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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

Gajapati District, Odisha

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

South Eastern Region, Bhubaneswar

Government of India

MINISTRY OF JAL SHAKTI, DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

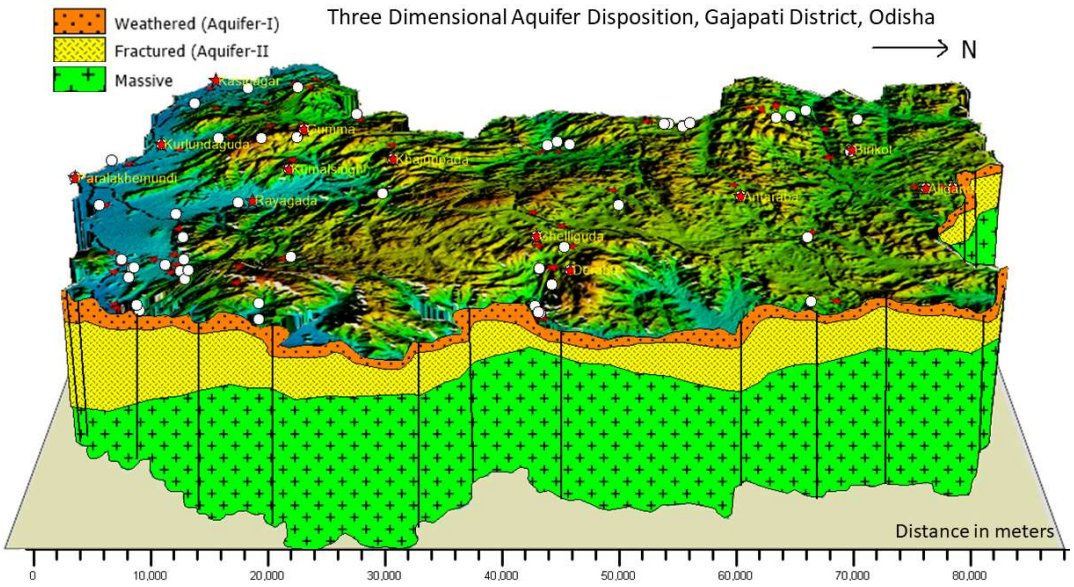
REPORT ON

AQUIFER MAPPING AND MANAGEMENT PLAN IN GAJAPATI DISTRICT, ODISHA

By

Chirashree Mohanty

Scientist-C



CENTRAL GROUNDWATER BOARD

South Eastern Region, Bhubaneswar

August-2021

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South Eastern Region, Bhubaneswar
September-2021

FOREWORD

Gajapati District has been named after Maharaja Sri Krushna Chandra Gajapati Narayan Deo. It got a District status on 2nd October 1992 after being bifurcated from Ganjam District. The mountain-clad district is endowed with vast natural resources but is one of the agriculturally undeveloped districts of Odisha. The district is underlain by consolidated hard rock formation of the Eastern-ghat group of rocks. Managing the existing groundwater resource is the prime challenge especially in the high elevated areas before the authority. The agrarian development of the district can be boosted by tapping these enormous groundwater resources through dugwells, medium-deep bore wells.

The present stage of groundwater development is only 33.52%, leaving a vast scope for future groundwater development in the district. Judicious utilization of groundwater can ensure increased agricultural production, drinking water scarcity, and enhancement of the industrial sector.

The study area includes seven blocks of Gajapati district viz. Paralakhemundi, Rayagada, Kashinagar, Gumma, R.Udayagiri, Mohana and Nuagada covering an area of 4325 sq. km. An attempt has been made in this report to compile all relevant information collected through field investigation and earlier hydrogeological studies taken up in the district. **Smt. Chirashree Mohanty, Scientist- 'C'**, has compiled and prepared the present report on **"Aquifer Mapping and Management Plan of Gajapati District, Odisha."** Her sincere efforts in the execution of this report will no doubt be very useful and beneficial for the district. It is hoped that it will be of immense help to different groundwater user agencies, administrators, and planners in preparation for groundwater development plans and will be a handy tool in the effective management of groundwater resources in the district.

Place: Bhubaneswar
Date: September-2021

Regional Director

GAJAPATI DISTRICT AT A GLANCE

I.	**GENERAL PARTICULARS**		
	(a) Location	:	$18^0$46' to 19^0 39' North Latitude $83^0$48' to 84^0 27' East longitude
	(b) Area	:	4325 Sq. Km
	(c) District Headquarters	:	Paralakhemundi
	(d) Subdivision	:	Paralakhemundi
	(e) Tehsils	:	7
	(f) Blocks	:	7
			Paralakhemundi, Rayagada, Kashinagar, Gumma, R.Udayagiri, Mohana and Nuagada.
	(g) No of Gram Panchayats (i) No of villages	:	149 1616
	(j) Population (as per 2001 census)	:	577817 Male: 2,82,882 Female: 2,94,935 Rural: 5,07,151 Urban: 70,666
	(k) Workforce	:	Cultivators : 65,062 Agricultural labourers: 1,53,199 Total workers : 2,93,933
	(l) Literacy	:	53.49% Male- 64.34%, Female-43.18%
II	**CLIMATOLOGY**	:	
	(a) Normal annual rainfall	:	1413 mm
	(b) Maximum temperature	:	46°C
	(c) Minimum temperature	:	11°C

III	**LAND USE**	:		
	(a) Total forest area	:	2,47,123 Ha	
	(b) Net area sown	:	75,037 Ha	
IV	**IRRIGATION POTENTIAL CREATED** (Source wise, up to 2010-11)		Kharif	Rabi
	(a) Major/ Medium Irrigation Projects	:	-	-
	(b) Minor Irrigation Projects (flow)	:	15,830 Ha	314 Ha
	(c) Minor Irrigation Projects (lift)	:	5,460 Ha	4,100 Ha
	(d) Groundwater Structures		2,051 Ha	1,361 Ha Summer: 837 ha
V	**EXPLORATORY WELLS**	:		
	Bore wells drilled by CGWB under Normal Exploration Programme	:	4 EW, 2 OW by CGWB 10 EW, 1 OW by WAPCOS	
VI	**MONITORING WELLS**	:	CGWB NHS wells: 37 Key wells established: 31	
VI	**GROUNDWATER RESOURCES (2020)**			
	a) Annual Extractable GW Resources	:	19861 Ham	
	b) Total Extraction	:	6657 Ham	
	c) Allocation for Domestic use	:	1771 Ham	
	d) Net GW availability for future use	:	13105 Ham	
	e) Stage of groundwater development	:	33.52%	

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EXECUTIVE SUMMARY

- Gajapati district has a total geographical area of about 4325 km^2 with 7 Community Development blocks, 7 Tehsils, and 149 Gram Panchayats with 1616 villages. The literacy rate of the district is 53.49. Gajapati is the 16^{th} district in terms of size and 28^{th} in terms of the population of the state. It is the 13^{th} urbanized district in the state having 12.23% of its population live in urban areas as against 16.69% of the state's population living in urban areas.

- Agriculture is the principal source of livelihood for people in the district. The net sown area is 75,037 Ha. Irrigation potential created in the district (2015-16) is 23,341 Ha during Kharif and 5,775 Ha during rabi season. Paddy is the principal crop grown in the district. About 88475 Ha (~57%) of the total geographical area constitutes forest area.

- The district enjoys a humid sub-tropical climatic condition which is hot and dry in summer, cold and dry in winter, and cold and humid during the rainy season. The maximum temperature may be 42^0C during the summer months (May & June) and the minimum temperature comes down to 15^0C during the winter period

- Physiographically, the district comprises rugged and hilly terrain with thick forest covers, intermontane valleys, and extensive tracts of buried pediments with narrow valley fills. The alluvial plains are restricted to the southern parts of the district and along the major river valleys. The important hills in the district are Dandamera Parbat (1103m), Tangiri Parbat (1155m), and Mahendra Giri (1499m). The important geomorphological interest is the abrupt rise of the hill masses from the adjoining coastal plains. The soils in the districts can broadly be grouped into Alfisols or Red Soils and Entisols or Alluvial soil.

- The river Vansadhara along with its tributaries such as Mahendratanaya, Harbhangi, Badanadi, etc form the major drainage system of the districts. The master slope of the ground is towards the South and NWN direction. The drainage pattern is mostly

dendritic but at places, it is rectangular where it is structurally controlled by joints, fractures, and other lineaments.

- The study area comprises a group of highly metamorphosed rocks of Eastern Ghat facies belonging to the Archean Complex of the Indian Peninsula. The development of laterite is rare and wherever it's seen it occurs as thin-film capping the crystalline rocks. Discontinuous patches of Alluvium are restricted to major river courses. It occurs as an elongated patch along the major and minor river channels. The crystalline complex representing Eastern Ghat Super Group consisting of Khondalite suite, Charnockite suite, Granite and Granite Gneisses, metabascis, and veins of quartz and pegmatite are exposed in the entire Gajapati district.

- Hydrogeologically the district can be divided into consolidated formations belonging to the Eastern Ghats, and unconsolidated alluvial formations occupying the southern parts of the district and along with the major river courses. The weathered residuum and the fracture systems at deeper levels in the hard rock areas, and the granular porous formations in alluvium form the main groundwater repositories in the district.

- The unconsolidated formations consist of laterite and alluvium. Unless highly consolidated, the laterites bear moderate to good groundwater potential. The alluvium, comprising an admixture of clay, silt, sand, and calcareous concretions often forms prolific aquifers.

- Depth to water level in the pre-monsoon period (May 2019) varies from 1.86 m bgl (Gosani) to 15.0 m bgl (Ramagiri), the average being 5.68 m bgl. Depth to water level in the post-monsoon period (Nov-2019 and 2020) varies from 0.21 m bgl (Mandimera, Mohana block) to 7.53 (Tarabada, Nuagada block) m bgl, the average being 2.60 m bgl.

- Fluctuation of groundwater table between pre and post-monsoon period in the study area varies from 0.35 m bgl (Tumbagarh, Rayagada) to 9.81 m bgl (Ramagiri, R. Udayagiri) the average being 3.19 m bgl. The general range of fluctuation in water level in the study area is between 2-4m bgl.

- The long-term trend analysis indicates that out of 26 stations, 10 stations (41.6%) show a rising trend and the rest 14 stations (58.3%) show a falling trend in the Pre-monsoon season and 7 stations (31.8%) show a rising trend and 15 stations (68.1%) show a falling trend in post-monsoon seasons. The area around Chandiput, Chandragiri, Kirama, Santinagar, Rayagada have shown a significant falling trend ranging from 20-90 cm/year. In all other stations, the extent of fall is not significant.

- The chemical analysis of 26 samples collected from shallow dugwells and 22 samples from Tube wells reveal that all chemical parameters lie within the permissible limit for drinking and irrigation purposes except few samples of some isolated pockets. Fluoride and Nitrate in excess of the permissible limit have been found in certain villages due to geogenic and anthropogenic causes.

- The entire district can be divided into two major aquifer systems. 1) Aquifer-I (Unconfined Aquifer) occurs in the entire area except for rocky outcrops, formed by the weathered mantle atop all crystalline and discontinuous alluvial tracts along major river channels. This aquifer generally occurs down to a maximum depth of 50 m bgl. 2) Aquifer-II (Semi-Confined to Confined Aquifer): occurs as fracture zone aquifers in the entire area irrespective of rock types. Thus the maximum depth for the Aquifer-II has been taken as 150 m bgl.

- The transmissivity (T) of the unconfined aquifer-I aquifers is recorded as 176 m^2/day in valley-fill deposits and the T value in fractured aquifer ranges from 0.41 to 13.31 m^2/day.

- The total annual dynamic groundwater resource or the annual extractable groundwater resources of the district is assessed to be 19861 Ham. The existing gross groundwater draft or extraction in the district stands at 6657 Ham, out of which the irrigation draft is 4876 Ham (~73% of the total draft). The draft for domestic and drinking constitute 25% of the gross draft which is 1671.43 Ham. The annual utilizable resource which remains for irrigation use (after allocation for domestic and drinking up to the year 2025) has been estimated at 13105 Ham. The stage of groundwater development varies between the minimum of 14.95 % in the Mohana block and the

maximum of 50.25 % in the Paralakhemundi block, with the average stage of groundwater development for the district as 33.52%.

- The static or in-storage groundwater resource of the 1st Aquifer System for the district has been estimated as 34075 Ham. The in-storage groundwater resource of the second aquifer is calculated as 45229 Ham

- It has been found that there is a demand and supply gap of 227.8 MCM for the whole district. Further additional groundwater development potential of 52.6 MCM can be created by developing the stage of groundwater development up to 60%.

- By construction of 7504 farm ponds, 15.99 mcm water can be harvested. A total number of 12,852 households in the districts with more than 150 sq.m of rooftop area can be taken up for the construction of rooftop rainwater harvesting structures. Around 2.192 mcm water can be generated and recharged or conserved for various uses there by increasing the net availability of groundwater for extraction from 198.61 mcm to 216.8 mcm. The total stage of groundwater development is reduced to 30.70% from 33.52%.

- Irrigation potential of an additional area of 52.6 mcm can be created to utilize the available surplus groundwater. The total number of additional Dugwells worked out to be feasible in the district to utilize 50% of the available surplus groundwater resource (considering development up to 60%) stands at 10,116. The total number of additional Borewells worked out to be feasible in the district to utilize 50% of the available surplus groundwater resource (considering development up to 60%) stands at 1190.

- In the water scarcity areas, where the bore wells either fail to yield or yield a meager volume of water, large-diameter dug wells (5-10m wide) tapping the entire weathered residuum can give ample water for the needs of irrigation and drinking.

- The groundwater source points (hand pumps, dug wells) which yield water with fluoride concentration > 1.5 mg/L should be stopped immediately from use. Any

alternate safe aquifer or pipe water supply for drinking and domestic use should be explored. In many cases, the dug wells yield less groundwater fluoride.

- The areas showing depth to water levels more than 3.0 m bgl can be adopted for artificial recharge to groundwater. The area suitable for artificial recharge has been assessed at 1046 km^2. The total volume of water required to fill the volume of voids has been worked out to be 83.88 mcm. The total number of recharge structures calculated as 168 percolation tanks, 84 sub-surface dykes, 84 contour bunds and 168 number of check dams.

1.0 INTRODUCTION

1.1 Objective

Central Groundwater Board (CGWB), Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti had been assigned to carry out National Aquifer Mapping and Management Programme (NAQUIM) country wide under XIIth five-year plan in 1: 50,000 scale. NAQUIM involves the integration of micro-level hydrogeological, geophysical, hydrochemical data and information on geology, geomorphology, soil, hydrometeorology, hydrology, land use, cropping pattern, etc on a GIS platform to formulate district, block, or aquifer-wise Groundwater Management Plan. The formulation of a sustainable groundwater management plan would help in achieving the demand for drinking, irrigation, and industrial need for water with minimal stress on the aquifer.

The unplanned Groundwater Development due to intensive agricultural practices and unorganized urban acclamation, erratic rainfall has led to stressed groundwater scenarios with long-term water table decline, desaturation of aquifers, and groundwater pollution. It is very essential to understand the complex geometry of the aquifer systems of the area to prepare implementable groundwater management plans taking care of the demand and supply-side management. The activities under NAQUIM are aimed at identifying the aquifer geometry, aquifer characteristics their yield potential along with the quality of water occurring at various depths, aquifer-wise assessment of groundwater resources, and development. Aquifer mapping itself is an improved form of groundwater management-recharge, conservation, harvesting, and protocols of managing groundwater. With these aims, Aquifer Mapping was carried out in the Gajapati district of Odisha covering all seven blocks of the district namely, Paralakhemundi, Rayagada, Kashinagar, Gumma, R.Udayagiri, Mohana, and Nuagada.

1.2 Scope of the Study

Aquifer mapping is a multidisciplinary exercise wherein a combination of geological, geophysical, hydrological, hydrogeological, meteorological, and hydro-chemical information is integrated to characterize the spatial and temporal variation of quantity and quality of the aquifer system and identification of local groundwater-related problems and issues.

To resolve such issues, the NAQUIM study was carried out with the following broad objectives: 1) to define the aquifer geometry with precise lateral and vertical demarcation down to the depth of 200 m bgl, 2) to define the behaviour of groundwater regime in time and space, 3) to study the hydraulic characteristics of both shallow and deeper aquifers, 4) to study the hydrochemistry of aquifer systems, 5) to prepare Aquifer Maps indicating the disposition of aquifers along with their characterization and 6) to formulate the Aquifer Management Plans for sustainable development and management of groundwater resources.

1.3 Approach and Methodology

A multi-disciplinary approach involving geological, geophysical, hydrological, hydrogeological, and hydro-geochemical surveys would be carried out to meet the aim and objectives listed above. A Geographical Information System (GIS) would be used to prepare the maps. The Geological Survey of India has geologically mapped the entire Gajapati district. Systematic Hydrogeological surveys have been conducted in different parts of the district by Sh. S.N Sar and Sh A. K Ghosh on 1: 50,000 scale during 1978-1984. Which was followed by a compilation of survey data and preparation of district reports by Sh. Rana Chatterjee, Scientist-B and Sh S.K Samanta, Scientist-B in the year 1996 and subsequently by Sh G.C Pati, Scientist-D in 2008.

1.3.1 Compilation of Existing Data and Identification of Data Gaps

The important aspects of the Aquifer Mapping Programme are the synthesis of a large volume of data already generated during specific studies by CGWB and other government organizations like R.W.S.S (Rural Water Supply and Sanitation), GSI (Geological Survey of India), ORSAC (Odisha Remote Sensing Application Center), PHD, Watershed Development Board and other water-related state govt. Department. The available data are assembled, analyzed, examined, synthesized, and interpreted usually available in a non-computerized form which will be converted to GIS-based databases to identify the data gaps in the study area. To bridge the data gap, the data generation program has been formulated in an organized way. Exploration work, Geophysical investigation work have been carried out in different segments of the district by WAPCOS. Aquifer parameters have been evaluated. Groundwater regime monitoring has been strengthened by the establishment of additional key wells.

1.3.2 Hydrogeological Investigations

Review of background information will lead the study teams to carry out further studies in the field, where they will employ various techniques to determine the three-dimensional extent and aquifer characteristics of the significant water-bearing formations. Key Observation wells representing the different aquifers have to be established and monitoring to be carried out. Well inventory and collection of relevant data are to be carried out to strengthen the database. The analysis of the data has to be carried out for the preparation of thematic maps.

1.3.3 Geo-hydrochemical Investigations

Water samples are to be collected, analyzed, and interpreted to bring out the groundwater quality scenario of the study area.

1.3.4 Generation of Thematic Layers Using GIS

- Drainage
- Soil
- Land use and land cover
- Geomorphology
- Geology
- Hydrogeological map
- Aquifer disposition
- Groundwater quality

1.3.5 Development of Aquifer-Wise Management Plan

The dimension and disposition of the aquifer are figured out based on integrated study of the geologic, hydrogeological, hydrological, geochemical, and geophysical information. Determining aquifer potential and characteristics are essential for their effective management and sustainable development. Local groundwater-related issues should be identified and studied in detail to make plans to solve them.

1.4 Study Area

During XII five-year plan, the National Aquifer Mapping and Management (NAQUIM) program were taken up under the Annual Action Plan (AAP) 2020-21 for detailed hydrogeological investigation and Aquifer Mapping in the Gajapati district. Gajapati District has been named after Maharaja Sri Krushna Chandra Gajapati Narayan Deo, the Ex–Raja Sahib of Paralakhemundi estate (the 1st Prime Minister of Odisha State), who is remembered for his contribution to the formation of a separate Odisha province and inclusion of Paralakhemundi estate in Odisha. It got a District status on 2nd October 1992 after being bifurcated from Ganjam District. The district is bounded by 18046' to 19039' North Latitude and 83048' to 840 27' East Longitude. It was Paralakhemundi sub-division in Ganjam and yet it is the only sub-division in Gajapati. There are 7 Tahasils, 7 Blocks, 1,534 Villages, 149 Gram Panchayats, and 11 Police stations in the district. ***Figure 1.1*** The District is surrounded by Andhra Pardesh in its South, Ganjam District in its East, Rayagada in its West, and Kandhamal in its North. The total Geographical area is 4325 sq km as reported by the Surveyor General of India constituting 2.78% of the total area of the state. The mappable area of the district is under NAQUIM is 1411 sq. Km, after excluding the hilly areas from the total area of the district. More than 60 percent of the area of the districts are situated in hilly terrain and high lands. The index map of the study area is presented **Figure *1.2*** while an administrative map is presented in **Figure *1.2***. The study area is part of Mahendratanaya and Bansadhara river basin. The district headquarters Gajapati (Paralakhemundi) is just five km away from the Andrapradesh border. The nearest railway station is Palasa which is in Srikakulam district of Andhrapradesh around 40 km from the district headquarters. Gajapati district is connected by an all-weather

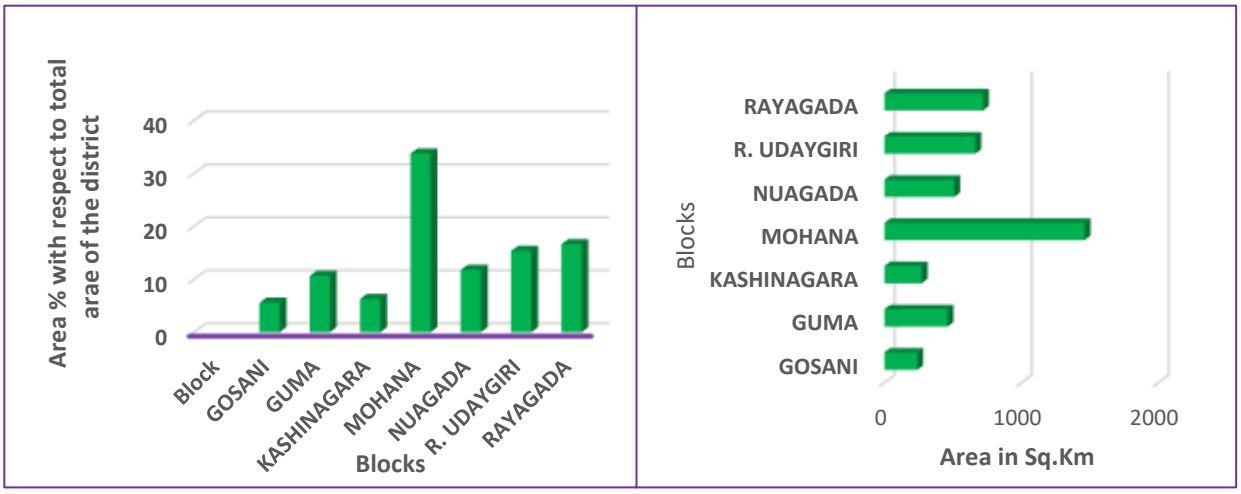


Figure 1.1 Blockwise area percentage of the Gajapati District, Odisha

metalled road from capital city Bhubaneswar (280 km) via Berhampur. The nearest Airport is Visakhapatanam (170km). The block-wise demographic details are shown in **Table 1.1**.

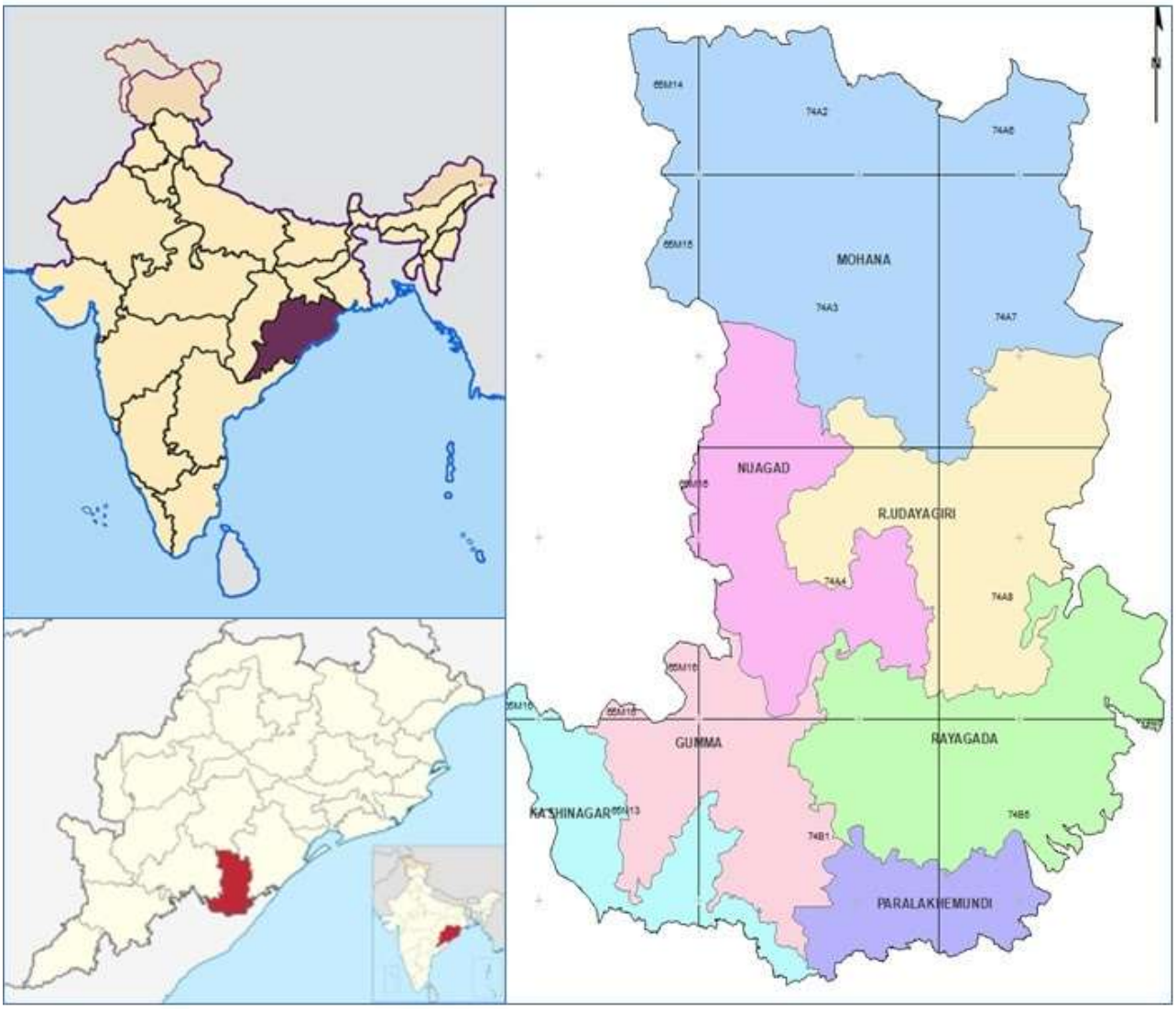


Figure 1.2 Index Map of the Gajapati District, Odisha

Gajapati is the 16th district in terms of size and 28th in terms of the population of the state. It is the 13th urbanized district in the state having 12.23% of its population live in urban areas as against 16.69% of the state's population living in urban areas. More than 30% of the area of the district is occupied by Mohana block situated in the northern part of the district. The lowest area is occupied by Paralakhemundi block in the south Gajapati is the 16th district in terms of size and 28th in terms of the population of the State. In terms of population density, it is the 27th densely populated district of the state. Gajapati is ranked 2nd in terms of the sex ratio in the state. There are 113 uninhabited villages of the district whereas no village is having a total population of more than 5000. Chandragiri is the most populated village having 4467

population. R.Udayagiri police station is having the highest number of villages(301) and Paralakhemundi is having the lowest number of villages(70) in the district.

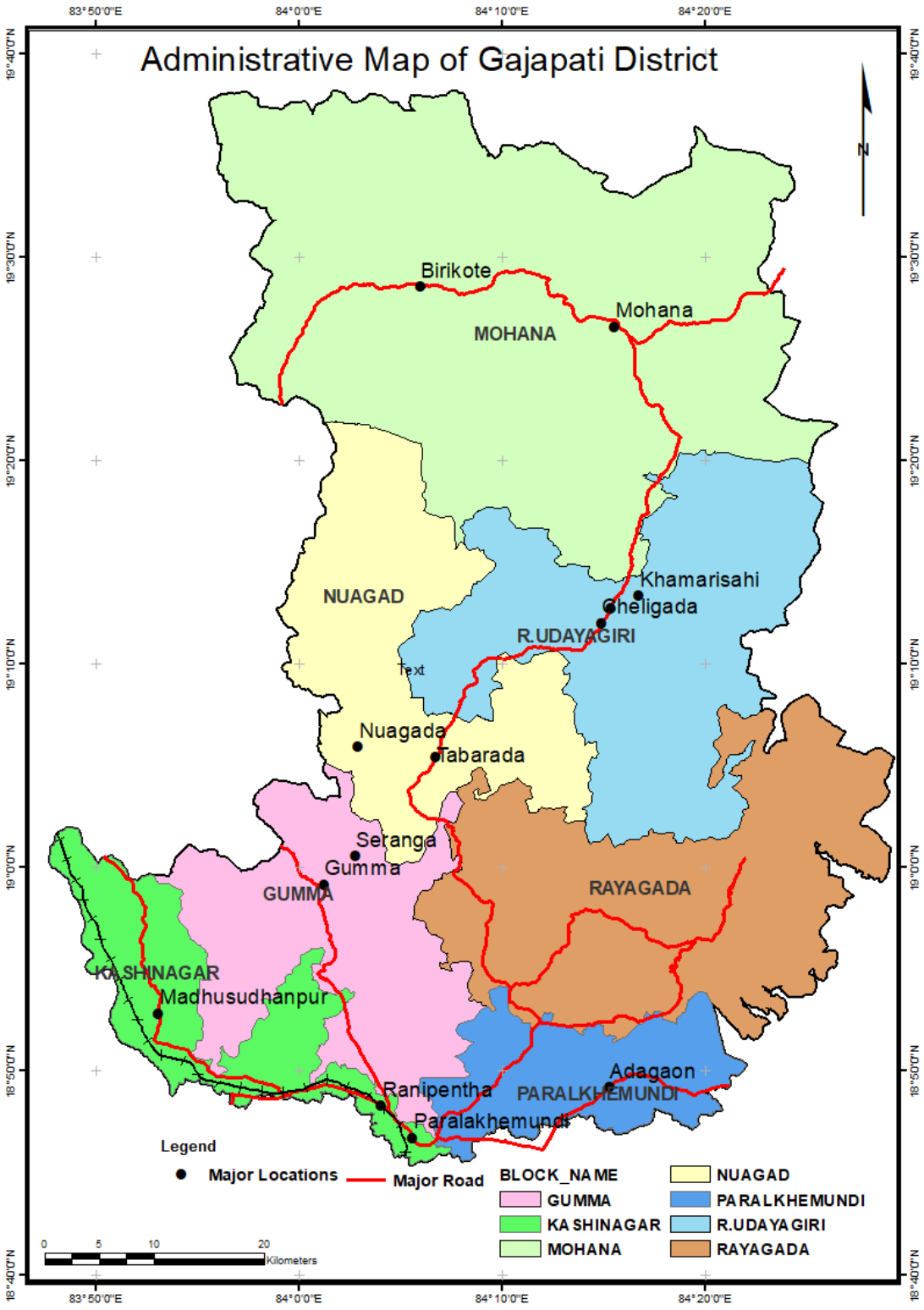


Figure 1.3 Administrative Map of Gajapati District, Odisha

Table 1.1 Block-Wise Demographic Details of Gajapati District, Odisha

Sl. No	Block	Area in Sq.km	Gram Panchayats	Number of Villages
1	Paralakhemundi	241.12	21	136
2	Gumma	461.41	20	220
3	Kashinagar	272.24	12	103
4	Mohana	1461.79	39	499
5	Nuagada	510.34	19	188
6	R.Udaigiri	665.01	17	247
7	Rayagada	720.3	21	223
8	**Gajapati**	**4332.21**	**149**	**1616**

Source: District Census Handbook, Gajapati District, Odisha

Table 1.2 Police Station-wise Population details in Gajapati District

	Sub Districts	Population (2011)			Percentage decadal variation			Sex Ratio
Sl.no	(Police Stations)	Rural	Urban	Total	Rural	Urban	Total	
1	Adaba	59,262	0	59,262	17.75	0	17.75	1,054
2	Mohana	69,139	5,197	74,336	5.59	0	13.53	1,039
3	R.Udaygiri	81,383	4,851	86,234	10.95	0	17.56	1,041
4	Serango	77,720	0	77,720	18.92	0	18.92	1,057
5	Kashinagar	42,223	9,684	51,907	5.13	-1.09	3.91	1,035
6	Paralakhemundi	31,373	46,272	77,645	10.87	7.37	8.76	997
7	Gurandi	45,010	0	45,010	-7.35	0	-7.35	1,049
8	Rayagada	41,534	4,662	46,196	0.07	0	11.3	1,084
9	Garabandha	29,492	0	29,492	12.17	0	12.17	1,036
10	Ramagiri	30,015	0	30,015	12.86	0	12.86	1,063
11	**Total**	**50,7151**	**70,666**	**57,7817**	**86.96**	**0**	**11.37**	**1,043**

Source: District Census Handbook, Gajapati District, Odisha

Table 1.3 CD Block-wise Population details in Gajapati District

Blocks	Rural Population 2011			Urban Population 2011			
	Male	Female	Total	Male	Female	Total	Total
Mohana	62,610	65,791	1,28,401	2,687	2,510	5,197	1,33,598
R.Udaygiri	29,105	30,167	59,272	2,428	2,423	4,851	64,123
Nuagada	26,650	28,046	54,696	-	-	-	54,696
Gumma	38,841	40,679	79,520	-	-	-	79,520
Kashinagar	25,446	25,968	51,414	4,591	5,093	9,684	61,098
Gosani	33,256	34,388	67,644	23,185	23,087	46,272	1,13,916
Rayagada	31,747	34,457	66,204	2,336	2,326	4,662	70,866
Total	2,47,655	2,59,496	5,07,151	35,227	35,439	70,666	5,77,817

1.5 Rainfall and Climate

The district enjoys a humid subtropical climatic condition which is hot and dry in summer, cold and dry in winter, and cold and humid during the rainy season. The maximum temperature rises to 42^0C during the summer months (May & June) and the minimum temperature comes down to 15^0C during the winter period i.e., in December. The humidity of the area is generally high, especially in the monsoon and pre-monsoon months. The relative humidity is around 60 to 70 % throughout the year. In general, April is the driest month, whereas July and August, are the wettest. Southwest monsoon is the principal source of precipitation in the district. The average annual rainfall of the district is 1413 mm, out of which 85% to 90% is received during the monsoon period (mid-June to mid-October). Monthly rainfall data for the period from 1991 to 2020 along with the monthly normal Rainfall data and average monthly rainfall data have been studied. It shows that the district received the minimum rainfall of 901 mm during the year 1996 and the maximum precipitation of 2120 mm during 1990 **Table 1.4**. The rainfall is highly erratic both in space and time. The rainfall pattern over the years also shows variations. Under the period of observation, both mild and normal droughts have occurred during different periods in different blocks of the district **Table 1.5**.

The climate of the district is tropical with hot and dry summer, cold winter, and erratic rainfall in monsoon. The humidity of the air is high during the monsoon season and decreases due to cold waves from the end of November. The mean monthly potential evapotranspiration values rangers from 45mm (in December) to 470mm (in May). The wind is generally light to moderate. The southern part of the district is prone to cyclonic storms.

The average annual rainfall over the last 30 years is 1413 mm with a positive increasing trend of 2.99 mm/year **Figure *1.5***. 88% of the district receives normal rainfall from over 30 years long period and none of the areas is under acute drought c**on**dition. The rainfall data indicates that the rainfall in Nuagada Block has a declining trend in the long-term analysis.

The isohyetal map of the district taking the average annual rainfall (station wise) is presented in **Figure *1.4***. The highest rainfall is recorded in and around Nuagada block and the lowest is recorded in the southern part of the district in Paralakhemundi and Kasinagar block. The majority parts of the district are covered by medium-range rainfall 1400mm to 1500mm.

The drought analysis shows that none of the years the district experienced any acute drought condition. Only in Kasinagar and Paralakhemundi, the district experienced 2 years and 1-year severe drought conditions. The district only experienced moderate drought conditions with -25 to -50% departure. In Kasinagar, Paralakhemundi, Nuagada, and R. Udayagiri blocks, the district received excess than normal rainfall in 17% of the years to the total number of years of analysis.

