भारत सरकार
Government of India
जल शक्ति मंत्रालय
Ministry of Jal Shakti
जल संसाधन,नदी विकास और गंगा संरक्षण विभाग
Department of Water Resources, River Development & Ganga Rejuvenation
केंद्रीय भूमि जल बोर्ड
Central Ground Water Board

जलभृत मानचित्रण और भूजल प्रबंधन योजना
सीतामढ़ी जिला, बिहार
Aquifer Mapping and Ground Water Management Plan
Sitamarhi District, Bihar

क्षेत्रीय कार्यालय
मध्य-पूर्वी क्षेत्र, पटना
Regional Office
Mid-Eastern Region, Patna

May 2023

Report on

जलभृत मानचित्रण और भूजल प्रबंधन योजना
सीतामढ़ी जिला, बिहार
Aquifer Mapping and Ground Water Management Plan
Sitamarhi District, Bihar

AAP –2022-23

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Table of Contents

List of Figures

List of Tables

CHAPTER 1

INTRODUCTION

The vagaries of rainfall, inherent heterogeneity of aquifer systems, over exploitation of once copious aquifers, lack of regulation mechanism etc. has a detrimental effect on ground water scenario of the Country in last decade or so. Thus, prompting the paradigm shift from "Traditional Groundwater Development concept" to "Modern Groundwater Management concept". Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implement table ground water management plans. This leads to concept of Aquifer Mapping and Ground Water Management Plan. Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. The proposed management plans will provide the "Road Map" for ensuring sustainable management and equitable distribution of ground water resources, thereby primarily improving drinking water security and irrigation coverage. Thus the crux of NAQUIM (National Aquifer Mapping) is not merely mapping, but reaching the goal-that of ground water management through community participation.

During XII five year plan (2012-17) National Aquifer Mapping (NAQUIM) study was initiated by CGWB to carry out detailed hydrogeological investigation. The Aquifer Mapping programme has been continued till 2023 to cover whole country. The present studies of Sitamarhi district have been taken up in AAP 2018-19 as a part of NAQUIM Programme. The aquifer maps and management plans will be shared with the administration of Sitamarhi district and other user agencies for its effective implementation.

1.1 Objective and Scope

The major objectives of aquifer mapping are

- Delineation of lateral and vertical disposition of aquifers and their characterization
- 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.

The groundwater management plan includes Ground Water recharge, conservation, harvesting, development options and other protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e., the aquifer map and management plan.

The main activities under NAQUIM are as follows:

a). Identifying the aquifer geometry

b). Aquifer characteristics and their yield potential

c). Quality of water occurring at various depths

d). Aquifer wise assessment of ground water resources

e). Preparation of aquifer maps and

f). Formulate ground water management plan.

The demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control. The robust and implementable ground water management plan will provide a "Road Map" to systematically manage the ground water resources for equitable distribution across the spectrum.

1.2Approach and Methodology

The on-going activities of NAQUIM include hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 200 meters.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilization for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:

Compilation of existing data (Central & State Govt.)
↓
Generation of different thematic layer
↓
Identification of Primary Aquifer
↓
Identification of data gaps
↓
Data generation (water level, exploration, geophysical,
↓
Aquifer Maps with 3D disposition
↓
Preparation of Aquifer Management Plan
↓
Capacity building in all aspects of ground water through IEC Activities

1.3Area Details

Sitamarhi district, located in the northern part of Bihar State was carved out the old Muzaffarpur in the year 1972. The district is an acclaimed pilgrim centre and boasts of its important position in the mythological accounts for being the birth place of the Hindu goddess Sita. In the north it shares international boundary with Nepal and is bounded in the east by Madhubani and Darbhanga district, in the west by East Champaran and in the south by Muzaffarpur district.

Sitamarhi district consist of 17 blocks, viz., Bairgania, Bajpatti, Belsand, Bathnaha, Bokhara, Charaut, Dumra, Majorganj, Nanpur, Parihar, Parsauni, Pupri, Riga, RuniSaidpur, Sonbarsa, Suppi, Sursand. It extends between north latitudes 26°-17' 19'' and 26°-57' 33" and east longitudes 85°-10'-01" and 85°-47'22" falling in the Survey of India toposheet no. 72 F/5F/9,F/6,F/10,F/14,F/7,F/11,F/15 and with geographical area of 2185 Sq. Km.

Administrative details of Sitamarhi district are given below in Table 1:

Table 1: Sitamarhi Sub-divisions and blocks

Sub-division	**No. of Blocks**	**Name of Blocks**
Sadar	9	Bairgania, Bathnaha , Dumra, Majorganj, Parihar, Riga, RuniSaidpur, Sonbarsa, Suppi
Belsand	2	Belsand, Parsauni
Pupri	6	Sursand, Nanpur, Pupri, Bajpatti, Bokhara, Charaut

The district boundaries, administrative divisions, major roads, rail, and rivers are shown in **Figure 1.**

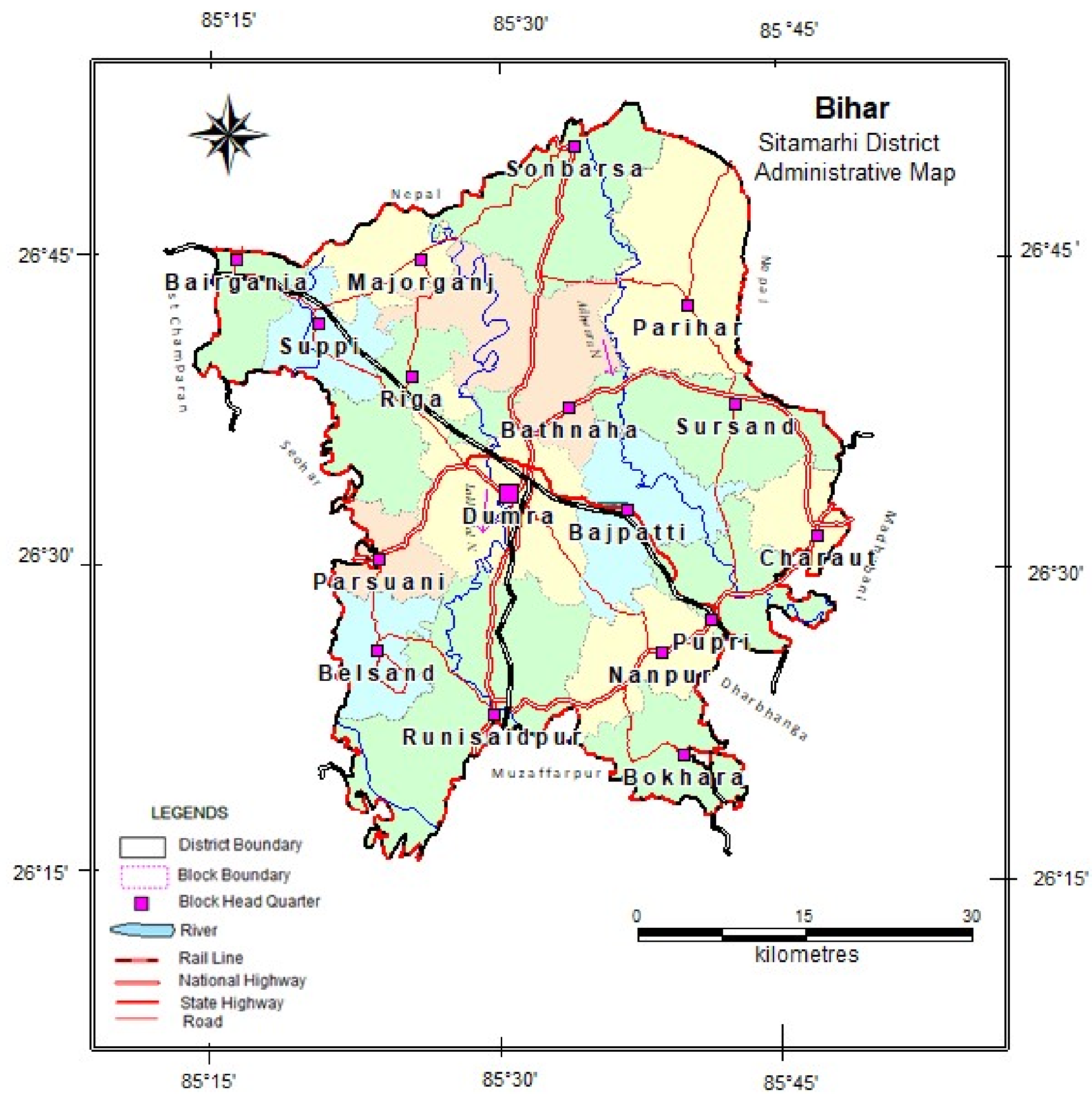


Figure 1: Administrative Map

Table 2: Demographic details

S. No.	BlockName	GeographicalArea (Sq. Km)	No. of Panchayats	TotalPopulation	MalePopulation	FemalePopulation	ChildPopulation
1	Bairgania	67.06	8	89259	47115	42144	16593
2	Bajpatti	139.32	19	215507	113078	102429	42328
3	Bathnaha	199.95	21	262527	138384	124143	52263
4	Belsand	76.88	9	100340	52973	47367	19247
5	Bokhara	86.01	11	130886	68711	62175	24980
6	Charaut	73.66	7	79310	41740	37570	14466
7	Dumra	195.42	28	354748	188181	166567	69958
8	Majorganj	75.54	8	102785	54031	48754	19987
9	Nanpur	107.49	17	182429	94901	87528	35251
10	Parihar	212.21	27	338222	177463	160759	68872
11	Parsauni	59.14	7	86016	45441	40575	17026
12	Pupri	93.09	13	156473	81631	74842	30692
13	Riga	129.14	16	206979	109257	97722	41331
14	RuniSaidp	263.15	33	372579	197632	174947	70355
15	Sonbarsa	176.33	20	251248	131668	119580	50613
16	Suppi	85.75	11	122239	64616	57623	23477
17	Sursand	145.06	18	209945	109991	99954	40297
	Urban			162082	86439	75643	25491
	Total	2185.2	273	3423574	1803252	1620322	663227

Source-District Census Handbook - 2011

As per the 2011 Census, the total population of the district stands at 34, 23,574 with a population density of 1492 persons per Sq Km. Sitamarhi is the 9th densely populated district in the state with1, 492 persons per sq.km as against the state's 1,106. Sitamarhi ranks 31st in terms of sex-ratio (899) against the state's 918. Sitamarhi ranks 26th in terms of child sex-ratio (930) against state's 935. There are 26 uninhabited villages (out of 834 total villages) in the district of Sitamarhi.

1.4 Physiographic Setup and Geomorphology

The district forms a part of Indo-gangetic plain. It is a flat alluvial terrain and devoid of any prominent topographical irregularity. The main slope of the ground is towards south. The only diversities can be seen on the surface are caused by the fluvial action of rivers. The uniformity of flatness is quite often disturbed by marshy land, natural depression etc.As the district mainly lies in flood plain area of the Bagmati river, hence flood is the main natural disaster here.

Broadly the entire tract can be divided as alluvial tract, upland tract and diara land.

Alluvial Low Tracts: They are most commonly found in the immediate vicinity of river Gandak which is subjected to periodical submergence by flood water.

Upland tract: These are older alluvial plain which lie quite above the flood limit of the river. They are considered very suitable for cultivation.

Diara Land: They are nothing but heap and sands, brought by rivers during flood and usually found in the bed of the river Gandak. There is a gradual slope from the north western to south eastern direction. The general slope varies between 70.69 mt MSL to 57.09 mt MSL. In general the surface gradient is about 0-11 m/km in the area.

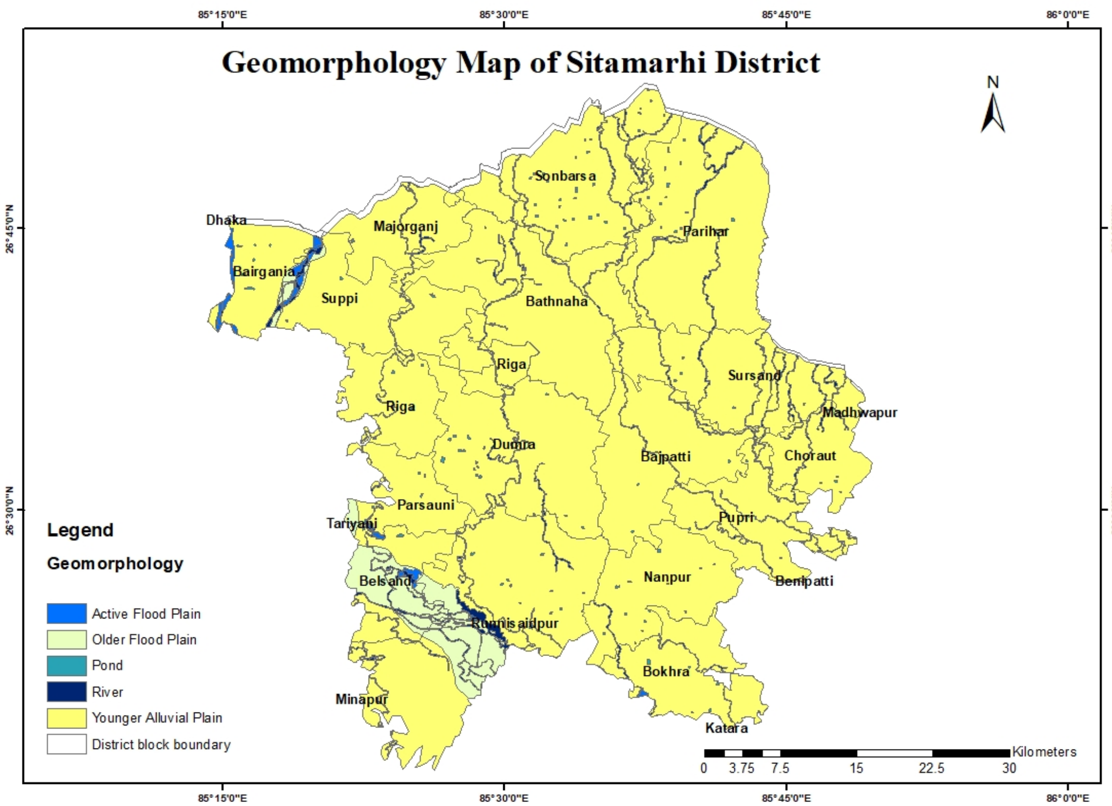


Figure 2: Geomorphology Map

The map shows that most part of Sitamarhi district shows younger alluvium deposit & flood plain deposit found in eastern part along the course of Bagmati river.

1.4.1Rainfall-spatial and Temporal Distribution

The climate of the district is sub-tropical to sub-humid in nature. Hot weather commences from the month of March when hot westerly winds often accompanied by dust storms begin to blow during the day while during the night the wind blows from east and the temperature is comparatively low. Rain sets in during the third week of June and continues till September. Rainfall normally ranges from 1100 to 1370 mm. The district also receives some winter rains which improves the prospects of rabi cultivation. Humidity is recorded between 68 and 83%.

Table 3: Rainfall Departure

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*
2016	0	-100	0	-100	0	-100	0	-100	50.5	-29	115.6	-42	191.6	-52	61.6	-80	322.6	79	2.2	-97	0	-100	0	-100
2017	0	-100	0	-100	11.8	19	51.1	100	57.1	-20	110.8	-45	325.2	-18	365.7	19	79.6	-56	1.9	-97	0	-100	0	-100
2018	0	-100	0	-100	4.2	-58	0	-100	38.8	-46	100.3	-50	405.8	2	275	-11	90.2	-50	0	-100	0	-100	0	-100
2019	0.8	-90	22.7	144	0.8	-92	63.7	149	23.8	-67	96.2	-50	621.4	62	56.5	-82	294.8	67	1.7	-97	0	-100	11.2	59
2020	14.8	85	22.7	144	18.7	95	104	306	108.1	51	331.9	74	685.1	78	225.7	-27	293.6	67	2.8	-96	0	-100	0	-100

Source:-IMDCustomized Rainfall Information System (CRIS) (imd.gov.in)

1.4.2 Land Use

The area is dominated by cultivatable land. About 20% area is not available for cultivation and about 2% of the area is fallow land. The table inferred that the principal utilisation of land is under agriculture and almost evenly distributed in the district.It occupies nearly 80% of the area reported for LULC (2185 Sq. Km). Area under uncultivable land excluding fallow land includes 2% of the area and forest cover 2% of the area reported. Other major land utilisations are the lands put under non-agriculture use. The Net sown area during the year 2019-20 was about 60% of the area reported. Total 60436 hectare area sown more than once. The cropping intensity during the year reported is about 143%. Landuse Statistics of the districts given is **Table-4.**

Table 4: Land Use Statistics

Name of the Block	No. of Gram Panchayats	Total Geographical Area(ha)	Area under Forest(ha)	Area under Wasteland(ha)	Area under other uses(ha)
Bairgania	8	6647	139	2976.2	32.38
Bajpatti	19	13932	345	6923.96	688
Bathnaha	21	19995	640	2776.2	2372
Belsand	9	25630	425	5199.69	608
Bokhara	11	8591	250	2826.91	400
Charaut	7	6864	207	562.58	106
Dumra	28	18537	655	6969.6	984
Majorganj	8	14754	208	4814.89	502
Nanpur	17	19349	406	6292.17	510
Parihar	27	21221	415	4468.04	890.7
Parsauni	7	5914	240	1219.67	340
Pupri	13	16365	340	1344.48	120
Riga	16	14676	355	2788.04	343
RunniSaidpur	33	26315	699	6961.87	2524
Sonbarsa	20	17633	414	6338. 72	850
Suppi	11	8840	130	2827. 78	330
Sursand	18	14506	498	6329.68	1010
Total	273	2185.2	6376	71631.48	12622

Source: District Irrigation Report

A Map from the ‘Bhuvan’ website has also been downloaded on 10.05.2023 to observe the spatial distribution of land use land cover.

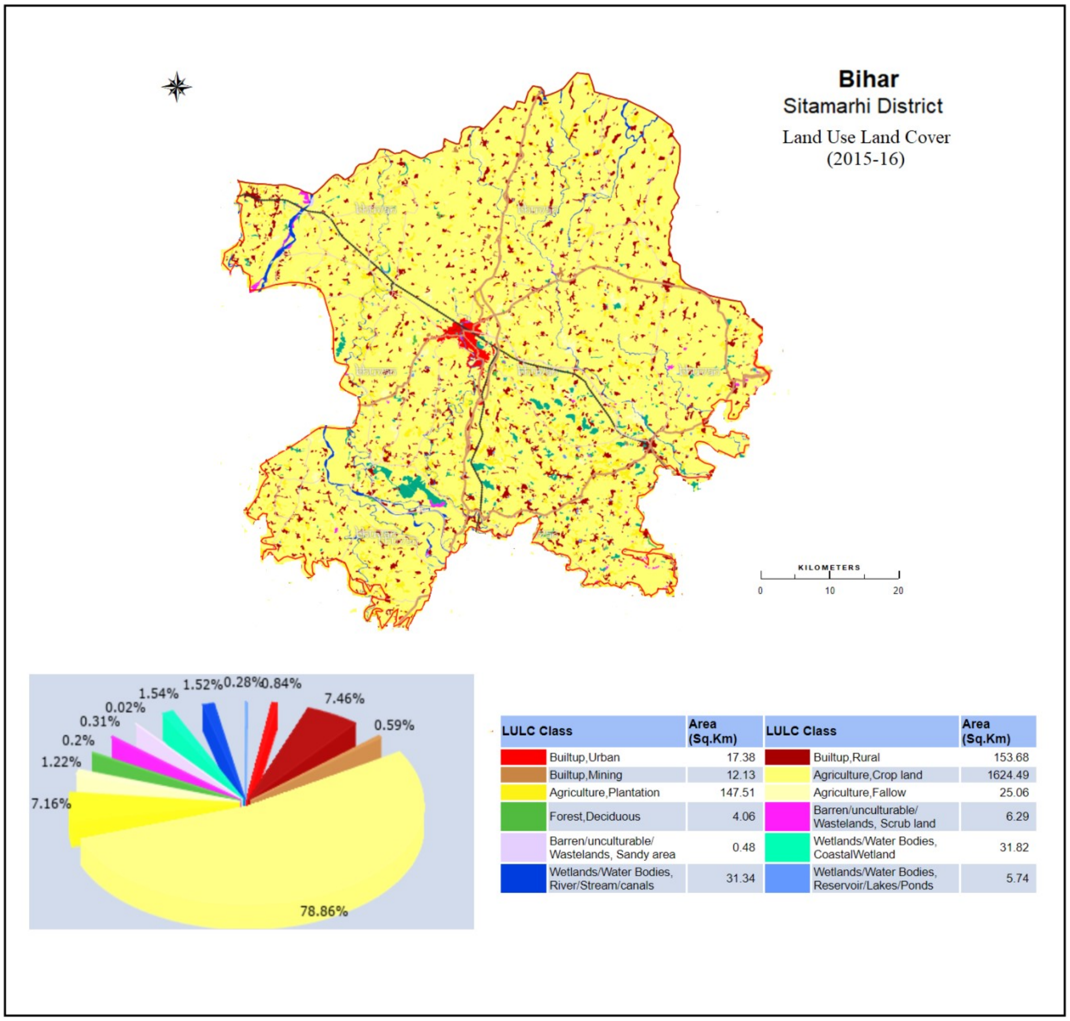


Figure 3: Land use & Land Cover Map

The map shows that mostly land are used for agriculture purpose almost 85% of area. Forest covers very less (~ 1%). About 7% lands fall under rural area category and 1 % for urban category.

1.4.3Soil

Entisols i.e., light friable loam with higher proportion of sand and silt are the younger soils which fringes the eastern and northern bank of Bagmati in the central and western part of the district. These soils are deficient in nitrogen and phosphoric acid but generally rich in potash and lime. The calcareous alluvial soils (Inceptisols) occur mostly in the northern part of the district. These are generally richer in lime content. In the southern part of the district, fairly matured soils with developed profiles (alfisols) which are subject to continuous leaching operation, leading to formation of calcareous nodules and ferruginous clay pans are found.

