केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण
विभाग, जल शक्ति मंत्रालय
भारत सरकार

Central Ground Water Board

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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

GARHWA DISTRICT
JHARKHAND

मध्य पूर्वी क्षेत्र, पटना
Mid Eastern Region, Patna

भारतसरकार

Government of India

जल शक्ति मंत्रालय

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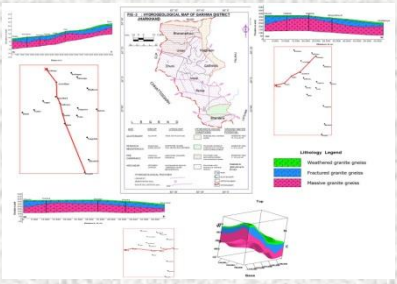
Central Ground Water Board

AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN , GARHWA DISTRICT, JHARKHAND STATE

जलभृत नक्शे तथा भूजल प्रबंधन योजना

गढ़वा जिला, झारखंड



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सितंबर, 2022

State Unit Office, Ranchi

Mid- Eastern Region, Patna,

September 2022

REPORT ON AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN OF GARHWA DISTRICT, JHARKHAND, 2020-21

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REPORT ON NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN OF GARHWA DISTRICT, JHARKHAND, 2020 - 21

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REPORT ON AQUIFER MAPS AND MANAGEMENT PLAN OF GARHWA DISTRICT, JHARKHAND STATE (2020 – 21)

1.0 INTRODUCTION

The vagaries of rainfall, inherent heterogenity & unsustainable nature of hard rock aquifers, 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 implementable 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 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 study of Garhwa district has been taken up in AAP 2020-21 as a part of NAQUIM Programme. The aquifer maps and management plans will be shared with the administration of Garhwa district and other user agencies for its effective implementation.

1.1 Objective and Scope of the study:

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.

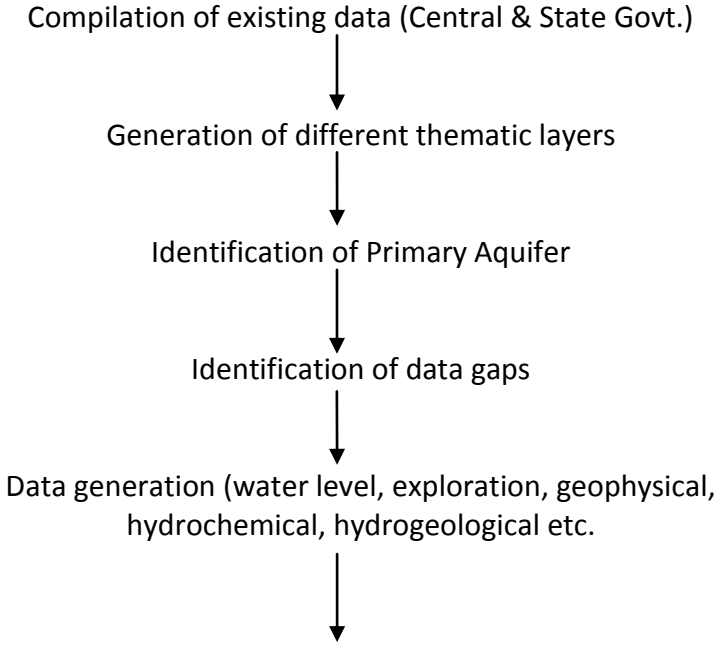
The main activities under NAQUIM are as follows:
a). Identifying the aquifer geometry
b). Aquifer characteristics and their yield potential
c). Quality of water occurring at various depths
d). Aquifer wise assessment of ground water resources
e). Preparation of aquifer maps and
f). Formulate ground water 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.

1.2. Approach and methodology:

The ongoing 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 in hard rock area

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 Aquifermapping is as given below:



Robust Aquifer Maps with 3D disposition

↓

Preparation of Aquifer Management Plan

↓

Capacity building in all aspects of ground water through IEC Activties

1.3 Area details: The erstwhile Garhwa Subdivision of Palamau district was separated from Palamau district as an independent district "Garhwa" with effect from 1st April 1991.Garhwa district is a part of Palamau Commissionery consisting of 19 blocks (Garhwa, Meral,Ranka, Bhandariya, Majhiyaon, Nagar-Untrai, Bhawanathpur,Dhurki, Dandai, Chiniya,Kharoundhi, Ramna, Ramkanda, Kandi, Danda, Ketar, Bishunpura, Bardiha, Sagma.)and two subdivisions namely Garhwa & Nagar-Untrai. Garhwa district located in the North – West Part of Jharkhand with a geographical area of 4044.75 Sq. Km. It is an under developed and draught prone district having diverse terrain. The district lies between 23° 60' and 24° 39' north latitude and 83° 22' and 84° 00' east longitude. It falls in the survey of India Toposheet No. 63P/07, 63P/08, 63P/11, 63P/12, 63P/15, 63P/16, 64M/09, 64M/13 and 64M/14. Garhwa district bordered by river Sone on the north, Palamau district of Jharkhand state on the east, Surguja district of Chhattisgarh state on the south and Sonebhadra district of Uttar Pradesh on the west.

There are 196 Gram Panchayats,916 inhabited villages and 62 un-habited villages in this district. According to the 2011 census Garhwa district has a population of 1,322,387. Location of Garhwa district is shown in figure – 1.

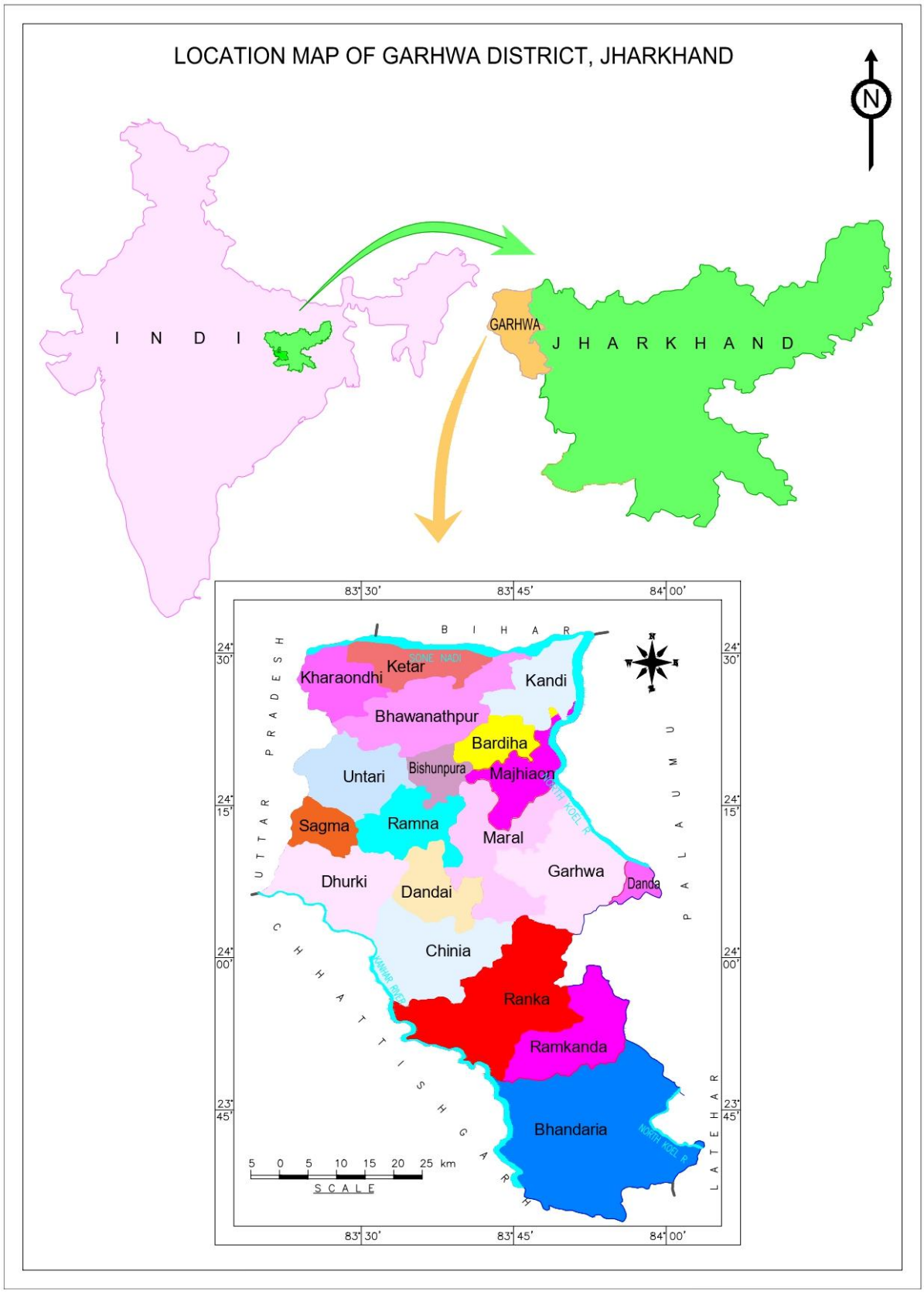


Figure -1: Location map of Garhwa district

1.4 Data Availability, Data Adequacy and Data Gap Analysis

1.4.1. Data availability: Central Ground Water Board has carried out exploratory drilling in the district and drilled total 31 exploratory and 02 observation wells in the district. At least Two exploratory and one observation wells are to be drilled in each block to know the sub – surface geology, depth and thickness of water bearing formation with their yield and determine the different aquifer parameters.

In addition, 11 numbers of permanent observation well (HNS) of Central Ground Water Board located in the district for monitoring of ground water regime and to assess the chemical quality of ground water.

1.4.2 Data Adequacy and Data Gap Analysis: The available data of the Exploratory wells drilled by Central Ground Water Board, State Unit Office, Ranchi, Geophysical Survey carried out in the area, ground water monitoring stations and ground water quality stations monitored by Central Ground Water Board were compiled and analyzed for adequacy of the same for the aquifer mapping studies.

After taking into consideration, the available data of ground water exploration, geophysical survey, ground Water monitoring and ground water quality, the data adequacy is compiled and the summarised details of required, existing and data gap of exploratory wells, ground water monitoring and ground water quality stations is given below in Table-1.

Table – 1: **Data adequacy and data gap analysis**

Exploration data			**Geophysical data**			**GW monitoring data (HNS)**			**GW quality data**		
Req.	Exist.	Gap	Req.	Exist.	Gap	Req.	Exist.	Gap	Req.	Exist.	Gap
57	33	22	95	92	03	38	11	27	38	11	27

The data gap has been identified for Exploratory Wells, Geophysical Survey (VES), Ground Water Monitoring Wells and Ground Water Quality. Each three numbers of exploratory wells and one observation well are required in Kharaondhi, Bardiha and Danda blocks, two numbers of exploratory wells and one observation well are required in each block of Bishunpur, Sagma, Dandai, Ketar, Kandi and Manjhiaon of the district. Similarly, at least one exploratory well and one observation wells are required in Ramkanda, Ranka, Chinia, Nagar Utari, Bhawnathpur and Dhurki blocks. One exploratory and one observation wells are required in Ramna and Garhwa blocks.

1.5 Climate and Rainfall: The climate of this district is humid and subtropical. The winter season starts from November and last till February, it followed by summer season which continued up to early June. The monsoon season begins from middle of June and continued up to middle of October.

The district belongs to the rainfed class with large annual variation. The average rainfall last five years (2015 – 2019) of the distinct is 917.02 mm. District wise average rain fall varies from

503.88 (Kandi block) to 1297.5 mm (bhandaria block). The maximum rainfall occurs during the first half of July to August and contributes about 50 % of the total rainfall. The monsoon season contributes about 85 % of the total annual rainfall. However dry spell of 4-8 days have been very common in the month of July and /or August. The maximum humidity is observed during the monsoon season with mean value of 85%, where as the minimum humidity is observed during April-May which is 27 %. Generally the weather during the other seasons is more or less dry and in the comfortable zone. Month wise rain fall data (2015-2019) of the district is given in Annexure –I. Block wise annual rainfall and average rain fall data is given below in table – 2.

Table-2: Last five years annual and average rain fall data (mm) of Garhwa district (2015 – 2019)

Sr. No.	Block	Year wise annual rain fall (mm)					Average rain fall (mm)
		2015	2016	2017	2018	2019	
1	Garhwa	760.7	1495.2	479.3	448.0	483.1	733.26
2	Meral	668.5	1143.1	390.4	440.0	422.3	612.86
3	Dandai	692.5	1523.9	--	--	--	1108.2
4	Majhiaon	684.2	1442.5	726.9	782.9	834.1	894.12
5	Kandi	410.5	884.0	223.0	260.0	741.9	503.88
6	Ranka	1068.2	1924.0	317.7	453.5	888.0	930.28
7	Chinia	412.0	1459.6	872.0	1058.9	1190.9	998.68
8	Ramkanda	813.4	1561.4	607.3	725.5	675.1	876.54
9	Bhandaria	1260.6	1703.7	1033.0	1609.5	880.7	1297.5
10	Nagar Utari	551.3	1315.0	804.0	1131.4	1006.0	961.54
11	Ramna	641.8	1479.8	745.5	708.3	1136.5	942.38
12	Dhurki	667.5	1517.6	923.0	825.0	1414.3	1069.48
13	Bhavnathpur	645.8	1383.5	686.3	865.3	1008.3	917.84
14	Kharaondhi	292.8	1639.3	981.9	1189.6	855.5	991.82

1.6 Geomorhpology: The district of Garhwa presents a highly rugged topography with thick green forest all over its area. The hills are widely scattered and rise up to 1164 meters above m.sl in the southern parts of the district. Average height of the hills varies from 700 – 900 meters while the elevation of plain ranges from 250 – 500 meters. The master slope of the district is towards north.

The district can broadly, be divided in (a) east – west trending hills ranges consisting of crystalline and metamorphic rocks in the southern parts of the district (b) the sub-plateau area lying east of the plains and separated by narrow valleys in parts of Bhawnathpur, Meral and Majhiaon blocks and (c) the narrow valleys along the coarses of major rivers.

1.7 Land use: The district is predominantly agrarian and majority of population in rural areas depend on agriculture and other allied activities, which do not give steady and sufficient income. Therefore, poverty and illiteracy dominate the rural scenario. The land mass is fixed, but the competition among different kinds of uses for this land is increasing because of rapidly

rising global population. Therefore, integrated land resource planning and management are required to resolve these conflicts. Out of total geographical area of the district i.e. 961.19 Sq. km, about 24 % area comes under net sown area, 43% under forests and the rest area falls under barren, cultivable waste, pasture and other agricultural use. Block wise land utilization data of the Garhwa district for the year 2020 - 21 is given in table – 3.

Table: 3: Land use pattern of Garhwa district (2020 – 2021)

(Figures in Hectare)

Block	Area of the block (Sq. km.)	Forest land	Barren & non cultiva-ble land	Culti-vable waste land	Perm-anent past-ures & other grazing land	Land under miscell-aneous trees	Current fallow	Fallow land other than current fallow	Net area sown	Area sown more than once
Bardiha	97.70	3073.94	403.36	13.46	--	132.84	404.86	692.20	3765.34	126.18
Bhandaria	661.18	48067.29	2990.73	700.32	703.89	317.49	3877.05	3859.38	4298.88	238.08
Bhawnathpur	286.88	15519.14	1062.77	81.79	158.83	83.69	485.80	2185.46	5002.89	394.47
Bishunpura	79.23	3585.56	752.93	61.37	--	24.77	163.00	144.19	11525.78	7826.89
Chinia	285.83	17771.34	2658.24	1690.91	219.47	515.78	401.96	479.60	3507.69	834.20
Danda	31.86	474.57	31.49	--	--	19.24	79.05	194.59	1920.38	1986.70
Dandai	138.33	3925.46	538.52	360.26	--	242.57	775.34	2719.75	4939.05	555.72
Dhurki	211.46	13285.94	474.39	2.95	--	124.20	2213.76	3300.77	3460.99	842.36
Garhwa	273.55	4014.92	839.17	--	42.31	272.07	4879.23	7701.40	7123.15	2151.46
Kandi	176.98	2944.45	2165.19	291.58	121.91	135.82	1315.41	2468.93	3339.90	2100.41
Ketar	154.05	6039.11	1488.30	293.66	--	43.34	2250.45	1935.87	3034.90	1040.02
Kharaondhi	141.08	5846.62	538.00	512.29	263.23	346.14	1084.63	1057.61	4535.47	673.18
Majhiaon	141.47	2283.24	1700.59	344.08	201.64	198.79	10240.86	21489.32	6313.75	133.03
Meral	263.87	6104.52	3505.26	315.99	139.86	214.04	2640.83	3650.48	7846.58	321.25
Ramkanda	221.85	6622.24	1449.26	1550.18	29.99	39.86	987.49	1489.83	5478.27	894.61
Ramna	154.21	4624.76	812.30	328.25	732.66	107.57	2412.11	2476.92	4213.96	541.69
Ranka	427.43	21924.03	4662.30	3069.81	261.47	660.55	2752.24	3278.36	4662.54	29.50
Sagma	99.83	3534.68	235.18	1.66	--	85.32	215.48	283.56	2080.36	1382.88
Utari	197.96	5203.32	535.61	63.40	69.65	70.13	1782.90	2752.04	9069.38	195.22
Total	**4044.75**	**174845.10**	**26843.59**	**9681.96**	**2944.91**	**3634.21**	**38962.45**	**62160.26**	**96119.26**	**22267.85**

Source: - Office of the Director Statistic office, Ranchi, GOJ

1.8 Soil: There is heterogeneity in the soils of the district. This heterogeneity of soil may be attributed to uneven topography, variation in rainfall over the area and composition of the parent rocks. The soil of the area is light grey and fine texture in nature. The soil profile changes from reddish brown colour in the upland areas to grayish yellow in the low valley area of the district. The soil of the district can be broadly be grouped into three classes –

I. Heavy clay: This soil is locally known as Kewal soil. The soil becomes hard when dry and sticky when wet. This soil can hold moisture for a longer period and as a result considered to be favorable for rabi crops.

II Sandy soil: This soil is locally known as Balsundar and consists of coarse sand to a large extend and facilitates production of paddy, fruits and vegetables.
III. Loamy soil: This soil is locally known as Dorasa and consists of mixture of sand and clay. This soil is suitable for growing Sugarcane.

1.9 Hydrology and Drainage: There are twelve major and medium projects have been constructed in the district. These projects were planned originally for giving water to Kharif and Ravi seasons. Details of these projects are given below in table 4.

Table-4: Details of major and medium irrigation projects of Garhwa district

Sr. No.	Name of the project	Block	Main canal length (in km.)		Distributaries (in km.)	Total irrigation capacity (in thousand hectare)		
			Left	Right		Kharif	Ravi	Total
1	Anraj project	Garhwa	14.87	--	13.14	4.17	1.50	5.67
2	Danro project	Dandai	19.00	9.00	--	3.25	1.62	4.87
3	Chirka project	Chimia	15.01	--	8.12	1.00	0.44	1.44
4	Phulwaria irrigation project	Meral	4.26	2.85	--	0.60	--	0.60
5	Saraswati irrigation project	Garhwa	9.57	8.40	--	0.87	--	0.87
6	Pandarwa project	Nagar Utari	6.10	--	2.01	0.64	0.60	1.24
7	Banyi Banki project	Nagar Utari	5.80	4.70	0.80	1.10	0.10	1.20
8	Banyi Banki project	Ramna, Majhiaon	27.90	25.00	18.55	5.27	0.81	6.08
9	Chataniya Ghat project	Bhawnathpur	2.68	3.35	--	0.42	--	0.42
10	Babhnikhand project	Nagar Utari	3.60	--	6.46	0.54	0.12	0.66
11	Uttamahi irrigation project	Dhurki	6.61	--	--	0.60	--	0.66
12	Kawaldag irrigation project	Bhawnathpur	9.14	--	8.95	1.20	0.20	1.40

The district is forming Sone sub basin of the Upper Ganga basin. Hydrologically the area is very interesting. The river North Koel is the main river of the district, which flows south to north direction and forms north – east boundary of the district. The river Sone flows from west to east direction and forms the northern boundary of the district. One another major river Kanhar flows from North West to south east direction and forms the south west boundary of the district. The tributaries of the main river i.e. South Koel are flowing almost west to west direction. All these drainage is characterized by rapid surface run – off. All these rivers are seasonal in nature. The drainage pattern of the district is dendritic. Drainage map of the district is shown in 2.

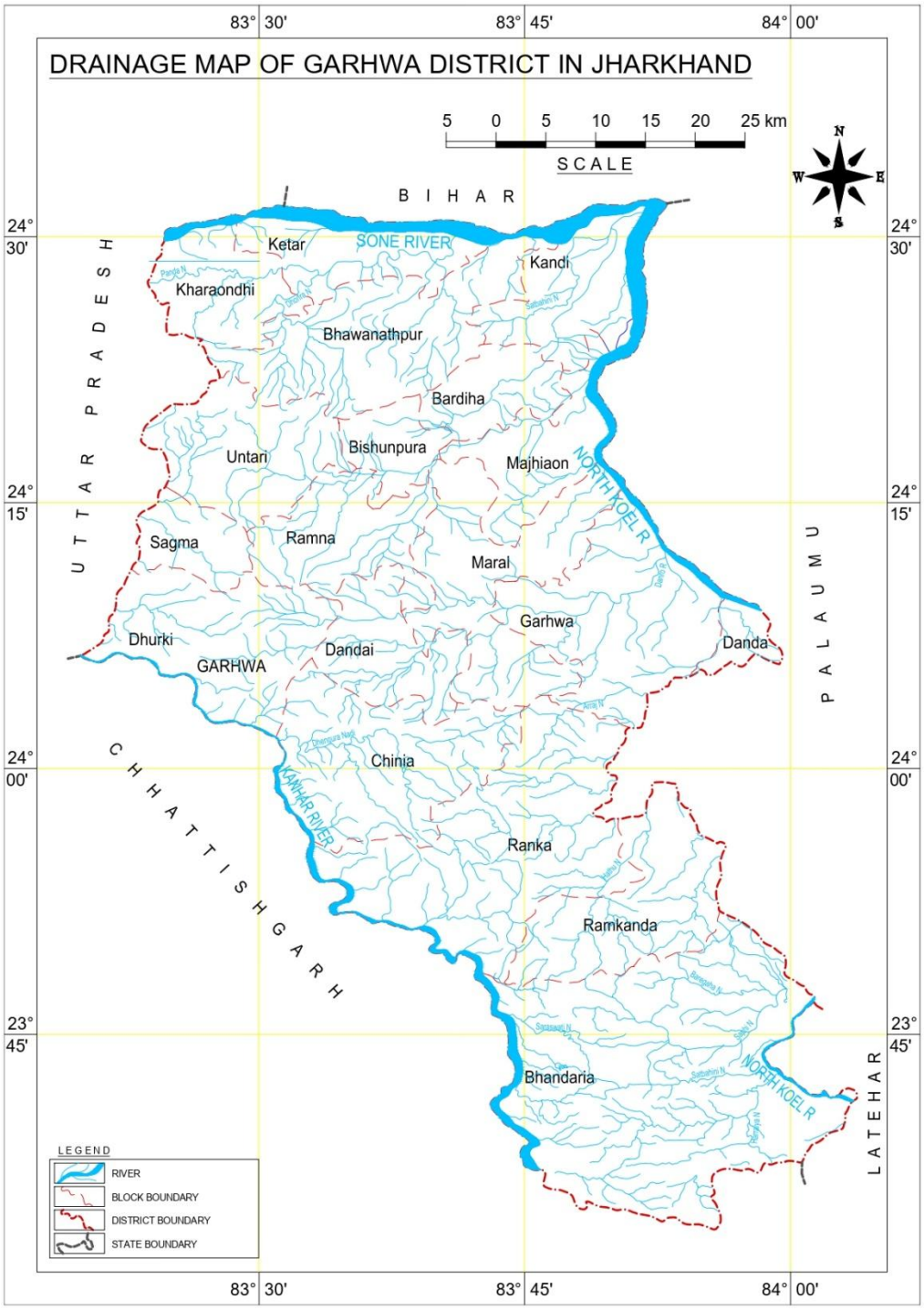


Figure – 2: Drainage map of Garhwa district.

1.10 Agriculture and Irrigation practice:

Agriculture is the major occupation of the rural population of the district. Since the density of population is high, there is acute pressure on land for agriculture use. But the land available for cultivation is limited because of rugged and hilly geomorphological set-up.

Surface flow and lift irrigation schemes are main surface water sources in this district and irrigated some hectare of land. The most common ground water source is the dug well, but this is not a very dependable source of irrigation. The major part of the district being rocky in nature, it is difficult to dig wells. The undulating nature of land makes it possible to store rain water by bunding. Apart from being dependent upon rains, these are by no means adequate. The result is that failure of rains invariably involves failure of crops. However, as per 5th Minor Irrigation census for the year 2013-14, about 91% irrigation of the district is depend on ground water sources. Block wise number of irrigation structure and source wise irrigation data of the district is given in table – 5 & 6 respectively.

Table – 5: Block wise number of irrigation structure of Garhwa district (2013-14)

Block	No. of surface water irrigation structures			No. of ground water irrigation structures			
	Surface flow scheme	Lift flow scheme	Total	Dug well	Shallow tube/bore well	Deep tube/bore well	Total
Bardiha	59	3	62	209	0	0	209
Bhandaria	303	5	308	678	1	0	679
Bhawnathpur	217	54	271	678	147	264	1089
Bishunpura	32	97	129	162	1	106	269
Chinia	48	2	50	132	0	0	132
Danda	120	1	121	65	3	0	68
Dandai	187	22	209	476	3	0	479
Dhurki	168	49	217	427	5	2	434
Garhwa	85	13	98	312	35	1	348
Kandi	80	50	130	400	18	0	418
Ketar	100	9	109	381	1	15	397
Kharaondhi	85	151	236	534	16	346	896
Majhiaon	31	5	36	178	16	6	200
Meral	100	27	127	440	1	2	443
Ramkanda	182	15	197	324	0	0	324
Ramna	390	34	424	1082	62	26	1170
Ranka	29	9	38	310	5	0	315
Sagma	197	111	308	674	14	0	688
Utari	435	60	495	1544	34	2	1580
Total	**2848**	**717**	**3565**	**9006**	**362**	**770**	**10138**

(Source: 5th Minor Irrigation census, GOI)

Table – 6: Source wise irrigation data of Garhwa district, 2013-14 (Area in Hectare)

Block	Surface water irrigation (in hectare)	Ground water irrigation (in hectare)
Bardiha	27	104.50
Bhandaria	158	425.25
Bhawnathpur	173	5924.25
Bishunpura	126	2182.25
Chinia	22	66
Danda	49	37
Dandai	101	242.50
Dhurki	126	261
Garhwa	50	228.50
Kandi	100	277
Ketar	61	539.62
Kharaondhi	215	7211
Majhiaon	18	233
Meral	72	261.50
Ramkanda	91	162
Ramna	158	1018.75
Ranka	22	162.50
Sagma	212	358
Utari	246	863
Total	**2027**	**20557.62**

(Source: 5th Minor Irrigation census, GOI)

1.11 Cropping pattern:

The main economic activity in the district is agriculture. Paddy and Maize are the two main crops in the district. However, in the absence of assured irrigation facility, agriculture in the district is primarily rain fed and as a result, mainly mono-cropping and subsistence farming is practiced in the district. As per the agro-climatic zones delineated by Planning Commission, Garhwa district falls under Zone (VII) i.e., eastern plateau and hill region. It requires strategic planning so as to maximize the use of rainwater, increased ground water utilization level to achieve balanced crop production. Water resources also need to be developed through dug wells and lift irrigation. Watershed development also holds promise in the district. The cropping pattern followed in the region is by and large under rain fed conditions. 85% of kharif is under paddy. The other main kharif crops are maize, arhar and urad. Rabi crops are grown only in areas where there is irrigation facility. Main rabi crop of the district is vegetables like potato, tomato, cauliflower etc. Productivity of agriculture is poor in the district. The erratic nature of the rainfall and its long inter spell gaps lead to frequent crop failure over a large part of the district. Area under crop for the year 2020 – 21 of the district is presented in table - 7.

