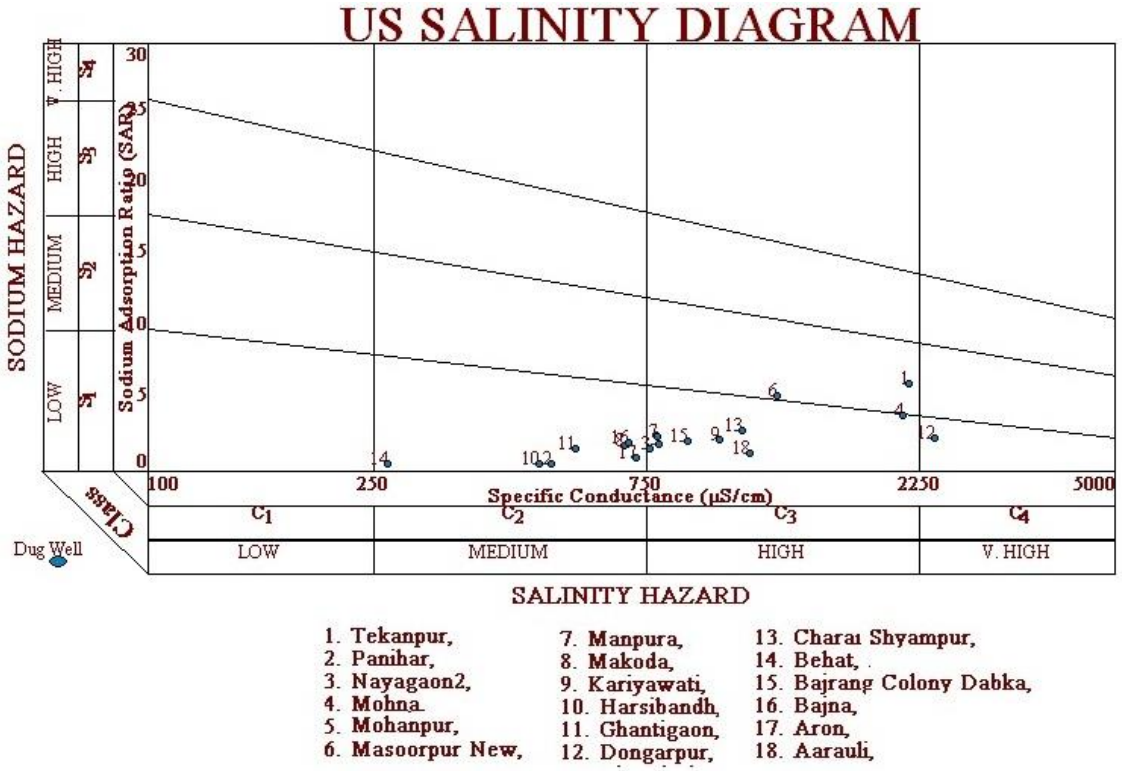


Table 10 Ground water Quality data of Gwalior district May 2020.

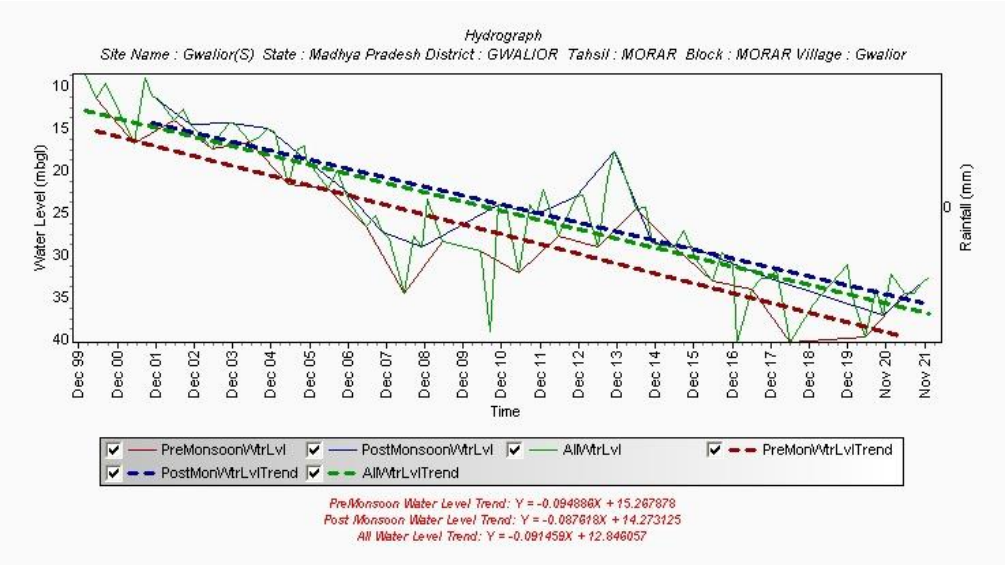
S. No.	District	Block	Location	Lat.	Long.	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
						at 25°C	µS/cm at 25°C	mg/l													
1	Gwalior	Morar	Aarauli	26.160	78.455	7.86	1146	0	279	127	12	160	0.05	BDL	32	431	105	41	57	2.3	745
2	Gwalior	Ghatigaon	Aron	25.952	77.931	7.61	723	0	225	45	8	98	0.25	BDL	23	267	91	10	35	3.2	470
3	Gwalior	Bhitarwar	Bajna	25.843	77.952	7.29	702	0	194	87	19	40	0.07	0.1	28	198	61	11	65	1.2	456
4	Gwalior	Morar	Bajrang Colony Dabka	26.154	78.433	7.93	888	0	261	130	12	18	0.05	BDL	26	262	63	25	76	2.6	577
5	Gwalior	Morar	Behat	26.174	78.543	7.76	265	0	91	17	8	11	0.06	BDL	19	94	18	12	10	3.2	172
6	Gwalior	Ghatigaon	Charai Shyampur	25.975	77.831	7.53	1109	0	261	180	14	80	0.15	BDL	21	297	89	18	113	1.9	721
7	Gwalior	Bhitarwar	Dongarpur	25.822	77.964	7.67	2415	0	456	390	22	285	0.27	BDL	24	861	267	47	152	1.8	1570
8	Gwalior	Ghatigaon	Ghantigaon	26.050	77.933	7.95	565	0	188	52	14	22	0.35	0.1	26	168	46	13	46	2.1	367
9	Gwalior	Bhitarwar	Harsibandh	25.762	77.929	7.87	489	0	243	20	10	3	0.06	BDL	33	198	42	23	17	1.4	318
10	Gwalior	Dabra	Kariyawati	25.819	78.180	7.67	1012	0	444	77	12	9	0.42	BDL	35	297	81	23	85	1.6	658
11	Gwalior	Dabra	Makoda	26.036	78.256	7.62	689	0	158	115	14	20	0.31	BDL	42	203	63	11	56	2.1	448
12	Gwalior	Morar	Manpura	26.164	78.355	7.32	788	0	383	32	12	12	0.31	0.1	19	208	61	13	78	3.5	512
13	Gwalior	Dabra	Masoorpur New	25.830	78.244	7.63	1279	0	352	237	8	9	0.95	BDL	26	233	53	24	182	1.5	831
14	Gwalior	Morar	Mohanpur	26.208	78.249	7.81	792	0	340	52	14	12	0.42	BDL	28	233	51	25	65	1.6	515
15	Gwalior	Ghatigaon	Mohna	25.897	77.777	7.52	2112	0	267	497	25	47	0.62	BDL	13	574	168	37	212	2.7	1373
16	Gwalior	Ghatigaon	Nayagaon2	26.118	78.021	7.73	765	0	340	55	9	23	0.54	0.2	24	243	71	16	56	8.1	497
17	Gwalior	Ghatigaon	Panihar	26.106	78.027	7.62	512	0	249	20	14	7	0.05	BDL	22	203	63	11	17	2.1	333
18	Gwalior	Dabra	Tekanpur	25.985	78.284	7.89	2168	0	516	390	55	6	0.86	BDL	26	426	97	45	291	2.5	1409