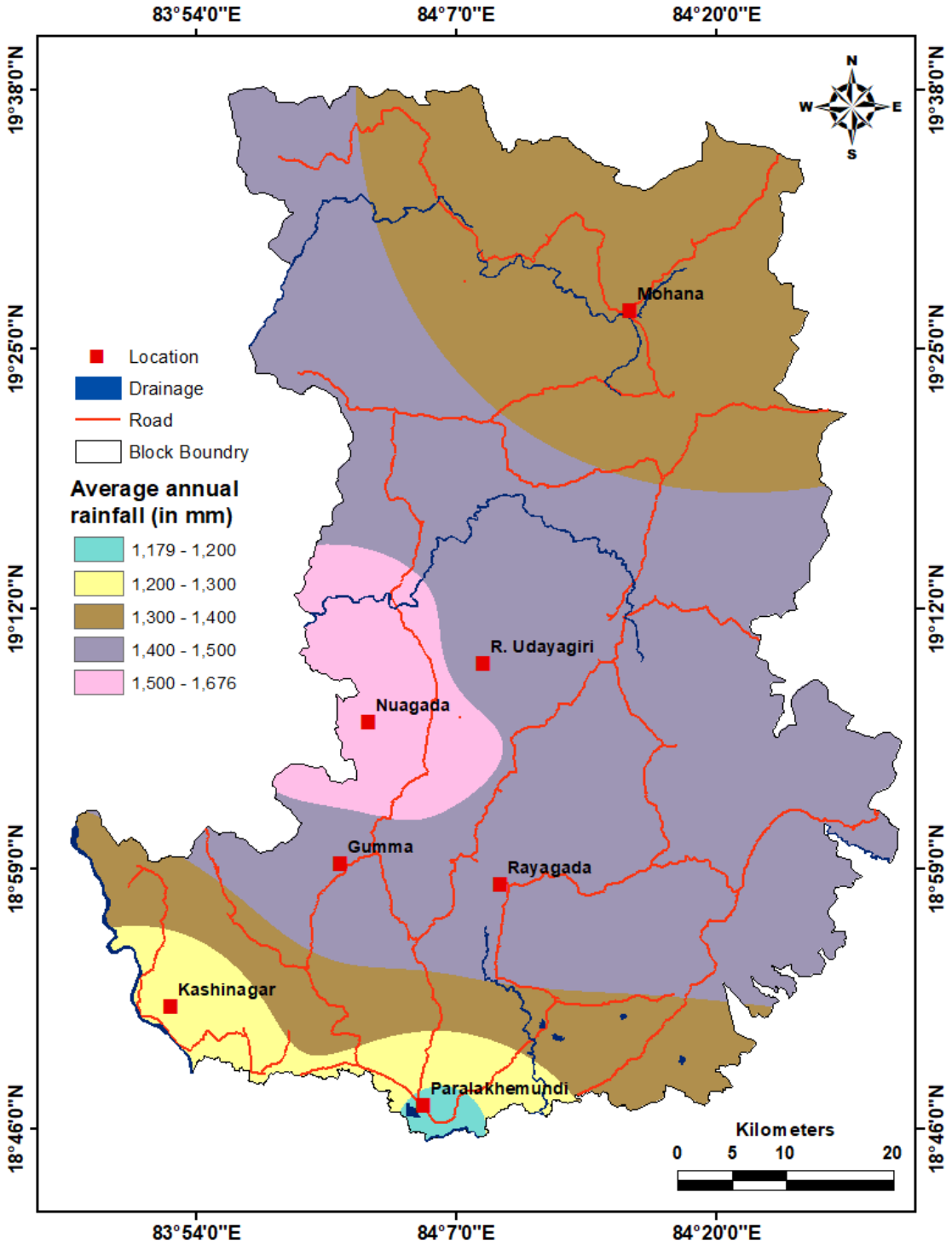


Figure 1.4 Isohyet Map of Gajapati District, Odisha

Table 1.4 Long Term Rainfall and Drought analysis from (1991-2020)

Station	Yrs	Average Annual Rainfall	Coefficient of Variation (%)	Droughts (No of yrs, % of Tot. Yrs)			Rainfall Received (No of yrs, % of Tot. Yrs)		Rainfall Trend (mm/year)
				Moderate	Severe	Acute	Normal	Excess	
				-25 to -50%	-50 to -75%	above -75%	-25 to +20%	> +25%	
				Departure	Departure	Departure	Departure	Departure	
Kasinagar	30	1207	29	2, 7%	2, 7%	0	21, 69%	5, 17%	16.165
Paralakhemundi	30	1178	30	5, 17%	1, 3%	0	19, 63%	5, 17%	21.104
Rayagada	30	1463	20	3, 10%	0	0	23, 77%	4, 13%	3.606
Gumma	30	1451	22	5, 17%	0	0	22, 73%	3, 10%	6.923
Nuagada	30	1675	27	3, 10%	0	0	22, 73%	5, 17%	-2.232
R.Udaygiri	30	1475	23	4, 13%	0	0	21, 70%	5, 17%	3.809
Mohana	30	1318	24	6, 20%	0	0	20, 67%	4, 13%	5.154
Gajapati	31	1413	20	3,10%	0	0	25, 80%	3, 10%	2.991

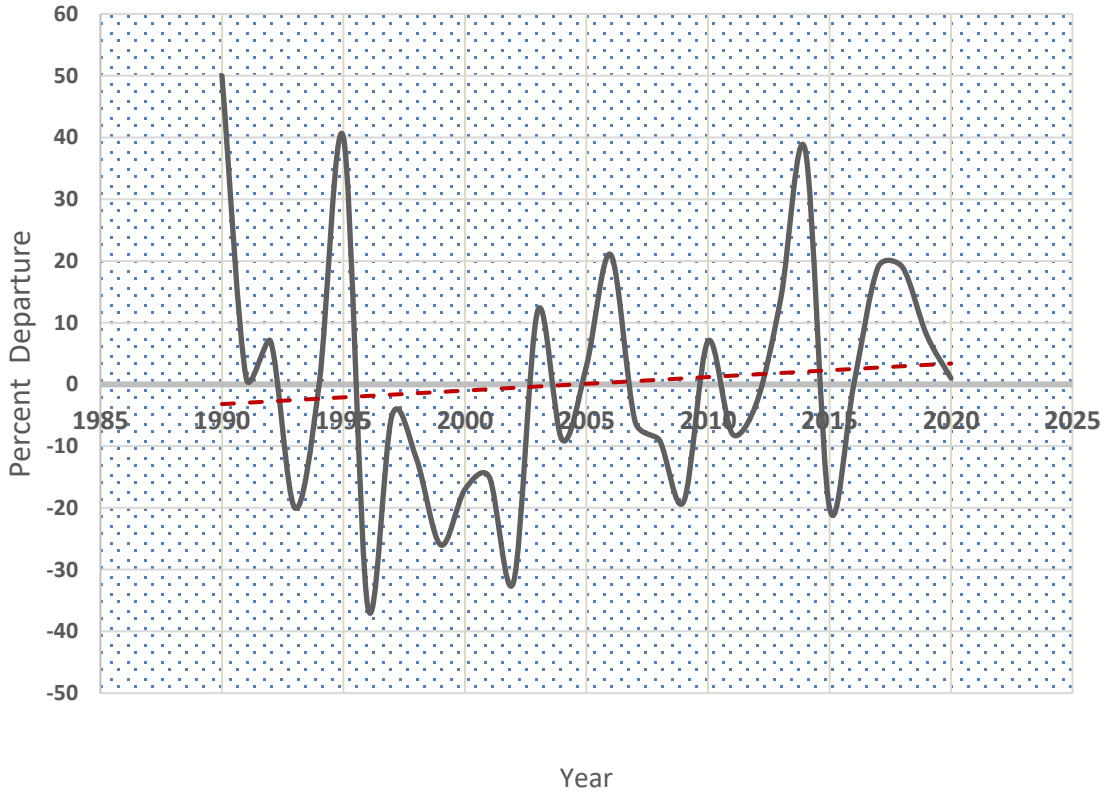


Figure 1.5 Rainfall analysis Percent deviation from normal

Table 1.5 Table: Monthly, Actual and Average Rainfall of Gajapati District

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1990	0.0	87.0	122.1	20.7	492.3	195.5	148.7	333.3	224.4	276.2	213.4	6.7	2120.2
1991	17.7	0.4	14.3	45.1	45.3	159.1	470.0	179.1	308.1	105.9	84.9	0.0	1430.0
1992	7.8	43.5	0.0	19.9	64.7	158.1	451.4	217.1	333.6	188.7	21.3	0.0	1506.1
1993	0.0	0.0	28.4	56.8	92.8	204.5	279.8	160.8	193.3	106.4	8.4	0.0	1131.0
1994	0.0	34.6	11.8	109.7	89.8	122.9	258.8	300.3	302.9	175.5	9.2	0.0	1415.4
1995	16.0	0.6	36.9	84.2	524.4	70.1	293.3	278.7	196.6	313.4	167.1	1.1	1982.5
1996	8.2	5.2	10.2	22.1	36.2	185.6	73.7	262.0	190.5	91.1	16.7	0.0	901.4
1997	4.0	7.9	57.4	146.6	55.9	139.0	204.1	262.9	288.8	85.7	38.1	45.5	1335.7
1998	1.7	47.9	61.6	40.5	37.5	198.0	227.1	157.4	183.0	162.9	129.3	0.0	1246.9
1999	0.0	0.0	0.0	11.4	150.9	187.3	151.8	152.1	161.2	203.1	32.1	0.0	1049.8
2000	0.0	59.1	0.0	51.2	125.4	196.1	172.7	274.7	170.0	106.1	11.2	0.0	1166.4
2001	0.0	2.8	45.7	37.8	60.0	255.2	180.0	286.7	109.2	162.1	59.0	0.0	1198.4
2002	23.7	0.0	4.8	37.2	91.3	193.2	134.9	222.2	136.6	117.1	2.3	0.0	963.2
2003	0.0	43.6	48.2	57.0	35.6	99.1	267.9	268.2	171.4	544.2	13.7	33.1	1581.9
2004	9.6	9.8	15.0	145.8	45.1	169.9	296.5	150.6	137.7	286.8	14.5	0.0	1281.0
2005	9.0	0.5	53.8	66.6	69.1	128.4	187.2	178.9	499.9	205.1	54.1	0.0	1452.6
2006	0.0	0.0	31.4	73.1	137.1	216.3	412.5	447.1	312.9	59.5	16.4	0.0	1706.4
2007	0.0	0.5	20.4	57.6	118.8	339.1	119.9	294.4	271.7	100.4	2.4	0.0	1325.1
2008	31.7	36.6	70.5	33.1	97.8	97.4	267.3	322.5	293.9	26.1	2.4	0.0	1279.2
2009	0.0	0.0	17.7	13.8	43.0	131.3	372.8	271.5	166.2	79.4	53.9	0.0	1149.4
2010	32.7	1.2	3.1	20.6	130.9	132.9	262.2	277.4	221.2	262.8	78.7	82.7	1506.4
2011	3.1	35.3	0.0	159.9	94.2	185.5	185.5	419.0	156.4	53.9	0.0	0.5	1293.3
2012	32.0	0.0	3.3	148.0	70.6	139.5	294.7	195.3	271.2	75.3	134.0	0.0	1363.9
2013	2.9	3.2	1.5	112.1	79.3	365.6	231.0	-	238.7	559.9	12.5	0.4	1607.1
2014	0.0	5.9	64.0	59.6	263.6	100.6	310.3	361.3	362.0	389.9	23.4	2.5	1943.0
2015	9.3	14.4	7.4	95.0	46.6	277.6	137.9	202.8	233.9	57.2	21.1	23.1	1126.2
2016	4.5	7.1	36.7	21.0	157.0	208.5	248.5	192.1	360.3	157.5	12.8	0.0	1406.0
2017	0.0	0.0	81.4	24.0	109.7	195.8	345.9	463.2	200.9	195.5	70.7	0.0	1687.2
2018	0.0	0.0	6.6	131.8	103.4	149.3	367.3	325.7	202.4	320.2	0.9	77.9	1685.6
2019	0.0	2.1	19.6	81.0	124.9	59.8	233.9	323.0	329.2	326.4	12.5	8.3	1520.5
2020	5.5	48.5	70.2	92.2	54.0	228.7	222.2	196.0	162.0	334.5	14.4	0.0	1428.1
Average	**7.1**	**16.1**	**30.4**	**66.9**	**117.6**	**177.1**	**251.9**	**265.9**	**238.4**	**197.7**	**42.9**	**9.1**	**1421.2**

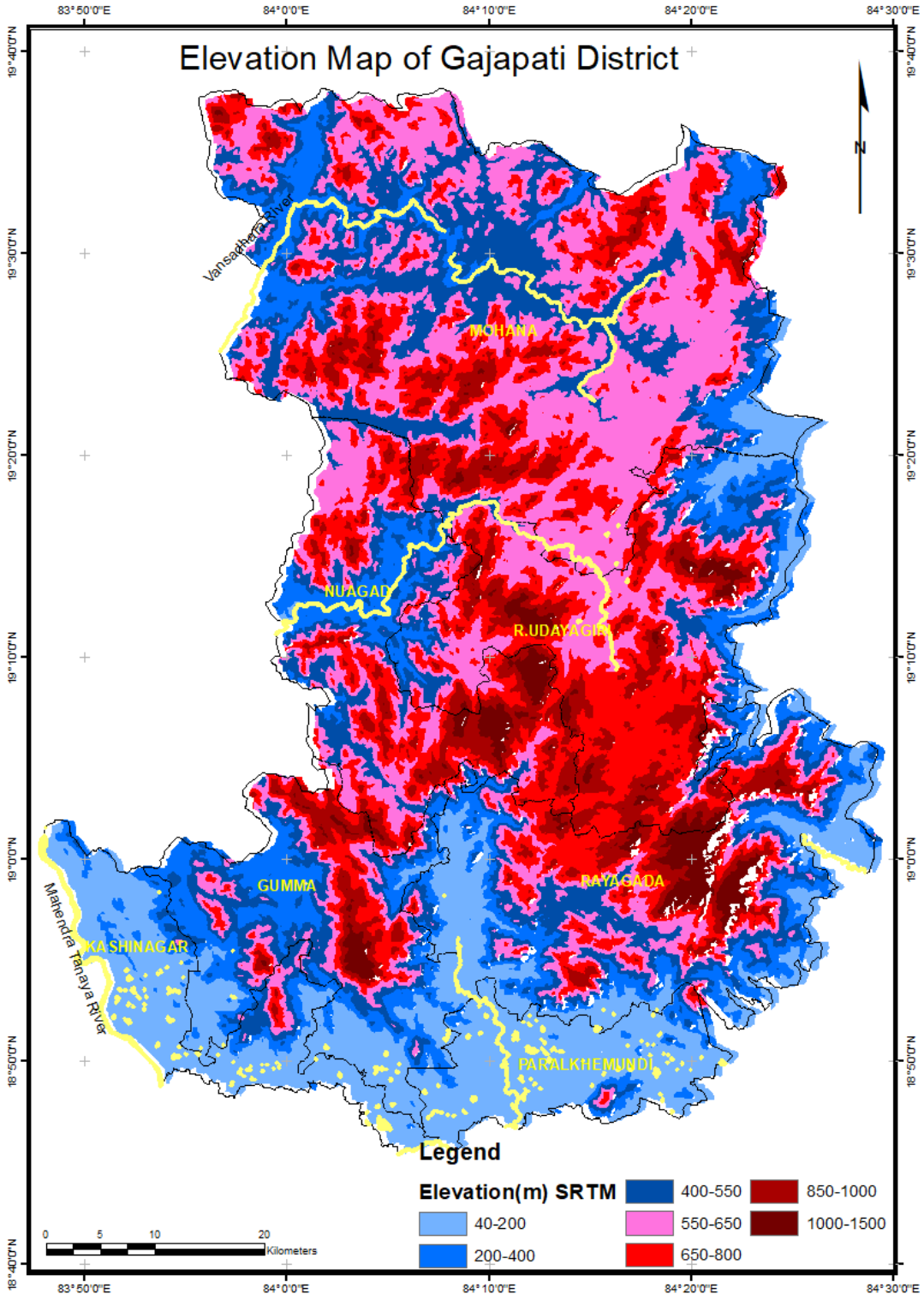


Figure 1.6 Elevation Map (from MSL), Gajapati District, Odisha

1.6 Physiographic Setup

The most of Gajapati district is covered with rugged forest and mountainous terrain of Eastern Ghats rocks with narrow intermontane valleys with occasional flat tops. The important geomorphological interest is the abrupt rise of the hill masses from the adjoining coastal plains. This is attributed to some fault pattern along which the blocks may have been up thrown. The lofty mountain ranges of the Eastern Ghats in this area rise steeply and abrupt at the end of the western continuation of the coastal plains of Andhra Pradesh. The average elevation of hills ranges from 500 to 1200m above mean sea level. The important hills in the district are Dandamera Parbat (1103m), Tangiri Parbat (1155m), and Mahendra Giri (1499m). The area in and around Mohana, Chandragiri, Chandiput, and Paralakhemundi constitute the pediment of undulating plains which have undergone intense weathering. The variation in land elevations above MSL is shown in **Figure *1.6***. The district has two distinct geographical and agro-climatic divisions. The Plains in the south and southeast covering Paralakhemundi and Kashinagar block. The remaining parts of the district consist of the hilly tableland.

A major part of the area is extremely mountainous consisting of a series of high hill ranges with occasional flat tops. The monotony of the long chains of N-S running hill ranges is interrupted by deep narrow and transverse gorge-like valleys at intervals. Patches of small low-lying plain and fallow land are sporadically scattered in the depressions within the mountainous regions which are full of a network of shallow rivulets with steep slopes. In general, the mountainous tract is restricted to the northern and north-eastern sectors which is flinged in the west and south with a comparatively flat rolling ground with altitude ranging between 70 to 400m. Most of the undulating plain is with either alluvium or residual soil. The highest point 1506 m above mean sea level forms the peak of stupendous hill masses of Mahendragiri. The average elevation of the valleys in most of the area is approximately 450 m and the lowest point in the south is about 75m above mean sea level. The area represents a typical succession of the Eastern-ghat facies of the Archaean age. The rock types encountered are broadly grouped as (l) Khondalitic suite, (2) charnockitic suite, (3) garnetiferous granite gneiss, (4) pegmatites, and quartz veins, and (5) laterite.

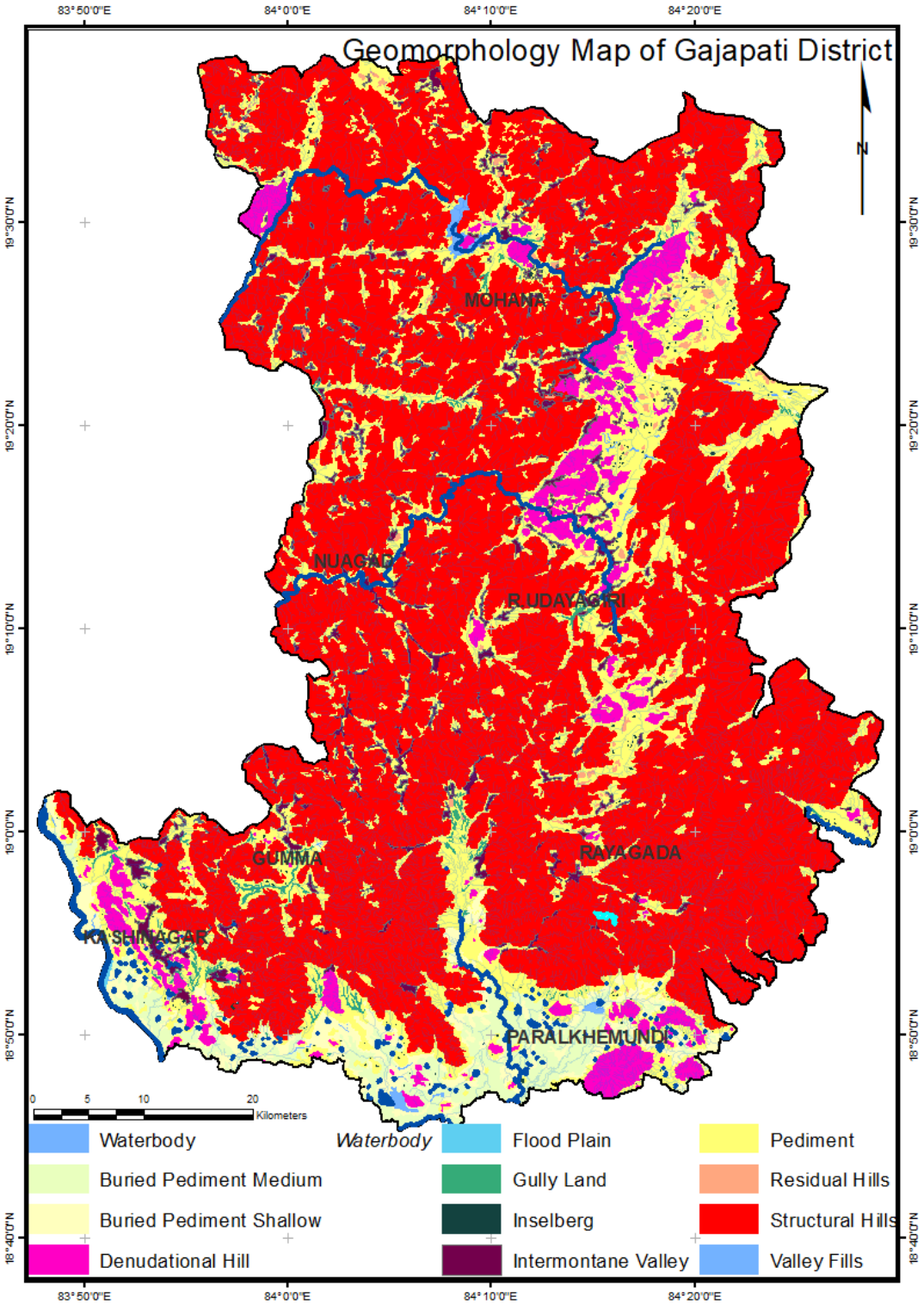


Figure 1.7 Geomorphology Map, Gajapati District, Odisha

1.7 Hydrogeomorphology

The only two blocks of the district Kasinagar and Paralakhemundi are having plain land and more than 60% of the landmass are covered by high lands and hilly terrain. The plains are narrow

because of the absence of big rivers. The main point of geo-morphological interest is the abrupt rise of the hill masses from the adjoining coastal plains. This is attributed to some fault pattern along which the blocks may have been upthrown. Few radial faults have been mapped which are the weak zones that ultimately gave rise to steep-sloped valleys. These weak zones along the contacts have ultimately given rise to the rivulets. The different geomorphic important features are depicted in Figure 1.7 and described as follows.

1.7.1 Flood Plains

They occur along a narrow stretch with limited thickness and areal extent along the course of the Vansadhara and Mahendra Tanaya rivers and their tributaries. They comprise loose unconsolidated materials like sand, silt, clay, pebbles, boulders, etc. Fine to coarse sand forms potential aquifer zones and yield a good quantity of water. The flood plains, owing to the availability of granular zones in the sediment profile, bear good prospects for forming potential aquifers. Groundwater in these areas may be developed through dugwells and shallow tube wells.

1.7.2 Deep Buried Pediment

This is the most extensive, common unit in the area covering parts of each block of the district. They are characterized by a thick weathered zone with thickness varying from 10-15 m and forms a potential phreatic aquifer. Groundwater development can be through dugwells and dug-cum-bore wells.

1.7.3 Shallow Buried Pediment

This is distributed throughout the area having an overburden of less than 10 m. This area is marked by flat topography and forms a less prolific phreatic aquifer.

1.7.4 Intermontane Valley

Several Intermontane Valleys with major rivers and their tributaries have developed viz. Haribhanga nadi, Badanala, Kandakuti nala. etc which have been formed by deep incise weathering of denudational hills.

1.7.5 Valley Fills

These are the deposits restricted to the linear depressions which are mostly joint/fractured controlled. These are types of deposits developed by the processes of deeper sedimentation in

an erosional environment in hard rock terrains. Sand, silt, clay, kankar nodules with gravels constitute the valley fills. The slope remains low, and the moisture content and vegetation cover remain more in this geomorphic unit. Thus, they form important units for groundwater development in hard rock terrains and acts as a very good area for storage and movement of groundwater. Dugwells located in these areas yield fairly a good amount of water.

1.7.6 Inselbergs

This landform occurs as isolated hillocks. These are developed due to active weathering and denudation in humid tropical climatic conditions. This unit does not have any significance on the occurrence and movement of groundwater.

1.7.7 Structural Hills

The hills with escarpment characterize the feature steep slopes and narrow gorges. These are structurally controlled hills with complex folding, faulting, and traversed by numerous joints/fractures facilitating infiltration and mostly act as run-off zone.

1.7.8 Residual Hills

This unit mainly consists of residual masses of granites. This unit behaves as a runoff zone.

1.7.9 Denudational Hills

Denudational hills are identified by their high relief representing resistant hill ranges. The rate of infiltration is very poor except along fractures/joints. These generally act as run-off zone.

1.8 Landuse and Cropping Pattern

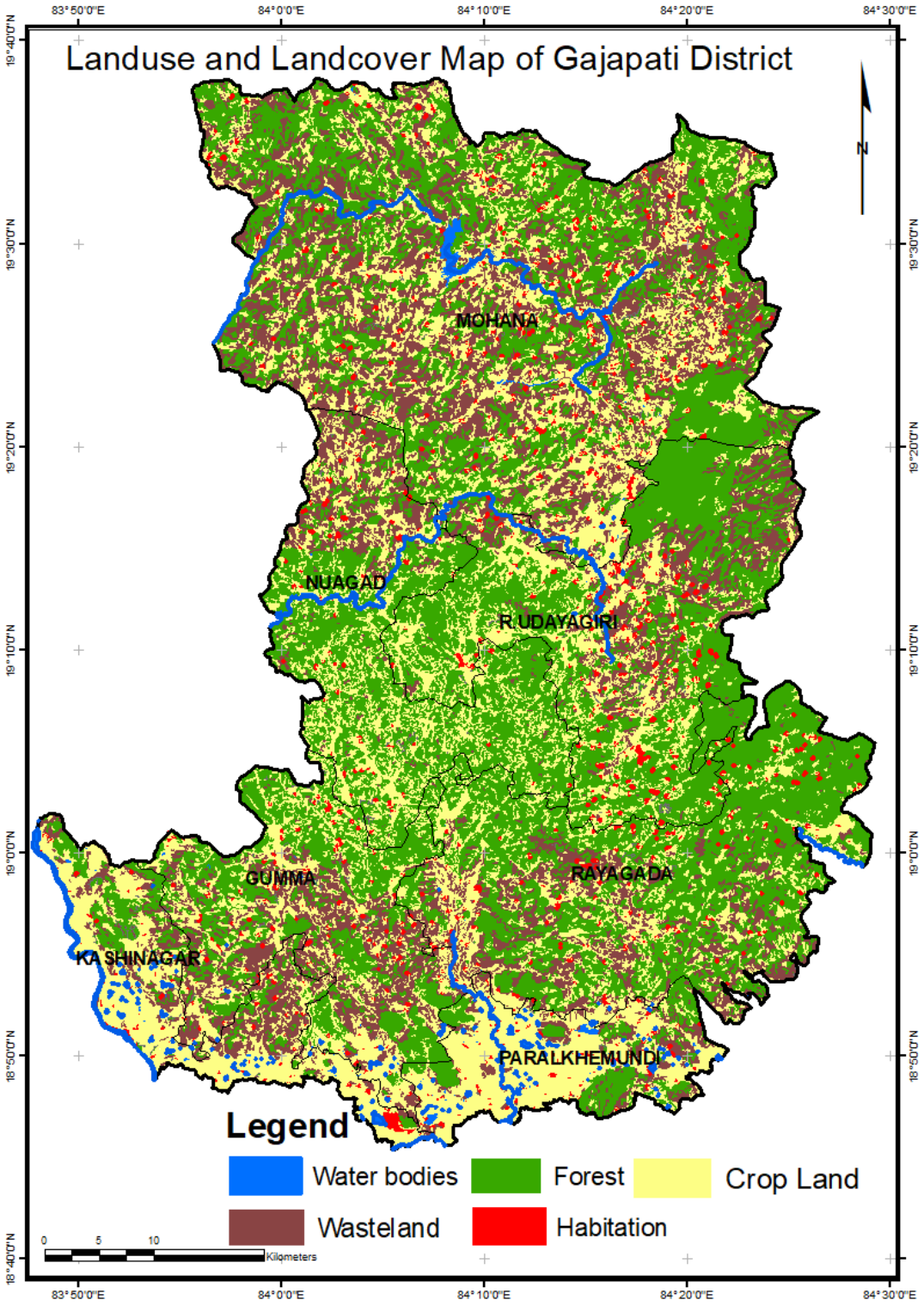


Figure 1.8 Landuse Map Gajapati District, Odisha

The study area shows wide variation in the pattern of land utilization. Landuse pattern is closely related to the geomorphology and climatic condition of the area. The forest area is 57% of the total geographical area of the district and 4.25% of the state of Odisha. The net sown area of the district is 75,037 Ha with maximum cropping intensity in Kashinagar block which is 223%. The cropping intensity of the district is very good. The average cropping intensity is 193%. There is further scope of increasing the cropping intensity by increasing the area under irrigation. The area under wasteland is low and maximum in the blocks of Kashinagar, Nuagada, and Rayagada. Agriculture is the mainstay for the rural population of the district. The block-wise land use pattern is shown in **Table 1.6,** and block-wise area under agriculture is depicted in **Table 1.7** and the thematic map on land use is shown in **Figure 1.8**

The cultivation is mainly in the Kharif season. Rabi cultivation is restricted to areas with irrigation facilities. The different crops grown in the area are paddy, maize, pulses (Arhar, Green and Black gram) and vegetables (potato, onion, garlic, turmeric, ginger, and seasonal vegetables), fruits (mango, coconut, guava), etc. Gajapati district's irrigated area accounts for 28% of the TCA(Total Cropped Area) and the remaining 78% of the TCA is under rainfed. This shows a huge gap between the ultimate irrigation potential and the present net irrigated area. Substantial dependency on monsoon rainfall makes cultivation in the unirrigated area a high-risk, less productive farming profession. The district has limited irrigation facilities. There is no major or medium irrigation project command area in the district. Minor Irrigation Projects (Flow), lift irrigation projects, and groundwater are the main source of irrigation which caters to about 47% of the net sown area. In terms of net sown area, Nuagada block is having almost (17.11%) of the total district area followed by Kasinagar (16.9%) and Rayagada (15%) with the lowest area in R. Udayagiri(9.8%).

The crop-wise and block-wise irrigated and rainfed area in Gajapati district is presented in **Table 1.9**. The total gross cropped area is about 1.33 lakh ha out of which 0.37 lakh ha(28.2 % of TCA) is irrigated and 0.96 lakh ha(71.8% TCA) is under rainfed area. The blocks like Gosani and Kasinagar have a higher percentage of irrigated area compared to other blocks. Among the different crop groups, cereals account for 52.2% of the irrigated area followed by vegetables 19.2%, oilseeds 9%, pulses 5.8%, horticulture & Plantation 5.6%, spices 2.4%, fiber 0.4 %, and other crops 0.2%. this indicates that a major source of water in agriculture is being used for the cultivation of cereals like paddy and maize.

1.8.1 Agriculture:

Agriculture in the Gajapati district continues to be characterized by low productivity due to traditional agricultural practices, inadequate capital formation, and low investment, inadequate irrigation facilities, low water use efficiency, uneconomic size of holdings, etc. The agricultural development plan in today's context has to be holistic, well defined, and focused on the overall wellbeing of the farming community. Major growing crops are paddy, maize, sugarcane, sunflower, mustard, brinjal, chili, cabbage, tomato, etc. among all the paddy contributes maximum area. Maize is mostly grown in slopping areas. Cultivable land is grouped into the irrigated and rainfed areas. Under irrigated area again it is classified as grossed irrigated area and net irrigated area. Partially irrigated/ Protective irrigation area under rainfed has been assumed to be 5% of the net irrigated area.

Table 1.6 Land Use Pattern in Gajapati District

Block	Gross Cropped Area	Net sown Area	Area sown more than once	Cropping Intensity in %	Forest	Waste Land	Other uses
Rayagada	20,023	11,414	11,115	175	37,050	13,302	3,184
Nuagada	12,180	10,004	12,661	122	40,261	15,232	8,589
Mohana	19,523	10,404	10,131	188	33,814	12,321	2,782
Gumma	19,674	10,427	10,227	189	33,938	12,366	2,547
R.udayagiri	17,589	7,448	7,252	236	26,206	7,620	1,160
Gosani	27,165	12,496	10,219	217	34,111	12,424	766
Kasinagar	28,650	12,844	12,581	223	41,743	15,210	3,380
Total	**1,44,804**	**75,037**	**74,186**	**193**	**2,47,123**	**88,475**	**22,408**

Source: District Irrigation Plan, Gajapati, March 2016 Area in Hectares

Table 1.7 Irrigation based classification- Block wise

Block	Total Irrigated Area	Net Irrigated Area	Partially/Protective Irrigation	Totally Rainfed
Gosani	11,524	11,707	579	11,573
Gumma	3,718	3,718	746	14,915
Kasinagar	10,467	6,943	729	14,587
Mohana	3,324	3,210	766	15,316
Nuagada	2,039	1,150	480	9,604
R.udayagiri	2,460	2,058	728	14,553
Rayagada	3,908	3,239	750	15,004
Total	**37,440**	**32,425**	**4,778**	**95,550**

Source: District Irrigation Plan, Gajapati, March 2016 Area in Hectares

Table 1.8 Status of Water Availability (Area in ha)

Sl.no	Source	Kharif	Rabi	Summer	Total
1	**Surface Irrigation**				
i	Canal(Major & Medium Irrigation)	-	-	-	-
ii	Minor Irrigation tanks	15,830	314	-	16,144
iii	Lift Irrigation/Diversion	5,460	4,100	3,050	12,610
iv	Various Water Bodies including Rainwater Harvesting	7,680	2,432	-	10,112
v	Treated Effluent Received from STP	-	-	-	-
vi	Untreated Effluent	-	-	-	-
vii	Perennial Source of Water	-	-	-	-
	Sub Total	**28,970**	**6,846**	**3,050**	**38,866**
2	**Ground Water**				
i	Open Well	541	288	-	829
ii	Deep Tube Well	292	220	163	675
iii	Medium Tube Well	590	325	265	1,180
iv	Shallow Tube Well	628	528	409	1,565
	Sub Total	**2,051**	**1,361**	**837**	**4,249**
Total		**31,021**	**8,207**	**3,887**	**43,115**

Table 1.9 Crop wise and block wise irrigated and rainfed area in Gajapati District

Block	Ceceals		CoarseCereals		Pulses		Oilseed		Fibre		Vegetables		Spices		Anyother		Hort&Plantation		Total		
	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	TCA
Gosani	6,752	410	327	400	461	8,368	865	773	41	49	2,808	789	83	113	65	-	121	671	11,523	11,573	23,096
Gumma	2,410	512	307	4,506	11	4,576	131	943	-	41	563	3,100	38	443	-	-	258	793	3,718	14,914	18,632
Kasinagar	4,686	743	163	2,301	1,692	5,698	1,579	2,045	-	789	1,673	2,101	444	459	11	-	218	451	10,466	14,587	25,053
Mohana	1,815	615	189	5,251	-	3,131	186	609	-	102	759	3,141	29	1,307	-	-	346	1,160	3,324	15,316	18,640
Nuagada	1,125	471	121	2,478	-	2,342	247	333	102	1,332	172	1,387	73	379	-	-	200	881	2,040	9,603	11,643
R.udayagiri	1,329	1,076	134	4,653	10	2,450	109	845	-	51	363	2,741	116	1,107	-	-	399	1,628	2,460	14,551	17,011
Rayagada	1,793	707	363	3,592	-	4,637	254	359	-	702	838	2,189	120	743	-	-	540	2,074	3,908	15,003	18,911
Total	**19,910**	**4,534**	**1,604**	**23,181**	**2,174**	**31,202**	**3,371**	**5,907**	**143**	**3,066**	**7,176**	**15,448**	**903**	**4,551**	**76**	**-**	**2,082**	**7,658**	**37,439**	**95,547**	**1,32,986**

1.9 Soil

Based on the physical and chemical characteristics, mode of origin, and occurrence, soils of the district can broadly be grouped into two types as Alfisols and Entisol . Soils of the district are generally having average to good fertility status. All common types of crops can be grown in the district.

Alfisols or Red Soils: The Alfisols include red sandy soils and red loamy soils. red sandy soils are conspicuously available is almost all blocks except in Paralakhemundi block which is characterized by red loamy soils These soils are neutral to slightly alkaline (pH varies from 5.5 to 8.5). The characteristic features of red soils are (i) light texture, porous and friable structure, (ii) absence of lime kankar and free carbonates, and (iii) soluble salts in small quantity usually not exceeding 0.05%. These are usually deficient in nitrogen, phosphate, organic matter and lime. These soils are suitable for cultivation of paddy and other crops.

Entisols or Alluvial soil: are younger in origin deficient in nitrogen, phosphoric acid and humus. They are comparatively rich in potash, lime and alkaline is nature. The texture varies from sandy to loamy. These are the most fertile soils in the district. Alluvial soils are mostly confined to the valley areas and along the major and minor river channels. These types of the soil are less abundant as compared to the red soils which occupy more than 90% area of the district.

Soils of the districts are generally having average to good fertility status. All common types of crops are grown in the districts.

Soil erosion is a common disaster due to high slope and runoff which is to be managed through soil and water conservation structures. Around 64% of the total area of the districts are falling under 8-25% slope.

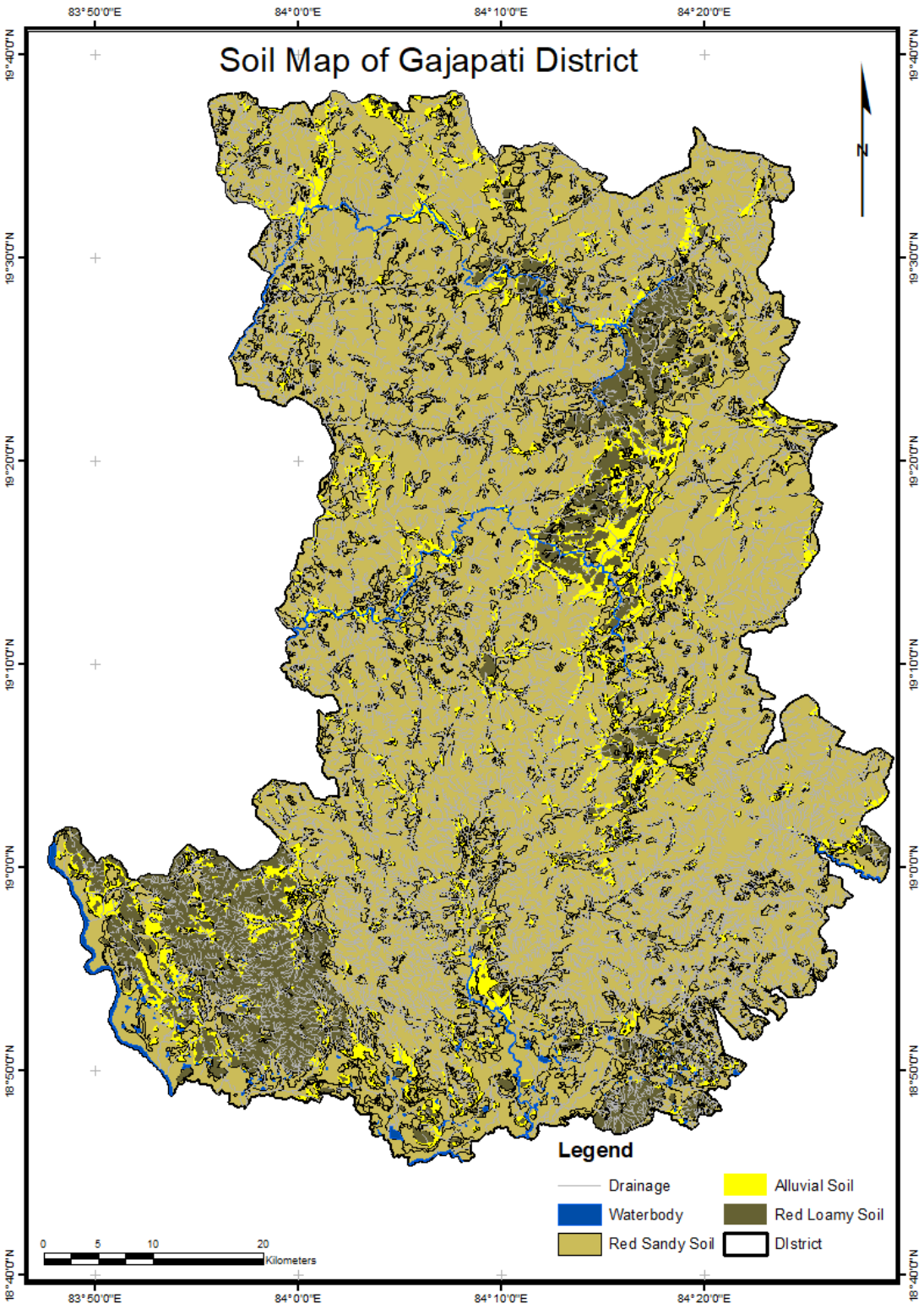


Figure 1.9 Soil Map, Gajapati District, Odisha

1.10 Drainage and Hydrology

The river Vansadhara along with its tributaries, Mahendratanaya, Harbhangi, Badanadi, etc form the major drainage system of the districts. The master slope of the ground is towards the South and NWN direction. The drainage pattern is mostly dendritic but at places, it is rectangular due to being structurally controlled by joints, fractures, and other lineaments. During the summer season, there is hardly any surface flow in the streams except the Vansadhara river which is perennial. All the streams are effluent in nature. The drainage map of the area is shown in **Figure 1.10**. Several streams both perennial and ephemeral are the major source of water for drinking and sometimes for irrigation too.

The Vansadhara and Mahendratanaya river mainly controls the drainage pattern of the area. Mahendratanaya river originates at Mahendra Giri and rushes down the hill slope to the south through Burrikhatta pass. But near Kaipuram the river takes a turn to the west and flows at a gentle gradient to the W.N.W for about 12 km and meets a Nala east of Jirang, which flows to the southwest along a fault zone from Sana Soda. From Jirang the Mahendratanaya river continues further westward, in a meandering course over the granitic country and ultimately meets another Nala near Burji which flows down from north of Rayagada. Several small rivers such as Rato Nadi, Barha jhara, Gurhas nala, Kapat nala, Gumma nala contribute to the drainage system of the district. Harabhangi Irrigation Project is one of the 18 World Bank Aided Medium Irrigation Projects taken up by the Odisha Government for utilization of Water Resources of Vansadhara Basin. This project is located about 6 km North-West of Adava village in Gajapati District. Inter-basin transfer of water is being carried out from Vansadhara Basin to Ruishikulya Basin through a five kms long water conductor system of 20 cumecs capacity.

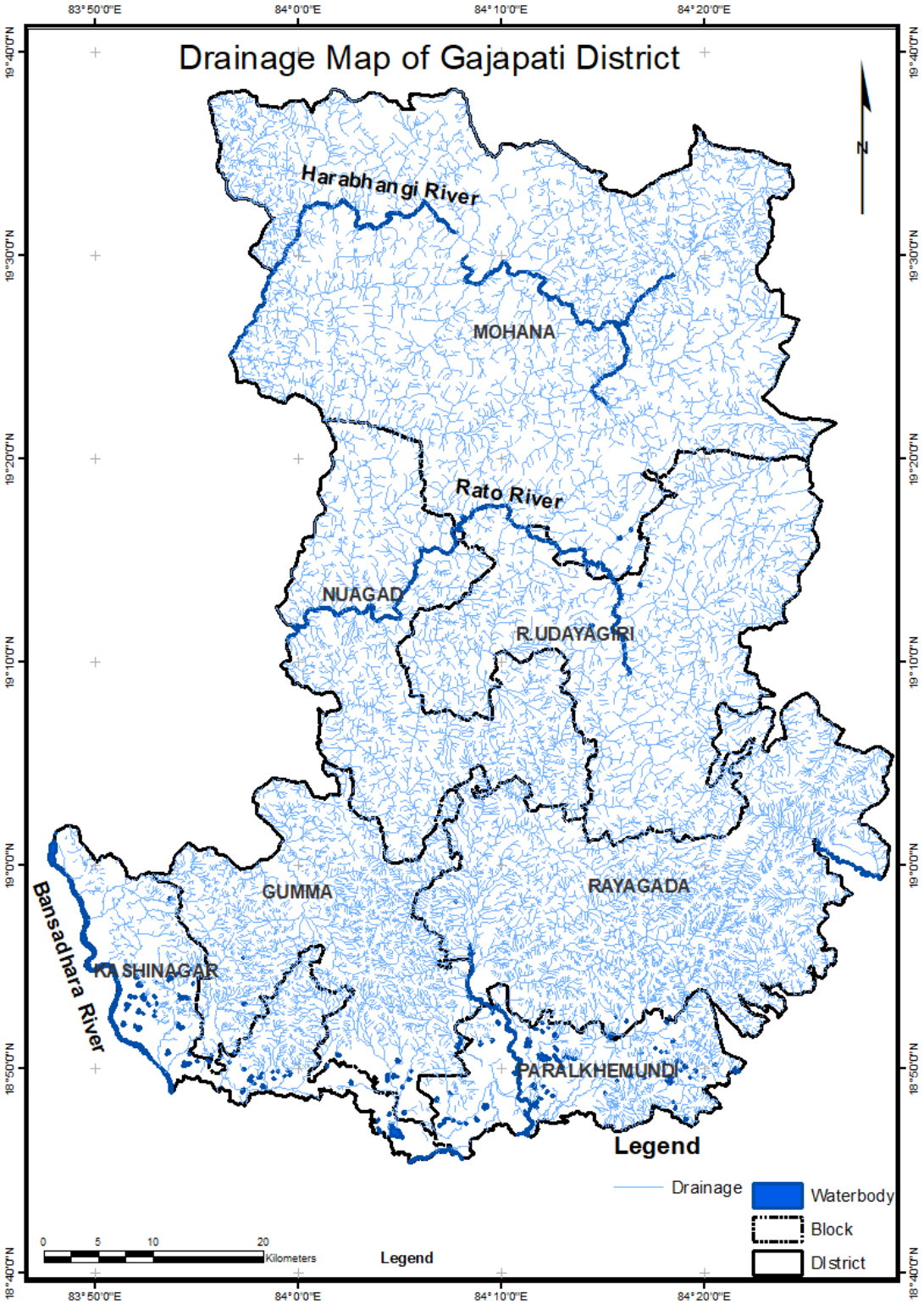


Figure 1.10 Drainage Map, Gajapati District, Odisha

2.0 DATA COLLECTION AND GENERATION

2.1 Geology

The study area comprises a group of highly metamorphosed rocks of Eastern Ghat facies belonging to the Archean Complex of the Indian Peninsula. The development of laterite is rare and where ever it is seen it occurs as thin-film capping the crystalline rocks. Discontinuous and elongated patches of alluvium are restricted along the major and minor river channels. In the hard rock terrain, alluvium occurs as narrow and discontinuous valley-fill deposits. The generalized stratigraphic sequence is depicted in **Table 2.1**.

Table 2.1 Generalized Stratigraphic Sequence in Gajapati District.

Age	Group	Lithology
Recent	Residual Soil and Alluvium	Sand, Silt, Clay in varying proportion
Sub-Recent	Laterite	Laterite and Lateritic gravels
UNCONFORMITY		
Archean	Eastern Ghat Granite Suite	Pegmatite and Quartz vein, Porphyroblastic Granite Gneiss
		Biotite Granite
		Garnetiferous Granite Gneiss
	Charnockite Suite	Hypersthene Granite and Gneiss, Acid intermediate and Basic varieties
		Basic pyroxene granite
	Khondalite Suite	Quartz-Feldspar-Garnet-Silimanite schists and gneiss
		Garnetiferous Sillimanite, Quartzite Calc Silicate rocks
Base not Seen		

The crystalline complex representing Eastern Ghat Super Group consisting of Khondalite suite, Charnockite suite, Granite and Granite Gneisses, Metabascis, and veins of quartz and Pegmatite is exposed in the entire Gajapati district. Alluvium representing younger formations have restricted occurrence and the same is seen in the area as detached and isolated units **Figure *2.1***.