Table – 7: Cropping pattern of Garhwa district (2020 - 21)

(Area in hectare)

Sr. No.	Block	Major Crops					
		Paddy	**Pulses**	**Maize**	**Oil seeds**	**Vegetable**	**Wheat**
1.	Bardiha	3535.15	1106.65	2057.65	432.30	217.70	102.70
2.	Bhandaria	6391.38	561.20	1617.95	430.40	272.55	991.60
3.	Bhawnathpur	6865.91	938.96	1922.68	1251.27	467.66	1066.26
4.	Bishunpura	3579.10	342.76	1432.45	638.80	163.80	1131.50
5.	Chinia	4992.80	675.00	2487.40	451.72	248.35	1082.30
6.	Danda	4641.60	279.03	1602.55	157.50	142.71	1076.80
7.	Dandai	5954.45	721.88	2631.00	229.64	116.05	1160.80
8.	Dhurki	5041.76	745.03	2171.00	409.10	356.31	1268.70
9.	Garhwa	9758.58	2452.24	4459.80	1028.17	858.07	1212.20
10.	Kandi	8231.80	349.25	2724.05	239.35	142.35	1026.60
11.	Ketar	5143.21	441.05	1405.20	1060.47	296.97	1061.30
12.	Kharaondhi	5639.14	677.47	1380.65	232.80	597.47	450.70
13.	Majhiaon	5995.97	960.21	2955.20	592.01	270.55	3051.75
14	Meral	9324.53	1239.27	4846.60	959.74	322.34	1186.80
15	Ramkanda	5320.10	631.10	2337.10	795.50	247.49	1277.30
16	Ramna	4844.22	549.97	3026.05	185.90	195.76	1126.30
17	Ranka	6440.30	793.36	1086.80	1009.45	490.52	1086.11
18	Sagma	3928.54	576.60	1410.25	165.65	450.77	1266.10
19	Utari	9000.71	2078.82	3965.20	817.72	538.28	1606.88
Total		**114629.3**	**16119.85**	**45519.58**	**11087.49**	**6395.70**	**22232.70**

Source: - Office of the Director Statistic office, Ranchi, GOJ

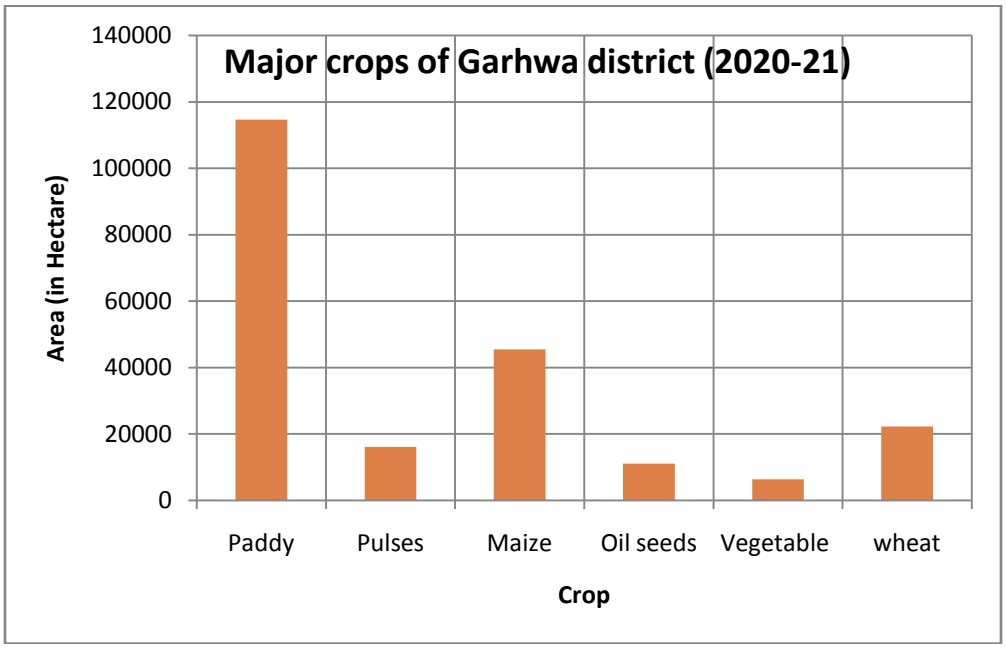


Figure – 3: Major crops of Garhwa district (2020-21)

1.12 Geology of the area: Major part of the district is occupied by granite gneiss of Archaean age. Sedimentary rocks of Vindhyan super group are exposed around Bhawnathpur in north western parts and Gondwana rocks in the southern parts of the district. The general geological succession of the district may be given as under –

Age	Formation	Lithology
Quaternary	Younger Alluvium	Sand, Silt, Clay
……Unconformity……		
Upper traiassic	Mahadeo Formation	Brownish Sandstone
Lower Triassic	Panchet Formation	Grey sandstone and Shale
Upper Permian	Panchet formation	Yellow Sandstone and Shale
Lower Permian	Barakar Formation	Coal bearing sandstone & shale
	Karharbari Formation	Coal bearing sandstone & conglomerate
Permo-carboniferous	Talchir Formation	Sandstone, shale and boulder bed
……Unconformity……		
Pre cambrian	Kaimur group	Kaimur sandstone
	Semri group	Rohtas Stage: Limestone, shale & sandstone
		Khenjua Stage: Limestone and shale
		Basal Stage: Limestone, Conglomerate
……Unconformity……		
Archaean	Chhotanagpur Granitic gneiss complex	Granite-gneiss, Dolerite dykes, pegmatites and quartz veins, porphyritic granite
……Unconformity……		
Older Amphibolites, quatz-schist, graphite-garnet-sillimanite schist etc.		

Chhotanagpur granite – gneiss complex: The oldest formation exposed in the area is granite gneiss complex of Archaean age consisting of pink granite, porphyritic granites, banded gneisses etc. Banded gneiss is characterized by alternation of dark coloured hornblende and light coloured micas. These granite gneisses occur as a intrusive in the older metamorphic. The older metamorphics occur in isolated lenses in the form of remnant rocks. These are constituted of graphite – schist, dolomite and quartzite etc. Chhotanagpur granite gneiss and amphibolites are exposed near the village Ranka where the strike is in E – W direction. Dolomite dykes trending in E – W direction are exposed near Barwadih. Graphite bearing schist and dolomites are mined on small scale near Nagar Utari.

Semri Group: Sandstone, Limestone, shale and porcettanites of Semri group are exposed near Nagar Utari and Bhawnathpur. Most of the areas, where Semri series are exposed being covered by forest.

Kaimur Group: Kaimur group is exposed in the north – western parts of the district near the Panda in the north of Bhawnathpur. Rocks of Kaimur group support good cultivation where they are overlain by thick weathered mantle.

Gondwana Super Group: Rocks of Gondwana Super Group are exposed in the district at Hutar coal field. This coal field is located very near to Barwadih. Gondwana rocks occupy nearly 200 Sq. Km. area around Hutar coal field. Barakar and Karharbari formations cover the major part of Hutar coal field. These two formations attain the thickness of about 300 m. Talchirs are also developed in this area for about 20 kms. Mahadeo formation occurs on the western part of the coal field.

Alluvium: Appreciable alluvium occurs along the Sone and north Koel rivers in the northern and eastern parts of the district. The sediments deposited by Sone river can be divided into two parts the newer and older alluviums. The newer alluvium consisting of sand, silt and clay occupies the flat valley area. The thickness of alluvial sediments varies from 10 – 15 m. The older alluvium consisting of ferruginous sediments occurs near the foot hills around Majhiawan block. The thickness of this alluvium varies from 30 – 50 m.

Structural Features: Granite and granite gneisses which is product of Satpura orogeny-dominate the Geology of the area. These rocks trend in ENE – WEW direction which is also the trend of major fault system occurring in the area. A number of major faults have been delineated in the area. These faults control the coal seams of the district. The major faults are –

1. Rajhara Fault: It occurs in the north of Daltonganj with a E – W trend and separates the Gondwana from the granite gneisses of Archaean age.

2. Hutar Fault: This fault is also known as Balbal fault and can be noticed in South – West of barwadih and Hutar coal field. The trend of this fault is E – W direction. Hot springs occurs along this fault and temperature of water has been recorded to be 34^0 C of one such hot spring at Talha.

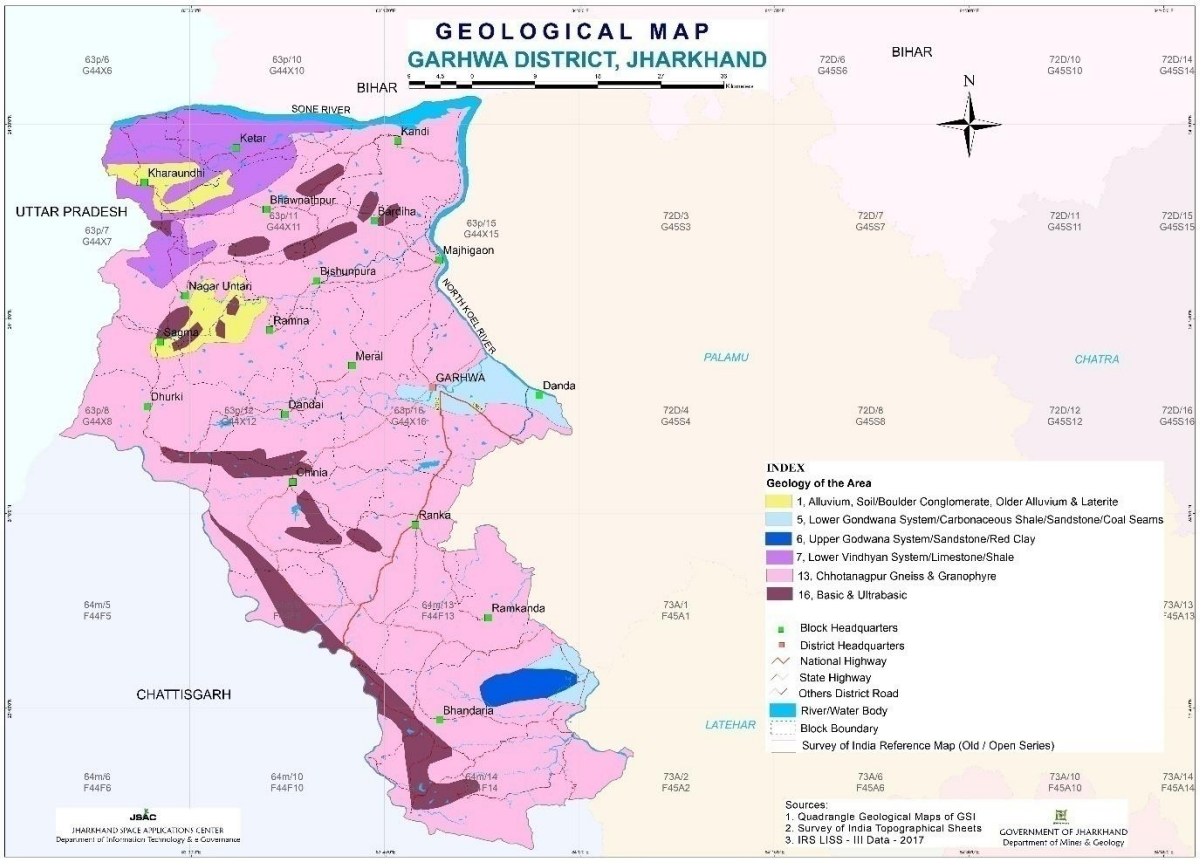


Fig-4. Geological Map of Garhwa District, Jharkhand

2.0 DATA COLLECTION AND DATA GENERATION

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 has carried out exploratory drilling in the district and drilled 5 exploratory wells by departmental rig during the year 1990-1993. Similarly, 26 exploratory wells and 02 observation wells were drilled through outsourcing drilling during the year 2020-21.

2.1 Data Collection, Compilation and Data Generation

2.1.1 Data Collection and Compilation:

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

i. Hydrogeological Data: Water level data of 41 key wells (during Nov. 2020) and historical water level trend of monitoring wells were collected and compiled representing Aquifer-I. Compilation of litholog, collected depth and thickness of water bearing zones with their yielding capacity, aquifer geometry, data from exploratory and observation wells were drilled in the district.

ii. Hydrochemical Data: To evaluate the quality of ground water, 39 samples were collected from dug wells and 41samples from hand pumps representing shallow aquifer (Aquifer – I) and deeper aquifer (Aquifer – II) respectively.

iii. Geophysical survey: 92 VES were carried out through outsourcing activity during 2021-22 to identified the weathered zone resistivity and its thickness as wells as find out deeper fracture zone in hard rock formations.

vi. Exploratory drilling: 31 exploratory and 02 observation wells were drilled in hard rock area of the district.

vii. Hydrometeorological Data: Collected last five years (2015 – 2019) annual rainfall data for each of the block from the office of Director Statistics, GOJ, Ranchi.

viii. Land use and cropping pattern data: Data of land use and cropping pattern from the office of Director Statistics, Ranchi.

2.1.2 Data Generation: After taking into consideration, the data available with CGWB on ground water monitoring wells (GWMW), ground water quality, geophysical survey and ground water exploration, the data adequacy was compiled and it indicated that 22 numbers of exploratory wells are required in the district. Additional Data in respect to water quality and Monitoring wells were generated. The requirement, availability and gap of major data inputs i.e., exploratory wells, geophysical data, ground water monitoring wells and ground water quality data are detailed in the table – 1.

2.2 Hydrogeology: Ground water in the district occurs within the weathered mantle of hard rocks in general and fractures, fissures occurring in fresh rock at select places. Ground water is also available in limited volume in alluvial deposits occurring along the Sone and North koel rivers. The source of ground water recharge is entirely by rainfall as most of the rivers of the district are effluent which do not contain in appreciable water during lean period to recharge

the ground water at lower reaches. The ground water condition in various hydrogeological units are described as below –

Older Metamorphics: The ground water potential of older metamorphics are poor to moderate with a a discharge of about 2 lps. The rate of recuperation is quicker in these rocks than the adjoining granitic terrain. The depth of weathering varies from 8 – 15 m below ground level.

Granite gneiss complex: Weathered granite gneiss forms the main repository of ground water in the district. Ground water also occurs in the secondary opening (Joints, fractures, fissures foliation etc.) formed within the underlying granite gneisses. The thickness of the weathered mantle varies from 3 to 16 m bgl in general.

The Vindhyan Sandstone and Limestone: Sandstone is compact in nature but weathering is varying extent has made it porous and permeable and thus good repository ground water. Moderate yield prospect of ground water is expected in this unit. Limestone shows some sink holes at places which indicate the possibility of getting water in good quantity at selected place. Dug cum bore wells are suitable structures in this hydogeological unit.

Gondwana formation: Gondwana rocks are exposed mainly around Hutar and Daltonganj coal fields. Arkosic sandstones and shales of Barakar and Karharbari series along with shales of Talchir series are exposed in the area. Weathered sandstones and fractures are the main aquifers in this formation.

Dolerite and Pegmatite: These are the younger intrusive in the Archaean rocks. Tectonic movements have created secondary porosity in it and have been weathered to varying extent. The depth of open wells are usually more in these rocks and goes up to 20 m bgl and discharge in such well is about 1 lps.

Alluvium: The alluvial sediments mainly occur along the Sone and North Koel rivers. The thickness of alluvial deposit varies from less than a meter to over 20 m and mainly large diameter dug wells have been constructed in this formation which give a sustained yield of 5 – 15 lps for a continuous pumping of 5 -6 hrs with a drawdown of 1 – 2 meter only. Near full recouperation of wells take place in about 10 hrs which enables the farmer to draw water every day. All the seasonal crops requiring irrigation are grown in such alluvial areas. Hydrogeological map of the Garhwa district is shown in figure 4.

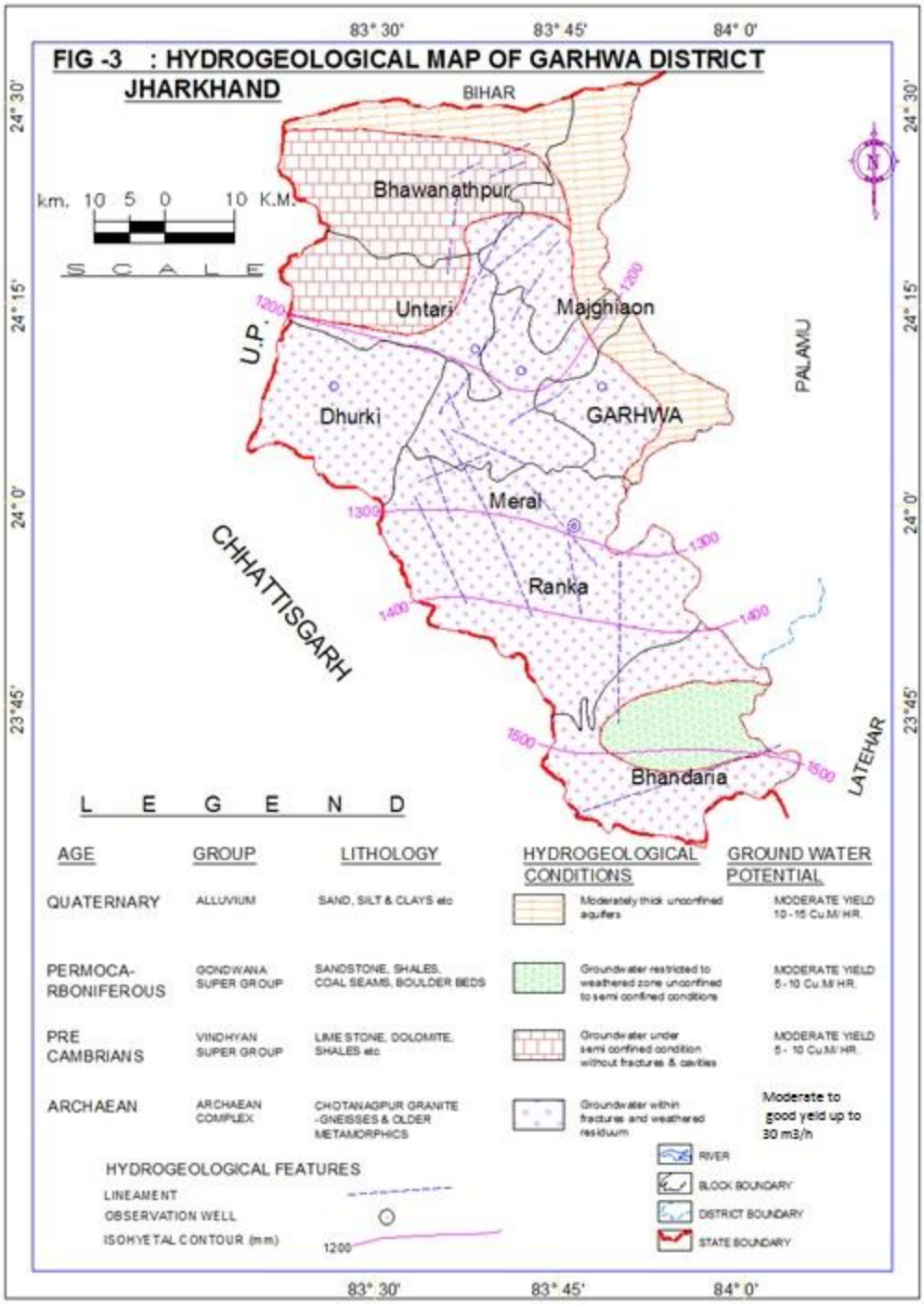


Figure – 5: Hydrogeological map of Garhwa district

2.2.1 Ground Water in Aquifer-I (Weathered):

Generally two types of aquifers are found in the district namely, the weathered aquifer and fractured aquifers. Thickness of weathered aquifers varies from 5.60 – 35 m in general in granite gneiss terrain. Within the depth zone of dug wells, the weathered zone influences to a greater in the hard rock formation constitute potential phreatic shallow aquifer. In the weathered and less fractured zone, the yield of the open wells is good with intermittent pumping. This zone should be developed either through large diameter open wells for domestic

as well as irrigating small holdings of land. Hand pumps generally tap first fracture zones and its depth is 9 - 50 mbgl constructed by State Government Department.

2.2.2 Ground Water in Aquifer-II (fractured): 35 numbers of boreholes have been constructed by CGWB in the district under the ground water exploration programme up to maximum depth of 206.00 m. These borehole data reveals that, in general potential fractures are encountered between 9-164 m. The yield of exploratory wells found between 0.50 to 10.76 LPS. Table-9 shows the Potential Fracture encountered during Ground Water Exploration in Garhwa district.

Table – 9: Potential fractures encountered during ground water Exploration in Garhwa district, Jharkhand

S. No.	Location	Block	Depth drilled (mbgl)	Casing depth (mbgl)	Major lithology encountered	Potential fractured zone (mbgl)	SWL (mbgl)	Yield (LPS)
1	Bhandaria	Bhandaria	201.00	24.90	Granite Gneiss	139.00 – 141.00 160.00 – 161.00	10.77	3.15
2	Tamega Kalan	Ranka	127.00	11.70	Granite Gneiss	30.00 – 32.00 92.00 – 93.00	4.16	6.70
3	Peska	Meral	201.00	13.20	Granite Gneiss	91.20 – 93.50	5.72	3.15
4	Dumaria	Garhwa	96.00	20.85	Granite Gneiss	63.00 – 65.50	17.10	10.76
5	Dandai	Dandai	201.00	17.30	Granite Gneiss	53.40 – 55.00	5.30	4.42
6	Dudhvania	Ramna	148.00	5.60	Granite Gneiss	11.00 – 11.50 60.00 – 60.50 143.00 – 143.50	4.49	3.15
7	Hariharpur	Bhawnath-pur	95.00	34.60	Granite Gneiss	40.00 – 41.50	6.04	4.80
8	Ramna	Ramna	114.07	--	Granite Gneiss	9.00 – 15.90 21.00 – 23.61 38.85 – 46.40 54.09 – 60.00 64.50 – 68.00 110.70 – 114.50	5.04	5.5

Source: CGWB

On the basis of field investigations and results of exploratory wells drilled in the district, salient findings are summarized as:-

- In general in fissured formations, discharge of well has been found in the range of 0.50 - 10.76 LPS.
- Overall in the district the major potential fractures zones are found upto 164 m.

- First potential fracture zone encountered in the district widely varies from 9.00 - 164 m.
- Sometimes the potential fractures were encountered at very shallow level 30.00-32.00 m with very high yielding wells(Tamagia Kalan-6.70 LPS) . These potential fractures may be tensile in nature occurring at shallow level, which is found to be potential repository of ground water. Some of the exploratory wells encountered upto the depth of 96.00 m which yielded high discharge e.g. Hariharpur (4.80 LPS) and Dumaria (10.76 LPS).
- Some of high yielding well where multiple fractures were encountered within 161 m depth are Bhandaria (3.15 LPS), Dudhvania (3.15 LPS), and Ramna (5.5 LPS).

2.2.3 Ground Water Dynamics

2.2.3.1 Ground water monitoring wells: 41 key wells were established to assess the ground water scenario of shallow aquifer (Aquifer-I) of the area. The depth of these dug well varies from 4.28 to 13.80 mbgl. Similarly, the diameters of key wells (dug wells) ranges from 1.16 to 4.55 m. Due to COVID – 19, pre monsoon water level data could not generated. However, the post monsoon depth to water level (Nov. 2020) data has been generated through establishing of key wells. The post monsoon depth to water level (nov. 20220) in the dug wells monitored between 0.83 to 13.30 mbgl.

2.2.3.2 Water Level Scenario – Aquifer – I (Shallow Aquifer): Water level scenario of shallow aquifer was generated by utilizing water level data of 41 monitoring wells representing shallow aquifer. The post monsoon (Nov. 2020) depth to water level monitored between 0.83 to 13.30 m bgl. The pre monsoon depth to water level (May. 2020) could not be taken due to **COVID – 19.** Post monsoon depth to water level map has been prepared for the year 2020 and presented in figure – 5.

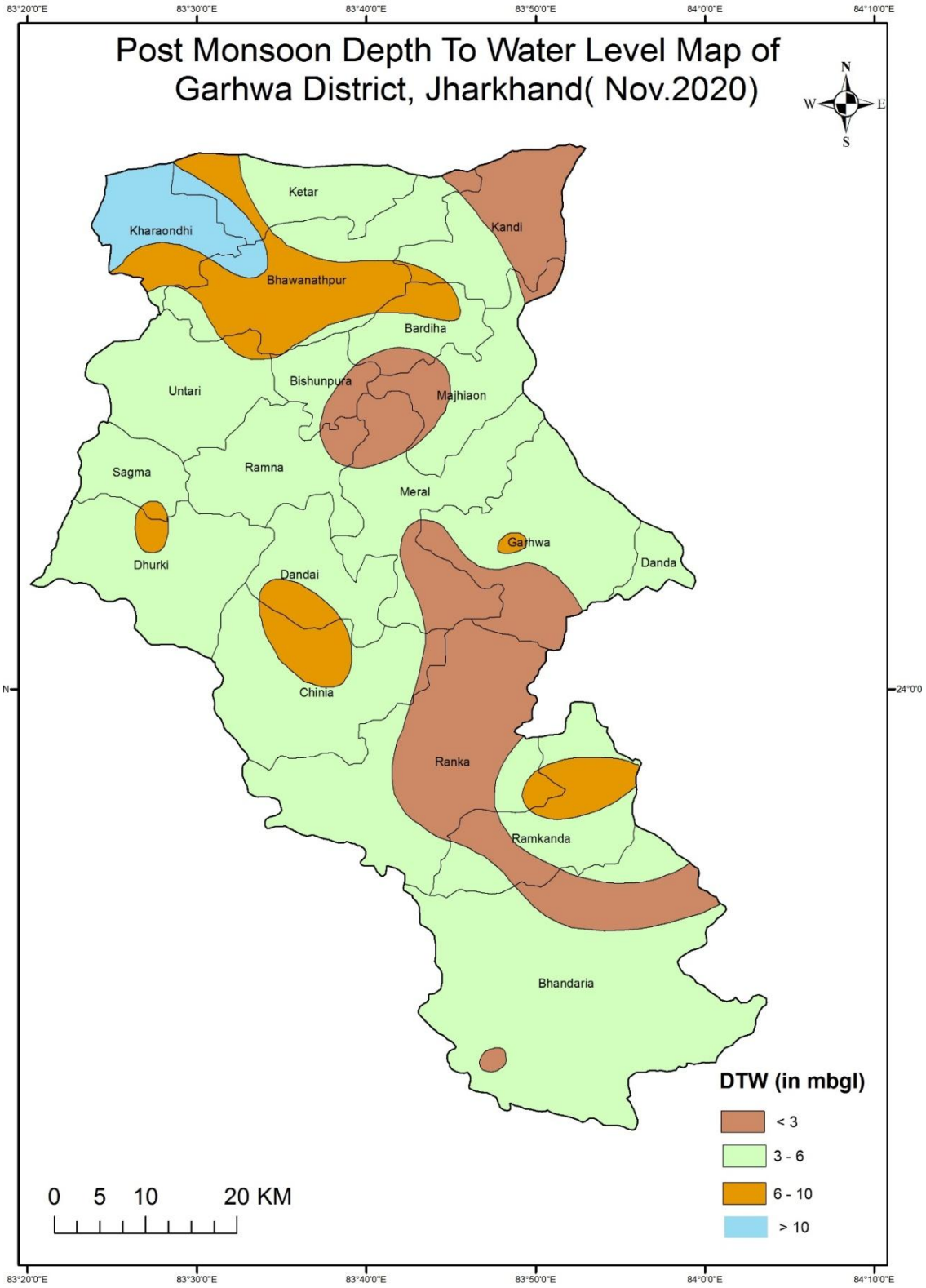


Figure – 6: Post monsoon depth to water level map of Garhwa district (Nov. 2020)

2.2.3.3 Last ten years long term water level trend (2010 – 2019): In order to study long term behaviour of the water levels and also the effect of various developmental activities with time, the data for the period 2010 - 2019 have been computed ,analyzed and presented in table - 10. The post monsoon water level trend analysis showing rising trend in 71% wells. It may be due to extraction of ground water from dug well is very less because sufficient availability of hand pumps in recent years. The dug well was main source for ground water extraction 20 - 30 years back.