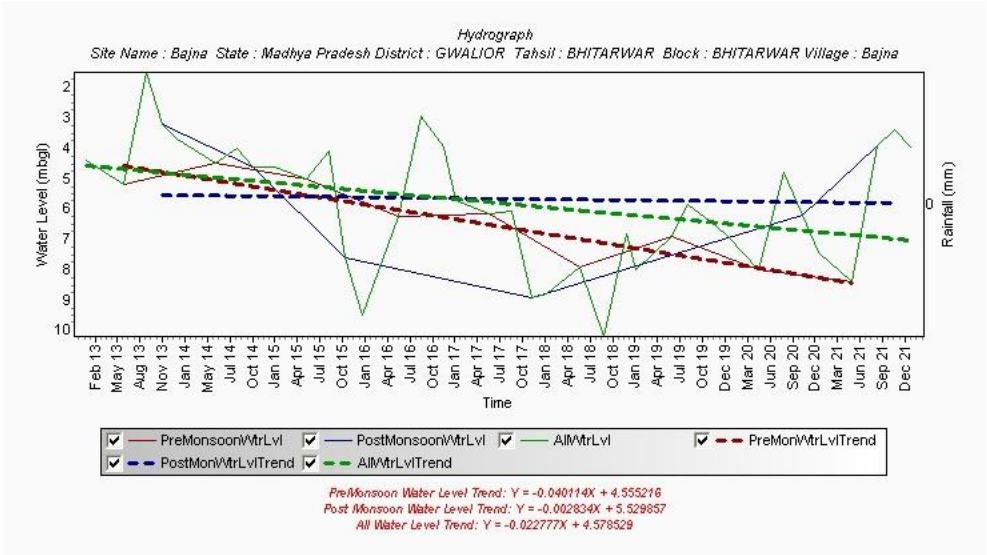
7. Ground Water Related Issues

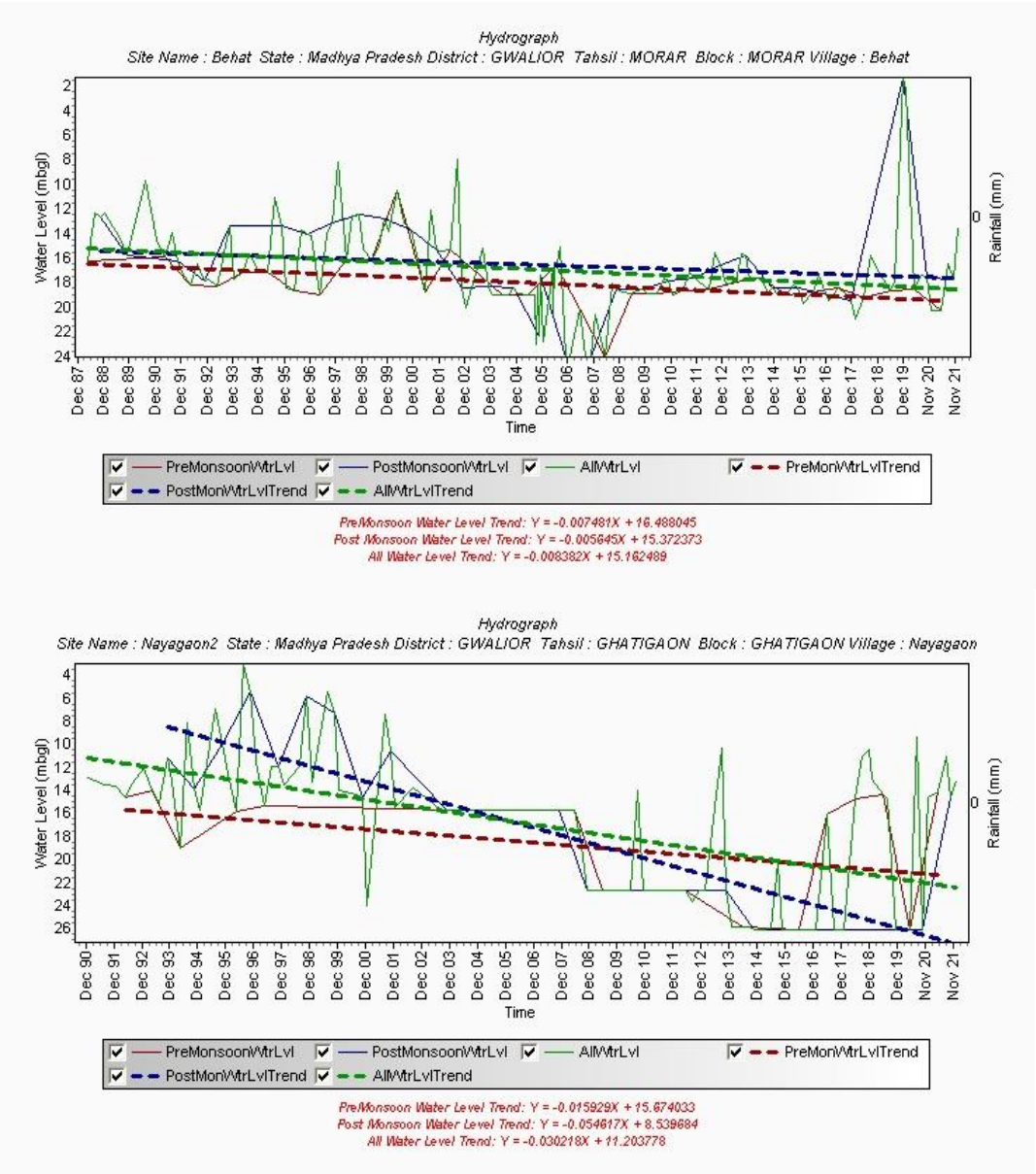
7.1 Declining of water level

The long-term water level trend analysis indicates mixed results. During pre-monsoon season, out of 21 Hydrograph Stations, 4 are showing declining trend (Fig. 17). Similarly, during post-monsoon season, out of 21 stations 4 stations are showing falling trend in the district and all stations of Ghatigoan and Gwalior urban and Morar blocks are showing depletion of water levels in the area. Ground Water Resource Estimation also reveals that out of 5 Blocks of the district 1urban unit have crossed 70% stage of ground water development

Fig 17: Hydrographs showing declining water level trend during Pre-monsoon and Post-Monsoon at sites Gwalior and Bajana, Behat and Nayagoan Gwalior District, Madhya Pradesh







7.2 Ground water quality issue

The nitrate concentration in the Gwalior districts ranges in between 3 to 285 mg/l. In the district, 27.8% samples have nitrate concentration more than the acceptable limit i.e. 45 mg/l, while rest 72.2% samples have concentration less than acceptable limit. Highest nitrate have been recorded in the villages of Aarauli (160 mg/l) and Dongarpur (285 mg/l).

8. Ground Water Management Strategies

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

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

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

Supply Side Management – Augmentation of Ground Water Resources through Artificial Recharge

Artificial recharge to ground water is one of the most efficient, scientifically proven and cost-effective technology to mitigate the problems of over exploitation of ground water resources. The artificial recharge techniques simultaneously rejuvenate the depleted ground water storage, reduces the ground water quality problems and also improves the sustainability of wells in the affected areas.

The supply side management plan for Gwalior district has been formulated using the basic concepts of hydrogeology. Sub-surface storage is calculated by multiplying the total