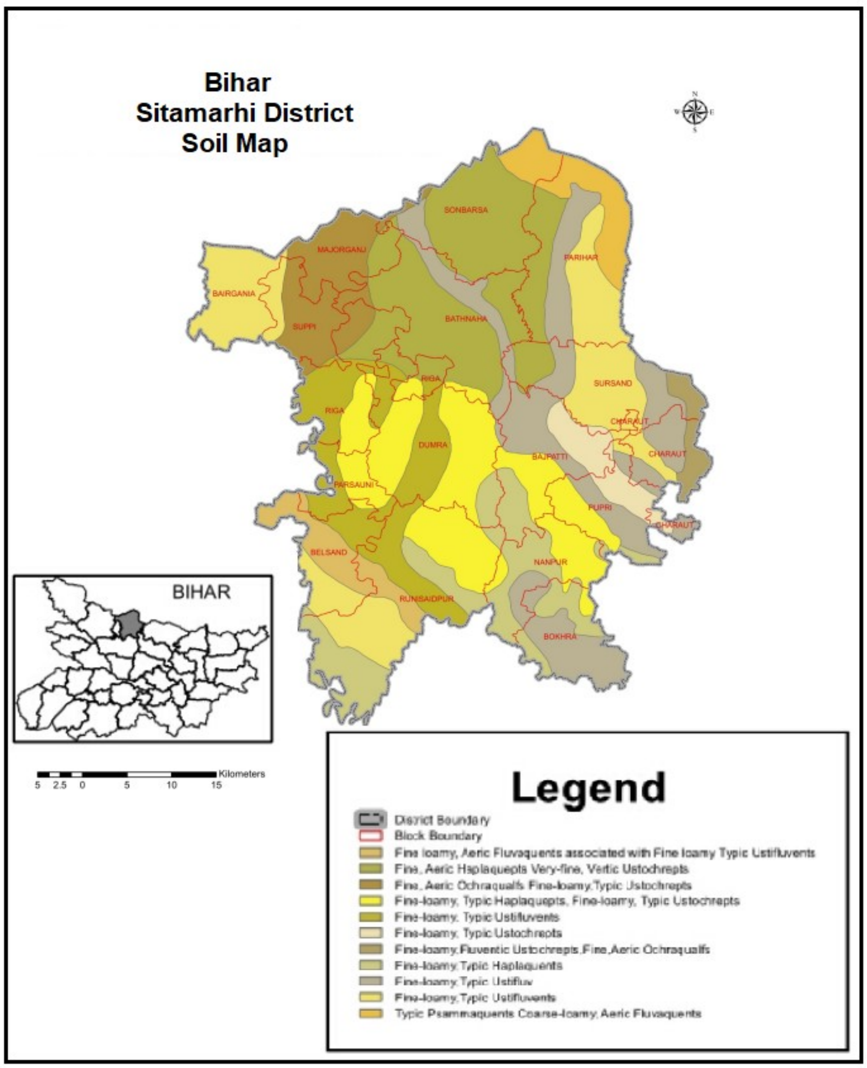


Figure 4: Soil Map

Source: District Irrigation Report

1.4.4Hydrology and Drainage

The rainfall in the region is received through South West Monsoon during June to end of September in the area. During the rest of the period the rainfall is sporadic or scanty. The average rainfall reported from the area is 744.1 mm. The district is characterised by the only sub-basin i.e. Bagmati .The drainage sub basin is utilised for hydrogeological and meteorological studies in water resource management. The district is principally drained by the Bagmati river which after emerging from the Himalayan foothill enters the district 3 Km north of Dheng Railway station. The Bagmati river flows in the N-S direction and take southeast turn from Kishunpur.

Apart from the major river Bagmati, there is a network of ephemeral streams such as Bagmati Purani Dhar, Lakhendei, adhwara and Mara etc. All these streams coming from Nepal loaded with silts. In course of time their bed gets silted and their course starts shifting. During the process of shifting these rivers leave behind cut off meanders, abandoned channels and marshes locally known as CHAURS. These chaurs are responsible for water logging in the area by spreading their span with onset of monsoon.

1.4.5Agriculture

Sitamarhi district's economy is primarily based on agricultural production. There are three agricultural seasons in the district viz., Rabi, Kharif and Zaid. Rabi season starts in October or November and harvesting is done in March and April. The important crops are Rice, wheat, maize, mustard, toria, greengram and lentil etc. Kharif season starts in July and the harvesting is done in October or November. The millets, maize, arhar, rice and sugarcane etc. are the main crops of Kharif season. Zaid crops which are of relatively little importance, occupy the fields from April to July.

Table 5:Area wise, crop wise irrigation status

Crop Type	Kharif Area (Ha)		Rabi Area (Ha)		Summer Area (Ha)	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Cereals	99282	21794	78189	17164	0	0
Coarse	10288	2257	15439	3882	477	108
Pulses	1835	406	9938	2182	588	136
Oil seeds	1501	329	8458	1859	23	7
Fibre	0	0	0	0	0	0
Any other	0	0	0	0	0	0
Horticulture& Plantation (Annual)					18400	10813

Source: District Irrigation Report

Out of this, the maximum extent of irrigated area is in Rabi season (51,452 ha) followed by Kharif season (27,945 ha) and Out of the total area under cultivation in the district, 43.5 percent area (1, 21,076 ha) is covered by cereals crop during Kharif season, 34.3 percent (95,353 ha) during Rabi season and nil during summer season. In case of Pulses, it occupies 5.4 percent (15,085 ha) of the gross cropped area of the district. During Kharif season, 0.8 percent of the gross cropped area of the district is covered by pulses while the same during Rabi and summer are 4.4 percent and 0.3 percent respectively. The area under Oilseed is limited to the tune of 4.4 percent (12,177 ha) of the gross cropped area of the district. Most of the pulses are cultivated during Rabi season. No Fibre crops are grown in the district. Horticulture and Plantation occupies 0.7 percent (29,213 ha) of the Gross cropped area most of which 64 percent is irrigated.

Table 6:Area under Crops in Sitamarhi District for the Year Ending 2019-20

State/Crop/District	Season	Area (Hectare)	Production (Tonnes)	Yield (Tonnes/Hectare)
Bihar				
Arhar/Tur				
1.SITAMARHI	Kharif	59	134	2.27
Total - Arhar/Tur		59.00	134	2.27
Barley				
1.SITAMARHI	Rabi	9	4	0.44
Total - Barley		9.00	4	0.44
Castor seed				
1.SITAMARHI	Kharif	69	66	0.96
Total - Castor seed		69.00	66	0.96
Coriander				
1.SITAMARHI	Whole Year	52	47	0.90
Total - Coriander		52.00	47	0.90
Garlic				
1.SITAMARHI	Whole Year	40	61	1.53
Total - Garlic		40.00	61	1.53
Khesari				
1.SITAMARHI	Rabi	103	85	0.83
Total - Khesari		103.00	85	0.83
Linseed				
1.SITAMARHI	Rabi	87	75	0.86
Total - Linseed		87.00	75	0.86
Maize				
1.SITAMARHI	Rabi	3335	18619	5.58
	Summer	277	777	2.81

	Total	3612	19396	5.37
Total - Maize		3612.00	19396	5.37
Masoor				
1.SITAMARHI	Rabi	2400	3115	1.30
Total - Masoor		2400.00	3115	1.30
Moong(Green Gram)				
1.SITAMARHI	Summer	3371	2350	0.70
Total - Moong(Green Gram)		3371.00	2350	0.70
Onion				
1.SITAMARHI	Rabi	143	2020	14.13
Total - Onion		143.00	2020	14.13
Other Rabi pulses				
1.SITAMARHI	Rabi	163	164	1.01
Total - Other Rabi pulses		163.00	164	1.01
Peas & beans (Pulses)				
1.SITAMARHI	Rabi	16	15	0.94
Total - Peas & beans (Pulses)		16.00	15	0.94
Potato				
1.SITAMARHI	Rabi	4552	61293	13.47
Total - Potato		4552.00	61293	13.47
Ragi				
1.SITAMARHI	Kharif	45	36	0.80
Total - Ragi		45.00	36	0.80
Rapeseed &Mustard				
1.SITAMARHI	Rabi	620	785	1.27
Total - Rapeseed &Mustard		620.00	785	1.27
Rice				
1.SITAMARHI	Autumn	14470	27512	1.90
	Winter	83978	178922	2.13
	Total	98448	206434	2.10
Total - Rice		98448.00	206434	2.10
Sesamum				
1.SITAMARHI	Kharif	42	36	0.86
Total - Sesamum		42.00	36	0.86
Sugarcane				
1.SITAMARHI	Whole Year	24565	1317149	53.62
Total - Sugarcane		24565.00	1317149	53.62
Wheat				
1.SITAMARHI	Rabi	88934	270832	3.05
Total - Wheat		88934.00	270832	3.05

Source:APY1_Public (dac.gov.in)

Sitamarhi district is part of Agro-climatic zone - I of Bihar. Fertile alluvial plain of the district coupled with favourable climate boosted agricultural activity. Rice is the main crop of Kharif season. Other Kharif crops are maize and potato grown in the district. Wheat is grown during Rabi season in the district. Other Rabi crops in the district are Pulses, Linseed, etc. Vegetables are also grown throughout the year. The cropping intensity of the district is 143%.

Table 7: Blockwise Agricultural details of Sitamarhi district, Bihar

Name of the Block	No. of Gram Panchayats	Gross cropped	Net Sown Area(ha)	Area Sown more than once(ha)	Cropping Intensity
Bairgania	8	6492.8	5517	976	118%
Bajpatti	19	10968.39	10760	208	102%
Bathnaha	21	8292.8	5517	2776	150%
Belsand	9	10535.2	5336	5200	197%
Bokhara	11	4896.87	2070	2827	237%
Charaut	7	4118.91	3556	563	116%
Dumra	28	18234.79	11265	6970	162%
Majorganj	8	5228.99	4441	4785	118%
Nanpur	17	10899.53	4607	6292	237%
Parihar	27	20651.19	16183	4468	128%
Parsauni	7	2471.2	1252	1220	197%
Pupri	13	9843.51	8499	1344	116%
Riga	16	14315.2	11527	2788	124%
RuniSaidpur	33	26000.39	19039	6962	137%
Sonbarsa	20	17427.6	11089	6339	157%
Suppi	11	3088.81	2608	481	118%
Sursand	18	14271.59	8042	6230	177%
Total	273	187743.8	131314	60436	143%

Source: District Irrigation Report

1.4.6Irrigation

There are two major source of irrigation in the district – canal and tube well (ground water) for the year 2018-19. The district forms part of the Gangetic Plains and is principally drained by Bagmati River which enters the district after emerging from the Himalayan foothills and brings in huge amount of silt. The network of other ephemeral streams which drains the district is Lakhandei, Adhawara and Marha etc all of which enters the district from Nepal.

Tube wells are main source of groundwater withdrawal for irrigation in the district.During the year 2012-13(5th MI Census) tube wells are categorised based on their depth. Depth of the shallow tube well is down to 35 m bgl, medium tube well is between 35 to 70 m bgl and deep tub well is more than 70 m bgl.

However, in the tablethe depth range of 35-40 m of 5th MI census data has been merged to create the depth range of 20-40 m. There is no well has been categorised within the depth range of 35-40 m during 5th MI census.

Table 8: Number of tube wells in 5th MI Census

SN	Block	5th MI Census				
		00-20	20-40	40-60	6070	>70
1	Bairgania	3	194	0	0	0
2	Bajpatti	87	1792	0	0	0
3	Bathnaha	69	1122	0	0	0
4	Belsand	3	59	0	0	0
5	Bokhra	7	308	0	0	0
6	Choraut	20	370	0	0	0
7	Dumra	70	939	0	0	7
8	Majorganj	24	323	0	0	0
9	Nanpur	3	537	0	0	0
10	Parihar	4	1140	0	0	0
11	Parsauni	12	251	0	0	0
12	Pupari	0	55	0	0	1
13	Runnisaidpur	2	203	0	0	0
14	Sonwarsa	0	2	0	0	1
15	Sursand	0	1	0	0	1
16	Riga	0	0	0	0	0
17	suppi	0	0	0	0	0
	Total	304	7296	0	0	10

The above table shows blockwise no. of wells in 5th mi census. Number of shallow tube wells increased in 5th MI census.

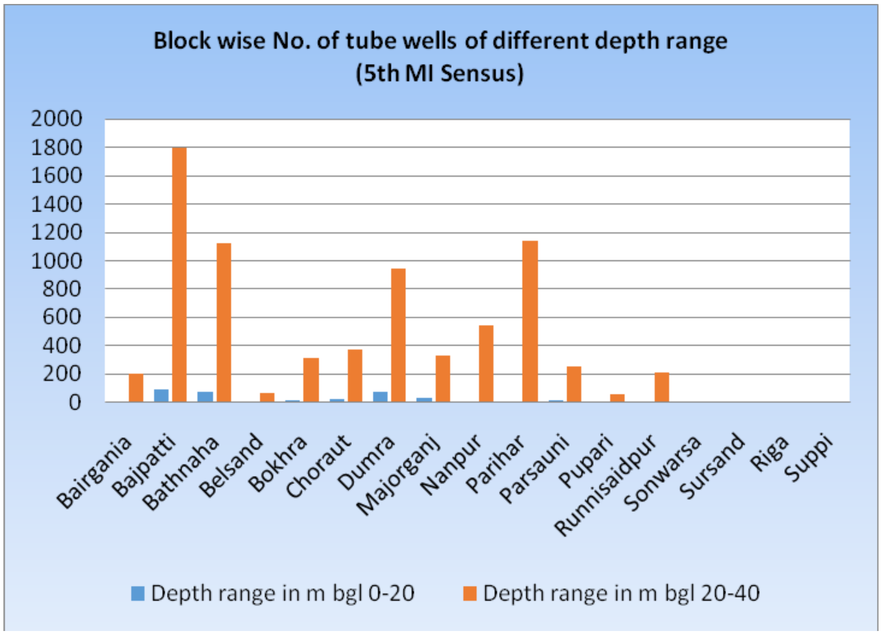


Figure 5: Block wise and depth wise Number of tube wells in 5th Minor Irrigation Census

Thus, there may be more dependency on stream and river network for irrigational purpose and also on shallow potential aquifer as there are very few canal network found.

1.4.7 Climate

The district of Sitamarhi is known for its hot summers and severe winters. The summer season starts from the end of March with average temperature of about 35º C and maximum temperature of 46º C in the months of May and June. In winter season the temperature goes down to 4 - 5º C. Lowest temperature is reported from the end of December to January.

CHAPTER 2

2. DATA COLLECTION AND GENERATION

The primary Data such as water level, quality, geophysical data and exploration details available with CGWB has been collected and utilised as baseline data. The Central Ground Water Board has established a network of observation wells under National Hydrograph Network programme to study the behaviour of ground water level and quality of ground water in the district. To understand the sub–surface geology, identify the various water bearing horizons including their depth, thickness and compute the hydraulic characteristics such as transmissivity and storativity of the aquifers, exploratory drilling programme was carried out by Central Ground Water Board. For other inputs such as hydrometeorological, Landuse, cropping pattern etc. were collected from concerned state and central Govt departments and compiled.

2.1 Data collection and Compilation:

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

i. *Hydro geological Data:* Water level data of 28 key wells and historical water level trend of monitoring wells were collected and compiled.
ii. *Hydro chemical Data*: To evaluate the quality of ground water, 23 samples were included which have been collected in the year 2022 from dug wells
iii. *Exploratory drilling:* Total10 exploratory wells, located in Sitamarhi district have been taken forthe present study.
iv. *Hydro meteorological Data:*Rainfall data for the study has been taken for the Indian meteorological Department...
v. *Land use and cropping pattern data:* The data of land use and cropping pattern obtained from the District Irrigation Plan.

2.2 Data Generation

The data has been generated and collected for various components as given below:

2.2.1 Ground water Monitoring Wells:Total 28 wells have been monitored toassess the ground water scenario of shallow aquifer (Aquifer-I) of the area. The depth of these dug well varies from 1.40 to5.30mbgl.

2.2.2 Ground Water Exploration:10 exploratory well constructed in the district has been taken for study.

The area is underlain by thick deposits of quaternary alluvium deposited by the river Bagmati and its tributaries flowing from north to south. No basement has been encountered down to the explored depth of 310 m in exploratory drilling. Sub-surface lithology shows that there is alternating layers of sand silt and claywith some zones having sand and clay mixed with Kankar.

2.2.3 Ground Water Quality:To assess the quality of ground water, 23 samples were collected and analysed from dug wells representing Aquifer – I

2.2.4 Thematic Layers:The following thematic layers were also generated which supported the primary database and provided precise information to assess the present ground water scenario and also to propose the future management plan.

1. Drainage
2. Geomorphology
3. Elevation
4. Land use
5. Geology & structure etc.

CHAPTER 3

DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation, thematic layers was interpreted and integrated. Based on this the various aquifer characteristic maps on hydrogeology, aquifer wise water level scenario both current and long term scenarios, aquifer wise ground water quality, sub-surface disposition of aquifers by drawing fence and lithological sections, aquifer wise yield potential, aquifer wise resources, aquifer maps were generated and as discussed in details.

3.1 Geological set-up

The entire district consists of a thick pile of unconsolidated sediments of Quaternary period varying in age from late pleistocene to recent. Geological Survey of India (GSI) has given classification of Quaternary alluvium based on topography, drainage and nature of alluvial deposits.

Startigraphic Succession

The general stratigraphic succession found in Sitamarhi district is given below.

Table 9: Stratigraphic Succession of Sitamarhi District

Geological Time	Formation	Lithology
Holocene to Recent	Diara Formation	Unconsolidated sand, soil & clay
Holocene	Jaynagar Formation= Vaishali formation	Unoxidised unconsolidated clayey silt
Late Pleistocene to Early Holocene	Hajipur Formation	Oxidised Yellowish brown silty clay impregnated with caliche nodules

The Hajipur formation is the oldest formation exposed in the district. The formation mainly occupies palaeo levee areas and its age ranges from Late Pleistocene to Early Holocene. Vaishali formation occupies the older flood plains of the district. The Diara formation is the youngest formation and it occupies the recent flood plain area.

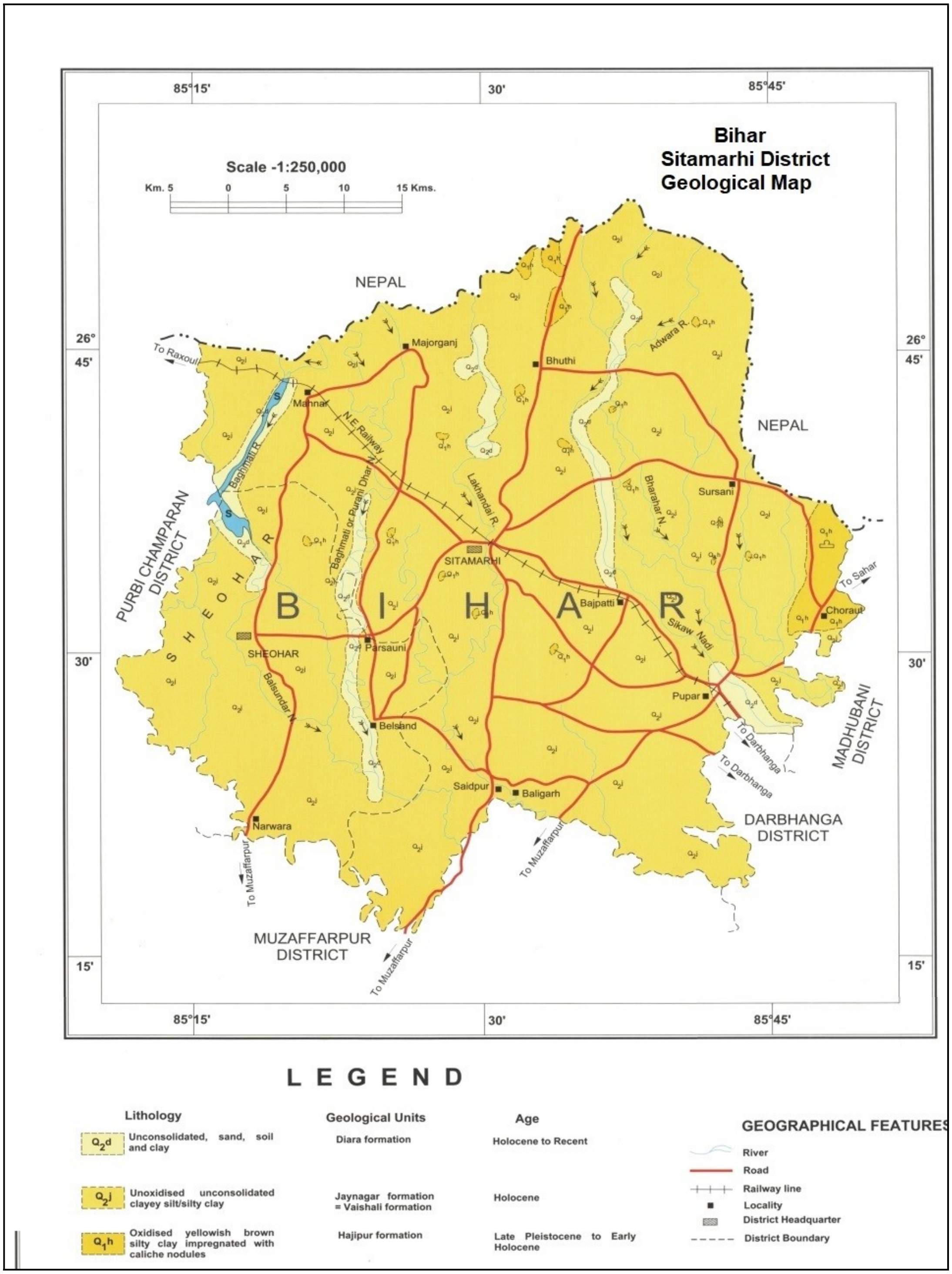


Figure 6: Geological Map

Source: DRM G.S.I.

The northeast extension of NE-SW trending West Patna Fault is expected to pass through the central part of Muzaffarpur district and southern part of Sitamarhi district. Also the NW-SE Sitamarhi Fault which is followed by the course of Baghmati River traverses the area. It is reported that faults have impacted the subsurface structures, drainage network, channel flows and fluvial geomorphology, overall which control the disposition and granularity of the aquifers.

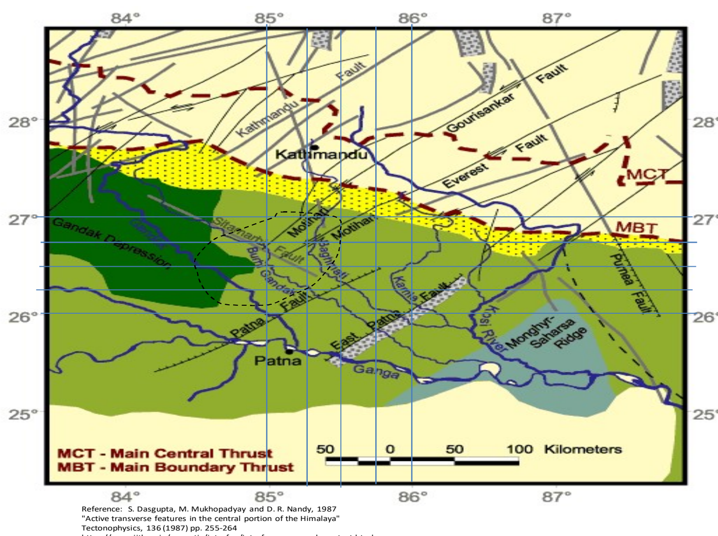


Figure 7: Map showing tectonic elements of North Bihar

3.2 Hydrogeology

Rainfall is the primary source of ground water recharge. Out of total rainfall about 20-30% goes to ground water and rest are evaporated, absorbed by vegetation and recharge to surface runoff. Apart from rainfall influent streams also recharge to the ground water in the district. The quaternary alluvial sand deposits from the major aquifer of the district.

The entire alluvial tract is exposed to fluvial action. Ground water occurs under unconfined conditions in the phreatic aquifer, which is generally disposed within 70 m below ground. Aquifers situated at deeper levels have ground water levels under semi confined to confined condition.

The hydrogeological map of the district is shown in Fig. below.