Table - 10: Last ten years long term water level trend of Garhwa district (2010 – 2019)

Sr. No.	Location	Water level trend (m/year)			
		Pre monsoon		Post monsoon	
		Rise	Fall	Rise	Fall
1	Bhawnathpur	--	0.0365	0.0989	--
2	Garhwa	--	0.2931		0.0749
3	Godarmana	0.0332	--	0.0129	--
4	Majhiaon	--	0.8633	--	0.9454
5	Nagar Utari	0.1561	--	0.0931	--
6	Ramna			0.4649	--
7	Ranka	--	0.1588	0.0837	--

2.2.3.4 Hydrograph Analysis: Analysis of six hydrograph network stations, were carried out using GEMS software (Figure - 7 a- 7f) and analysed for the period from 2010-2019. It is observed that the long-term water level trends during pre monsoon seasons are declining trend in 29% hydrographs of shallow aquifer-I represented by dug wells. Similarly, post monsoon long term water level trend is observed rising trend in the wells located at Bhawnathpur, Godarmana, Nagar Utari, Ramna, and Ranka while declining trend observed in the wells located at Garhwa and Majhiaon.

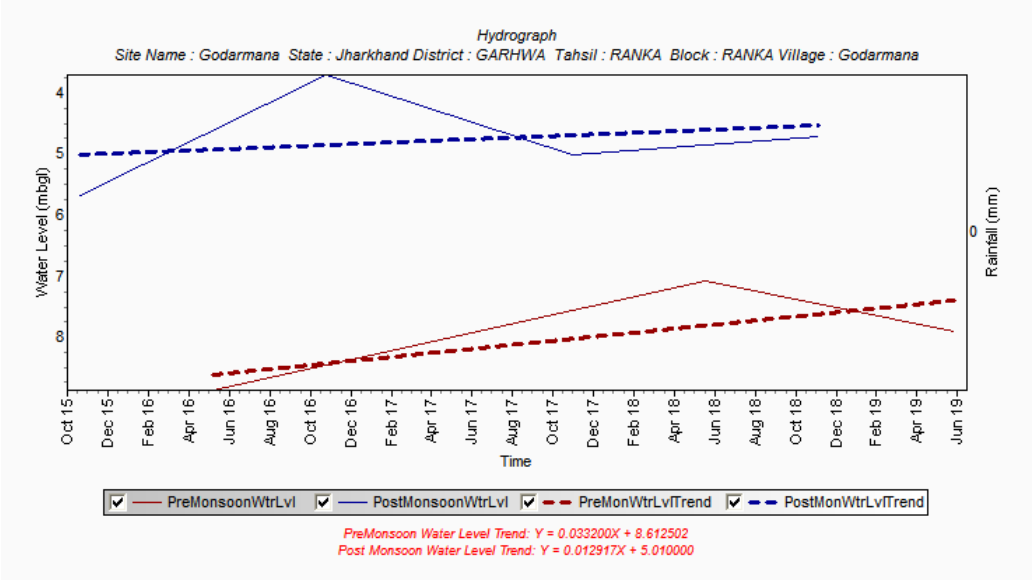


Figure – 7 (a): Hydrograph (2010-2019) of Godarmana network station

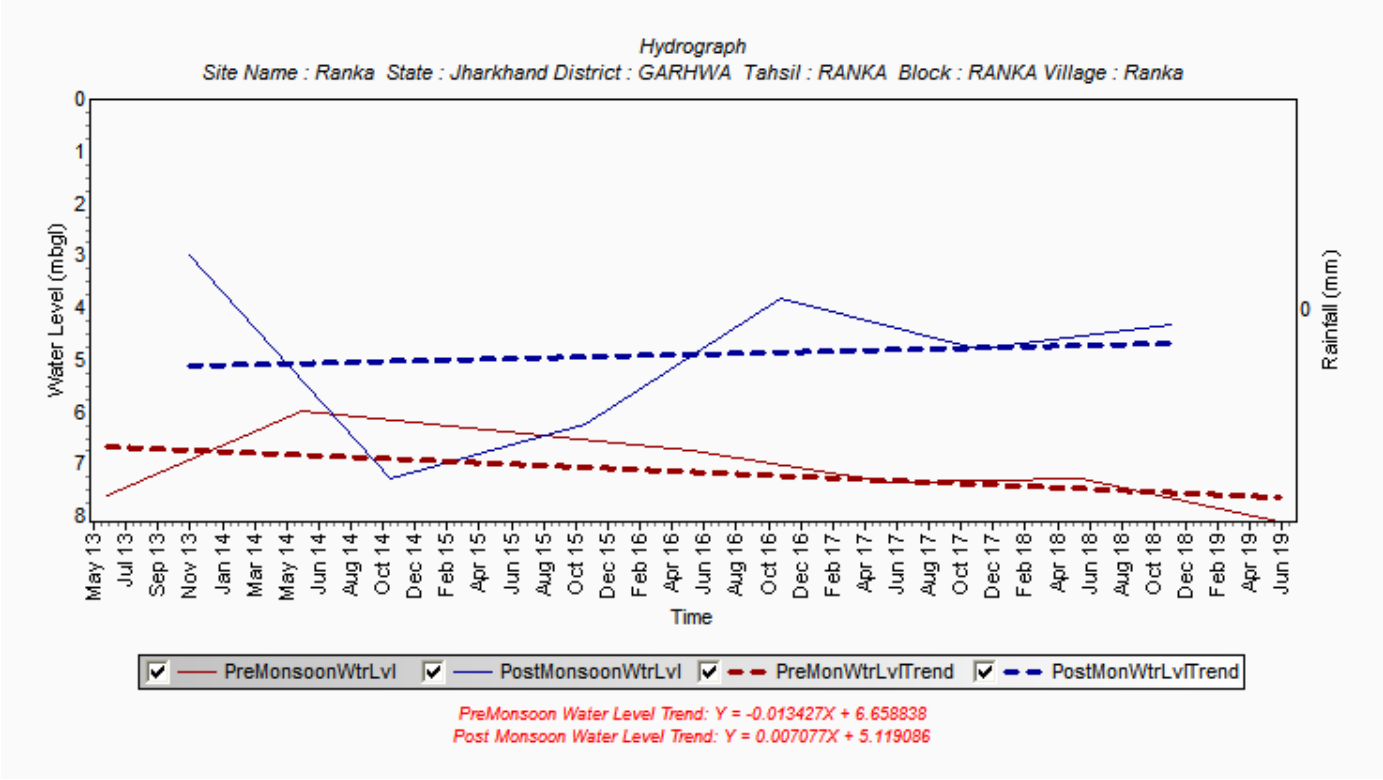


Figure –7 (b): Hydrograph (2010-2019) of Ranka network station

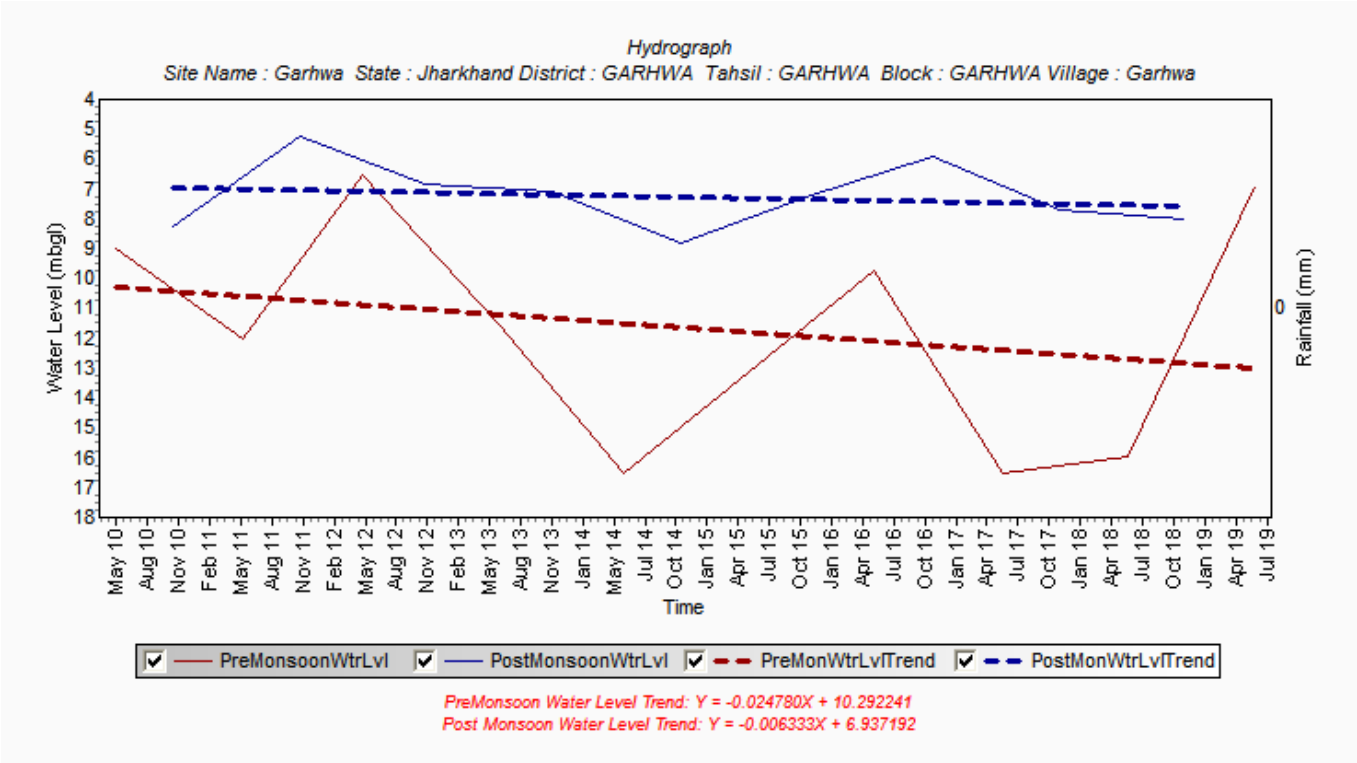


Figure – 7 (c): hydrograph (2010-2019) of Garhwa network station

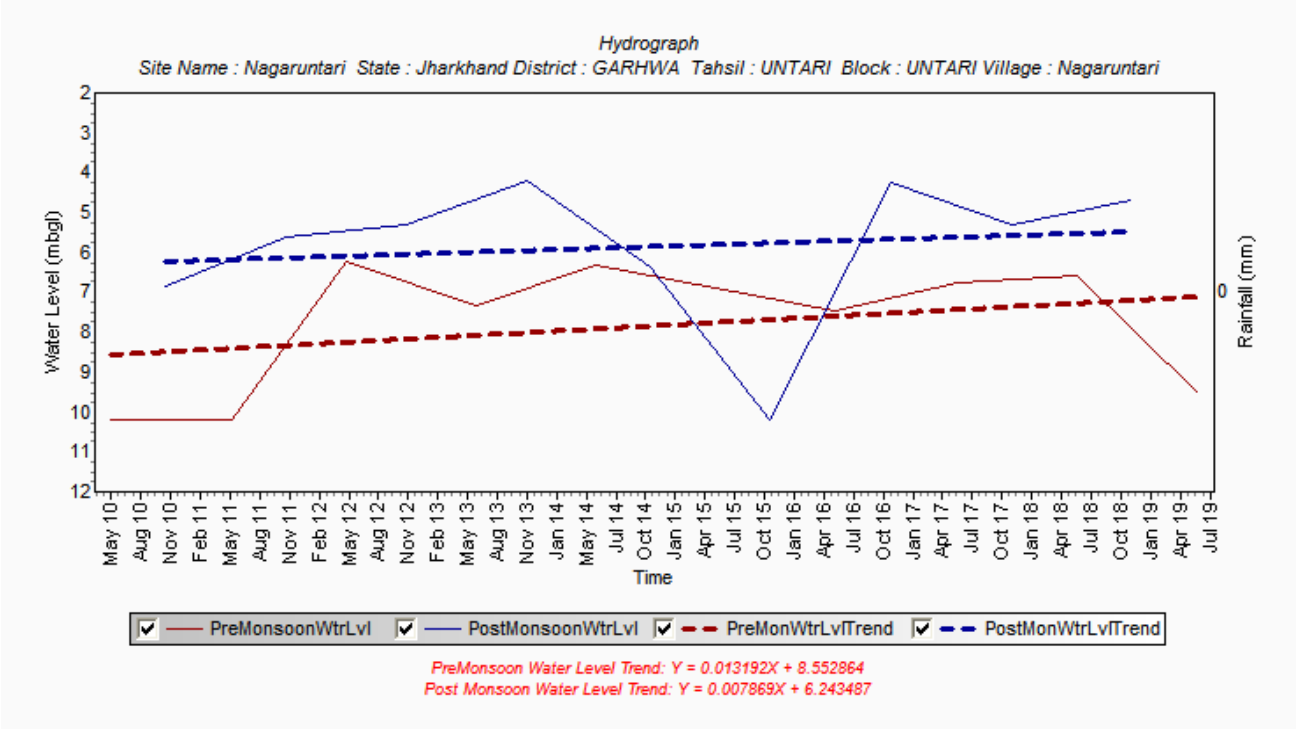


Figure – 7 (d): hydrograph (2010-2019) of Nagar Utari hydrograph network station

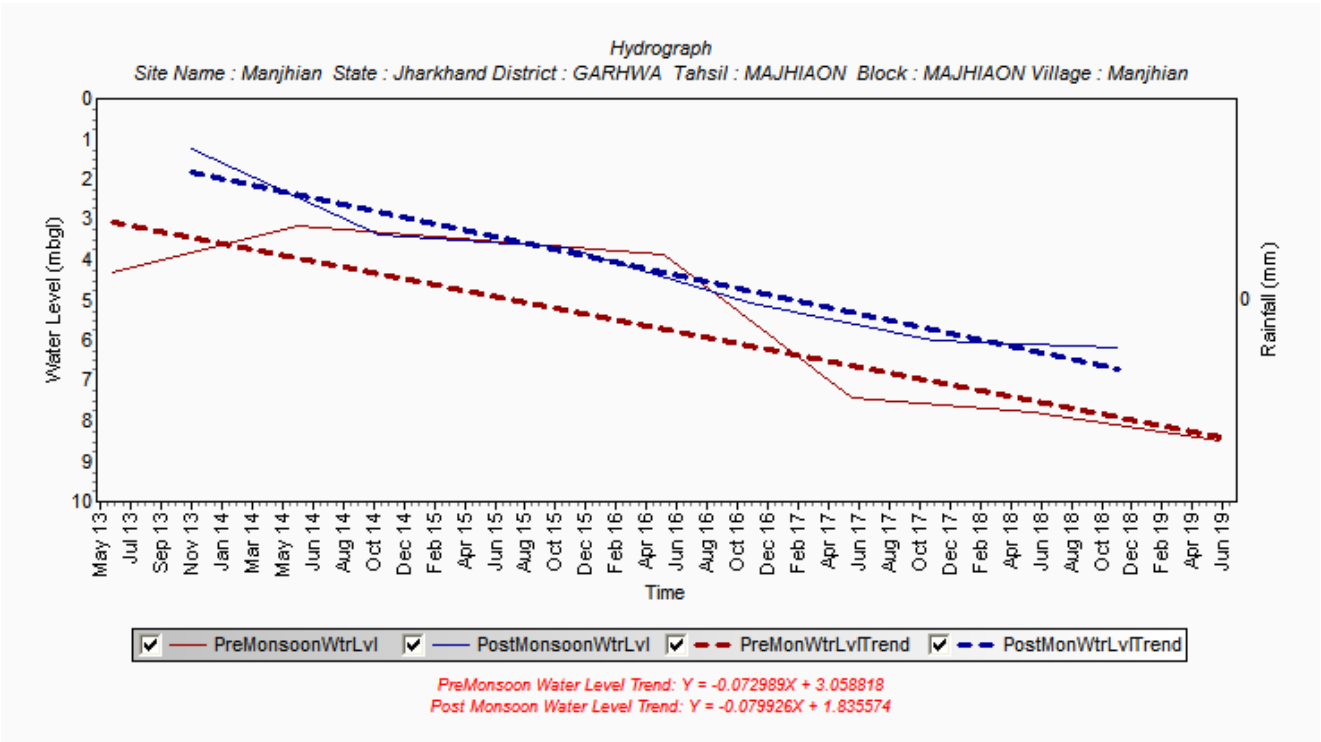


Figure – 7 (e): hydrograph (2010-2019) of Majhiaon hydrograph network station

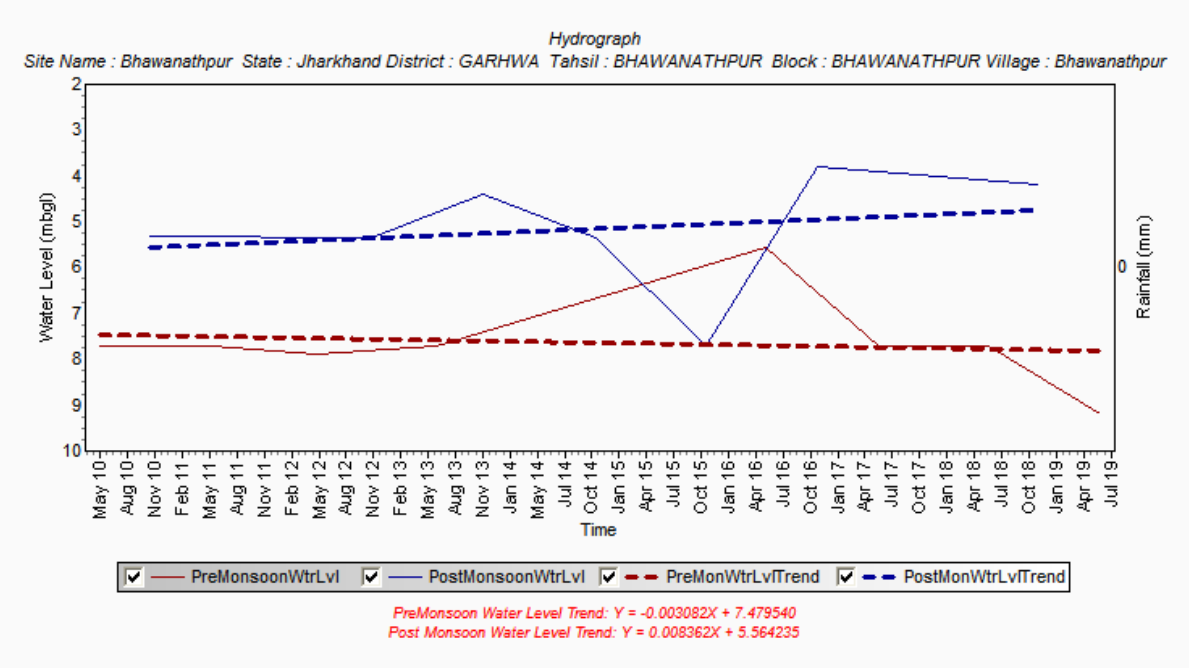


Figure –7 (f): Hydrograph (2010-2019) of Bhawnathpur network station

2.3 Geophysical survey: 92 number of VES were carried out through outsourcing activity during 2021-22 to identified the weathered zone resistivity and its thickness as wells as find out deeper fracture zone in hard rock formations. Based on the interpreted result of these 92 VES data, 9 VES sites the top weathered zone is very thin which is less than 9.00 m and at 25 VES weathered zone depth is more than 9.00 m. However, some VES sites weathered zone extends more than 37 m depth. The resistivity range 50 to 300 ohm m at shallow depths are considered as semi weathered formation and that of at deeper depths these are considered as less compact formations. Again these zones are considered water bearing or aquifer when the range is between 50 and 150 ohm m. On the basis of these considerations 25 sites are detected to be semi weathered zones/ less compact zones with aquifer. The fractured zones have been delineated at so many sites. These are generally delineated on the basis of curve break techniques and current increase methods. On the basis of these methods in 36 nos. of VES the fracture zones are detected. The secondary porosity fractured zone has developed moderately in the district. Water bearing deeper fracture zones are limited and their yield may varies from poor to moderate.

2.4 Ground Water Quality:

The quality of water plays prominent role in promoting both the standards of agriculture production and human health. To evaluate the quality of ground water, samples have been collected from 39 dug wells and 41 representatives bore wells (hand pumps). The analytical results of water samples dug wells and hand pumps are given in Annexure- IV and V respectively. The ground water samples were analyzed for major chemical constituents by using standard procedure at chemical laboratory in CGWB, MER, Patna. These samples have been

considered to assess the chemical quality of ground water and its suitability for drinking and irrigational purposes. Since the samples are collected from the dug wells, they represent the quality of Aquifer I (phreatic/ shallow zone) and the bore well samples represent the Aquifer II (deeper zone) quality of ground water.

2.4.1 General range of chemical parameter of Aquifer-I in the area: - Evaluation of ground water suitability in relation to its different purposes has been classified for drinking / domestic and irrigation. Water is very essential for life. Many a times it has raw consumption or indirectly (in food). Hence, it should be free from turbidity, odor, bacterial and poisonous contents and also chemically soft, low T.D.S value and other chemical constituents should range within low to tolerable limits. Excessive and longer use of water beyond these limits may endanger too many health problems.

The distribution of different constituent in ground water can be described as follows:-

Hydrogen ions activity:

It is expressed in terms of pH and shows the acidity & basicity of the solution. Natural water reacts with H+ & H- ions and forms H_3O or ions. The recommended limit (6.5 to 8.5) by BIS, 2012 is base on taste, corrosion and scale formation criteria. The pH value in Aquifer-I ranges from 6.67 to 7.84.

Electrical Conductivity:

Generally, the water's electrical conductivity increases in the dry periods because of evaporation and decreases in the rainy days because of the precipitation and also to the surface runoff flow into reservoir. The EC value in Aquifer-I ranges from 71 to 1307.

Carbonate & bicarbonate:

Naturally occurring carbondioxide is the foremost source of carbonate and bicarbonate ions in ground water along with the carbon cycle and carbonaceous rocks. Leaching of calcite or dolomite bearing rocks (mainly carbonate) is also a principal source of these ions at places. Carbonate content of the area is not detectable. The bicarbonate concentration ranges between 24.60 295.20 mg/l.

Chloride:

The chloride anions in a certain water environment are characterized by a high stability. Thus, the concentration of chlorides shows little change after long flow distance because the dissolution of chloride is greater in water and the reaction between Cl^- and other ions in stratum is insignificant. The Chloride concentration ranges between 3.54 to 255.24 mg/l.

Sulphate:

Sources of sulphate are minerals pyrite (FeS_2), anhydrite ($CaSO_4$). Under some conditions considerable quantities of sulphate may be obtained from organic Sulphur compounds. The generalized formulae for sulphate reaction ius;

$$SO_4^{2-} + 2CH_2O \rightarrow 2HCO_3^- + H_2S$$

The Sulphate value ranges between 5.28 to 63.87 mg/l.

Sodium:
Sources of sodium are halite, sea spray, brines and some silicates. Common sodic silicates include plagioclase. The only common sink for sodium is reverse ion exchange that occurs when highly saline waters come in contact with calcium rich clays.
The Sodium concentration ranges between 1.00 to 133.20 mg/l.

Calcium: In mineral form, it is found as Calcite, aragonite, gypsum, anhydrite, anorthite, diopside etc. The Calcium concentration ranges between 8 to 120 mg/l.

Magnesium:
The most common source of large quantities of magnesium in natural waters is dolomite. Magnesium is also derived from the silicates olivine, pyroxene and amphibole. The main sink is montmomorillonite. The Magnesium concentration ranges between 2.43 to 29.20 mg/l.

Total Hardness:
It is expressed in terms $CaCO_3$ and it is equal to Calcium + Magnesium equivalent per liter. It can be classified as under:-

Hardness range (mg/l CaCO3)-	Class	
0- 60	-	Soft
61-120	-	Moderately hard
121-180	-	Hard
>180	-	Very Hard

In the study area, the total hardness value ranges from 35 to 345 mg/l.

The ground water of shallow aquifers in the area is alkaline in nature. The TDS value observed between 46.15 to 849.55 mg/l. Nitrate concentration found between 0.17 to 33.94 mg/l within the district.

2.4.1.1 Suitability of ground water of Aquifer – I (shallow aquifer) for drinking purposes: - The suitability of ground water for drinking purposes is determined on the basis of drinking water specification adopted by the Bureau of India Standards IS 10500 – 91 Revised 2012 and approved by World Health Organization (WHO). The number of water samples falling under various categories of permissible and desirable limits of various constituents and its percentage are given in table – 11

.

Table - 11: Suitability of ground water of Aquifer- I for drinking purposes

Chemical constituents and quality parameters	Ranges Desirable		No. of samples under desirable limits	No. of samples under permissible limit	No. of samples under excessive limits
	Desirable limit	Permissible limits in the absence of alternate source			
pH	6.5 to 8.5	No relaxation	39 (100%)	Nil	Nil
TDS (ppm)	500	2000	21 (53.85%)	18 (46.15%)	Nil
TH as $Caco_3$ (ppm)	200	600	18 (46.15%)	21 (53.85%	Nil
Ca (ppm)	75	200	38 (97.44%)	01 (2.56%)	Nil
Mg (ppm)	30	100	22 (56.41%)	17 (43.59%)	Nil
Cl (ppm)	250	1000	38 (97.44%)	01 (2.56%)	Nil
SO_4 (ppm)	200	400	39 (100%)	Nil	Nil
HCO_3 (ppm)	200	600	10 (25.64%)	29 (74.36%)	Nil
NO_3 (ppm)	45	No relaxation	35 (89.74%)	--	04 (10.26%)

On the perusal of table – 11, all the water samples are filling in desirable to permissible category except 10.26% Nitrate concentration found beyond permissible limit. In general, the ground water quality of Aquifer – I of the district is suitable for drinking purposes.

2.4.1.2 Suitability of ground water of Aquifer – I for irrigation purposes: - Apart from domestic consumption, irrigation is consuming a major share of ground water for agricultural activities. The quality of water used for irrigation is an important factor in productivity and quality of irrigated crops. The suitability of water for irrigation purpose depends upon the Total Dissolved Solid in terms of EC value, concentration of Na, bicarbonate and its relative proportion to Mg and Ca. All these mentioned above either individual or with combination create concentration of Sodium (salinity) bicarbonate and alkalis type of hazard.
To better understanding the suitability of ground water for irrigation purpose chemical result of collected water samples have been analyzed and described the different classifications.

Sodium Percentage classification: -EC and sodium concentration are very important in classifying irrigation water. The salts, besides affecting the growth of the plants directly, also affect soil structure, permeability and aeration, which indirectly affect plant growth. Sodium is a major ion used for the classification of irrigation water due to its reaction with soil that reduces its permeability. Percentage of Na is generally used for assessing the suitability of water for irrigation purposes. Na is expressed as percent sodium or soluble-sodium percentage (Na %) using Eq.

$$Na\ \% = \left(\frac{Na^{+}+K^{+}}{Ca^{2+}+Mg^{2+}\ Na^{+}\ K^{+}}\right) * 100$$

Table- 12: Classification of ground water of Aquifer - I based on sodium percent.

Sl No.	Water class or category	Sodium percent	No. of samples falling	Percentage of samples
1	Excellent	< 20 %	01	2.56%
2	Good	20 – 40 %	24	61.54%
3	Permissible	40 – 60 %	11	28.21%
4	Doubtful	30 – 80 %	03	7.69%
5	Unsuitable	> 80 %	Nil	Nil

(Where all ions are expressed in epm)

On the perusal of table 12, about 92.31 % of water samples of aquifer – I (dug wells) falling under excellent to permissible category and rest 7.69% under doubtful water class category.