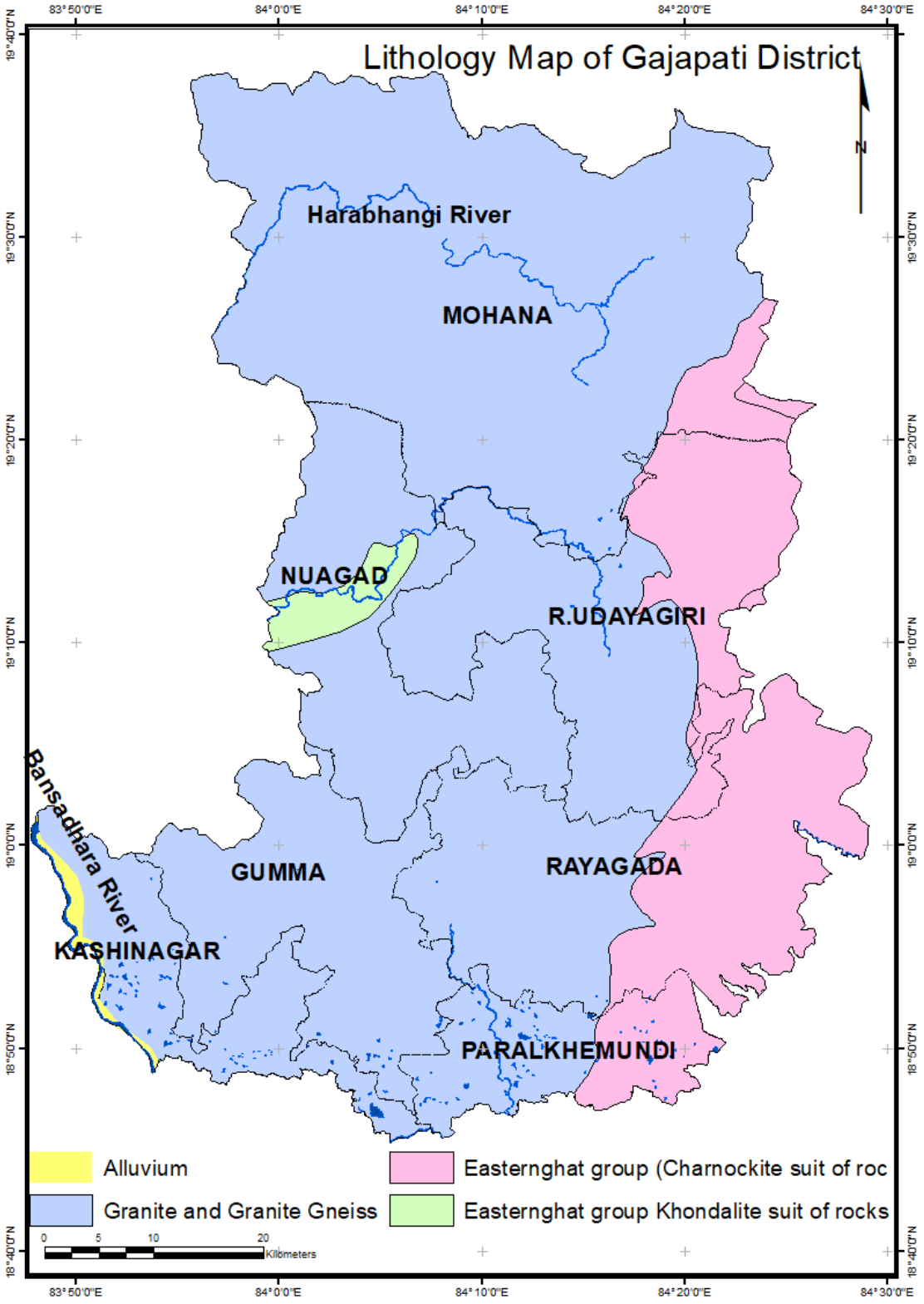


Figure 2.1 Lithology Map of Gajapati District, Odisha

2.1.1 Khondalite Suite of Rocks

These comprise quartz-garnet-sillimanite schists and gneisses and calc-silicate rocks. The typical Khondalites are reddish brown in colour with specs of pink or red garnets and sillimanite needles aligned to the schistosity of the rock units. Khondalites generally occur in the form of steep and rugged hill ranges. Another peculiarity of Khondalites is their scattered and sporadic occurrence. The foliations developed in Khondalites are almost always vertical and steep, the dip ranging between 76 and 80 degrees.

2.1.2 Charnockite Suite of Rocks

These occupy most of the hilly areas of the district and are more predominant than the Khondalites. These include acid, intermediate and basic Charnockites. They strike N35°E with vertical dips. These have undergone spheroidal weathering. The depth of weathering in the rocks ranges up to 15 m depending on the topographic situation. The Charnockite suite of rocks consists of hypersthene-granite and gneisses, pyroxene-granulites, amphibolites, etc. The hypersthene-granites are fine to medium-grained light grey to greenish grey in color, hard and compact. Amphibolites occurring as inclusions in garnetiferous granite gneiss are dark-colored, medium-grained having faint schistosity, Pyroxene granulites are dark-colored and medium-grained, occurring as bands, lenticles, etc.

2.1.3 Granite Gneiss

These are extensively found throughout the district and include garnetiferous granite gneiss, biotite gneiss of medium to coarse-grained. Granite gneiss in the area can be termed as Granodiorite Gneiss varieties. These rocks cover large areas occasionally forming high hill ranges, sometimes forming low residual hills and mounds and undulating plain areas. These are usually grey to light grey and fine to light grey and fine to coarse-grained in texture.

2.1.4 Pegmatite and Quartz veins:

The occurrence of small veins of quartz and pegmatite traversing the granite gneisses, charnockites and khondalites is an important feature. These exhibit criss-cross cutting relationships with the country rocks and are limited in occurrence. The quartz veins have been sheared and fractured at places. Due to limited extent and occurrence, they have of least significance from the groundwater point of view.

2.1.5 Laterite:

The sub-recent formation of the area is represented by some occurrence of brown to yellowish-brown laterite. The laterites occur as a cap rock over all kinds of formations like granite gneisses, charnockites, and khondalites in the undulating plains and low-lying areas as small patches. These are found below the soil cover with a depth ranging from 1.0 to 3.5 m. They are highly porous and permeable. The thickness of laterites usually varies from 3 to 20m.

2.1.6 Valley Fill Deposits:

They occur as narrow strips along with the stream courses and intermontane valleys. These are heterogenous comprising of pebble, gravel, coarse and fine sand, silt, and clay. The width of the stripes varies from 10m to less than a km. the thickness of the deposits ranges from a few centimeters to a few meters.

2.1.7 Residual Soil and Alluvium:

These comprise various grades of sand, gravel with subordinate silt, and clay. The occurrence is restricted to the southern parts of Gajapati district, on the southern bank of river Vansadhara, and along the other riverbanks. The thickness of the alluvium varies from less than a meter along the fringe of rock exposures to more than 10m and is largely controlled by the topography of the basement crystallines. The alluvium as discontinuous patches is also encountered along the major streams. The composition of the soil is largely controlled by the composition of rock types of the area. Soil derived from Khondalites is reddish-brown in color and rich in aluminum, Iron, and Manganese while that of acid charnockite and granite gneiss is more calcareous. Granite gneiss at places also produces sandy residual soil of a reddish-brown color. This color is due to richness in iron hydroxide which is derived from biotite and garnet. Extensive soil cover is also noted along the valley running N-S and in Gandahati and around Gurandi.

2.2 Structure

The district forms a part of the Eastern Ghats, and the regional trend of foliation is NNE-SSE. Banding is prominent in the Gneisses and Khondalites. Various sets of joints occur in different rock formations. The rocks have been sheared and mylonitised at places. The Khondalites and Charnockites are well foliated, while the charnockites are massive. All the rock types have multiple

sets of sub-vertical to vertical joints. The dip of the foliation of all rocks is very steep ranging from 70-90 degrees. The area is highly faulted due to orogenic activity. The faults of the area are of radiating pattern from a central high mass. From this, it appears that there was block faulting and upliftment in stages along the fault plains. Very steep high slope, the rocky basement of nalas flat top of hill ranges, rejuvenation of drainage pattern of the area support the idea of block faulting. The absence of lateritic caps over some of the hill ranges indicates that the lateritic caps have been eroded by the excessive drainage caused by the rejuvenation of the drainage pattern and this rejuvenation can take place only in case of mutual vertical displacement of the blocks relative to one another along fault plains.

2.3 Hydrogeology

Hydrogeologically the district can be divided into consolidated formations belonging to the Eastern Ghats, and unconsolidated alluvial formations occupying the southern parts of the district and along with the major river courses. The hydrogeological map of the area is presented in **Figure 2.2.**

In a major part of the district, groundwater occurs under phreatic and semiconfined conditions, the water is stored in the secondary conduits viz. weathered mantle, fractures, and joint planes, etc. Infiltration of atmospheric precipitation is the principal source of groundwater recharge. Besides other contributory sources are the seepage from irrigation canals, return seepage from applied irrigation, and seepage from the reservoirs. Most of the rainfall in the hilly terrain goes as surface run-off whereas, in the moderately undulating plains and valley areas, rainfall contributes significantly to the groundwater recharge to form potential aquifers under favourable conditions.

2.3.1 Water Bearing Formations

A. Consolidated and Fissured Formation

Except for small strips along with major drainage courses, almost the entire district is occupied by consolidated formations comprising of Granite gneiss, Quartzites, Charnockites, and Khondalites. These rocks are very hard and compact and lack primary porosity. Groundwater is stored mainly in the secondary porosity resulting from weathering and fracturing of rocks. Weathering plays an

important role in groundwater occurrence and movement in these rocks. Under favorable conditions, the weathered residuum forms a potential phreatic aquifer. The fissures and joints, when interconnected depending on the extent, size, openness, continuity form potential groundwater repositories at favorable locales. Groundwater occurs under water table conditions in the weathered zones while it occurs under semi-confined conditions in the deeper fracture zones. The topography, extent of weathering, and development of joints and fractures contribute immensely towards the occurrence, storage, and movement of groundwater in the consolidated formations. Community dugwells and the bore wells fitted with hand pumps exist in the district for rural water supply. The water level in the dugwells depletes in peak summer and quite often wells support little columns of water which prelude heavy drawal of water. Usually, two to four water-bearing fracture zones occur down to a depth of 100 m bgl.

2.3.1.1 Granite Gneiss and Its Variants

Granite Gneiss constitutes one of the major hydrogeological units in the district forming undulating terrain dotted with hills, typically of Eastern Ghat topography. On weathering, these rocks yield loose kaolinized sandy residuum. The weathered zone acts as a good repository of groundwater and can be developed through dugwells and bore wells. These rocks are weathered to form a heterogeneous mixture of clayey and granular materials ranging in depth from 5 to 15m depending upon the mineralogical composition and topography. The well foliated and jointed nature of these rocks has largely controlled and accentuated the weathering process. The groundwater potential of this unit is quite significant because of the open nature of joints and the porous nature of the weathered residuum. The irrigation wells are constructed with a large diameter in the topographic lows. The yield of dugwells in the formation generally ranges from 0.5 to 3 lps and that of dug-cum-borewell ranges up to 5 lps. In general, these rocks can sustain yield from 2 to 10 lps depending on the topographic setting, the thickness of the weathered residuum, the number of saturated fracture zones encountered, and their interconnection.

2.3.1.2 Charnockites

This is one of the predominant rock types occurring extensively in the eastern hilly parts of the district mostly in the Rayagada and R Udayagiri block. Charnockite generally form hilly terrain but at places occur as undulating terrain dotted with hills. The weathering in these rocks is neither uniform

not extensive, the thickness of weathered mantle ranges from 10m to 30m depending upon the topographic setup. The groundwater potential of this litho unit is poor. The specific capacity of Dugwells varies from 10 lpm/m to 37 lpm/m. Borewells yield less than 1 lps.

2.3.1.3 Khondalites:

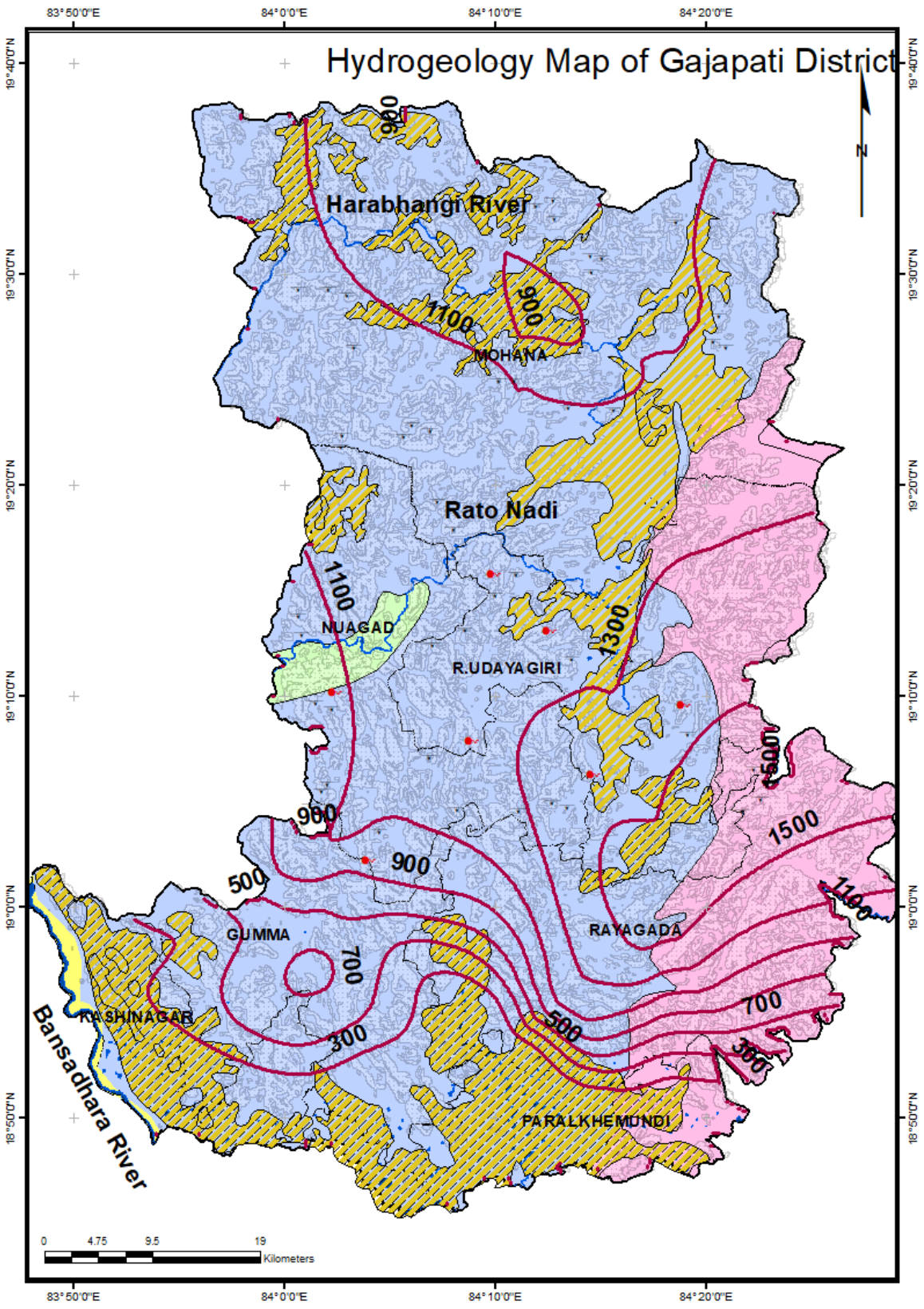
These rocks generally form undulating hilly terrains. Moderately weathered rocks exhibit the development of porosity with moderate water yielding capacity. Intensive weathering results in the formation of kaolin reducing permeability. The depth of weathering varies from 8 m to 30 m. The yield of borewells is poor and less than 3 lps in dugwells and 5 lps in dug cum borewell.

2.3.1.4 Quartzites:

These rocks occur as distinct bands and are very resistant to weathering. The weathered mantle is thin and joints are less developed. As such these rocks do not form good aquifers.

2.3.1.5 Pegmatite and Quartz veins:

These are coarse-grained and hard. These form good aquifers when fractured and friable. The contour lines in the hydrogeology map depict the water table above the mean sea level. The general slope is of the groundwater table is towards the south. The area where there is the scope of groundwater development through various groundwater abstraction structures is also evident in the map. The area is mostly valley fills, buried pediments, and where there is conspicuous thick weathered sediment.


Hydrogeology Map of Gajapati District
83°50'0"E
84°0'0"E
84°10'0"E
84°20'0"E
19°40'0"N
19°30'0"N
19°20'0"N
19°10'0"N
19°0'0"N
18°50'0"N
N
Harabhangi River
MOHANA
Rato Nadi
NUAGAD
R.UDAYAGIRI
RAYAGADA
GUMMA
KASHINAGAR
PARALKHEMUNDI
Bansadhara River
900
1100
1300
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0
4.75
9.5
19
Kilometers

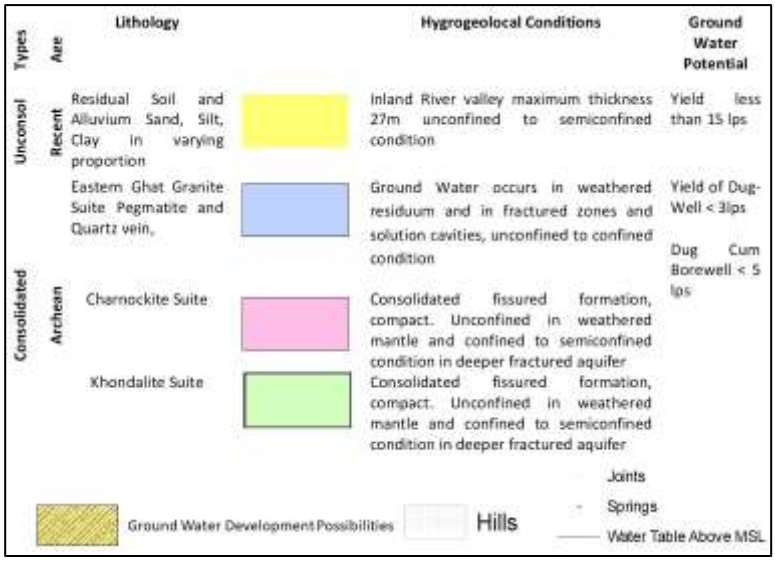

Figure 2.2 Hydrogeology map of Gajapati District, Odisha

B. Unconsolidated Formation

They generally comprise Laterites, Alluvium and Valley fill deposits.

2.3.1.6 Laterites and Alluvium:

Laterite and alluvium of sub recent to Recent age constitute the unconsolidated formation. laterites occurring as capping over older formations are highly porous and form good aquifers to be tapped through dug wells. The alluvial deposits of recent origin occur as discontinuous patches along the prominent drainage channels and particularly in the flood plains of the Vansadhara river. These deposits mainly consist of silt, sand with gravel, and attain a thickness of about 10 to 26m in the flood plains. The yield of the shallow tube well is up to 15 lps. Thick alluvial patches occur along major nalas where the thickness varies from 10 to 27 m. These comprise coarse sand with gravels and pebbles mixed with silt and clay. The specific capacity index of the dug wells in this formation varies from 4 lpm/m/m2 to 9 lpm/m/m2.

2.3.1.7 Valley Fill Deposit:

They occur as narrow strips along with present and old river channels in the rugged topography. These are essentially coarse sediments comprising pebble, gravel, and sand which are highly permeable. The thickness of the sediments varies from a few meters to 15 m whereas the same

extends laterally from a few meters to up to 1 km. The specific capacity index varies from 3 lpm/m/m2 to 40 lpm/m/m2.

2.4 Groundwater Exploration

Exploratory drilling has been taken up by the Central Groundwater Board in the southern part of the Gajapati district to delineate deeper water-bearing fractures in the consolidated formation and their yield potentiality within a maximum depth of 200m. Only 4 exploratory and 2 observation wells have been drilled under the groundwater exploration program by Central Ground Water Board. All the wells under the groundwater exploration program were built in Granite gneiss. The depth of the wells drilled ranges from 80.2 to 185.6 m and yield varies from 2 lps to a maximum of 14 lps. The weathered zone is on average, 28m thick and the longest casing length required was 36 m at Paralakhemundi. On average 2-3 sets of fracture zones are encountered which are generally restricted to about a maximum of 80m depth. A very high discharge well is located at Kasinagar (7 lps). The yield of the rest of the two wells are 2 lps and 2.3 lps respectively.

Exploratory wells and observation wells are shown in **Figure 2.3**. In the consolidated formations the piezometric heads of the deeper water-saturated fracture zones are broadly co-relatable with the water table elevations, thus indicating that the weathered and fractured zones within a depth of about 50 m, acts as a single aquifer system occurring under phreatic or near phreatic condition. The deeper aquifers are hydraulically interconnected with shallow weathered zones. To decipher the aquifer characteristics WAPCOS has drilled 10 exploratory wells and 1 observation wells in the district. The depth of the wells is 200m in each location except in Cheligada. The weathered zone varies from 12 m to 50.3m. The yield of the wells varies from 0.4 lps to 13 lps (Cheligada). The detail of the exploratory programme is summarized in **Annexures *I***. 49 number of exploratory drillings conducted by Rural Water Supply and Sanitation, Govt of Odisha were collected to study the aquifer disposition in vertical and horizontal directions.

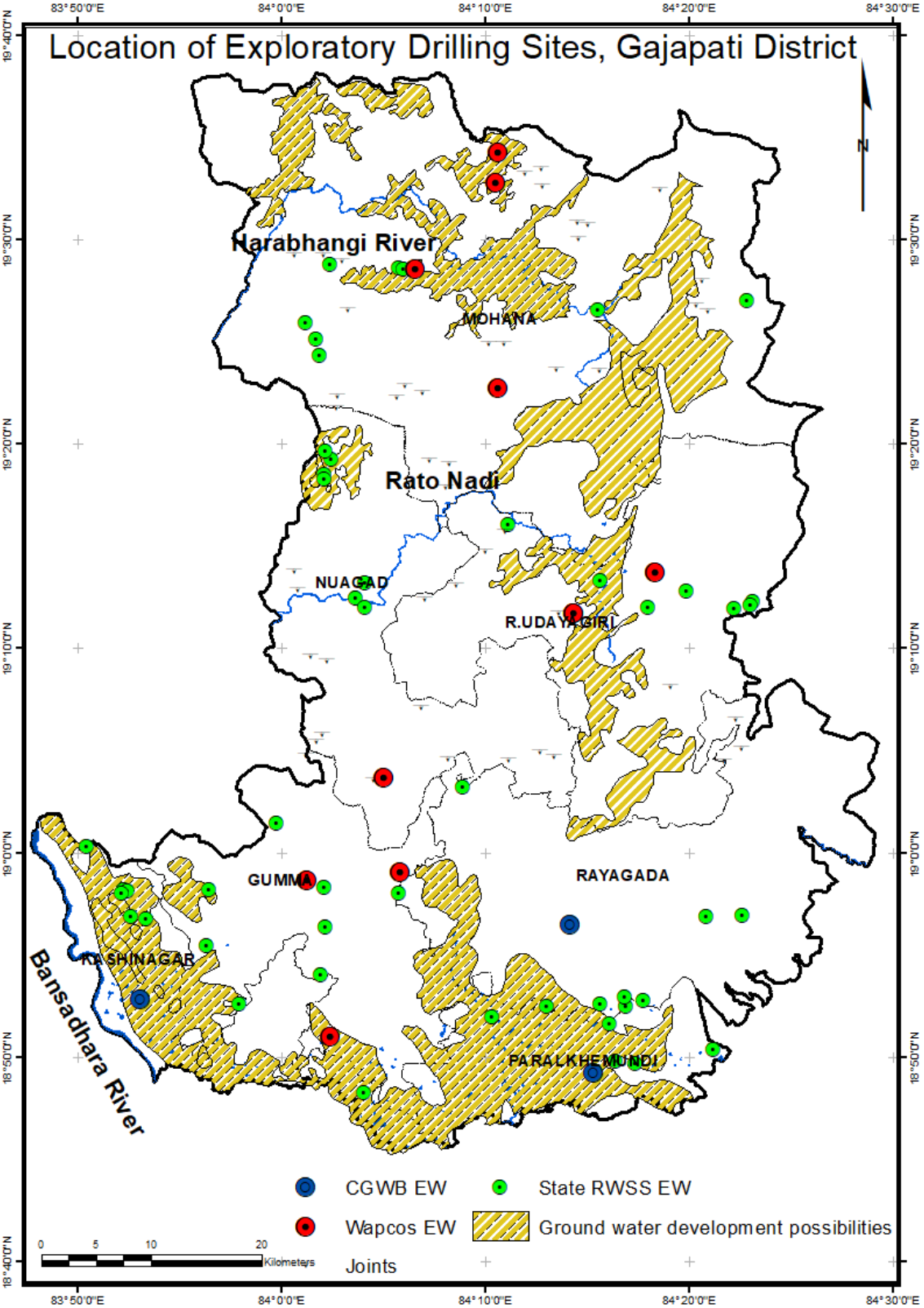

Figure 2.3 Location of Exploratory wells

2.5 Monitoring of Groundwater Regime

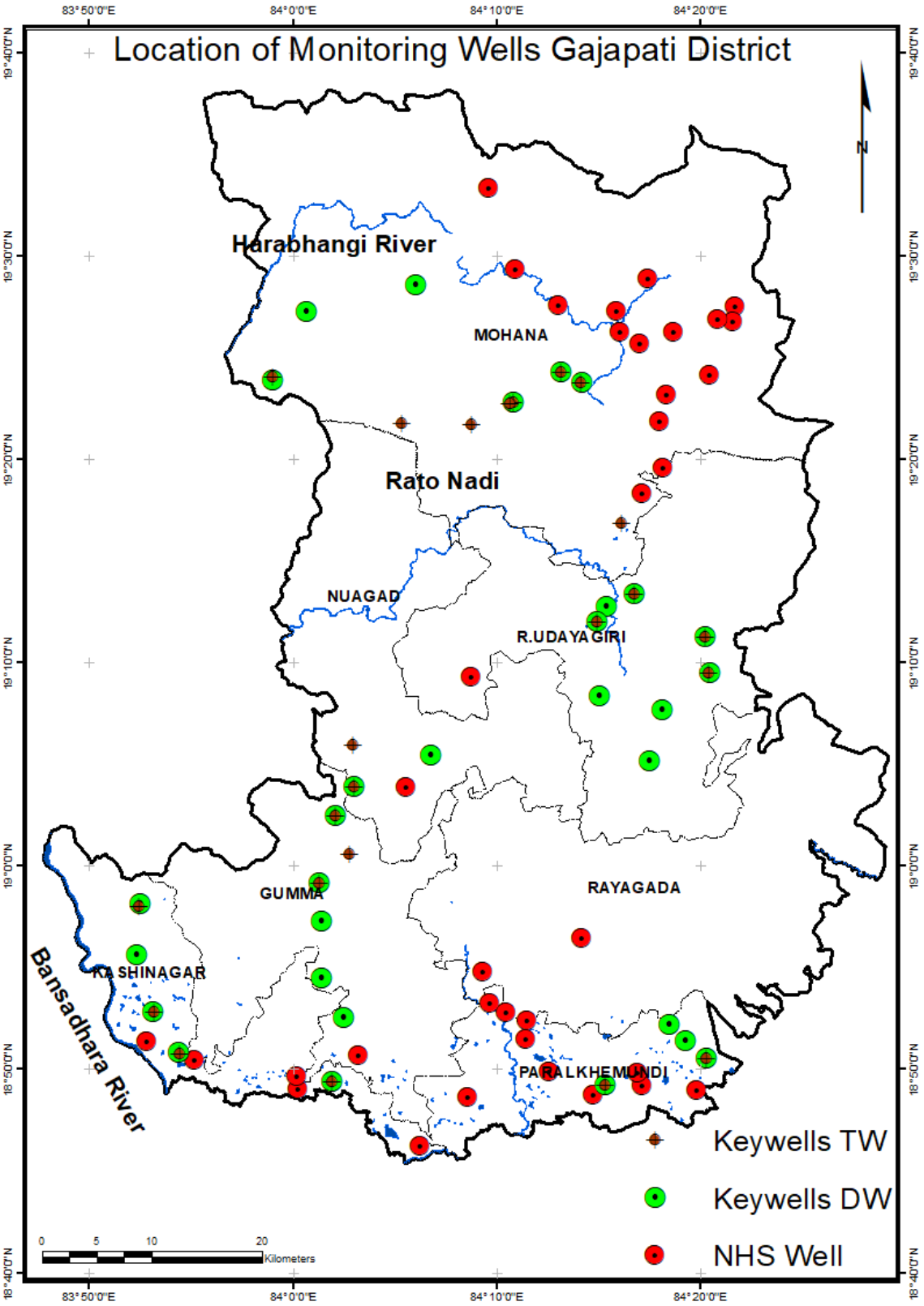

Figure 2.4 Location of Monitoring wells Gajapati District

Under NAQUIM program, the groundwater regime of the phreatic aquifer was monitored during pre-and post-monsoon periods in the year 2019-20 in 37 National Hydrograph Network Stations (NHNS), 31 Key Observation wells (dug wells) in 2020-21, and 2 wells from the State Groundwater Department ***Annexures II***. The data collected through field investigation were used for the analysis and interpretation of water level contour patterns in the district. The details of the monitoring wells stations are shown in **Figure 2.4**. The chemical quality of groundwater in the district is monitored annually on a routine basis by CGWB through its National Hydrograph Network Stations. During the NAQUIM programme, 49 water samples were collected from the key monitoring wells and the result of their chemical analysis is shown in ***Annexures III*****.**

3.0 DATA INTERPRETATION, INTEGRATION, AND AQUIFER MAPPING

3.1 Shallow Aquifer

Groundwater occurs in the phreatic condition in shallow aquifers and is utilized through dug wells or shallow tube wells. The depth of the dug wells used as observation points vary from 4.5 to 15 mbgl and their diameter ranges from 0.8 m to 4.60 m. The wells are generally lined to the total depth of the well.

3.1.1 Pre-monsoon Depth to Water Level

Depth to the water level in the pre-monsoon period (May 2019) varies from 1.86 m bgl (Gosani) to 15 m bgl (Ramagiri), the average being 5.68 m bgl. In general, the study area has the depth to the water level in between 4 to 8 m bgl during the pre-monsoon. Waterlogging condition (<3 m bgl) is found in very few locations during the pre-monsoon. The shallower water level of 2-4 m bgl is observed in Paralakhemundi and Mohana blocks. Deeper water levels (> 4 m bgl) are found mostly in almost all the blocks. The locations where the depth to water level more than 8 m bgl are found in 12 locations in Kasinagar, Gumma, R Udayagiri, Rayagada and Nuagada Blocks. The pre-monsoon depth to water level map is shown in **Figure 3.1.**

3.1.2 Post-monsoon Depth to Water Level

Depth to the water level in the post-monsoon period (Nov-2019 and 2020) varies from 0.21 m bgl (Mandimera, Mohana block) to 7.53m bgl (Tarabada, Nuagada block), the average being 2.60 m bgl. The depth to the water level of the study area during post-monsoon is in general within 4 m bgl. The areas in the valleys have a shallow water level of less than 3 m bgl. At 12 locations the depth to water level is more than 4 m bgl in the blocks of Nuagad, Rayagada, R Udaigiri, and Gumma. The post-monsoon depth to water level map is shown below in **Figure 3.2.**

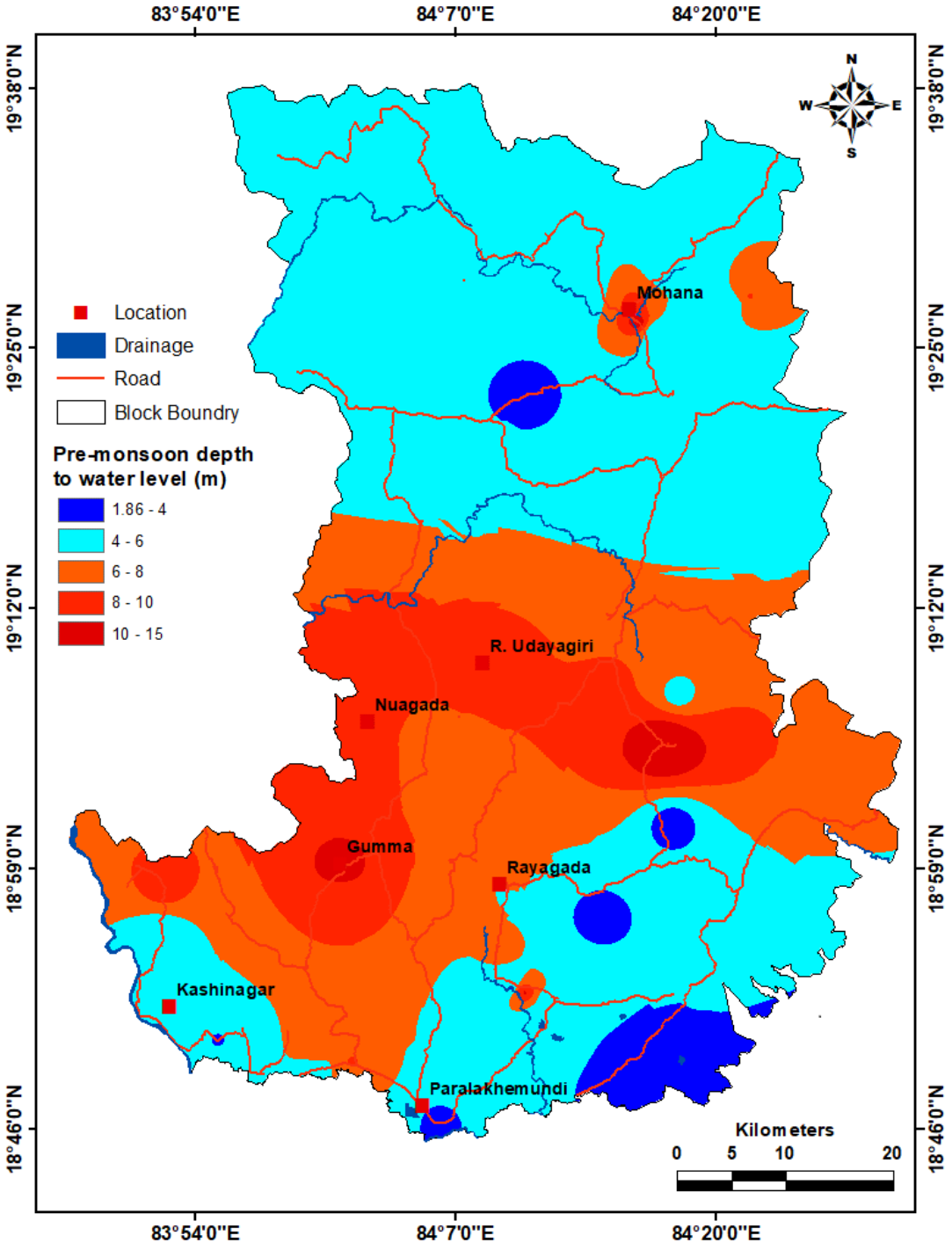

Figure 3.1 Pre-Monsoon DTWL Map in mbgl (Phreatic Aquifer)

3.1.3 Seasonal Fluctuation of Water Level

Fluctuation of groundwater table between pre- and post-monsoon period in the study area varies from 0.35 (Tumbagarh, Rayagada) to 9.81(Ramagiri, R. Udayagiri) m bgl, the average being 3.19 m.

The general range of fluctuation in water level in the study area is between 2-4m. These are generally found in all parts of the district covering parts of each block. The locations where the fluctuation of water level is more than 5 m bgl are Kesapur, Gumma block, Singipur and Allada in Kasinagar block, in Luhagada, Ladurma and Mohana in Mohana block, in R. Udayagiri and Randiba in R Udayagiri block, and in Sebakpur in Rayagada block. The shallow post-monsoon water level along with fluctuation pattern indicates that the annual replenishment of phreatic aquifer due to monsoon rainfall is adequate in the district but deeper summer level is due to rapid dewatering of the phreatic aquifer due to steep gradient towards the rivers which surround three-quarter of the district. The seasonal fluctuation of the water level of Aquifer-I is shown in **Figure 3.3.**

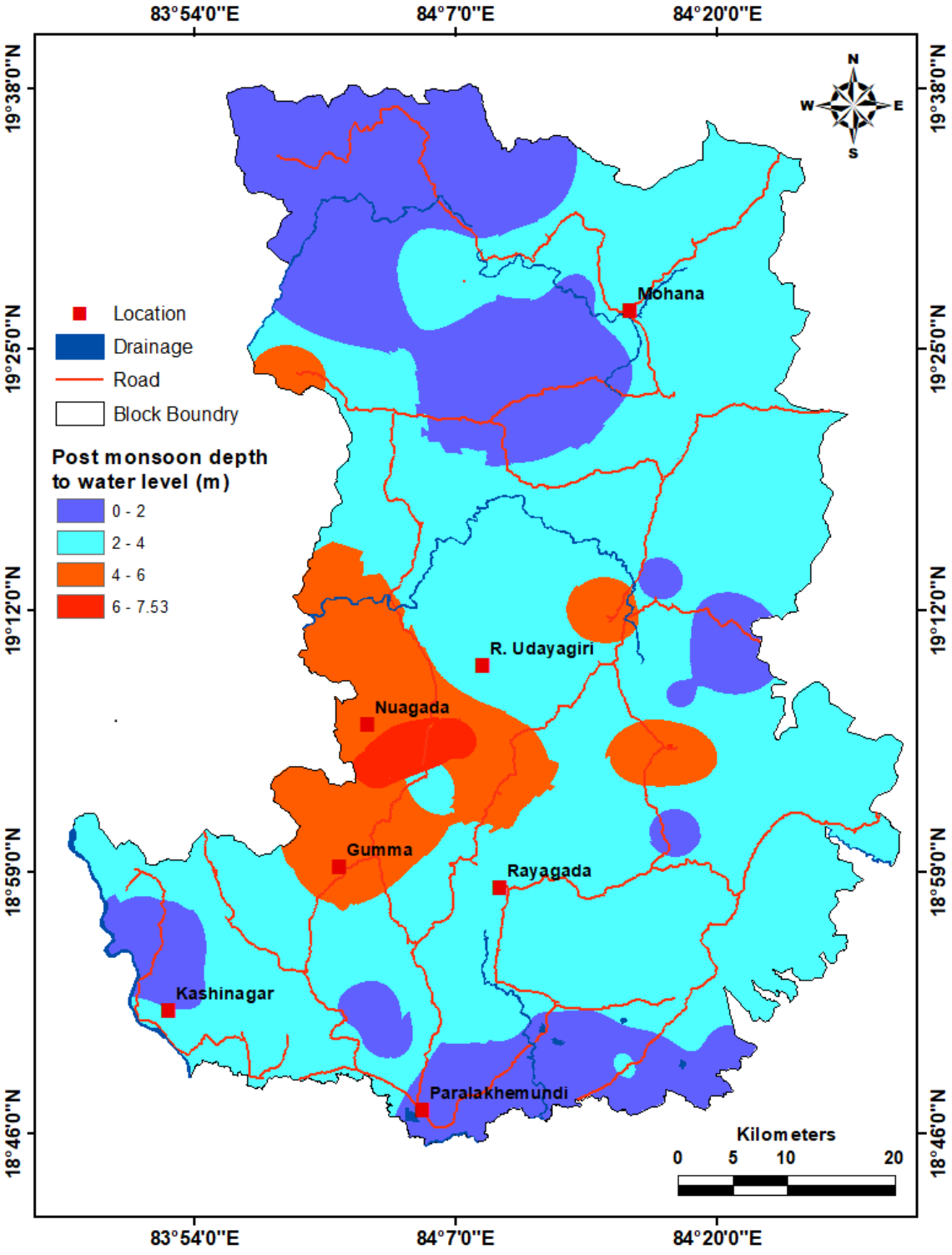

Figure 3.2 Post-Monsoon DTWL in mbgl (Phreatic Aquifer)

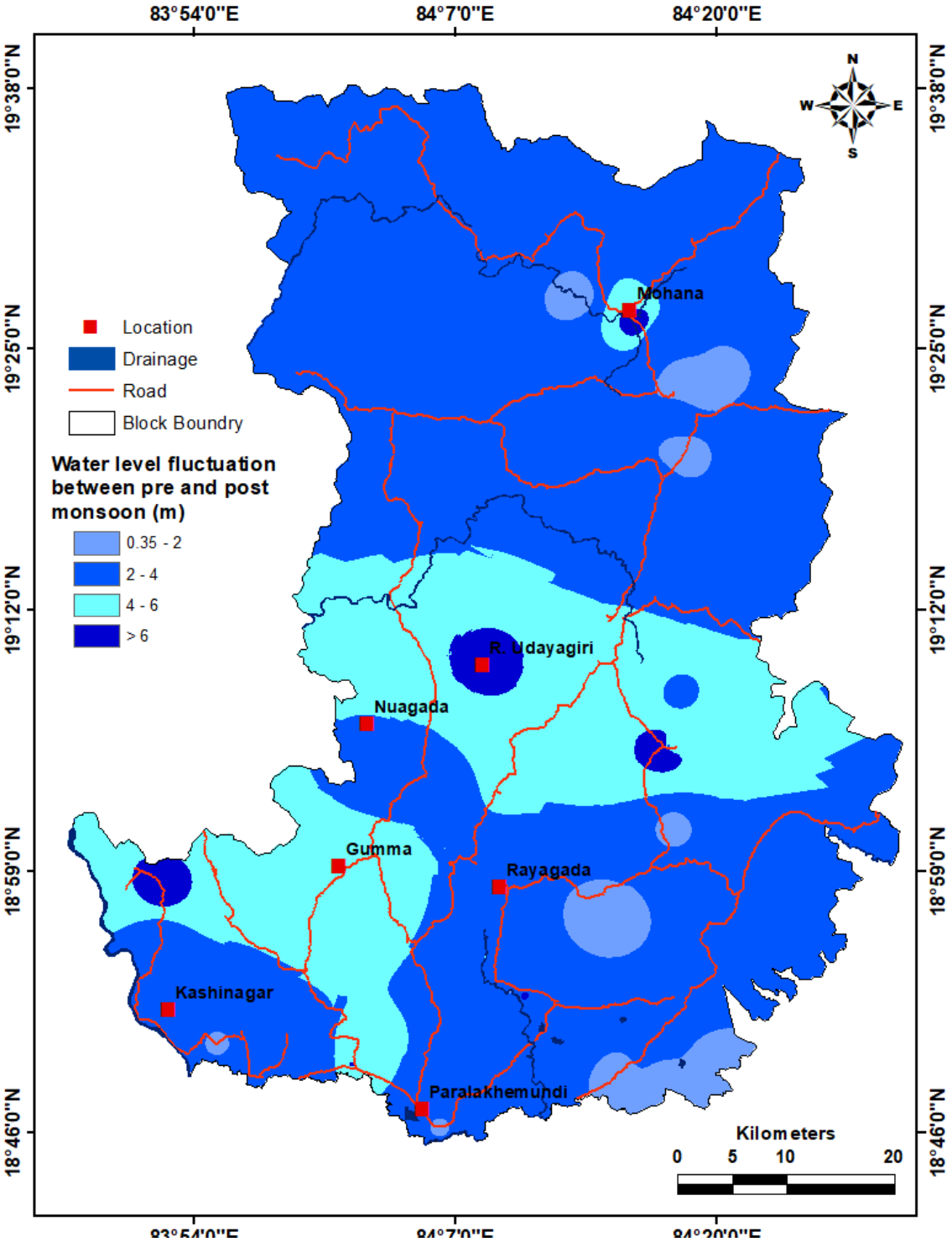

Figure 3.3 Seasonal Fluctuation mbgl in Phreatic Aquifer

3.1.4 Decadal Water Level Trend

There are 26 National Hydrograph Station (NHS) in the district, the data from which are considered for analysis of long-term decadal trend for the period 2010-2019. The decadal trend of water level

for both pre-monsoon and post-monsoon periods was analyzed. The results of trend analysis have been shown in **Table 3.1**. The long term trend analysis indicates that out of 26 stations, 10 (41.6%) show a rising trend and the rest 14 stations (58.3%) show a falling trend in the Pre-monsoon season and 7 stations (31.8%) show a rising trend and 15 stations (68.1%) show a falling trend in post-monsoon seasons. The area around Chandiput, Chandragiri, Kirama, Santinagar, Rayagada have shown a significant falling trend ranging from 20-90 cm/year. In all other stations the extent of fall is not significant.