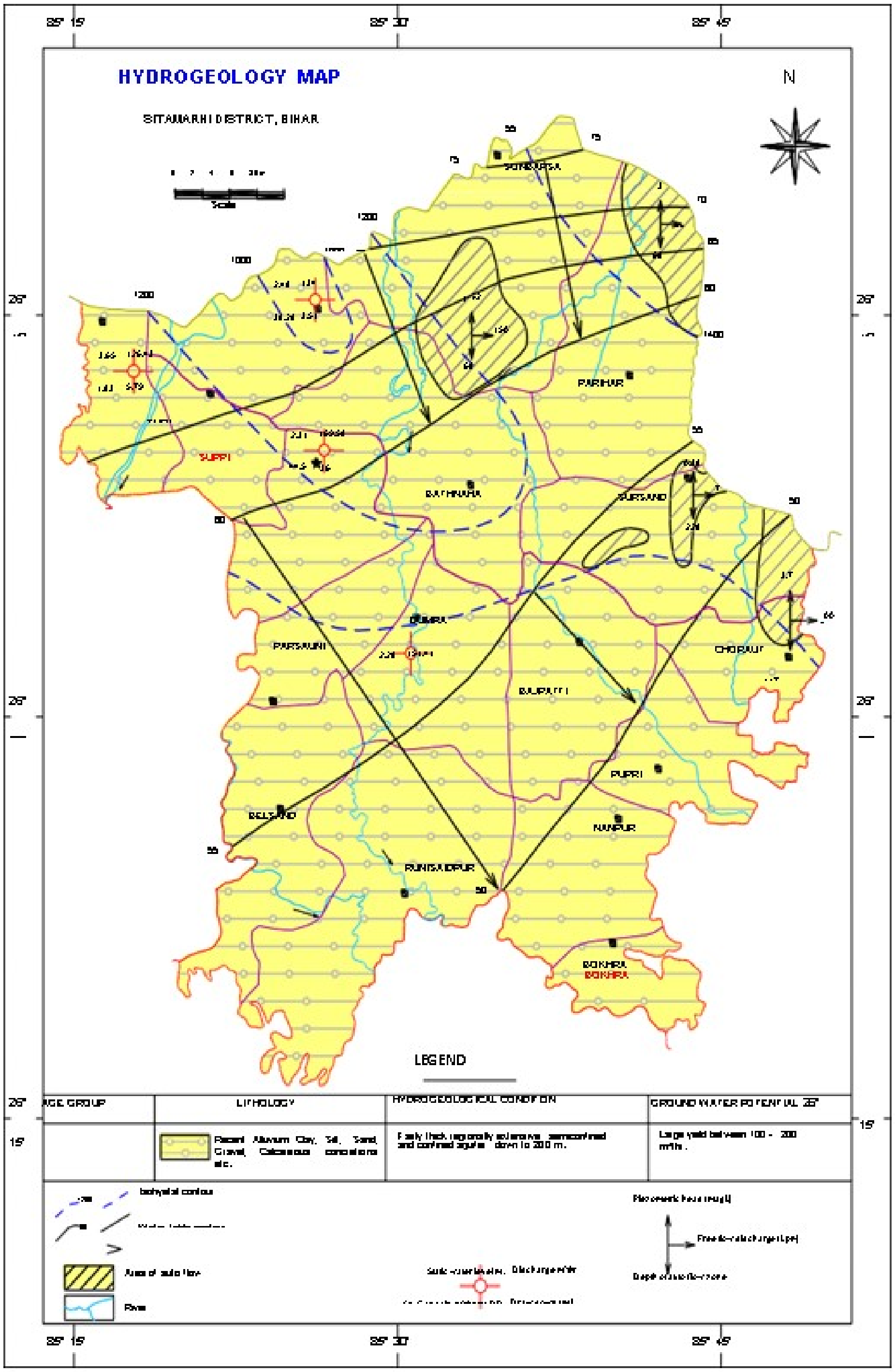


Figure 8: Hydrogeological map of the district

Source: Ground Water Information Booklet ,CGWB

3.2.1 Depth to Water Level

Depth to water level is influenced by various factors like topography, proximity of drainage channel, and surface water bodies. Based Maps are prepared in GIS environment, using MapinfoTM and Vertical MapperTM softwares by taking collected field data (NHS). Data interpolation is done through Natural Neighbour Interpolation method. The data then converted to delineate area in the classes of 0-2, 2-5 and 5-10 m bgl water level and for water level fluctuation 2 meter interval has been taken.

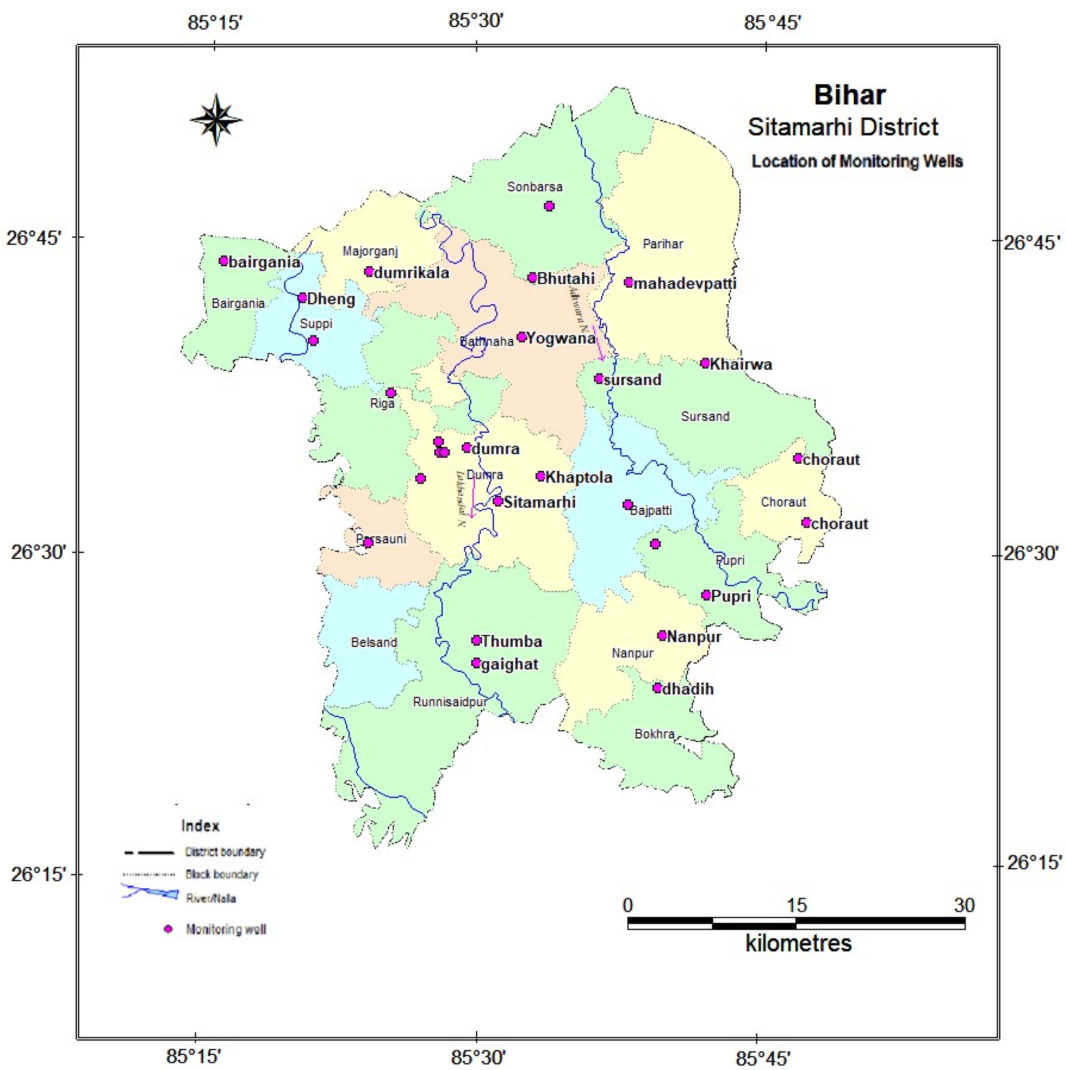


Figure 9: Location of Monitoring Wells

Depth to water level – May 2022

During pre-monsoon period observed water level ranged from 1.14 to 5.20 m bgl. The average water level calculated to be 2.97 m bgl. Major part of the area is categorized under 2-5 m bgl water level. Shallowest water level category of 0-2 m bgl has been observed in 7locations in 6 blocks. There is 01 wells located in Suppi block where water level has been observed more than 5 m bgl.

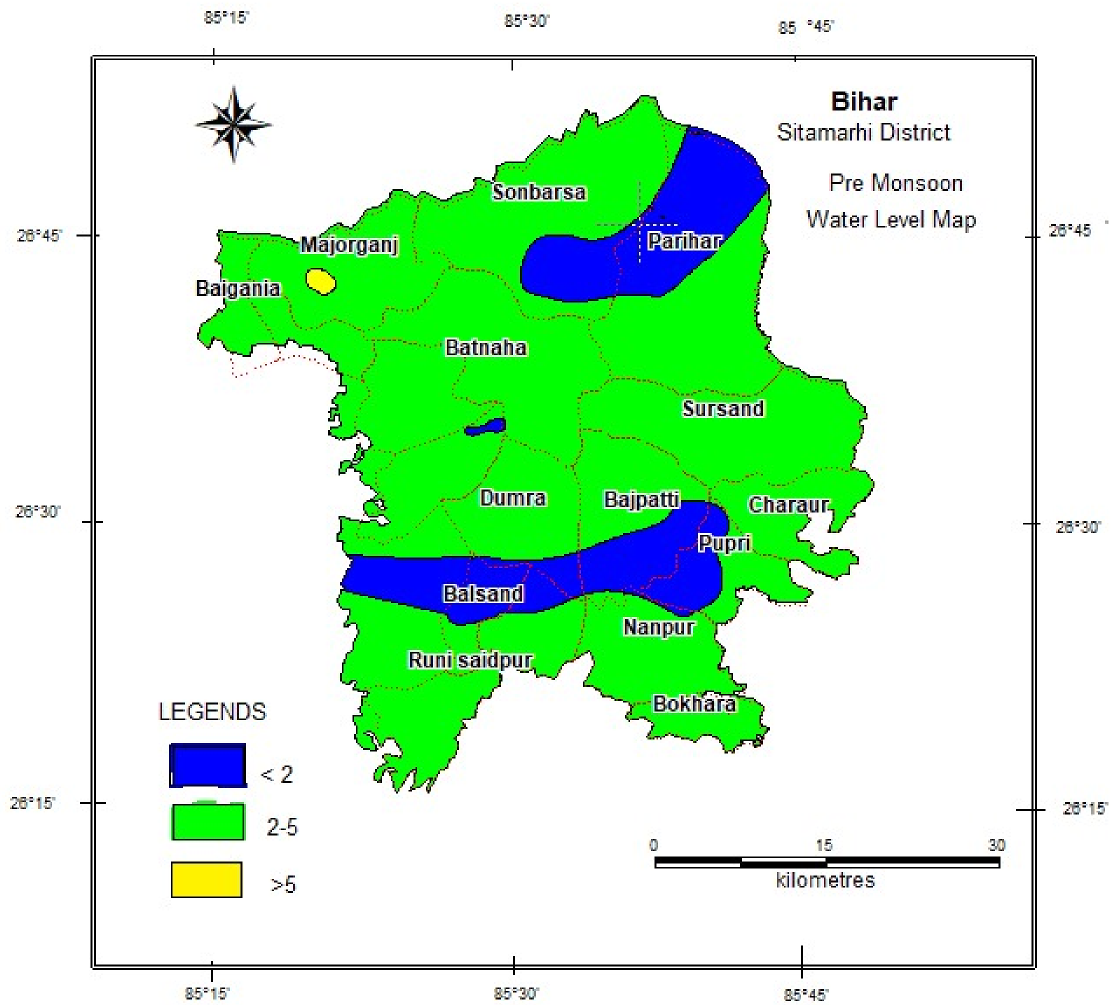


Figure 10: Depth to water level- May 2022

Depth to water level – November 2022

The water level monitored during month of November ranged from 0.73 to 3.4 m bgl. The Southern and western and middle part of the district areas (~45%) have shown category of 2 and 5 m bgl. Rest of the area (~55%) of the district is categorized < 2 m bgl.

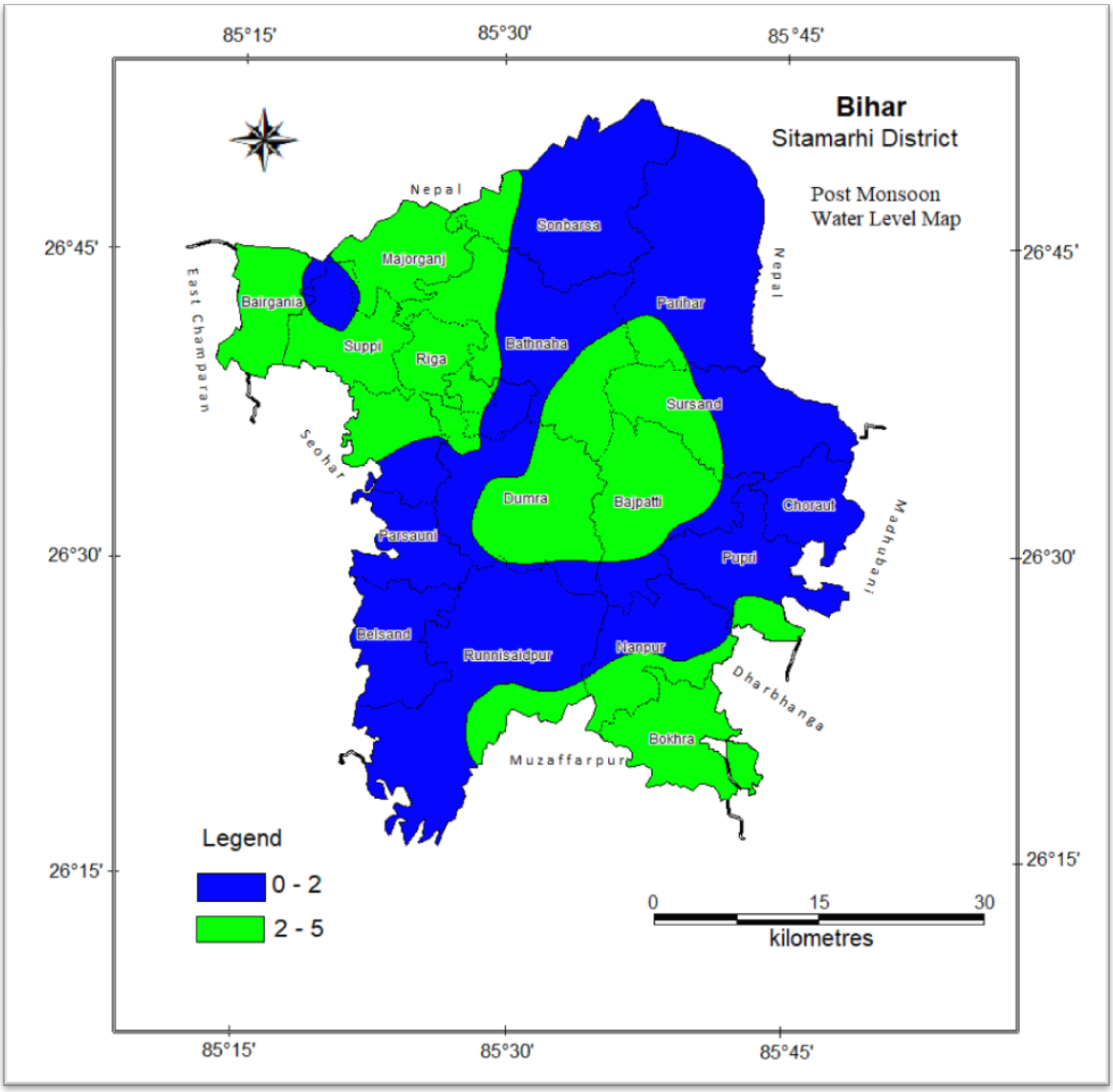


Figure 11: Depth to water level- November 2022

Monsoon fluctuation – November 2022 w.r.t. May 2022

Besides minor diurnal changes in the level of ground water, the water level is mainly influenced by the seasonal fluctuation, which are conspicuous and in direct response to change in ground water storage. Water level data monitored during Nov. 2022 has been compared with the water level data of May 2022 to know its monsoon fluctuation. The monsoon fluctuation of water level has been ranged from -0.13 to 3.92 m. About 82% area of the district has shown rise in water level up to 2 m. The area, in north-western about 12% area part of the district and a patch has been categorized more than 2 m rise. The area in northern part, about 6% area in Parihar & Bajpatti block shown falls in water level as monsoon fluctuation.

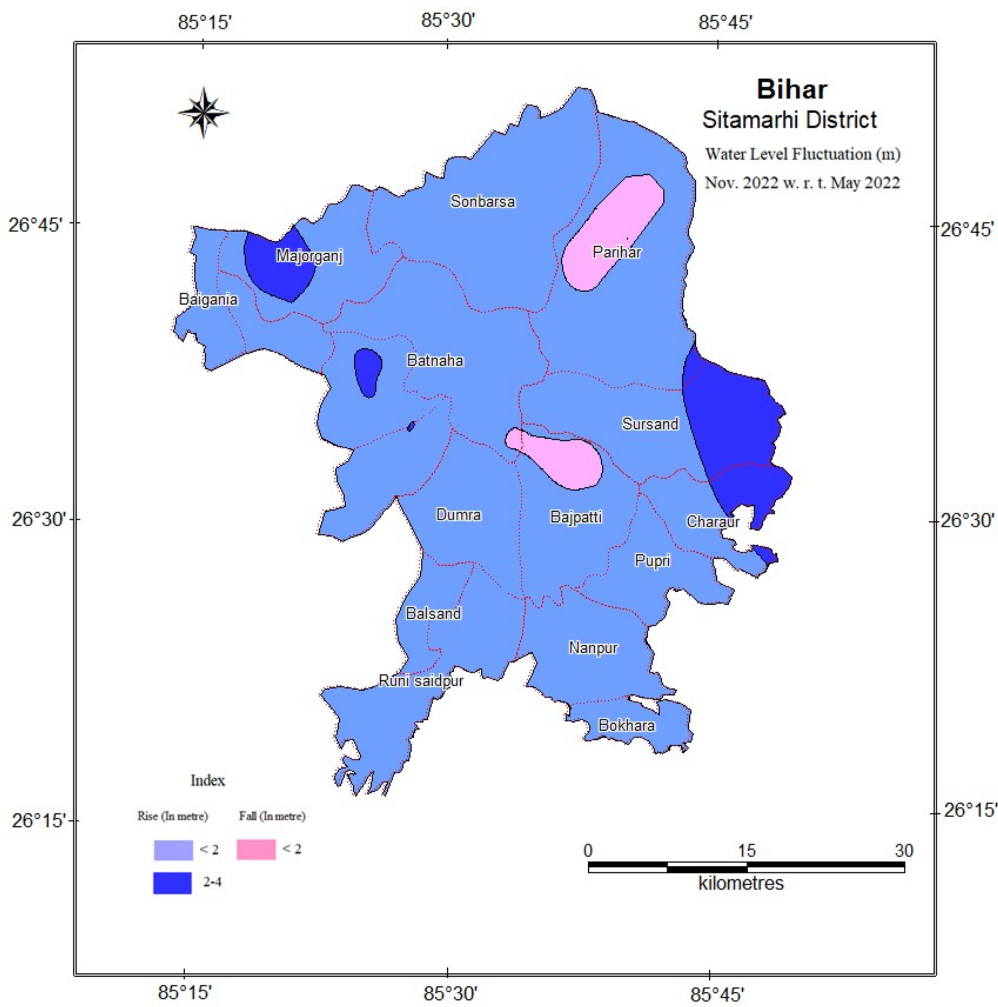


Figure 12: Water level Fluctuation Map

Water Table contour

The water level w.r.t. mean sea level monitored during Nov. 2022 has been taken to prepare the water table contour map. Blocks namely Bairgania and Sonbarsa who share border with Nepal has maximum contour value, whereas Runnisaidpur, Nanpur, Bokhra shows minimum contour value. The slope of water table is little undulating, but more or less it follows the topography. The contour map reveals that ground water flow direction almost follow the topography of the area, gently sloped from NW to SE direction with very little variation at Bairgania and Suppi where slope is west to east.

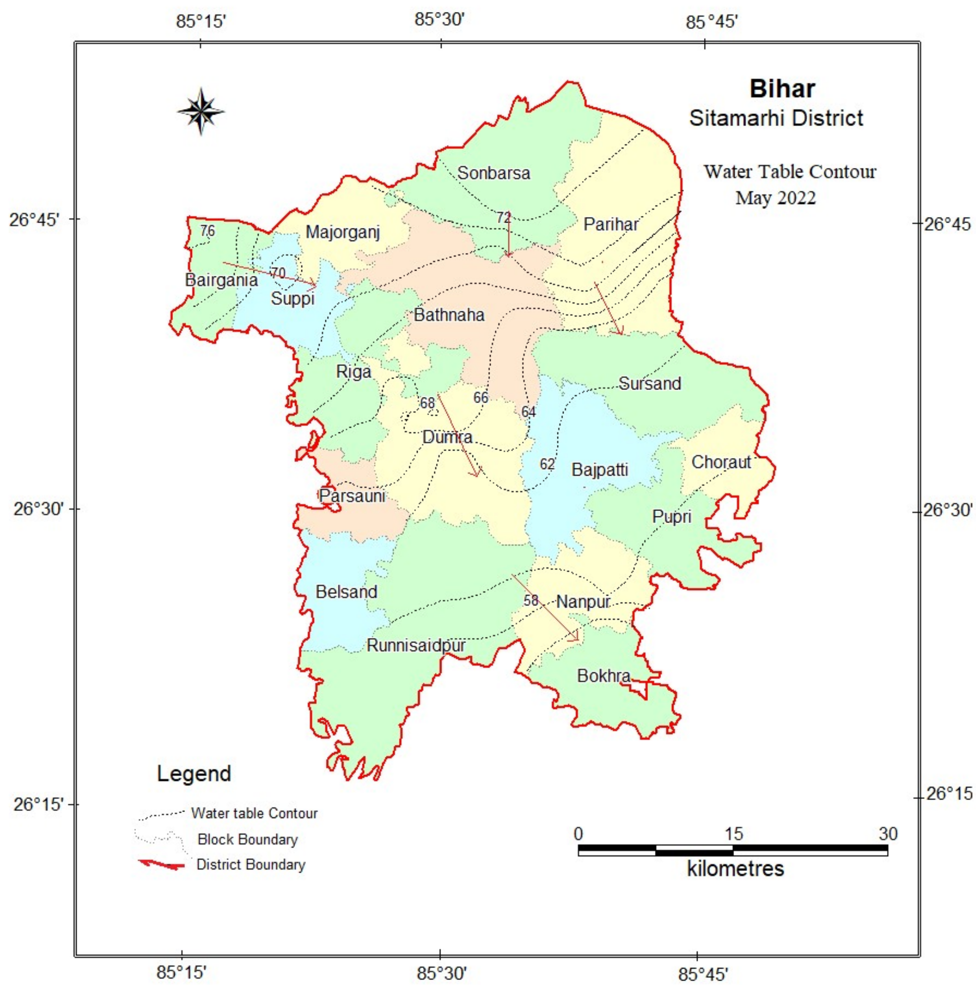


Figure 13: Water table Contour Map- May 2022

Hydrograph Analysis (Water level trend)

Analysis of two hydrograph network stations located at Jogwana bazar and Sursand were carried out using GEMS software and analyzed for the period from 2010-2019 (Figure). It is observed that the long-term water level trends during pre and post-monsoon seasons are declining at places, but not significantly.