Sodium adsorption ratio (SAR): -In assessment of the quality of water used for irrigation, sodium adsorption ratio (SAR) is a vital parameter. Enhanced salinity decreases the osmotic activity of plants as well as stops water to reach to the branches and leaves of plants resulting in inferior production. Moreover, irrigation water with high sodium and low calcium favors ion exchange by saturation of Na and is detrimental to the soil structure due to scattering of clay particles resulting in minor production because of difficulty in cultivation. The sodium adsorption ration is calculated from the ionic concentration of Sodium, calcium and magnesium according the following relationship:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

SAR values can be used to predict the degree to which irrigation water tends to enter into cation exchange section in soil. The higher value of SAR indicates damage of soil. Based on the SAR value the groundwater suitability classification is shown in Table 13 which is showing that all the water samples (100%) of aquifer – I (dug wells) pertain to excellent class.

Table -13: - Classification of ground water of Aquifer – I based on SAR value

Sl No.	Water class	Type of Water	SAR Value	No. of samples falling	Percentage of samples
1	Excellent	Low sodium water	< 10	39	100%
2	Good	Medium sodium water	10 – 18	Nil	Nil
3	Fair	High sodium water	18 – 26	Nil	Nil
4	Poor	Very high sodium water	> 26	Nil	Nil

Residual sodium carbonate content (RSC): -Water containing Co_2 on way gets saturated with Co_2 and forms bicarbonates. The excess bicarbonate of Mg and Ca are precipitated out as carbonates. This produces impermeability to the top soil. Bicarbonate concentration of water has been suggested as additional criteria of suitability for irrigation water. Groundwater

samples that had RSC indices of positive value imply that the cumulative concentration of CO_3^{2-} and HCO_3^{2-} is higher than the combined Ca^{2+} and Mg^{2+} concentrations. This would indicate that there is a residual carbonate to react with sodium, presenting sodium hazard to the soil when irrigated with such water. A negative value indicates no residual carbonate. Residual sodium carbonate is determined by using the formula –

$$RSC = (CO_3^{2-} + HCO_3^{2-}) + (Ca^{2+}) + (Mg^{2+}) \quad \ldots\ldots$$

(Where concentration is expressed in epm)

Table- 14: - Classification of ground water of Aquifer – I based on RSC value

Sl No.	RSC (mg/l)	Irrigational suitability	No. of samples falling	Percentage of samples
1	< 1.25	Safe for all type of crops	36	92.31 %
2	1.25 – 2.50	Safe for semi-tolerant to tolerant crops	02	5.13%
3	> 2.50	Safe with application of gypsum of the rate of 8.5g/ham of irrigation water applied for 1.0 ml/liter RSC	01	2.56%

(All the values are expressed in epm.)

On the perusal of table 14, about 97.62 % of water samples of aquifer - I falling under safe for all type of crops to safe for semi-tolerant to tolerant crops category and rest 2.56% of Safe with application of gypsum of the rate of 8.5g/ham of irrigation water applied for 1.0 ml/liter RSC.

Classification of irrigation water Piper's diagram is shown below

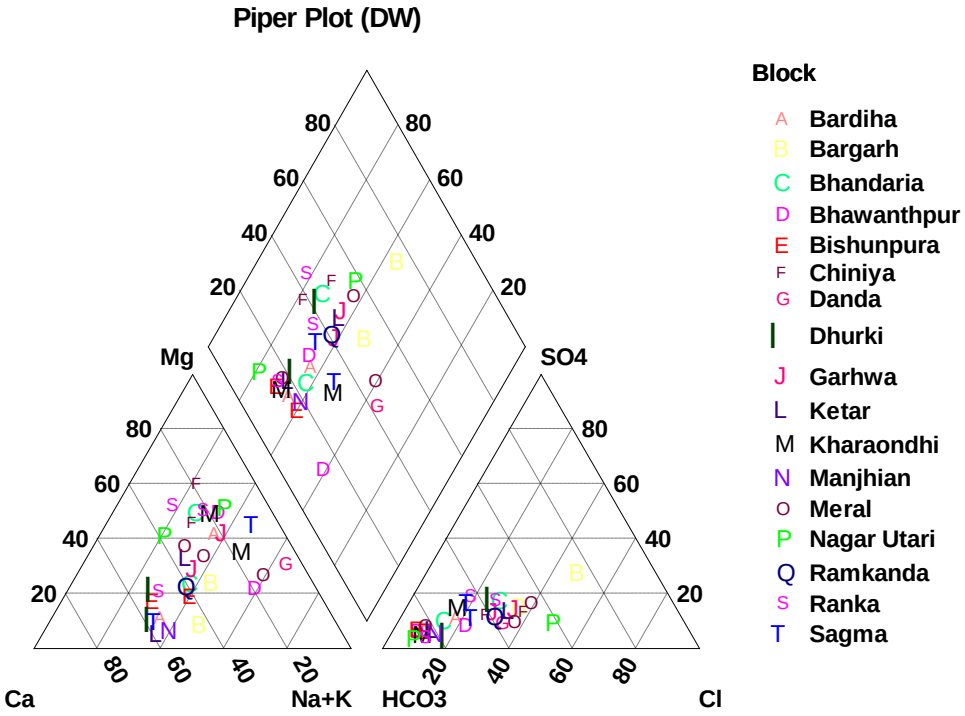


Figure – 8: Piper' diagram for shallow aquifer water samples of Garhwa district

Classification of Ground water

The Piper diagram is used to categorize the type of water. It comprises of three parts: one diamond shaped diagram in the middle and two trilinear diagrams sideways in the bottom. The comparative concentrations of cations (left diagram) and anions (right diagram) in each sample is depicted in the trilinear diagram. For presenting ions in a piper diagram, the cations are clustered into three major divisions: sodium (Na) plus potassium (K), calcium (Ca), and magnesium (Mg). The anions are likewise grouped into three main categories: bicarbonate (HCO_3^{2-}) plus carbonate (CO_3^{2-})), chloride (Cl^-), and sulfate (SO_4^{2-}). Each sample is denoted by a point in each trilinear diagram; the type of water samples will make the grade according to the symbolic area in piper diagram. Most of the samples from shallow aquifer fall in the region where alkaline earth's ($Ca+HCO_3$) exceed alkali metals (SO_4^2 + Cl). This suggests that in the study area shallow aquifer is dominated by Ca-HCO3 type water.

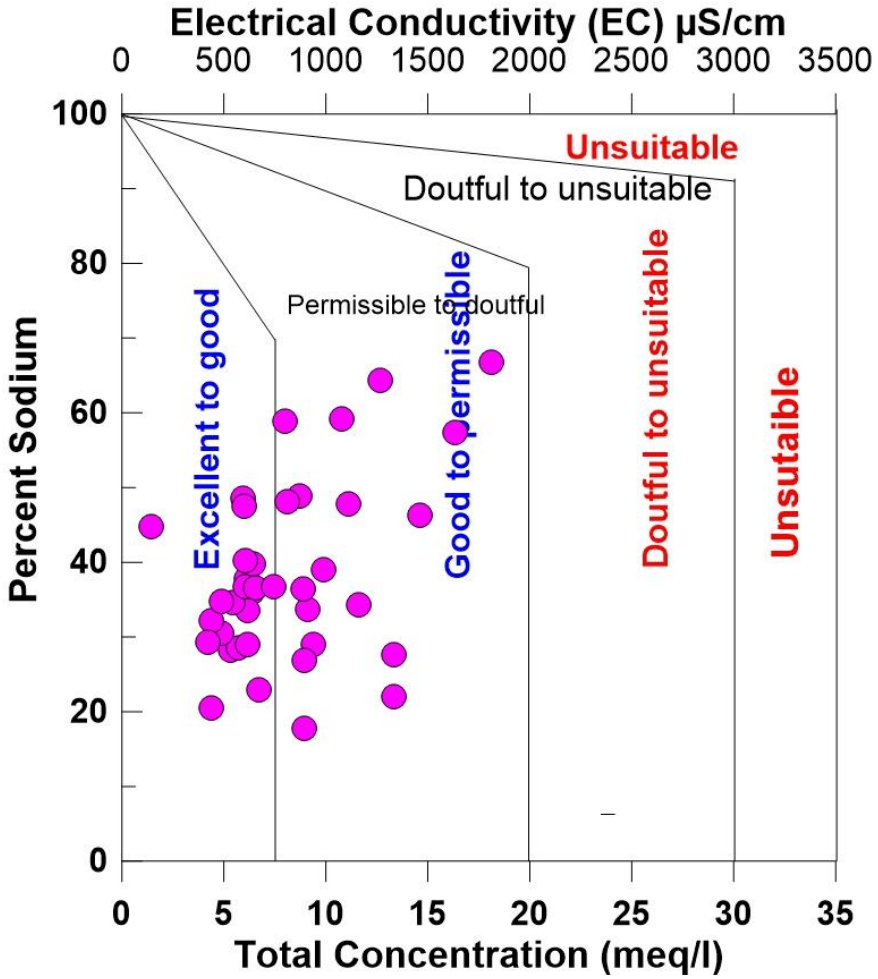
Suitability of ground water based on Electrical Conductivity (EC): - Wilcox 1948 suggested a water class classification for suitability of water for irrigation. The classification is given below as a table- 15.

Table - 15: - Classification of ground water of Aquifer - I based on electrical conductivity (EC)

Sr. No.	Water Class	Rages of EC	No. of samples falling	Percentage of samples
1	Excellent	< 250	01	2.56%
2	Good	250 – 750	20	51.28%
3	Permissible	750 – 2250	18	46.16%
4	Doubtful	2250 – 3000	Nil	Nil
5	Unsuitable	> 3000	Nil	Nil

On The perusal of table 16, about 2.56 % of samples falling under excellent water class and 51.28 % of water samples of Aquifer – I (dug wells) falling under good water class. Rest about 46.16 % of water samples falling under permissible water class.

EC maps of dug well samples i.e. Aquifer – I has been prepared and shown in figures- 9. The values for sodium percentage, SAR, RSC and EC of water samples Aquifer – I collected from dug wells are given in Table – 16.



Plot of sodium percent versus electrical conductivity (after Wilcox 1955)

Figure- 9: EC map of Aquifer – I of Garhwa district

Table - 16: Values of Sodium percentage, SAR, RSC and EC of water samples collected from Aquifer – I (Dug wells), Garhwa district

Sr. No.	Village	Block	District	Na %	SAR	RSC	EC
1	Ranka	Ranka	Garhwa	29.07	1.34	- 1.09	938
2	Phugmari	Ramkanda	Garhwa	36.22	1.33	- 0.69	640
3	Rodo	Bhandaria	Garhwa	62.18	1.44	0.40	611
4	Bhandaria	Bhandaria	Garhwa	26.86	1.07	- 2.10	895
5	Gothani	Bargarh	Garhwa	48.54	1.93	- 0.60	593
6	Barigawan	Bargarh	Garhwa	44.88	0.85	- 0.50	144
7	Godarmana	Ranka	Garhwa	17.84	0.70	- 2.79	896
8	Bishrapur	Ranka	Garhwa	28.29	0.86	0.60	534
9	Kaprat	Dandai	Garhwa	22.84	0.82	- 2.30	670
10	Chiniya	Chiniya	Garhwa	27.61	1.50	- 3.59	1336
11	Ranpura	Chiniya	Garhwa	22.13	1.05	- 2.49	1332
12	Dandai	Dandai	Garhwa	46.39	2.95	- 0.19	1463
13	Pangotwa	Dhurki	Garhwa	28.62	1.00	- 1.39	570
14	Dhurki	Dhurki	Garhwa	33.74	1.12	0.41	616
15	Sarda	Sagma	Garhwa	34.77	1.20	- 0.59	544
16	Sagma	Sagma	Garhwa	47.85	2.84	0.80	1111
17	Manjhgawan	Kharaondhi	Garhwa	47.37	2.14	0.50	598
18	Bajarmarwa	Kharaondhi	Garhwa	30.61	1.04	0.10	491
19	Dasipur	Ketar	Garhwa	32.24	1.03	0.20	437
20	Panchadumar	Ketar	Garhwa	37.39	1.29	- 0.89	606
21	Jhagra Khurd	Bhawnathpur	Garhwa	33.71	1.46	- 0.30	909
22	Kakri (Kandia tola)	Bhawnathpur	Garhwa	58.87	3.33	3.10	801
23	Ganki (Bilaspur)	Nagar Utari	Garhwa	20.48	0.47	0.00	438
24	Nagar Utari	Nagar Utari	Garhwa	34.37	1.78	- 2.60	1161
25	Morbe	Manjhian	Garhwa	39.84	1.30	0.71	643
26	Semaura	Kandi	Garhwa	57.36	4.37	1.41	1635
27	Wolma	Kandi	Garhwa	48.87	2.70	0.50	874
28	Bardiha	Bardiha	Garhwa	34.78	0.94	0.20	487
29	Kardiha	Bardiha	Garhwa	36.63	1.60	- 0.20	654
30	Sandhya	Bishunpura	Garhwa	40.27	1.65	1.10	607
31	Darjia	Bishunpura	Garhwa	29.44	0.71	0.30	420
32	Meral	Meral	Garhwa	59.24	3.96	0.90	1078
33	Ramna	Ramna	Garhwa	66.78	6.62	0.31	1809
34	Bahiyar Khurd	Ramna	Garhwa	48.02	2.56	0.30	812
35	Lagama	Meral	Garhwa	36.71	1.57	- 1.50	745
36	Chama	Meral	Garhwa	29.05	1.06	0.10	614
37	Beljampa	Garhwa	Garhwa	39.01	1.88	- 0.60	987
38	Danda	Danda	Garhwa	64.26	4.62	2.40	1267
39	Obra	Garhwa	Garhwa	36.46	1.43	- 1.59	888

2.4.2 General range of chemical parameter of Aquifer - II in the area: - The variation range of the concentration in ppm of different chemical constituents and quality parameters of Aquifer - II (hand pumps samples) represented in tables 17.

Table- 17: Ranges of chemical constituents of Aquifer - II in Garhwa district (hand pump samples)

Chemical Constituents and quality parameters	Ranges of the concentration(in ppm)	
pH	7.40	8.45
EC (micro siemens/cm at 25^0c)	219	1500
TDS (ppm)	142.35	975.00
TH as $CaCo_3$ (ppm)	65	570
Ca (ppm)	14	100
Mg (ppm)	2.43	82.62
Na (ppm)	11.67	145.32
K (ppm)	1.98	28.74
HCO_3 (ppm)	67.10	481.90
Cl (ppm)	14.20	230.75
SO_4 (ppm)	3.67	62.39
NO_3 (ppm)	0.62	40.01

The ground water of aquifer - II in the area is alkaline in nature. On the perusal of table - 19, the pH value ranges 7.40 to 8.45 mg/l. The EC value ranges between 219 to 1500 mg/l. Overall in the district, the TDS value varies from 142.35 to 975 mg/l. and the total hardness ranges between 65 to 570 mg/l. Calcium and Magnesium values varies from 14 to 100 mg/l and 2.43 to 82.62 mg/l respectively. Similarly, the Nitrate value ranges from 0.62 to 40.01 mg/l

2.4.2.1 Suitability of ground water of Aquifer – II (deeper aquifers) for drinking purposes: - To know the ground water quality of Aquifer - II, water samples were collected from bore wells (Hand pump). The number of water samples falling under various categories of permissible and desirable limits of various constituents and its percentage are given in table - 18.

Table - 18: Suitability of ground water of Aquifer- II for drinking purposes

Chemical constituents and quality parameters	Ranges Desirable		No. of samples under desirable limits	No. of samples under permissible limit	No. of samples under excessive limits
	Desirable limit	Permissible limits in the absence of alternate source			
pH	6.5 to 8.5	No relaxation	41 (100%)	Nil	Nil
TDS (ppm)	500	2000	28 (68.29%)	13 (31.71%)	Nil

TH as $Caco_3$ (ppm)	200	600	25 (60.98%)	16 (39.02)	Nil
Ca (ppm)	75	200	39 (95.12%)	02 (4.88%)	
Mg (ppm)	30	100	27(65.85%)	14 (34.15%)	
Cl (ppm)	250	1000	41 (100%)	Nil	Nil
SO_4 (ppm)	200	400	41 (100%)	Nil	Nil
HCO_3 (ppm)	200	600	11 (26.83%)	30(73.17)	Nil
NO_3 (ppm)	45	No relaxation	41 (100%)	Nil	Nil

On the perusal of table – 18, it is observed that about 100% ground water samples of aquifer – II falling under desirable limits to permissible limits category and the ground water quality of Aquifer – II of the district is good and suitable for drinking purposes.

2.4.2.2 Suitability of ground water of Aquifer – II for irrigation Purposes: To better understanding the suitability of ground water for irrigation purpose chemical result of collected water samples have been analyzed and described the different classifications.

Sodium Percentage classification: - Sodium content is usually expressed estimated using the formula –

Sodium percent $= \left(\frac{Na^{+}+K^{+}}{Ca^{2+}+Mg^{2+}\,Na^{+}\,K^{+}}\right) * 100$

Table- 19: Classification of ground water of Aquifer - II based on Na%

Sl No.	Water class or category	Sodium percent	No. of samples falling	Percentage of samples
1	Excellent	< 20 %	03	7.32%
2	Good	20 – 40 %	28	68.29%
3	Permissible	40 – 60 %	09	21.95%
4	Doubtful	30 – 80 %	01	2.44%
5	Unsuitable	> 80 %	Nil	Nil

(Where all ions are expressed in lpm or epm)

From Table 20, about 7.32 % of water samples of aquifer – II falling in excellent water class. About 90.24 % of water samples falling in good to permissible water class. Only 2.44 % of water sample (03 No.) falling under doubtful water class.

Sodium adsorption ratio (SAR): - The sodium adsorption ration is calculated from the ionic concentration of Sodium, calcium and magnesium according the following relationship:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Ground water classification into four classes based on SAR value is given in table- 20 which is showing that all the water samples (100%) of aquifer - II falling under excellent water class.

Table - 20: - Classification of ground water of Aquifer – II based on SAR value

Sl No.	Water class	Type of Water	SAR Value	No. of samples falling	Percentage of samples
1	Excellent	Low sodium water	< 10	41	100%
2	Good	Medium sodium water	10 – 18	Nil	Nil
3	Fair	High sodium water	18 – 26	Nil	Nil
4	Poor	Very high sodium water	> 26	Nil	Nil

(Where all ions expressed in lpm)

Residual sodium carbonate content (RSC): Residual sodium carbonate is determined by using the formula

$$RSC = (CO_3^{2-} + HCO_3^{2-}) + (Ca^{2+}) + (Mg^{2+}) \quad \ldots\ldots$$

(Where concentration is expressed in epm)

Table - 21: - Classification of ground water of Aquifer – II based on RSC value

Sl No.	RSC (mg/l)	Irrigational suitability	No. of samples falling	Percentage of samples
1	< 1.25	Safe for all type of crops	39	95.12 %
2	1.25 – 2.50	Safe for semi-tolerant to tolerant crops	01	2.44%
3	> 2.50	Safe with application of gypsum of the rate of 8.5g/ham of irrigation water applied for 1.0 ml/liter RSC	01	2.44%

(All the values are expressed in lpm or epm)

On the perusal of table - 21, about 95.12 % of water samples of aquifer - II falling under safe for all type of crops category. About 2.44 % of water samples falling under Safe for semi-tolerant to tolerant crops and Safe with application of gypsum of the rate of 8.5g/ham of irrigation water applied for 1.0 ml/liter RSC category. Classification of irrigation water modified Piper's diagram is shown below in figure –10.

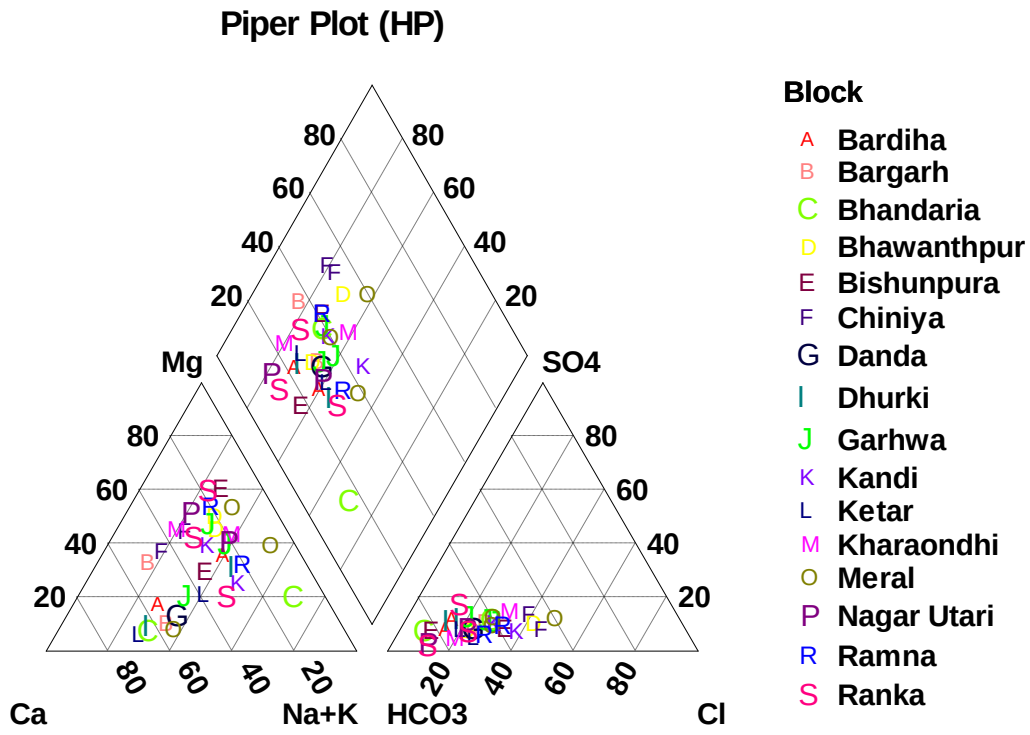


Figure – 10: Piper' diagram for deeper water samples of Garhwa district

Piper diagram revealed that majority of the samples belong to calcium-bicarbonate (Ca-HCO3) hydrochemical facies. This suggests that in the study area deeper aquifer is dominated by Ca-HCO3 type water.

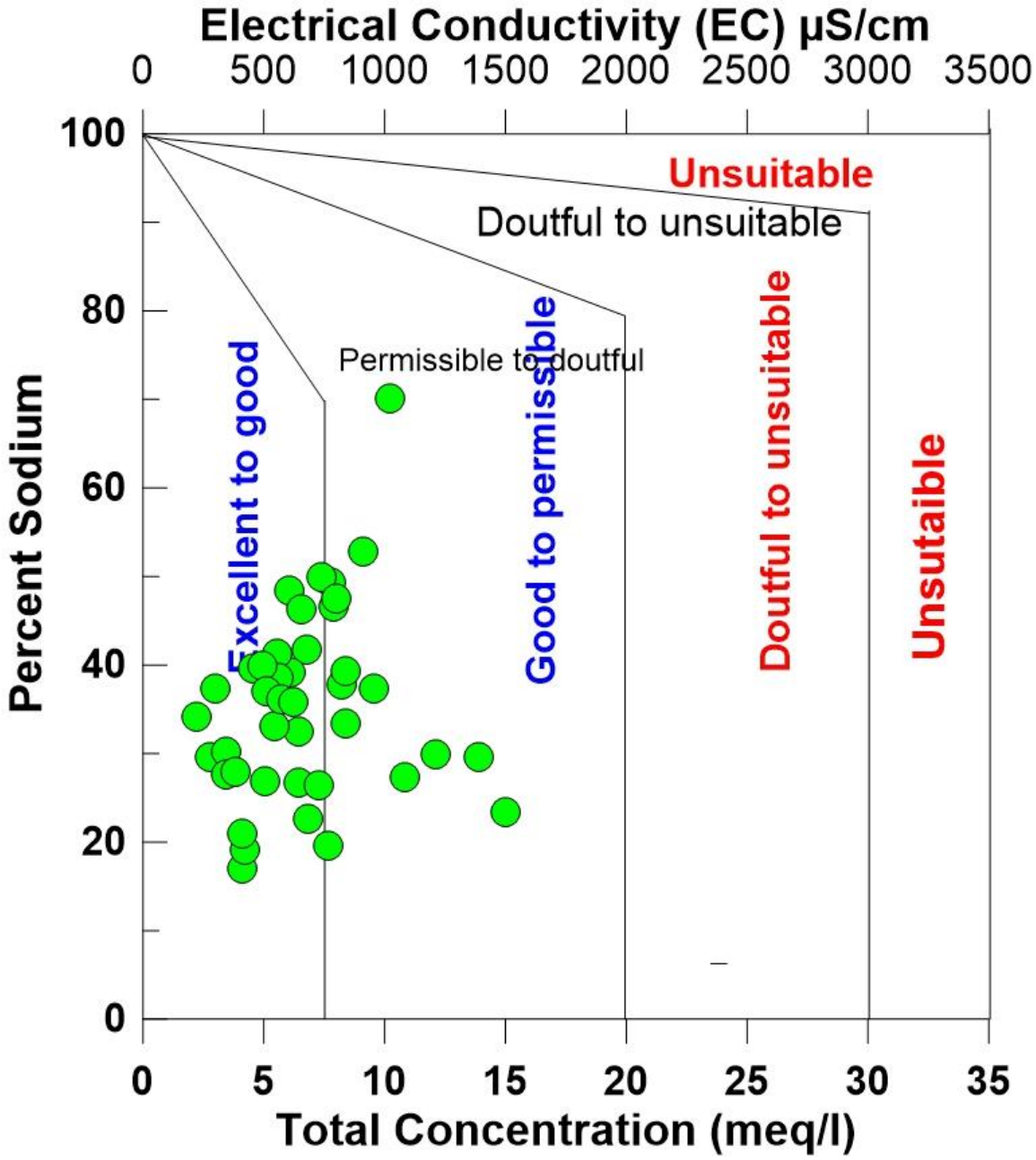
Suitability of ground water based on Electrical Conductivity (EC): - Wilcox 1948 suggested a water class classification for suitability of water for irrigation. The classification is given below as a table - 22.

Table - 22: - Classification of ground water of Aquifer - II based on (EC)

Sl No.	Water Class	Rages of EC	No. of samples falling	% of samples
1	Excellent	< 250	01	2.44%
2	Good	250 – 750	26	63.41%
3	Permissible	750 – 2250	14	34.15%
4	Doubtful	2250 – 3000	Nil	Nil
5	Unsuitable	> 3000	Nil	Nil

On The perusal of table 23, about 2.44 % of samples falling under excellent water class and 63.41 % of water samples of Aquifer – II (dug wells) falling under good water class. Rest about 34.15 % of water samples falling under permissible water class.

EC maps of dug well samples i.e. Aquifer – II has been prepared and shown in figures- 11. The values for sodium percentage, SAR, RSC and EC of water samples of Aquifer – II collected from hand pumps are given in table – 23.