Table 3.1 Decadal Water Level Trend Analysis of CGWB NHS (period 2010-2019) in Gajapati District.

Sl No.	Location	PREMONSOON		POSTMONSOON	
		Trend(m/yr)	Remark	Trend(m/yr)	Remark
1	Adaba	-0.0061	Fall	-0.0805	Fall
2	Bada Khoni	0.5272	Rise	-0.1397	Fall
3	Chandiput	-0.8707	Fall	-	-
4	Chandragiri	-0.4035	Fall	-	-
5	Dantarinalo	0.3106	Rise	0.1076	Rise
6	Garabandh	0.2791	Rise	0.0482	Rise
7	Gosani	-0.2946	Fall	-0.0637	Fall
8	K Sitapur	0.0563	Rise		
9	Kantragada	-0.2851	Fall	-0.2221	Fall
10	Kasinagar	-0.1089	Fall	-0.1017	Fall
11	Kattalakanita	0.2671	Fall	-0.0030	Fall
12	Kirama	-0.4400	Fall	-	-
13	Ladruma	-0.0338	Fall	0.4188	Rise
14	Lavanya Khotta	0.1439	Rise	-0.0679	Fall
15	Luhaguda	0.0468	Rise	-0.0066	Fall
16	Madhura-Amba	-0.0391	Fall	-0.3502	Fall
17	Minigaon	-	-	0.1842	Rise
18	Mohana	0.3970	Rise	-0.1470	Fall
19	Narayanpur	0.0134	Rise	-0.0749	Fall
20	Parasamba	0.0206	Rise	0.2151	Rise
21	Parlakhemundi	-0.0782	Fall	-0.0984	Fall
22	Pegoda	-		0.472	Rise
23	Raygarh	-0.3978	Fall	-0.0980	Fall
24	Santhi Nagar	-0.6533	Fall	-0.0248	Fall
25	Taramala	-0.1577	Fall	-0.0830	Fall
26	Tattipati	0.1003	Rise	0.0553	Rise
Gajapati District	Total Rise and Fall	Rise	10	Rise	7
		Fall	14	Fall	15
			24		22

3.1.5 Hydrograph analysis

The hydrographs of 12 groundwater monitoring stations from different blocks under NAQUIM in Gajapati district were analysed (

Figure *3.4*- Error! Reference source not found.). In short term and long term, the water levels vary depending on the rate of natural recharge from rainfall and the groundwater withdrawal to meet the requirements in domestic, agriculture and industry. The analysis of hydrographs shows that the annual rising limbs in hydrographs indicate the natural recharge of groundwater regime due to monsoon rainfall, as the monsoon rainfall is the only source of water. The recession limbs indicate the combined effect of baseflow and the groundwater draft for various uses.

Though, the hydrographs a few locations during either/or both the pre- and post-monsoon periods exhibit rising trends in water levels, at several locations they show downward declining trend. It indicates that the groundwater resources are not replenished or recharged fully and the groundwater levels are under continuous stress and depleting at several locations. It has also been observed that there were few years when the recharge exceeded draft for a particular period or year but in the next successive year, the draft again exceeded recharge.

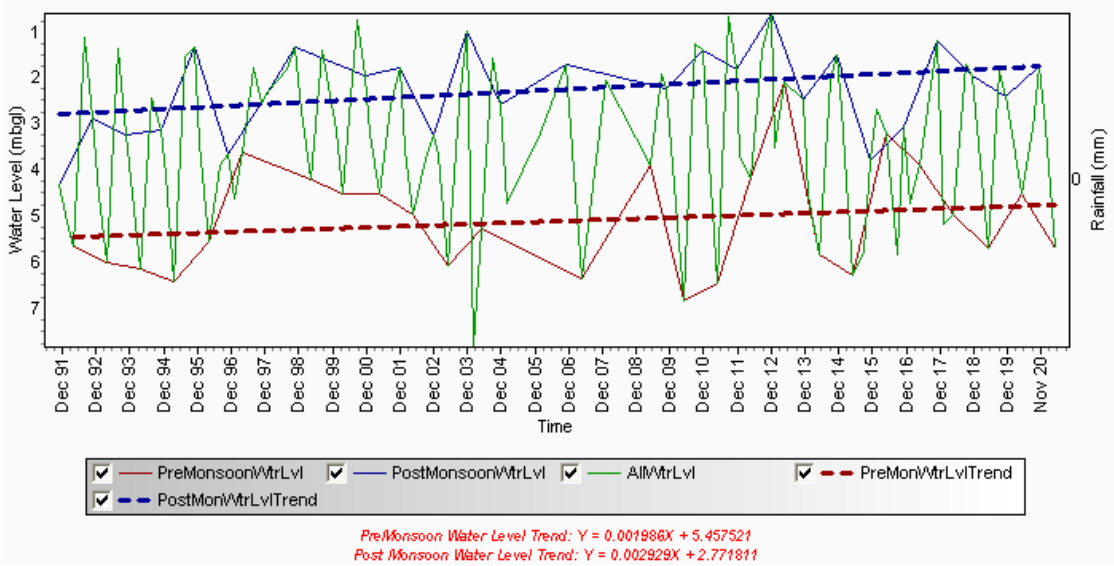

Figure 3.4 Hydrograph of Kasinagar, Kasinagar Block, Gajapati district

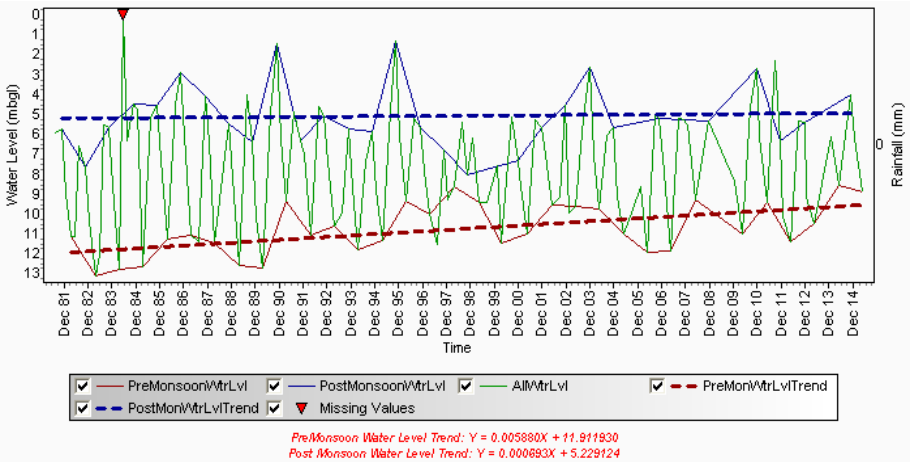

Figure 3.5 Hydrograph of Chandragiri, Mohana Block, Gajapati district

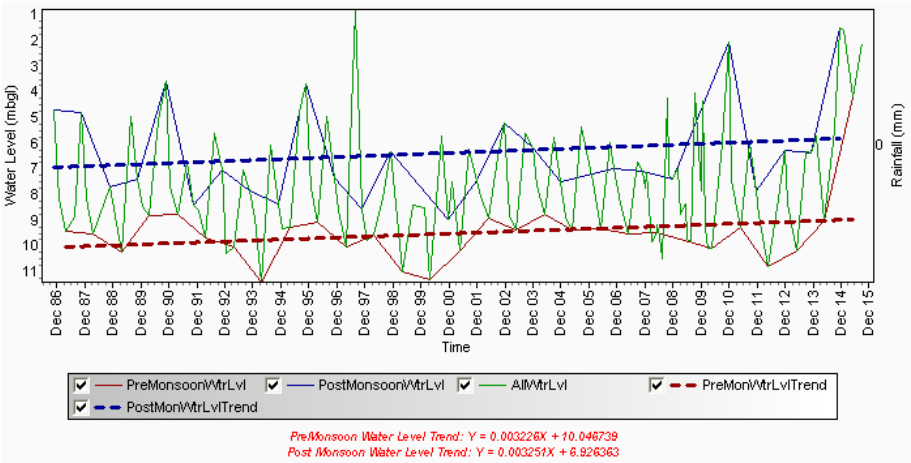

Figure 3.6 Hydrograph of Chandiput, Mohana Block, Gajapati district

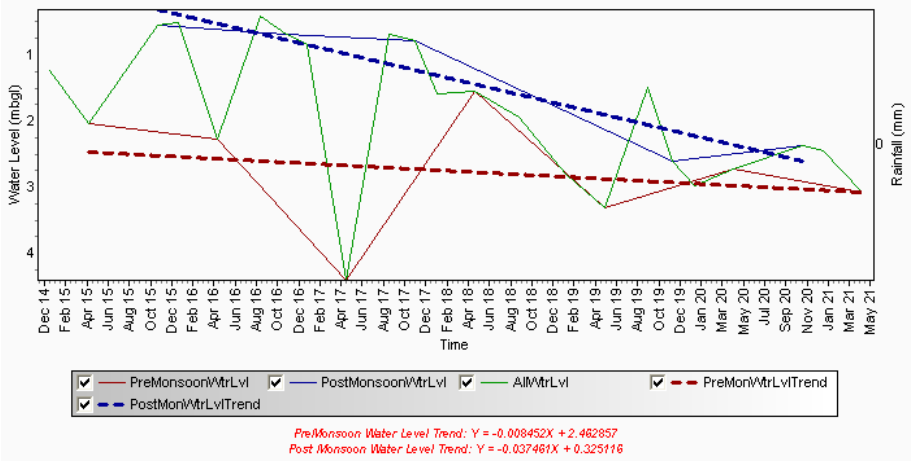

Figure 3.7 Hydrograph of Lilygada, Mohana Block, Gajapati

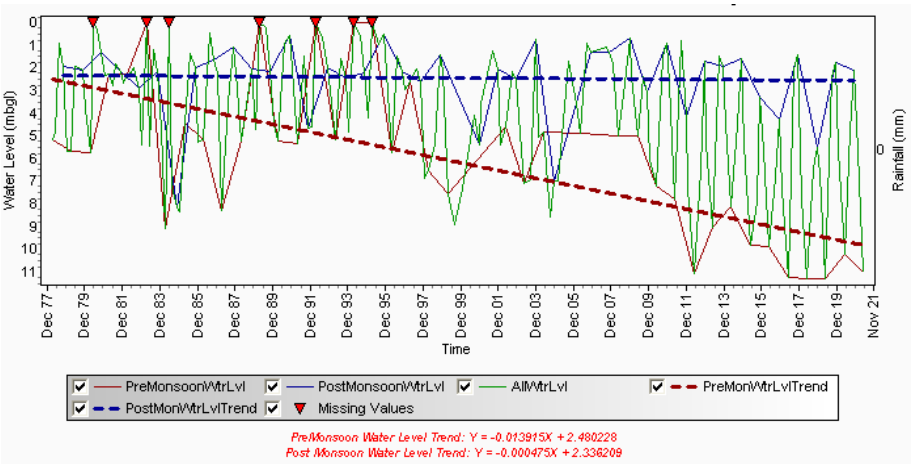

Figure 3.8 Hydrograph of Mohana, Mohana Block, Gajapati

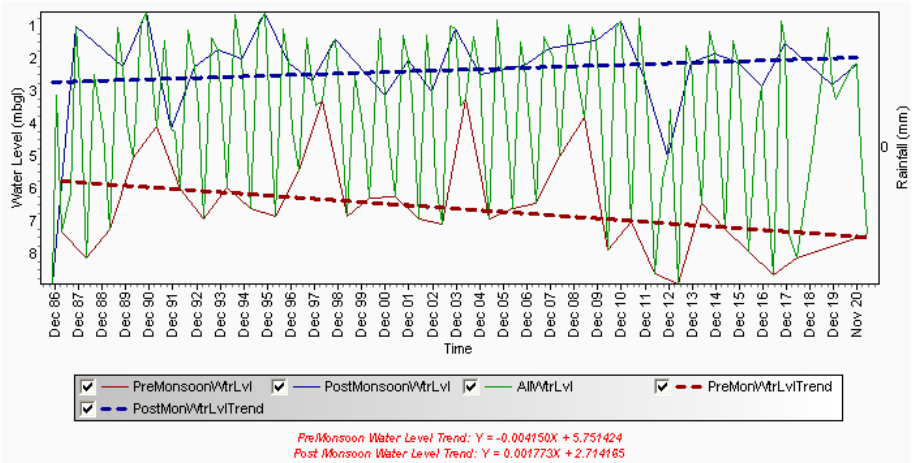

Figure 3.9 Hydrograph of Chandiput, Mohana Block, Gajapati district

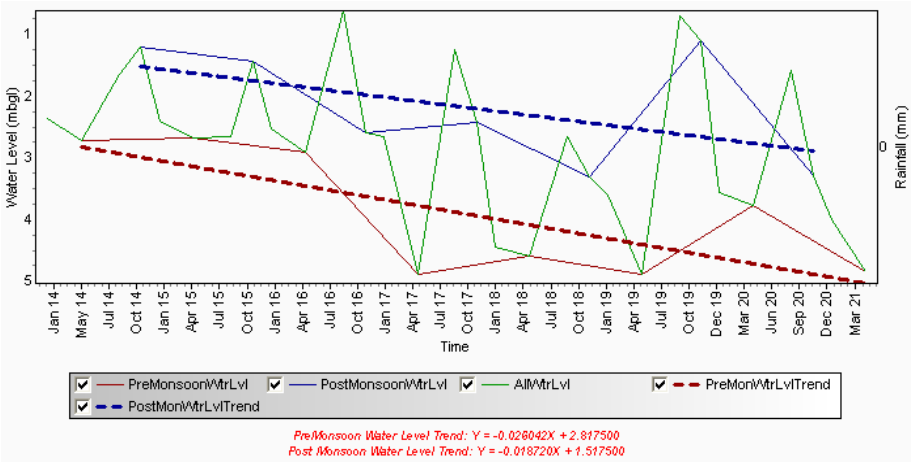

Figure 3.10 Hydrograph of Badakhoni, Mohana Block, Gajapati district

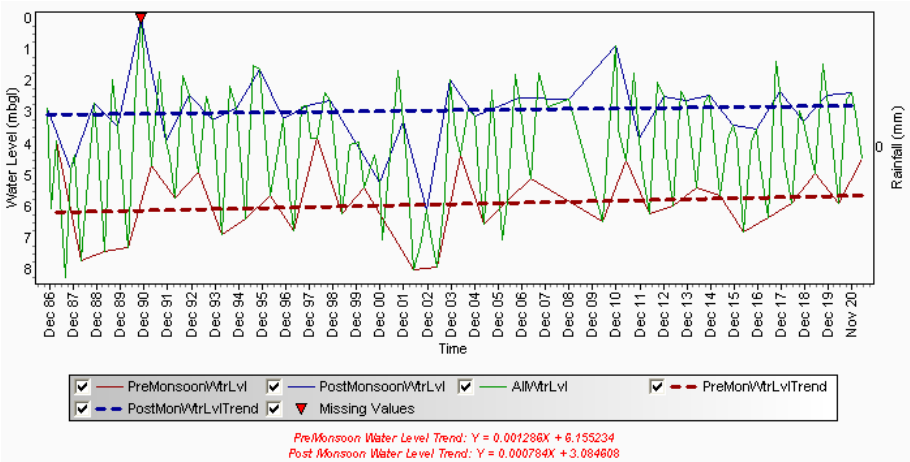

Figure 3.11 Hydrograph of Adaba, Mohana Block, Gajapati district

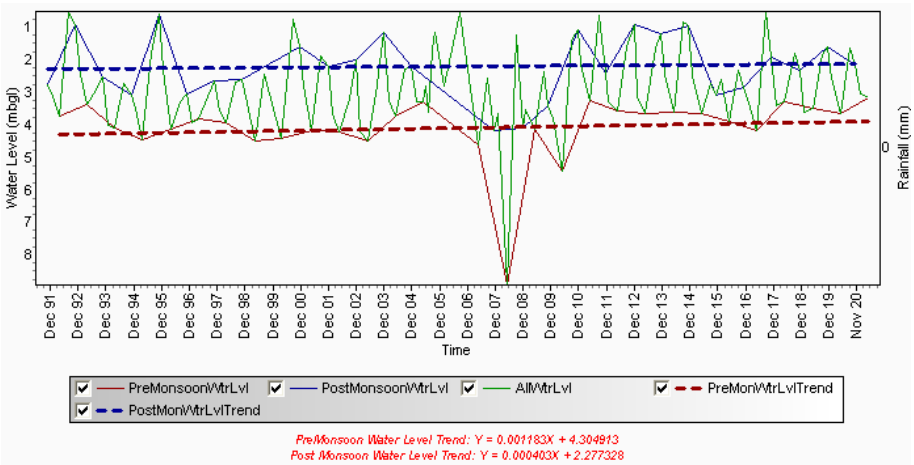

Figure 3.12 Hydrograph of Paralakhemundi, Paralakhemundi Block, Gajapati district

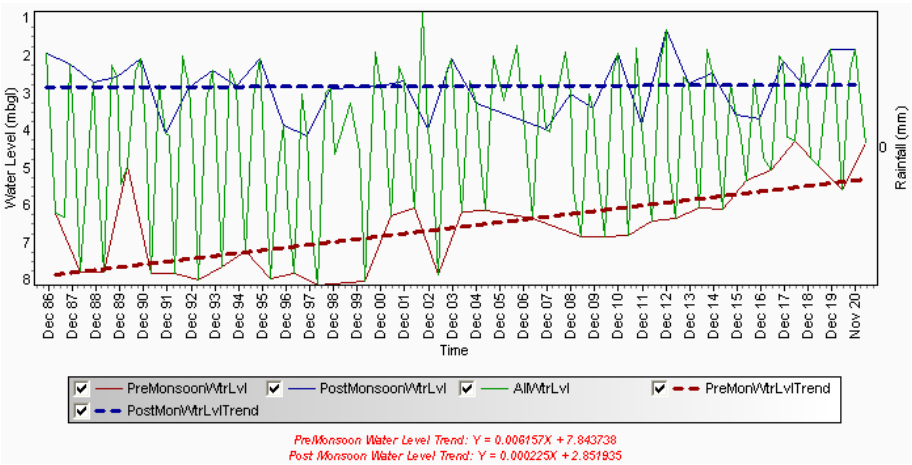

Figure 3.13 Hydrograph of Kattalakanita, Paralakhemundi Block, Gajapati district

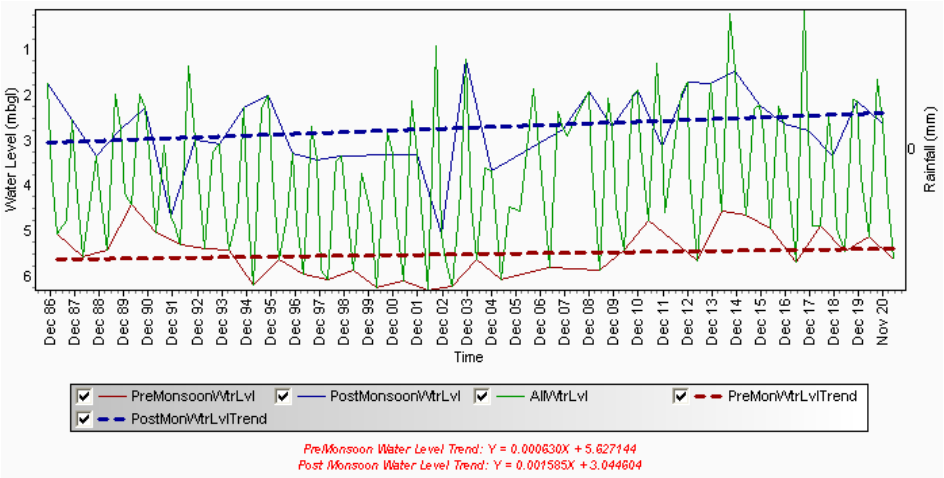

Figure 3.14 Hydrograph of Narayanpur, Paralakhemundi Block, Gajapati district

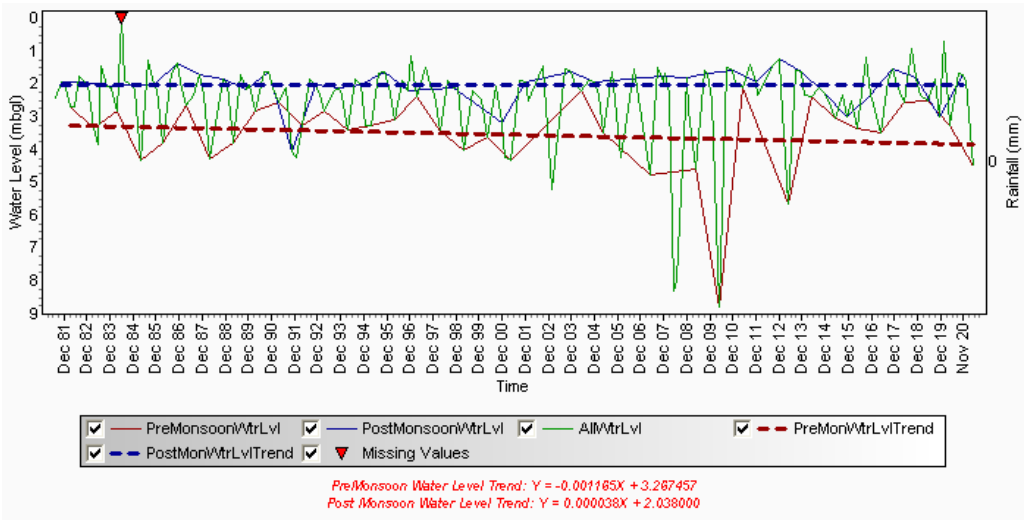

Figure 3.15 Hydrograph of Rayagarh, Paralakhemundi Block, Gajapati district

3.1.6 Aquifer Characteristics of Phreatic Aquifer

The pumping tests were conducted on selected dug wells representing different hydrogeological units and the aquifer characteristics were evaluated in terms of transmissivity and storativity value. **Table 3.2** summarises the aquifer characteristics of the phreatic aquifers. The wide range of yield is due to the heterogeneous nature of the weathered zone in lateral extension as well as the variation of thickness of this zone.

Table 3.2 Aquifer Characteristics of Major Hydrogeological Units in Gajapati District

Sl. No	Hydrogeological Unit	Aquifer Characteristics
1	Weathered Granite Gneiss	<2 lps Dugwells, < 5 lps Tube wells
2	Weathered Charnockite	2 to 3 lps
3	Khondalites	1 to 2 lps
5	Valley Fills	3.0 to 9 lps
6	Alluvium	Yield: 15-25 lps

3.2 Deeper Aquifer

Unlike phreatic aquifer, groundwater occurs under confined to semi-confined conditions in the deeper aquifer. The deeper aquifer comprises the jointed and fractured consolidated or crystalline formations. In general, it is confined on top by weathered formations and bottom by massive rocks.

CGWB has constructed 4 EW and 2 OW in the Gajapati district through its Groundwater Exploration Programme, whose depths range from 80 m bgl to 185 m bgl. The static water level varies from 2.19 m bgl to 9.75 m bgl. The discharge of successful borewells varies from 2.3 lps to a maximum of 14 lps. The drawdown varies from 6.8 m to 29 m. WAPCOS Ltd. Has constructed 10 EW and 1 OW for CGWB at various locations mostly in the areas that were not explored by CGWB exploratory program. The depth of the exploratory wells by WAPCOS is up to 200m bgl. Two wells at Deraba (R.Udayagiri) and Majhi Kirimba (Mohana) are found to be dry as no aquifer zones were encountered. The weathered thickness varies from 12 to a maximum of 50m bgl at Kurludunga in Gumma block. The static water level varies from 0.22m bgl to 13.35m bgl. The discharge of the wells varies from 0.4 lps (Kurludunga, Gumma) and 13.35 lps at Chelligada (R.Udayagiri).

The transmissivity (T) of the aquifers ranges from 0.41 m^2/day (Birikote, Mohana) to 177 m^2/day (Chelligada) and the storativity value was recorded as 6.80x10-4 at Chelligada. The details of the exploratory wells are given in **Annexures I**. Generally, 1 to 4 potential fracture zones are encountered within the depth range of 200 m bgl. The first promising zone occurs in the depth range of 15 to 35 m bgl, which is just below the zone of weathering. The depth range of prime importance is from 40 to 100 m. Normally, the fracture zones in this depth range have high water yielding

capabilities, and the majority of successful bore wells in the study area tapped zones within this depth range. Granitic suite of rocks have more promising aquifers in comparisons to other rocks like Charnockites and Khondalites. However, the success of bore wells is site-specific and depends on topographic and hydrogeological conditions.

3.3 Groundwater Quality

The quality of groundwater is an important factor for assessing its suitability for various uses in drinking, irrigation, and industrial activities. Groundwater quality depends upon the lithological and chemical composition of the aquifer, climatic conditions, quantum of recharge and its movement through the aquifer, rock-water interactions, and activities of micro-organisms, temperature, and presence of contaminants in the environment. The chemical quality of groundwater in the district is monitored annually on a routine basis by CGWB through its national Hydrograph Network Stations. The quality of groundwater from deeper aquifers was assessed during the exploration activities like drilling and pumping tests. The suitability of groundwater for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water. Taking the results of chemical analysis during NAQUIM work and the available historical chemical data, the aquifer wise ranges of different chemical constituents present in ground water, are determined and shown in **Table 3.3.** 26 samples were collected from shallow dug wells and 22 samples were collected from tube wells ranging from a depth within 100 m bgl.

Based on the chemical analysis of water samples from different sources, it was observed that almost all chemical parameters lie within the permissible limit for drinking and irrigation purposes except few samples of some isolated pockets. The maximum permissible limit for NO3 concentration is 45 mg/l. In most of the cases, it is well within the maximum permissible limit and in a few samples as per **Table 3.4**, the concentration reported marginally above the maximum permissible limit.

The quality of groundwater from deeper aquifers is assessed during the drilling and pumping tests. The chemical data of 28 water samples collected during the exploration is given in ***Annexures IV*****.** The details chemical analysis of the NHS wells collected during 2019 is shown in ***Annexures V*****.**

Table 3.3 Aquifer-Wise Ranges of Chemical Constituents in Gajapati District

Parameters (Major ions in mg/L)	Shallow Phreatic Aquifer		Deeper Aquifer		Standards	
	Min.	Max.	Min.	Max.	WHO (2012)	BIS (2012)
pH	7.3	8.19	7.35	8.24	7.0-8.5	6.5-8.5
EC	65	1677	89	917	750	-
TDS	45	1021	55	601	500	500
TH	24.7	414.2	29.6	246.6	500	300
TA	14	348	19	119	-	-
Ca^{++}	5.9	108.5	8	69	75	75
Mg^{++}	2.4	34.3	2.4	22.5	30	30
Na^{+}	5	151	6.4	98	200	-
K^{+}	1.4	57.6	0.8	14.2	-	-
$CO_3^{=}$	0	0	0	0	-	-
HCO_3^{-}	17.4	424.1	23.2	234.4	200	200
NO_3^{-}	0	56.2	0.1	53.1	45	
Cl^{-}	9.3	223	11.6	137.2	250	250
$SO_4^{=}$	7.3	57.9	7.2	43.6	200	200
F^{-}	0.02	2.01	0.08	1.72	0.6-1.5	1
Uranium	0.001	0.005	0.001	0.013	-	0.03

The higher concentration of NO3 in water may be due to the contamination of groundwater from human and animal wastes or manure and fertilizers which may be validated again.

Table 3.4 High Concentration of Nitrate in Gajapati District.

Sl.no	Site Location	Block	Types	Nitrate(mg/l)
1	Madhusudhanpur	Kasinagar	DW	49.9
2	Allada	Kasinagar	DW	52.9
3	Singipur	Kasinagar	DW	52
4	Kesapur	Gumma	DW	48.6
5	Poipani	R.Udayagiri	DW	49.3
6	Tabarsingh	R.Udayagiri	DW	56.2
7	Ramagiri	R.Udayagiri	DW	54.3
8	Kirimasahi	Mohana	DW	46.3
9	Birikote	Mohana	DW	49.4
10	Allada	Kasinagar	TW	52.9
11	Kirting	Mohana	TW	53.3
12	Bada Galama	Mohana	TW	49.5

For example, fluoride in excess of the permissible limit has been found in few villages. The iso-conductivity map of phreatic and deeper aquifers of the district has been prepared and presented in ***Figure 3.16*** **and** ***Figure 3.17*** respectively. The quality of groundwater is generally good with EC ranging from 65 to 1677 µs/cm for phreatic aquifer and 85 and 917 µs/cm for the deeper aquifer.

The analytical results of 26 groundwater samples collected from the phreatic aquifer have been plotted in the Piper diagram for both phreatic **Figure 3.22** and deeper aquifer **Figure 3.21**. It shows that the groundwater in the Gajapati district is more of the calcium-magnesium-bicarbonate (Ca-Mg-HCO3) type. The detailed analysis of the constituents indicated the general predominance of Ca^{2+} over the other cations. Similarly, HCO^{3-} remained predominant anions in the groundwater samples. Thus, the groundwater types were predominantly mixed Ca-Mg-HCO3 types followed by Ca-Mg-Cl types. The general predominance of cations and anions in the shallow groundwater were found in the orders of Ca^{+2}+Mg>Na+>K+ and $HCO3^{-}$>Cl^{-}>$SO42^{-}$>$CO32^{-}$ respectively. This indicates a transitional or mixing environment between the younger water and resident water.

The groundwater in the deeper fracture aquifers is also predominated by the cation Ca2+ and to some extent Na, Mg2+. Among the anions, it is the bicarbonate ion ($HCO3^{-}$) only, that predominate in most of the groundwater samples. Thus, hydrochemically, the water in the fracture aquifers are mostly Ca-HCO3 types followed by mixed Ca-Mg-HCO3 types. It might be indicating the semi-confined to the unconfined character of the deeper fracture aquifers in the district.

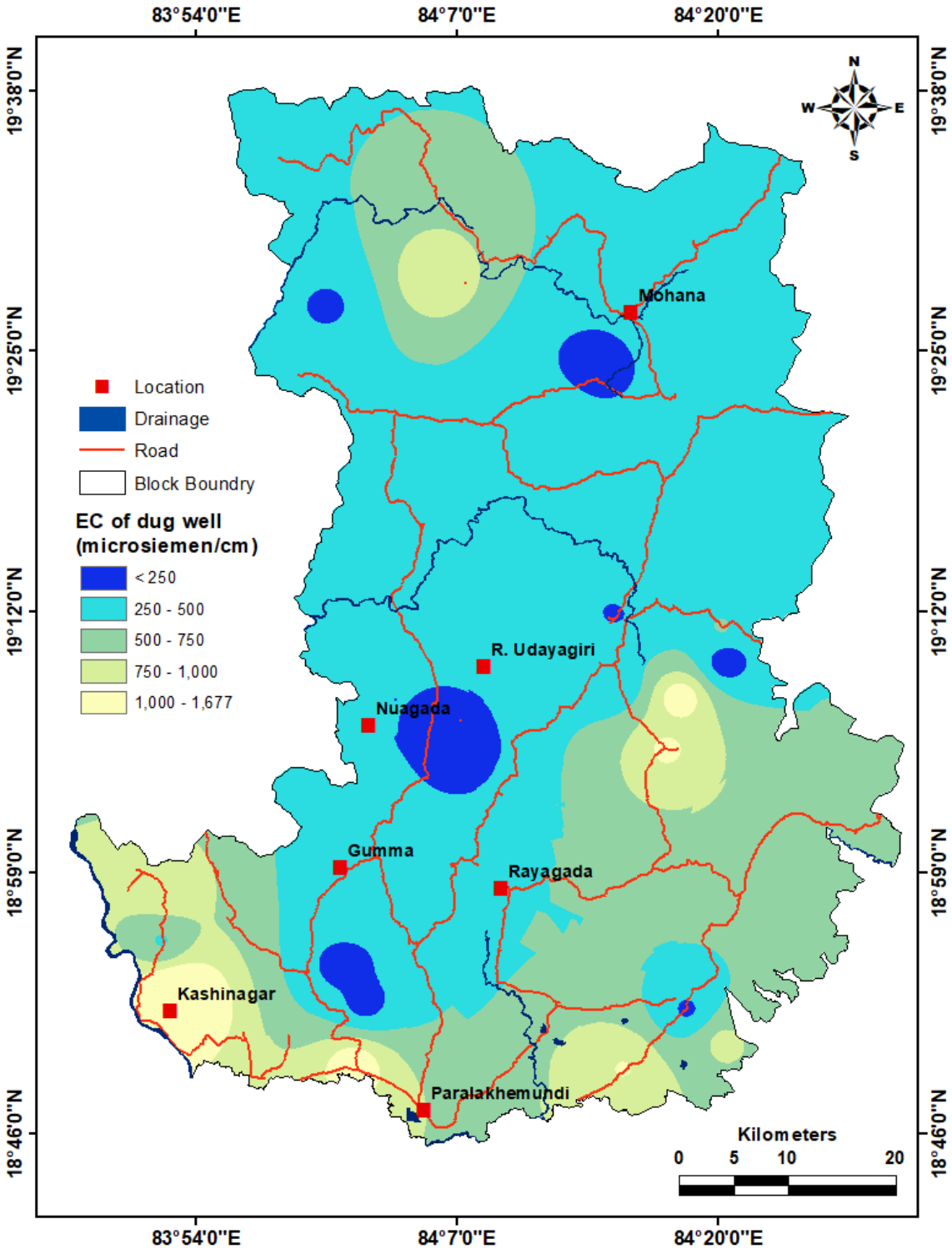

Figure 3.16 Isoconductivity Map (Phreatic Aquifer)

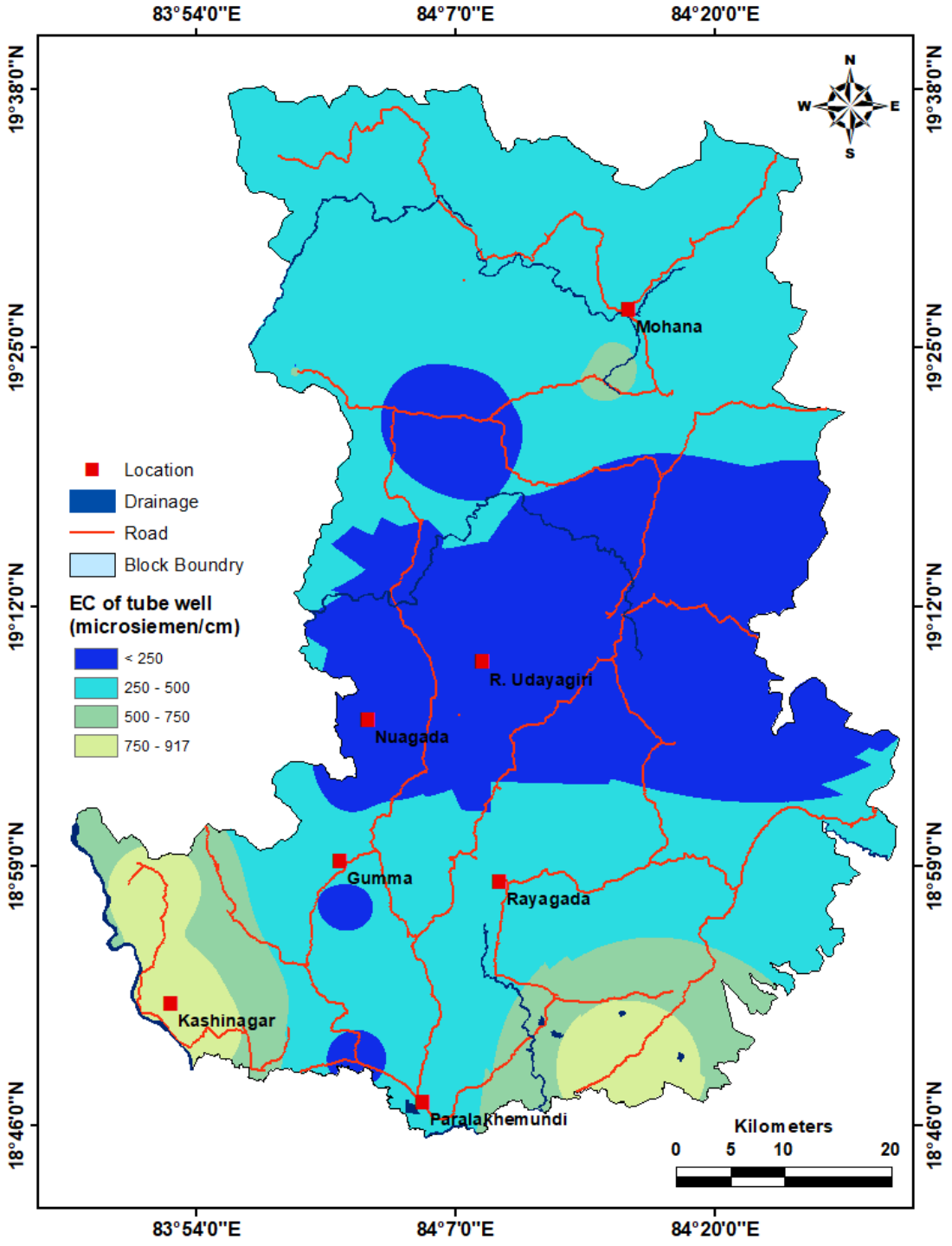

Figure 3.17 Isoconductivity Map (Deeper Aquifer)

3.3.1 Suitability for irrigation

The total concentration of soluble salts in irrigation water can be expressed as low (EC = <250 µS/ cm), medium (250-750 µS/cm), high (750-2250 µS/cm) and very high (>2250 µS/cm) and defined as

C-1, C-2, C-3, and C-4 salinity zone respectively (USSL 1954). A high salt concentration in water leads to the formation of saline soil and a high sodium concentration may cause the development of alkaline soil. The sodium or alkali hazard in the irrigation water is expressed in terms of sodium adsorption ratio (SAR) has been estimated by the following relation:

$$\text{Sodium adsorption ratio } (SAR) = \frac{Na^{+}}{\sqrt{\frac{Mg^{+2} + Ca^{+2}}{2}}}$$

The sodium alkali hazard has been classified into four categories as S-1 (SAR<10), S-2 (10-18), S-3 (18-26), and S-4 (>26). The plot of analytical data of water quality of the shallow aquifer on the USSL (1954) diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, water samples are mostly in C1S1, C2S1 and few in C3S1 categories indicating the good quality of water for irrigation **Figure *3.18***. The groundwater samples fall in the C3S1 category which represents the moderate quality of water for irrigation. This water can be used in irrigation for salt-tolerant crops under favorable drainage conditions.