area with the respective specific yield (considering the variable lithology) and the unsaturated zone thickness obtained by subtracting 3 mts from the post-monsoon water level. The volume of ground water recharge generated through pre-existing rain water harvesting/water conservation structures is subtracted from the sub-surface storage to assess the available storage potential. Thus, the surface water requirement to completely saturate the sub-surface storage is obtained by multiplying a factor of 1.33 to available storage potential. A runoff coefficient factor of 0.23 has been considered for Gwalior district to calculate the total surface water runoff, 30% of which accounts to the non-committed runoff which is available to sustain the proposed artificial recharge structures. Further, the number of structures has been calculated by allotting 35%, 35% and 20% of non-committed runoff to Percolation tanks, Recharge shafts/Tube wells and Nala bunds/Check dams/Cement Plugs respectively. The remaining 10 % runoff is considered to restore the pre-existing village tanks, ponds and water conservation structures. A detailed calculation of the proposed artificial recharge structures is presented in the Table no. 11.

A financial outlay plan has also been chalked out, assuming the cost for the artificial recharge structures to be Rs. 20 lakhs each for percolation tanks, Rs. 10 lakhs each for Nala bunds/Check Dams/Cement Plugs, Rs. 5 lakhs each for Recharge shafts/Tube wells and Rs. 2 lakhs each for renovation of Village tanks/ponds/WCS. This accounts to a total of Rs. 186 Crores to successfully implement the supply side management strategy. Table no. 12 represents the complete financial outlay plan for the district.

Table 11: Ground Water Management– Supply Side, Gwalior District, Madhya Pradesh

Block	Area (Sq.KM)	Normal Annual Rainfall (mm)	Average Post-monsoon Water Level - 2018 (m bgl)	Suitable Area for AR (sq.km)	Un-Saturated Zone (m) col5-3	Specific Yield	Sub-surface storage (mcm) Col6x7x8	Sub-Surface water required (mcm) Col 9x1.33	Runoff /sq.km	Runoff (mcm) Col 3x11	Non Commuted Runoff (mcm) Col 12x0.3	Available water required/ Non Commuted Runoff (mcm) Col 10 or 13 which ever less	Resource water for Percolation tanks (mcm) Col 14x0.35
Ghatigaon	1469	870.00	5.30	1569.00	2.30	0.03	108.26	143.99	0.16	238.0	71.39	43.74	15.3
Morar	797	870.00	10.30	795.00	7.30	0.06	348.21	463.12	0.16	129.1	38.73	38.73	13.6
Bhitarwar	900.00	870.00	5.70	307.00	2.70	0.06	49.73	66.15	0.16	145.8	43.74	14.92	5.2
Dabra	974.00	870.00	7.18	312.00	4.18	0.06	78.25	104.07	0.16	157.8	47.34	15.16	5.3
Total	4140	3480	7.12	2983	4.12	0.0525	584.45	777.32	0.16	670.6	201.20	112.55	39.39

Table 12: Financial Outlay Plan- Supply Side Management, Gwalior District, Madhya Pradesh