Plot of sodium percent versus electrical conductivity (after Wilcox 1955)

Figure- 11: EC map of Aquifer – II of Garhwa district

Table - 23: Values of Sodium percentage, SAR, RSC and EC of water samples collected from Aquifer – II (hand pumps), Garhwa district

Sr. No.	Village	Block	District	Na %	SAR	RSC	EC
1	Ranka	Ranka	Garhwa	22.62	0.53	- 1.10	684
2	Phugmari	Ramkanda	Garhwa	41.54	1.85	- 0.10	679
3	Rodo	Bhandaria	Garhwa	70.18	5.18	4.90	1022
4	Bhandaria	Bhandaria	Garhwa	29.37	0.65	- 0.40	279
5	Gothani	Bargarh	Garhwa	17.09	0.40	-1.20	412
6	Barigawan	Bargarh	Garhwa	34.34	0.73	-0.20	219
7	Godarmana	Ranka	Garhwa	48.42	1.94	0.60	603
8	Bishrapur	Ranka	Garhwa	26.93	0.77	0.70	505
9	Kaprat	Dandai	Garhwa	39.09	1.40	0.20	608
10	Chiniya	Chiniya	Garhwa	23.37	1.24	-4.98	1500
11	Ranpura	Chiniya	Garhwa	19.65	0.58	-2.59	766
12	Dandai	Dandai	Garhwa	39.68	1.24	0.80	456
13	Pangotwa	Dhurki	Garhwa	30.30	0.87	0.00	343
14	Dhurki	Dhurki	Garhwa	46.61	2.29	1.00	786
15	Sarda	Sagma	Garhwa	37.28	1.07	-0.30	300
16	Sagma	Sagma	Garhwa	27.47	1.22	-2.29	1084
17	Manjhgawan	Kharaondhi	Garhwa	37.82	1.66	-1.00	820
18	Bajarmarwa	Kharaondhi	Garhwa	19.05	0.57	-0.60	423
19	Dasipur	Ketar	Garhwa	41.29	1.58	0.30	556
20	Panchadumar	Ketar	Garhwa	27.71	0.74	-0.30	341
21	Jhagra Khurd	Bhawnathpur	Garhwa	32.48	1.26	-0.10	645
22	Kakri (Kandia Tola)	Bhawnathpur	Garhwa	29.66	1.74	-3.48	1390
23	Ganki (Bilaspur)	Nagar Utari	Garhwa	20.92	0.45	-0.20	409
24	Nagar Utari	Nagar Utari	Garhwa	38.46	1.41	0.40	560
25	Manjhian	Manjhian	Garhwa	46.15	2.16	0.30	654
26	Morbe	Manjhian	Garhwa	49.32	2.28	1.60	775
27	Semaura	Kandi	Garhwa	33.21	1.05	-0.80	542
28	Wolma	Kandi	Garhwa	50.00	2.51	-0.10	739
29	Bardiha	Bardiha	Garhwa	39.73	1.41	0.10	493
30	Kardiha	Bardiha	Garhwa	27.95	0.72	0.00	381
31	Sandhya	Bishunpura	Garhwa	37.13	1.43	0.50	511
32	Darjia	Bishunpura	Garhwa	26.75	0.92	-1.10	643
33	Meral	Meral	Garhwa	52.83	2.84	1.01	910
34	Ramna	Ramna	Garhwa	26.45	0.88	-1.50	730
35	Bahiyar Khurd	Ramna	Garhwa	47.44	2.29	0.50	798
36	Lagama	Meral	Garhwa	37.29	1.83	-2.20	957
37	Chama	Meral	Garhwa	33.41	1.46	-1.00	839
38	Beljampa	Garhwa	Garhwa	39.21	1.89	-0.20	838
39	Danda	Danda	Garhwa	36.20	1.42	0.21	570
40	Obra	Garhwa	Garhwa	25.87	1.28	-0.29	620
41	Garhwa	Garhwa	Garhwa	29.98	1.70	-1.49	1209

2.4.3 Flouride Contamination

As a part of MOU between CGWB & GSI, ground water samples from Tubewell/Bore well/Hand Pump of select villages in North Garhwa has been collected during May 2022 and analysed in CGWB, MER, Patna Lab. The chemical analysis results shows that out of 50 samples, all 50 have F concentration more than the desirable limit of 1.5mg/l. Flouride concentration ranges from 1.51-3.31 mg/lit. Location details of F concentration found beyond permissible limit is given in Annexure-V and Table-24.

Table-24 High Flouride Concentration in Ground Water in Northern Part of Garhwa District, Jharkhand

Sl_No	Block	Village	F^- in mg/l	Sl_No	Block	Village	F^- in mg/l
1	Majhiaon	Burhikhand	2.604	26	Bardiha	Lawachampa	2.058
2	Bishunpura	Deogurwa	3.066	27	Meral9	Siho	2.352
3	Bishunpura	Saro	2.562	28	Majhiaon	Kharsota	2.94
4	Bishunpura	Saro	2.436	29	Meral	Latdag	1.98
5	Kandi	Adhawra	2.016	30	Meral	Bana	1.77
6	Kandi	Ghordag	2.415	31	Kharaundhi	Parswan tola	2.086
7	Kandi	Ghordag	2.205	32	Bhawanathpur	Ghagra Kormahi	3.11
8	Kandi	Subuadamar	2.17	33	Bhawanathpur	Ghagra	1.56
9	Kandi	Mukhapi	2.28	34	Bhawanathpur	Phulwar	2.79
10	Bardiha	Khardiha	2.562	35	Bhawanathpur	Shiv Nagar	2.04
11	Bardiha	Jikabukcham	2.93	36	Meral	Serasam	2.88
12	Bardiha	Salaya Damar	2.688	37	Meral	Banua	1.88
13	Bardiha	Salga	2.786	38	Meral	Loadag	2.1
14	Bardiha	Sikiahi	2.62	39	Meral	Bhimkhad	1.69
15	Bardiha	Pachhiyara tola	2.34	40	Bardiha	Adar	2.7
16	Bhawanathpur	Amuadih	2.226	41	Bardiha	Amiliya tola	1.7
17	Bhawanathpur	Beherwakhadi	1.89	42	Bardiha	Lewa tola	3.02
18	Kandi	Daaridah	1.96	43	Bardiha	Semri	1.85
19	Bardiha	Sarsatia	2.058	44	Meral	Khundhara	2.12
20	Meral	Chhaparwar khurd	2.31	45	Meral	Bajaria	3.06
21	Meral	Kholra	2.39	46	Meral	Pindra	2.107
22	Meral	Chandwa	2.24	47	Meral	Akalwani	1.78
23	Meral	Jaharsarai	3.318	48	Meral	Mural tola	2.58
24	Meral	Sangwaria	1.68	49	Kandi	Ratangara	2.22
25	Meral	Patariya	2.485	50	Meral	Kormahi	1.51

2.5 Ground Water Exploration: To assess the potentiality of the deep fractured rock total 31 exploratory wells and 02 observation wells were drilled in Garhwa district by Central Ground Water Board. The drilling results have indicated that granite gneiss of different shades varying from grey to dark grey to pink, having course grained texture sometime porphyritic, are the most dominant rock types met in the area. In the bore wells upper weathered zones are cased and only the fractured zones are tapped in the uncased well. The details of the exploratory and observation wells drilled in Garhwa district are presented in annexure – III. Summary of success bore wells drilled by Central Ground Water Board in the district is given in table – 7.

Based on the exploratory well data, it is observed that one to six sets of fractures have been encountered in the bore wells drilled in Garhwa district. Based on morphotectonic analysis and exploratory drilling results, it confirms that the area has undergone several phases of tectonic deformations which lead to various sets of fractures, fissures, and faults etc which are ground water repositories. Various sets of fractures have been identified, on ground water point of view. The shallow fractured aquifers up to the depth of 100 m and deep fractured aquifer exist up to 164.00 m bgl within the explored depth of 206.00 m.

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 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, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, aquifer wise yield potential, aquifer wise resources, aquifer maps were generated which has been discussed in details.

3.1 Aquifer Disposition

3.1.1 Hydrogeological Cross Section: To study the aquifer disposition in detail, various hydrogeological cross section indicating aquifer geometry has been prepared viz. I-NNW - SSE direction in middle part, II- B-B' (west – east direction in middle part) and III-C-C' (west - east direction middle to nortern part). X and Y axis represent Elevation in MSL and Horizontal distance respectively.

3.1.1.1 Hydrogeological cross section-I: Hydrogeological cross section represents the area in NNW – SSE direction in middle portion of the district. The data of 7 exploratory wells i.e. Baskatiya, Bhawnathpur, Bhitarkhurd, Dudhvania, Dandai, China and Bargarh have been utilised. The Aquifer- I ranges 5.60 – 26.30 m representing weathered Granite Gneiss, while Aquifer-II ranges from 11.00 – 150.50 m representing fractured Granite Gneiss. Generally 1- 3 fracture zones were encountered. Hydrogeological cross section is shown in figure- 12.

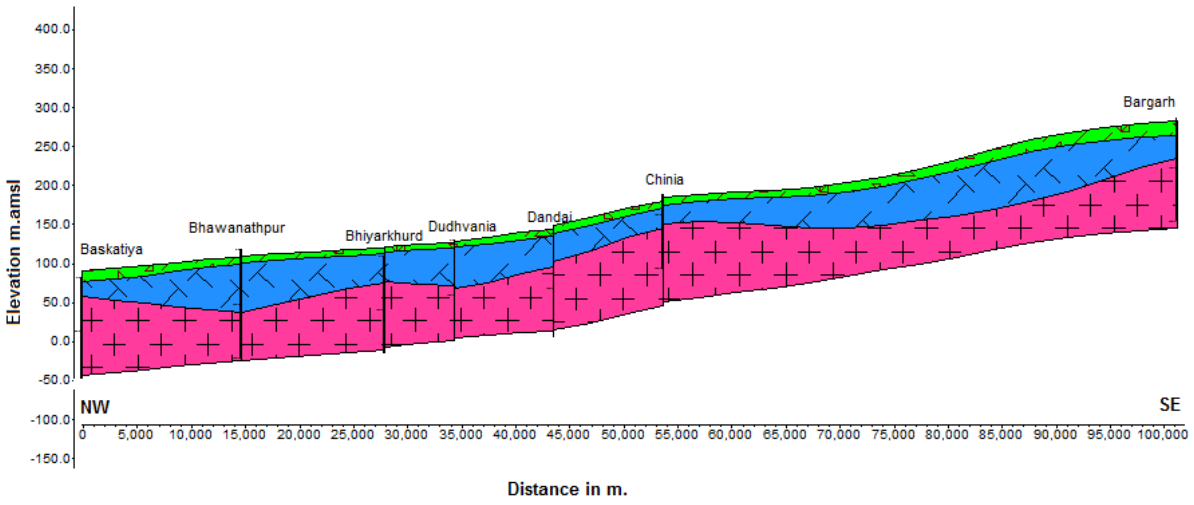
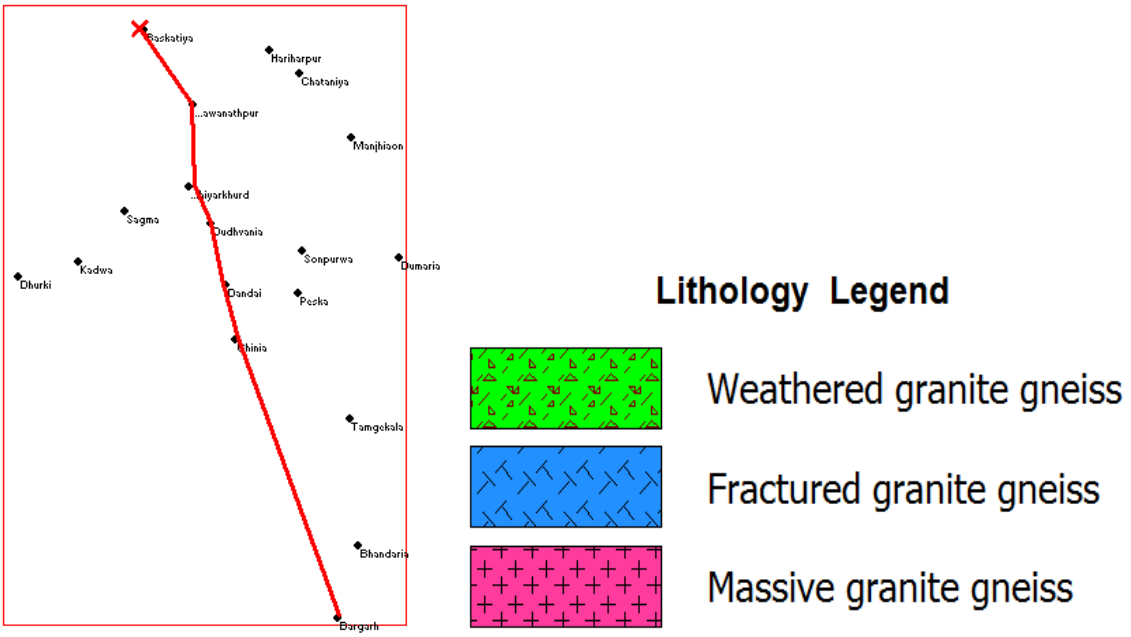


Figure – 12: Location map of cross section



3.1.1.2 Hydrogeological cross section-II: Hydrogeological cross section represents the area in NW part of Gahwa district. The data of 5 exploratory wells i.e. Dhurki, Kadwa, Sagma, Bhaiyarkhurd and Chatania have been utilised. The Aquifer- I ranges 5.60 – 15.35 m representing weathered Granite Gneiss, while Aquifer-II ranges from 9.90 – 155 m representing fractured Granite Gneiss. Generally 1 - 2 fracture zones were encountered. However, this section well yield varies from 0.14 – 0.78 lps. Hydrogeological cross section is shown in figure - 13.

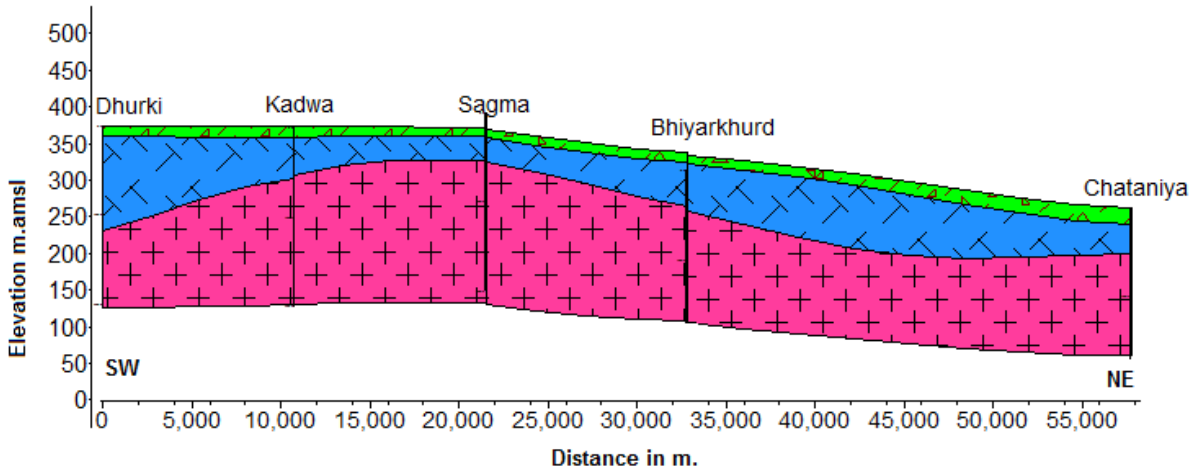
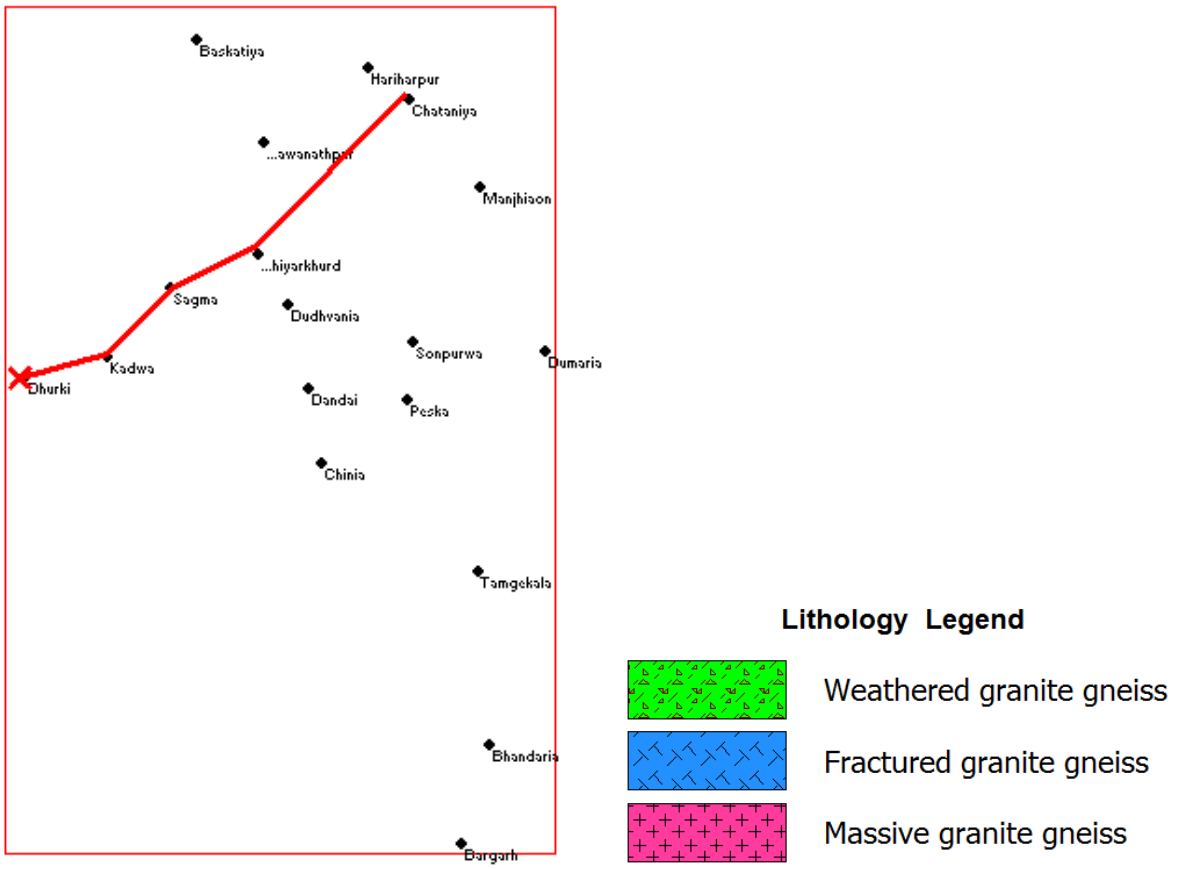


Figure – 13: Hydrogeological cross section



3.1.1.3 Hydrogeological cross section-III: Hydrogeological cross section represents the area in W-E direction in central part of Garhwa district. The data of 5 exploratory wells i.e. Dhurki, Kadwa, Dandai, Peska and Dumaria have been utilised. The Aquifer- I ranges 9.00 – 20.85 m representing weathered Granite Gneiss, while Aquifer-II ranges from 53.40 – 155.00 m representing fractured Granite Gneiss. Generally 1 fracture zone was encountered. However, this section well yield varies from 0.14 – 10.76 lps. Hydrogeological cross section is shown in figure – 14.

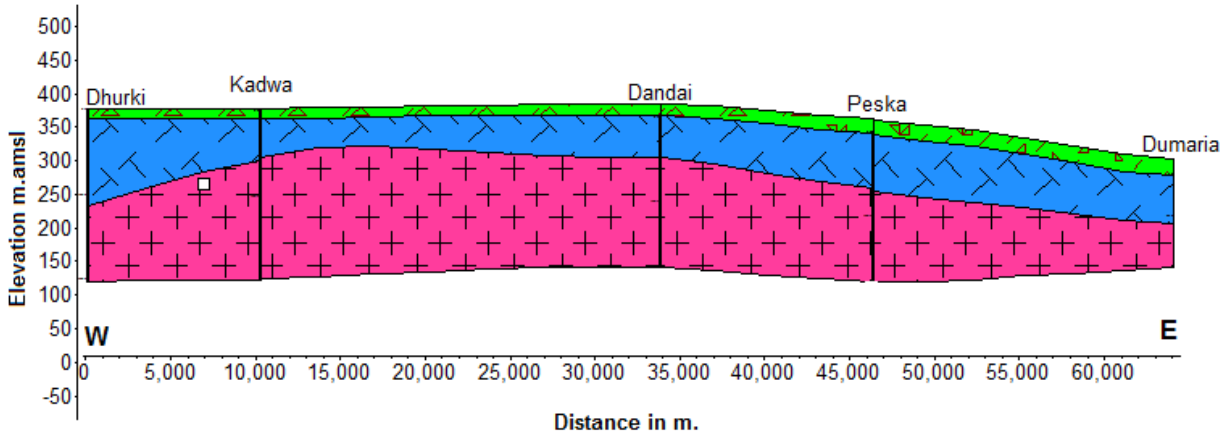
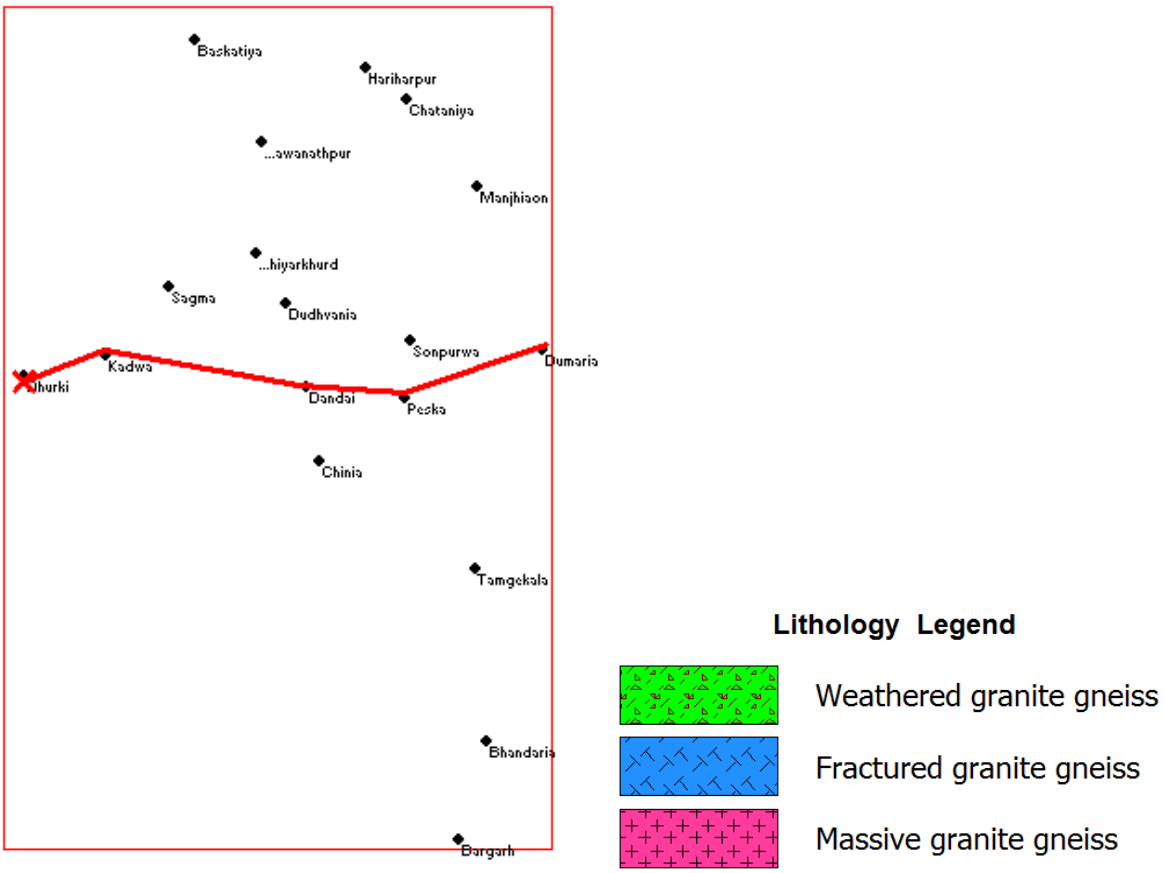


Figure – 14: Hydrogeological cross section



3.1.2 3-D Aquifer Disposition: The 3-D map in hard rock area of the district showing spatial disposition and vertical extent of Aquifer-I indicating its depth of weathering while the Aquifer – II showing occurrence of fractured rock thickness is presented in **figures – 11**. Based on the drilling data of exploratory wells maximum thickness of Aquifer - I (weathered zone) in **hard rock area** is 34.60 m. The depth of Aquifer – II (fracture zone) ranges from 9.00 to 161.00 m bgl.

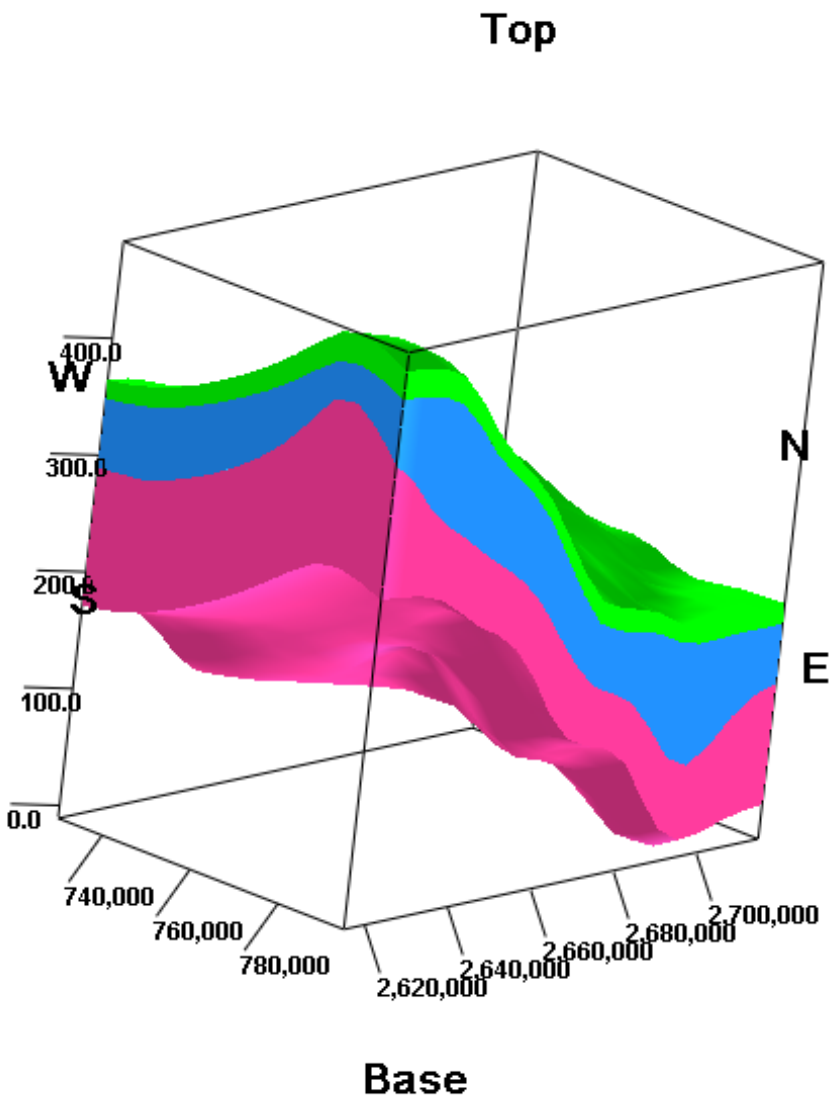


Figure – 15: 3D subsurface lithological models with Aquifer Disposition in hard rock areas of Garhwa district

Hydrogeological cross section of I, II, &III shown in figure- 12, 13, 14 has been prepared based on exploratory well data of CGWB.The inferred imaginary line between fractured rock zone and massive rock zone depicted in Fig 12, 13, 14 are also based on exploratory data. This is a regional model of hydrogeological cross setion. The heterogeneity of hard rock aquifer being high, the hydrogeological cross sections drawn by inferring the continuity of fracture zones in the second aquifer is tentative. Any additional data from the area in future may change the geometry of aquifer that can consider as well.

3.2 Aquifer Characteristics: -

Based on exploratory wells drilled in the district, pumping tests as well as preliminary yield test (PYT) were conducted for evaluating the well characteristics and for determining the hydraulic parameters of the deeper fractured aquifer- II. The drawdown data of and residual drawdown data of aquifer performance test (APT) and PYT were analyzed and calculated aquifer parameters such as Transmissivity (T) and Storage coefficient (S) value of Aquifer – II. Summarized result of aquifer performance test (APT) is given below in table – 25.