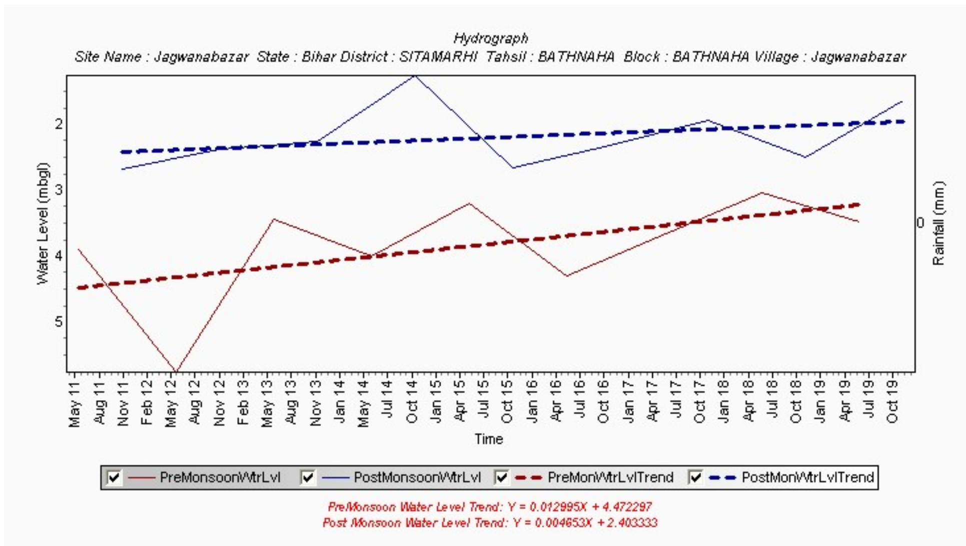


Figure 14: Water level trend at Jogwana bazar, Sitamarhi district

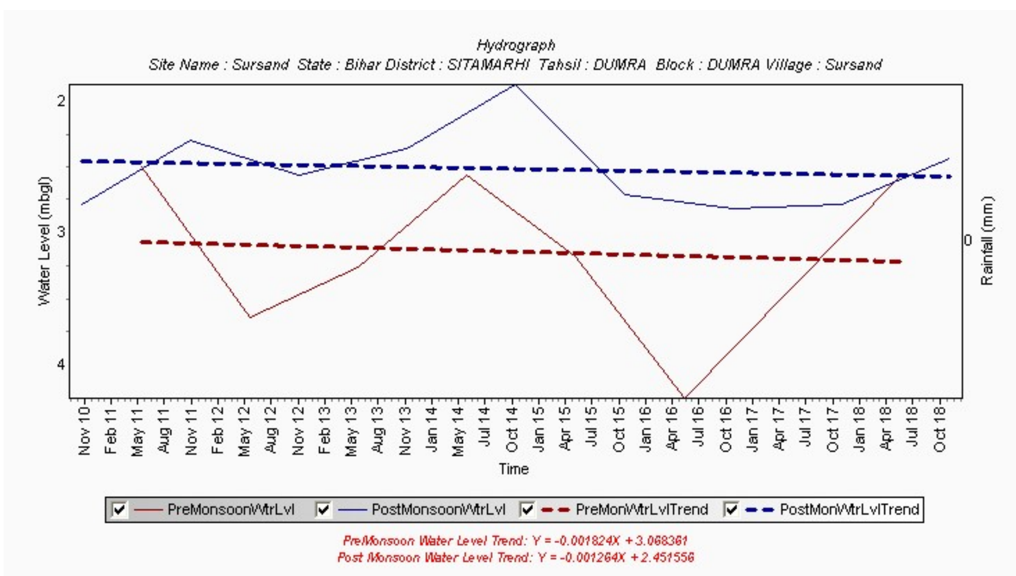


Figure 15: Water level trend at Sursand, Sitamarhi district

3.3 Ground Water Quality

The suitability of groundwater towards drinking and irrigation purpose is governed by its quality and quantity. The rapid increase in industrialization and continuous environment degradation is poorly affecting the water quality. The factors affecting the chemical quality of ground water could be either physical or chemical, topography of the area, microorganism growth, climatic conditions or maybe anthropogenic. A total of 23 samples were collected from Sitamarhi district from various locations during Pre-Monsoon 2022 and were analyzed for basic parameters in the chemical lab of CGWB MER. . All the samples were analyzed as per standard methods (APHA 2005) for the determination of pH, EC, CO_3^{2-}, HCO_3^-, Cl^-, F^-, NO_3^-, SO_4^{2-}, TH, Ca^{2+}, Mg^{2+}, Na^+ and K^+.

Following observations were made from the analysis results **(Annexure II)**-

pH: It is one of the most important parameters determining the alkaline/acidic nature of water on a scale range of 0-14. In the collected ground water samples, the pH value ranges from 7.6 to 8.28 with an average 7.97 indicating the ground water is alkaline in nature.

Electrical Conductivity (EC): It is a measure of the total mineralization occurring in water and indicates degree of salinity. It is influenced by the presence of dissolved cations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe, Al^{3+} etc.) and anions (Cl^-. NO_3^-, PO_4^{3-}, SO_4^{2-} etc.). The electrical conductivity (EC) values were in the range of 303-2040 µS/cm with an average value of 522.61 µS/cm, respectively. In all samples the EC values were well within permissible limit of 3000 µS/cm.

Total Hardness (TH)

Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations and is usually expressed as milligrams of calcium carbonate per litre

Table 10:Hardness Classification of ground water sample of Sitamarhi District

Hardness (mg/L)	Water Class	% Sample
0-75	Soft	0
75-150	Moderately hard	52.17
150-300	Hard	47.83
>300	Very hard	0

The TH in the district ranges from 95-615 mg/L, with an average value of 177.61 mg/L.

Nitrate

Nitrate contamination occurs in surface water and groundwater. Irrigation water containing fertilizers is a common culprit as are septic systems, wastewater treatment plants, milk industries and natural conditions. The nitrate concentration in the district ranges from 0.65-13.31 mg/L, with an average value of 2.45 mg/L. No samples collected from Sitamarhi have shown high Nitrate value over its acceptable limit.

Chloride:

The concentration of chloride (Cl^-) controls the taste of the water and its maximum permissible limit is 250 mg/L by BIS, (10500- 2012). The chloride concentration in water samples collected from Sitamarhi district varies between 7.1 and 287.55 mg/L (Avg. 29.48 mg/L). Out of 23 samples only 01 sample had chloride concentration greater than the permissible limit for drinking purpose.

Carbonates and Bicarbonates:

In all collected water samples the concentration of carbonates (CO_3^{2-}) was nil. Concentration of bicarbonate (HCO_3^-) varies from a minimum of 146.4 mg/L to a maximum value of 616.1 mg/L, with an average value of 250.63 mg/L.

Sulphate

Sulphate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. High sulphate levels in drinking water results in gastro-intestinal disorders, and hence BIS (2012) has prescribed 200 mg/L as acceptable limit and 400 mg/L as permissible limit for sulfate in absence of alternate source for drinking and other domestic usage.

The concentration of sulphate in the district ranges from 0 to 88.72 mg/L with average values of 6.70 mg/L. In all sample sulphate concentration is well within permissible limit and is good for drinking as well as irrigational purposes.

Fluoride

In groundwater, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. The permissible limit for fluoride in drinking water as suggested by BIS (10500- 2012) is 1.5 mg/L. Excess fluoride intake causes different types of fluorosis, primarily dental and skeletal fluorosis. In collected groundwater samples fluoride was found in the range of 0.10 to 0.58 mg/L, with an average value of 0.30 mg/L respectively. In all samples the concentration of fluoride was within the permissible limit of 1.5 mg/L.

Calcium and Magnesium ions

The dissolved solids like Calcium and Magnesium in ground water are essential to human nutrition and beneficial to the heart and nervous system of human beings respectively. The acceptable/maximum permissible limits for Calcium and Magnesium in drinking water are 75/200 mg/L and 30/100 mg/L respectively.

In collected samples the concentration of calcium ranges between 4 to 130 mg/L, with an average value of 33.39 mg/L. The concentration of magnesium ranges from 9.72 to 70.47 mg/L, with an average value if 22.87 mg/L.

Sodium

Sodium concentration in the district ranges between 5.14 and 156.7 mg/l, with an average value of 33.76 mg/L. High concentration is harmful for those suffering fromhypertension, cardiac and renal diseases.

Potassium

In the collected water samples the concentration of potassium was in the range of 1.17 and 40.5 mg/L, with an average value of 4.24 mg/L.

Suitability of groundwater towards Irrigation

The presence of sodium ions in irrigation water adversely affects the soil structure and its permeability by replacing calcium and magnesium in the soil. The United States Soil Laboratory (USSL) diagram explains the combined effect of sodium hazard and salinity hazard while classifying the irrigation water. This diagram classifies water samples into 16 categories based on its salinity and sodacity values. This diagram is plotted between sodium adsorption ratio value and electrical conductivity.

As can be seen from Figure 1, most of the samples were in the category of C2-S1 type, suggesting low sodium hazard and high salinity hazard. Most of the samples in study area were found suitable for irrigation exceptionally a value has been categorised under C4 class. It is an empirical approach hence the other factor such as dilution, drainage, soil type etc. may also be considered.

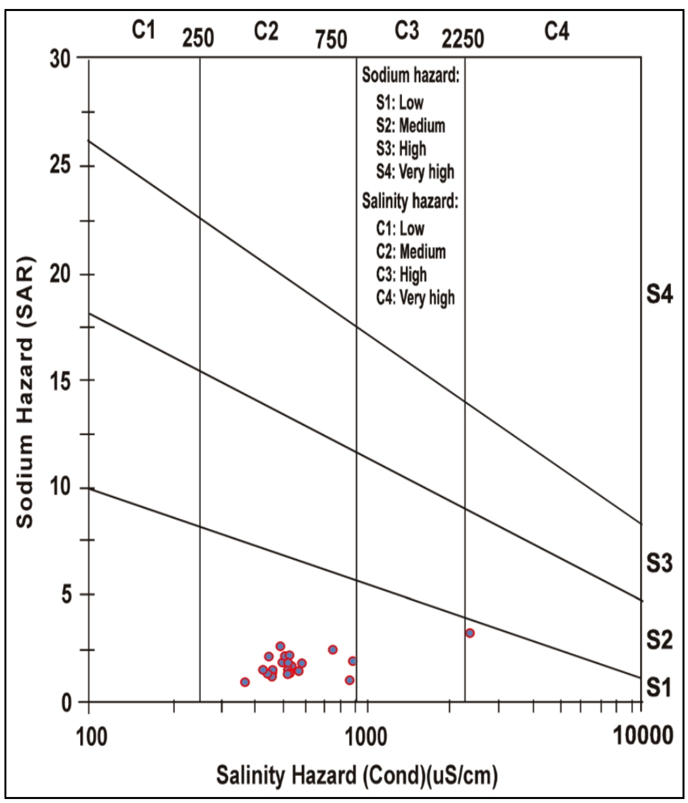


Figure 16: USSL diagram of samples collected from Sitamarhi district

A Wilcox plot can be used to determine the suitability of water for irrigation purpose. A Wilcox plot is given in Figure 2, which relates sodium percent with salinity. It can be seen that most of the samples were in the excellent to good and good to permissible category towards irrigation purpose. No samples were found in the permissible to doubtful category, doubtful to unsuitable category and unsuitable category.

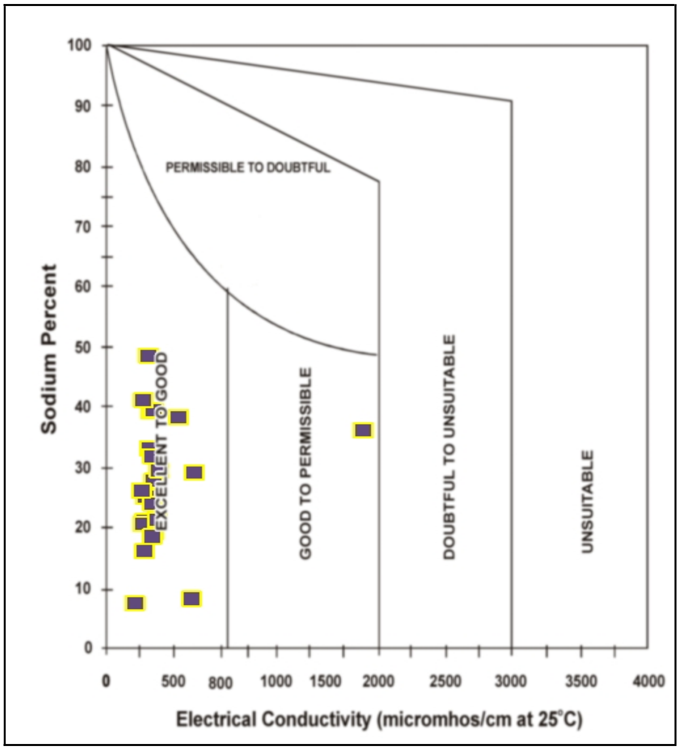


Figure 17: Wilcox plot of samples collected from Sitamarhi district

In Table 2, a classification based on SAR value and % sodium value is given for water samples towards irrigation purpose.

Table 11: Classification of Groundwater Samples towards Irrigation purpose

Parameter	**Range**	**Classification**	**% Of samples**
SAR value	<10	Excellent	100
	10-18	Good	0
	18-26	Doubtful	0
	>26	Unsuitable	0

	<20	Excellent	13.04
	20-40	Good	65.22
% Sodium	40-60	Permissible	21.74
	60-80	Doubtful	0
	>80	Unsuitable	0

HYDROCHEMICAL FACIES OF WATER

A modified piper diagram, Chadha's diagram was plotted to compare the ionic composition in the collected water samples.

The facies mapping using Chadha's diagram (Figure 3) suggests that the maximum ground water sample from Sitamarhi district comes under the Ca^{2+}-Mg^{2+}-HCO_3^- type followed by Na^+-K^+-HCO_3^- type.

It was observed that the study area was dominated by HCO_3^- ions, and alkaline earth metals (Ca^{2+} and Mg^{2+}) dominating over alkali metals (Na^+ and K^+). The Ca -HCO_3^- water results from dissolution of carbonate bearing minerals.

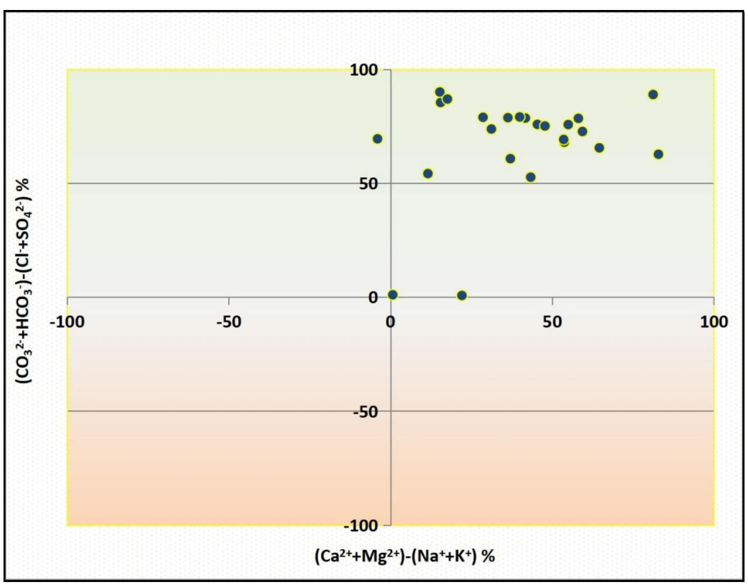


Figure 18: Chadha's plot of samples collected from Sitamarhi district

The analytical result, its maximum, minimum and average value against the BIS Standards 2012 for drinking purpose has been shown in the table

Table 12: Chemical quality of phreatic aquifer

	Location	pH	EC(microsi-emens/cm)	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-
Range	Minimum	7.074	351	24	4.86	172.2	2.2	1.81	0.24	0.13
	Maximum	8.33	1599	66	78.97	455.1	286	81.22	30.4	0.84
BIS	*Acceptable limit*	*<6.5*	200	*75*	*30*	*200*	*250*	*200*	*NA*	*1*
	Permissible limit (in the absence of alternate source)	*>8.5*	600	*200*	*100*	*600*	*1000*	*400*	*45*	*1.5*

Value in mg/l

From the above table it can be inferred that in general, water is potable.

3.4 Geophysical Survey in Sitamarhi District

3.4.1 Resistivity Survey in Sitamarhi District:

Surface geophysical resistivity surveys are usually designed to measure the electrical resistivity of sub-surface materials by making measurements at the earth surface. In Vertical Electrical Sounding (VES), the vertical (depth wise) variations in the resistivity of the sub-surface are measured. This is done by imposing an electrical field in the ground by a pair of electrodes at varying spacing expanding symmetrically from a central point, while measuring the surface expression of the resulting potential field with additional pair of electrodes at the appropriate spacing (Figure 19). For an array of current electrodes (C1 & C2) or A & B, and potential electrodes (P1 & P2) or M & N, the 'apparent resistivity', 'ρa' is expressed by the equation:

$$\rho_a = 2 \pi R * [\{(AB/2) + (MN/2)\} * \{(AB/2) - (MN/2)\}] / MN.$$

Where, R = resistance { R = △V / I },
I is the current introduced in the earth,
△V is the potential difference between the potential electrodes,
AB = distance between the current electrodes A & B and
MN = distance between the potential electrodes M & N

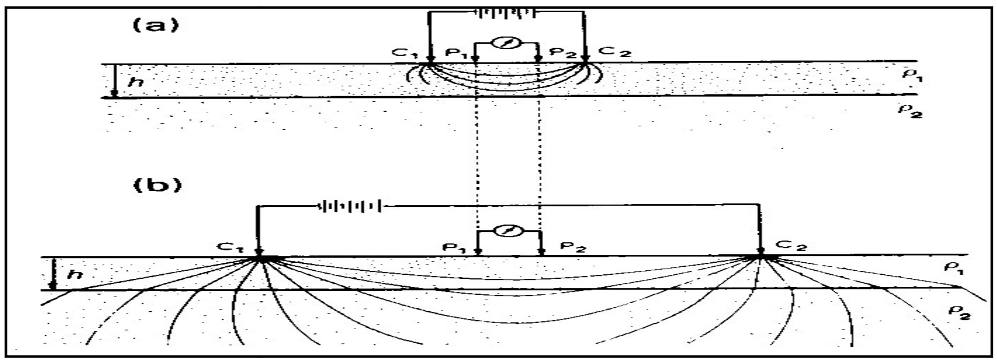


Figure 19:Vertical Electrical Sounding with Schlumberger array. (a) electrodes position for shallow measurements. (b) electrodes position for deeper measurements, keeping the observation points same.

The values of apparent resistivity (ρa :- product of resistance and geometric factor) in ohm-m are plotted against the related half-current electrode separation on double logarithmic scale paper of module 62.5 mm, for interpretation by curve matching technique and Resistivity Sounding Interpretation software. The interpreted result gives the resistivity of different layers and the depth of various interfaces underneath.

A total of 18VES were conducted in the district given in figure below.

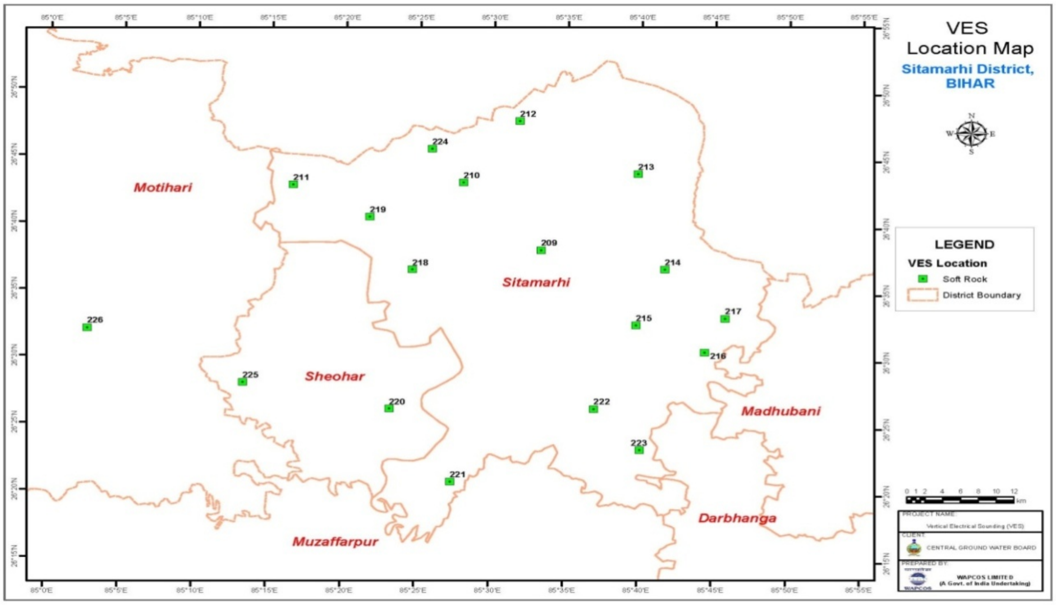


Figure 20: Map of Sitamarhi district showing VES locations

Comparison of VES Results with Borehole Information

At first to standardize the interpreted results of VES, they were compared with the lithological and resistivity log information obtained from the existing nearby boreholes in the area. The Chilara BH (DD: 308.5 m) is in the northern part of the district. It encountered fine to medium sand, clay, sandy clay, kankar and gravel. The depth-wise lithology and associated resistivity (apparent resistivity) obtained from 64” Normal resistivity log are given in Table **13**.

It indicates that clay and clayey sand has a resistivity within 30 to 40 ohm.m. The mixing of kankar or gravel either to clay or sand increases the resistivity. Also, there is an overlapping of resistivity because of which it may not be possible to differentiate fine sand from fine to medium sand only on the basis of resistivity values. As such the resistivity values for clay and clayey sand and fine to medium sand are on higher side compared to other places in the Ganga plain.

There are 4 VES (VES 210, 212, 213 and 224) located towards south of the Chilara BH amongst which VES 212 is within 6 km from the BH. The synthetic VES curves generated from the 64” N resistivity log of the BH with top and bottom layer resistivities obtained from VES are shown inFigure **21** and Figure **22**. The synthetic and field VES curves do not match. The inversion of data with fixed depth to layer interfaces gives a satisfactory match. Since it is not possible to get 25 to 30 layer interfaces from VES, the BH deduced layers were grouped judiciously and mean resistivity if the grouped layer was computed. The BH grouped layer mean resistivity biased interpretation with fixed interfaces and the direct interpretations of VES 212 and 213 are shown in Figures below and the details for VES 212 are given in Table 13. The inferences drawn from VES 212 and 213 to some extent match with those obtained from resistivity log. The VES-BH correlations for BHs at Sursand, Parashpatti and Madhaul are given in Tables 13, 14 and 15. Overall, the VES-BH correlation has revealed a higher order of resistivity for all the lithounits. The same lithounit occurring at deeper horizons shows higher resistivity compared to that at shallow level. Also, the same lithounit at different sites shows varied resistivities. Therefore, it is difficult to characterize the lithology from VES except that the lithological predominance can be assessed.