Block	Resource water for Percolation tanks (mcm) Col 14x0.35	No of percolation tanks col 15/.2	Cost of percolation tanks in crores @ 0.20 crores / pt col 16X0.2	Resource water for Check Dams with RS (mcm) col 14x0.45	No of Check Dams col 18/0.03	Cost of Check Dams in crores @0.06 crores / pt	No of Recharge shaft in each CD 18/.03	Cost of Recharge shaft in each CD @ 0.001crore Col 21x.001	Resource water for Nala bunds/ Cement plugs (mcm)	No of nala bunds/cement plugs Col 23/0.01	Cost of nala bund/cement plugs in crores @0.01 crores /NB,CP Col 24x0.01	Resource water for Village Ponds mcm Col 14x0.05	No of village ponds/ Farm Ponds in each village	Cost of village pond in crores @0.025 crores per Col x0.025	Total Cost(in crores)
Ghatigaon	15.3	77	15.4	19.68	656	39.36	656	6.56	6.56	656	6.56	2.19	219	5.47	70.41
Morar	13.6	68	13.6	17.43	581	34.86	581	5.81	5.81	581	5.81	1.94	194	4.84	63.21
Bhitarwar	5.2	26	5.2	6.71	224	13.44	224	2.24	2.24	224	2.24	0.75	75	1.87	26.25
Dabra	5.3	27	5.4	6.82	227	13.62	227	2.27	2.27	227	2.27	0.76	76	1.90	26.69
Total	39.39516	198	39.6	50.65	1688	101.2	1688	16.88	16.88	1688	16.88	5.63	563	14.06	186

Artificial Recharge in Urban Areas

Rooftop Rainwater Harvesting has been considered in four Cities having population of more than one Million Gwalior Urban. 30 % of the total household (as per 2011 Census) have been considered for Roof Top Rainwater Harvesting. Total 408937 households are considered for RTRWH. Considering average 50 Sq m area for each household, total roof area is estimated as 3380625 Sq m (3.38sq. km). It is estimated that 2.94 MCM/yr will recharge from these measures.

The average expenditure on providing the necessary arrangements through pipe fittings, filters etc. to divert the roof water to existing structure Tubewell/Borewell/Dugwell) has been considered as Rs. 20000/- per house. The total cost of Roof Top Rainwater Harvesting in the urban areas of the State works out Rs. 135.22Crore. The estimates for construction of rooftop rainwater harvesting structures are given in table 13

Table 13 Roof Top Rainwater harvesting in Urban Area

Name of city	No. of House holds	No. of Houses Considered for RTRWH (Col 2X0.30)	Roof top area considering 50 Sq m/House (Col 3x50	Total Area of roof top (Sq.km col4/10^6	Normal Annual Rainfall in (m)	Available recharge potential (MCM) Col. 5x6	Total Volume of water to be Recharged (MCM) col 7x0.80	Cost of RTRWH(in lakhs) @ Rs. 0.2 lakhs /House hold Col 3X 0.20
1	2	3	4	5	6	7	8	9
Gwalior	225375	67612.5	3380625	3.38	0.87	2.94	2.35	13522.5

8.2. Post-Intervention Impact

The expected outcome of the proposed interventions from both supply side and demand side has been described in Table no 14. It can been revised that the Stage of groundwater development for the entire Gwalior district, would reduce to 31.47% as compared to the present stage of ground water development of 27.7 % after implying and successful implementation of proposed interventions.

Table 114: Post-Intervention Impact, Gwalior District, Madhya Pradesh

Block	Net GW Availability	GW Draft for Irrigation	GW Draft for Domestic & Industrial	Gross Draft	Stage of Development	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	Draft after sprinkler & additional area created for agriculture (Sq.KM)	Stage of Development W/O GW use for additional Area Irrigation
BHITARWAR	219.15	43.66	2.28	45.940	20.96	43.74	262.89	45.94	17.47
DABRA	209.48	38.03	4.10	42.131	20.11	38.73	248.21	42.1305	16.972
GHATIGAON	150.15	30.21	5.60	35.817	23.85	14.92	165.07	35.817	21.69
GWALIOR_URBAN	24.68	0	21.09	21.090	85.45	2.5	27.18	21.09	77.59
MORAR	133.4	67.64	4.47	72.118	54.06	15.16	148.56	72.1182	48.54
DISTRICT TOTAL	736.89	194.32	37.540	231.864	31.47	112.55	849.44	231.86	27.29

8.3 Block-Wise Aquifer Mapping and Management Plan

1. Block: BHITARWAR

Geographical area	**900.00** Sq. km (NAQUIM Recharge worthy area **839.00** Sq. Km)
Basin/Sub Basin	Ganga Basin/Chambal
Principal Aquifer System	Alluvium, Sandstone, Shale & Granite
Major Aquifer System	Weathered/Fractured Sandstone, Shale & Granite
Normal Annual Rainfall	870.00mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 0 Observation Wells : 0 Piezometer Well: 0
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL(m bgl): 3.85-6.95 Yield (lps): 1 to 6 Specific yield :0.094 Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL(m bgl): 11 - 20 Yield (lps): Meager to 10 Specific yield :0.094
Ground water Monitoring Status	NHS: 03DW, Piezometer Well: 0
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 219.15 MCM GW Draft:45.94 MCM Stage of GW Development: 20.96%
Existing and Future water Demand	Present Demand for All Uses:45.94 MCM Future Demand for Domestic and Industrial Use: 2.99 MCM