Table – 25: Summarized result of APT/PYT

Sr. No.	Location	Block	Discharge (m^3/day)	Drawdown (m)	T (m^2/day)	S
1	Bhandaria, EW (APT)	Bhandaria	259.20	24.84	75.43	--
2	Bhandaria, OW (APT)			3.12	42.05	4.20×10^{-5}
3	Tamega Kalan (APT)	Ranka	559.87	7.71	59.68	--
4	Peska, EW (APT)	Meral	259.20	40.05	39.12	--
5	Peska, OW (APT)			6.09	7.79	4.87×10^{-5}
6	Dumaria (APT)	Garhwa	598.75	6.92	56.30	--
7	Dandai (APT)	Dandai	393.12	30.86	5.76	--
8	Bhawnathpur (PYT)	Bhawnathpur	184.03	11.02	4.89	--
9	Dudhvania (APT)	Ramna	504.58	25.85	8.93	--
10	Baskatiya (PYT)	Ketar	146.88	29.50	1.15	--
11	Hariharpur (APT)	Bhawnathpur	432.00	20.70	45.52	--
12	Garhwa (PYT)	Garhwa	198.72	30.00	7.3	--

Based on Aquifer Parameters evaluation in the district, Transmissivity value of deep fractured aquifer is found to be between 1.15 to 75.43 m^2/day. High value of Transmissivity correlates to tensile fracture system. The Storage co-efficient value ranging from 4.20×10^{-5} to 4.87×10^{-5} which indicates semi-confined to confined aquifer system in the district. The sustainability of ground water Resources is better understood by the aquifer properties. The Table - 26 depicts the Aquifer Wise Characterstics in Garhwa district.

Table 26: Aquifer characteristic of Garhwa district

Type of aquifer	Formation	Depth range of the aquifer (mbgl)	SWL (mbgl)	Thickness (m)	Yield (LPS)	Aquifer parameter	
			Post Monsoon (2020)			T (m^2/day)	Sy/S
Aquifer - I	Weathered Granite gneiss	5.00 – 34.60	0.83 – 13.30	5 - 10	O.1-1.0	--	--
Aquifer - II	Fractured Granite gneiss	9.00 – 161.00	--	0.50 – 6.00	0.25 – 10	1.15 – 75.43	4.20×10^{-5} to 4.87×10^{-5}

3.3 Aquifer Map:- Based on Aquifer Disposition, Aquifer Geometry, Aquifer Characteristics, Aquifer Maps in Garhwa district have been prepared as under in Fig-25

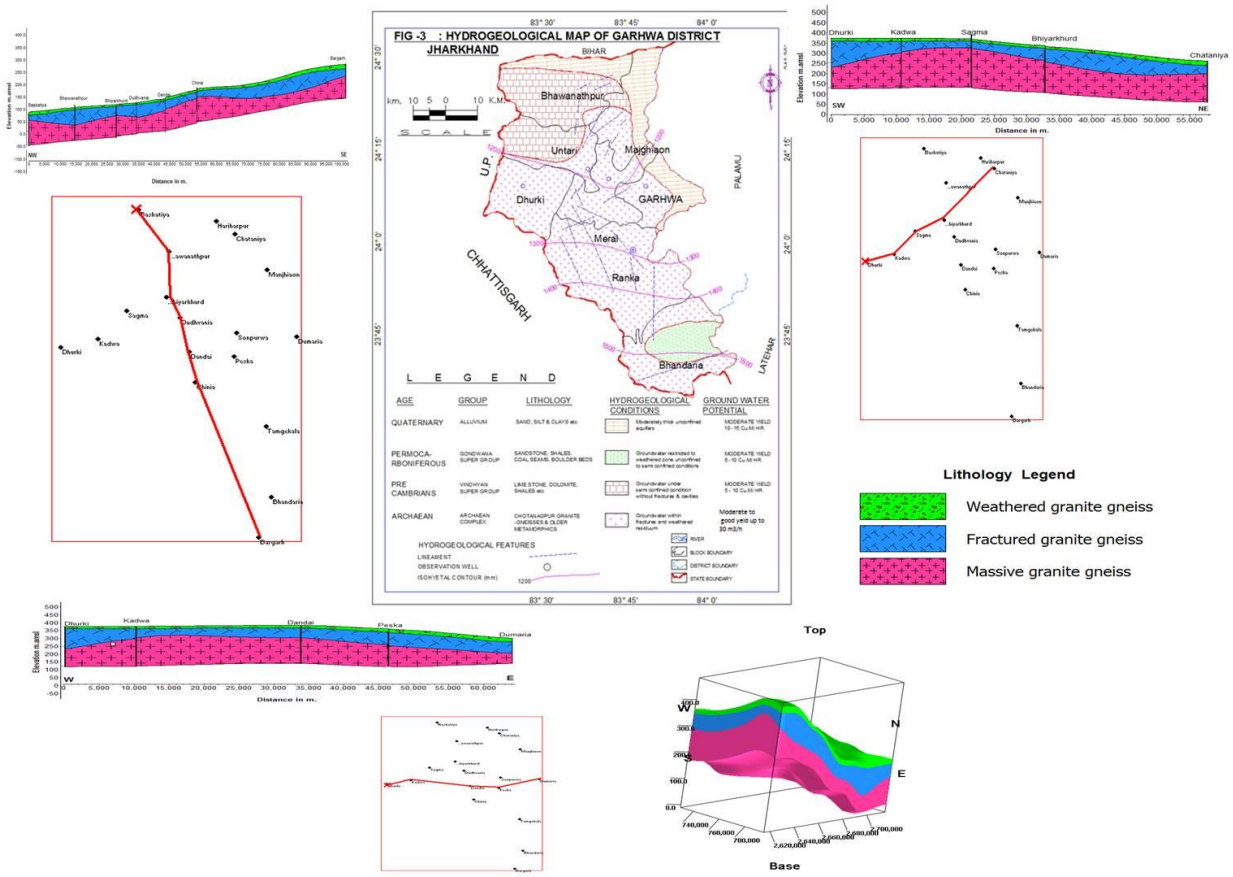


Fig-16. Aquifer Maps, Garhwa District

4. GROUND WATER RESOURCE

Ground Water Resource of the area has been estimated block wise based on for base year as on 31st March-2020. In the present report GEC 2015 methodology has been used and based on the assessment has been made using appropriate assumptions. This methodology recommends aquifer wise ground water resource assessment of both the Ground water resources components, i.e., Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources. The assessment of ground water includes assessment of dynamic and in-storage ground water resources, but 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 replenishable annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

4.1 Assessment of Annually Replenishable or Dynamic Ground Water Resources (Unconfined Aquifer i. e Aquifer-I)

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

ΔS= RRF+RSTR+RC+RSWI+RGWI+RTP+RWCS±VF ± 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 dynamic Ground Water Resources has been assessed by CGWB, SUO, Ranchi in association with State Ground Water Directorate, Jharkhand based on GEC, Methodology 2015. The summarized detail of Annually Replenishable or Dynamic Ground Water Resources of Garhwa district is in Table-27.

Table-27: Dynamic Ground Water Resources of Garhwa district (As on 31st March -2020)

S. No.	Items	
1	Area in ha	404475
2	Annual Extractable Ground Water Recharge in ham	27991.49
3	Current Annual Ground Water Extraction for irrigation in ham	7531.87
4	Current Annual Ground Water Extraction for domestic in ham	1742.82
5	Current Annual Ground Water Extraction for industrial in ham	11.25
6	Current Annual Ground Water Extraction for All uses in ham	9285.93
7	Annual GW Allocation for Domestic Use as on 2025 in ham	846.62
8	Net Ground Water Availability for future use in ham	18693.46
9	Stage of Ground Water Development (%)	36.14

4.1.1 Recharge Component: During the monsoon season, the rainfall recharge is the main recharge parameter, which is estimated as the sum total of the change in storage and gross draft. The change in storage is computed by multiplying groundwater level fluctuation between pre and post monsoon periods with the area of assessment and specific yield. Monsoon recharge can be expressed as:-

$R = h \times Sy \times A + DG$

Where,

h = rise in water level in the monsoon season, Sy = specific yield

A = area for computation of recharge, DG = gross ground water draft

The monsoon ground water recharge has two components- rainfall recharge and recharge from other sources. The other sources of groundwater recharge during monsoon season include seepage from canals, surface water irrigation, tanks and ponds, ground water irrigation, and water conservation structures. During the non-monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) method. Recharge from other sources is then added to get total non-monsoon recharge.

The season wise assessment of recharge from various components such as rainfall and other sources was done and presented in table - 28 and figure - 17. The recharge from rainfall contributes maximum component 24600.47 ham during monsoon season and recharge from other sources is 2392.72 ham, whereas during non-monsoon season, recharge from rainfall is 1051.99 and the recharge from other sources is 2343.26 ham. The total annual ground water recharge is 30394.44 ham and total natural discharge is 2402.95 ham. Annual extractable ground water resource after natural discharge is estimated as 27991.49 ham.

Table – 28: Recharge Components evaluated for Resource Estimation 2020

Block	Total area (ha)	Recharge from other sources during monsoon season (ham)	Recharge from rainfall during monsoon season (ham)	Recharge from other sources during non monsoon season (ham)	Recharge from rainfall during non monsoon season (ham)	Total annual ground water recharge (ham)
Bardiha	9770	37.82	418.1	44.25	15.63	515.80
Bhandaria	66118	117.51	4122.61	149.25	160.89	4550.26
Bhawnathpur	28688	310.58	2360.25	475.63	88.23	3234.69
Bishunpura	7923	167.17	1075.35	90.42	44.43	1377.37
Chinia	28583	47.22	1319.63	44.33	70.75	1481.93
Danda	3186	6.98	156.85	4.59	7.93	176.35
Dandai	13833	51.22	557.92	64.59	27.67	701.4
Dhurki	21146	94.55	835.59	100.06	46.86	1077.06
Garhwa	27355	364.45	1514.91	154.05	56.63	2090.04

Kandi	17698	109.4	2305.38	126.36	86.18	2627.32
Ketar	15405	77.73	1975.66	125.50	73.86	2252.75
Kharaondhi	14108	97.03	945.09	156.64	41.56	1240.32
Majhiaon	14147	45.74	567.52	68.28	24.14	705.68
Meral	26387	89.22	1750.37	93.10	65.43	1998.12
Ramkanda	22185	186.08	891.06	88.30	49.97	1215.41
Ramna	15421	213.31	601.45	161.05	33.73	1009.54
Ranka	42743	76.67	1402.53	83.14	78.65	1640.99
Sagma	9983	124.77	567.27	105.02	22.12	819.18
Utari	19796	181.27	1232.93	208.70	57.33	1680.23
Total	**404475**	**2398.72**	**24600.47**	**2343.26**	**1051.99**	**30394.44**

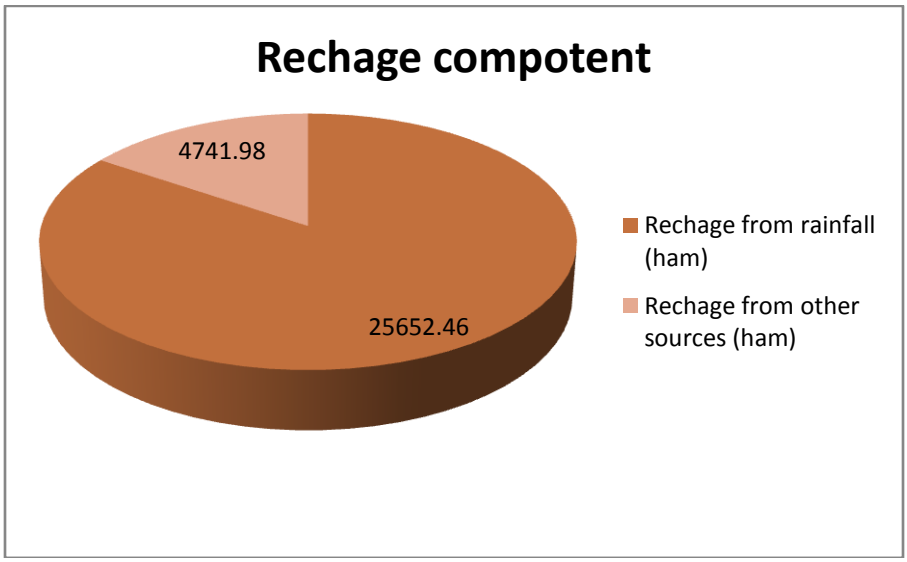


Figure – 17: Recharge from various sources

4.1.2 Ground Water Availability, Draft and Stage of GW development

The utilization of available ground water resources for various purposes is provided in table – 29 (As on 31st March 2020). The annual gross draft for all uses is estimated at 9285.93 ham with domestic sector being the major consumer having a draft of 1442.82 ham. The annual draft for irrigation use was estimated 7531.86 ham. The allocation of net ground water available for future use is 18693.46 ham. The stage of ground water development is low i.e., 36.14%.

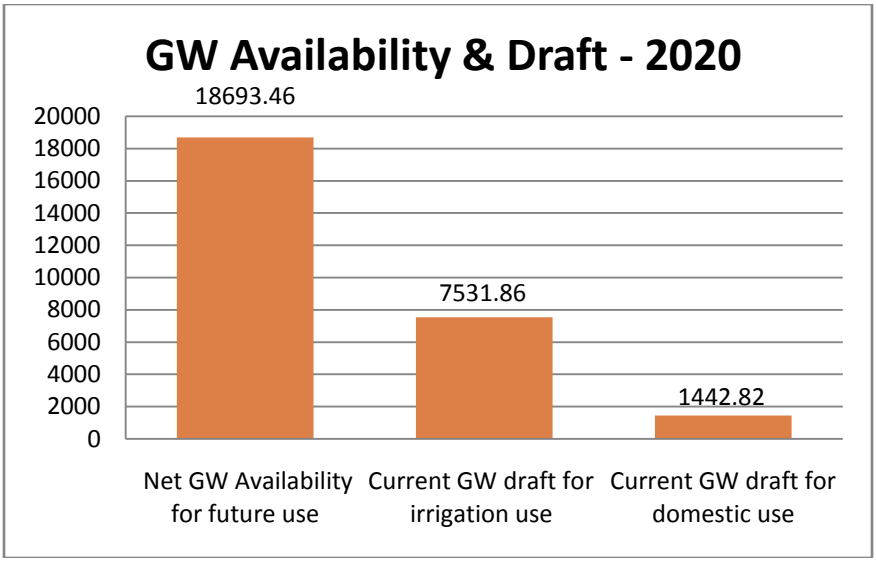


Figure – 18: Net GW Availability & Draft of Garhwa district (2020)

Table – 29: Block wise dynamic ground water resource of Garhwa district (As on 31st March 2020)

Assessment Units (block)	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use	Ground Water Extraction for Domestic Use	Ground Water Extraction for Industrial Use	Total Extraction for all uses	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(%)
Bardiha	464.22	104.5	50.05	0	154.55	309.32	33.29
Bhandaria	4322.74	425.25	87.21	0	512.46	3809.67	11.85
Bhawnathpur	2911.22	2050.25	118.66	3.72	2172.63	737.77	74.63
Bishunpura	1308.5	204.75	42.55	0	247.29	1060.92	18.90
Chinia	1407.84	66	51.24	0	117.24	1290.24	8.33
Danda	167.53	37	23.56	0	60.56	106.8	36.15
Dandai	666.33	242.5	84.01	0	326.51	339.24	49.00
Dhurki	969.36	261	73.20	0	334.19	634.67	34.48
Garhwa	1881.03	228.5	319.24	7.54	555.29	1323.52	29.52
Kandi	2364.59	277	24.44	0	301.44	2062.98	12.75
Ketar	2027.47	539.625	67.06	0	606.68	1420.32	29.92
Kharaondhi	1178.3	696.5	67.93	0	764.43	413.4	64.88
Majhiaon	670.26	233	114.79	0	347.79	321.67	51.89
Meral	1798.31	261.5	171.95	0	433.45	1363.67	24.10
Ramkanda	1093.87	162	58.66	0	220.66	872.81	20.17
Ramna	908.59	487.5	93.14	0	580.64	327.3	63.91
Ranka	1476.89	162.5	119.40	0	281.90	1194.16	19.09
Sagma	778.22	330.5	40.11	0	370.61	407.33	47.62
Utari	1596.22	762	135.62	0	897.61	697.67	56.23
Total	**27991.49**	**7531.86**	**1442.82**	**11.26**	**9285.93**	**18693.46**	**Avg. 36.14**

5. GROUND WATER RELATED ISSUES

Agriculture is the major occupation of the rural population of the Garhwa district. About 95% population of the district is living in rural areas and depends on agriculture. Since the density of population is high there is acute pressure on land for agriculture use. But the land available for cultivation is limited because of undulating topographical set-up. The district of Garhwa is mainly a dissected upland of ancient crystalline rocks which covers the major parts of this district.

5.1 Low Ground Water Development: One major issue of the area that is low ground water development. At present the overall stage of ground water development is only around 36.14%, based on Ground water resource assessment as on 2020. The Block wise stage of ground water development (SOD) of the district varies from 8.33 to 74.63 percent. Block wise stage of development of the district is shown in figure – 19.

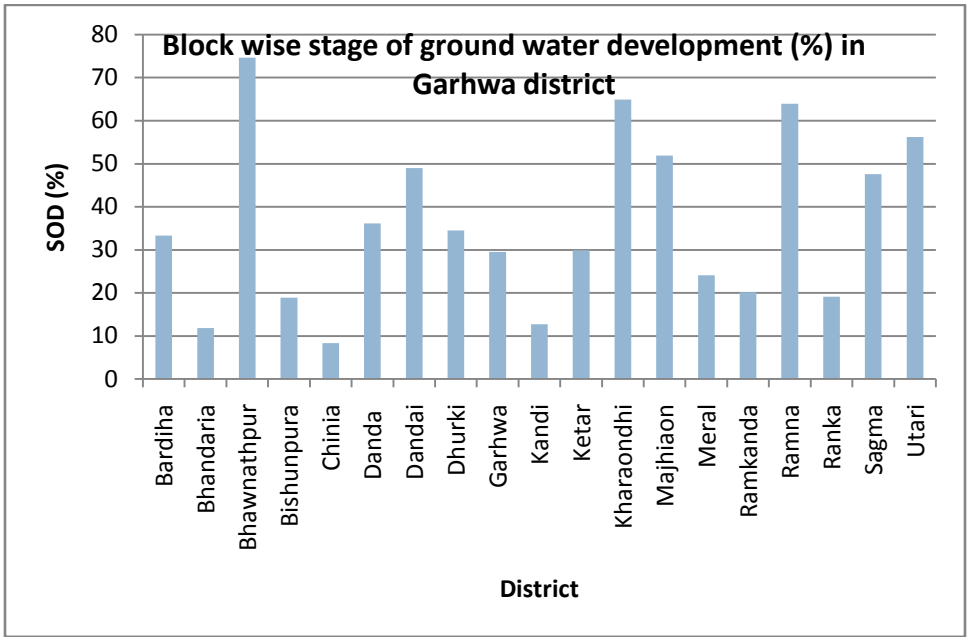


Figure – 19: GW Stage of development in Garhwa district

5.2 Low Ground Water Potential / Limited Aquifer Thickness / Sustainability: Central Ground Water Board has constructed 31 exploratory wells in hard area of the district. The percentage of success bore wells (more than 3 lps discharge) is 25.81% with 32.26% of dry wells. Average thickness of weathering is 17 m and average thickness of fracture zones is 1.56 only. Low to medium Transmissivity value observed which varies from 1.15 to 75.43 m^2/day of fractured aquifer. The yield of bore wells drilled in the area is classified and presented below in figure – 20.

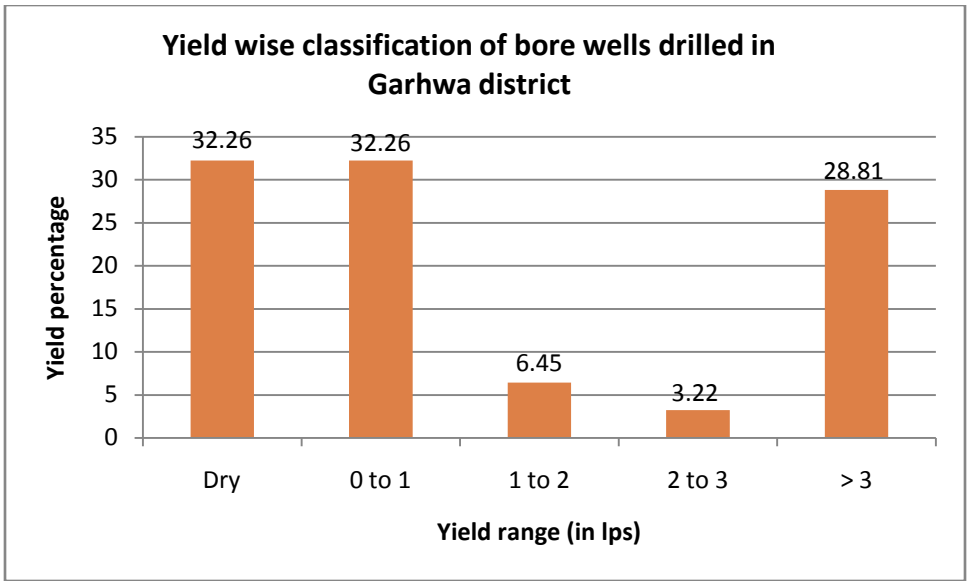


Figure – 20: Yield wise classification of bore wells drilled in Garhwa district

5.3 Ground water contamination: Analytical result of water samples collected from the district, it is found the Flouride and Nitrate concentration is beyond permissible limit .

5.3.1 Flouride Contamination:

Consumption of water with fluoride concentration above 1.5 mg/l is harmful which results in acute to chronic dental fluorosis where the tooth become coloured from yellow to brown. Skeletal fluorosis which causes weakness and bending of the bones also results due to long term consumption of water containing high fluoride. Presence of low or high concentration of fluoride in groundwater is because of geogenic or anthropogenic causes or a combination of both.

As a part of MOU between CGWB & GSI, ground water samples from Tubewell/Bore well/Hand Pump of select villages in North Garhwa has been collected during May 2022 and analysed in CGWB, MER, Patna Lab. The chemical analysis results shows that out of 50 samples, all 50 have F concentration more than the desirable limit of 1.5mg/l. Flouride concentration ranges from 1.51-3.31 mg/lit(Annexure-V)

5.3.2. Nitrate contamination: A variety of chemical constituents including Nitrate can pass through the soil and potentially contaminate ground water. Nitrate comes from the nitrogen, plant nutrient supplied by inorganic fertilizer and animal manure. Beneath agriculture land, nitrate is primary form of Nitrogen. It is soluble in water and can easily pass through soil to the ground water table. Nitrate can persists in ground water for decades and accumulated to high levels as more nitrogen is applied to the land surface every year. Nitrate is one of the most common ground water contaminations in rural areas. It is regulated in drinking water primarily because excess level can cause methemoglobinemia or blue baby disease. Nitrate can be removed from drinking water by distillation, reverse osmosis or ion exchange.

In shallow aquifer about 10.25% water samples have been found more than the permissible limit of NO_3 (45mg/l). Location details of NO_3 concentration found beyond permissible limit is given in table 30.

Table – 30: Location details of Nitrate concentration found beyond permissible limit in ground water of shallow aquifer in Garhwa district

Sr. No.	Village	Block	Nitrate value (mg/l)
1	Chinia	Chinia	45.93
2	Ranpura	Chinia	45.6
3	Dandai	Dandai	55.12
4	Semaura	Kandi	56.97

6. MANAGEMENT STRATEGIES

As discussed in previous chapter, the major ground water related issue in the Garhwa is low ground water development owing to many socio-economic and hydrogeological reasons. To overcome these, it is imperative to have a robust ground water resource development plan for the district.

6.1 Supply Side Management

At present as per Ground Water Resource Estimation 2020, the stage of ground water development is low i.e., 36.14 % and all the blocks of the district come under safe category, ecept Bhawnathpur which is under semi-critical. There is scope for further ground water development. In some parts of the district long term declining trend has been noticed. Therefore, the ground water development should also be coupled with ground water augmentation, so that there is no stress on ground water regime of the area.

The supply side interventions envisage Ground Water Resource Development Strategy & construction of Rainwater Harvesting and Artificial Recharge structures in the areas feasible for construction of recharge structures based on the long-term water level scenario and recharge potential of the aquifer.

6.1.1 Ground Water Resource Development Strategy: In view of above, the focus of proposed management plan was to enhance the overall ground water development from the present 8.33% to 74.63%. Total 5509 dug wells (15-20 m depth) and 1339 shallow depth bore wells/tubewell (50-70 m depth) can be safely construted in feasible areas. Proposed number of abstraction structure is given below in tables – 31 & 32.

Table – 31 Proposed number of additional Abstraction Structures

District	Net GW Availability for Future Development (Ham)	future irrigation potential available (ha) considering (Δ) 0.45m	60% of future irrigation potential created (ha)	Proposed number of ground water structure (Dug wells)	Proposed number of ground water structure (Shallow Tubewell/ Bore wells)
Bardiha	309.32	687	412	99	24
Bhandaria	3809.67	8466	5080	1219	296
Bhawnathpur	737.77	SOD 74.63% (not proposed)			
Bishunpura	1060.92	2358	1415	339	83
Chinia	1290.24	2867	1720	413	100
Danda	106.8	237	142	34	8
Dandai	339.24	754	452	109	26
Dhurki	634.67	1410	846	203	49

Garhwa	1323.52	2941	1765	424	103
Kandi	2062.98	4584	2750	660	160
Ketar	1420.32	3156	1894	455	110
Kharaondhi	413.4	SOD 64.88% (not proposed)			
Majhiaon	321.67	715	429	103	25
Meral	1363.67	3030	1818	436	106
Ramkanda	872.81	1940	1164	279	68
Ramna	327.3	SOD 63.91% (not proposed)			
Ranka	1194.16	2654	1592	382	93
Sagma	407.33	905	543	130	32
Utari	697.67	1550	930	223	54
Total	**18693.46**	**39900**	**23939**	**5509**	**1339**

It is necessary that proposed Additional ground water abstraction structure may be constructed in three phases with proper site selection through Hydrogeological and geophysical Studies. The results of the first phase of ground water development together with studies of the behavior of ground water regime will guide futher ground water development to achieve 100% utlisation.

6.1.2 Supply Side Interventions:

At present as per Ground Water Resource Estimation 2020, the stage of ground water development is low i.e., 36.14 % and all the block of the district comes under safe category except Bhawnathpur block. However in some parts of the district long term declining trend has been noticed. Therefore, the ground water development should also be coupled with ground water augmentation, so that there is no stress on ground water regime of the area. The supply side interventions envisages construction of Rainwater Harvesting and Artificial Recharge structures in the areas feasible for construction of recharge structures based on the long term water level scenario and recharge potential of the aquifer as well as dilution of ground water contamination such as Nitrate observed in the district. The implementation of water conservation through artificial recharge measures will have a positive impact on drinking water sources of the area. It will ensure that the wells don't go dry during summer/lean/stress period in the areas of implementation and sufficient ground water availability is there in the wells even during the summer season. Thus not only the drinking and domestic water sources will be strengthened but additional irrigation potential can be created through artificial recharge structures.

Artificial recharge to Ground Water Master plan 2020

Recently in 2020, artificial recharge to Ground Water master plan 2020 of Jharkhand state has been prepared. The area identified for artificial recharge has been made based on post monsoon depth to water level (Nov. 2020) more than 3 m bgl with declining trend of more than 0.1 m/yr (2009 – 2018). In addition, area with water level more than 9 m bgl in the district has been considered for identifying the area. The volume of unsaturated zone available for

recharge in identified areas is determined by computation of average depth of the unsaturated zone below 3 m bgl and then multiplied by area considered for recharge. Based on this master plan, number of feasible artificial recharge structures is given in Table- 32.

Table - 32: Artificial recharge structures feasible in Garhwa district.