Table 13: The VES-BH correlation attributes, Chilara borehole and VES 212

Borehole (BH)	Chilara BH 64" N Resistivity Log Details					Geoelectrical Layer Parameters deduced from VES 212						
	Depth (m)		Thickness (m)	Resistivity (ohm. m)	BH Litholog Details	Modified BH deduced layer Res	Layer	Mod. Grouped Layer Mean Res.	Thick	Depth	Actual Grouped Layer Mean Res	Inferred Lithological Predominance
	From	To										
1	2	3	4	5	6	7	8	9	10	11	12	13
Chilara (DD: 308.5 m)	0	10	10	--	Surface Soil		BH Log biased Interpretation (Mean Res. of Grouped Layers) of VES 212					Lithology as per BH litholog
	10	21	11	40	Clayey Sand	74.2	1	61.2	0.9	0.9		Top Soil
	21	26	5	60	Fine Sand	71.4	2	29.5	9.3	10.2		Clay
Nearest VES : VES 212 Located 5.9 km SW of BH	26	30	4	40	Clayey Sand	46.5	3	79.1	68.6	78.8	36.6	Fine Sand
	30	35	5	55	Fine Sand	67.3	4	226.1	24.0	102.8	95.5	Fine Sand &Kank
	35	60	25	30	Clay, Kank	128.9	5	53.7			60.1	Fine to Med. Sand & Clay
	60	66	6	50	Fine Sand	67.7	Direct Interpretation of VES 212					
The VES 212 is located in the northern part of the	66	80	14	30	Clay, Kank	63.6	1	62.9	0.8	0.8		Top Soil
	80	93	13	80	Fine Sand	137.1	2	30	11.5	12.3		Clay
	93	103	10	120	Fine Sand, Kank	188.2	3	93.3	128.6	140.9		Fine Sand &Kank

district	103	118	14	35	Clayey Sand & Grv	51.4	4	54.3				Fine to Med. Sand & Clay
	118	126	8	80	Fine Sand	96.8						
	126	147	21	30	Clayey Sand Kank	45.1						
	147	157	10	150	Fn-Md Sand, Grv	178.6						
	157	160	3	50	Sandy Clay, Kank	51.5						
	160	163	3	70	Fn sand	72.1						
	163	168	5	40	Clay, Kankar	41.9						
	168	174	6	90	Fn Sand, Grev	95						
	174	194	20	30	Clayey Sand Kank	34.6						
	194	204	10	85	Fn-Md Sand	88.7						
	204	214	10	30	Clay, Kank	31.4						
	214	220	6	105	Medium Sand	106.6						
	220	228	8	40	Clay, Kank	40.9						
	228	252	24	125	Fn-Md Sand	129						
	252	256	4	40	Clay	40.1						
	256	267	11	110	Fn-Md Sand	110.7						
	267	271	4	40	Clay	40.1						
	271	277	6	80	Fn Sand, Grv	80.1						
	277	282	5	40	Clay, Grv	40						
	282	290	8	125	Fn-Md Sand	125						
	290	296	6	40	Clay	40						
	296	302	6	105	Fn-Md Sand							

Explanation

The VES 212 is located on the east bank of Lakhandei river. The Chilar BH is located 5.9 km NE of VES on the bank of other eastern river. The lithology of BH reveals fine sand clay up to 194 m and thereafter fine to medium sand and clay up to 308 m depth. The 64" N resistivity log reveals a prominent sand zone in the depth ranges 80-103 m, 147-157 m and 228-252 m. At first a forward model was generated using the layer resistivities and interfaces from the 4" N resistivity log. The generated VES curve does not match with the VES in any aspect (Figure **21**). Then the interfaces were kept fixed and resistivities were kept free. The resistivities got modified (column 7) and the resulting VES curve matched with the field curve. The layer resistivity modification is pronounced in the shallow part up to 93 m depth, revealing the presence of thicker sand bed at shallow depth at VES 212 compared to that at the BH. Further the layers obtained through res. log were grouped and the synthetic curve generated whose layer parameters are shown above. Also the layer parameters obtained through direct inversion are shown above. It indicates that thickening of shallow clay bed at BH prevented from matching of the VES results with BH log.

BH Resistivity log derived litho-resistivities

Clay; 40 ohm.m

Clay &Kankar : 30-40 ohm.m

Clayey Sand: 40 ohm.m

Fine Sand: 50-80 ohm.m

Fine Sand &Kankar: 120 ohm.m

Fine sand & Gravel: 80-90 ohm.m

Fine to Medium Sand: 80-125 ohm.m

Fine to Medium Sand & Gravel: 150 ohm.m

The important aspects of resistivity log to be considered are that (i) it also measures apparent resistivity and (ii) for thin beds whether clay (low resistivity) or sand (moderate to high resistivity) the measured apparent

resistivity would-be respectively much higher and lower than the actual (true) resistivity.

Table 14: The VES-BH correlation attributes Sursand borehole and VES 214

Borehole (BH)	Sursand BH 64" N Resistivity Log Details					Geoelectrical Layer Parameters deduced from VES 214					
	Depth (m)		Thickness (m)	Resistivity (ohm. m)	BH Litholog Details	Layer	Modified Grouped Layer Mean Res.	Thick	Depth	Actual Grouped Layer Mean Res	Inferred Lithological Predominance
	From	To									
1	2	3	4	5	6	7	8	9	10	11	12
Sursand BH	0	7	7	90	Surface Soil	(a) Forward Model based on 64"N Res log derived grouped layer resistivities and depths					
(DD: 308.5 m)	7	12	5	95	Fine Sand	1	60.9	1.5	1.5		Top Soil
	12	27	15	25	Clayey Sand & Knk	2	12.3	11.2	12.7		Clay
	27	33	6	35	Clayey Sand, Knk	3	146.9	27.3	40.0	46.8	Fine Sand, Kankar
Nearest VES : VES 214	33	40	7	60	Fine Sand	4	49.2	14.0	54.0	33	Clayey Sand
Located 3.2 km SW of	40	54	14	33	Clayey Sand, Knk	5	174.9	74.0	128.0	70.9	Fine Sand
BH	54	70	16	80	Fine Sand	6	36.7	25.0	153.0	30.7	Clayey Sand
The VES	70	75	5	35	Clay	7	126.6	59.0	212.0	85.8	Fine Sand, Kankar
214 is located in	75	87	12	85	Fine Sand	8	65.5	58.0	270.0	52.1	Fine Sand, Clay
the eastern part of the	87	92	5	20	Clay	9	63			32.7	Fine Sand, Clay
district	92	102	10	85	Fine Sand	(b) Forward Model based on 64"N Res log derived grouped layer resistivities and depths					
	102	104	2	43	Clay	1	60	1.5	1.5		Top Soil
	104	128	24	95	Fine Sand	2	12.7	10.8	12.3		Clay
	128	144	16	20	Clayey Sand , Knk	3	117.7	257.7	270	55.7	Fine Sand, Kankar
	144	153	9	63	Sandy Clay	4	50.5			32.7	Fine Sand & Clay
	153	176	23	105	Fine Sand &Knk	**Explanation**					
	176	180	4	65	Clayey Sand	The VES- BH correlation has been tried with all possible combination of layer resistivities and thicknesses derived from the resistivity log. The best possible models are presented above. The 4-layer model is possible from the VES and is acceptable. The resistivity of 118 ohm.m obtained from VES is supported by the					
	180	188	8	92	Fine Sand						
	188	191	3	42	Clay						

	191	200	9	90	Fine Sand	resistivity log of Parashpatti BH.
	200	207	7	65	Clayey Sand, Knk	
	207	212	5	82	Sandy Clay, Knk	**Litho-Resistivity Ranges from 64”N Resistivity Log**
	212	221	9	27	Clay	
	221	230	9	80	Fine Sand	**Clay: 15-27 ohm.m(9-10 m thick) -35-43 ohm.m(3-5 m thick)**
	230	240	10	15	Clay	**Clayey Sand &Kankar(Knk): 20-35 ohm.m**
	240	252	12	92	Fine Sand	**Fine Sand: 60-110 ohm.m**
	252	255	3	35	Clay	
	255	270	15	110	Fine Sand	
	270	286	16	28	Clayey Sand, Knk	
	286	290	4	73	Fine Sand	
	290	303	13	30	Clayey Sand, Knk	

Table 15: The VES-BH correlation attributes Parashpatti borehole and VES 209

Borehole (BH)	Parashpatti BH 64” N Resistivity Log Details					Geoelectrical Layer Parameters deduced from VES 209					
	Depth (m)		Thickness (m)	Resistivity (ohm.m)	BH Litholog Details	Layer	Modified Grouped Layer Mean Res.	Thick	Depth	Actual Grouped Layer Mean Res	Inferred Lithological Predominance
	From	To									
1	2	3	4	5	6	7	8	9	10	11	12
Parashpatti	0	13	13	--		BH resistivity log grouped layer mean resistivity biased model					
BH	13	18	5	20	Clay	1	95.7	2.0	2.0		Top Soil
(DD: 308.5 m)	18	26	8	32	Clayey Sand	2	33	7.6	9.6		Clay
	26	35	9	90	Fine Sand, Kankar	3	50.5	15.1	24.7		Clayey Sand
	35	38	3	55		4	92.9	72.0	96.7	90.5	Fine Sand
Nearest VES : VES	38	40	2	70		5	55	46.5	143.2	91.3	Fine to Medium Sand & Clay
209 Located 9.2	40	47	6	40	Clay	6	73.4	134.3	277.5	105.7	Fine Sand
km NE of BH	47	60	14	100	Fine Sand	7	46.1			72.6	Sand & Clay
	60	65	5	70	Sandy Clay						

<table>
<tr><td rowspan="20">The VES 209 is located in the east central part of the district</td><td>65</td><td>100</td><td>35</td><td>115</td><td>Fn-Md Sand</td><td rowspan="7">Explanation

The VES curve generated through 25-layer parameters obtained from BH resistivity log is shown in the VES-BH correlation diagram. The synthetic curve so generated does not match with the field VES curve. The inversion of 25-layer layer model keeping the layer interfaces fixed gave a satisfactory match with modified resistivities. Further, the VES generated through grouped layer resistivities was generated. Its inversion modified the layer resistivities shown above.</td></tr>
<tr><td>100</td><td>104</td><td>4</td><td>40</td><td>Clay</td></tr>
<tr><td>104</td><td>130</td><td>26</td><td>115</td><td>Fn-Md Sand, Kank</td></tr>
<tr><td>130</td><td>142</td><td>12</td><td>75</td><td>Sandy Clay</td></tr>
<tr><td>142</td><td>174</td><td>32</td><td>120</td><td>Fine Sand</td></tr>
<tr><td>174</td><td>178</td><td>4</td><td>75</td><td>Clayey Sand</td></tr>
<tr><td>178</td><td>186</td><td>8</td><td>100</td><td>Fine Sand</td></tr>
<tr><td>186</td><td>194</td><td>8</td><td>40</td><td>Clay</td><td rowspan="13">Litho-resistivity ranges from BH resistivity log

Clay: 20-40 ohm.m

Fine Sand : 85-120 ohm.m

Fine Sand &Kankar: 130 ohm.m

Sandy Clay: 70-80 ohm.m

Fine to Medium Sand: 115 ohm.m</td></tr>
<tr><td>194</td><td>206</td><td>12</td><td>120</td><td>Fine Sand</td></tr>
<tr><td>206</td><td>210</td><td>4</td><td>80</td><td>Sandy Clay</td></tr>
<tr><td>210</td><td>226</td><td>16</td><td>115</td><td>Fine Sand</td></tr>
<tr><td>226</td><td>230</td><td>4</td><td>40</td><td>Clay</td></tr>
<tr><td>230</td><td>276</td><td>46</td><td>130</td><td>Fine Sand, Kankar</td></tr>
<tr><td>276</td><td>280</td><td>4</td><td>40</td><td>Clay</td></tr>
<tr><td>280</td><td>288</td><td>8</td><td>85</td><td>Fine Sand</td></tr>
<tr><td>288</td><td>297</td><td>9</td><td>70</td><td rowspan="2">Fine Sand, Clay, Kankar</td></tr>
<tr><td>297</td><td>307</td><td>10</td><td>85</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 16: The VES-BH correlation attributes Madhaul borehole and VES 221

Borehole (BH)	Madhaul BH 64" N Resistivity Log Details					Geoelectrical Layer Parameters deduced from VES 221					
	Depth (m) From	Depth (m) To	Thickness (m)	Resistivity (ohm. m)	BH Litholog Details	Layer	Modified Grouped Layer Mean Res.	Thick	Depth	Log derived actual Grouped Layer Mean Res	Inferred Lithological Predominance
1	2	3	4	5	6	7	8	9	10	11	12
Madhaul BH	0	10	10	--	Surface Soil	BH resistivity log grouped layer mean resistivity biased – Model 1					
	10	27	17	22	Clayey Sand	1	46.1	0.8	0.8		Top Soil
(DD: 308.5	27	54	27	120	Fine Sand	2	25.0	13.6	14.4		Clay
m)	54	60	6	40	Clay	3	35.3	19.4	33.8		Clayey Sand
	60	66	6	90	Fine to Medium Sand &Kankar	4	137.7	71.7	105.5	96.3	Fine-Med Sand
	66	74	8	75		5	49.1	43.8	149.3	48.6	Fine-Med Sand & Clay
Nearest VES : VES	74	92	18	110		6	67.6	154.0	303.3	86.4	Fine-Med Sand & Clay
221 Located 3.3	92	96	4	35	Clay	7	29.2				Clay
km SW of BH	96	100	4	60	Fine-Med. Sand	BH resistivity log grouped layer mean resistivity biased – Model 2					
	100	108	8	35	Clayey Sand	1	47.1	0.8	0.8		Top Soil
The VES 221 is	108	128	20	65	Fn-Md. Sand, Kank	2	25.2	14.5	15.3		Clay
located in the	128	136	8	30	Clay	3	35.7	17.1	32.4		Clayey Sand
southern part of the	136	143	7	60	Fn-Md. Sand, Kank	4	129.4	60.5	92.9	96.3	Fine-Med Sand
district	143	146	3	45	Clayey Sand	5	70.8	208.0	300.3	74.4	Fine Sand
	146	153	7	100	Fine-Med. Sand	6	26.9				Clay
	153	162	9	45	Sandy Clay	Direct interpretation					
	162	170	8	110	Fine Sand	1	43.8	0.9	0.9		Top Soil
	170.	174	4	70	Clayey Sand	2	24.8	12.9	13.8		Clay
	174	218	44	115	Fine Sand	3	39.8	24.2	38.0		Clayey Sand
	218	222	4	75	Clay	4	150	66.4	104.4		Fine-Med Sand

	222	258	36	120	Fine Sand , Kankar	5	48.7				Fine Sand & Clay
	258	295	37	50	Sandy Clay						
	295	300	5	110	Fine –Med. Sand						

Explanation

The 2 VES models generated through BH resistivity log derived grouped layer resistivities are given above. These models reveal that by VES the relatively less resistive (group layer resistivity: 48.6 ohm.m) layer in the depth range 92-143 m cannot be delineated. The direct interpretation of VES is also given above.

Litho-resistivity ranges from BH resistivity log

Clay : 30-40 ohm.m

Clayey Sand : 22-35 ohm.m (shallow), 45-70 ohm.m (deep- thin)

Fine Sand: 110-120 ohm.m

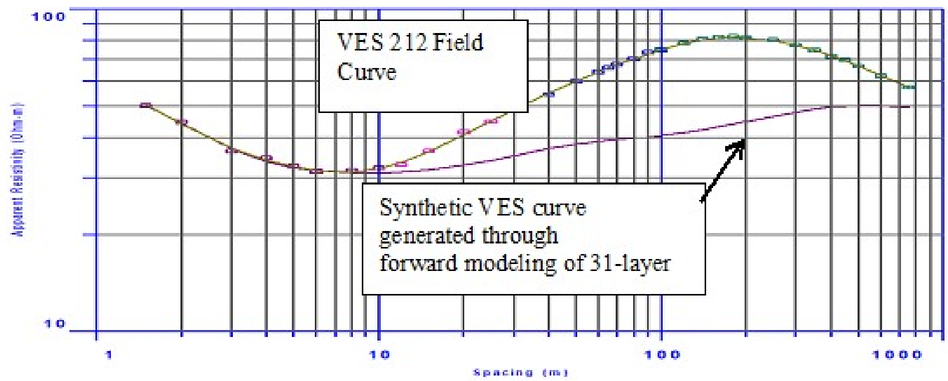
Fine-Medium Sand : 60- 65 ohm.m (shallow)

Fine-Medium Sand: 110-120 ohm.m (deep)

Table 17: The litho-resistivity ranges deduced from resistivity log of boreholes, Sitamarhi district

Lithology	Range of resistivity values recorded by 64" N Resistivity log of Boreholes				
	Shallow and deep occurrences within the depth of BH drilled	Chilara (DD: 308.5 m)	Sursand (DD:308.5 m)	Parashpatti (DD:304.8 m)	Madhaul (DD: 308.5 m)
Clay	Shallow	40	15-27	20-40	30-40
	Deep				
Clay &Kankar	Shallow	30-40			
	Deep				
Sandy Clay/Clayey Sand	Shallow	40	20-35	70-80	22-35
	Deep				45-70
Fine Sand	Shallow	50-80	60-110	85-120	110-120
	Deep				
Fine to Medium Sand	Shallow	80-125		115	60-65
	Deep				110-120

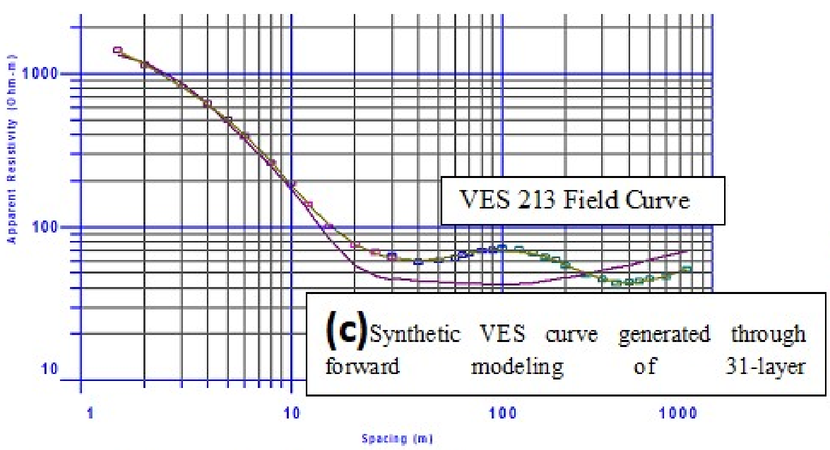
Fine Sand &Kankar	Shallow	120		130	
	Deep				
Medium Sand	Shallow				
	Deep				
Fine Sand & Gravel		80-90			
Fine to Medium Sand & Gravel		150			
Medium to Coarse Sand	Shallow				
	Deep				
Coarse Sand	Shallow				
	Deep				



The site of VES 212 is 5.9 km SW of Chilara Borehole

For generating synthetic VES curve through forward modeling,the top layer resistivity is taken from VES and the last layer resistivity is taken from the trend of the last segment of the VES curve.

Figure 21: The VES 212 field curve and the synthetic VES curve generated through forward modeling of layer parameters deduced from 64" N resistivity log of Chilara borehole without any parametric modification



For generating synthetic VES curve through forward modeling,the top layer resistivityis taken from VES andthe last layer resistivity is takenfrom the trend of the last segment of the VES curve.

The site of VES 213 is 14 km SE of Chilara Borehole

Figure 22: The VES 213 field curve and the synthetic VES curve generated through forward modeling of layer parameters deduced from 64" N resistivity log of Chilara borehole without any parametric modification

Interpreted Results of VES

Two types of VES curves are obtained from this area - the curves with ascending last segment and the other with descending last segment. The interpretation of VES passed through several stages. At first the VES were interpreted through direct inversion. It gave an idea about the layering and the layers which can be delineated. The presence of near surface layers of very high and very low resistivities brings in additional error in layer parameter estimations which already suffer from equivalence. It is followed by standardization of layer parameters through 64"N resistivity logs of the existing boreholes in the area, which require forward modelling as mentioned above. The VES gives average or mean resistivity of depth zones, for which the interfaces are defined by layer resistivity contrast and layer thickness. Therefore, the deeper layers are not distinctly picked up by VES. A typical example is VES 212, which is located near Chilara BH. The deeper 24 m thick resistive layer occurring in the depth range 228-252 m with resistivity about 125 ohm.m (64" N resistivity log) could not be delineated by VES. The curve of VES 212 shows a K-type trend in its later part and the resistivity high (80-120 ohm.m) is because of the 23 m thick resistive layer in the depth range 80-103 m (64" N resistivity log). The layer resistivities get subdued due to the layers of lesser resistivities of the underlying and overlying layers. Similarly, from the VES 214 located near Sursand BH a very thick layer of average resistivity 118 ohm.m in the depth range 12-270 m is delineated against the several layers of 90-110 ohm.m resistivity separated by clay interbeds. Finally the interpretation of VES is reviewed and modified through preparation of hydrogeophysical cross-sections. Overall, the interpreted results of VES could be used to get a generalized subsurface litho-picture. In this area broadly the layers with resistivities more than 50 ohm.m could be considered as representing aquifers in fine sands and those with resistivities less than 50 ohm.m could be predominant in clay. The layer resistivities even around 90-100 ohm.m are indicative of fine sands only. Further increase in resistivities is either due to the presence of kankar or medium sand.

3.4.2 Hydrogeophysical Cross-Section

The layer parameters obtained from VES have been used to prepare 4 hydrogeophysical cross-sections (Figures 24 to 26). These cross-sections shown in Google map inset as (a), (b), (c) and (d) are oriented in NW-SE direction and are positioned from east to west covering the district. The resistivity logs of Chirala and Sursand BHs reveal a contrasting change in lithofacies as shown in cross-section (a) Figure below.