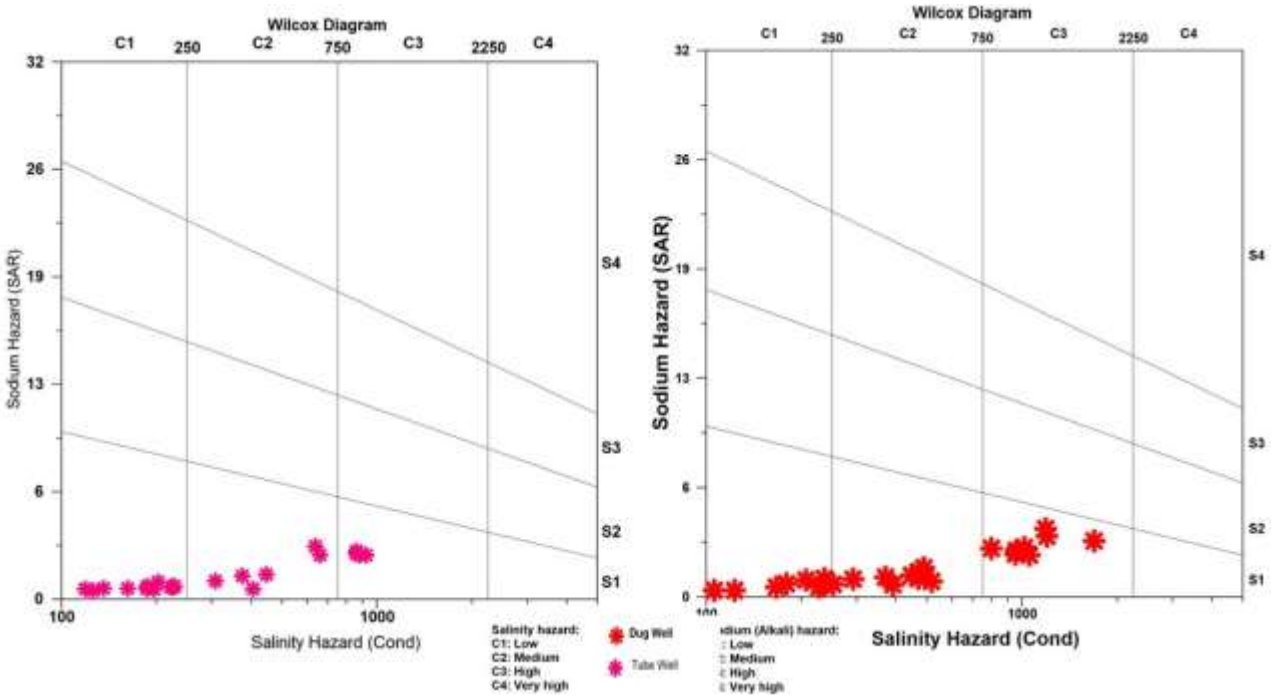

Figure 3.18 USSL salinity diagram, Deeper Aquifer (Right) and Phreatic Aquifer(Left)

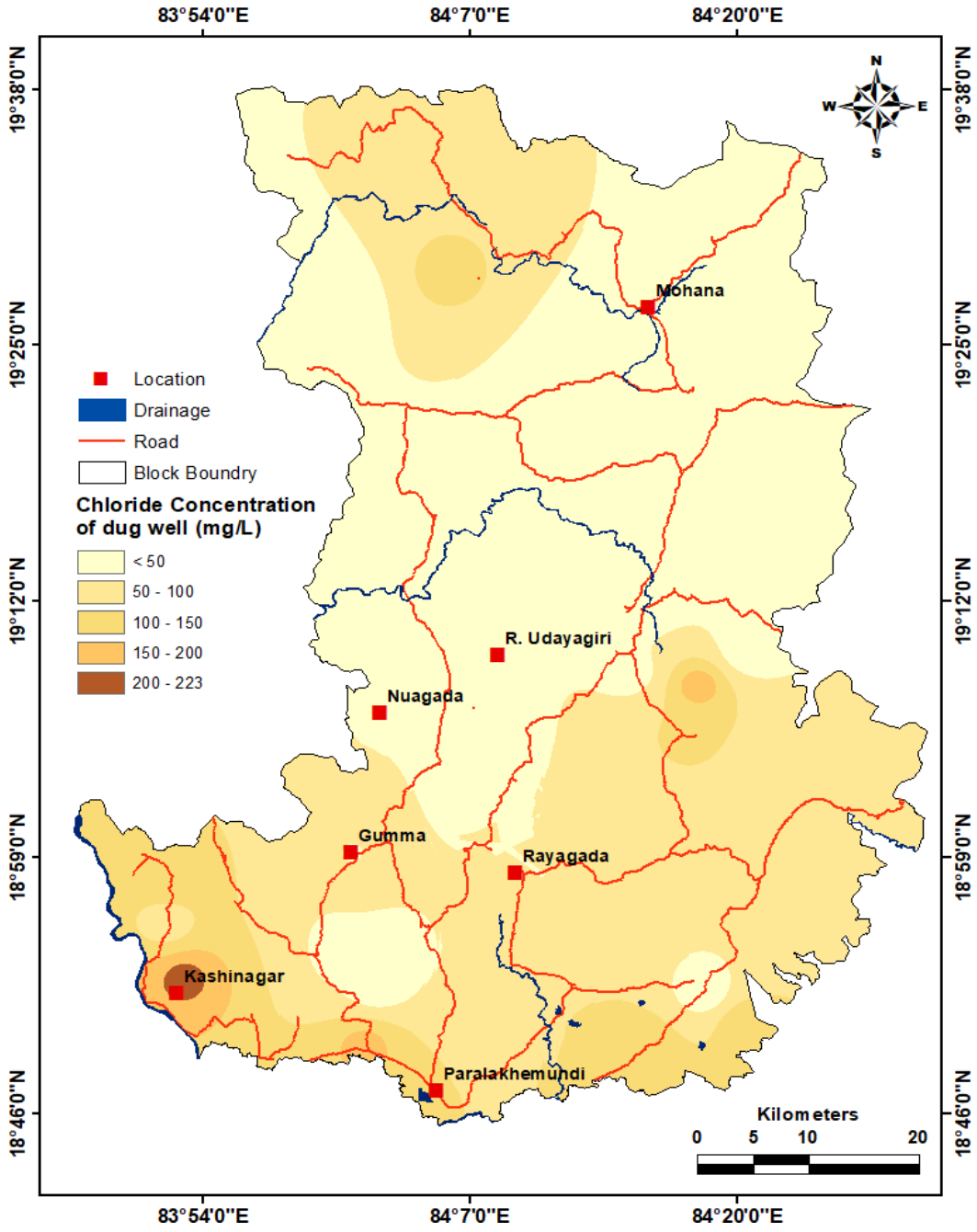

Figure 3.19 Iso-chloride Map Phreatic, Gajapati District, Odisha

The chloride concentration is an indicator of the salinity index. The data for chloride is within the range of 223mg/l for the phreatic aquifer which suggests a very good quality of water for domestic and irrigation purposes. The Isochloride map for the shallow phreatic aquifer is presented in **Figure 3.19**

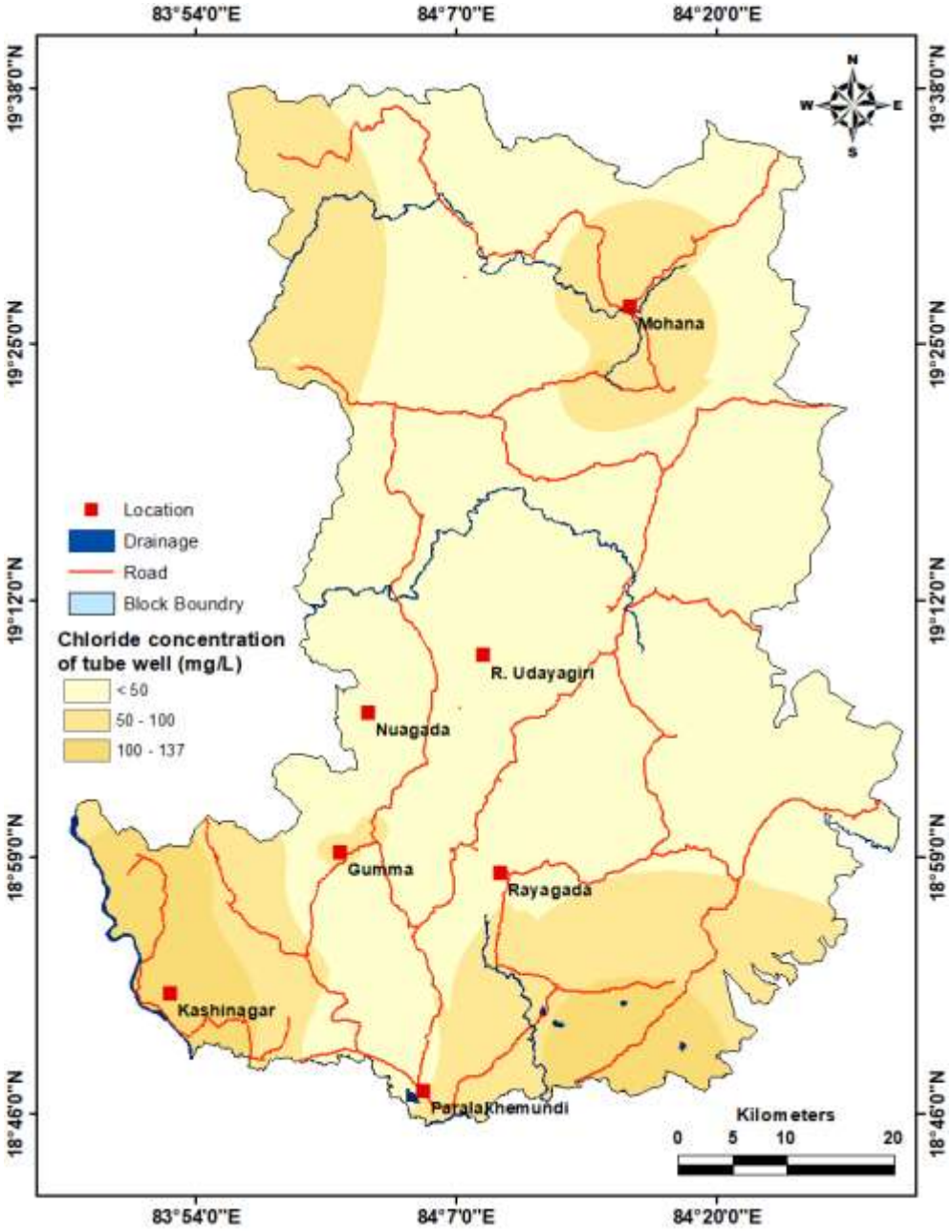

Figure 3.20 Iso-chloride Map Deeper, Gajapati District, Odisha

The chloride concentration is an indicator of the salinity index. The data for chloride is within the range of 137 mg/l for the deeper aquifer which suggests a very good quality of water for domestic and irrigation purposes. The quality of deeper aquifer is having a very good quality than that of the shallow aquifer in terms of chloride value. The Isochloride map for the shallow phreatic aquifer is presented in **Figure 3.20**

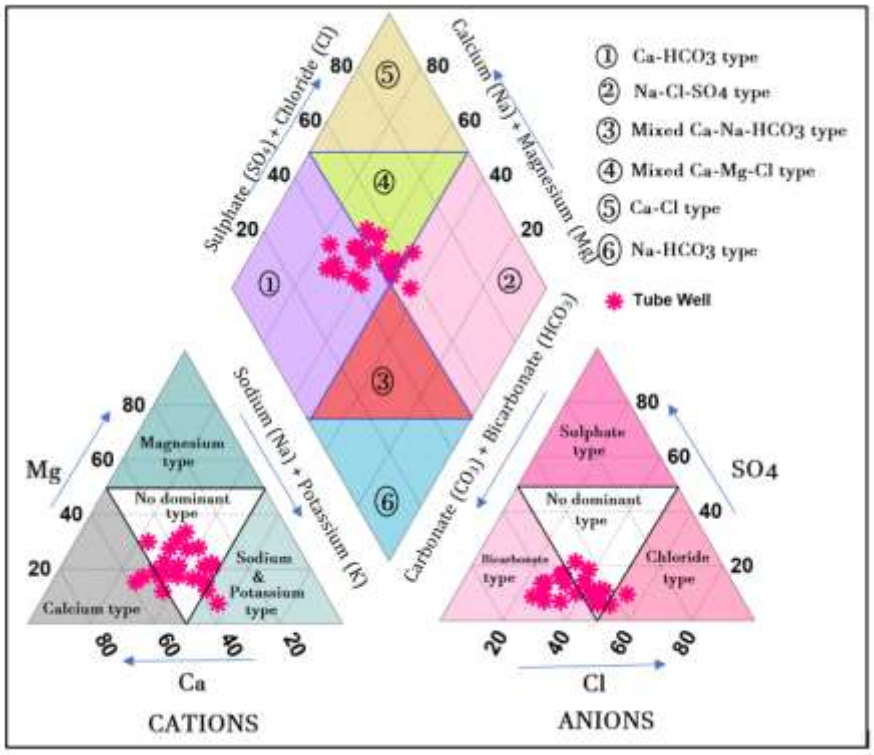

Figure 3.21 Piper Diagram for Deeper Aquifer

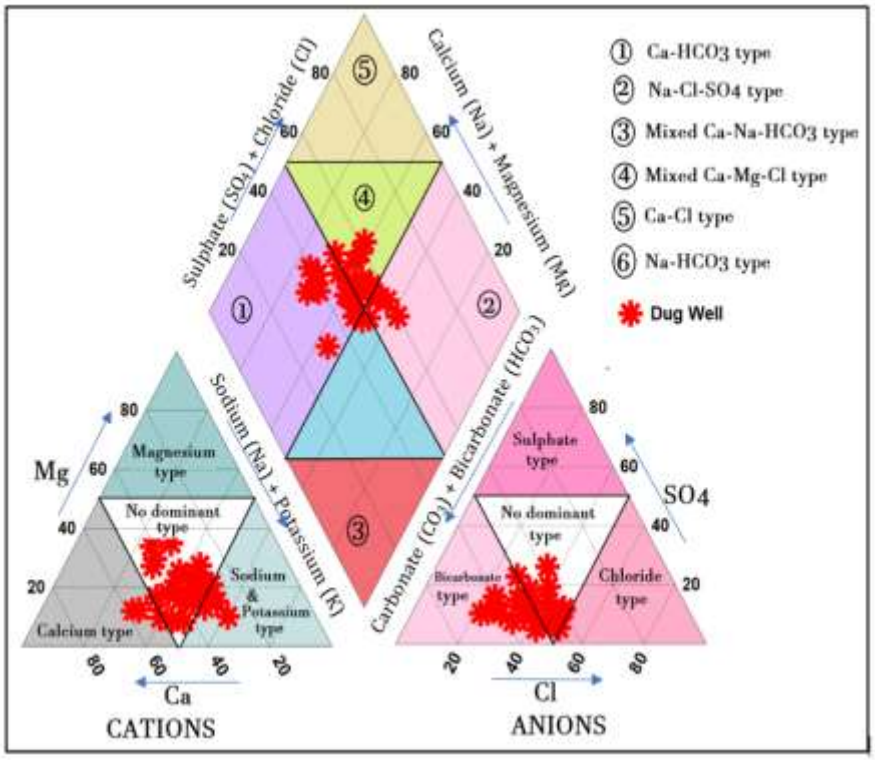

Figure 3.22 Piper Diagram for Phreatic Aquifer

3.4 Aquifer Groups and Their Demarcation

Based on extensive analysis of historical data, micro-level hydrogeological survey data generated, and groundwater exploration carried out in the area, three major types of Aquifers can be demarcated. Using the weathered zone thickness map at the top, a 3D aquifer model of the district has been prepared displaying three aquifer types

and **Figure *3.25*** (1) weathered zone aquifer; (2) Precambrian fractured aquifer, and (3) Massive Zone. Massive zones cannot be taken as aquifer systems that are beyond the depth of 150 m bgl as very few productive aquifers are encountered. Keeping the distribution pattern and the productivity of fracture zones the entire district can be divided into two major aquifer systems (1) **1st Aquifer System** within the depth of 50 m bgl, which includes the weathered zone aquifer, and (2) the **2nd Aquifer System** within the depth range of 50 to 150 m bgl. Thus, the 1st aquifer system also includes the weathered zone aquifer at the top and the alluvial aquifer in the southern parts of the district. The aquifer systems have been briefed in the following lines.

3.4.1 Aquifer- I (Unconfined Aquifer):

Unconfined aquifer occurs in the entire area formed by the weathered mantle atop crystalline rocks and discontinuous alluvial tracts along major river channels. This aquifer generally occurs down to a maximum depth of 50m bgl. Based on field observations, the isopach map of Aquifer–I is generated and shown in **Figure 3.23**

3.4.2 Aquifer-II (Semi-Confined to Confined Aquifer):

Semi-confined to confined aquifer occurs as fracture zone aquifers in the entire area irrespective of rock types. However, the aquifer properties and the yield of bore wells constructed in them depend on the rock types. As per the groundwater exploration, carried out by CGWB and WAPCOS. Aquifer-II in Granitic rocks has a better yield in comparison to Charnockites and Khondalites. In general, most of the fracture zones are encountered within 0 to 100 m bgl and seldom beyond that. Thus the maximum depth for the Aquifer-II has been taken as 150 mbgl. Beyond that, there occurs a massive zone that is devoid of any secondary porosity like, fractures, joints, faults. Few locations can have fracture zones beyond 150 m bgl but with negligible discharge so can not be tapped. The zones are classified as massive zone or compact zones the depth of which is for reference is taken as 200m.

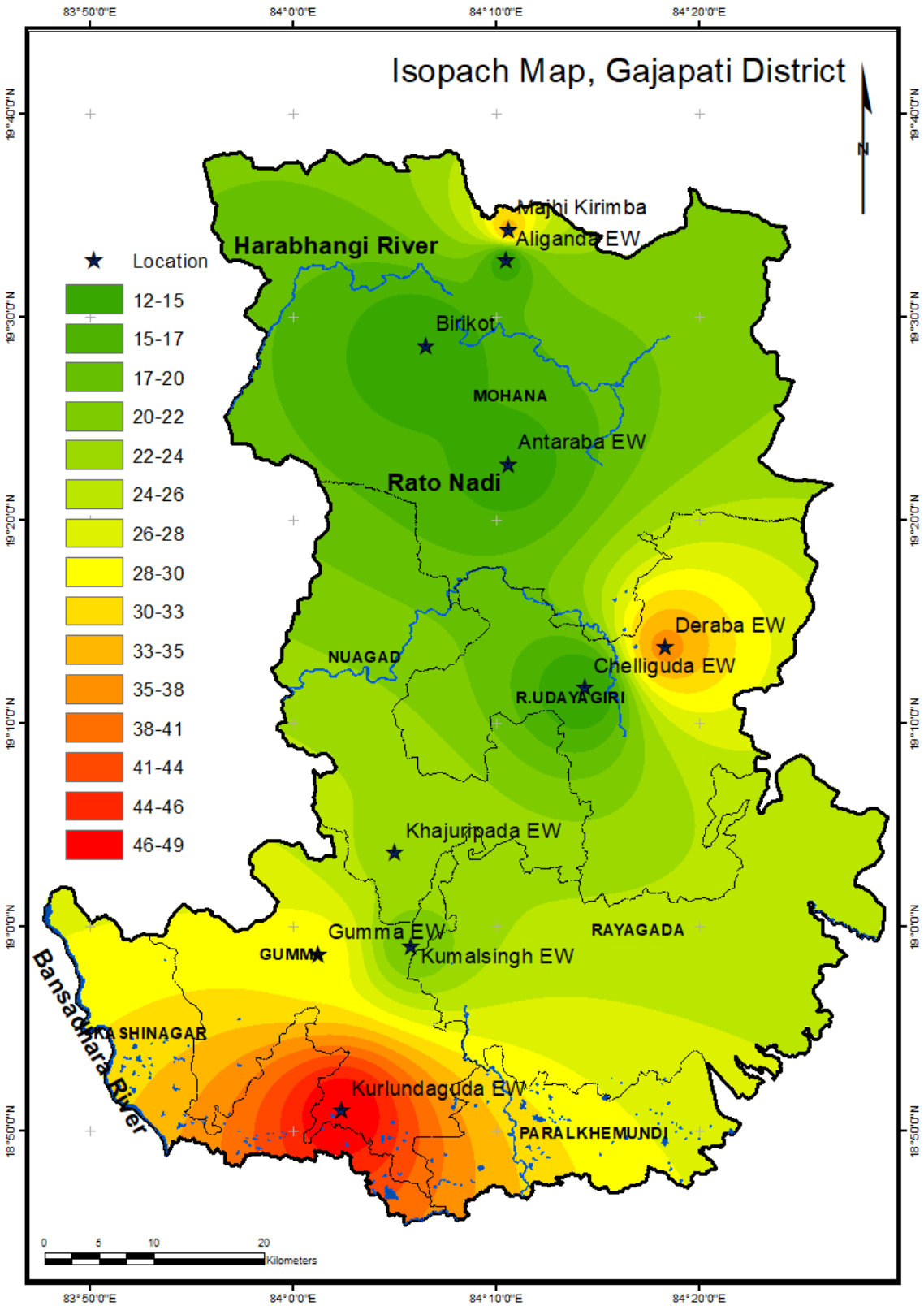

Figure 3.23 Isopach Map of Weathered Zone (Aquifer-I) in Gajapati District.

Table 3.5 Characteristics of Aquifer Groups in Gajapati District.

Type of Aquifer Group	Formation	Depth range (mbgl)	Yield	Aquifer parameter	Suitability for drinking/ irrigation
Aquifer-I (Phreatic)	**Unconsolidated and Weathered Recent**: Soil, Alluvium & Laterite **Precambrian**: Granite Gneiss, Charnockite, Khondalite,	0-50	2-15lps	Transmissivity varies from 176 m2/day in valley-fill deposits	Yes for both
Aquifer-II (Semi-confined to Confined)	**Fractured** Granite Gneiss, Charnockite, Khondalite, Gondwanas	50-150	0.8 to 4 lps	Transmissivity: 0.41 to 13.31 m2/day	Yes for both

3.5 Aquifer Disposition

The groundwater exploration data has been used to generate the 3D disposition of the aquifer system. It comprises all existing litho-units and the zones tapped during the groundwater exploration, forming an aquifer. Based on the groundwater exploration and micro-level hydrogeological survey data and aquifer delineation method, a schematic 3-D aquifer disposition is prepared and shown in **Figure *3.25*.** 2D schematic sections were drawn along lines A-B, C-D, E-F, G-H, I-J, and K-L which are shown in plain view in **Figure 3.26.** The sections were drawn taking into consideration the exploration done by CGWB, WAPCOS, the data collected from RWSS, Gajapati, Odisha, and the VES (Vertical Electrical Sounding) conducted in the entire districts of Gajapati. The schematic 3-D and 2-D are plotted with the help of software like Rockworks, MapInfo, Paints, etc. The 3-D fence diagram **Figure 3.33** is plotted with the VES data conducted in the southern part of the districts.

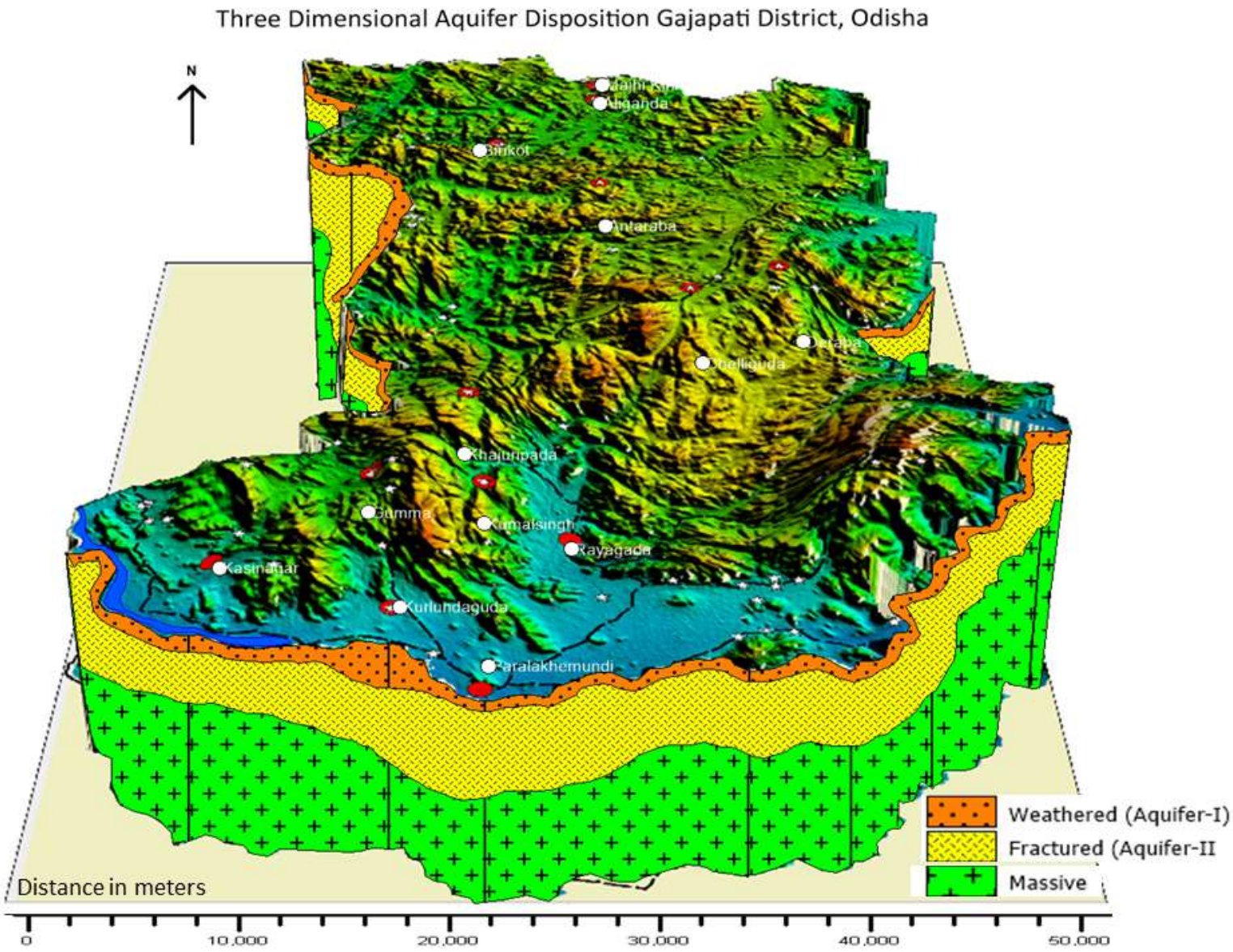

Figure 3.24 Schematic 3D Aquifer Disposition (North-South) in Gajapati District.

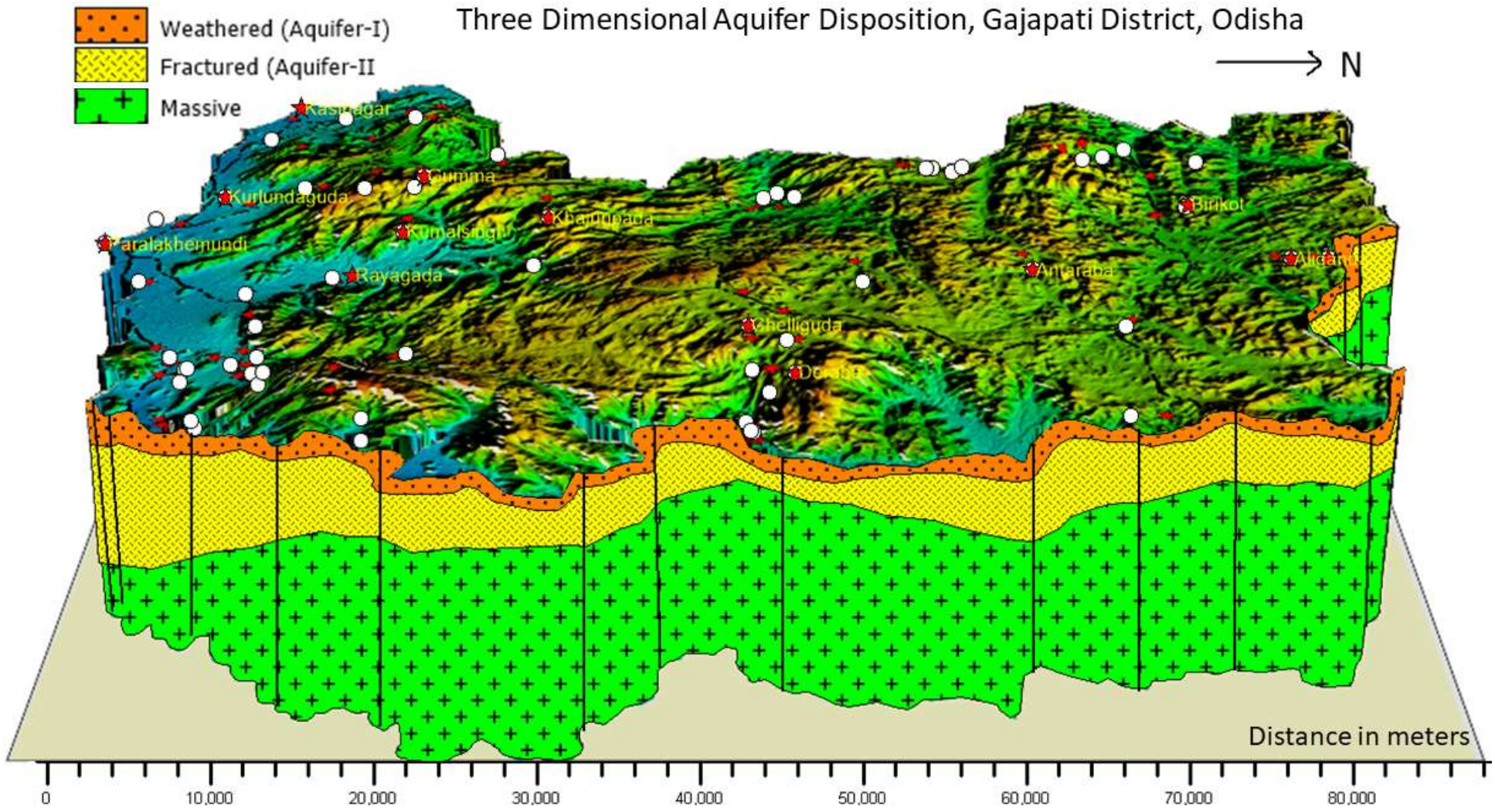

Figure 3.25 Schematic 3D Aquifer Disposition (East-West) in Gajapati District.

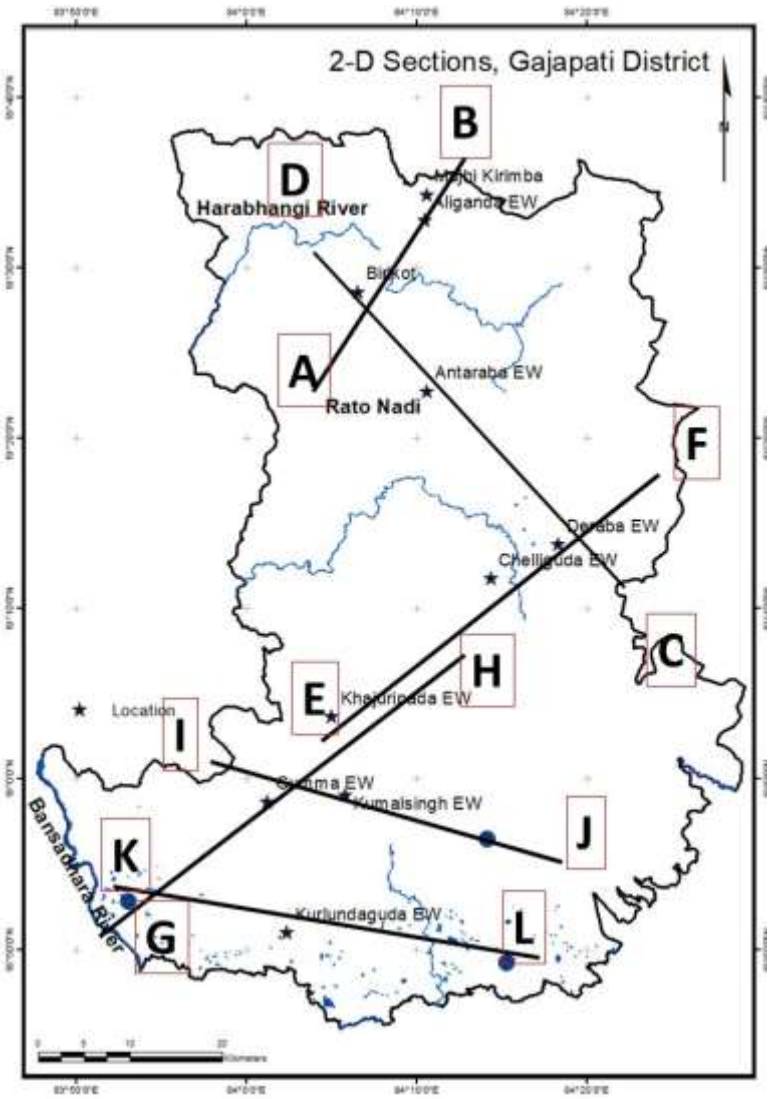

Figure 3.26 Aquifer 2D Section Lines along A-B, C-D, E-F, G-H, I-J, and K-L.

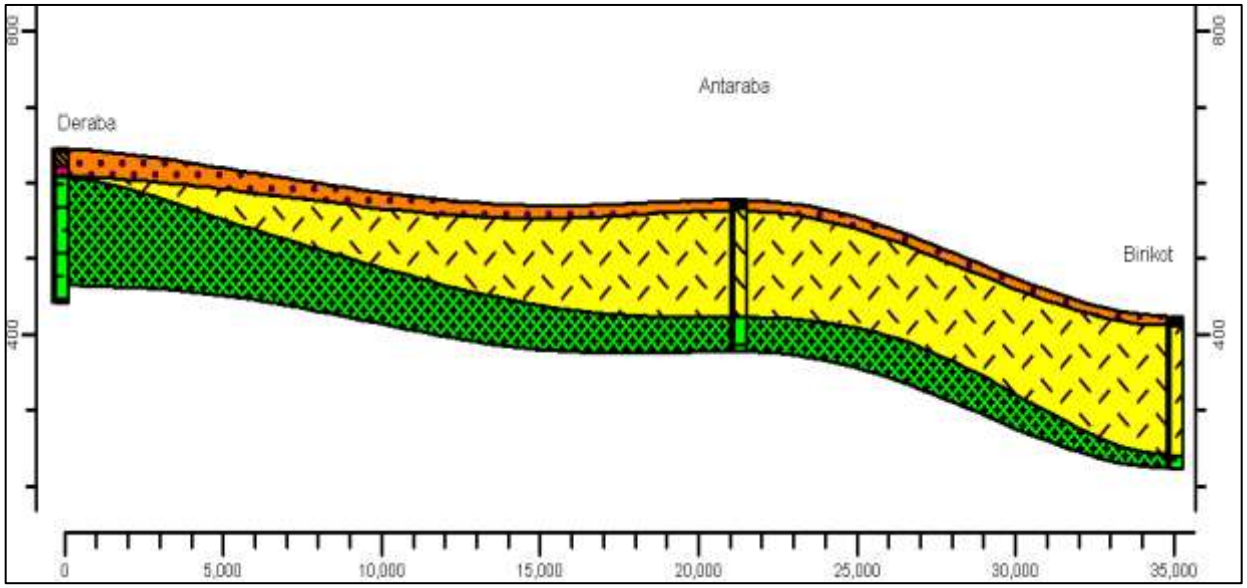

Figure 3.27 Cross-Section Along A-B (Birikot-Aliganda-Majhikirimba) in Gajapati District

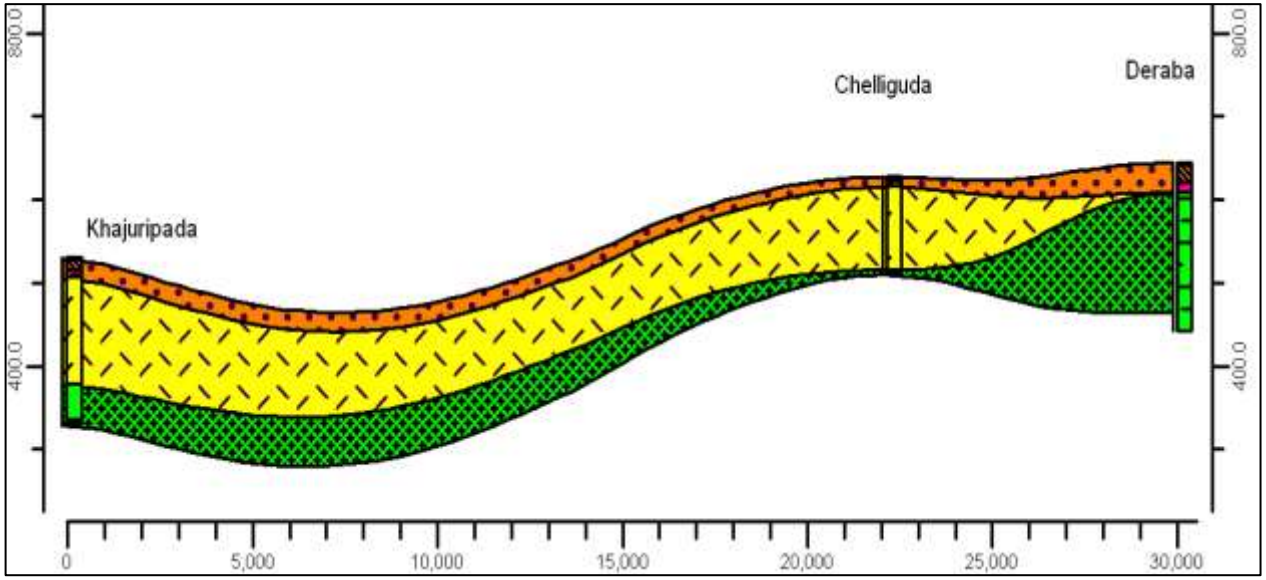

Figure 3.28 Cross-Section Along C-D(Deraba-Antaraba-Birikot) in Gajapati District

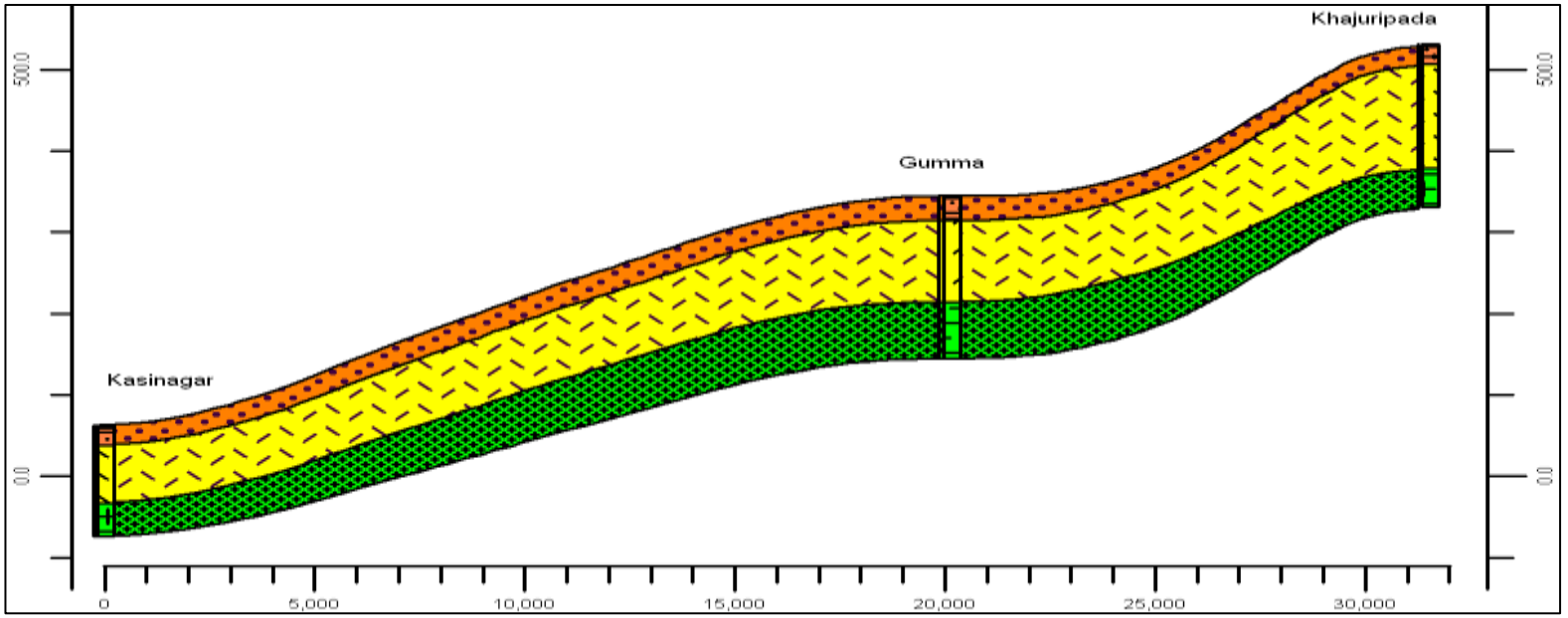

Figure 3.29 Cross-Section Along E-F (Khajuripada-Chelliguda-Deraba) in Gajapati District

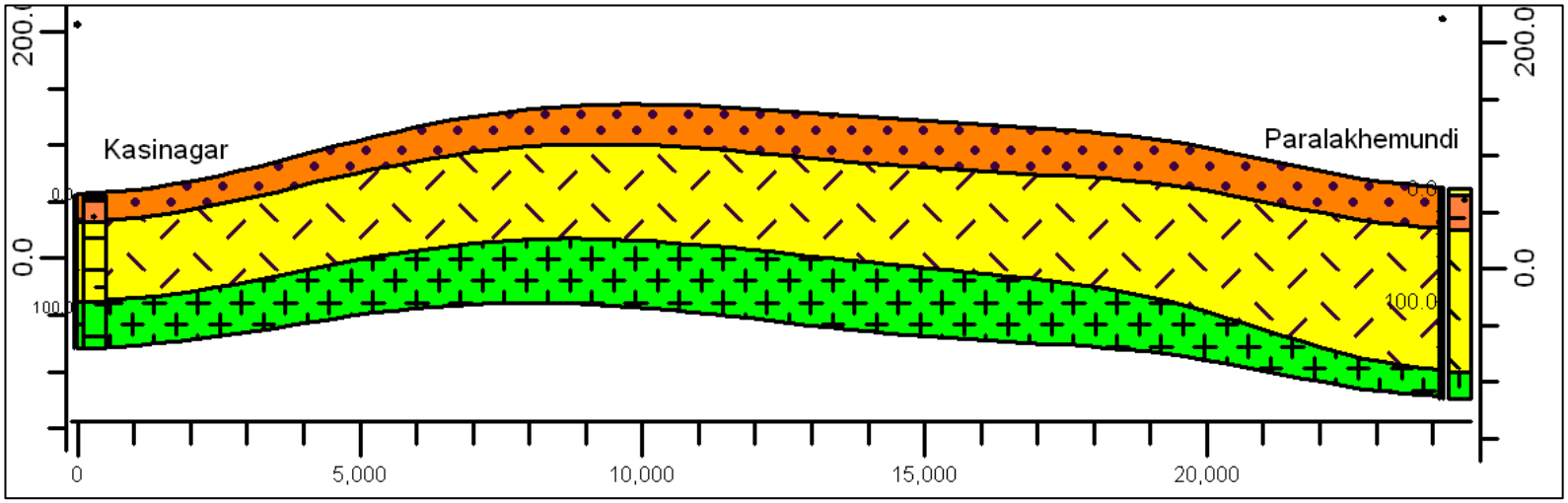

Figure 3.30 Cross-Section Along G-H (Kasinagar-Gumma-Khajuripada) in Gajapati

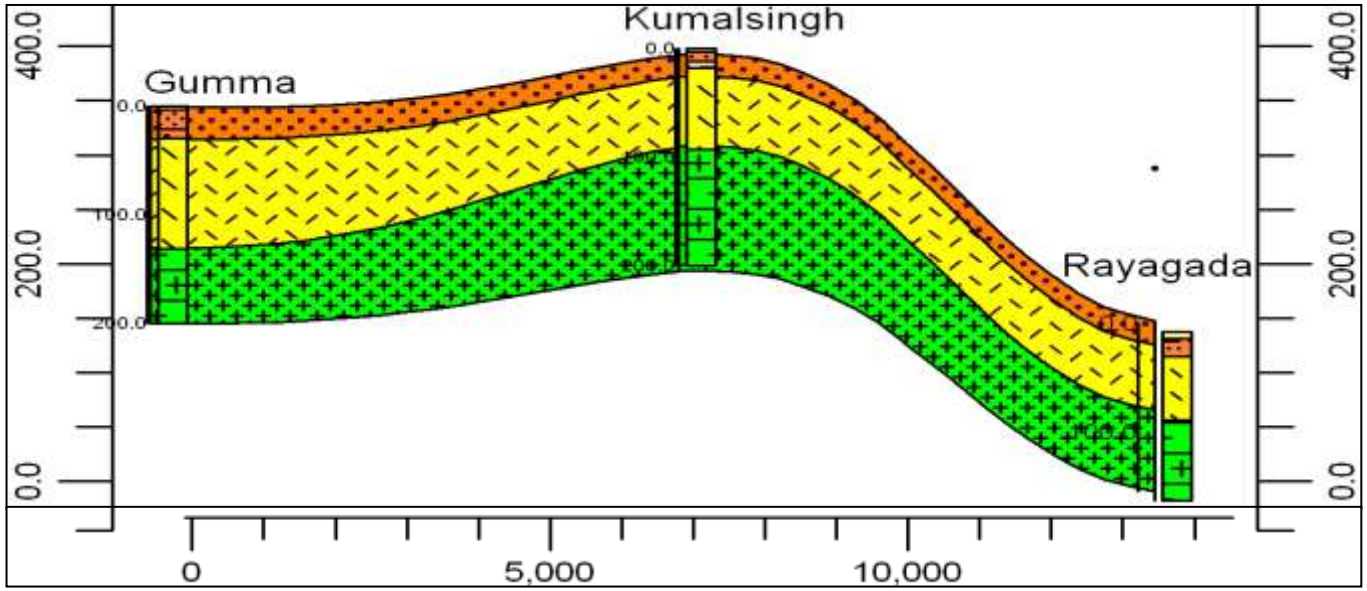

Figure 3.31 Cross-Section Along I-J (Kasinagar-Paralakhemundi) in Gajapati District