Area identified for artificial recharge (Sq. Km.)	Volume of unsaturated zone available for recharge (MCM)	Total volume of Available Water for Recharge (MCM)	Proposed numbers of recharge structures (No's)	
			Percolation Tank	Nala Bund/ Check dam / Gully Plug
441.66	998.15	76.67	88	552

6.2 Demand side Management

It is always essential to address the issue of constraining demand for groundwater abstraction since this will normally contribute more to achieving the groundwater balance. The concept of real water savings is critical in this regard. The main demand side interventions may be: -

1. Promote improved irrigation technologies (drip or sprinkler irrigation, etc.)
2. Crop choice management and diversification (promote less intensive crops like pulses and horticulture)
3. Promote treated municipal waste water for irrigation and construction use.
4. Managing energy and irrigation nexus (provide quality power supply when needed through separate feeders, high voltage distribution lines, solar pumps, etc.)

6.3 Ground water management strategy for Nitrate and Fluoride affected areas:

Nitrate contamination occurring in granite gneiss of Chinia, Dandai and Kandi blocks, Hoever Flouride contamination occur in several parts of Garhwa district. Remedial measures recommended for Nitrate and Fluoride affected areas are as follows-

1. Purification/Filtration: Purification/filtration of Nitrate and Fluoride contaminated ground water by distillation, reverse osmosis or ion exchange etc.

2. Awareness raising Program /Participatory approach: Peoples should aware about the ground water pollution of Nitrate and Flouride. Management of schemes or project related Nitrate and Flouride removal should be in hand of local peoples, so that peoples will keep the proper maintenance of machines and equipments.

6.3.1 Urban and Rural water supply: Drinking Water & Sanitation Department (DWSD), Garhwa has constructed large numbers of bore wells to solve the water scarcity problem of the rural area of the district. In addition, numbers of small rural water supply schemes have been implemented by the Drinking Water & Sanitation Department, Garhwa in rural area. Similarly, DWSD, Garhwa has established many pipe line water supply schemes for urban areas.

7.0 Sum-up

- The district of Garhwa located almost the north - western parts of Jharkhand state. The district which acquired the status of an independent district on 1st April, 1991, has a close linkage with the parent district Palamu.
- The Chottanagpur plateau is a region of large physical inequalities and presents a rich panorama of topographical features. The general configuration of region varies from valley fills to structural ridges.
- As per Planning Commission, the district falls in the eastern plateau and hills region Agro climatic sub-zone-VII with average annual rainfall 917.02 mm. The mean monthly temperature range from 3^0C in winter to 47^0C in summer.
- The major part of the district is having dendritic drainage pattern. The district is forming Sone sub basin of the Upper Ganga basin. The river North Koel is the main river of the district, which flows south to north direction in the eastern part and form eastern boundary of the district. One another important river of the district is Kanhar which forms the south – western boundary of the district.
- Geologically the district of Garhwa is mainly underlain by Archaean crystalline rocks which are highly deformed and metamorphosed. Major part of the district is occupied by granite gneiss. Gondwana formation is occupy a small patch in eastern part of the district while Vindhyan Super Group occur in north – west part of the district.
- In general in fissured formations, discharge of well has been found in the range of 0.50-10.76 LPS. Overall in the district the major potential fractures zones are found up to 130 m. First potential fracture zone encountered in the district widely varies from 9 -160 m.
- Ground water occurs in unconfined to semi-confined state in Aquifer-I (up to the depth of 30 m). Yield of the wells in Aquifer-I is restricted in weathered Granite-Gneiss.
- The Chotanagpur granite-gneiss, belonging to Archaean age constitutes the group of fissured formation hydrogeological units and to some extent Vindhyan and Barakar sandstone as an Aquifer-II i.e deeper Aquifer in the area. The Potential fractured deeper aquifers (Aquifer-II) in the district have been observed up to 161 mbgl with the yield potential up to 38.74 m^3/hr.
- The analysis of aquifer parameters in the district shows that the transmissivity value ranges from 1.15 – 75.43 m^2/day. The storativity value also varies from 4.20 x 10^{-5} to 4.87 x 10^{-5}, which shows that aquifers are under semi-confined to confined condition.
- Ground Water quality is generally potable, except high concentration of Flouride in several parts of the district and high Nitrate in few patches.
- Based on Ground water Resources estimation 2020, the stage of ground water development in Garhwa district is 36.14% and the entire block comes under safe category except Bhawnathpur block, which is under semi-critical. Therefore there is sufficient scope for further ground water development.
- Three major ground water related issues in Garhwa district are High Flouride in Ground Water, low ground water development, low ground water potential and Nitrate contamination in the area.

- To suggest a sustainable ground water management plan there are two options-Supply Side Management Options & Demand Side Management Options

- The supply side interventions-I envisages Ground Water Management strategy through construction of 5509 dug wells and 1339 shallow bore/tubewell in the feasible areas in the district. Rain water harvesting and artificial recharge to be encouraged in feasible areas for ground water augmentation
- The supply side interventions-II also envisages construction of feasible artificial recharge structures - 88 percolation tank, 552 Nala Bund/Check Dam/Gully Plug Lohardaga district, which is Based on Artificial recharge to Ground Water master plan 2020 of Jharkhand state
- The demand side intervention envisages the real water savings. The main demand side interventions may be-i) Promote improved irrigation technologies (drip or sprinkler irrigation, etc.), ii) Crop choice management and diversification (promote less intensive crops like pulses and horticulture), iii) Promoting treated municipal waste water for irrigation and construction use, and iv) Managing energy and irrigation nexus (provide quality power supply when needed through separate feeders, high voltage distribution lines, solar pumps, etc.) The government should encourage and provide incentive the use of drip irrigation and sprinkler system.
- Alternative surface water supply in fluoride infested blocks of Garhwa district may be extended. In addition a purification/filtration of Flouride/Nitrate may also be adopted.

Annexure – I

Five years monthly rainfall data of Garhwa district, Jharkhand (2015 – 2019)

Year - 2015

Block	Month												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Garhwa	39.7	--	20.4	17.6	--	86.3	400.0	149.2	38.0	9.5	--	--	760.7
Meral	30.5	--	15.0	15.0	--	76.0	328.5	164.0	37.5	2.0	--	--	668.5
Dandai	15.5	--	30.0	12.0	--	56.0	338.0	169.0	60.0	12.0	--	--	692.5
Majhiaon	7.4	--	4.0	6.2	12.2	47.2	480.0	109.0	6.0	12.2	--	--	684.2
Kandi	9.4	--	6.0	5.5	--	16.5	179.0	127.5	62.6	4.0	--	--	410.5
Ranka	34.8	--	27.0	29.0	15.4	47.0	594.0	233.0	58.0	30.0	--	--	1068.2
Chinia	13.0	--	7.0	5.0	--	7.0	209.0	148.0	21.0	2.0	--	--	412.0
Ramkand	15.0	--	15.8	35.4	--	105.4	376.2	254.6	11.0	--	--	--	813.4
Bhandaria	13.4	--	31.6	40.2	--	132.2	728.0	250.4	40.8	24.0	--	--	1260.6
Nagar Utari	10.0	--	44.0	10.0	6.0	40.5	232.2	160.5	41.1	7.0	--	--	551.3
Ramna	30.5	--	11.5	57.0	--	35.0	328.0	126.5	53.3	--	--	--	641.8
Dhurki	6.0	--	42.0	28.0	--	30.0	300.0	176.0	71.5	14.0	--	--	667.5
Bhavnathpur	24.5	--	10.0	19.0	8.0	67.8	251.0	239.5	10.0	16.0	--	--	645.8
Kharaondhi	--	--	11.2	38.2	--	20.8	168.4	38.7	6.0	9.5	--	--	292.8

Year - 2016

Block	Month												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Garhwa	--	--	320.0	--	53.0	101.5	326.0	467.1	125.6	102.0	--	--	1495.2
Meral	--	--	136.0	--	33.0	93.0	343.0	386.4	103.5	48.2	--	--	1143.1
Dandai	--	--	57.0	--	32.0	64.5	518.6	548.3	133.5	170.0	--	--	1523.9
Majhiaon	--	--	11.0	--	13.9	106.0	334.0	573.6	284.0	120.0	--	--	1442.5
Kandi	--	--	53.0	--	8.0	29.0	136.0	390.0	196.0	72.0	--	--	884.0
Ranka	--	--	38.0	--	32.0	61.0	462.0	713.0	368.0	250.0	--	--	1924.0
Chinia	--	--	47.0	--	35.0	74.0	435.0	630.6	179.0	59.0	--	--	1459.6
Ramkand	--	--	22.8	--	2.4	102.0	404.7	609.0	308.0	112.5	--	--	1561.4
Bhandaria	--	--	38.6	--	5.0	138.0	466.1	683.0	286.0	87.0	--	--	1703.7
Nagar Utari	--	--	10.5	--	18.0	77.0	299.0	569.5	242.5	98.5	--	--	1315.0
Ramna	--	--	45.8	--	39.5	52.5	490.0	568.5	205.0	78.5	--	--	1479.8
Dhurki	--	--	49.0	--	41.0	111.5	430.7	521.2	282.2	82.0	--	--	1517.6
Bhavnathpur	--	--	18.0	--	31.0	70.0	452.0	546.5	180.0	86.0	--	--	1383.5
Kharaondhi	--	--	28.8	--	14.0	24.2	715.0	596.9	206.4	54.0	--	--	1639.3

Year - 2017

Block	Month												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Garhwa	--	--	--	--	--	39.5	208.0	128.8	52.8	26.4	23.8	--	479.3
Meral	--	--	--	--	--	36.5	186.5	109.5	31.5	13.2	13.2	--	390.4
Dandai	--	--	--	--	--	--	--	--	--	--	--	--	--
Majhiaon	--	--	--	--	--	97.0	433.0	138.9	30.0	14.0	14.0	--	726.9
Kandi	--	--	--	--	--	37.0	173.0	5.0	8.0	--	--	--	223.0
Ranka	--	--	--	--	--	6.3	85.9	104.0	25.5	45.0	51.0	--	317.7
Chinia	--	--	--	--	--	56.0	332.0	343.0	51.0	45.0	45.0	--	872.0
Ramkand	--	--	--	--	--	41.0	360.5	183.8	22.0	--	--	--	607.3
Bhandaria	--	--	--	--	--	21.0	434.0	431.0	130.0	7.0	10.0	--	1033.0
Nagar Utari	--	--	--	--	--	116.0	412.1	210.9	23.0	21.0	21.0	--	804.0
Ramna	--	--	--	--	--	106.5	369.5	213.0	42.5	7.0	7.0	--	745.5
Dhurki	--	--	--	--	--	105.0	440.0	265.0	73.0	20.0	20.0	--	923.0
Bhavnathpur	--	--	--	--	--	126.0	390.0	121.1	27.2	7.0	15.0	--	686.3
Kharaondhi	--	--	--	--	--	177.0	507.9	176.0	72.6	24.2	24.2	--	981.9

Year - 2018

Block	Month												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Garhwa	--	3.6	--	--	5.3	45.0	145.7	71.8	162.6	14.0	--	--	448.0
Meral	--	3.9	--	--	6.5	40.5	139.5	85.0	151.5	17.0	--	--	440.0
Dandai	--	--	--	--	--	--	--	--	--	--	--	--	--
Majhiaon	--	24.9	--	--	8.5	120.0	243.0	144.0	230.5	12.0	--	--	782.9
Kandi	--	6.5	--	--	7.5	28.0	60.0	55.0	95.0	8.0	--	--	260.0
Ranka	--	8.0	--	--	3.0	39.5	98.5	82.0	157.5	65.0	--	--	453.5
Chinia	--	2.4	--	--	3.5	108.0	331.0	213.0	390.0	11.0	--	--	1058.9
Ramkand	--	2.0	--	--	1.0	25.2	234.3	186.4	267.2	9.4	--	--	725.5
Bhandaria	--	7.0	--	--	2.4	124.0	564.3	287.3	613.5	11.0	--	--	1609.5
Nagar Utari	--	2.5	--	--	11.6	184.3	339.1	222.8	363.1	8.0	--	--	1131.4
Ramna	--	3.0	--	--	15.0	173.3	220.5	95.0	194.0	7.5	--	--	708.3
Dhurki	--	7.0	--	--	10.0	128.0	298.0	164.0	213.0	5.0	--	--	825.0
Bhavnathpur	--	7.0	--	--	8.5	149.0	274.8	180.0	244.0	2.0	--	--	865.3
Kharaondhi	--	6.4	--	--	10.1	120.4	272.9	310.4	452.8	16.6	--	--	1189.6

Year - 2019

Block	Month												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Garhwa	2.4	3.8	--	--	--	39.6	161.0	164.7	82.6	12.0	--	17.0	483.1
Meral	9.0	4.5	--	--	--	36.5	123.8	139.1	82.0	11.0	--	16.4	422.3
Dandai	--	--	--	--	--	--	--	--	--	--	--	--	--
Majhiaon	9.0	2.0	--	--	--	7.5	240.6	360.0	202.0	7.0	--	6.0	834.1
Kandi	9.0	2.0	--	--	--	15.0	235.4	279.2	190.3	--	--	11.0	741.9
Ranka	5.0	2.0	--	--	--	43.0	247.0	361.0	198.0	18.0	--	14.0	888.0
Chinia	6.5	8.0	--	--	--	84.0	292.4	536.0	201.0	33.0	--	30.0	1190.9
Ramkand	5.5	2.5	--	--	--	10.5	193.0	304.8	152.8	--	--	6.0	675.1
Bhandaria	3.0	3.0	--	--	--	19.0	265.5	499.0	89.2	--	--	2.0	880.7
Nagar Utari	6.0	3.0	--	--	--	89.7	197.6	413.5	245.2	18.4	--	32.6	1006.0
Ramna	5.5	7.5	--	--	--	76.5	284.5	476.0	216.0	29.0	--	41.5	1136.5
Dhurki	12.0	5.0	--	--	--	33.0	235.0	654.9	322.0	132.0	--	20.4	1414.3
Bhavnathpur	3.0	2.0	--	--	--	28.0	268.0	367.3	309.0	5.0	--	26.0	1008.3
Kharaondhi	4.0	6.0	--	--	--	25.0	170.0	346.5	281.4	9.0	--	13.6	855.5

Annexure - II

DETAILS OF KEY WELLS ESTABLISHED FOR NATIONAL AQUIFER MAPPING STUDY OF GARHWA DISTRICT (2020 – 21)

Well No.	Village	Block	Owner	Location	Co-ordinates	Type of well	Lifting device	MP (magl)	Depth (mbgl)	Dia. (m.)	WL (mbgl) (Nov. 2020)
1	Ranka	Ranka	Govt.	Within the block office compound near staff quarter and Shiv temple	23^0 54'30" 83^0 47'30"	Dug well	R & B	0.38	7.35	2.15	2.95
2	Phugmari	Ramkanda	Subai Ram	RHS of Ramkanda – Daltonganj road on open field and about 02 km from Ramkanda	23^0 53'02" 83^0 53'21"	Dug well	R & B	0.32	7.68	3.00	6.31
3	Rodo	Bhandaria	Suresh Singh	About 12 km from Bhandaria on Ramkanda road and 200 m RHS from road near house of owner	23^0 48'29" 83^0 51'01"	Dug well	R & B + DP	0.59	9.15	2.72	2.13
4	Bhandaria	Bhandaria	Govt.	Forest range office campur near Shiv temple on Barwadih road	23^0 44'07" 83^0 49'42"	Dug well	R & B	0.50	9.42	1.35	4.45
5	Gothani	Bargarh	Govt.	NHO Suresh Das, 01 km from Bargarh on Tehri road	23^0 38'11" 83^0 47'35"	Dug well	R & B	0.45	7.60	1.80	2.97
6	Barigawan	Bargarh	Christopher Kachhap	08 km from Bhandaria – Bargah road, about 200 m LHS of road on open field	23^0 41'00" 83^0 48'03"	Dug well	R & B + DP	0.30	9.20	4.55	3.46
7	Godarmana	Ranka	Gautam Dube	Before entering the Godarmana market near house of owner, RHS of approach road	23^0 48'33" 83^0 42'42"	Dug well	R & B	0.32	11.68	3.00	5.63
8	Bishrapur	Ranka	Vishwajit Verma	About 13 km from Ranka on Godarmana road, LHS of road	23^0 53'49" 83^0 42'11"	Dug well	R & B + DP	0.35	13.55	3.40	2.80
9	Kaprat	Dandai	Lagan Singh	20 km from Garhwa on Chiniya road (RHS) NHO owner	24^0 04'27" 83^0 39'47"	Dug well	R & B	0.36	6.60	4.28	3.92

Well No.	Village	Block	Owner	Location	Co-ordinates	Type of well	Lifting device	MP (magl)	Depth (mbgl)	Dia. (m.)	WL (mbgl) (Nov. 2020)
10	Chiniya	Chiniya	Sudama Ram	LHS of the Chiniya – Ranpura road after Chiniya thana NHO owner	24^0 02'33" 83^0 57'48"	Dug well	R & B + EP	0.28	13.52	2.00	7.62
11	Ranpura	Chiniya	Maheshwari Singh	15 km from Chinia on Ambikapur road, NHO owner (RHS of road)	23^0 57'00" 83^0 36'27"	Dug well	R & B + EP	0.23	12.17	1.16	4.01
12	Dandai	Dandai	Govt.	Within Samudaik Bhawan campus inside the village	24^0 07'34" 83^0 37'03"	Dug well	R & B	0.38	7.97	2.61	3.72
13	Pangotwa	Dhurki	Tapeshwar Yadav	LSH of Dhurki – Dandai road, NHO owner	24^0 07'37" 83^0 32'27"	Dug well	DP	0.25	7.25	3.40	5.22
14	Dhurki	Dhurki	--	Back side of Forest office, LHS of Sagma – Dhurki road	24^0 08'31" 83^0 27'03"	Dug well	R & B	0.00	12.10	3.00	6.10
15	Sarda	Sagma	Sakodi Prasad Yadav	LHS of Dhurki – Sagma road near nala and house of owner (NHO)	24^0 10'27" 83^0 27'28"	Dug well	R & B + DP	0.33	7.67	4.10	6.27
16	Sagma	Sagma	Hazari P. Yadav	LHS of Sagma – Nagar Utari road, NHO owner	24^0 13'16" 83^0 27'31"	Dug well	DP	0.40	9.20	3.05	4.60
17	Manjhgawan	Kharaondhi	Jawahar Prajapati	About 07 km from Kharaondhi - Bhawnathpur road, near house of owner (LHS of road)	24^0 23'22" 83^0 28'18"	Dug well	R & B + DP	0.30	9.50	3.05	5.42
18	Bajarmarwa	Kharaondhi	Rajendra Saw	RHS and entrance of the village on open field, 01 km from Kharaondhi – Kon (UP) road.	24^0 25'35" 83^0 25'07"	Dug well	DP	0.20	13.80	2.85	10.90
19	Dasipur	Ketar	Jhari Saw	03 km from Ketar on Kharaondhi road (LHS) NHO	24^0 27'23" 83^0 31'30"	Dug well	R & B + DP	0.10	16.30	2.20	13.30
20	Panchadumar	Ketar	Karjhingan Ram	03 km North of Ketar, RHS of the road.	24^0 30'06" 83^0 33'11"	Dug well	DP	0.43	5.87	2.20	5.17
21	Jhagra Khurd	Bhawnathpur	Girja Mishra	Near Shiv temple, LHS of Bhawnathpur – Kharaondhi road	24^0 23'04" 83^0 31'07"	Dug well	DP	0.20	8.90	2.20	6.40

Well No.	Village	Block	Owner	Location	Co-ordinates	Type of well	Lifting device	MP (magl)	Depth (mbgl)	Dia. (m.)	WL (mbgl) (Nov. 2020)
22	Kakri (Kandia Tola)	Bhawnathpur	Manoj Ram	NHO owner, 03 km (RHS) from Bhawnathpur – Nagar Utari road	24^0 21'25" 83^0 33'35"	Dug well	R & B + DP	0.00	9.30	2.10	8.35
23	Ganki (Bilaspur)	Nagar Utari	Parshu saw	NHO owner, 10 km (RHS) of Nagar Utari – Dudhi (UP) Rd.	24^0 15'41" 83^0 24'58"	Dug well	R & B + DP	0.10	10.20	1.90	5.51
24	Nagar Utari	Nagar Utari	Govt.	Within the compound of PWD I.B., back side of rest house	24^0 17'00" 83^0 30'30"	Dug well	R & B	0.47	10.20	1.90	5.03
25	Manjhian	Manjhian	Govt.	Within the compound of health centre	24^0 19'22" 83^0 49'22"	Dug well	R & B + DP	0.60	4.30	1.90	3.95
26	Morbe	Manjhian	Shanbhu Saw	About 30 m RHS of Manjhian – Tundipur road near bridge on open field	24^0 23'53" 83^0 49'40"	Dug well	DP	1.00	7.30	3.10	2.45
27	Semaura	Kandi	Govt.	In front of Radha Krishna temple inside the village, 03 km from Kandi	24^0 28'47" 83^0 48'03"	Dug well	R & B	0.70	5.60	3.00	2.36
28	Wolma	Kandi	Sita Ram Ram	NHO owner, 01 km on Kandi - Manjhian road and ½ km RHS of the road.	24^0 27'45" 83^0 45'35"	Dug well	R & B + DP	0.45	8.95	3.05	3.38
29	Bardiha	Bardiha	Suman Paswan	Bardiha – Jika road (LHS) on open field	24^0 22'22" 83^0 43'47"	Dug well	DP	0.00	9.10	3.90	7.35
30	Kardiha	Bardiha	Jadu Yadav	NHO owner, 03 km (LHS) of Bardiha – Bishunpura road	24^0 21'25" 83^0 43'18"	Dug well	R & B + DP	0.25	7.05	2.30	3.79
31	Sandhya	Bishunpura	Jitendra Mehta	02km (LHS) of Bishunpura – Bardiha road, NHO owner	24^0 18'15" 83^0 40'15"	Dug well	R & B + DP	0.05	6.55	2.20	2.02
32	Darjia	Bishunpura	Anil Sukla	04 km from Bishunpura on Ramna road (RHS)	24^0 15'36" 83^0 37'52"	Dug well	R & B	0.10	8.90	4.00	2.58
33	Meral	Meral	Govt.	In Meral market opposite to papal tree about 100 m	24^0 10'56" 83^0 42'11"	Dug well	R & B	0.45	10.00	2.50	3.20
34	Ramna	Ramna	Govt.	LHS of Garhwa – Nagar Utari road, inside the market and adjoining Shiva temple	24^0 14'19" 83^0 36'36"	Dug well	R & B	0.20	7.35	2.35	3.38

Well No.	Village	Block	Owner	Location	Co-ordinates	Type of well	Lifting device	MP (magl)	Depth (mbgl)	Dia. (m.)	WL (mbgl) (Nov. 2020)
35	Bahiyar Khurd	Ramna	Sanjay Kumar Paswan	06 km from Ramna on Nagar Utari road (LHS).	24^0 15'31" 83^0 33'34"	Dug well	R & B + DP	0.10	8.00	3.05	4.91
36	Lagama	Meral	Gauri Shankar Choudhary	NHO owner, 08 km from Garhwa on Nagar Utari road (RHS)	24^0 10'19" 83^0 44'09"	Dug well	R & B + DP	0.55	9.20	3.40	3.32
37	Chama	Meral	Lagan Oraon	09 km from Garhwa on Chiniya road (LHS)	24^0 06'47" 83^0 44'32"	Dug well	R & B + DP	0.57	4.28	3.05	0.83
38	Beljampa	Garhwa	Ashok Chandra-vanshi	08 km from Garhwa on Bishrampur road. RHS at tri-junction of Garhwa – Bishrampur – Danda road	24^0 12'40" 83^0 52'20"	Dug well	R & B + DP	0.48	9.22	3.05	4.22
39	Danda	Danda	Budhram Choudhary	RHS of Thana road after tri-junction	24^0 09'02" 83^0 57'12"	Dug well	R & B + DP	0.48	9.02	3.05	4.19
40	Obra	Garhwa	HNS well	Garhwa to Ranka road, LHS in open field before 12 km from Ranka	24^0 07'19" 83^0 49'27"	Dug well	R & B + DP	0.30	8.25	3.05	2.90
41	Garhwa	Garhwa	Govt.	In the campus of SDPO's residence. By the side of vetnary hospital	24^0 08'30" 83^0 48'30"	Dug well	R & B	0.55	11.5	1.22	6.35

R & B = Rope & Bucket

DP = Diesel pump

EP = Electric pump

Annexure - III

DETAILS OF WELLS CONSTRUCTED IN HARD FORMATION OF GARHWA DISTRICT, JHARKHAND

Sl. No.	Location with coordinates	Block	District	Depth drilled (m)	Depth of Well (m)	Thickness of weathering (m)	Length of casing lowered with dia. (m)	Fractures Encountered (mbgl)		Aquifer	SWL (mbgl)	Dis-charge (lps)	D.D. (m)	T (m^2/d)	S (Storativity)
								From	To						
1	Ramkanda EW 23^0 52′ 18″ 83^0 52′ 56″	Ramkanda	Garhwa	201.00	201.00	17.50	17.80 (6.89″ dia.)	--	--	--	--	Dry	--	--	--
2	Saraidh EW 23^0 47′ 08″ 83^0 46′ 34″	Bhandaria	Garhwa	201.00	201.00	17.50	17.80 (6.89″ dia.)	--	--	--	--	Dry	--	--	--
3	Bhandaria EW 23^0 44′ 10″ 83^0 49′ 05″	Bhandaria	Garhwa	201.00	201.00	24.50	24.90 (6.89″ dia.)	139.00 160.00	141.00 161.00	Fractured Granite gneiss	10.77	3.15	24.84	75.43	--
4	Bhandaria OW	Bhandaria	Garhwa	147.00	147.00	21.00	21.55 (6.89″ dia.)	22.00	24.00	Fractured Granite gneiss	10.22	3.15	3.12	42.05	4.20×10^{-5}
5	Bargarh EW 23^0 37′ 52″ 83^0 47′ 03″	Bhandaria	Garhwa	201.00	201.00	26.00	26.30 (6.89″ dia.)	31.00 39.00	31.50 40.00	Fractured Granite gneiss	--	0.78	--	--	--
6	Chutru EW 23^0 52′ 29″ 83^0 38′ 44″	Ranka	Garhwa	201.00	201.00	23.50	23.90 (6.89″ dia.)	--	--	--	--	Dry	--	--	--
7	Ranpura EW 23^0 56′ 40″ 83^0 36′ 23″	Chinia	Garhwa	201.00	201.00	22.50	22.90 (6.89″ dia.)	--	--	--	--	Dry	--	--	--
8	Chinia - EW 24^0 02′ 21″ 83^0 37′ 45″	Chinia	Garhwa	201.00	201.00	11.50	11.70 (6.89″ dia.)	16.00 20.00	16.50 20.50	Fractured Granite gneiss	--	0.78	--	--	--
9	Tamega Kalan	Ranka	Garhwa	127.00	127.00	11.50	11.70	30.00	32.00	Fractured	4.16	6.70	7.71	59.68	--