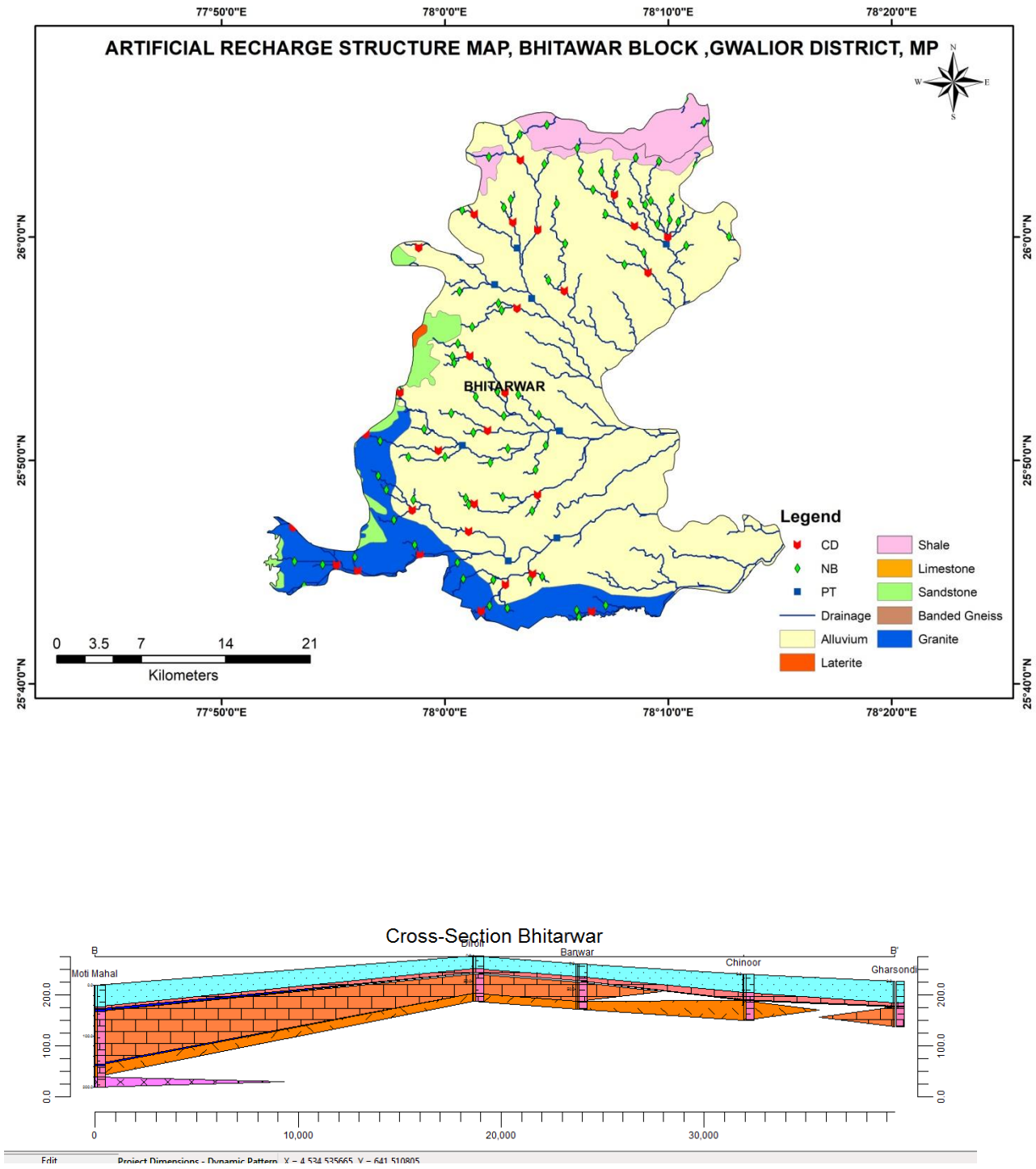


Fig 18: Artificial Recharge Structures location Map and 2D section of Bhitarwar Block

Salient Features

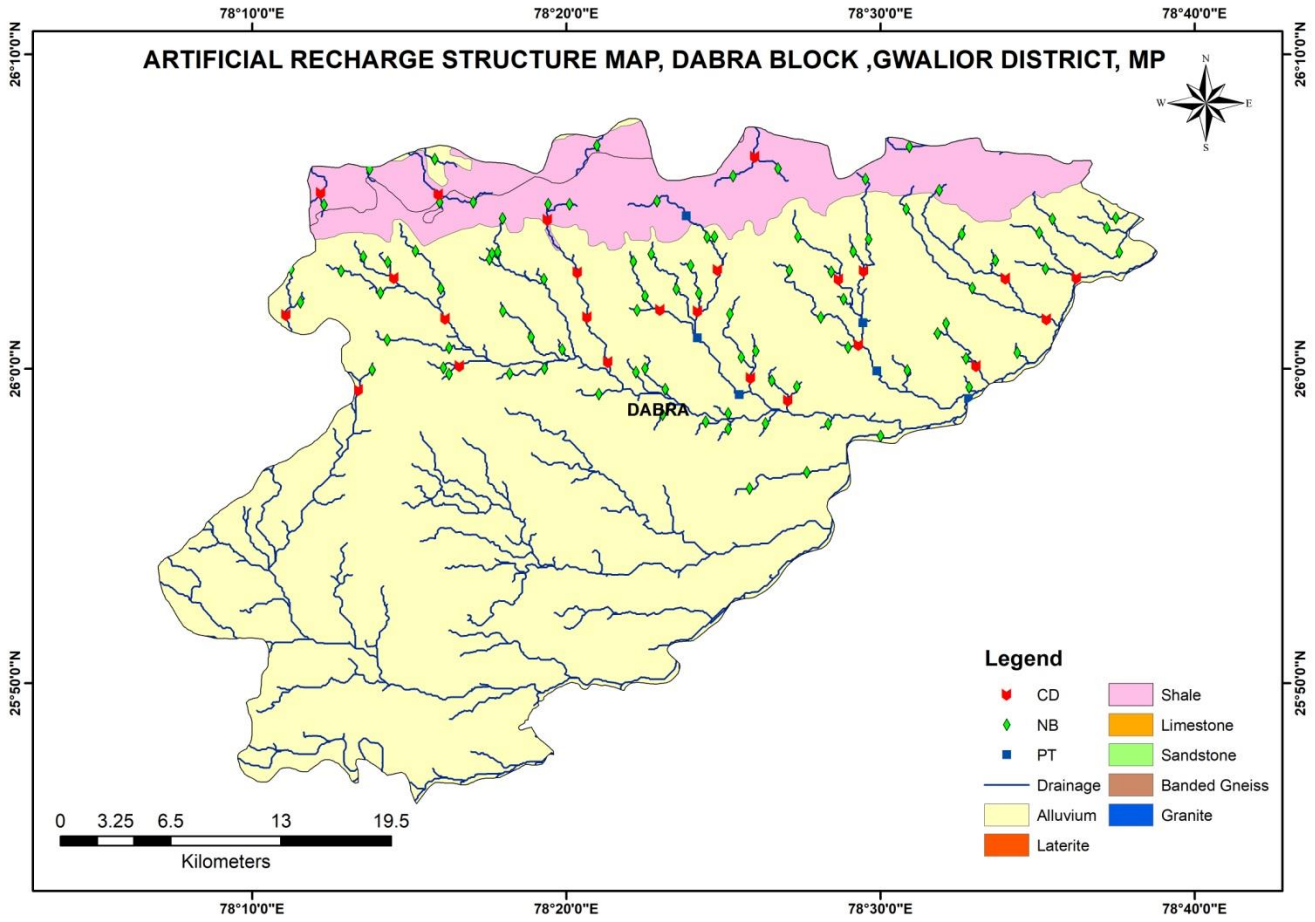
BLOCK	BHITARWAR
Shallow Aquifer	
Dynamic Resources (MCM)	**219.15**
In Storage Resources (MCM)	**206.629**
Total Resources (MCM)	**425.78**
Irrigation Draft	**22.2**
Domestic+Industries	**2.28**
Deeper Aquifer	
Static Resources (MCM)	**236.60**
GW Draft (MCM)	**21.46**
Total GW Resources (MCM)	**662.38**
Gross Ground Water Draft (MCM)	**45.94**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	26	5.2(Rs 20 Lakh Per Structure)
NB /CP	224	2.24(Rs 1.0 Lakh Per Structure)
CD	224	13.44(Rs 6.0 Lakh Per Structure)
Recharge Shaft	224	2.24(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	75	1.87(Rs 2.5 Lakh Per Structure)
Total Cost		26.25 **Crores**