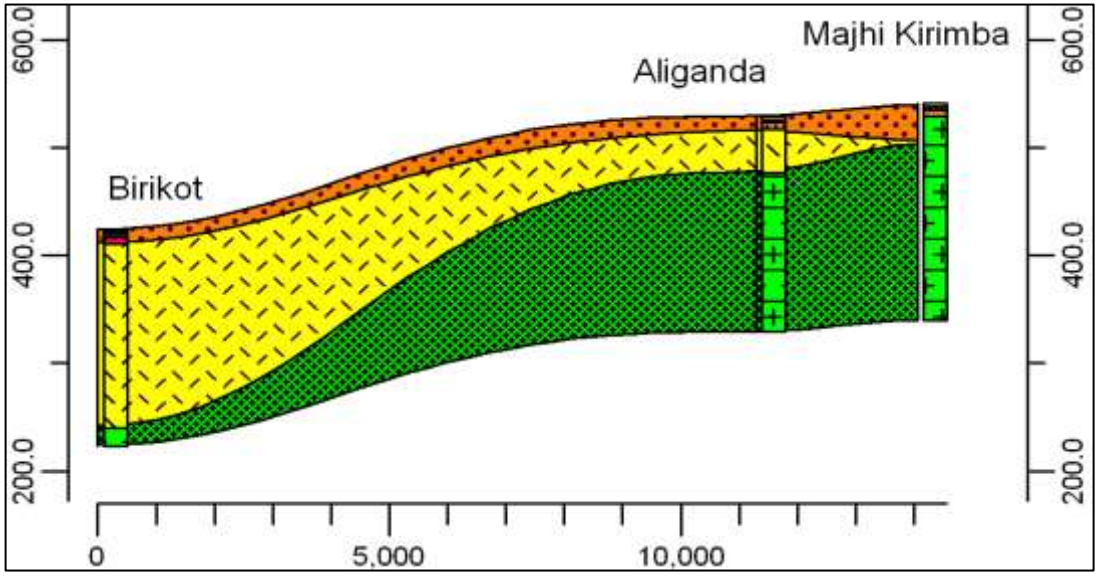

Figure 3.32 Cross-Section Along K-L (Gumma-Kumalsingh-Rayagada) in Gajapati District

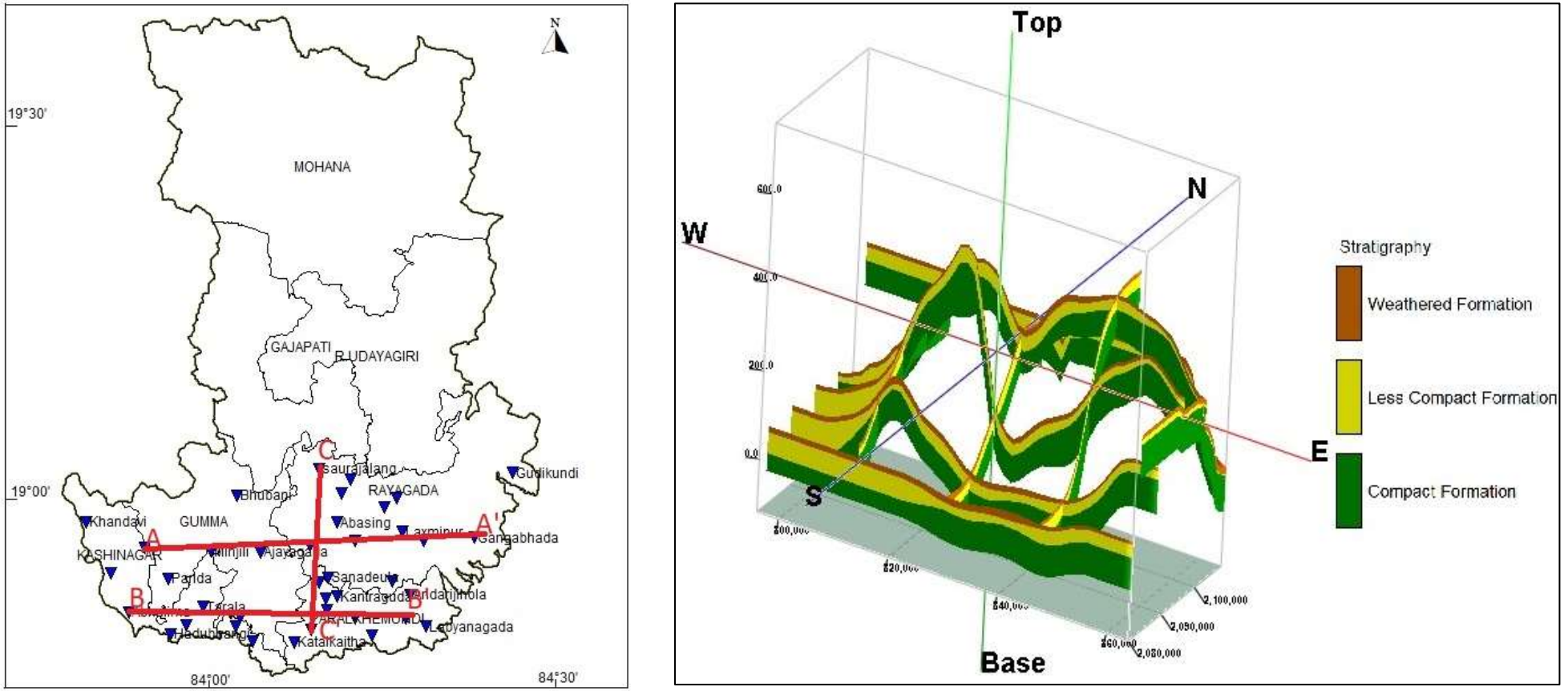

Figure 3.33 Schematic 3D-Fence Diagram (Southern part) in Gajapati District, Locations (Left) Fence Diagram (Right)

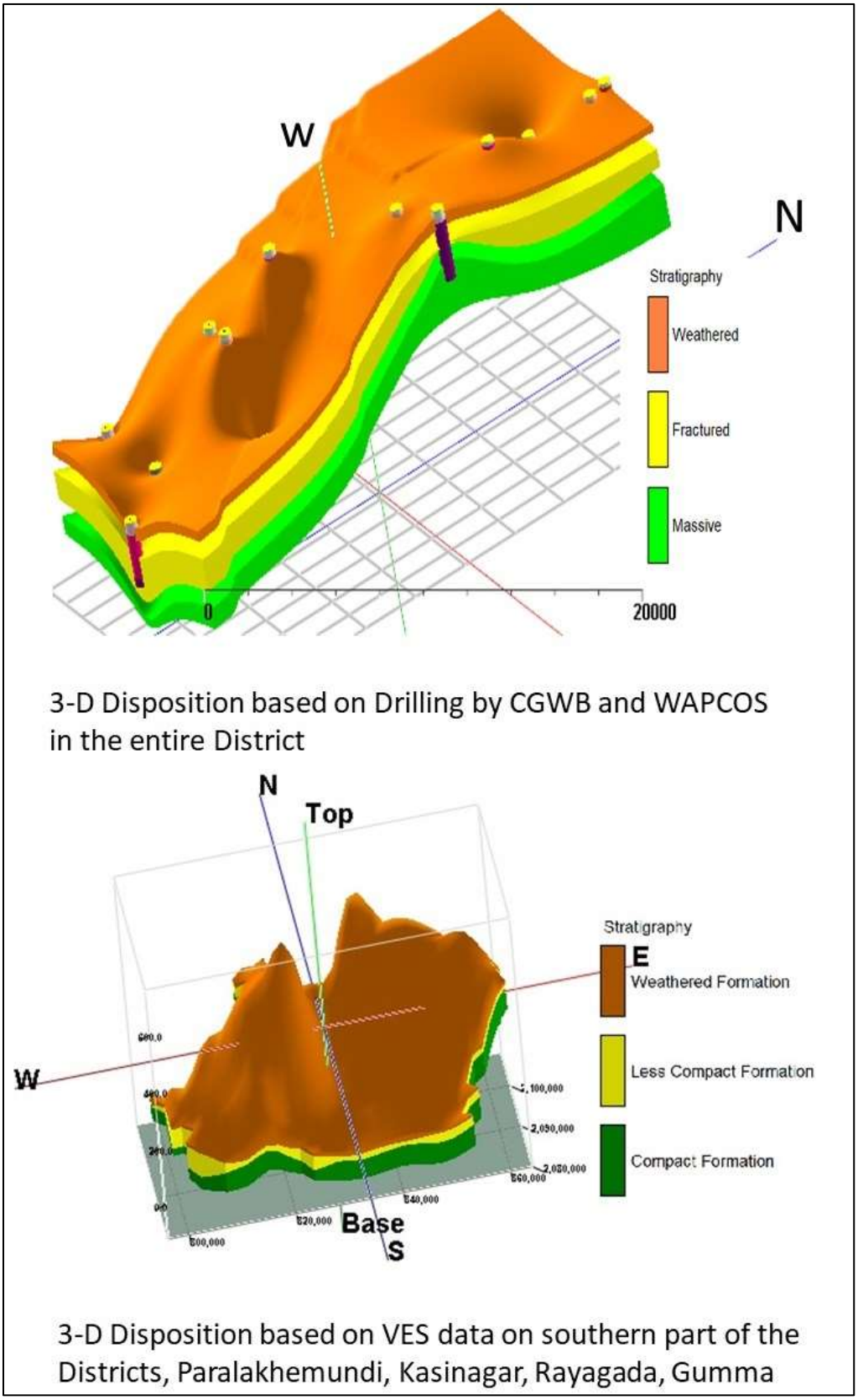

Figure 3.34 Aquifer Disposition Top (Entire District), Bottom (Southern Part)

3.5.1 Two-Dimensional Litho Sections

With the available information on borehole lithology, six hydrogeological sections have been prepared **Figure 3.26** (1) A-B from Birikote, Aligunda to Majhikirimba in Mohana block in the northern boundary of the state (2) C-D from Deraba-Antaraba and Birikote (3) E-F from Khajuripada-Cheligada to Deraba (4) G-H from Kasinagar-Gumma to Khajuripada (5) I-J from Kasinagar to Paralakhemundi and (6) K-L from Gumma-Kumalsingh to Rayagada. In all transects, the borehole lithologies have been drawn schematically. Approximate depths of the fractures encountered in each bore well have been provided. Yields in each of the bore wells have also been indicated. Fractures in the intervening areas have been drawn only schematically and may not bear any significance in field conditions. Brief descriptions about transects are given below:

3.5.1.1 Section A-B (Birikote-Aligunda-Majhikirimba)

It encompasses a total of 3 bore wells **Figure 3.27** Birikote, Aligunda and Majhikirimba. The bore wells were drilled to a depth of 200 m bgl. The predominant lithology remains the granite/granite gneiss. The thickness of the weathered zone varies from 12 m at Birikote and Aligunda and 35m at Majhikirimba. Three fracture zones are encountered at Birikote at a depth of 47, 106, and 183m bgl. From the Geophysical logging data, the fractures zone at 45-48m is tapped. The transmissivity value is found to be 0.41m^2/day and discharge recorded around 0.8 lps. At Aligunda one fracture was encountered at 52m depth with 0.4 lps discharge. The well drilled at Majhikirimba, has no fracture zones at all. Often, the fractures were obtained at the contact zones of the intrusions and the country-rock.

3.5.1.2 Section C-D (Deraba-Antaraba-Birikote)

It encompasses a total of 3 bore wells **Figure 3.28**, Deraba, Antaraba and Birikote. The bore wells were drilled to a depth of 200 m bgl. The predominant lithology remains the granite/granite gneiss. The thickness of the weathered zone varies from 14m at Antaraba and 36m at Deraba. At Antaraba two sets of fracture zones were encountered at around 90m and 155m bgl with the cumulative discharge of 0.8 lps. The well drilled at Deraba, has no fracture zones at all. Often, the fractures were obtained at the contact zones of the intrusions and the country-rock.

3.5.1.3 Section E-F (Khajuripada-Chelligada-Deraba)

It encompasses a total of four bore wells **Figure 3.29**, one at Khajuripada, 2 wells (1 no of Exploratory well and 1 no of observation wells) are drilled at Chelligada and one at Deraba. The bore wells were drilled to a depth of 200 m bgl. The predominant lithology remains the granite/granite gneiss. The

thickness of the weathered zone varies from 12 m at Chelligada and 23 m at Khajuripada. At Cheligada 2 sets of fracture, zones were encountered up to a depth of 121m bgl with the cumulative discharge of 13 lps. The transmissivity value was found to be 176.8 m^2/day and the storativity value around 6.80 X 10^{-4}. Three sets of fractures zones up to a depth of 152 m bgl were encountered at Khajuripada with the cumulative discharge of 0.8 lps and transmissivity value is found around 0.43 m^2/day. The fractures are found at the contact zones of the intrusions and the country-rock.

3.5.1.4 Section G-H (Kasinagar-Gumma-Khajuripada)

It encompasses a total of 3 bore wells **Figure 3.30** at Kasinagar, Gumma, and Khajuripada. There is an elevation difference of around 450m above msl from Kasinagar to Khajuripada. At all the borehole locations the predominant lithology remains the granite/granite gneiss. Two bore wells(1 no of Exploratory well and 1 no of observation wells) were drilled to a depth of 136m and 108m bgl respectively. The thickness of the weathered zone varies from 23 m at Kasinagar and 30 m at Gumma. At Kasinagar 3-4 sets of fracture zones were encountered up to a depth of 108 m bgl with the cumulative discharge of 8 lps. At Gumma 4 sets of fracture zones were encountered within a depth of 100 m bgl with discharge 1.4 lps and transmissivity value around 13.31 m^2/day. The fractures are found at the contact zones of the intrusions and the country-rock.

3.5.1.5 Section I-J (Kasinagar-Paralakhemundi)

It encompasses a total of 5 wells bore wells. 2 wells (one exploratory and one observation) at Kasinagar, 3 wells (two exploratory and one observation wells) at Paralakhemundi. At all the borehole locations the predominant lithology remains the granite/granite gneiss. 3-4 sets of fracture zones were encountered up to a depth of 162 m bgl with the cumulative discharge of 14 lps was recorded at Paralakhemundi. The weathered zone is on average, 28m thick and the longest casing length required was 36 m at Paralakhemundi.

3.5.1.6 Section K-L (Gumma-Kumalsingh-Rayagada)

It encompasses a total of 3 bore wells **Figure 3.32** at Gumma, Kumalsingh and Rayagada. All the borehole locations have predominant lithology as granite/granite gneiss. Three sets of fracture zones were encountered up to a depth of 80 m bgl with the cumulative discharge of 0.8 lps. At Rayagada the discharge was found around 2.3 lps. The weathered thickness is around 20 m at all the locations. The fractures are found at the contact zones of the intrusions and the country-rock.

4.0 GROUNDWATER RESOURCES

Precise quantifications of exploitable groundwater resources are essential prerequisites for any program for development, judicious and optimal exploitation of groundwater resources. It involves quantification and identification of various factors affecting groundwater recharge and discharge and demarcation of potential areas for groundwater development. The principal sources of recharge to groundwater are rainfall, seepage from canals, return flow from applied irrigation, seepage from tanks and ponds. Groundwater exploitation for domestic use in the district is mainly through private dug wells and hand pumps fitted government bore wells/tube wells. The extraction of groundwater for irrigation purposes is mainly through dug wells, dug-cum-bore wells, and to a lesser extent from bore wells. Groundwater occurs under water table conditions in the weathered residuum and the fracture zone which largely depends on the thickness of the weathered residuum. The weathered zone and the saturated fractured zones form the main repository of groundwater in the district. The dynamic groundwater resource is estimated based on the seasonal fluctuation of water level in the weathered zone, which represents the groundwater regime in the shallow weathered zone and the near-surface fractured zone hydraulically connected to it. Data on various parameters such as rainfall, water level fluctuation, specific yield, groundwater abstraction structures for various utilities, irrigation, and other data recorded and/or collected by CGWB, SE region and GWS & I, Government of Orissa, and other state government agencies have been utilized to estimate the dynamic groundwater resource of Gajapati district. The annual groundwater draft of a groundwater abstraction structure is computed by multiplying the average discharge and the annual working hours of the structure.

The dynamic groundwater resource of the district was jointly carried out in 2020 by Central Groundwater Board (CGWB) and Groundwater Survey and Investigation (GWS&I) adopting the methodology recommended by GEC 2015. The groundwater resource can be aquifer-wise divided into Dynamic and Static resources. The dynamic resource is the part of resource within the water level fluctuation zone which is also the annual replenishable resource. The resource below the water level fluctuation zone is termed as the In-storage (Static) resource. Mainly the water level fluctuation method was adopted for the calculation of recharge. The block-wise resource of the aquifer mapping blocks as of 2020 is given below in **Table 4.1**

4.1 Groundwater Resource Components

This section deals with the aquifer-wise estimation of different groundwater resource components for the 1st Aquifer System as well as the 2nd Aquifer System.

1. Annually replenishable dynamic groundwater resources and the in-storage groundwater resources up to the bottom of the shallow, unconfined/ weathered zone aquifer constitute the 1st Aquifer System. Static/ In-storage groundwater resource remains in reserve below the water level fluctuation zone beyond the deepest water level.

2. The Static/In-storage groundwater resource in the semi-confined/confined below the bottom of the weathered zone up to the bottom of the fracture zones constitutes the 2nd Aquifer System. In the district of Gajapati, it goes down to the depth of 150 m bgl.

3. Beyond this zone is massive and compact where the aquifers have either no fractures or negligible water-bearing fractures, so the calculation of the resource is not taken into consideration even if it is being encountered to a depth of 200 m bgl.

4.2 Dynamic groundwater resource

Based on the norms recommended by the Groundwater Estimation Committee (G.E.C. 2015) block-wise availability of dynamic groundwater resources for the district of Gajapati has been estimated (as on 31st March 2020). The total annual dynamic groundwater resource/Annual extractable groundwater resources of the Gajapati district is assessed to be 19861 Hectare meter (Ham) **Table 4.1**. The existing gross groundwater draft/extraction in the district stands at 6657 Ham, out of which the irrigation draft is 4876 Ham (~73% of the total draft). The draft for domestic and drinking constitute 25% of the gross draft which is 1671 Ham. The annual utilizable resource which remains for irrigation use (after allocation for domestic and drinking up to the year 2025) has been estimated at 13105 Ham. The stage of groundwater development varies between the minimum of 14.95% in the Mohana block and the maximum of 50.25% in the Paralakhemundi block, with the average stage of groundwater development for the district as 33.52%. There is only one block in the district, where the stage of groundwater development marginally exceeds 50%. Thus, there exists lots of scope for groundwater development for irrigation use in each block in the district.

Table 4.1 Dynamic Groundwater Resources of Aquifer-I in Gajapati District. (2020)

Assessment Unit Name	Annual Extractable Groundwater Resource	Groundwater Extraction for Irrigation Use	Groundwater Extraction for Industrial Use	Groundwater Extraction for Domestic Use	Total Extraction)	Annual GW Allocation for Domestic Use as on 2025	Net Groundwater Availability for future use	Stage of Groundwater Extraction (%)
GOSANI	3,355	1,346	27	312	1,686	323	1,659	50.25
GUMA	2,078	706	28	243	976	276	1,069	46.99
KASHINAGAR	2,010	923	19	186	1,129	192	877	56.14
MOHANA	6,361	553	12	386	951	409	5,386	14.95
NUAGADA	1,416	293	5	161	458	177	942	32.36
R. UDAYGIRI	2,662	491	8	186	685	194	1,970	25.72
RAYAGADA	1,980	564	10	197	772	201	1,204	38.99
GAJAPATI	19,861	4,876	109	1,671	6,657	1,771	13,105	33.52

4.3 In-storage groundwater resource

The static/in-storage groundwater resource for each block in the district has been estimated using the "Specific Yield Method", following the guidelines recommended by GEC 2015. The available thickness of the 1st Aquifer System has been found out using the following relation:

Bottom depth of the weathered System– Average pre-monsoon water level

The average and representative specific yield values have been taken for estimating the resource for each different block depending on the lithology. For the hard rock areas, such values were taken within 2.0 – 3.0%. The resources have been estimated using the following relation:

Area of the block suitable for recharge X thickness of the aquifer X Specific Yield.

4.3.1 In storage groundwater resource 1st Aquifer

The static/in-storage groundwater resource of the 1st Aquifer System has been produced in **Table 4.2**. The total in-storage resource for the district has been estimated as 34075 Ham. The In-storage resources are calculated for Aquifer-I and II separately. However the semi-confined to confined deeper aquifers have linkage to the unconfined aquifer through the fractures and receive the

continuous recharge. The total resources of Aquifer-I **Table 4.2** including the dynamic and in-storage groundwater resources is 53936 shown in **Table 4.4** below.

Table 4.2 In-Storage Groundwater Resources of Aquifer-I in Gajapati District.

Block	Assessment Area	Bottom Depth of Aquifer	Average Pre-monsoon Water Level	Total Effective Saturated Thickness	Average Specific Yield	In Storage Groundwater Resources
				(2-3)		[(1) *(4)*(5)]
	(Ha)	(mbgl)	(mbgl)	(m)		(Ham)
	1	2	3	4	5	6
GOSANI	24,112	14.23	6.27	7.96	0.02	3,839
GUMA	46,141	11.00	8.72	2.28	0.02	2,104
KASHINAGARA	27,224	14.12	6.41	7.71	0.02	4,198
MOHANA	1,46,179	12.68	6.20	6.48	0.02	18,945
NUAGADA	51,034	12.23	7.80	4.43	0.02	4,522
R. UDAYGIRI	66,501	8.00	7.93	0.07	0.02	93
RAYAGADA	72,030	6.00	5.74	0.26	0.02	375
GAJAPATI	4,33,221					34,075

Table 4.3 In-Storage Groundwater Resources of Aquifer-II in Gajapati District.

Block	Assessment Area	Top Depth of Aquifer	Bottom Depth of Aquifer	Total Saturated Thickness	Productive Zone	Avg. Sp. Yield	In Storage Groundwater Resources
	(Ha)	(mbgl)	(mbgl)	(m)	(5% of Total Thickness) (m)		(Ham)
	1	2	3	(4)=(3-2)	5	6	(7)=(1*5*6)
GOSANI	24,112	14.23	150	135.77	6.79	0.02	2,455
GUMA	46,141	11.00	150	139.00	6.95	0.02	4,810
KASHINAGARA	27,224	14.12	150	135.88	6.79	0.02	2,774
MOHANA	1,46,179	12.68	150	137.32	6.87	0.02	15,055
NUAGADA	51,034	12.23	150	137.77	6.89	0.02	5,273
R. UDAYGIRI	66,501	8.00	150	142.00	7.10	0.02	7,082
RAYAGADA	72,030	6.00	150	144.00	7.20	0.02	7,779
GAJAPATI	4,33,221						45,230

Table 4.4 Total Groundwater Resources of Aquifer-I in Gajapati District. (2020)

Block	Dynamic GW Resource	In-storage GW Resource	Total GW Resource
GOSANI	3,355	3,839	**7,194**
GUMA	2,078	2,104	**4,182**
KASHINAGARA	2,010	4,198	**6,208**
MOHANA	6,361	18,945	**25,305**
NUAGADA	1,416	4,522	**5,937**
R. UDAYGIRI	2,662	93	**2,755**
RAYAGADA	1,980	375	**7,194**
GAJAPATI	19,861	34,075	**4,182**

4.3.2 Static/in-storage resource of 2nd Aquifer System

The 2nd Aquifer System in the district largely extends between the depth ranges 50-150m m bgl. This constitutes the fracture systems of the aquifers. 5% effective thickness of the aquifer system has been considered. The resources have been estimated as 45230 Ham using the relation Table 4.3.

Area of the block suitable for recharge (deducting the alluvial areas) X thickness of the aquifer X percent of fracture/granular zone X Average specific yield.

5.0 AQUIFER MANAGEMENT PLAN

The highly diversified occurrence and considerable variations in the availability and utilization of groundwater make its management a challenging task. Scientific development and management strategy for groundwater has become imperative to avert the looming water crisis. In this context, various issues such as prioritization of areas for development of groundwater resources vis-a-vis its availability, augmentation of groundwater through rainwater harvesting and artificial recharge, pricing and sectoral allocation of resources, and participation of the stakeholders must be considered. In the present scenario, groundwater plays a significant role in the food supply and the national economy. Unscientific and rampant exploitation of the available aquifers for irrigation at several places in the country has created serious conditions of groundwater decline, which has become very difficult to revive. Judicious and scientific exploitation of aquifers, keeping in mind the aquifer sustainability, has been of paramount significance. To give justice to both the aquifer sustainability and the growing demand for groundwater for different needs, the aquifer management plan is the need of the hour. With the help of the studies carried out in this aquifer mapping program, integrating all the available information from the older studies, data available with the state governments, the aquifer management plan for the district has been prepared. To formulate the aquifer management plan, the need was to delineate the aquifer/groundwater-related issues in the district. The major issues identified in the district are as below:

1. Under-utilization of the available groundwater resource.
2. Low yield of aquifers and groundwater scarcity
3. Groundwater fluoride contamination in pockets
4. Groundwater Problem in Hilly Area
5. Less Productive Deeper Aquifer
6. Depleted Water Level in Phreatic Aquifer

5.1 Groundwater Related Issues

5.1.1 Under Utilization of Groundwater Resources

As per the groundwater resource estimated jointly by CGWB and State Govt. in 2020, the Net Groundwater Availability of Gajapati district is 19861 Ham. The stage of groundwater development varies between the minimum of 14.95% in the Mohana block and a maximum of 50.25% in the Paralakhemundi block, with the average stage of groundwater development for the district as 33.52%. There is only one block in the district, where the stage of groundwater development marginally exceeds 50%. Thus, there exists lots of scope for groundwater development for irrigation use in each block in the district.

5.1.2 Low yield of aquifers and groundwater scarcity

In Gajapati district, in several areas in granitic rocks, the yield of the bore wells remains very low, even less than 1.0 lps, which can seldom meet the requirements. In such water scarcity areas, large-diameter dug wells (5-10 m wide) tapping the entire weathered residuum can give ample water for the needs of irrigation and drinking.

5.1.3 Fluoride in Ground Water

The desirable limit of Fluoride in ground water is 1.0 mg/L and the maximum permissible limit is of 1.5 mg/L. incidences of minor patches of high concentration of fluoride in groundwater of Gajapati district have been detected in 3 locations during the sampling of NAQUIM Keywells **Figure *5.1***. Chemical analysis of detailed sampling 49 locations were analyzed in the NABL accredited CGWB laboratory. The following table reveals the details of the occurrence of fluoride. The occurrence is mainly attributed to geogenic reasons.

Table 5.1 Fluoride Point Sourced Villages in Gajapati District.

Sl No	Village	Source	Block	Latitude	Longitude	Fluoride (mg/L)
1	Madhusudhanpur	DW	Kasinagar	83.88511	18.88034	2.01
2	Madhusudhanpur	TW	Kasinagar	83.88557	18.88027	1.72
3	Kirting	DW	Mohana	84.23687	19.39646	1.23

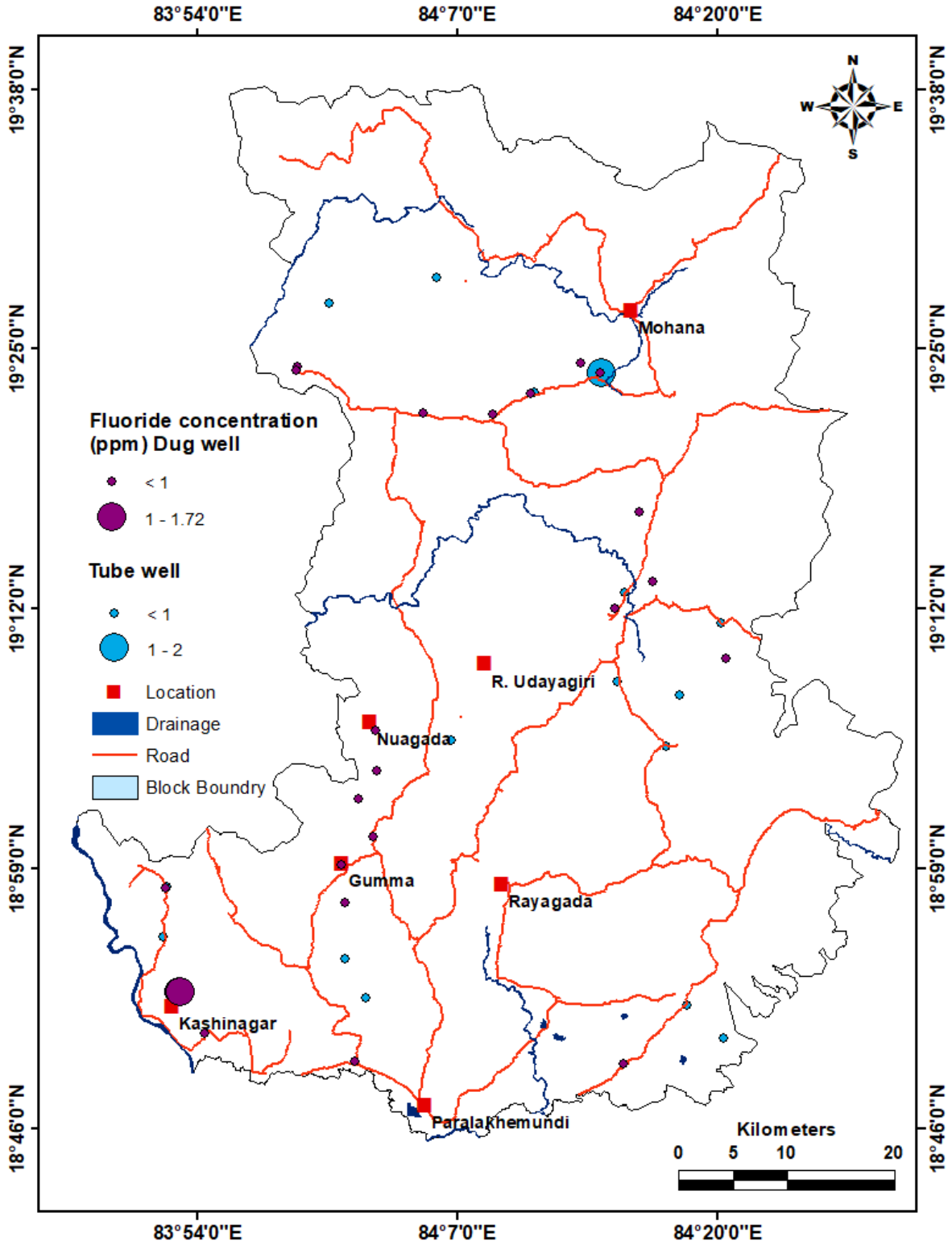

Figure 5.1 Location showing high Fluoride, Gajapati district, Odisha

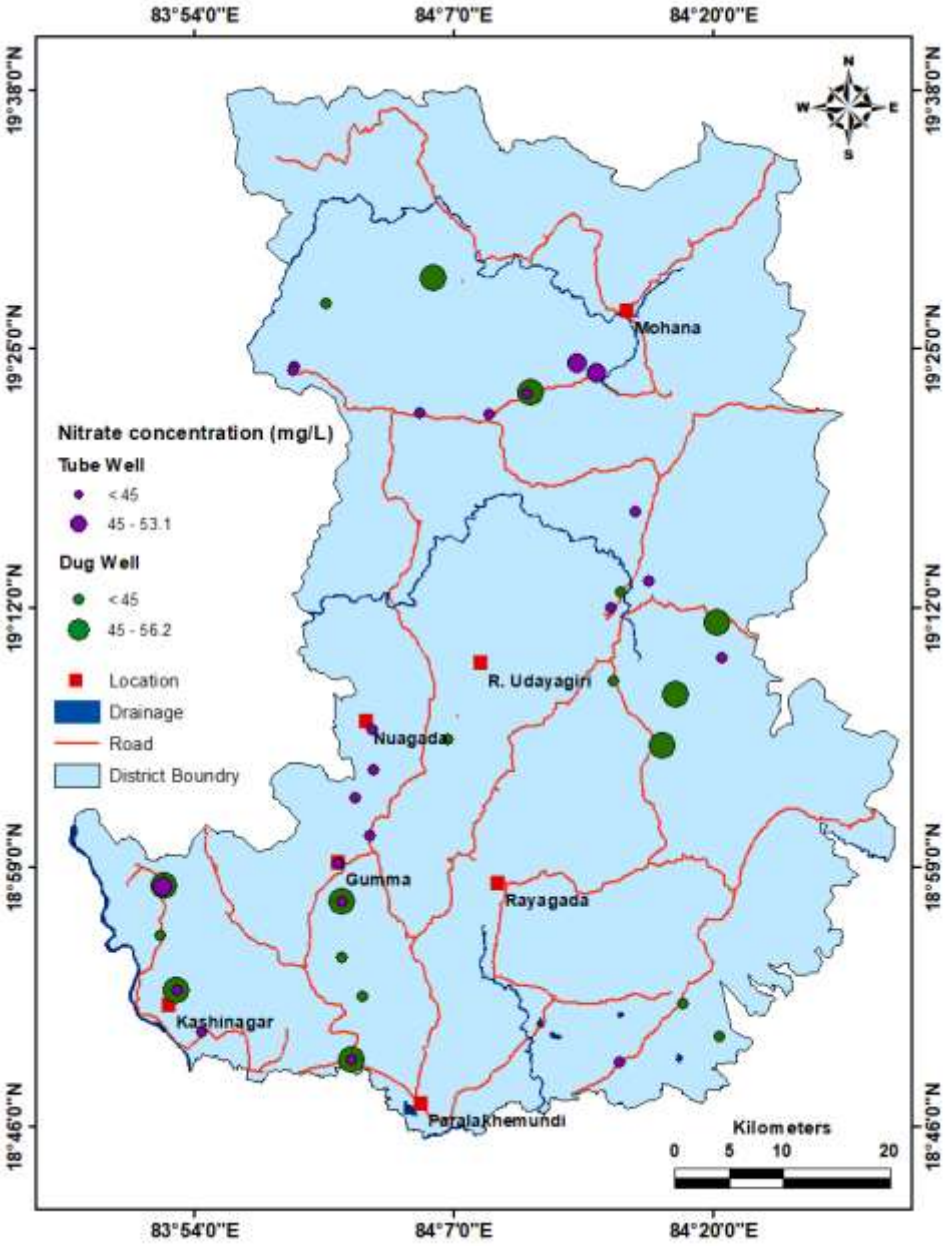

Figure 5.2 Location showing high Nitrate contamination

Groundwater in dug wells tapping weathered residuum with Charnockite is generally of $NaHCO_3$ type which plays an important role in presence of high F^- in this type of water. The Mixed type water resembles both $Ca(HCO_3)_2$ type, $NaHCO_3$ type waters, and F^- concentrations from 0.02 to 2.01 mg/L have been observed in these wells. The studies also reveal that the high bicarbonate concentrations are indicative of surface water recharge to the aquifers which while percolating down through the

subsurface materials, extract F^- from the fluoride bearing minerals, exchange Ca^{++} with Na^+ ions and finally appear as $NaHCO_3$ type water with high fluoride content.

5.1.4 Groundwater Problem in Hilly Areas

Gajapati district receives adequate rainfall, and the normal annual rainfall is 1413 mm. Except for the southern part, mostly area falling in Paralakhemundi and Kasinagar block all other blocks are of high hilly terrain. They can be classified as high run-off zone. They act as recharge zones as well as good reservoirs of ground water. Once they get saturated, during monsoon the excess water flows as run off and base flow. During the post-monsoon period, the thin weathered zones soon lose the entire storage water due to base flow. So water is scarce in these areas in the lean and summer season.

5.1.5 Less Productive Deeper Aquifer

The exploratory drilling in the district reveals that the deeply fractured aquifer is less productive. Many of the borewells drilled in the district have very poor discharge. The failure rate of borewells is very high in the Easternghat Group of rocks like the Charnockites and Khondalites. Granite gneiss is comparatively better for laying bore wells.

5.1.6 Depleted Water Level in Phreatic Aquifer

The groundwater level in the phreatic aquifer is found to be deep in many parts of the district. Depth to water level during pre-and post-monsoon periods is deeper (>4m bgl) in parts of Gumma, Kasinaragar, Nuagada, and R. Udayagiri block. The maximum water level during the premonsoon is recorded at about 12m in the Mohana block. Long term Decadal trend is also showing a falling trend in many locations such as Lyligada, Mohana, Badakhoni, Chandiput, etc. The decadal trend from 2010-2019 shows that 58.3% of wells are showing a falling trend during the Pre-monsoon season and 68.1% show a falling trend in post-monsoon seasons. The area around Chandiput, Chandragiri, Kirama, Santinagar, Rayagada have shown a significant falling trend ranging from 20-90 cm/year. The seasonal fluctuation in some of the villages in this area indicates that the recharge due to monsoon is inadequate and such villages face problems of water scarcity around the year.

5.2 Aquifer Management Plan

5.2.1 Demand Vs Supply Scenario of Ground Water:

The demand in various sectors like the domestic demand, crop water demand, cattle demand, and the industrial demand is calculated for the district and the availability for the whole district in terms of surface water (District irrigation plan) and groundwater (as per CGWB resource calculation-2020) is depicted in ***Table 5.2.*** It has been found that there is a demand and supply gap of 227.8 MCM for the whole district. Further additional groundwater development potential of 52.6 MCM can be created by developing the stage of groundwater development up to 60%. ***Table 5.6***. There is a surplus water scenario and no water demand-supply gap in Nuapada block for the development of irrigation potential. But groundwater scenarios can be developed to overcome the deeper water level condition and to improve the overall scenario of the districts.

5.2.1.1 Proposed Demand Side Interventions:

There is very little scope for the demand side interventions as the district experiences an acute shortage of water during the lean seasons. But for the sustainability of the present scenario and for enhancing the agriculture production, the following demand-side interventions can be suggested:

1. Optimization of irrigation water requirement by use of water-efficient farm techniques such as drip, sprinkler, and mulching.
2. Switching over cropping pattern from water-intensive paddy to green gram, wheat, or millets in high and midland areas.

5.2.1.2 Proposed Supply Side Interventions:

As already discussed, only groundwater cannot meet the future irrigation demand of the district. Thus, the following supply-side measures are suggested:

1. Further groundwater development in under-utilized blocks, like the Mohana block.
2. Creation of additional surface water irrigation potential through river lift water schemes and minor irrigation projects.
3. Enhancement of surface and groundwater storage through rainwater harvesting and artificial recharge.

Table 5.2 Demand-Supply side Management

Block	Existing Water Demand (MCM)					Water Supply for Irrigation (MCM)			Demand-Supply Gap For Irrigation (MCM)	Further Groundwater Development Potential (MCM)
	Domestic	Livestock	Irrigation	Industrial	Total	Surface Water	Ground Water	Total		
GOSANI	2.6	0.6	127.6	0.4	131.2	33.2	13.5	46.7	84.5	3.27
GUMA	3.0	0.7	40.8	0.5	45.0	9.7	7.1	16.7	28.3	2.7
KASHINAGARA	1.9	0.5	106.4	0.3	109.1	25.6	9.2	34.8	74.3	0.78
MOHANA	5.1	2.1	33.6	0.8	41.5	8.2	5.5	13.7	27.8	28.65
NUAGADA	2.1	0.6	21.6	0.3	24.5	52.0	2.9	54.9	-30.4	3.91
R. UDAYGIRI	2.5	0.7	24.1	0.4	27.7	5.6	4.9	10.5	17.3	9.13
RAYAGADA	2.7	0.7	36.5	0.4	40.3	8.7	5.6	14.3	26.0	4.16
Total	20.0	5.8	390.5	3.0	419.4	142.9	48.8	191.6	227.8	52.6

5.2.2 Enhancement of Groundwater Resources by adoption of Farm Recharge and Roof Top Rainwater Harvesting Structures

To mitigate the ever-increasing demand on groundwater where the district average stage of groundwater development has reached 33.52%, certain management strategies have been applied to enhance the resource by the construction of farm ponds and rooftop rainwater structures in the district. Feasible areas in each block for the construction of farm ponds excluded the area of wasteland, water bodies, build-up area, and forests. Construction of farm pond (one pond per hector) to arrest the rainwater for recharge **Table 5.3**. Similarly, 10% of the household will be considered in a particular village (with an average rooftop area of 150 sq. meters per house) for the calculation of recharge from rooftop rainwater **Table 5.4**. Average five years rainfall to the tune of 1421 mm is taken for the calculation. Coefficient of rainfall taken 15% for farm recharge and 80% for rooftop rainfall recharge.

By construction of 7504 farm ponds, 15.99 MCM water can be harvested. A total number of 12,852 households in the districts with more than 150 sq.m of rooftop area can be taken up for the construction of rooftop rainwater harvesting structures. Around 2.192 MCM water can be

generated and recharged or conserved for various uses thereby increasing the net availability of groundwater for extraction from 198.61 mcm to 216.8 mcm. The total stage of groundwater development is reduced to 30.70% from 33.52%. The overall demand for groundwater will be fulfilled and the recharge structures will add to the groundwater storage.