Sl. No.	Location with coordinates	Block	District	Depth drilled (m)	Depth of Well (m)	Thickness of weathering (m)	Length of casing lowered with dia. (m)	Fractures Encountered (mbgl)		Aquifer	SWL (mbgl)	Dis-charge (lps)	D.D. (m)	T (m^2/d)	S (Storativity)
								From	To						
	EW 23^0 55′ 10″ 83^0 48′ 34″						(6.89″ dia.)	92.00	93.00	Granite gneiss					
10	Peska - EW 24^0 06′ 17″ 83^0 43′ 49″	Meral	Garhwa	201.00	201.00	13.00	13.20 (6.89″ dia.)	91.20	93.50	Fractured Granite gneiss	5.72	3.15	40.05	39.12	--
11	Peska OW	Meral	Garhwa	201.00	201.00	16.50	16.90 (6.89″ dia.)	72.00	73.50	Fractured Granite gneiss	5.50	1.50	6.09	7.79	4.87×10^{-5}
12	Dumaria EW 24^0 09′ 13″ 83^0 53′ 32″	Garhwa	Garhwa	96.00	96.00	20.50	20.85 (6.89″ dia.)	63.00	65.50	Fractured Granite gneiss	17.10	10.76	6.92	56.30	--
13	Haliwanta EW 24^0 16′ 16″ 84^0 26′ 25″	Nagar Utari	Garhwa	201.00	201.00	16.00	16.30 (6.89″ dia.)	--	--	Note ; shale formation	--	Dry	--	--	--
14	Bhiyar Khurd EW 24^0 15′ 27″ 84^0 34′ 01″	Ramna	Garhwa	201.00	201.00	12.00	12.30 (6.89″ dia.)	14.00 18.00	14.50 18.50	Fractured Granite gneiss	--	0.78	--	--	--
15	Bishunpura EW 24^0 17′ 51″ 83^0 40′ 35″	Bishunpura	Garhwa	201.00	201.00	23.50	23.90 (6.89″ dia.)	--	--	--	--	Dry	--	--	--
16	Sagma EW 24^0 13′ 45″ 83^0 27′ 24″	Sagma	Garhwa	201.00	201.00	5.00	5.60 (6.89″ dia.)	9.90	10.50	Fractured Granite gneiss	--	0.20	--	--	--
17	Nagar Utari EW 24^0 16′ 51″ 83^0 30′ 14″	Nagar Utari	Garhwa	201.00	201.00	17.50	17.80 (6.89″ dia.)	--	--	--	--	-Dry	--	--	--
18	Dandai - EW 24^0 07′ 09″ 83^0 47′ 00″	Dandai	Garhwa	201.00	201.00	17.00	17.30 (6.89″ dia.)	53.40	55.00	Fractured Granite gneiss	5.30	4.42	30.86	5.76	--
19	Bhawnathpur	Bhawnathpur	Garhwa	201.00	201.00	8.00	8.35	133.00	133.50	Fractured	4.91	1.18	11.02	4.89	--

Sl. No.	Location with coordinates	Block	District	Depth drilled (m)	Depth of Well (m)	Thickness of weathering (m)	Length of casing lowered with dia. (m)	Fractures Encountered (mbgl)		Aquifer	SWL (mbgl)	Dis-charge (lps)	D.D. (m)	T (m^2/d)	S (Storativity)
								From	To						
	EW 24^0 22′ 57″ 83^0 34′ 11″						(6.89″ dia.)	150.00	150.50	Granite gneiss					
20	Dudhvania EW 24^0 12′ 34″ 83^0 35′ 38″	Ramna	Garhwa	148.00	148.00	5.00	5.60 (6.89″ dia.)	11.00 60.00 143.00	11.50 60.50 143.50	Jointed Granite Gneiss	4.49	3.15	25.85	8.93	--
21	Kadwa EW 24^0 09′ 24″ 83^0 22′ 59″	Dhurki	Garhwa	201.00	201.00	15.00	15.35 (6.89″ dia.)	25.20	25.70	Fractured Granite gneiss	--	0.14	--	--	--
22	Baskatiya EW 24^0 29′ 30″ 83^0 29′ 34″	Ketar	Garhwa	201.00	201.00	24.00	24.30 (6.89″ dia.)	31.00	32.00	Fractured Granite gneiss	9.30	1.44	29.50	1.15	--
23	Hariharpur EW 24^0 27′ 37″ 83^0 41′ 36″	Bhawnathpur	Garhwa	95.00	95.00	34.00	34.60 (6.89″ dia.)	40.00	41.50	Fractured Granite gneiss	6.04	4.80	20.70	45.52	--
24	Chataniya EW 24^0 25′ 32″ 83^0 44′ 25″	Kandi	Garhwa	201.00	201.00	10.00	10.20 (6.89″ dia.)	11.90	12.50	Fractured Granite gneiss	--	0.78	--	--	--
25	Manjhiaon EW 24^0 29′ 30″ 83^0 29′ 30″	Manjhiaon	Garhwa	201.00	201.00	11.00	11.60 (6.89″ dia.)	163.00	164.00	Fractured Granite gneiss	--	0.78	--	--	--
26	Parro - EW 23^0 44′ 18″ 83^0 57′ 51″	Bhandaria	Garhwa	201.00	201.00	9.50	9.90 (6.89″ dia.)	--	--	--	--	-Dry	--	--	--
27	Ramar EW 23^0 41′ 33″ 83^0 48′ 26″	Bhandaria	Garhwa	201.00	201.00	13.00	13.25 (6.89″ dia.)	--	--	--	--	-Dry	--	--	--
28	Bairiya EW	Ramkanda	Garhwa	201.00	201.00	19.00	19.40 (6.89″ dia.)	--	--	--	--	-Dry	--	--	--

Sl. No.	Location with coordinates	Block	District	Depth drilled (m)	Depth of Well (m)	Thickness of weathering (m)	Length of casing lowered with dia. (m)	Fractures Encountered (mbgl)		Aquifer	SWL (mbgl)	Dis-charge (lps)	D.D. (m)	T (m^2/d)	S (Storativity)
								From	To						
	23^0 48′ 20″ 83^0 47′ 58″														
29	Dhurki EW 24^0 08′ 15″ 83^0 17′ 15″	Dhurki	Garhwa	206	206	8.50	9.00 (7″ dia.)	154.00	155.00	Fractured Granite gneiss	4.15	0.75	--	--	--
30	Sonpurwa EW 24^0 10′ 00″ 83^0 44′ 20″	Garhwa	Garhwa	198.00	198	27.00	27.50 (7″ dia.)	87.60	88.60	Fractured Granite gneiss	3.75	0.50	--	--	--
31	Garhwa EW 24^0 10′ 00″ 83^0 44′ 20″	Garhwa	Garhwa	151.76	151.76			93.00 106.00 114.00 133.00 137.00	94.00 107.90 115.00 134.00 138.00	Fractured Granite gneiss	10.60	2.30	30	7.3	--
32	Ranka EW 24^0 54′ 00″ 83^0 47′ 00″	Ranka	Garhwa	198.48	198.48			20.00 44.50 76.60 96.80 102.00	21.00 45.00 77.60 98.40 103.00	Fractured Granite gneiss		0.42	--	--	--
33	Ramna EW 24^0 13′ 40″ 83^0 37′ 00″	Ramna	Garhwa	114.07	114.07			9.00 21.99 38.85 54.09 64.50 110.70	15.90 23.61 46.40 60.00 68.00 114.50	Fractured Granite gneiss	5.04	5.56	--	--	--

Annexure - IV

WATER QUALITY DATA OF AQUIFER - I (DUG WELL SAMPLES) OF AQUIFER MAPPING STUDY OF GARHWA DISTRICT (2020 - 21)

Sr. No.	Village	Block	Latitude & Longitude	pH	EC (µS/cm)	TDS	TH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3
1	Ranka	Ranka	23^0 54' 30" 83^0 47' 30"	8.1	938	609.7	325	92	23.08	55.64	9.3	329.4	56.8	78.16	20.15
2	Phugmari	Ramkanda	23^0 53' 02" 83^0 53' 21"	8.16	640	416	200	52	17.01	43.21	14.6	201.3	56.8	30.64	36.41
3	Rodo	Bhandaria	23^0 48' 29" 83^0 51' 01"	8.12	611	397	185	46	17.01	45.23	11.3	250.1	28.4	25.95	33.41
4	Bhandaria	Bhandaria	23^0 44' 07" 83^0 49' 42"	8.00	895	582	320	42	52.25	44.16	16.9	262.3	81.65	65.16	35.81
5	Gothani	Bargarh	23^0 38' 11" 83^0 47' 35"	8.11	593	385	150	50	6.07	54.12	18.7	146.4	63.9	35.26	36.63
6	Barigawan	Bargarh	23^0 41' 00" 83^0 48' 03"	8.28	144	93.6	35	8	3.65	11.51	2.64	12.2	14.2	10.8	24.15
7	Godarmana	Ranka	23^0 48' 33" 83^0 42' 42"	8.1	896	582	355	52	54.68	30.32	8.63	262	74.55	65.12	40.23
8	Bishrapur	Ranka	23^0 53' 49" 83^0 42' 11"	8.15	534	347	185	22	31.59	26.82	11.5	262.3	21.3	10.39	7.26
9	Kaprat	Dandai	24^0 04' 27" 83^0 39' 47"	8.1	670	436	255	42	36.45	30.14	7.97	170.8	92.3	32.71	34.41
10	Chiniya	Chiniya	24^0 02' 33" 83^0 57' 48"	8.03	1336	868	475	70	72.9	75.47	13.3	359.9	166.8	76.92	45.93
11	Ranpura	Chiniya	23^0 57' 00" 83^0 36' 27"	8.06	1332	866	495	46	92.34	53.5	18.6	451.4	117.1	71.19	45.6
12	Dandai	Dandai	24^0 07' 34" 83^0 37' 03"	7.96	1463	951	390	32	75.33	133.6	36.5	463.6	146	77.63	55.12
13	Pangotwa	Dhurki	24^0 07' 37" 83^0 32' 27"	8.22	570	371	200	56	14.58	32.43	7.29	158.6	46.15	40.02	36.6

Sr. No.	Village	Block	Latitude & Longitude	pH	EC (µS/cm)	TDS	TH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3
14	Dhurki	Dhurki	24^0 08' 31" 83^0 27' 03"	8.18	616	400	190	64	7.29	35.54	14.9	256.2	39.05	12.43	22
15	Sarda	Sagma	24^0 10' 27" 83^0 27' 28"	8.18	544	354	175	60	6.07	36.49	10.7	176.9	31.95	35.96	36.66
16	Sagma	Sagma	24^0 13' 16" 83^0 27' 31"	7.99	1111	722	285	16	59.53	110.5	16.6	396.5	85.2	51.84	36.64
17	Manjhgawan	Kharaondhi	24^0 23' 22" 83^0 28' 18"	7.93	598	389	150	20	24.3	60.12	3.69	213.5	28.4	35.18	30.76
18	Bajarmarwa	Kharaondhi	24^0 25' 35" 83^0 25' 07"	8.03	491	319	170	20	29.16	31.02	5.7	213.5	14.2	9.62	34.41
19	Dasipur	Ketar	24^0 27' 23" 83^0 31' 30"	8.1	437	284	145	30	17.01	28.61	5.3	189.1	17.75	12.04	15.36
20	Panchadumar	Ketar	24^0 30' 06" 83^0 33' 11"	8.15	606	394	185	68	3.65	40.36	15.6	170.8	63.9	34.68	36.5
21	Jhagra Khurd	Bhawnathpur	24^0 23' 04" 83^0 31' 07"	8.04	909	591	295	30	53.46	57.65	19.2	341.6	93.9	31.71	36.81
22	Kakri (Kandia Tola)	Bhawnathpur	24^0 21' 25" 83^0 33' 35"	7.96	801	521	160	30	20.65	96.43	15.4	384.3	21.3	21.39	32.66
23	Ganki (Bilaspur)	Nagar Utari	24^0 15' 41" 83^0 24' 58"	7.98	438	285	165	32	20.65	15.67	6.8	201.3	10.65	5.71	33.6
24	Nagar Utari	Nagar Utari	24^0 17' 00" 83^0 30' 30"	7.87	1161	755	360	32	68.04	77.81	15.3	280.6	191.7	48.49	25.94
25	Morbe	Manjhian	24^0 23' 53" 83^0 49' 40"	7.95	643	418	190	68	4.86	41.43	27.7	274.5	28.4	13.86	27.13
26	Semaura	Kandi	24^0 28' 47" 83^0 48' 03"	7.51	1635	1063	345	60	47.39	186.7	45.1	506.3	170.4	89.6	56.97
27	Wolma	Kandi	24^0 27' 45" 83^0 45' 35"	7.73	874	568	215	38	29.16	91.23	5.33	292.8	85.2	18.22	35.7
28	Bardiha	Bardiha	24^0 22' 22" 83^0 43' 47"	7.95	487	317	150	50	6.07	26.54	17.5	195.2	14.2	12.16	31.66

Sr. No.	Village	Block	Latitude & Longitude	pH	EC (µS/cm)	TDS	TH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3
29	Kardiha	Bardiha	24^0 21’ 25” 83^0 43’ 18”	7.71	654	425	205	28	32.80	52.57	2.95	237.9	35.5	29.07	36.48
30	Sandhya	Bishunpura	24^0 18’ 15” 83^0 40’ 15”	7.71	607	395	175	48	13.36	50.12	7.04	280.6	21.3	15.9	28.64
31	Darjia	Bishunpura	24^0 15’ 36” 83^0 37’ 52”	7.55	420	273	145	44	8.51	19.48	14	195.2	10.65	12.06	13.25
32	Meral	Meral	24^0 10’ 56” 83^0 42’ 11”	7.1	1078	701	215	30	34.02	133.8	17	317.2	127.8	44.75	34.53
33	Ramna	Ramna	24^0 14’ 19” 83^0 36’ 36”	7.44	1809	1176	300	52	41.31	263.3	23.3	384.3	330.1	80.23	36.65
34	Bahiyar Khurd	Ramna	24^0 15’ 31” 83^0 33’ 34”	8.14	812	528	210	40	26.73	85.43	6.63	274.5	74.55	33.52	36.73
35	Lagama	Meral	24^0 10’ 19” 83^0 44’ 09”	8.07	745	484	225	42	29.16	54.12	10.3	183	92.3	52.98	36.15
36	Chama	Meral	24^0 06’ 47” 83^0 44’ 32”	8.15	614	399	210	40	26.73	35.29	7.25	262.3	17.75	20.64	27.85
37	Beljampa	Garhwa	24^0 12’ 40” 83^0 52’ 20”	8.19	987	642	290	36	48.6	73.42	20.3	317.2	92.3	57.18	36
38	Danda	Danda	24^0 09’ 02” 83^0 57’ 12”	8.01	1267	824	215	12	44.95	156.2	36.8	408.7	138.5	52.32	35.94
39	Obra	Garhwa	24^0 07’ 19” 83^0 49’ 27”	7.75	888	577	275	60	30.38	54.55	30.4	237.9	95.85	52.81	36.07

Annexure - V

WATER QUALITY DATA OF AQUIFER - II (HAND PUMP SAMPLES) OF AQUIFER MAPPING STUDY AREA OF GARHWA DISTRICT (2020 -21)

Sr. No.	Village	Block	Latitude & Longitude	pH	EC (µS/cm)	TDS	TH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	F
1	Ranka	Ranka	23^0 54' 30" 83^0 47' 30"	7.9	684	445	260	24	48.6	19.49	26.2	250.1	31.95	48.65	31.79	0.86
2	Phugmari	Ramkanda	23^0 53' 02" 83^0 53' 21"	7.88	679	441	190	38	23.08	58.65	6.93	225.7	31.95	51.69	35.05	0.68
3	Rodo	Bhandaria	23^0 48' 29" 83^0 51' 01"	7.54	1022	664	150	20	24.3	145.3	28.7	481.9	28.4	33.39	25.25	0.97
4	Bhandaria	Bhandaria	23^0 44' 07" 83^0 49' 42"	7.4	279	181	95	34	2.43	14.56	6.43	91.5	24.85	13.28	5.23	0.83
5	Gothani	Bargarh	23^0 38' 11" 83^0 47' 35"	7.47	412	268	165	40	15.80	11.67	6.75	128.1	31.95	16.52	31.33	0.62
6	Barigawan	Bargarh	23^0 41' 00" 83^0 48' 03"	7.7	219	142	65	22	2.43	13.5	3.5	67.1	14.2	5.51	25.3	0.62
7	Godarmana	Ranka	23^0 48' 33" 83^0 42' 42"	7.63	603	392	155	38	14.58	55.12	19.8	225.7	42.6	17.37	30.57	0.97
8	Bishrapur	Ranka	23^0 53' 49" 83^0 42' 11"	7.89	505	328	175	30	24.3	23.43	10.5	256.2	21.3	4.01	4.68	0.53
9	Kaprat	Dandai	24^0 04' 27" 83^0 39' 47"	7.99	608	395	180	38	20.66	43.34	16.7	231.8	42.6	28.71	9.79	1.05
10	Chiniya	Chiniya	24^0 02' 33" 83^0 57' 48"	7.87	1500	975	570	96	80.19	68.36	19.4	390.4	231	52.45	33.1	1.10
11	Ranpura	Chiniya	23^0 57' 00" 83^0 36' 27"	8.01	766	498	295	64	32.81	22.84	17.6	201.3	99.4	46.13	32.04	0.85
12	Dandai	Dandai	24^0 07' 34" 83^0 37' 03"	8.1	456	296	130	40	7.29	32.32	11.9	207.4	21.3	6.18	1.64	0.93
13	Pangotwa	Dhurki	24^0 07' 37" 83^0 32' 27"	8.26	343	223	115	40	3.65	21.31	2.64	140.3	17.75	16.71	12.26	1.04
14	Dhurki	Dhurki	24^0 08' 31"	8.27	786	511	205	34	29.16	75.4	11.9	311.1	49.7	42.05	0.83	0.96

Sr. No.	Village	Block	Latitude & Longitude	pH	EC (µS/cm)	TDS	TH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	F
			83^0 27’ 03”													
15	Sarda	Sagma	24^0 10’ 27” 83^0 27’ 28”	8.45	300	195	90	32	2.43	23.44	1.98	91.5	21.3	20.44	23.78	0.95
16	Sagma	Sagma	24^0 13’ 16” 83^0 27’ 31”	8.14	1084	705	390	62	57.11	55.32	21.1	335.5	124.3	48.18	32.27	0.60
17	Manjhgawan	Kharaondhi	24^0 23’ 22” 83^0 28’ 18”	8.17	820	533	245	30	41.31	60.12	14.4	237.9	81.65	50.29	40.01	0.86
18	Bajarmarwa	Kharaondhi	24^0 25’ 35” 83^0 25’ 07”	8.26	423	275	170	30	23.09	17.13	2.42	170.8	24.85	7.96	24.64	0.54
19	Dasipur	Ketar	24^0 27’ 23” 83^0 31’ 30”	8.16	556	361	155	40	13.37	44.98	8.76	207.4	46.15	11.52	31.05	0.47
20	Panchadumar	Ketar	24^0 30’ 06” 83^0 33’ 11”	8.24	341	222	120	44	2.43	18.54	4.44	128.1	21.3	11.02	13.47	0.83
21	Jhagra Khurd	Bhawnathpur	24^0 23’ 04” 83^0 31’ 07”	8.13	645	419	210	28	34.02	42.2	7.26	250.1	46.15	20.83	31.71	0.85
22	Kakri (Kandia Tola)	Bhawnathpur	24^0 21’ 25” 83^0 33’ 35”	8.01	1390	903	480	56	82.62	87.32	9.54	372.1	191.7	62.39	32.44	0.88
23	Ganki (Bilaspur)	Nagar Utari	24^0 15’ 41” 83^0 24’ 58”	8.21	409	266	155	22	24.3	12.94	10.1	176.9	14.2	3.67	24.68	0.80
24	Nagar Utari	Nagar Utari	24^0 17’ 00” 83^0 30’ 30”	8.14	560	364	160	22	25.52	41.02	8.64	219.6	39.05	19.43	15.07	0.64
25	Manjhian	Manjhian	24^0 19’ 22” 83^0 49’ 22”	8.12	654	425	175	46	14.58	65.65	6.05	231.8	49.7	36.77	17.06	0.90
26	Morbe	Manjhian	24^0 23’ 53” 83^0 49’ 40”	8.21	775	404	185	36	23.09	71.32	19.6	323.3	28.4	36.78	32.07	0.91
27	Semaura	Kandi	24^0 28’ 47” 83^0 48’ 03”	8.28	542	352	180	30	25.52	32.43	14.7	170.8	49.7	22.67	29.97	0.69
28	Wolma	Kandi	24^0 27’ 45” 83^0 45’ 35”	8.12	739	480	180	36	21.87	77.3	9.36	213.5	88.75	22.31	31.31	0.95
29	Bardiha	Bardiha	24^0 22’ 22” 83^0 43’ 47”	8.22	493	320	135	22	19.44	37.54	6.15	170.8	21.3	21.62	25.46	1.26

Sr. No.	Village	Block	Latitude & Longitude	pH	EC (µS/cm)	TDS	TH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	F
30	Kardiha	Bardiha	24^0 21' 25" 83^0 43' 18"	8.22	381	248	125	38	7.29	18.43	6.68	152.5	17.75	12.61	4.21	1.23
31	Sandhya	Bishunpura	24^0 18' 15" 83^0 40' 15"	8.20	511	332	160	34	18.23	41.32	3.49	225.7	17.75	16.32	23.36	0.97
32	Darjia	Bishunpura	24^0 15' 36" 83^0 37' 52"	8.19	643	418	230	16	46.17	32.21	11.1	213.5	74.55	23.59	0.62	1.21
33	Meral	Meral	24^0 10' 56" 83^0 42' 11"	8.22	910	592	205	14	41.31	93.43	20.4	311.1	85.2	37.56	26.92	1.34
34	Ramna	Ramna	24^0 14' 19" 83^0 36' 36"	8.26	730	475	260	28	46.17	32.56	17.5	225.7	74.55	27.97	30.92	0.91
35	Bahiyar Khurd	Ramna	24^0 15' 31" 83^0 33' 34"	8.24	798	519	205	32	30.38	75.54	16.6	280.6	71	20.08	32.29	0.97
36	Lagama	Meral	24^0 10' 19" 83^0 44' 09"	8.2	957	622	285	100	8.51	71.12	11.6	213.5	149.1	49.58	33.05	0.87
37	Chama	Meral	24^0 06' 47" 83^0 44' 32"	8.16	839	545	275	22	53.46	55.78	12.9	274.5	74.55	44.09	32.82	0.98
38	Beljampa	Garhwa	24^0 12' 40" 83^0 52' 20"	8.1	838	545	245	34	38.88	68.11	7.97	286.7	74.55	42.46	32.35	1.04
39	Danda	Danda	24^0 09' 02" 83^0 57' 12"	8.17	570	371	175	56	8.51	43.32	3.88	225.7	46.15	21.18	9.48	0.90
40	Obra	Garhwa	24^0 07' 19" 83^0 49' 27"	8.18	620	403	190	52	14.58	40.45	14.1	213.5	39.05	31.57	32.64	0.98
41	Garhwa	Garhwa	24^0 08' 30" 83^0 48' 30"	7.97	1209	786	415	54	68.04	79.65	3.5	414.8	124.3	58.47	3.28	0.65

Annexure-V

Fluoride in Ground Water in Northern Garhwa District, Jharkhand

Sl_No	Latitude	Longitude	Elv	Source	District	Block	GP	Village	F^- in mg/l
1	24.36281	83.80035	155	TW	Garhwa	Majhiaon	Kharsota	Burhikhand	2.604
2	24.30401	83.58265	241	TW	Garhwa	Bishunpura	Patihari	Deogurwa	3.066
3	24.30554	83.59499	227	TW	Garhwa	Bishunpura	Piparia Kala	Saro	2.562
4	24.31149	83.60261	244	TW	Garhwa	Bishunpura	Piparia Kala	Saro	2.436
5	24.43771	83.80662	158	HP	Garhwa	Kandi	Shivpur	Adhawra	2.016
6	24.39796	83.74984	210	TW	Garhwa	Kandi	Chatania	Ghordag	2.415
7	24.39997	83.72117	220	BW	Garhwa	Kandi	Chatania	Ghordag	2.205
8	24.41768	83.73748	190	HP	Garhwa	Kandi	Chatania	Subuadamar	2.17
9	24.45359	83.83186	145	HP	Garhwa	Kandi	Kharamdha	Mukhapi	2.28
10	24.35365	83.71817	189	TW	Garhwa	Bardiha	Sukhnadi	Khardiha	2.562
11	24.37099	83.71709	204	TW	Garhwa	Bardiha	Bardiha	Jikabukcham	2.93
12	24.36563	83.71044	211	TW	Garhwa	Bardiha	Bardiha	Salaya Damar	2.688
13	24.3886	83.73848	215	TW	Garhwa	Bardiha	Salga	Salga	2.786
14	24.38608	83.72459	210	TW	Garhwa	Bardiha	Bardiha	Sikiahi	2.62
15	24.37956	83.72795	211	TW	Garhwa	Bardiha	Bardiha	Pachhiyara tola	2.34
16	24.38444	83.65317	240	TW	Garhwa	Bhawanathpur	Kailan	Amuadih	2.226
17	24.39232	83.6368	244	TW	Garhwa	Bhawanathpur	Kailan	Beherwakhadi	1.89
18	24.49772	83.7404	145	TW	Garhwa	Kandi	Dumarsota	Daaridah	1.96
19	24.34412	83.76361	171	TW	Garhwa	Bardiha	Obra	Sarsatia	2.058
20	24.26032	83.81419	180	TW	Garhwa	Meral	Checheriya	Chhaparwar khurd	2.31
21	24.25678	83.7869	191	TW	Garhwa	Meral	Chehariya	Kholra	2.39
22	24.2395	83.77586	206	HP	Garhwa	Meral	Biktam	Chandwa	2.24
23	24.212	83.72338	264	TW	Garhwa	Meral	Rampur	Jaharsarai	3.318
24	24.22969	83.69425	228	TW	Garhwa	Meral	Sangwaria	Sangwaria	1.68
25	24.27715	83.67343	196	TW	Garhwa	Meral	Paduhan	Patariya	2.485

Sl_No	Latitude	Longitude	Elv	Source	District	Block	GP	Village	F^- in mg/l
26	24.33273	83.71351	186	TW	Garhwa	Bardiha	Adar	Lawachampa	2.058
27	24.22611	83.77197	214	TW	Garhwa	Meral	Biktam	Siho	2.352
28	24.36905	83.79399	161	OW	Garhwa	Majhiaon	Majhiaon	Kharsota	2.94
29	24.19323	83.6696	260	TW	Garhwa	Meral	Gonda	Latdag	1.98
30	24.17435	83.66713	243	TW	Garhwa	Meral	Bana	Bana	1.77
31	24.44257	83.42592	203	TW	Garhwa	Kharaundhi	Sundi	Parswan tola	2.086
32	24.40868	83.62707	196	TW	Garhwa	Bhawanathpur	Pandaria	Ghagra Kormahi	3.11
33	24.40802	83.63668	197	OW	Garhwa	Bhawanathpur	Pandaria	Ghagra	1.56
34	24.42844	83.65453	172	TW	Garhwa	Bhawanathpur	Kailan	Phulwar	2.79
35	24.39761	83.62355	212	TW	Garhwa	Bhawanathpur	Sinduriya	Shiv Nagar	2.04
36	24.23723	83.70852	206	TW	Garhwa	Meral	Sangwaria	Serasam	2.88
37	24.24625	83.69757	229	TW	Garhwa	Meral	Sangwaria	Banua	1.88
38	24.24203	83.68031	224	TW	Garhwa	Meral	Loadag	Loadag	2.1
39	24.25851	83.70073	226	HP	Garhwa	Meral	Sangwaria	Bhimkhad	1.69
40	24.32614	83.69928	181	TW	Garhwa	Bardiha	Adar	Adar	2.7
41	24.35302	83.69244	213	TW	Garhwa	Bardiha	Sukhnadi	Amiliya tola	1.7
42	24.34158	83.67772	210	HP	Garhwa	Bardiha	Adar	Lewa tola	3.02
43	24.33665	83.66433	217	TW	Garhwa	Bardiha	Jatro Banjari	Semri	1.85
44	24.26623	83.69941	206	HP	Garhwa	Meral	Loadag	Khundhara	2.12
45	24.21023	83.76382	230	TW	Garhwa	Meral	Biktam	Bajaria	3.06
46	24.19051	83.78907	224	TW	Garhwa	Meral	Arangi	Pindra	2.107
47	24.18022	83.73023	226	TW	Garhwa	Meral	Arangi	Akalwani	1.78
48	24.16081	83.71608	217	TW	Garhwa	Meral	Meral East	Mural tola	2.58
49	24.45542	83.75914	171	TW	Garhwa	Kandi	Ghathuwakala	Ratangara	2.22
50	24.10993	83.77898	216	HP	Garhwa	Meral	Chama	Kormahi	1.51