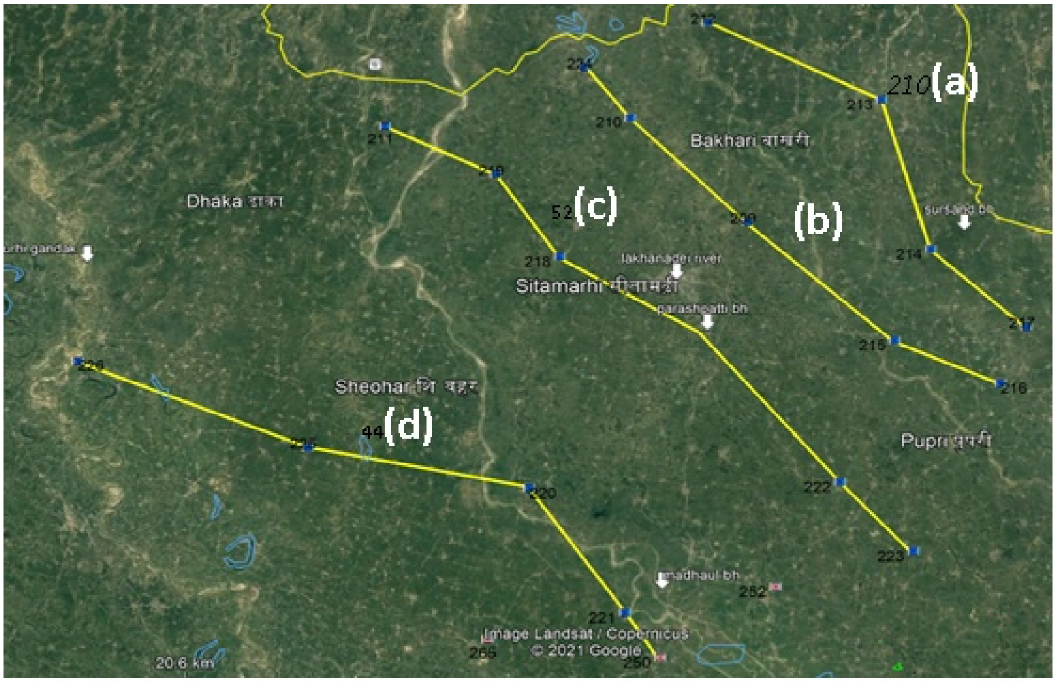


Figure 23: Locations of hydro geophysical cross-sections (a), (b), (c) and (d)

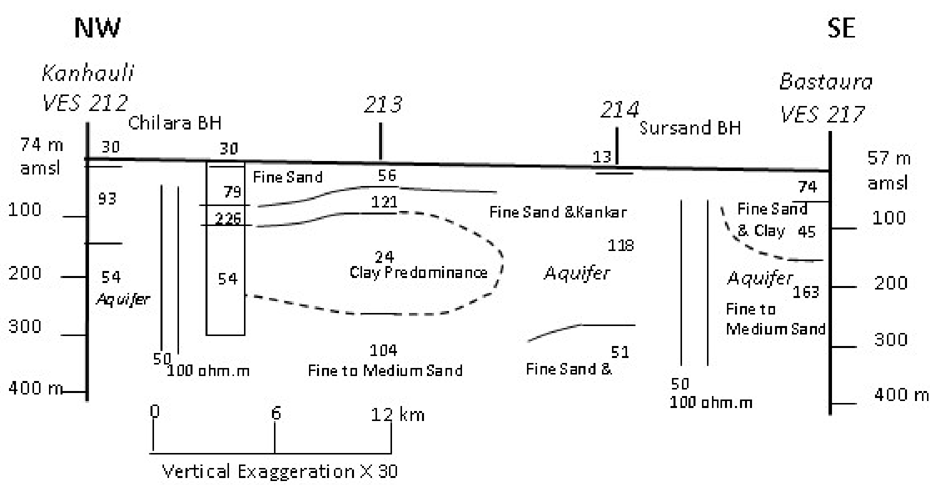


Figure 24 : The NW-SE Hydrogeophysical Cross-Section between Kanhauli & Bastaura

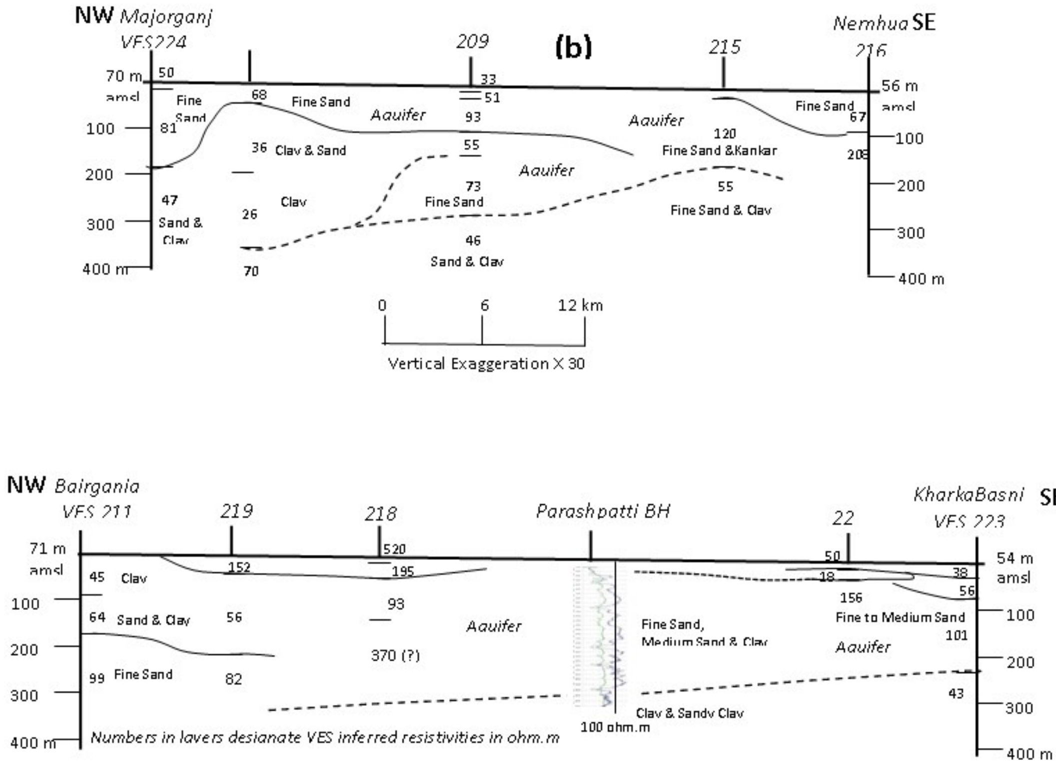


Figure 25: The NW-SE Hydrogeophysical Cross-Section between Majorganj & Nemhua and Bairgania & Kharlabasni

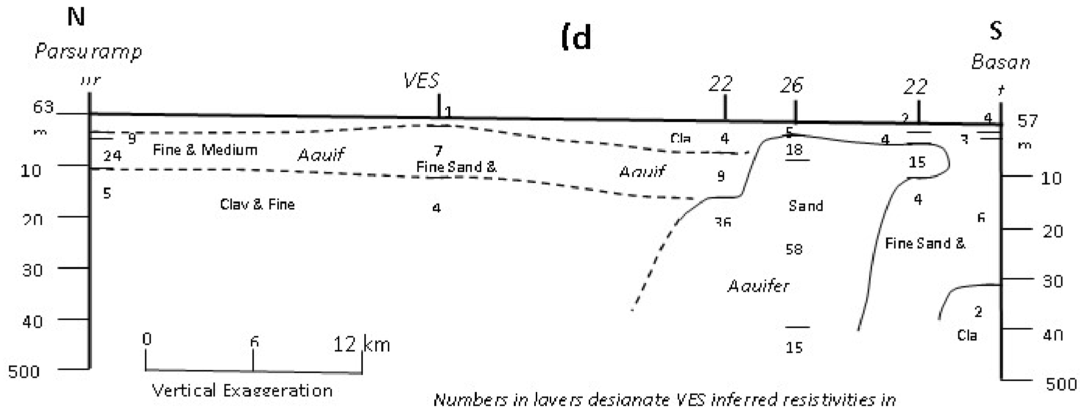


Figure 26: The N-S Hydrogeophysical Cross-Section between Parsuramp & Basan

While Chirala BH shows predominance of clay with thin sand beds, the Sursand BH shows the presence of thick sand beds throughout the depth drilled. The change in lithofacies is expected between VES 213 and VES 214. The cross-section (b) (Figure 25) also reveals the presence of clay and clay with sand (resistivity: 26-36 ohm.m) at VES 210. It indicates the presence of clay predominance up to about 30 m depth in the area encompassing Chirala BH, VES 212, 210 and 213) in the NE part of the district. Further, the cross-section (b) reveals general improvement in the granularity of sediments at shallow level (up to 278 m at VES 209 and 163 m at VES 215) in the SE part of the cross-section and finally the entire depth investigated at VES 216 holds fine sand and fine to medium sand at depth. The cross-section (c) (Figure 26) reveals in general the presence of finer sediments at depth beyond 230 to 300 m. The resistivity log of Parashpatti BH located between VES 216 and 222 reveals the presence of thick pile of sediments with resistivity 100-120 ohm. The Sursand BH also reveals the presence of thick pile of resistive sediments only with the difference that thin clay interbeds are frequent at Sursand BH. The cross-section (d) (Figure 27) in the western part of the district reveals a subsurface lithological disposition totally different from the other cross-sections. In the NW part of this cross-section holds fine to medium sands up to about 100 m depth and finer sediments and clay beyond 100 m depth. A highly resistive and very thick sand body is delineated from shallow level around VES 220, 265 and 221. As moved towards SW the sand body deepens up to about 300 m depth and is overlain by finer sediments, i.e., across Burhi Gandak river thick finer sediments are present. The presence of (i) highly resistive thick sands around VES 220, 221 and 265, (ii) thick finer sediments and clays in between Rivers Gandak and Burhi Gandak and (iii) thick finer sediments around VES 210, 212 and 213 are to be reviewed vis-a-vis the deposition of sediments in the fan and inter fan areas and the structural disturbances related to SW-NE trending West Patna Fault passing through the area.

Mean Resistivity Map

The Mean Resistivity maps for 30-100 m and 100-300 m depth ranges for Muzaffarpur and Sitamarhi districts combined are shown in Figures 27 and 28 respectively. The Mean resistivity for each VES is computed from the values of total Transverse Resistance and Longitudinal Conductance (Dar Zarrouk parameters) for the depth ranges mentioned above. The depth ranges represent shallow and deep borehole depths. It is observed from the 30-100 m depth map that the area along the course of River Burhi Gandak (falling in Muzaffarpur district) is predominant in sediments with lesser resistivities representing clay and shallow borehole drilling is not feasible in this part of Muzaffarpur district. The 100-300 m depth map also reveals the presence of clays at depth along the course of River Burhi Gandak but the spatial extents are limited. In Sitamarhi district clay predominance is expected in the NE part. The areas of clay predominance at deeper horizon in NE Sitamarhi and central Muzaffarpur districts are separated by a zone of higher resistivities. The NE extension of west Patna fault passes through the area and may also have some control on deposition of sediments at depth. The mean resistivity values have been used to assess the suitability of VES sites for shallow and deep drilling of boreholes.

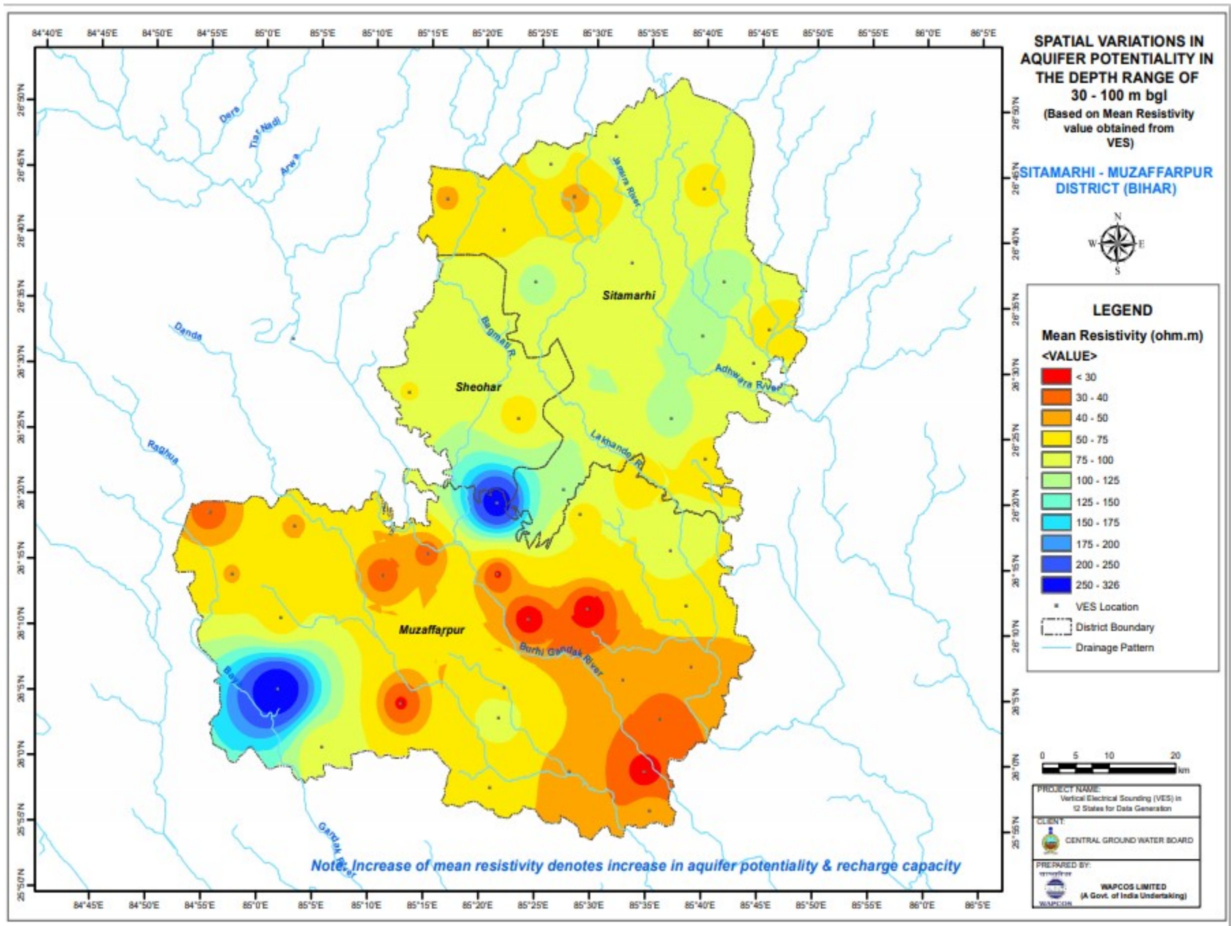


Figure 27: Spatial variations in aquifer potentiality in the depth ranges of 30-100 m bgl

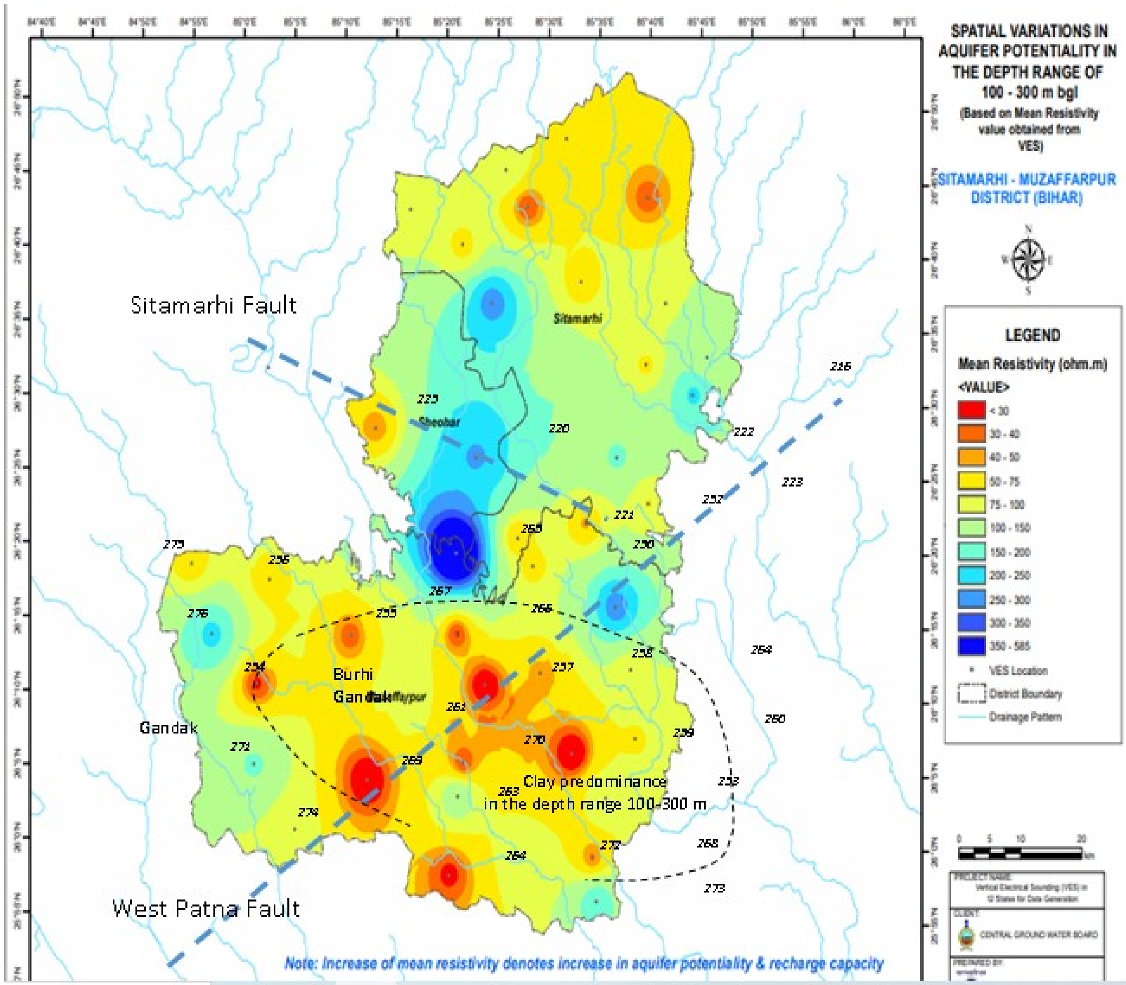


Figure 28: Spatial variations in aquifer potentiality in the depth ranges of 100-300 m bgl

Conclusions and Recommendations

The area of Sitamarhi district lies between Gandak and Kosi mega fans. In this area 18VES were conducted. The litho-resistivity ranges obtained through the correlation of VES layer parameters with the resistivity and lithological logs show a higher order of resistivities. The fine sands are prevalent in the area and are associated with resistivities more than 70 ohm.m and at places beyond 100 ohm.m. The clays are associated with resistivities around 40 ohm.m. The four NW-SE trending hydrogeophysical cross-sections prepared on the basis of VES results present the general subsurface lithological condition and aquifer disposition. The sites with thick layers of resistivity less than 60-65 ohm.m are expected to hold thin sand bed in a clay predominating environment and may be avoided from borehole drilling.

Areas with predominance of clay and clay with fine sand are in the NE part of the district around VES 210, 212 and 213 and in the SW part the area holding very thick highly resistive sand is around VES 220- VES 221 and VES 265 in the adjacent Muzaffarpur district. The presence of thick clay and sand predominance could be related to the depositional environment in the interfan area and also with the structural disturbance caused by the NE-SW trending west Patna fault which is expected to traverse the area. The mean resistivity for two depth ranges 30 to 100 m and 100 to 300 m representing shallow and deep borehole depths has been computed to assess the suitability of the VES sites for borehole drilling. The recommendations for BH drilling are given in Table below.

Table 18: VES site-wise recommendations for drilling based on 'Mean Resistivity' values.

VES No.	Location	Shallow Borehole (100 m depth)		Deep Borehole (300 m depth)			Remarks
		Mean Resistivity (ohm.m) for 30-100 m depth considered	Recommendation for BH Drilling	Mean Resistivity (ohm.m) for 100-300 m depth considered	Recommendation for BH Drilling		
209	Jukharpatti	90.5	R	65.4	R	P2	
210	Sahiara	39.8	NR	30.1	NR	--	Clay predominance
211	Bairgania	47.6	NR	84.3	R	P1	
212	Kanhauli	93.3	R	60.8	R	P2	
213	Ramnaika	70.9	R	34.3	NR	--	Clay predominance
214	Malahi	117.7	R	97.5	R	P1	
215	PachraNimahi	119.6	R	70.7	R	P2	
216	Nemuha	81.1	R	208.1	?	--	
217	Bastaura	54.9	NR	109.4	R	P1	
218	Kharsan	108.8	R	275.8	?	--	
219	Sisaula	65.8	NR	66.6	R	P2	
220	Madkhau	63.6	NR	255.7	?	--	The layer resisitivity beyond 147 m depth is 367 ohm.m. Test BH to be drilled to be confirm the lithology and if found suitable then BH cab be drilled at the sites of VES 216 and 218
221	Barheta	125.1	R	50.2	NR	--	Sand & Clay

222	Rasulganj	114.6	R	156.4	R	P1	
223	KharkaBasni	62.5	NR	74.3	R	P2	
224	Majorganj	81.0	R	95.0	R	P1	
225	Bhatha	73.8	R	41.3	NR	--	Clay predominance
226	Parsurampur	186.3	R	54.6	NR	--	Sand & Clay

R: Recommended

Shallow Borehole (up to 100 m depth)

NR: Not Recommended (Mean Resistivity < 65 ohm.m)

Deep Borehole (up to 300 m depth)

NR: Not Recommended (Mean Resistivity < 55 ohm.m)

P1: First Priority(Mean Resistivity :80-160 ohm.m, P2: Second Priority(<80 ohm.m),

CHAPTER 4

GENERATION OF AQUIFER MAP

4.1 Aquifer Disposition

As per the Annual Action Plan the Central Ground Water Board has been generating depth wise data through groundwater exploration, geophysical survey, drilling and also collecting from other agency etc. The tube wells, drilled by Central Ground Water Board as well as Production Well drilled by Bihar State Authorities also included here These data are further will be analysed in order to refine sub-surface disposition for the preparation of aquifer maps. Thefence diagram have been reproduced from district report-1993 to interpret the aquifer disposition.

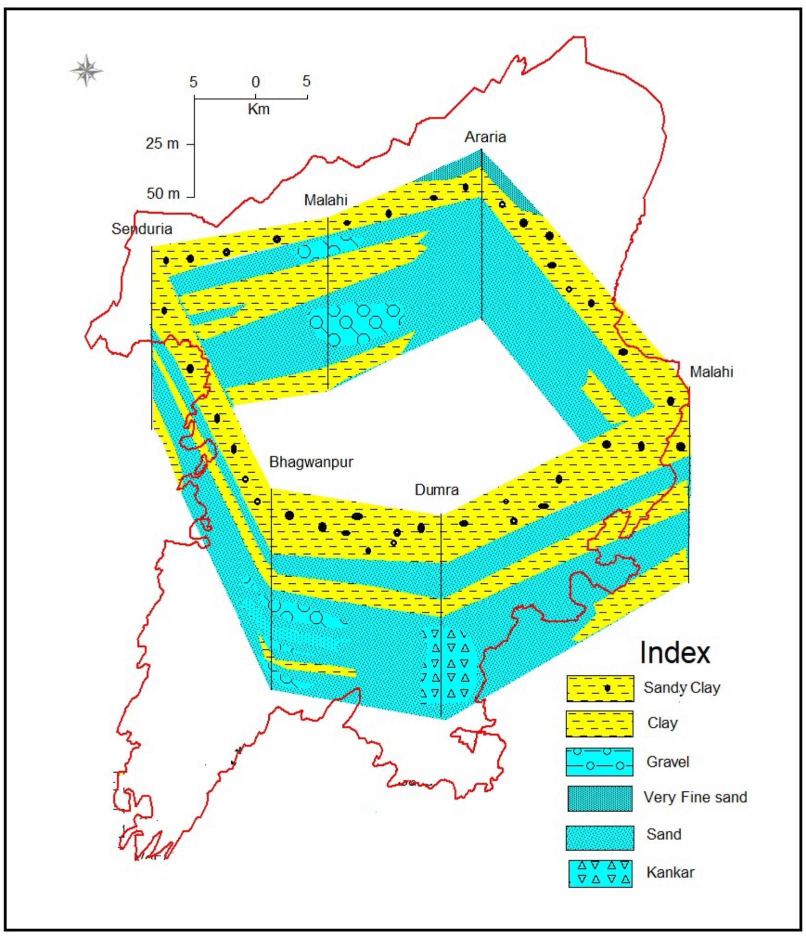


Figure 29: Fence Diagram showing Aquifer Disposition in Sitamarhi district

The lithological logs drilled by Exploratory tube well organization and State Tubewell Corporation inferred that finer clastics are more predominant in the western part of the district. The fence diagram indicates that there are three aquifers in the western part, two in the eastern part and southern part and one to two in the northern part.

The disposition of clay bed is uniform. It is interesting to note that 1st aquifer is overlained by 25 to 30 m thick sandy clay bed in the entire district except for the western part, where its thickness increases and its number increases. There is as many as four clay bed which pinches into sand horizon eastward. This number of clay beds in the western part makes the aquifer heterogeneous. This heterogeneity may results from the oscillating nature of Bagmati river. Though the heterogeneity observed in the western part but the presence of gravel and coarser sediment makes the aquifer more potential than eastern part aquifer, which contains mainly fine sediment. The 2nd aquifer which starts at ~40 m bgl being sandwiched by thick clay makes it confined, but may consider as semi confined to confine on regional scale. The 3rd aquifer starts from ~60 m and mainly composed of coarse sand. The 1st and 2nd aquifer merge and form a single hydrological unit east ward and south ward. So overall the aquifer disposition is heterogeneous resulting from the oscillatory sediment deposition of Bagmati river.