Table 5.3 Block-wise Number of Farm ponds feasible , Gajapati District

Block	Area for Farmponds in Ha	10%of area taken for farm recharge (Sq.m)	Total number of farm pond*	Annual Recharge in MCM (#)
Gosani	12,496	1,24,96,000	1,250	2.664
Gumma	10,427	1,04,27,000	1,043	2.223
Kasinagar	12,844	1,28,44,000	1,284	2.738
Mohana	10,404	1,04,04,000	1,040	2.218
Nuagada	10,004	1,00,04,000	1,000	2.132
R.Udayagiri	7,448	74,48,000	745	1.588
Rayagad	11,414	1,14,14,000	1,141	2.433
*** No of Farmpond per hactare for 10% area**			**7,504**	**15.99**
#=(Area*Runoff co-efficient(15%)*Rainfall (1.421m)				

Table 5.4 Block-wise Number of RTRWH structures feasible, Gajapati District.

Name of Sub districts	No of Households (2011 Rural)	No of Households (2011 Urban)	Total Households	No of Houshold for recharge calculation (10%)	Total RWHS*	Annual Recharge in MCM(#)
Gosani	16,986	10,664	27,650	2,765	2,765	0.471
Gumma	17,300	-	17,300	1,730	1,730	0.295
Kasinagar	12,310	2,428	14,738	1,474	1,474	0.251
Mohana	27,009	1,121	28,130	2,813	2,813	0.480
Nuagada	11,359	-	11,359	1,136	1,136	0.194
R.udayagiri	12,096	1,060	13,156	1,316	1,316	0.224
Rayagada	15,305	885	16,190	1,619	1,619	0.276
Total	**1,12,365**	**16,158**	**1,28,523**	**12,852**	**12,852**	**2.192**
*** 1 RWHS/10 Households**						
# No of households x avg rooftop area (150 sqm) x runoff coefficient (80%) x rainfall, 1.421m						

Table 5.5 GW Resource enhancement due to construction of Rechage/Conservation structures

Assessment Unit Name	Annual Extractable Groundwater Resource	Total Extraction	Stage of Groundwater Extraction	Farm Recharge or Conservation	RWH Recharge or Conservation	Total Recharge or Conservation	Extractable Resource enhanced	Reduced Stage of Development (%)
	Ham	Ham	(%)	MCM	MCM	MCM	MCM	(%)
Gosani	33.55	16.86	50.25	2.664	0.4715	3.1350	36.69	45.95
Guma	20.78	9.76	46.99	2.223	0.2950	2.5175	23.30	41.91
Kashinagara	20.10	11.29	56.14	2.738	0.2513	2.9890	23.09	48.87
Mohana	63.61	9.51	14.95	2.218	0.4797	2.6973	66.30	14.35
Nuagada	14.16	4.58	32.36	2.132	0.1937	2.3260	16.48	27.80
R. Udaygiri	26.62	6.85	25.72	1.588	0.2243	1.8119	28.43	24.08
Rayagada	19.80	7.72	38.99	2.433	0.2761	2.7090	22.51	34.29
Gajapati	**198.61**	**66.57**	**33.52**	**15.99**	**2.19**	**18.19**	**216.80**	**30.70**

5.2.3 Management Plan for Under-Utilization of Ground Water

Groundwater in Gajapati district is the main source of drinking in both the rural and urban areas. About 82% of the existing groundwater draft in the district goes to meet the irrigation needs. Industrial use of groundwater in the district is very limited. The need of the hour is for the sustainable development of the available groundwater resources to meet the present and other emerging needs. The groundwater in the district is mainly developed by the means of dug wells, hand pumps, dug-cum-bore wells, bore wells, and some tube wells.

The main objective of these irrigation projects is protective irrigation to mitigate the effect of drought in the district. Groundwater is also utilized for irrigation but to a limited extent and mostly on private ownership. However, considerable parts of the district remain fallow due to a lack of irrigation facilities and the vagaries of rainfall. Even in irrigation command areas patches of unirrigated land exist which are not covered by canal irrigation during *rabi* season. Drought condition is a frequent phenomenon, which adversely affects the agricultural activities in the

district. The main constraints of canal irrigation in the command areas are:

i) Frequency of erratic monsoon and drought conditions in the area.

ii) Nonsupply of irrigation water for summer cultivation restricting the crop intensity

iii) The per hectare low yield, which is probably due to the inadequate and untimely supply of irrigation water mostly in the tail-end areas of canal command.

For augmenting the irrigation facilities and to boost food grain production optimal utilization of both surface and groundwater is a must. In the present scenario, the average stage of groundwater development in the district is only 33.5 % with a minimum of 14.95 % in Mohana block and a maximum of 50 % in Paralakhemundi block. There is ample scope to enhance the groundwater utilization up to 60% to meet the challenges during the drought situations and in areas without the scope of canal water irrigation. The available surplus groundwater resources in the district can help in mitigating the vagaries in rain-fed agriculture and can assure food grain production. Although major parts of the district are underlain by crystalline rocks, favorable hydrogeological conditions for the construction of suitable groundwater abstraction structures exist in the undulating plains and intermontane valleys, where the weathered residuum is moderately thick and the rocks are intensely fractured.

The additional number of groundwater abstraction structures feasible in the districts is depicted in **Table 5.6**. Three kinds of structures have been suggested; dug wells (Dug wells), dug-cum-bore wells (DBWs), and bore wells (BWs). But while constructing additional groundwater abstraction structures, one should take into consideration of the safe spacing criteria between any two structures. The distance between any two Dug wells/DBWs fitted with the pump set should be kept at least 100 m, while that between two BWs may be kept between 150-200 m.

5.2.3.1 Dug well (DW):

The Dug wells are the most common groundwater abstraction structures in the district. The most favorable locations for Dug wells are topographic lows, abandoned and buried stream channels, areas in the close vicinity of rivers and streams, etc. In such areas, the water table is generally shallow and the thickness of the weathered residuum is maximum. In the areas with the shallow water table, centrifugal pumps can work satisfactorily and under favorable conditions, Dug wells

can cater to the irrigation needs of up to about 4 Ha area of land. Depending upon the hydrogeological setup, the thickness of the weathered residuum the yield may be up to 2 to 3 lps. The recommended dimensions of the DW in the district are depth 9 to 12 m, diameter 4.5 to 6 m. The wells may be fitted with 1.5 to 2 H.P. centrifugal pumps for extraction of water. In areas having a deeper water table (more than 6 m below ground level), submersible pumps may be installed and can run for 3 to 4 hours daily. The Dug wells should tap the whole saturated thickness of the weathered mantle till the hard rock is touched as far as practicable. The diameter of the Dug wells should be governed by the water requirement depending on the cropping pattern. In general, a well should be pumped for about 4 hours a day to irrigate about 1 Ha during *Kharif* and 0.5 Ha during *rabi* seasons and about 0.5 Ha during summer with low water requiring crops.

All the Dug wells should be energized for the optimal utilization of their potential. The total number of additional Dug wells worked out to be feasible in the district to utilize 50% of the available surplus groundwater resource (considering development up to 60%) stands at 10,116

5.2.3.2 Dug-cum-bore well:

The dug-cum-bore wells can be constructed in areas where the thickness of the weathered residuum is less than 15 meters deep. The vertical hole drilled in the DW increases the yield of the well. The depth of the DW should be up to 12 meters with a diameter of 4.5 to 6 meters. The depth of the vertical borehole should be about 25 to 30 meters. The diameter of the borehole maybe 102 or 152 mm.

The dug-cum-bore well should be facilitated by centrifugal pumps or submersible pumps, where necessary, for the optimal utilization of their potential.

5.2.3.3 Bore Wells:

The results of the recent surveys and groundwater exploration are quite encouraging for the exploitation of groundwater through bore wells in the southern parts of the district especially in Paralakhemundi and Kasinagar area. Deeper water-bearing fracture zones may be tapped through bore wells. Usually, two to five water-saturated fractured zones are encountered in a depth range of about 150 m and the fractured zones are more common within a depth of about 100m. The bore wells are suitable groundwater abstraction structures even in the areas where the water level is deeper and hard rocks are encountered at shallow depths. The bore wells maybe 100 to 150 m deep

having casing in the top weathered zone with a diameter of about 152 to 203 mm. Based on the availability of productive fractured zones, the depth of the bore well is decided. Depending upon the discharge and drawdown of the bore wells, suitable pumps may be fitted for the optimum utilization of groundwater resources. The recommended capacity is 2 to 3 H.P. submersible pumps and the yield of the wells may go up to 10 lps. The total number of additional BWs worked out to be feasible in the district to utilize 50% of the available surplus groundwater resource (considering development up to 60%) stands at 1190.

Table 5.6 Groundwater Development Potential of Gajapati District.

Assessment Unit Name	Annual Extractable Groundwater Resource (Ham)	Stage of Groundwater Extraction (%)	Total Extraction (Ham)	Groundwater draft at 60% Stage of deve. (Ham)	Addi. water to be deve. (Ham)	Number of BW/ STW assuming unit draft as 2.21 ham per structure per year) 50%	Number of DW assuming unit draft as 0.26 ham per structure per year 50%
GOSANI	3,355	50	1,686	2,013	327	74.0	629
GUMA	2,078	47	976	1,247	270	61.2	520
KASHINAGARA	2,010	56	1,129	1,206	78	17.6	149
MOHANA	6,361	15	951	3,816	2,865	648.2	5,510
NUAGADA	1,416	32	458	850	391	88.5	752
R. UDAYGIRI	2,662	26	685	1,597	913	206.5	1,755
RAYAGADA	1,980	39	772	1,188	416	94.1	800
GAJAPATI	**19,861**	**34**	**6,657**	**11,917**	**5,260**	**1,190.1**	**10,116**

5.2.4 Management Plan for Higher Concentration of Fluoride

Though there is fluoride in many of the villages as discussed earlier, they are mostly found in shallow aquifers (dug-wells) and medium-deep borewells mostly drilled by the state govt. agencies. The occurrence of fluoride is point-specific. Alternate sources available should be explored and the wells with high fluoride should be barred from public consumption. Deeper aquifers form a better alternative source for domestic use in this area.

5.2.5 Management Plan for Scarcity of Water in Hilly Areas

Due to uneven and hilly terrain and lower groundwater recharge and storage capacity, there are many areas where the phreatic aquifer quickly desaturates causing water scarcity during non-monsoon periods. To enhance groundwater availability, suitable measures for the augmentation of monsoon recharge should be taken up. In the foothill regions, contour trenching along with gabion structures should be constructed to arrest the surface runoff and improve rainfall recharge. The details of the structures proposed are discussed in detail under heading 5.2.5. The major crop types are rice and corn which are depicted in the Field photographs. Terrace farming is very common and is a very good practice of rainwater harvesting and conservation practices. The same should be encouraged to continue on a large scale. In hilly areas, the prominent groundwater features are dug wells and shallow Tube wells. The wells normally go dry in summer. The major task is to identify the perennial springs and tap the water through storage structures under gravity and supplying the drinking water to the nearby villages through the piped water supply. This is a very good practice to store the spring water, helping the loss of excess runoff due to high slopes and using the water without even consumption of electricity.

5.2.6 Management Plan for Less Productive Deeper Aquifer

Selection of proper site for drilling of bore wells, based on the favorable hydrogeological conditions has to be done. As discussed earlier, a lot of scopes exist for groundwater development. Priority should be given to the phreatic aquifer for extraction of groundwater through large-diameter dug-wells and dug cum borewells at hydrogeologically suitable locations.

5.2.7 Management Plan for Depleted Water Level in Phreatic Aquifer

Depletion of the phreatic aquifer in the foot-hills and piedmont zones of mountain belts is a common phenomenon during the summer seasons. The phreatic zone gets replenished through rainfall recharge and accounts for the dynamic groundwater resources. The weathered zone developed on massive crystalline is shallow and serves as the phreatic aquifer system for groundwater storage and movement. The rapid decline in water level during the post-monsoon period renders most of the shallow dug-wells drying up or unproductive. However, this lowering of groundwater level is due to out-flow from the basin in the form of base-flows through perennial and ephemeral streams in the area.

5.2.8 Artificial recharge structures feasible

The areas which show post-monsoon water levels beyond 3.0 m bgl have only been demarcated where artificial recharge to groundwater has been suggested. The total area suitable for artificial recharge to the groundwater comes as 1046 km^2, total thickness of the aquifer, aquifer volume and total volume of water required to recharge the aquifers have been worked out for different blocks in the district (considering raising the water level up to 3.0 m bgl). The volume of the aquifer that is proposed to be recharged has been calculated by using the following equation:

V in MCM = (Area in km2) x (Average post-monsoon DTWL in m - 3m)

The total volume of water required has been worked out to be 83.88 MCM. A specific yield value of 3% (depending on area hydrogeology) has been considered while estimating the volume of water to be recharged. **Table 5.7**.

Table 5.7 Estimation of volume of water required for artificial recharge to groundwater

Name of Blocks	Area of Blocks	Area suitable for Artificial Recharge	Average DTW	Total thickness of aquifer to be saturated	Volume of Aquifer to raise water level to 3 m bgl	Total volume of water required to reharge	Volume at 80% efficiency of structures
	Sq.km	Sq.km	m	m	mcm	mcm	mcm
MOHANA	1461.23	90.05	5.00	2.00	180.10	5.40	6.48
PARALAKHEMUNDI	241.03	50.50	4.20	1.20	60.60	1.82	2.18
RAYAGADA	720.07	150.09	5.20	2.20	330.20	9.91	11.89
R.UDAYAGIRI	664.80	330.00	5.00	2.00	660.00	19.80	23.76
GUMA	461.19	220.00	5.20	2.20	484.00	14.52	17.42
NUAGADA	510.12	205.00	6.00	3.00	615.00	18.45	22.14
Total	**4058.45**	**1045.64**	**5.10**	**12.60**	**2329.89**	**69.90**	**83.88**

Table 5.8 Number of feasible structures for artificial recharge to groundwater

Name of Blocks	Volume at 80% efficiency of structures	Number of Artificial Recharge Structures Feasible			
		Percolation tank (40%) @0.2 mcm	Sub-surface dyke (15%) @0.15 mcm	Nala bund/contour bunding (15%) @0.15 mcm	Check dams @0.15 mcm
MOHANA	6.48	13	6	6	13
PARALAKHEMUNDI	2.18	4	2	2	4
RAYAGADA	11.89	24	12	12	24
R.UDAYAGIRI	23.76	48	24	24	48
GUMA	17.42	35	17	17	35
NUAGADA	22.14	44	22	22	44
Total	83.88	168	84	84	168

The most feasible artificial recharge and rainwater harvesting structures are percolation tanks, sub-surface dykes, nala/contour bunding, small check dams, renovation of old tanks to percolation tanks, water spreading, gully plugging, gabion structures etc. The estimated feasible numbers of some artificial recharge structures in the district have been calculated. Allocation of different types of artificial recharge structures, been done based on the topography. The area is a kind of mid-land area with rolling topography (300-600 m asl elevation). Thus, as per the state artificial recharge plan, 40%, 15%, 15% and 30% have been considered for percolation ponds, sub-surface dykes, nala/contour bunding and check dams respectively. The number of structures to be constructed is worked out taking average gross capacity of one percolation tank as 200 TCM, for Nala bund/contour bunding/check dam as 150 TCM in multiple fillings. The total number of recharge structures feasible have been worked out as 168, 84, 84 and 168 for percolation tanks, sub-surface dykes, nala/contour bunding and check dams respectively **Table 5.8**.

The problem of water level depletion in the phreatic aquifers can be addressed through artificial recharge and through various water conservation structures. The foot hill areas are suitable areas for construction of recharge structures such as percolation tanks. Similarly, 2nd and 3rd order drainages are suitable for the construction of check dams. Tentative location of some of the artificial recharge structures have been presented in **Figure 5.3** For the mitigation of deeper water level areas in the district, the following measures can be taken up

1. Contour trenching, staggered trenching and gully plugging in foot-hill areas.
2. Construction of farm ponds and renovation of existing water bodies.

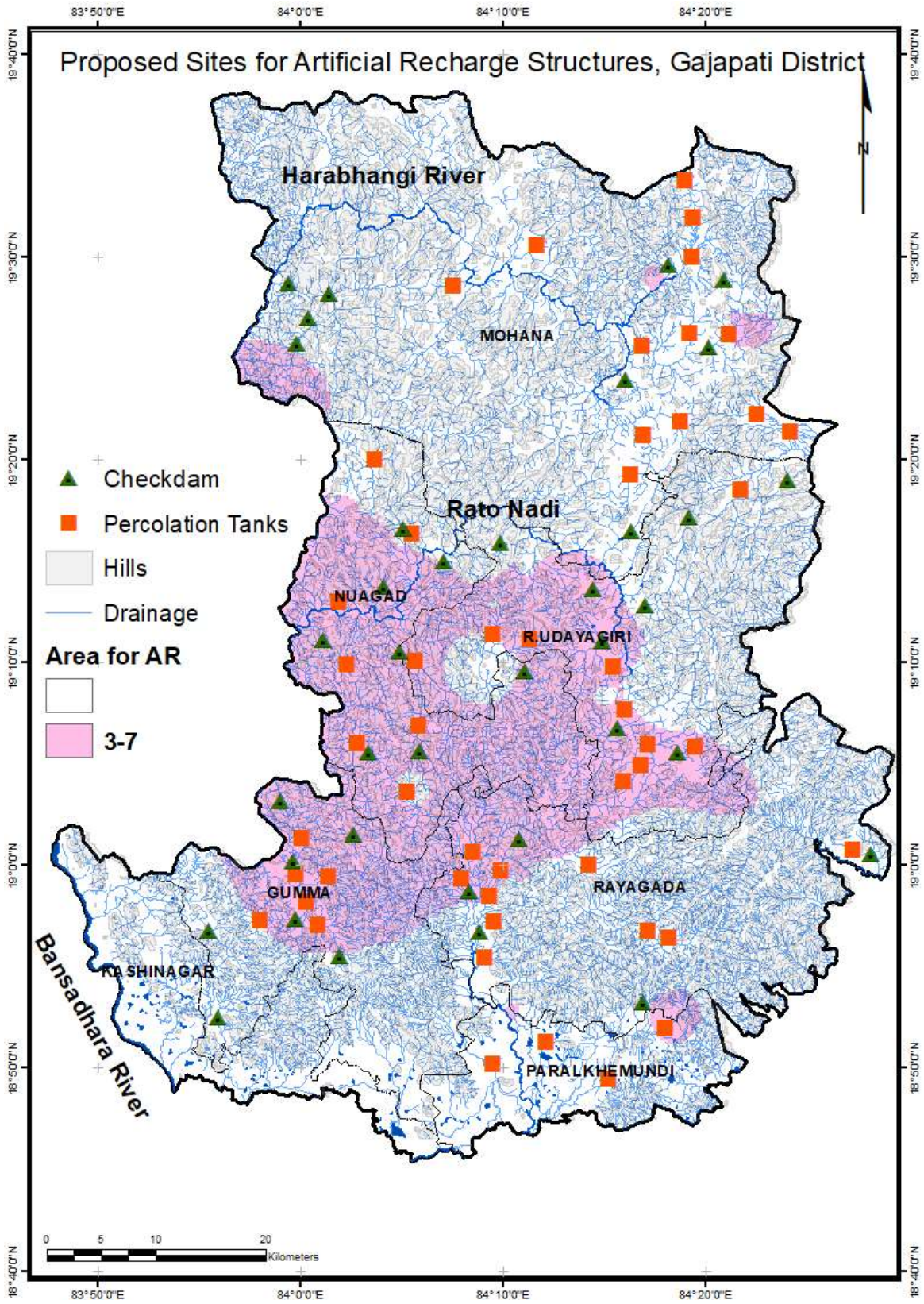

Figure 5.3 Proposed sites for Artificial Recharge Structures.

6.0 SUMMARY AND RECOMMENDATIONS

6.1 Summary

National Aquifer Mapping Programme (NAQUIM) was taken up for detailed hydrogeological investigation, data-gap analysis, and Aquifer Mapping and Management in the tribal district of Gajapati, covering seven blocks of the district namely, Paralakhemundi, Rayagada, Kashinagar, Gumma, R.Udayagiri, Mohana, and Nuagada covering a total of 4325 sq km during the period 2019-2020. The following are the summarised details.

1 The district is bounded by $18^0$46' to $19^0$39' North Latitude and $83^0$48' to 84^0 27' East Longitude under the SOI Toposheet Numbers 65 M/14, 15, 16, 65 N/13, 72 A/2,3,4, 74 A/6, 7, 8, 74 B/5. The mappable area under NAQUIM is 1411 sq. Km. This study area was taken up after excluding the hilly areas.

2 The average annual rainfall of the district is 1413 mm, out of which 85% to 90% is received during the monsoon period (mid-June to mid-October). The long-term rainfall analysis from 1991 to 2020, shows that the district received the minimum rainfall of 901 mm during the year 1996 and the maximum precipitation of 2120 mm during 1990.

3 Most of the district is covered with rugged forest and mountainous terrain of Eastern Ghats rocks with narrow intermontane valleys with occasional flat tops. The lofty mountain ranges of the Eastern Ghats in this area rise steeply and abrupt at the end of the western continuation of the coastal plains of Andhra Pradesh. The average elevation of hills ranges from 500 to 1200m above mean sea level. The important hills in the district are Dandamera Parbat (1103m), Tangiri Parbat (1155m), and Mahendra Giri (1499m).

4 The forest area is 57% of the total geographical area of the district and 4.25% of the state of Odisha. The net sown area of the district is 75,037 ha with maximum cropping intensity in Kashinagar block which is 223%. The cropping intensity of the district is very good. The average cropping intensity is 193%.

5 The soils of the district can broadly be grouped into two types as Alfisols and Entiisols. Soils of the district are generally having average to good fertility status. All common types of crops can be grown in the district.

6 The river Vansadhara along with its tributary, Mahendratanaya, Harbhangi, Badanadi, etc form the major drainage system of the districts. The master slope of the ground is towards the South and NWN direction. All the rivers exhibit dendritic drainage patterns and are structurally controlled.

7 The study area comprises a group of highly metamorphosed rocks of Eastern Ghat facies belonging to the Archean Complex of the Indian Peninsula. The development of laterite is rare and wherever it's seen it occurs as thin-film capping the crystalline rocks. Discontinuous patches of Alluvium are restricted to major river courses. It occurs as an elongated patch along the major and minor river channels.

8 The crystalline complex representing Eastern Ghat Super Group consisting of Khondalite suite, Charnockite suite, Granite and Granite Gneisses, metabasics and veins of quartz and pegmatite are exposed in entire Gajapati district, alluvium representing younger formations have restricted occurrence and the same is seen in the area as detached and isolated units.

9 CGWB has constructed 4 EWs and 2 OWs during the groundwater exploration program. WAPCOS has drilled 10 exploratory wells and 1 observation wells in the district. For the monitoring of groundwater level and quality CGWB has established 31 National Hydrograph Network Stations in the district. 31 Key Observation wells (dug wells) in 2020-21 and 2 wells from the State Groundwater Department was used for the analysis and interpretation of water level contour patterns in the district

10 Depth to the water level in the pre-monsoon period (May 2019) varies from 1.86 mbgl (Gosani) to 15 mbgl (Ramagiri), the average being 5.68 m bgl. Depth to the water level in the post-monsoon period (Nov-2019 and 2020) varies from 0.21 mbgl (Mandimera, Mohana block) to 7.53 (Tarabada, Nuagada block) mbgl, the average being 2.60 m bgl. Fluctuation of groundwater table between pre- and post-monsoon period in the study area varies from 0.35 (Tumbagarh, Rayagada) to 9.81 (Ramagiri, R. Udayagiri) mbgl, the average being 3.19 m. The general range of fluctuation in water level in the study area is between 2-4m. The long term trend analysis indicates that out of 26 stations, 10 (41.6%) show a rising trend and the rest 14 stations (58.3%) show a falling trend in the Pre-monsoon season, and 7 stations (31.8%) show a rising trend, and 15 stations (68.1%) show a falling trend in post-monsoon

seasons.

11 The chemical quality of groundwater both from shallow and deeper aquifers is good and can be suitably utilized for all purposes. 26 samples were collected from shallow dug-wells and 22 samples were collected from Tube wells. Fluoride and Nitrate have been detected in the district in sporadic locations. The deeper aquifer can provide alternative fluoride-free sources of water.

12 Three major types of Aquifers are demarcated (1) weathered zone aquifer; (2) Precambrian fractured aquifer and (3) Massive Zone. Massive zones cannot be taken as an aquifer system which is beyond the depth of 150m so the entire district can be divided into 2 major aquifer systems (1) 1st Aquifer System within the depth of 50 m bgl, which includes the weathered zone aquifer, and (2) the 2nd Aquifer System within the depth range of 50 to 150 m bgl. Thus, the 1st aquifer system also includes the weathered zone aquifer at the top and the alluvial aquifer in the southern parts of the district.

13 The total annual dynamic groundwater resource/Annual extractable groundwater resources of Gajapati district is assessed to be 19861 Hectare meter (Ham). The existing gross groundwater draft/extraction in the district stands at 6656.61 Ham, out of which the irrigation draft is 4875.80 Ham (~73% of total draft). The draft for domestic and drinking constitute 25% of the gross draft which is 1671.43 Ham. The annual utilizable resource which remains for irrigation use (after allocation for domestic and drinking up to the year 2025) has been estimated at 13105.11 Ham. The stage of groundwater development varies between the minimum of 14.95% in the Mohana block and the maximum of 50.25% in the Paralakhemundi block, with the average stage of groundwater development for the district as 33.52%.

14 By construction of 7504 farm ponds 15.99 MCM water can be harvested. A total number of 12,852 households in the districts with more than 150 sq.m of rooftop area can be taken up for construction of rooftop rainwater harvesting structures. Around 2.192 MCM water can be generated and recharged or conserved for various uses thereby increasing the net availability of groundwater for extraction from 198.61 mcm to 216.8 mcm. The total stage of groundwater development is reduced to 30.70% from 33.52%.

15 Total number of additional Dug wells worked out to be feasible in the district to utilize 50% of the available surplus groundwater resource (considering development up to 60%) stands at 10,116. Total number of additional BWs worked out to be feasible in the district to utilize 50% of the available surplus groundwater resource (considering development up to 60%) stands at 1190. The total number of recharge structures feasible have been worked out as 168, 84, 84, and 168 for percolation tanks, sub-surface dykes, nala/contour bunding and check dams respectively.

6.2 Recommendations

For sustainable groundwater development in the area, a systematic, economically sound, and politically feasible framework for groundwater management is required. Considering the local physiographical and hydrogeological set up the following groundwater management strategy is suggested.

- Priority should be given to the phreatic aquifer for extraction of groundwater through large-diameter Dugwells and dug cum borewells at hydrogeologically suitable locations. Selection of proper site for drilling of bore wells, based on the favorable hydrogeological conditions has to be done. In the construction of groundwater abstraction structures, such as dug wells, dug-cum-bore wells, and bore wells, for irrigation minimum safe spacing should be maintained to avoid interference of the wells.
- For irrigation, the requirement in relatively water-deficient areas, efficient irrigation techniques such as drip and sprinkler should be practiced. For optimum utilization of the groundwater potential, necessary steps should be taken for the energization of the wells. As there is large scope for the development of groundwater, suitable schemes may be launched for groundwater development to boost agricultural production in the district. The agricultural extension services should motivate and guide the farmers to adopt suitable cropping patterns to maximize the benefits of irrigation through dug wells / bore wells.
- The rapid decline in water level in uplands or hill slope areas during the post-monsoon period renders most of the shallow dug wells drying up or unproductive. Therefore, suitable structures like percolation ponds, sub-surface dykes, nala-contour bunding, check dams/weirs, and other surface run-off conservation measures should be adopted

as artificial recharge structures. The structures can be designed at suitable locations based on prevailing site-specific hydrological conditions in the area for the sustainable development of water resources. Rainwater harvesting should be adopted in all govt. and public buildings. This will increase the dynamic groundwater storage in the adjacent phreatic aquifer.

- Perennial springs are to be identified and spring water can be diverted through piped water supply by storing in water tanks along the hills thereby reducing the energy consumption.
- The farmers should be educated through agricultural extension services for adopting suitable cropping patterns for optimal utilization of available groundwater and surface water resources.
- Most of the productive fractures are located within the depth of 100 m below ground. The aquifers within this depth can be exploited for irrigation and drinking. This aquifer system gets regular recharge from rainfall.
- Reckless pumping from the bore wells for long durations should be avoided for sustainability. It may cause a rapid decline in water level.
- The yield of existing dug wells may be enhanced by converting those into dug-cum-bore wells wherever feasible and the wells should be provided with brick lining which will facilitate the free flow of groundwater into the well.
- The point sources (dug wells, hand pumps, bore wells) which yield groundwater with high fluoride content (>1.5 mg/L) should be stopped immediately from use. In that case, alternate sources of safe drinking may be provided. The occurrence of fluoride is point-specific. Deeper aquifers form a better alternative source for domestic use in this area.
- Detailed surface geophysical survey aided by photogeological & remote-sensing studies may be taken up in the district to identify the exact thickness of weathered zone and occurrence and extent of lineaments, which form potential aquifer zones.
- Groundwater monitoring in the district, for water level and water quality, through National Hydrograph Stations should be strengthened to assess the impact of envisaged groundwater development on the groundwater regime.

Field Photographs

Contour farming along the hill slope, Gumma block

Large dia dugwell a common abstraction medium, Kasinagar

Exfoliation weathering in granitic rock, Paralakhemundi

Weathered top soil, Mahendragarh to Ramagiri

Small scale checkdams, Nuagada block

Fractured developed in granitic gneissic rocks, R. Udayagiri

Field Photographs 1

Field Photographs

Maize a common harvest in hill slopes, Nuagada

Typical well to harness the spring water, R.Udayagiri

Stony walled dug well very common in the area

Tanks to harvest spring water under gravity, Mohana block

Harabhanga Resorvoir, Mohana Block

Paddy mostly spring fed, Gumma block

Field Photographs 2

7.0 BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, GAJAPATI DISTRICT, ODISHA

7.1 BLOCK MOHANA

1. SALIENT INFORMATION	
Name of the Block and Area (in Sq.Km)	**Mohana** **Area**: 461.79 sq.km. **Gram Panchayats**: 39 **Villages**: 499
Population	1,33,598 as per 2011 census
Rainfall	Average Annual Rainfall 1318 mm
Agriculture and Irrigation	**Principal crops:** Paddy, Maize, Cereal, Pulses, Oil Seeds, Vegetable Crops **Gross cropped area:** 195.23 sq.km **Net sown area:** 104.04 sq. km. **Cropping intensity:** 188% **Area under forest:** 338.14 Sq.Km **Area under waste land:** 123.21 Sq.km **Total irrigated area:** 33.24 Sq.km **Net irrigated area:** 32.10 Sq.km **Partially protective irrigation:** 7.66 Sq.km **Total Rainfed area:** 153.16 Sq.km
Major River and Soil Types	Harabhangi river and tributaries, Red Sandy soil, Red Loamy soil and Alluvial soil
Major Rock Types	Eastern Ghat Super Group, Charnockite suite, Granite and Granite Gneisses, metabascis and veins of quartz and pegmatite
Groundwater resource availability and extraction (Dynamic)	**Total extractable GW resource (Dynamic**): 6360.69 Ham **Total Groundwater extraction**: 951.23 Ham **Allocation for Domestic use**: 409.16 Ham **Net availability for future use**: 5386.08 Ham **Stage of GW extraction**: 14.95%
Groundwater resource availability and extraction (In-storage) Aquifer-I and II	Aquifer -I (Instorage+ Dyanmic) 18945+6361=25305 Ham Aquifer-II 15054.98 Ham
Water level behaviour	Pre monsoon water level: 2.25m bgl to 5.18 mbgl

	Post monsoon water level: 0.21 mbgl to 5.05 mbgl Water level fluctuation: 0.5 mbgl to 5.3mbgl
2. AQUIFER DISPOSITION	
Number of aquifers	Aquifer-I (Dynamic+Instorage) up to a depth of 30m Aquifer-II up to the depth of 150m fractured aquifer.
Exploration	3 EWs up to the depth of 200m, 0.8 lps discharge, 0.41 m^2/day Trasmissivity
3-D aquifer disposition and basic characteristics of each aquifer	Refer to the panel diagram
3. CHEMICAL QUALITY OF GROUNDWATER AND OTHER ISSUES	
Chemical quality	Electrical Conductivity (µS/cm): 89-945 TDS (mg/l): 55-558 Ca^{++}(mg/l): 7.88-65.01 Mg^{++}(mg/l): 2.36-15.36 Na^{+}(mg/l): 6.35-85.78 K^{+}(mg/l): 0.86-18.44 HCO_3(mg/l): 23-221 $SO_4^{=}$ (mg/l): 7.64-54.62 Cl (mg/l): 11.63-120.9 NO_3^{-}(mg/l): 0.0-54.62 F (mg/l): 0.116-1.23 *At Kirting, high value of fluoride is found due to geogenic reasons. Marginally high value of Nitrate is found at Sialilata and Kirimasahi due to Antrhopogenic or cattle breeding causes*.
Other issues	Total Water Demand: 41.5 MCM Total Water Vaialability: 13.7 MCM Demand supply Gap: 27.8 MCM
4. GROUNDWATER RESOURCE ENHANCEMENT	
Management Plan for the block	**Surplus GW** available at 60% stage of extraction: 28.65 MCM **No of additional Borewells proposed:** 648 **No of additional Dugwells proposed:** 5,510 **Total number of Farm ponds proposed:** 1040 & Total Annual recharge will be 2.218 MCM

	Total number of RTRWH proposed: 2,813 & Total Annual recharge will be 0.480 MCM **Total number recharge structures proposed to accommodate the volume of unsaturated zone**- 6.48 MCM Percolation Tank-13 Sub-surface dyke-6 Nala bunding-6 Check dams-13