2. Block: DABRA

Geographical area	974.00 Sq. km (NAQUIM Recharge worthy area 913.00 Sq. Km)
Basin/Sub Basin	Ganga Basin/Chambal
Principal Aquifer System	Alluvium, Sandstone, Shale& Granite
Major Aquifer System	Weathered/Fractured Sandstone, Shale& Granite
Normal Annual Rainfall	870.00 mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 2 Observation Wells : 0 Piezometer Well: 01
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL (m bgl): 3.76-10.90 Yield (lps): 1 to 6 Specific yield :0.08 Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL (m bgl): 16 - 25 Yield (lps): Meager to 10 Specific yield :0.08
Ground water Monitoring Status	NHS: 04 DW, Piezometer Well: 01
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 209.48 MCM GW Draft:42.13 MCM Stage of GW Development: 20.12%
Existing and Future water Demand	Present Demand for All Uses:42.13 MCM Future Demand for Domestic and Industrial Use: 4.16 MCM



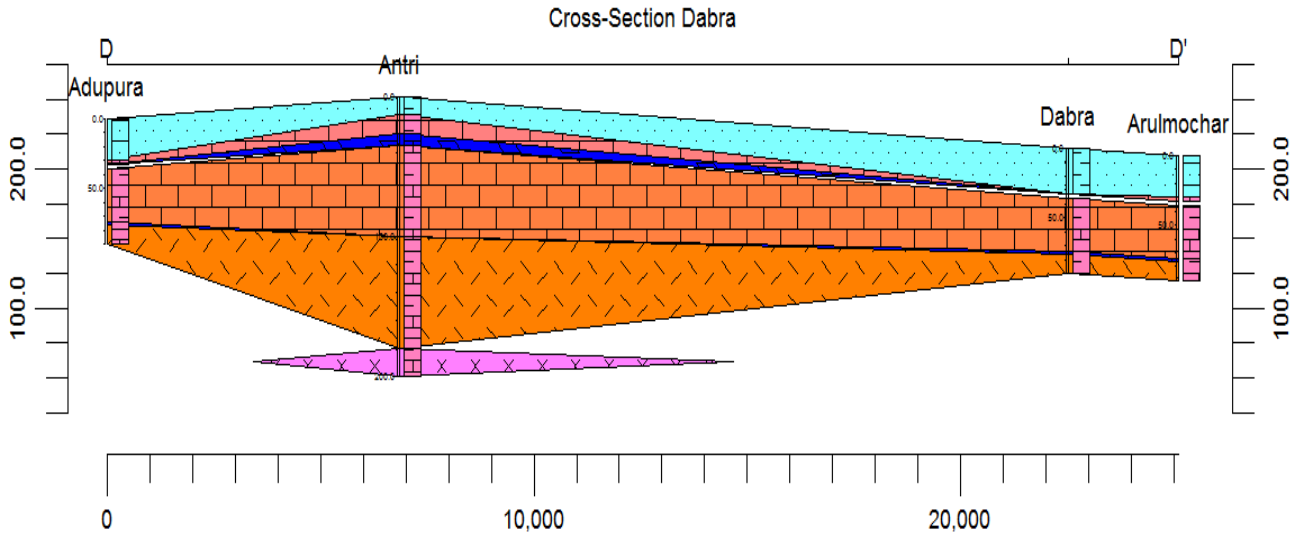


Fig 19: Artificial Recharge Structures Location Map and 2D section of Dabra Block

Salient Features

BLOCK	DABRA
Shallow Aquifer	
Dynamic Resources (MCM)	**209.48**
In Storage Resources (MCM)	**123.438**
Total Resources (MCM)	**332.92**
Irrigation Draft	**17.6505**
Domestic+Industries	**4.10**
Deeper Aquifer	
Static Resources (MCM)	**129.24**
GW Draft (MCM)	**20**
Total GW Resources (MCM)	**462.15**
Gross Ground Water Draft (MCM)	**42.13**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	27	5.4(Rs 20 Lakh Per Structure)
NB /CP	227	2.27(Rs 1.0 Lakh Per Structure)
CD	227	13.62(Rs 6.0 Lakh Per Structure)
Recharge Shaft	227	2.27(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	76	1.90(Rs 2.5 Lakh Per Structure)
Total Cost		26.69 **Crores**

3. Block: GHATIGAON

Geographical area	974.00 Sq. km (NAQUIM Recharge worthy area 913.00 Sq. Km)
Basin/Sub Basin	Ganga Basin/Chambal
Principal Aquifer System	Alluvium,Sandstone,Shale&Granite
Major Aquifer System	Weathered/Fractured Sandstone,Shale&Granite
Normal Annual Rainfall	870.00 mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 6 Observation Wells : 0 Piezometer Wells: 02
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):8 DTWL (m bgl): 5.10-8.12 Yield (lps): 1 to 6 Specific yield :0.03 Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL (m bgl): 7.46 – 46.62 Yield (lps): Meager to 10 Specific yield :0.03
Ground water Monitoring Status	NHS: 06 DW, Piezometer Wells: 02
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 150.15 MCM GW Draft:35.82 MCM Stage of GW Development: 23.85%
Existing and Future water Demand	Present Demand for All Uses:35.82 MCM Future Demand for Domestic and Industrial Use: 6.74 MCM