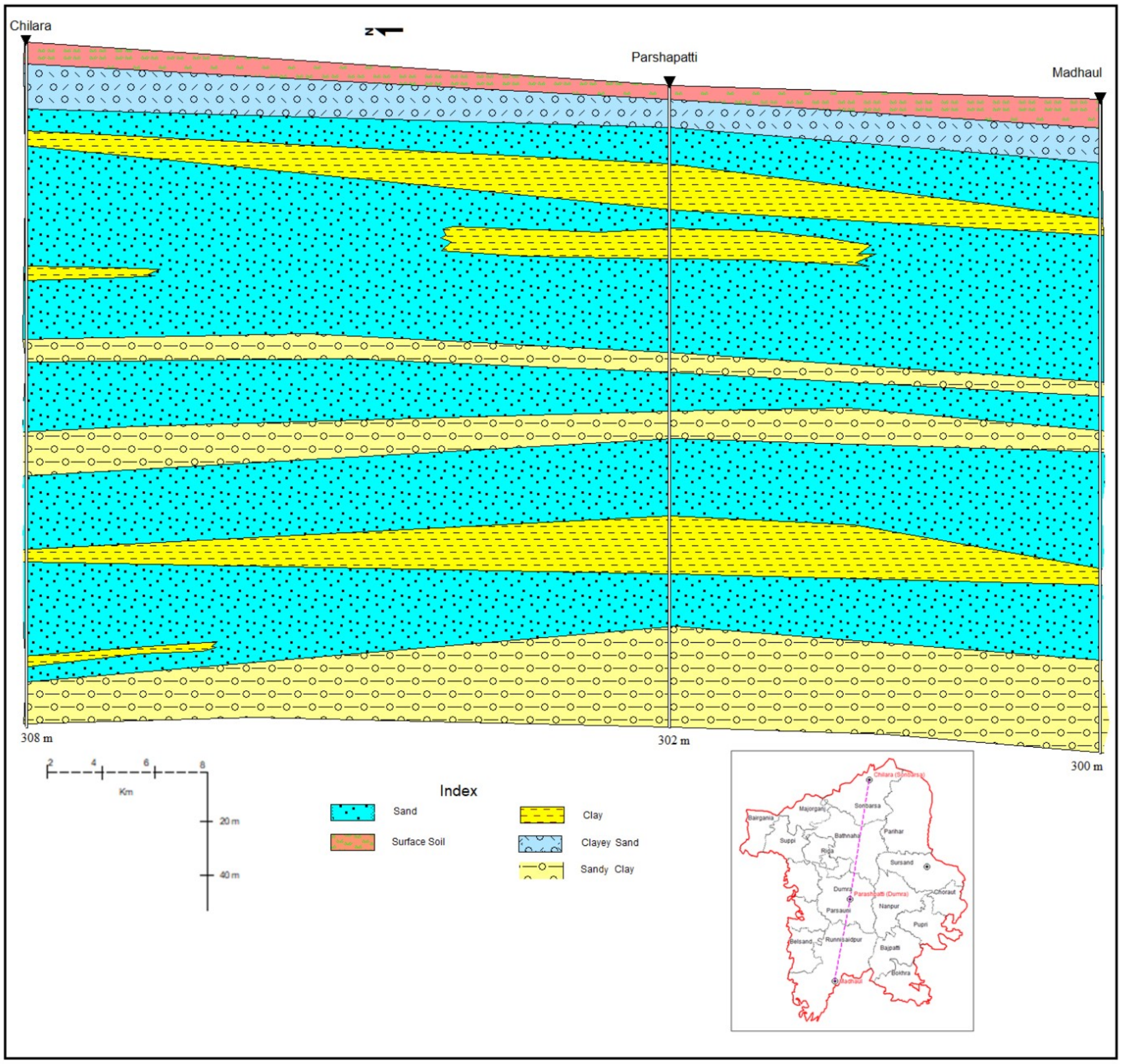


Figure 30: Cross Section showing Aquifer Disposition of Sitamarhi District

The above cross section is taken along N-S direction of the district. The section shows a number of clay lenses and layers and its thickness also varies. So overall the aquifers are heterogeneous. In all 3 locations after ~ 10m thick topsoil is found. Thereafter ~20 m thick clayey sand is found. At 50 m bgl depth a no. of clay beds of variable thickness is found. The thickness of clay layer is more as we go towards Parashpatti, Dumra. This indicates the oscillating pattern of depositional system caused by changes in Bagmati river. There are 3 major aquifer can be identified from which, 1st one is characterized as unconfined aquifer. The 2nd aquifer can be characterized as semi confined to confined. The 3rd aquifer may characterize as confined aquifer.

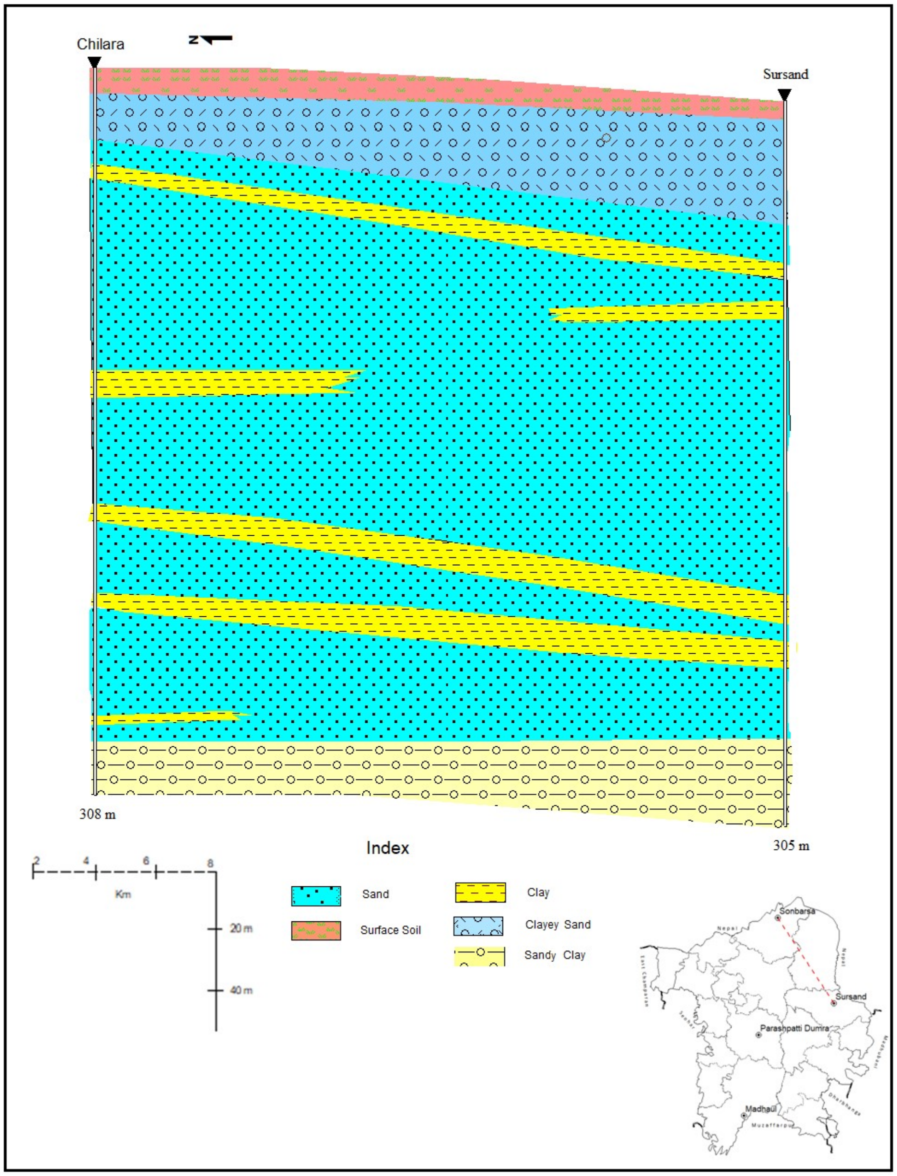


Figure 31: Cross Section showing Aquifer Disposition of Sitamarhi District

The above cross section is taken along NNW-SSE direction of the district. As Sursand lies 85 m above msl and Sursand lies 69 m above msl, section showing tilting of sediments towards Sursand. The no. of clay lenses are more at Sonbarsa as compare to Sursand and three prominent clay layer found as shown in above figure. Here 4 aquifers can be demarcated, of which 1st one is unconfined (40-80m) which is upto 40 m bgl at Sonbarsa & 80 m bgl at Sursand. The below 3 aquifers can be characterized as semi confined to confined.

4.1.1 Aquifer Characteristics

Ground water occurs both under phreatic and confined condition and at places they are also found to be under autoflow conditions. In the west and north western part of the district the wells piercing down to 90- 100 m bgl yielded 126.43 to 169.58 m^3/hr for a drawdown ranging from 5.79 to 3.81 m in about 4 hours of pumping. In central part of district, when tapping the aquifer at similar depth 100 m bgl have yielded 154 m^3/hr for a drawdown of 3.81 m in about five hours of pumping, the specific capacity of the wells tapping granular zone with in 100 m bgl is found to range 21.83 to 44.5 m^3/hr/m of drawdown. It is reported that the transmissivity of the sediments has been calculated at two locations by private agencies. It is found out to be 2500 m^2/day at Bairgania block and 1800 m^2/day at Malahi in Sursand block.

Apart from the previous exploration recently four exploratory wells and two observation wells are drilled by CGWB through outsourcing agency at Sursand, Dumra, Sonbarsa and Runnisaidpur block. The exploratory well are drilled upto a depth of 308.5 m in all four locations. The specific capacity of the wells range between 242.46 to 426.28 m3/day of drawdown. The transmissivity of the exploratory well range between 435 to 1378 m2/day. The storativity of the aquifer drilled at Dumra and Sonbarsa are $1.4x10^{-4}$ and $6x10^{-4}$ respectively.

Table 19: Exploration data of Sitamarhi district

Sl.No.	Location/ Block	Depth Drilled mbgl.	Static Water level mbgl.	Duration Of Pumping Test minutes	Discharge m^3/day.	Drawdown m.	Specific Capacity m^3/day of drawdown	Trans-missivity m^2/day	Storativity	Year
1	**Sursand/ SURSAND** 26.62858 85.72098	308.5	4.1	1000	3990	9.36	426.28	1378	-	2021
2	**Chilara/ SONBARSA** 26.829686 85.572551	308.5	4.1	1000	3957	16.32	242.46	570	$6X10^{-4}$	2021
	OW	279	3.9			2.84	-	1114		
3	**Madhaul/ RUNNISAIDPUR** 26.364295 85.483082	308.5	4.0	1000	3897	11.23	347.01	1585	-	2021
4	**Parashpatti/ DUMRA** 26.554144 85.521719	308.5	4.0	1000	3957	15.98	247.6	435	$1.4X10^{-4}$	2021
	OW	291	4.08			3.75	-	727		

During the systematic survey carried out by CGWB it was noticed that there is extension of the belt of auto flowing well in Sub-Tarai zone in the district. In all five areas have been delineated, where wells have been tapped the auto flow zone. These areas mentioned below with autoflow data of tubewells.

Table 20: Autoflow data of Tubewell

Area of auto-flow zone	Toposheet& Quadrant No.	Location	Piezometric Head m.a.g.l.	Free flow discharge lpm.
I	72 F/9 (3A) & 72 F/10 (1A)	Dostiya-Bhutahi	1.5-1.52	60-150
II	72 F/9 (2C)	Bela-Khanwa	1.75-3.35	40-150
III	72 F/10 (3A)	Sursand-Malahi	0.38-0.50	7-45
IV	72 F/14 (3A)	Bhemua-Bhilwahi	0.28-3.70	5-200
V	72 F/10 (2B) (2C)	Bajidpur-Jawahir	Not Measurable	Not Measurable

Source: Old CGWB report 1993

CHAPTER 5

GROUND WATER RESOURCES

Rainfall is the principal source of water to recharge ground water. Major part of the total annualrecharge takes place during monsoon period. Besides rainfall, seepage from canal, return flow from irrigation*etc.* also recharge the ground water. On the other hand, besides base flow of ground water and evapotranspiration, ground water extraction carried out for its drinking, domestic, irrigation and industrial purposes.

Thus the methodology for ground water resources estimation is based on the principle of water balance as given below –

Inflow – Outflow = Change in Storage (of an aquifer)

The equation can be further elaborated as

$$\Delta S = RRF+RSTR+RC+RSWI+RGWI+RTP+RWCS \pm VF \pm LF - GE - T - E - B$$

Where,

ΔS – Change is storage, RRF – Rainfall recharge, RSTR- Recharge from stream channels, RC – Recharge from canals, RSWI – Recharge from surface water irrigation, RGWI- Recharge from ground water irrigation, RTP- Recharge from Tanks & Ponds, RWCS – Recharge from water conservation structures, VF – Vertical flow across the aquifer system, LF- Lateral flow along the aquifer system (through flow), GE-Ground Water Extraction, T- Transpiration, E- Evaporation, B-Base flow

The recharge and extraction of ground water is calculated from the above equation. Stage of development (SOD) is the ratio of ground water recharge and itsextraction calculated in percentage.Roughly, stage of development up to 70% is considered as safe.

The assessment of ground water includes assessment of dynamic and in-storage ground water resources. The development planning should mainly depend on dynamic resource only as it gets replenished every year. Changes in static or in-storage resources reflect impacts of ground water mining. Such resources may not be replenish able annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

5.1 Dynamic Ground Water Resources

The dynamic Ground Water Resources has been assessed by CGWB, Mid-Eastern Region, Patna in association with Minor Water Resources Department, Government of Bihar based on GEC, Methodology 2015. The summarized detail of Annually Replenishable or Dynamic Ground Water Resources of Sitamarhi district is in table below.

The assessment of dynamic ground water resources (as on March 2022) has been done.

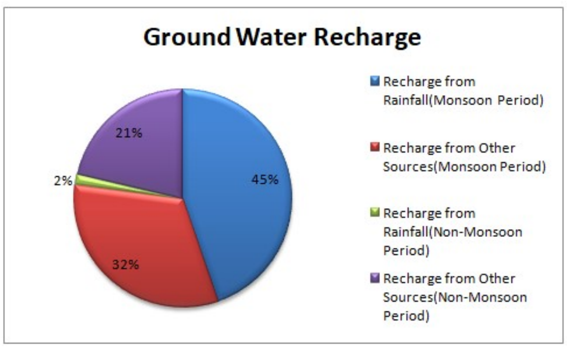
Table 21: Net ground water availability (GWRE - 2022)

Block	Ground Water Recharge (Ham)				Total Annual Ground Water Recharge (Ham)	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
	Recharge from Rainfall Monsoon Season	Recharge from Other Sources Monsoon Season	Recharge from Rainfall Non Monsoon	Recharge from Other Sources Non Monsoon Season			
Bairgania	1500.95	140.52	127.77	121.68	1890.92	94.54	1796.38
Bajpatti	3832.22	301.64	265.45	238.33	4637.64	463.77	4173.87
Bathnaha	4001.69	450.55	380.98	393.73	5226.95	261.35	4965.60
Belsand	2114.71	235.63	146.48	189.85	2686.67	268.66	2418.01
Bokhra	2365.84	160.18	163.88	135.94	2825.84	282.58	2543.26
Choraut	2026.14	77.13	140.35	63.49	2307.11	230.71	2076.40
Dumra	5034.50	373.02	372.35	312.90	6092.77	304.64	5788.13
Majorganj	1718.51	191.38	143.93	148.06	2201.88	110.09	2091.79
Nanpur	2365.47	219.58	204.81	198.41	2988.27	149.41	2838.86
Parihar	3891.45	324.07	404.34	291.56	4911.42	491.14	4420.28
Parsauni	1626.74	164.29	112.68	129.85	2033.56	203.35	1830.21
Pupri	2560.59	150.85	177.37	124.02	3012.83	301.28	2711.55
Riga	2439.40	258.83	246.06	189.97	3134.26	156.71	2977.55
Runnisaidpur	7238.36	679.20	501.40	521.18	8940.14	894.02	8046.12
Sonbarsa	3909.18	334.17	335.97	284.94	4864.26	243.22	4621.04
Suppi	1572.46	159.51	163.38	110.97	2006.32	200.64	1805.68
Sursand	3990.11	133.70	276.39	128.65	4528.85	452.88	4075.97
Total	52188.32	4354.25	4163.59	3583.53	64289.69	5108.99	59180.70

Table 22: Assessment of Dynamic Ground Water Resources (2022)

Block	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	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-Exploited/Critical/Semi critical/Safe/Saline)
Bairgania	1796.38	744.27	0.00	507.44	1251.71	551.32	500.79	69.68	safe
Bajpatti	4173.87	1535.12	0.00	671.76	2206.88	729.85	1908.90	52.87	safe
Balsand	4965.60	2531.14	0.00	818.32	3349.47	889.09	1545.36	67.45	safe
Bathnaha	2418.01	1162.48	0.00	422.67	1585.16	459.21	796.31	65.56	safe
Bokhara	2543.26	725.47	0.00	407.98	1133.45	443.27	1374.52	44.57	safe

Charaut	2076.40	372.64	0.00	247.22	619.86	268.60	1435.16	29.85	safe
Dumra	5788.13	1743.10	0.00	1196.6	2939.72	1300.09	2744.93	50.79	safe
Majorganj	2091.79	994.11	0.00	320.39	1314.50	348.10	749.58	62.84	safe
Nanpur	2838.86	909.93	0.00	568.65	1478.58	617.82	1311.11	52.08	safe
Parihar	4420.28	1320.95	0.00	1054.2	2375.22	1145.44	1953.89	53.73	safe
Parsauni	1830.21	836.19	0.00	268.12	1104.31	291.31	702.71	60.34	safe
Pupri	2711.55	727.58	0.00	568.58	1296.16	617.75	1366.22	47.80	safe
Riga	2977.55	1194.07	88.00	645.17	1927.25	700.97	994.50	64.73	safe
RuniSaidpur	8046.12	3347.76	0.00	1161.3	4509.13	1261.80	3436.56	56.04	safe
Sonbarsa	4621.04	1506.65	0.00	783.17	2289.82	850.89	2263.50	49.55	safe
Suppi	1805.68	776.66	0.00	381.03	1157.70	413.98	615.03	64.11	safe
Sursand	4075.97	500.69	0.00	654.42	1155.11	711.01	2864.27	28.34	safe
Total	59180.70	20928.82	88.00	10677.	31694.0	11600.5	26563.34	53.55	Safe



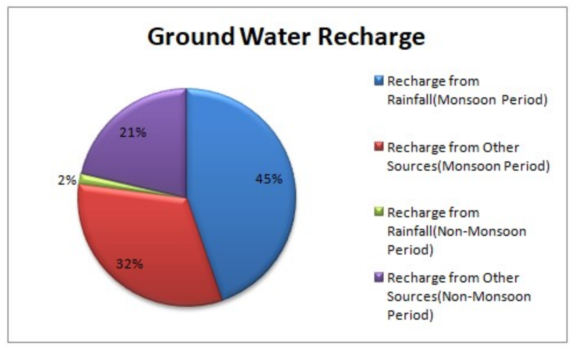


Figure 32: Percentage of Ground water Recharge and Ground Water Draft

As per the Ground Water Resource Assessment – 2022, stage of development ‘Stage of Ground Water Extraction ‘of ground water resources of the district is 53% only. Block wise calculated Stage of Groundwater Extraction is ranged from 28.34% (Sursand) to 69.68% (Bairgania). All 17 blocks fall under safe category of ground water extraction.

About 50 % blocks have the stage of ground water development is around 60% and approaching to the safe limit of 70%. It indicates the dependency on ground water to fulfil the domestic, industrial and irrigation need. But still there are blocks like Sursand & Charaut, where stage of development is below 30%. Therefore, ample scope existed in the district for the further development of ground water up to the safe limit of the Stage of Groundwater Extraction of 70%.

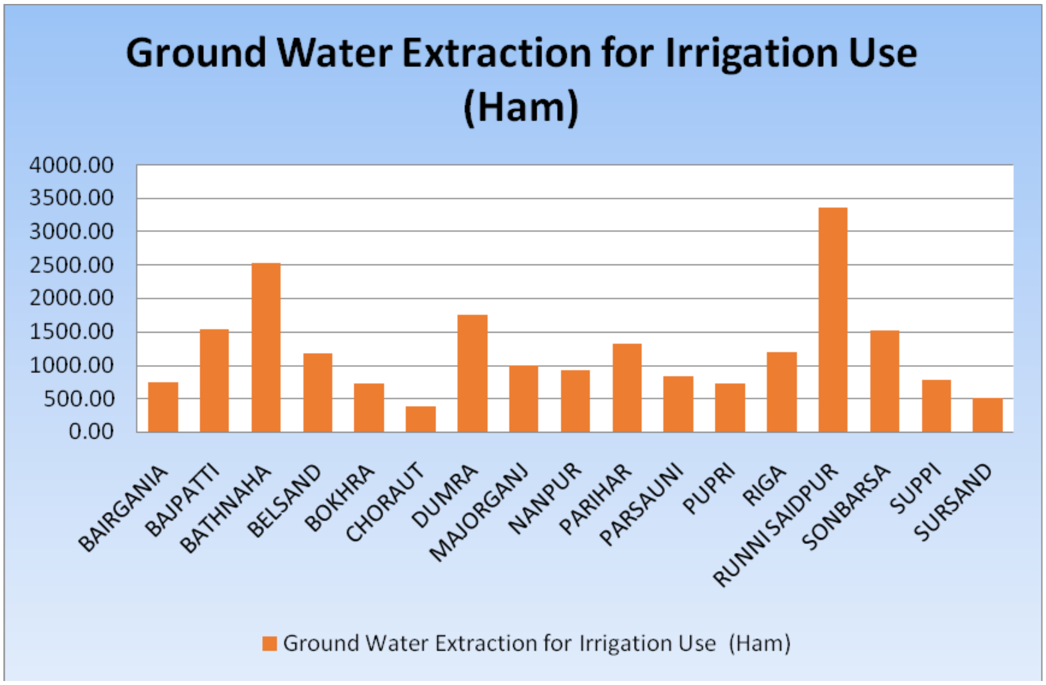


Figure 33: Block-wise stage of groundwater extraction in Sitamarhi district

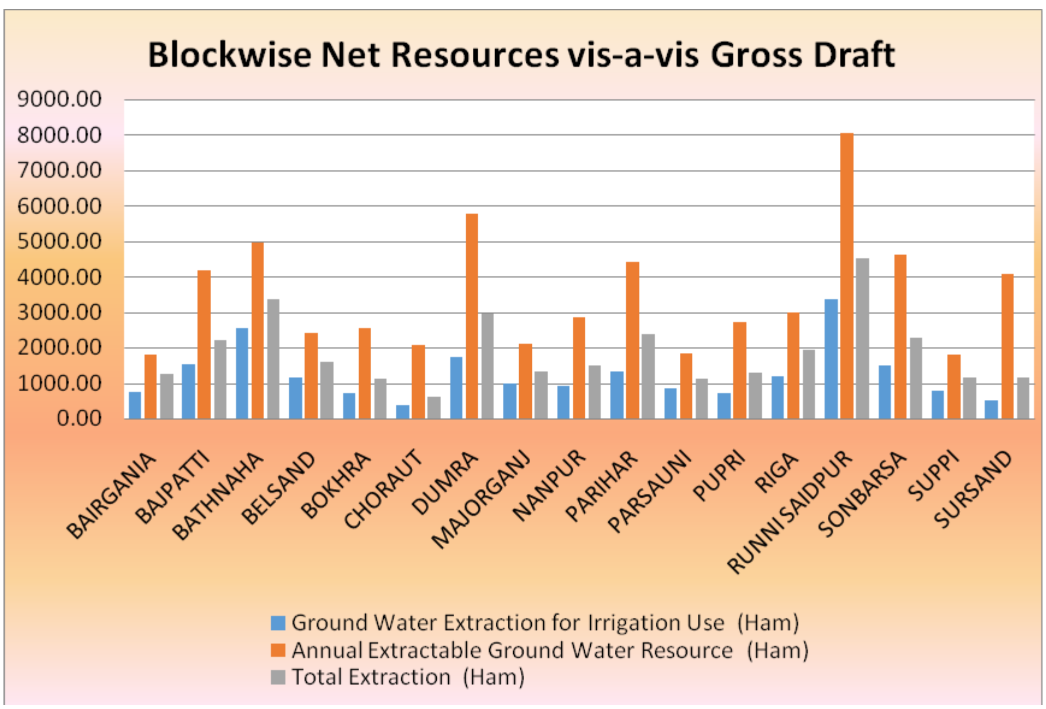


Figure 34: Blockwise Net Resources vis-a-vis Gross Draft

CHAPTER 6

GROUND WATER RELATED ISSUES

Sitamarhi district falls in Mithila region of Bihar have agrarian based economy. Total geographical area is sq km out of which cultivable area is sq km. Dumra is the administrative headquarter of the district. Economy of this district mainly relies on the agriculture. Geologically the district is characterised by the alluvium having alternating layers of sand silt and clay which favours the possibility of surface water irrigation as well as from ground water. As Sitamarhi district is situated on flood plain, it suffers heavy flooding. One of the objectives of this study is to prepare management plan after identifying ground water related issues in terms of its quantity and quality. Quality of ground water of Sitamarhi district, in general, has been found suitable for domestic and irrigation purposes. The issues related quantity of ground water has been discussed below:

6.1Major Ground Water Issues

The major issues identified are:

1. As per the Ground water Resources assessment 2022Stage of ground water extraction is 53% only. Stage of ground water extraction in majority of block is around 50%. It indicates that ample scope exists for the further development of ground water safely. All the 17 blocks fall under safe category.
1. The MI census data and fence diagram prepared indicates that in general, there is a presence of productive aquifer after down to 25 m depth. Hence the number of irrigational tubewell is maximum within the depth range of 20-40 m bgl. Hence this productive zone may be kept under regular monitoring to know its behaviour in time and space.
2. The long term water level trend shows that the effect of population growth on water level. At places it is declining. Hence there is need of artificial recharge. A detail study is required for the better planning.
3. There is water logging problem found in parts of Sitamarhi district especially due to oscillating nature of Bagmati river.
4. As per the previous record, in general, ground water is suitable for irrigation and domestic purpose.