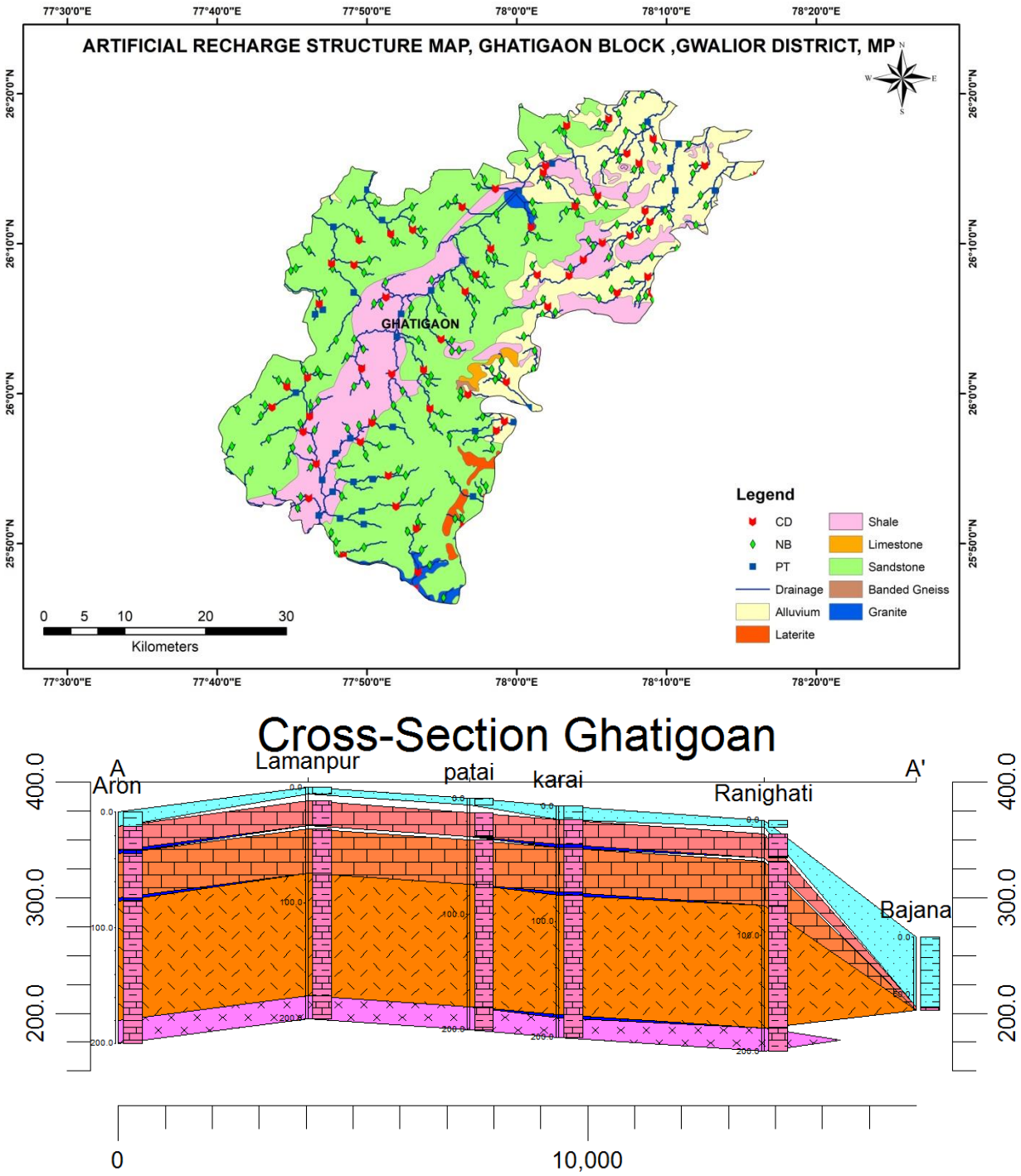


Fig 20: Artificial Recharge Structures location Map and 2D section of Gahtigoan Block

Salient Features

BLOCK	GHATIGAON
Shallow Aquifer	
Dynamic Resources (MCM)	**150.15**
In Storage Resources (MCM)	**56.588**
Total Resources (MCM)	**206.74**
Irrigation Draft	**7.12**
Domestic+Industries	**5.60**
Deeper Aquifer	
Static Resources (MCM)	**92.71**
GW Draft (MCM)	**23**
Total GW Resources (MCM)	**299.45**
Gross Ground Water Draft (MCM)	**35.82**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	77	15.4(Rs 20 Lakh Per Structure)
NB /CP	656	6.56(Rs 1.0 Lakh Per Structure)
CD	656	39.36(Rs 6.0 Lakh Per Structure)
Recharge Shaft	656	6.56(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	219	5.47(Rs 2.5 Lakh Per Structure)
Total Cost		70.41 **Crores**

4.Block: MORAR

Geographical area	897.75.00 Sq. km (NAQUIM Recharge worthy area 897.75 Sq. Km)
Basin/Sub Basin	Ganga Basin/Chambal
Principal Aquifer System	Alluvium, Sandstone, Shale & Granite
Major Aquifer System	Weathered/Fractured Sandstone, Shale & Granite
Normal Annual Rainfall	870.00 mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 12 Observation Wells : 0 Piezometer Well: 01
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL (m bgl): 10.30-20.20 Yield (lps): 1 to 6 Specific yield :0.081 Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL (m bgl): 7.46 – 46.62 Yield (lps): Meager to 10 Specific yield :0.081
Ground water Monitoring Status	NHS: 04 DW, Piezometer Well: 01
Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 133.40 MCM GW Draft:72.12 MCM Stage of GW Development: 54.06%
Existing and Future water Demand	Present Demand for All Uses:72.12 MCM Future Demand for Domestic and Industrial Use: 5.03 MCM

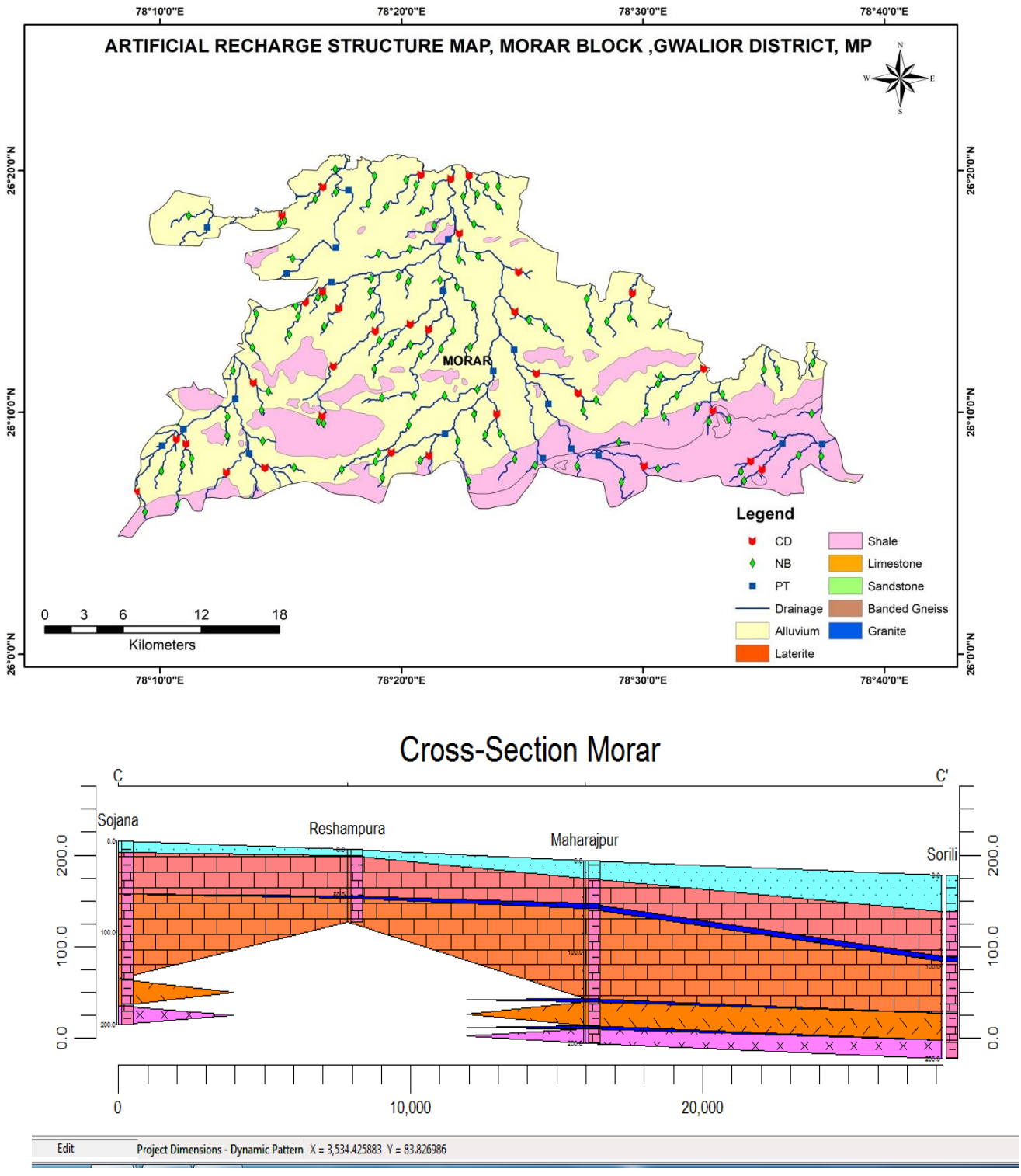


Fig 21: Artificial Recharge Structures location Map and 2D section of Morar Block

Salient Features

BLOCK	MORAR
Shallow Aquifer	
Dynamic Resources (MCM)	**133.4**
In Storage Resources (MCM)	**150.559**
Total Resources (MCM)	**283.96**
Irrigation Draft	**29.14**
Domestic+Industries	**4.47**
Deeper Aquifer	
Static Resources (MCM)	**51.09**
GW Draft (MCM)	**39**
Total GW Resources (MCM)	**335.05**
Gross Ground Water Draft (MCM)	**72.12**

TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	68	13.6(Rs 20 Lakh Per Structure)
NB /CP	581	5.81(Rs 1.0 Lakh Per Structure)
CD	581	34.86(Rs 6.0 Lakh Per Structure)
Recharge Shaft	581	5.81(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	194	4.84(Rs 2.5 Lakh Per Structure)
Total Cost		63.21 **Crores**

9. Conclusions and Recommendations

On the basis of prevailing hydrogeological condition in the studied area, the following conclusions are drawn.

The studied area occupies an area of 4564 Sq. Km. It is divided into, four administrative blocks viz. Morar, Dabra, Gatigoan and Bhitarwar forming blocks.

Ground water accounts almost 46% of irrigation in studied area and canal irrigation account 49%.

The maximum elevation is 440 m amsl in Bhitarwar Block and minimum elevation is 160 m amsl in Morar Block .The surface gradient is south to. North in Morar block, west to east and North West to south east in Dabra and Bhitarwar blocks.

Central hilly and northern and southern plain form Ganga basin. The area is mainly drained by Sindh River flowing northerly and its tributaries which are effluent in nature.

The major part of the district is occupied by Alluvium consisting of clay silt &sand whose thickness used up to 40 m. Bundelkhand granite occupies Southern and central part of the area and Gwalior series in the central part of the area.

The ground water occurs under unconfined condition and semi confined to confined condition. The pre monsoon water level in year 2021-2022 north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range of 9-12 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging 12-15 m bgl constituting only about 15% of wells in this category have been observed only in small pocket in the northern and eastern part of Gwalior district. Ground water levels of more than 15m bgl have been recorded in the eastern part of the area.

The alluvium, weathered, jointed and fracture granite and bedded shale form the aquifer in the area. It is observed that Sp. Capacity of well area ranges 1.93 to 29.70 l/m. One to two aquifer zones are encountered in alluvial area. While in Mortar shale and granite area, it is diversified.

Long term water level trend show declining in Ghatigoan, Morar, Dabra, and Bhitarwar

On the prevailing hydrogeological conditions and data collected, the following recommendations are made for the development & management of ground water.

After the implemented of project interventions in the report, the stage of development is expected to improve by 10 % i.e. from 27.29 % to 31.47 % for the Gwalior district and additional area for the irrigation will be 231.86 Sq.Km.

- As per the Management plan prepared under NAQUIM of all the Block of Gwalior District, a total number of 198 Percolation Tanks, 1688 Recharge Shafts/Tube wells and 1688 Nala Bunds/Check Dams and 563 Village pond Cement Plugs have been proposed and these structures can recharge 112 MCM.
- Financial expenditure is expected to be Rs 186 Crores in Gwalior District for sustainable development and management of ground water resources.
- The number of artificial recharge structure and financial estimation has been proposed based on the CGWB Master plan 2020. It may be differ from the field condition as well as changes in dynamic Ground water resources.

ACKNOWLEDGEMENT

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

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

Thanks, are also extended to S/Sh.Vishal Wagh, Young professional for preparation of Maps of this report.