CHAPTER 7

MANAGEMENT STRATEGIES

7.1 Ground Water Development

Development of groundwater potential in the area has to be viewed against the backdrop of a predominant agrarian economy. The aquifer system present in the district is highly potential. As per Ground Water Resources Assessment 2022, the stage of ground water extraction in the district is 53%. There is still lot of scope for further development of ground water. A shallow tube well within the depth range of 20-40 m, tapping granular zone of 10-15 mbgl and 25- 30 mbgl respectively can yield as high as 75 m^3 /hr. A well assembly of 76 mm diameter or 102 mm diameter with 6 to 12 m of slotted pipes can be used for construction of tube wells. Medium tube wells can be constructed by tapping potential aquifer present in the depth range of 50-100 m bgl. A well down to a depth of 70-100 meters tapping the aquifer of 50-80 m bgl can yield on an average of 180 m^3 /hr discharge for nominal drawdown. The slot size should be recommended as per the grain size. For medium to coarse-grained sand the slot opening may be 1/16". The distance between two shallow tube wells should be 150 to 200 m and between two deep tube wells may be 500 to 600m for safe discharge.

Table 23 : Proposed Well Assembly in Sitamarhi District for Well Construction (CGWB District Report, 1993)

Sl.No	Discharge m3/hr	Proposed depth of well	Proposed Well Assembly		H.P. of Motor
			Diameter of the pipe	Length of the pipe (m)	
1	150	100	306 mm Housing 153 mm Slotted pipe 153 mm Blank pipe	25 24 51	22
2	200	150	357 mm Housing 204 mm Slotted pipe 204 mm Blank pipe	30 30 90	35
3	250	180	357 mm Housing 204 mm Slotted pipe 204 mm Blank pipe	35 35 110	42

Possibility of construction of additional shallow tube wells On the basis of Dynamic Ground Water Resources Assessment - 2022, additional number of shallow tube well for alluvium area for each block has been calculated within the safe limit of the Stage of extractionup to 70% by considering unit draft for each tube well 1.82 ha m. Out of 17 blocks 9 blocks are taken based on stage of ground water development and as per the calculation, a total of 1880 number of tube wells can be constructed to fulfil the future demand of ground water. The block wise additional number of tube well is given in table below.

Table 24: Additional Nos. of STW feasible based on GW availability

Assessment Unit Name	Total Annual Ground Water (Ham) Recharge	Annual Extractable Ground Water Resource (Ham)	Total Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Stage of Ground Water Extraction (%)	Category	Projected SOD (%)	GW draft at Projected SOD	Additional Resource Available	Unit Draft of STW	Additional Nos. of STW feasible based on GW availability
Bajpatti	4637.64	4173.87	2206.88	729.85	52.87	Safe	70	2921.71	522.31	1.82	287
Bokhra	2825.84	2543.26	1133.45	443.27	44.57	Safe	70	1780.28	319.71	1.82	176
Choraut	2307.11	2076.40	619.86	268.60	29.85	Safe	70	1453.48	354.32	1.82	195
Dumra	6092.77	5788.13	2939.72	1300.09	50.79	Safe	70	4051.69	436.35	1.82	240
Nanpur	2988.27	2838.86	1478.58	617.82	52.08	Safe	70	1987.20	233.84	1.82	128
Parihar	4911.42	4420.28	2375.22	1145.44	53.73	Safe	70	3094.20	180.64	1.82	99
Pupri	3012.83	2711.55	1296.16	617.75	47.80	Safe	70	1898.09	195.72	1.82	108
Sonbarsa	4864.26	4621.04	2289.82	850.89	49.55	Safe	70	3234.73	535.42	1.82	294
Sursand	4528.85	4075.97	1155.11	711.01	28.34	Safe	70	2853.18	511.78	1.82	281

7.2 Water Conservation and Artificial Recharge

Although, all the 17 blocks are in safe category the artificial recharge should be encouraged to arrest the decline of ground water level caused by the increasing demand of ground water.

By considering entire non-monsoon rainfall as committed, excess monsoon rainfall can be safely harnessed to replenish groundwater table without affecting surface water resource.

For the present calculation for artificial recharge, 60% of the normal monsoon rainfall for identified feasible areas is considered as available non- committed surface runoff.

Table 25: Identified Area, Computed Storage Volume and Source Water availability for Artificial Recharge

	Area Identified for AR	Volume of Desaturated zone	Source Water Requirement	Total Surplus Runoff available
(sq.km.)	(sq.km.)	(MCM)	(MCM)	(MCM)
2185.20	168.94	24.46	37.67	1638.67

Table 26:Type-wise Feasible Numbers/ Area (Sq. Km) / Length (Km) of various Artificial Recharge Structures in Bihar

District	Percolation Tank	Gully Plug	Contour Bunding& Trenching	Check Dam	NalaBunding	Contour Bunding& Trenching	Lateral Recharge Shaft	Recharge Shaft	Percolation Tank	De-silting of existing tank /pond /talao	De-silting of Mauns (Ox-bow lake) (Sq. km)	Injection Well in Village Tank	Renovation of traditional Ahar-Pyne System (km)
Sitamarhi	0	0	0	0	1	0	6	12	1	21	0	29	0

Table 27: Type-wise Cost Estimate in Bihar (in lakh Rs.)

District	Percolation Tank	Gully Plug	Contour Bunding& Trenching	Check Dam	NalaBunding	Contour Bunding& Trenching	Lateral Recharge Shaft	Recharge Shaft	Percolation Tank	De-silting of existing tank /pond /talao	De-silting of Mauns (Ox-bow lake)	Injection Well in Village Tank	Renovation of traditional Ahar-Pyne System	District Total
Sitamarhi	0	0	0	0	1	0	12	60	30	105	0	116	0	**324.0**

The number and type of the recharge structure is based on the published report on "Master Plan to Artificial Recharge"

Annexure I

SN	Location	Latitude	Longitude	May_22	Nov_22	Fluctuation	Altitude	May_22	Nov_22
				m bgl		m	m amsl	m amsl	
1	Belsand	26.51472	85.40306	3.7	1.9	1.8	67.3	63.6	65.4
2	Sursand	26.64611	85.61	3.3	2.8	0.5	66.3	63	63.5
3	Dumra	26.59056	85.49167	1.95	1.22	0.73	70	68.05	68.78
4	Gaighat	26.41902	85.50032	2.6	1.9	0.7	61.1	58.5	59.2
5	Sasula Kala	26.67583	85.35472	3.1	2.32	0.78	74	70.9	71.68
6	Awapur	26.51389	85.65889	1.7	1.3	0.4	62.8	61.1	61.5
7	Choraut	26.53056	85.79389	3.7	1.14	2.56	63.6	59.9	62.46
8	Choraut	26.58194	85.78639	3.6	1.24	2.36	63.9	60.3	62.66
9	Dhadih	26.39917	85.66111	3.8	3.1	0.7	58.7	54.9	55.6
10	Mahadevpatti	26.72278	85.63639	1.8	1.93	-0.13	73.9	72.1	71.97
11	Dumrikala	26.73111	85.40444	3.6	3.3	0.3	74.8	71.2	71.5
12	Bairgania	26.74	85.27528	3.7	2.92	0.78	79.7	76	76.78
13	Thumba	26.43667	85.50028	1.4	0.73	0.67	62.7	61.3	61.97
14	Sitamarhi	26.54806	85.51917	4.75	3.1	1.65	66	61.25	62.9
15	Khaptola	26.56778	85.5575	3.21	3.21	0	68	64.79	64.79
16	Bangaon	26.54472	85.63444	3.3	3.4	-0.1	64.8	61.5	61.4
17	Pupri	26.47278	85.705	2.23	1.98	0.25	62	59.77	60.02
18	Nanpur	26.44028	85.66556	1.14	1.04	0.1	61.7	60.56	60.66
19	Riga	26.63444	85.42361	4.3	2.18	2.12	72.2	67.9	70.02
20	Dheng	26.71083	85.34528	5.2	1.28	3.92	74.7	69.5	73.42
21	Yogwana	26.67917	85.54083	2.48	1.78	0.7	69	66.52	67.22
22	Karhaniya Chowk	26.56639	85.45028	2.4	1.37	1.03	68	65.6	66.63
23	Dastiya	26.78306	85.56472	2.45	1.8	0.65	77.7	75.25	75.9
24	Bhutahi	26.727	85.550	1.54	0.85	0.69	71.1	69.56	70.25
25	Khairwa	26.658	85.704	3.6	1.7	1.9	66	62.4	64.3
26	Sursand	26.596	85.467	2.8	2.4	0.4	67	64.2	64.6
27	Panaura	26.587	85.467	4.1	1.07	3.03	67.3	63.2	66.23
28	Kodwara Tola	26.587	85.471	1.9	1.2	0.7	69.3	67.4	68.1

Annexure II

Result of Chemical Analysis of Ground Water (2022)

No	Block	Location	pH	EC(µS/cm @25°C)	TDS	F^-	Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}	NO_3^-	PO_4^{3-}	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+
1	Runnisaidpur	Gaighat	8.14	2040	1326	0.23	287.55	616.1	0	88.72	13.31	0.31	615	130	70.47	156.7	40.5
2	Runnisaidpur	Thumba	8.28	448	291.2	0.43	10.65	219.6	0	6.37	11.98	0.22	155	6	34.02	26.92	4.09
3	Sitamarhi	Sitamarhi	8.15	382	248.3	0.38	17.75	183	0	3.47	5.23	0.39	145	30	17.01	18.59	2.51
4	Sitamarhi	Khaptola	8.17	383	248.95	0.45	14.2	201.3	0	2.62	1.63	0.15	135	4	30.375	22.07	2.1
5	Bajpatti	Bangaon	8.02	416	270.4	0.38	14.2	213.5	0	0.63	2.31	0.28	130	28	14.58	31.98	2.07
6	Sursand	Sursand	7.9	450	292.5	0.58	14.2	237.9	0	2.73	1.25	0.12	155	46	9.72	29.58	1.74
7	Pupri	Pupri	8.05	409	265.85	0.1	21.3	207.4	0	0.61	1.02	0.09	95	16	13.365	46.2	1.93
8	Nanpur	Nanpur	7.99	425	276.25	0.12	10.65	237.9	0	0.36	0.92	0	120	22	15.795	39.07	2.24
9	Pupri	Awapur	8	442	287.3	0.21	7.1	244	0	0.54	1.27	0	125	14	21.87	40.93	2.27
10	Choraut	Choraut	7.9	436	283.4	0.34	17.75	225.7	0	1.29	1.31	0.12	160	42	13.365	24.38	2.79
11	Choraut	Choraut	7.9	437	284.05	0.18	17.75	219.6	0	2.1	2.33	0.18	140	30	15.795	32.65	1.9
12	Bokhra	Dhadih	8.18	371	241.15	0.24	28.4	170.8	0	1.5	1.02	0	100	22	10.935	35.06	2.36
13	Riga	Riga	7.91	381	247.65	0.17	14.2	183	0	10.84	2.1	0	155	18	26.73	13.71	2.79
14	Suppi	Dheng	7.71	736	478.4	0.19	14.2	420.9	0	0.34	0.87	0	330	78	32.805	12.25	5.94
15	Bairgania	Bairgania	7.6	638	414.7	0.31	14.2	359.9	0	0.66	1.5	0	185	40	20.655	58.85	1.31
16	Majorganj	Dumri	7.82	303	196.95	0.38	14.2	146.4	0	7.24	0.87	0	135	24	18.225	5.14	1.17
17	Bathnaha	Yogwana	8.02	443	287.95	0.25	14.2	237.9	0	3.44	1.23	0.26	170	28	24.3	19.57	1.97
18	Sitamarhi	Karhaniya	7.95	367	238.55	0.35	10.65	189.1	0	6.18	1.12	0.34	140	40	9.72	17.23	2.53
19	Parihar	Mahadevp	7.74	756	491.4	0.58	49.7	366	0	3.1	1.55	0.19	255	58	26.73	47.37	11.03
20	Sitamarhi	Dumra	7.93	435	282.75	0.44	17.75	225.7	0	4.12	0.74	0	170	28	24.3	18.27	2.85
21	Suppi	Sasaula	8	478	310.7	0.32	24.85	244	0	1.41	0.65	0	180	26	27.945	23.68	2.32
22	Sonbarsa	Dastiya	8.1	491	319.15	0.13	17.75	256.2	0	0	0.89	0	165	26	24.3	34.73	1.24
23	Belsand	Belsand	8.02	353	229.45	0.19	24.85	158.6	0	5.12	1.25	0.31	125	12	23.085	21.47	2.12
		Minimum	7.6	303	197	0.1	7.1	146.4	**0**	0	0.65	0	95	4	9.72	5.14	1.17
		Maximum	8.28	2040	1326	0.58	288	616.1	**6**	88.7	13.3	0.39	615	130	70.5	157	40.5

Annexure III

Location			:	Parshapatti,Dumra, Sitamarhi
Coordinate			:	26.554144,85.521719
S.No.	Depth (in m)		Thickness	Composite Lithology
	From	To	(m)	
1	0	10	7	**Sandy soil** : Greyish in colour
2	10	21	11	**Clayey sand** : Greyish in colour
3	21	26	5	**Sand :** Fine sand, greyish in colour
4	26	30	4	**Clayey sand** : Greyish in colour
5	30	35	5	**Sand :** Fine sand, greyish in colour
6	35	60	25	**Clay** : With kankar, greyish in colour
7	60	66	6	**Sand :** Fine sand, greyish in colour
8	66	80	14	**Clay** : With kankar, greyish in colour
9	80	104	24	**Sand** : Fine Sand with kankar, greyish in colour
10	104	118	14	**Clayey sand** : With gravel, greyish in colour
11	118	126	8	**Sand :** Fine sand, greyish in colour
12	126	147	21	**Clayey sand** : With Kankar, greyish in colour
13	147	157	10	**Sand** : Fine to medium sand with gravel, greyish in
14	157	168	11	**Sandy clay :** with kankar, greyish in colour
15	168	174	6	**Sand :** Fine sand with gravel, greyish in colour
16	174	194	20	**Clayey sand** : With Kankar, greyish in colour
17	194	204	10	**Sand :** Fine to medium sand, greyish in colour
18	204	214	10	**Clay :** With kankar, greyish in colour
19	214	220	6	**Sand :** Medium sand, greyish in colour
20	220	228	8	**Clay :** With kankar, greyish in colour
21	228	252	24	**Sand :** Fine to medium sand, greyish in colour
22	252	256	4	**Clay :** Greyish in colour
23	256	267	11	**Sand** : Fine to medium sand, light grey in colour
24	267	270	3	**Clay :** Greyish in colour
25	270	277	7	**Sand :** Fine sand with gravel, greyish in colour
26	277	282	5	**Clay :** With gravel, greyish in colour
27	282	290	8	**Sand** : Fine to medium sand, light grey in colour
28	290	296	6	**Clay :** Greyish in colour
29	296	302	6	**Sand** : Fine to medium sand, light grey in colour

Location			:	Chilara, Sonbarsa, Sitamarhi
Coordinate			:	26.829686,85.572551
S.No.	Depth (in m)		Thickness	Composite Lithology
	From	To	(m)	
1	0	10	10	**Surface soil** : with few sand, greyish in colour
2	10	28	18	**Clayey sand** : greyish in colour
3	28	40	12	**Sand** : Fine sand intermixed with kankar, grey in
4	40	46	6	**Clay** : greyish in colour
5	46	60	14	**Sand** : Fine sand, grey in colour
6	60	65	5	**Sandy clay** : greyish in colour
7	65	100	35	**Sand** : Fine to medium sand, light grey in colour
8	100	104	4	**Clay** : greyish in colour
9	104	130	26	**Sand** : Fine to medium sand intermixed with kankar,
10	130	142	12	**Sandy clay** : greyish in colour
11	142	174	32	**Sand** : Fine sand, grey in colour
12	174	178	4	**Clayey sand** : greyish in colour
13	178	186	8	**Sand** : Fine sand, grey in colour
14	186	192	6	**Clay** : greyish in colour
15	192	206	14	**Sand** : Fine sand, grey in colour
16	206	210	4	**Sandy clay** : greyish in colour
17	210	226	16	**Sand** : Fine sand, grey in colour
18	226	230	4	**Clay** : greyish in colour
19	230	276	46	**Sand** : Fine sand intermixed with kankar, grey in
20	276	280	4	**Clay** : greyish in colour
21	280	288	8	**Sand** : Fine sand, grey in colour
22	288	308	20	**Sandy clay** : Intermixed with kankar greyish in colour

Location			:	Sursand, Sitamarhi
Coordinate			:	26.62858,85.72098
S.No.	Depth (in m)		Thickness	Composite Lithology
	From	To	(m)	
1	0	7	7	**Surface soil**: greyish in colour
2	7	12	5	**Sand :** fine sand, greyish in colour
3	12	36	24	**Clayey sand** : with kankar, greyish in colour
4	36	40	4	**Sand** : fine sand, greyish in colour
5	40	54	14	**Clayey sand** : with kankar, greyish in colour
6	54	70	16	**Sand** : fine sand, greyish in colour
7	70	75	5	**Clay** : greyish in colour
8	75	87	12	**Sand** : fine sand, greyish in colour
9	87	92	5	**Clay** : greyish in colour
10	92	102	10	**Sand** : fine sand, greyish in colour
11	102	104	2	**Clay** : greyish in colour
12	104	128	24	**Sand** : fine sand, greyish in colour
13	128	144	16	**Clayey sand** : with kankar, greyish in colour
14	144	176	32	**Sand** : fine sand, greyish in colour
15	176	180	4	**Clayey sand** : greyish in colour
16	180	188	8	**Sand** : fine sand, greyish in colour
17	188	191	3	**Clay** : greyish in colour
18	191	200	9	**Sand** : fine sand, greyish in colour
19	200	212	12	**Clayey sand** : with kankar, greyish in colour
20	212	221	9	**Clay** : greyish in colour
21	221	230	9	**Sand** : fine sand, greyish in colour
22	230	240	10	**Clay** : greyish in colour
23	240	252	12	**Sand** : fine sand, greyish in colour
24	252	255	3	**Clay** : greyish in colour
25	255	270	15	**Sand** : fine sand, greyish in colour
26	270	286	16	**Clayey sand** : with kankar, greyish in colour
27	286	290	4	**Sand** : fine sand, greyish in colour
28	290	305	15	**Clayey sand** : with kankar, greyish in colour

Location			:	Madhaul, Runnisaidpur, Sitamarhi
Coordinate			:	26.364295,85.483082
S.No.	Depth (in m)		Thickness	Composite Lithology
	From	To	(m)	
1	0	10	10	**Surface soil** : Greyish in colour
2	10	30	20	**Clayey sand** : Greyish in colour
3	30	54	24	**Sand** : Fine sand, light grey in colour
4	54	60	6	**Clay** : Greyish in colour
5	60	92	32	**Sand** : Fine to Medium sand with kankar greyish in
6	92	96	4	**Clay** : Greyish in colour
7	96	100	4	**Sand**: Fine to Medium sand greyish in colour
8	100	108	8	**Clayey sand**: Greyish in colour
9	108	128	20	**Sand** : Fine to Medium sand with kankar
10	128	136	8	**Clay** : Greyish in colour
11	136	143	7	**Sand** : Fine to Medium sand with kankar greyish in
12	143	146	3	**Clayey sand** : Greyish in colour
13	146	153	7	**Sand** : Fine to Medium sand greyish in colour
14	153	162	9	**Sandy clay** : Greyish in colour
15	162	170	8	**Sand** : Fine sand Greyish in colour
16	170	174	4	**Clayey sand** : Greyish in colour
17	174	218	44	**Sand** : Fine sand, greyish in colour
18	218	222	4	**Clay** : Greyish in colour
19	222	258	36	**Sand** : Fine sand intermixed with few kankar, greyish
20	258	300	42	**Sandy clay** : Greyish in colour

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1. Ground Water Year Book – 2021-22
2. Ground Water Exploration Report – Bihar
3. District Brochure of Sitamarhi District.
4. Dynamic Ground Water Resources Estimation of Bihar- 2022
5. District Irrigation Report.
6. Technical Report on Hydrogeology and Groundwater Resources of Sitamarhi District, Bihar (October 1993).

Disclaimer

The Report has been prepared based on the available data, observations from fields and discussion with the local farmers. Additional data, incorporated in future, may change the understanding of hydrogeological scenario of the area.