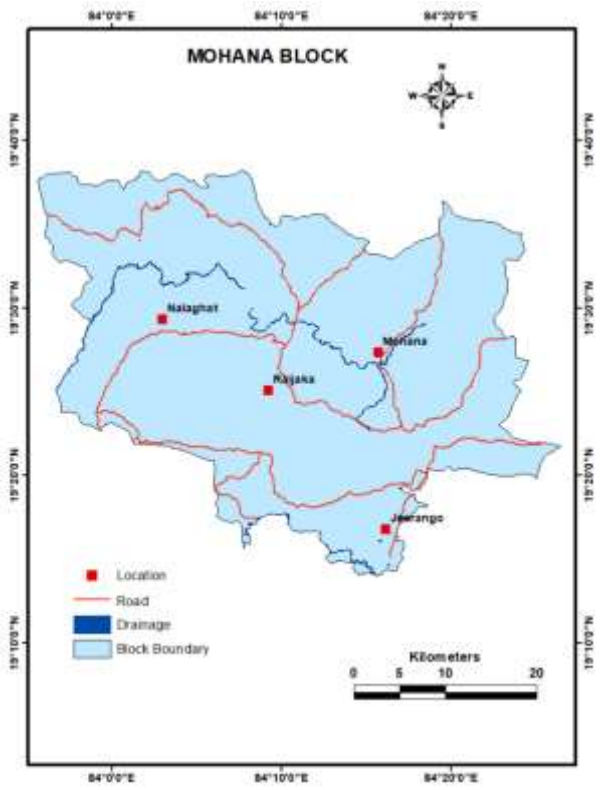

Figure 7.1 Administrative Map, Mohana, Gajapati

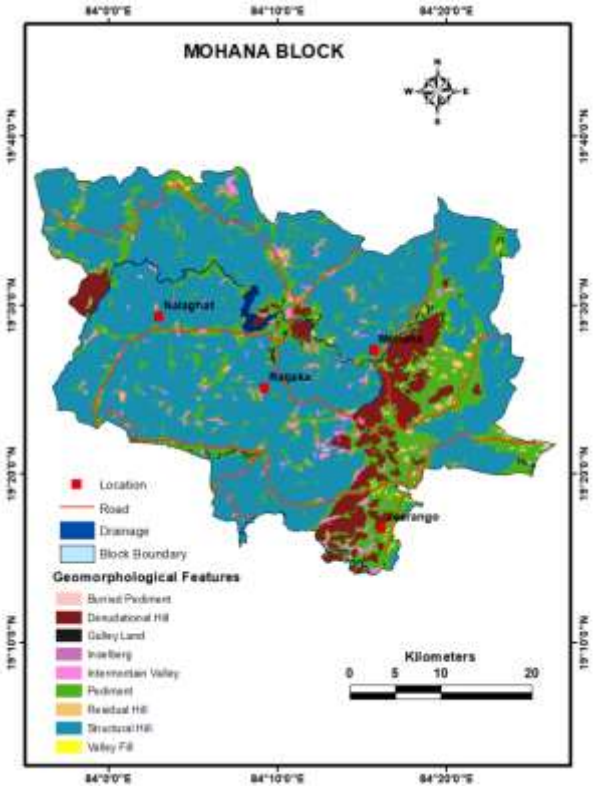

Figure 7.2 Geomorphology Map, Mohana, Gajapati

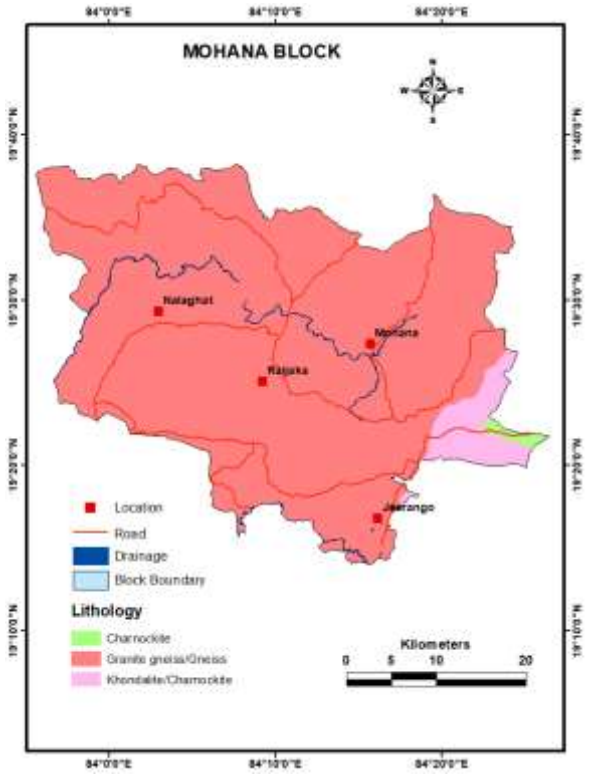

Figure 7.3 Lithology Map, Mohana, Gajapati

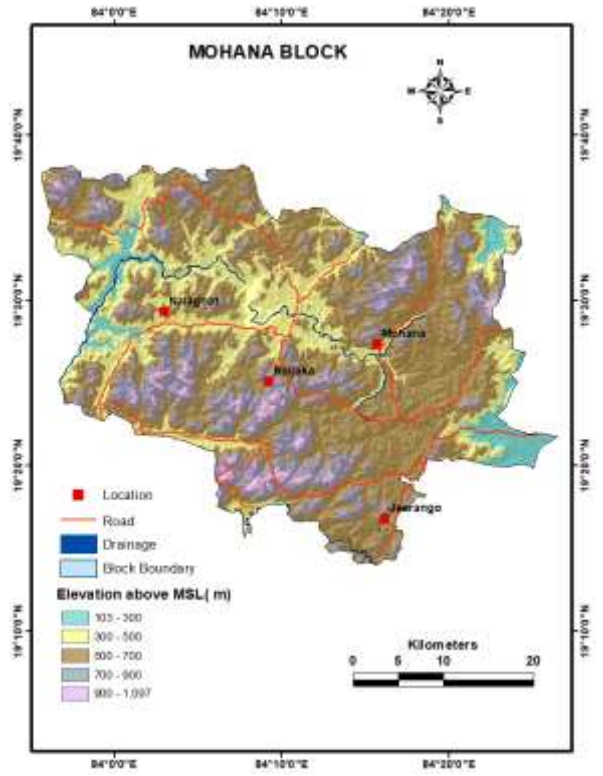

Figure 7.4 Elevation Map, Mohana, Gajapati

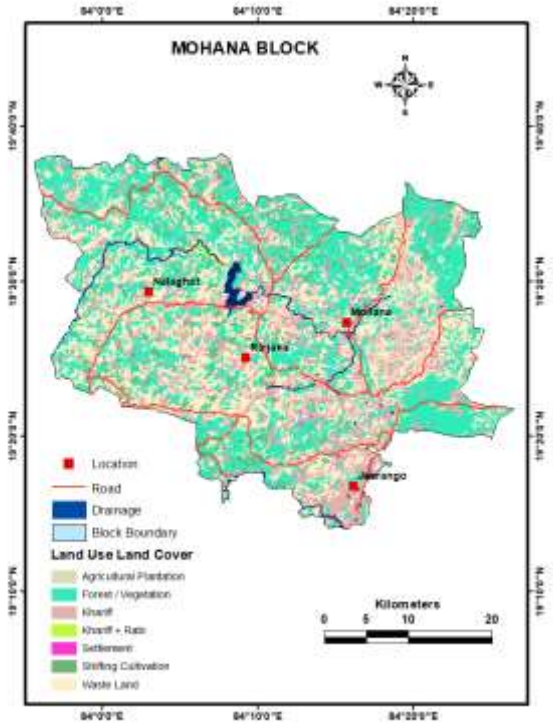

Figure 7.5 Landuse Map, Mohana, Gajapati

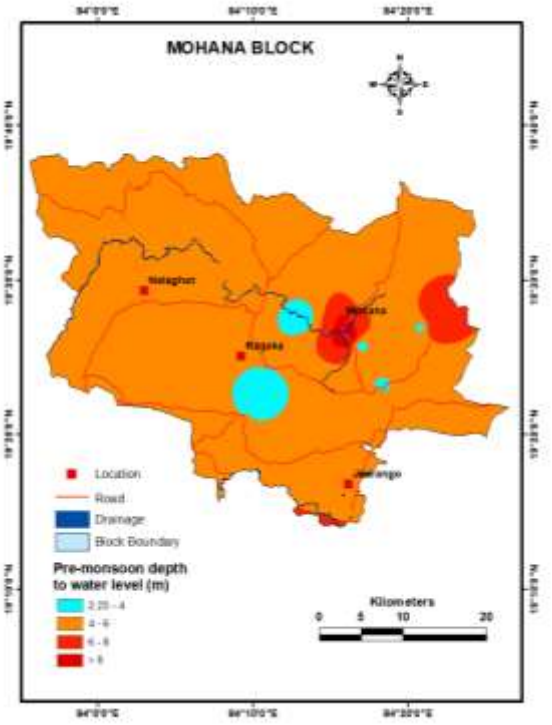

Figure 7.6 DTWL Pre-Monsoon Map, Mohana, Gajapati

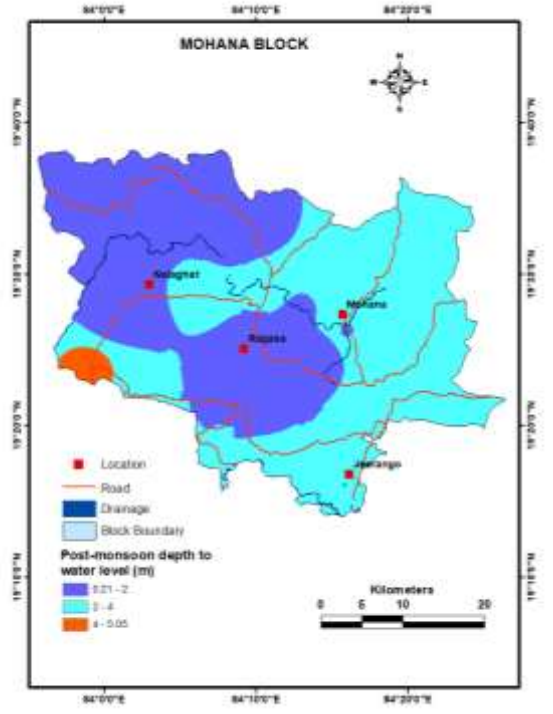

Figure 7.7 DTWL Post-Monsoon Map, Mohana, Gajapati

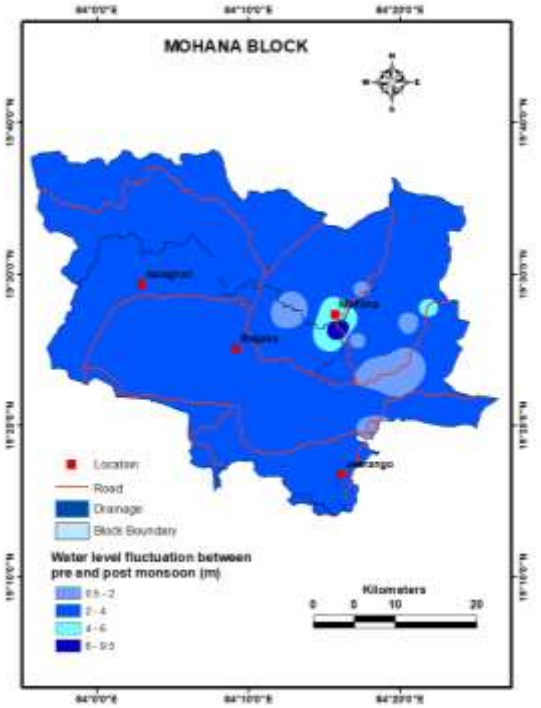

Figure 7.8 WT Fluctuation Map, Mohana, Gajapati

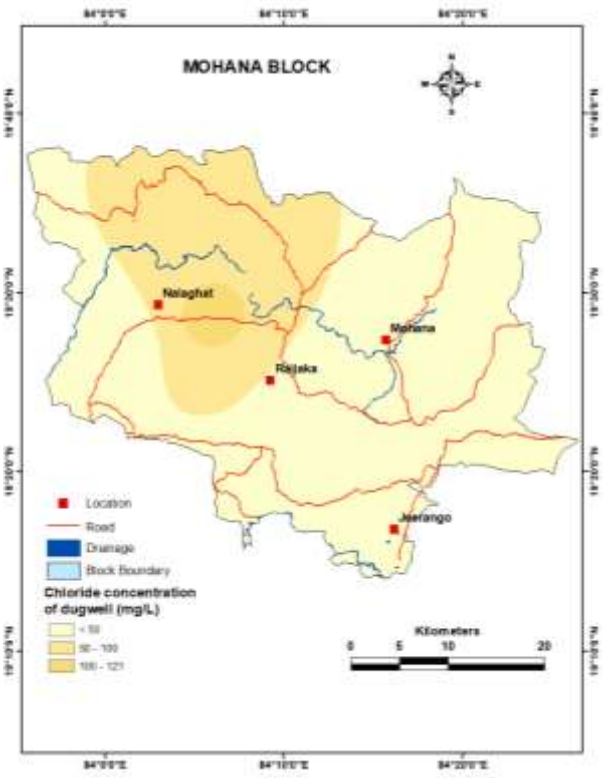

Figure 7.9 Isochloride (dug well) Map, Mohana, Gajapati

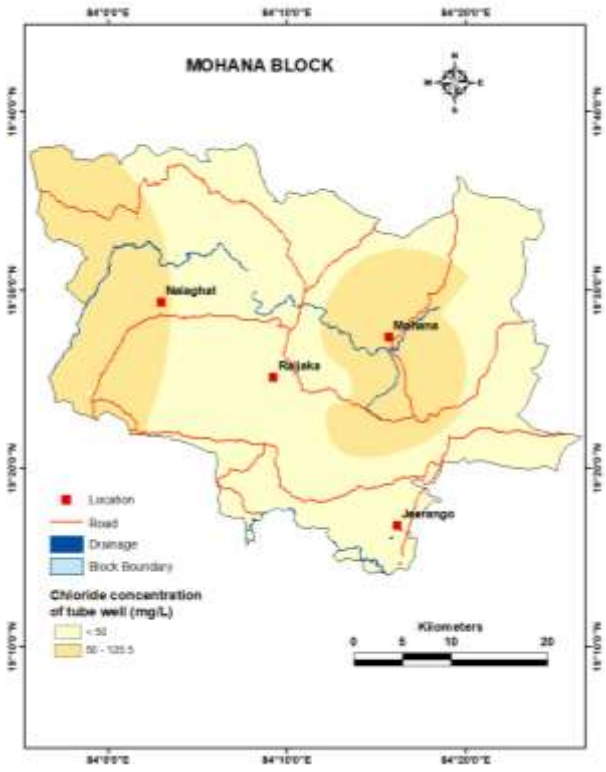

Figure 7.10 Iso-chloride (Tube well) Map, Mohana, Gajapati

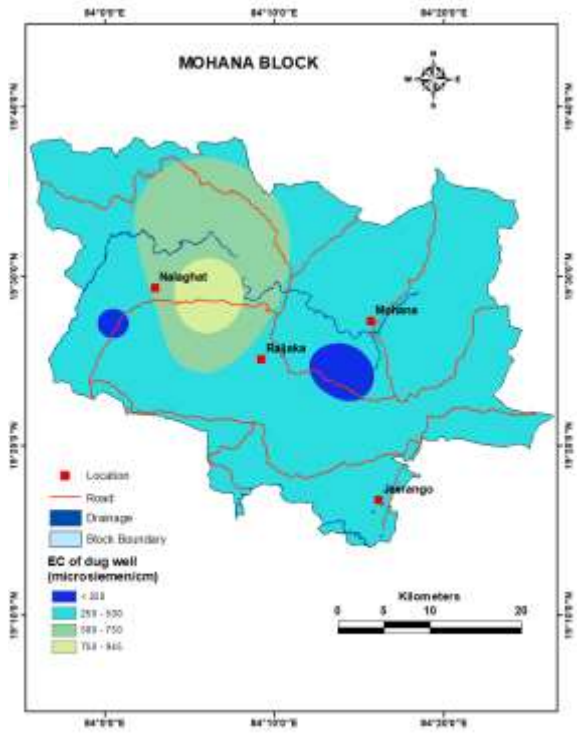

Figure 7.11 Iso-conductivity Map (dug well), Mohana, Gajapati

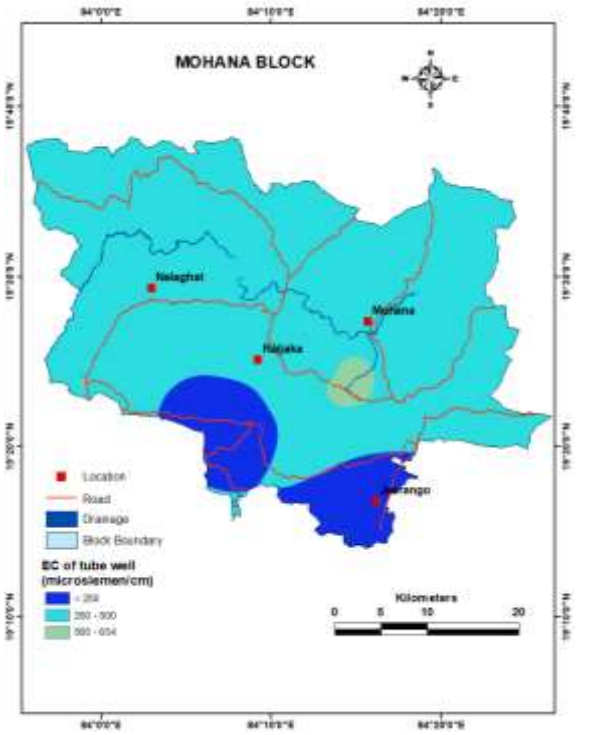

Figure 7.12 Iso-conductivity Map(Tubewell), Mohana, Gajapati

7.2 BLOCK R. UDAYAGIRI

1. SALIENT INFORMATION	
Name of the Block and Area (in Sq.Km)	**R.Udayagiri** **Area**: 665 sq.km. **Gram Panchayats**: 17 **Villages**: 247
Population	64,123 as per 2011 census
Rainfall	Average Annual Rainfall 1475 mm
Agriculture and Irrigation	**Principal crops:** Paddy, Maize, Cereal, Pulses, Oil Seeds, Vegetable Crops **Gross cropped area:** 175.89 sq.km **Net sown area:** 74.48 sq. km. **Cropping intensity:** 236 % **Area under forest:** 262.06 Sq.Km **Area under waste land:** 76.20 Sq.km **Total irrigated area:** 24. 60 Sq.km **Net irrigated area:** 20.58 Sq.km **Partially protective irrigation:** 7.28Sq.km **Total Rainfed area:** 145.53 Sq.km
Major River and Soil Types	Mahendratanaya, Rato nadi and tributaties Red Sandy soil, Red Loamy soil and Alluvial soil
Major Rock Types	Eastern Ghat Super Group, Charnockite suite, Granite and Granite Gneisses, metabascis and veins of quartz and pegmatite
Groundwater resource availability and extraction (Dynamic)	**Total extractable GW resource (Dynamic**): 2662.03 Ham **Total Groundwater extraction**: 685 Ham **Allocation for Domestic use**: 196 Ham **Net availability for future use**: 1970 Ham **Stage of GW extraction**: 25.72%
Groundwater resource availability and extraction (In-storage) Aquifer-I and II	Aquifer -I (Instorage+ Dyanmic) 93.10+2662=2755 Ham Aquifer-II 7082 Ham

Water level behaviour	Pre monsoon water level: 5.0 bgl to 9.58 mbgl Post monsoon water level: 0.43 mbgl to 6.31 mbgl Water level fluctuation: 3.27 mbgl to 6.82 mbgl
2. AQUIFER DISPOSITION	
Number of aquifers	Aquifer-I (Dynamic+Instorage) up to a depth of 30m Aquifer-II up to the depth of 150m fractured aquifer.
Exploration	2 EWs and 1 OW up to the depth of 200m, 10 lps discharge, 176.8 m^2/day Trasmissivity
3-D aquifer disposition and basic characteristics of each aquifer	Refer to the panel diagram
3. CHEMICAL QUALITY OF GROUNDWATER AND OTHER ISSUES	
Chemical quality	Electrical Conductivity (µS/cm): 105-1191 TDS (mg/l): 73-828 Ca^{++}(mg/l): 9.6-71 Mg^{++}(mg/l): 2.4-21.3 Na^{+}(mg/l): 5.4-132 K^{+}(mg/l): 0.9-57.6 HCO_3(mg/l): 34.9-278.9 $SO_4^{=}$ (mg/l): 7.2-57.9 Cl (mg/l)- 9.3-188.3 NO_3^{-}(mg/l): 2.1-53.1 F (mg/l): 0.02-1.0 *At Poipani and Burupada marginally high value of Nitrate is found due to Antrhopogenic or cattle breeding causes*.
Other issues	Total Water Demand-27.7 MCM Total Water Vaialability-10.5 MCM Demand supply Gap-17.3 MCM
4. GROUNDWATER RESOURCE ENHANCEMENT	
Management Plan for the block	**Surplus GW** available at 60% stage of extraction: 9.12 Ham **No of additional borewells proposed:** 206 **No of additional Dugwells proposed:** 1755

	Total number of Farm ponds proposed: 744 & Total Annual recharge will be 1.588 MCM **Total number of RTRWH proposed:** 1316 & Total Annual recharge will be 0.224 MCM **Total number recharge structures proposed to accommodate the volume of unsaturated zone**- 23.76 MCM Percolation Tank-48 Sub-surface dyke-24 Nala bunding-24 Check dams-48

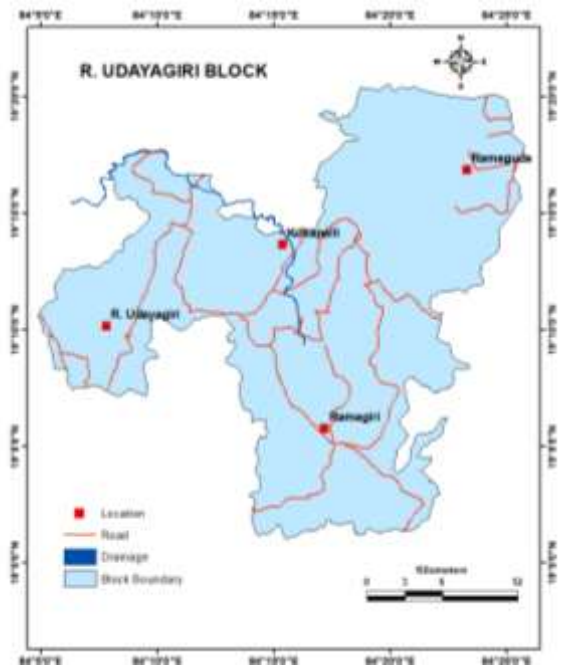

Figure 7.13 Administrative Map, R.Udayagiri, Gajapati

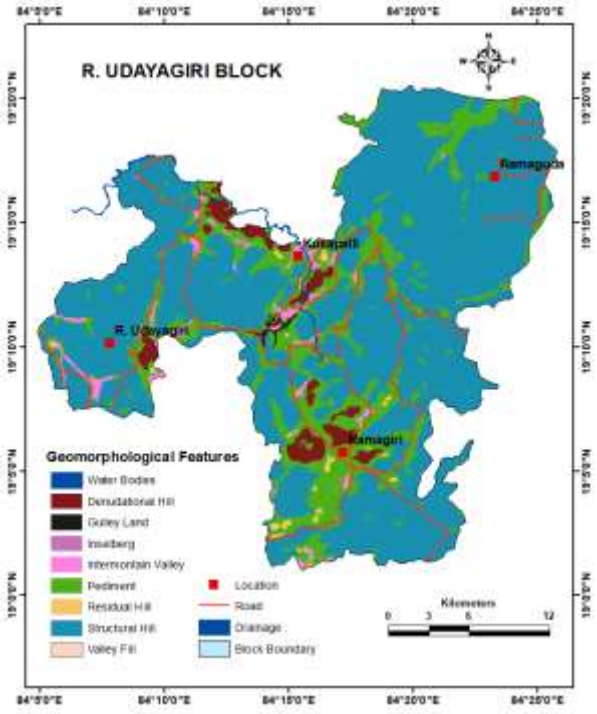

Figure 7.14 Geomorphology Map, R.Udayagiri, Gajapati

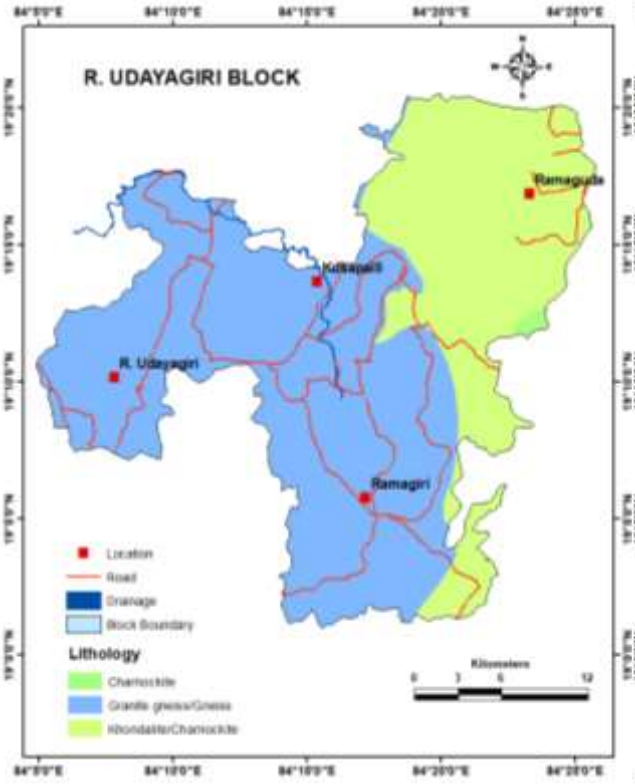

Figure 7.15 Lithology Map, R.Udayagiri, Gajapati

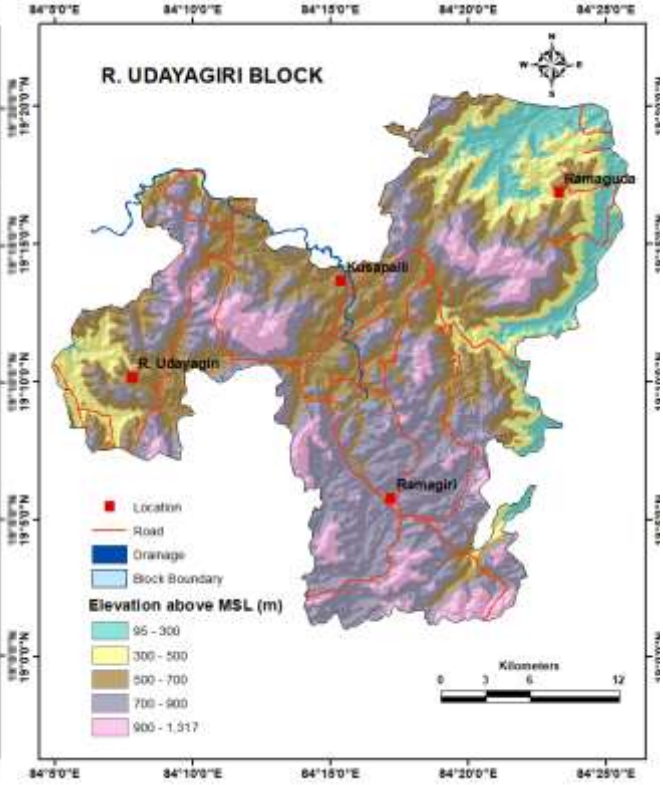

Figure 7.16 Elevation Map, R.Udayagiri, Gajapati

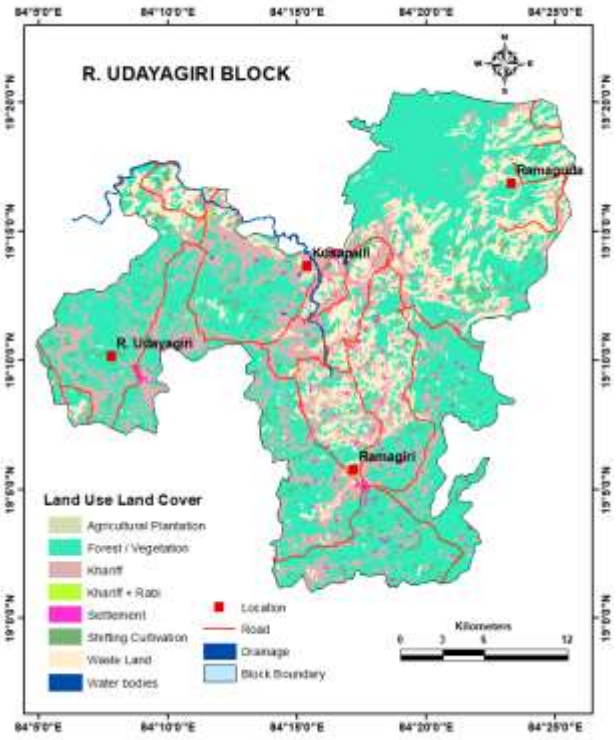

Figure 7.17 Landuse Map, R.Udayagiri, Gajapati

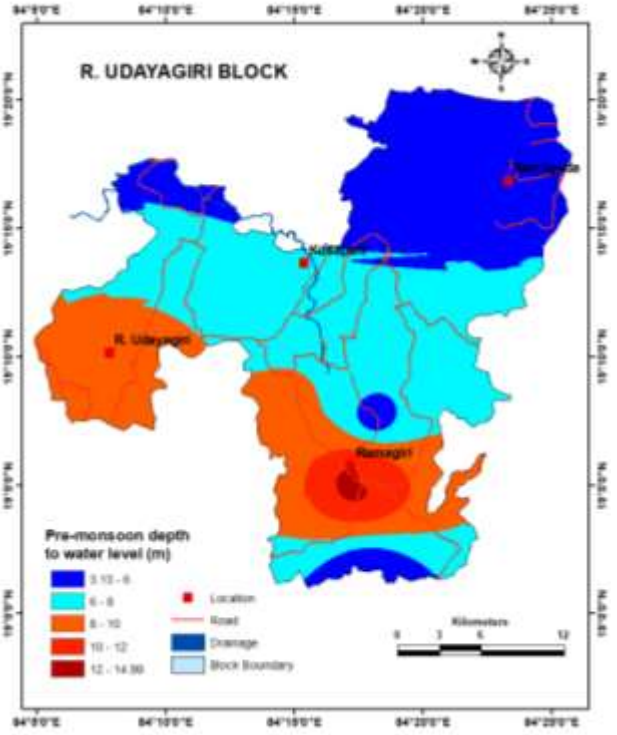

Figure 7.18 DTWL Pre-Monsoon Map, R.Udayagiri, Gajapati

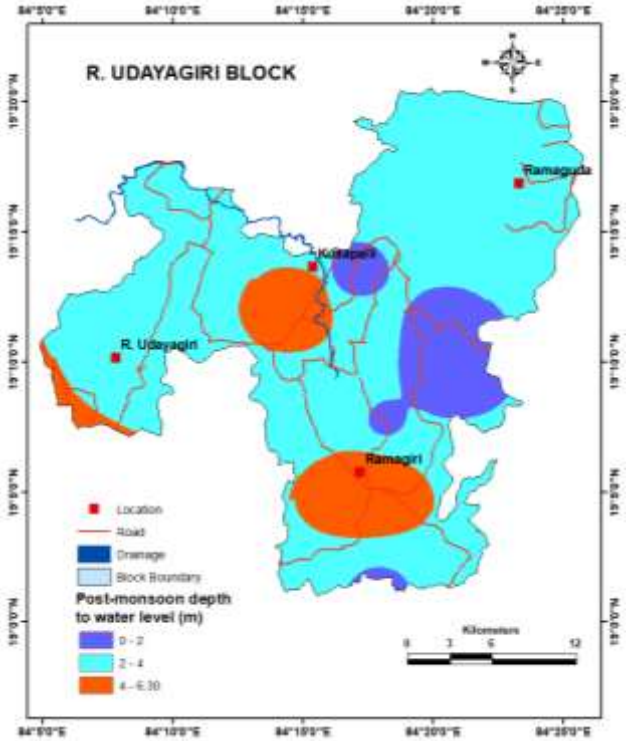

Figure 7.19 DTWL Post-Monsoon Map, R.Udayagiri, Gajapati

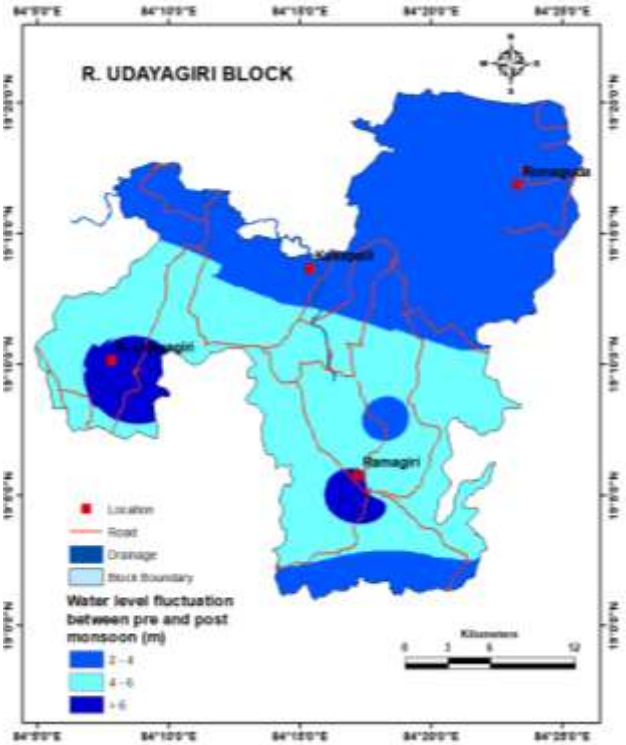

Figure 7.20 WT Fluctuation Map, R.Udayagiri, Gajapati

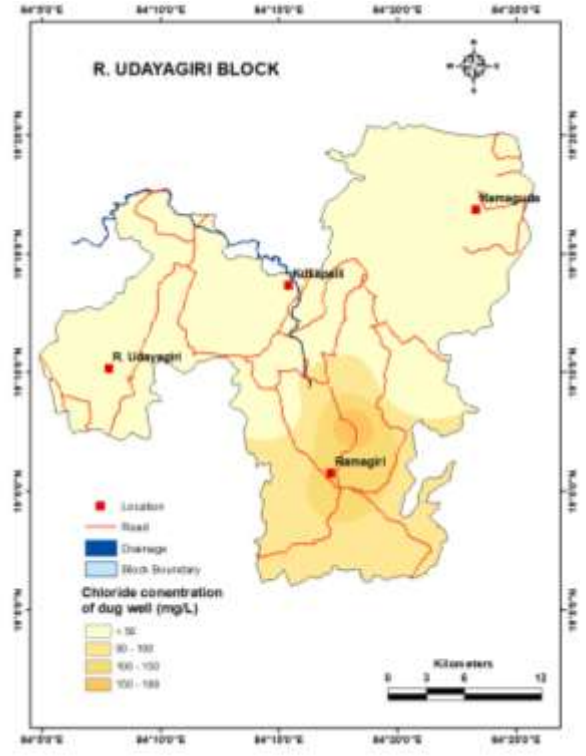

Figure 7.21 Isochloride(Dugwell) Map, R.Udayagiri, Gajapati

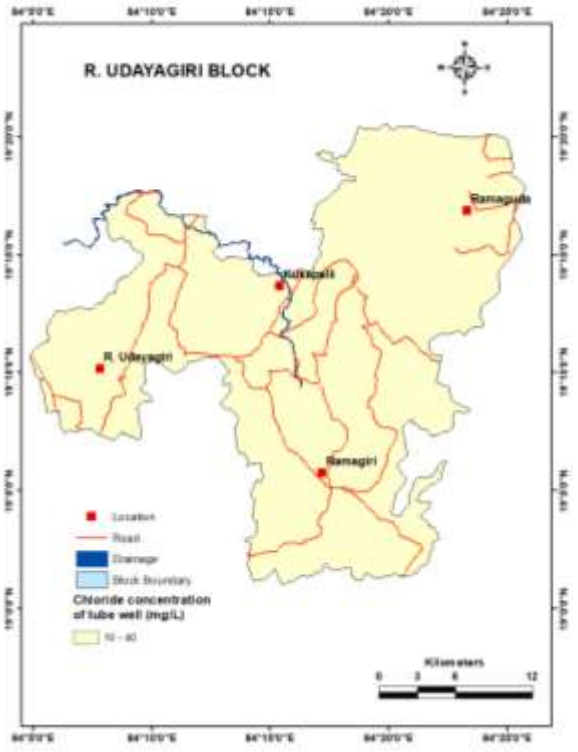

Figure 7.22 Isochloride (Tube well) Map, R.Udayagiri, Gajapati

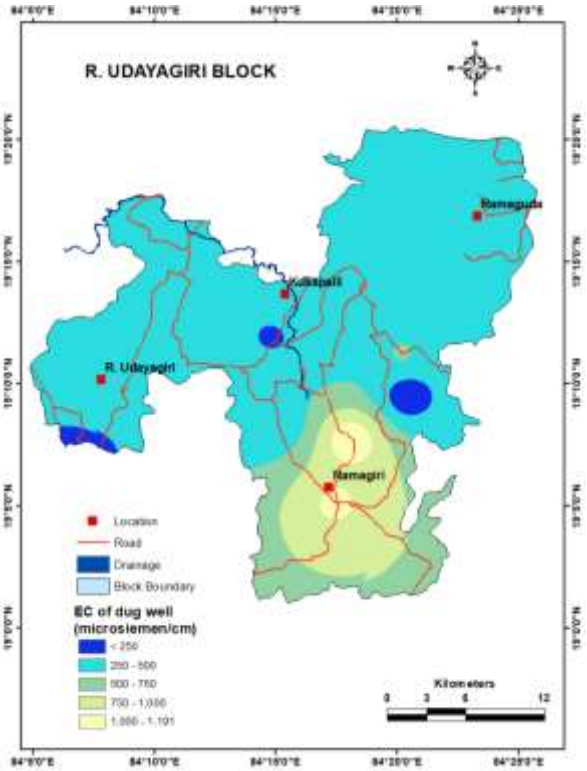

Figure 7.23 Iso-conductivity Map(Dugwell), R.Udayagiri,

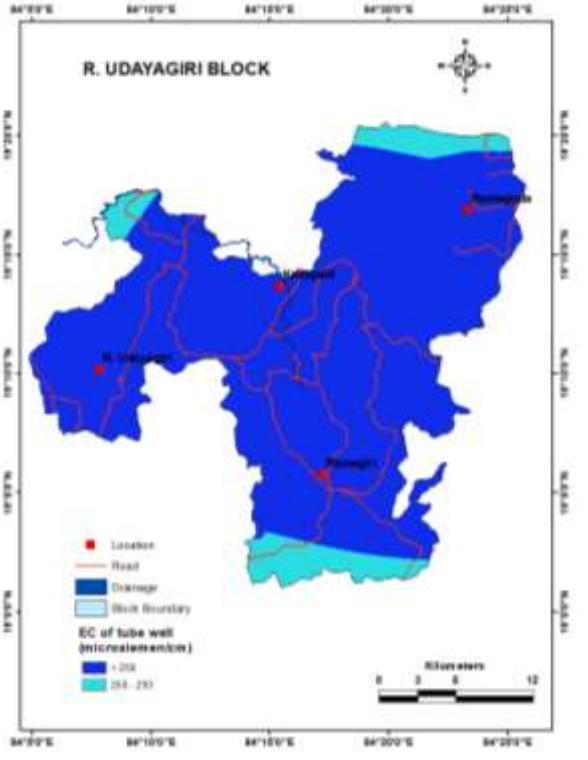

Figure 7.24 Iso-conductivity Map (Tubewell), R.Udayagiri,i

7.3 BLOCK RAYAGADA

1. SALIENT INFORMATION	
Name of the Block and Area (in Sq.Km)	**Rayagada** **Area**: 720 sq.km. **Gram Panchayats**: 21 **Villages**: 223
Population	70,866 as per 2011 census
Rainfall	Average Annual Rainfall 1463 mm
Agriculture and Irrigation	**Principal crops:** Paddy, Maize, Cereal, Pulses, Oil Seeds, Vegetable Crops **Gross cropped area:** 200.23sq.km **Net sown area:** 114.14sq. km. **Cropping intensity: 175** % **Area under forest: 370.50** Sq.Km **Area under waste land: 133.30** Sq.km **Total irrigated area:** 19.08 Sq.km **Net irrigated area:** 32.39 Sq.km **Partially protective irrigation:** 7.50Sq.km **Total Rainfed area:** 150.04 Sq.km
Major River and Soil Types	Mahendratanaya, Rato nadi and tributaties Red Sandy soil, Red Loamy soil and Alluvial soil
Major Rock Types	Eastern Ghat Super Group, Khondalite, Granite and Granite Gneisses, metabasics and veins of quartz and pegmatite
Groundwater resource availability and extraction (Dynamic)	**Total extractable GW resource (Dynamic**): 1980 Ham **Total Groundwater extraction**: 771 Ham **Allocation for Domestic use**: 201 Ham **Net availability for future use**: 1204 Ham **Stage of GW extraction**: 38.99 %
Groundwater resource availability and extraction (In-storage) Aquifer-I and II	Aquifer -I (Instorage+ Dyanmic) 374 +1980 =2354 Ham Aquifer-II 7779 Ham

Water level behaviour	Pre monsoon water level: 2.79 bgl to 10.0 mbgl Post monsoon water level: 0.35 mbgl to 3.7 mbgl Water level fluctuation: 0.35 mbgl to 6.4 mbgl
2. AQUIFER DISPOSITION	
Number of aquifers	Aquifer-I (Dynamic+Instorage) up to a depth of 30m Aquifer-II up to the depth of 150m fractured aquifer.
Exploration	1 no of EW by CGWB and 1 no by WAPCOS up to the depth of 200m, 2.3 lps discharge, 0.74 m^2/day Trasmissivity
3-D aquifer disposition and basic characteristics of each aquifer	Refer to the panel diagram
3. CHEMICAL QUALITY OF GROUNDWATER AND OTHER ISSUES	
Chemical quality	Electrical Conductivity (µS/cm): 500-1000 TDS (mg/l): 259-552 Ca^{++}(mg/l): 39-61 Mg^{++}(mg/l): 15-20 Na^{+}(mg/l): 40-54 K^{+}(mg/l): 2-116 HCO_3(mg/l): 259-391 $SO_4^{=}$ (mg/l): 3-37 Cl (mg/l)- 22-92 F (mg/l): 0.27-0.28
Other issues	Total Water Demand-40.3MCM Total Water Vaialability-14.3 MCM Demand supply Gap-26 MCM
4. GROUNDWATER RESOURCE ENHANCEMENT	
Management Plan for the block	**Surplus GW** available at 60% stage of extraction: 4.16 MCM **No of additional borewells proposed: 94** **No of additional Dugwells proposed: 800** **Total number of Farm ponds proposed: 1141** & Total Annual recharge will be 2.433 MCM **Total number of RTRWH proposed: 1619** & Total Annual recharge will be 0.276 MCM

	Total number recharge structures proposed to accommodate the volume of unsaturated zone- 11.89 MCM Percolation Tank-24 Sub-surface dyke-12 Nala bunding-12 Check dams-24

Figure 7.25 Administrative Map, Rayagada, Gajapati

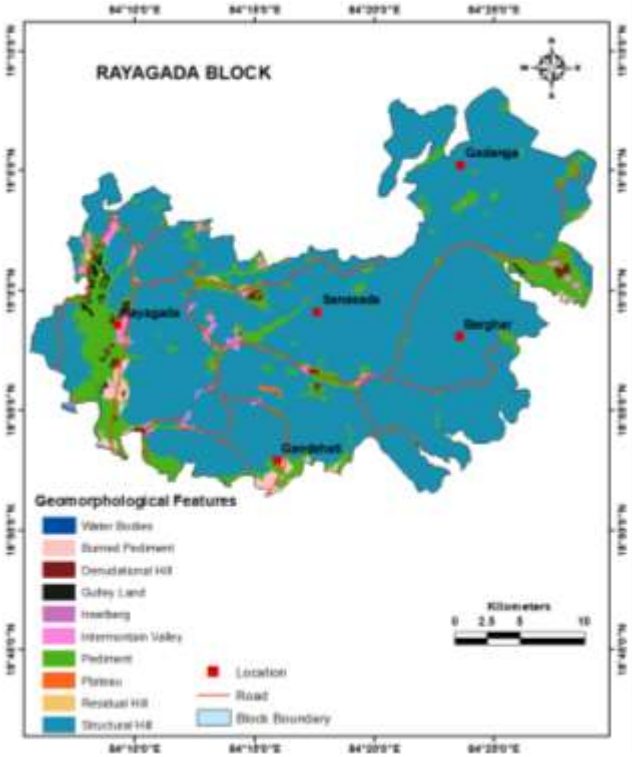

Figure 7.26 Geomorphology Map Rayagada, Gajapati

Figure 7.27 Lithology Map, Rayagada, Gajapati

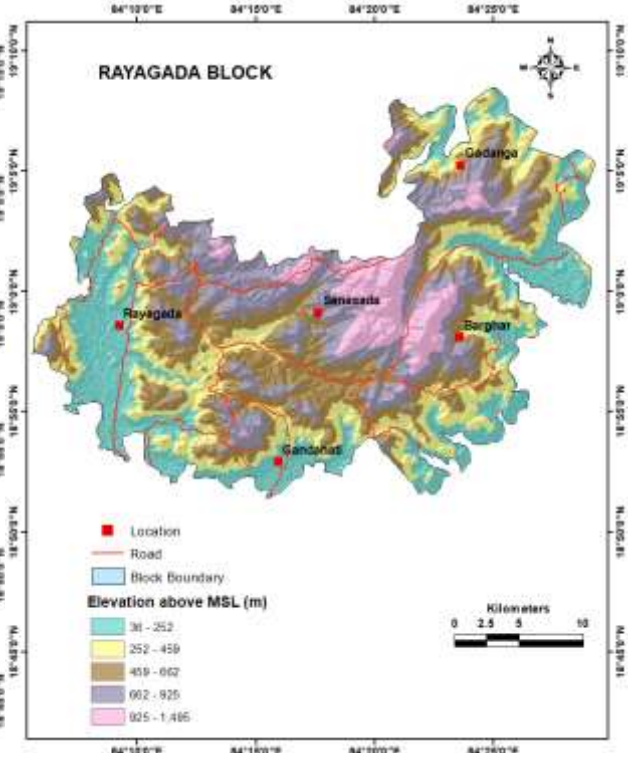

Figure 7.28 Elevation Map, Rayagada, Gajapati

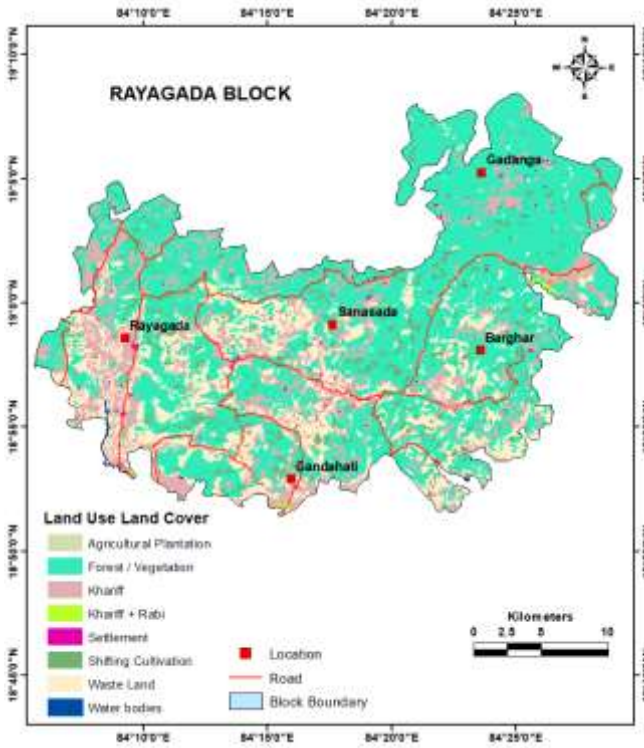

Figure 7.29 Administrative Map, Rayagada, Gajapati

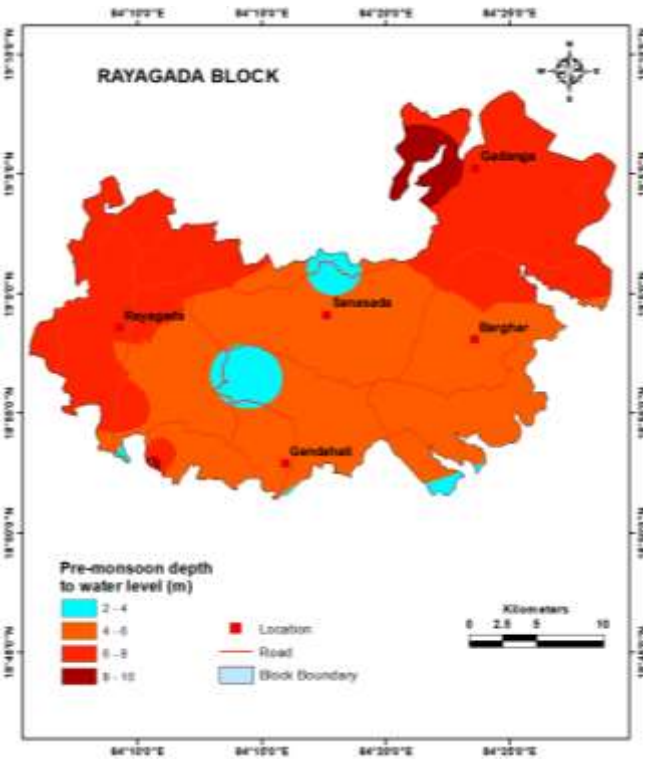

Figure 7.30 Geomorphology Map, Rayagada, Gajapati

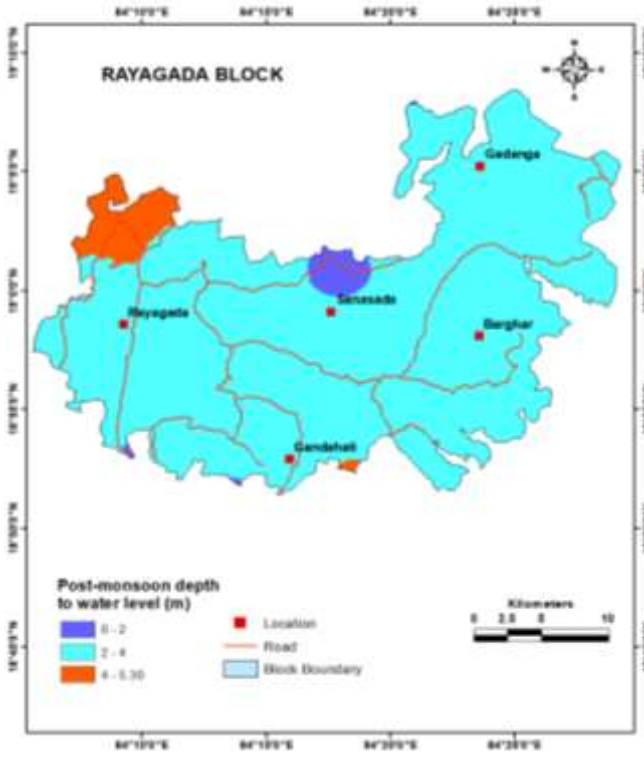

Figure 7.31 Lithology Map, Rayagada, Gajapati

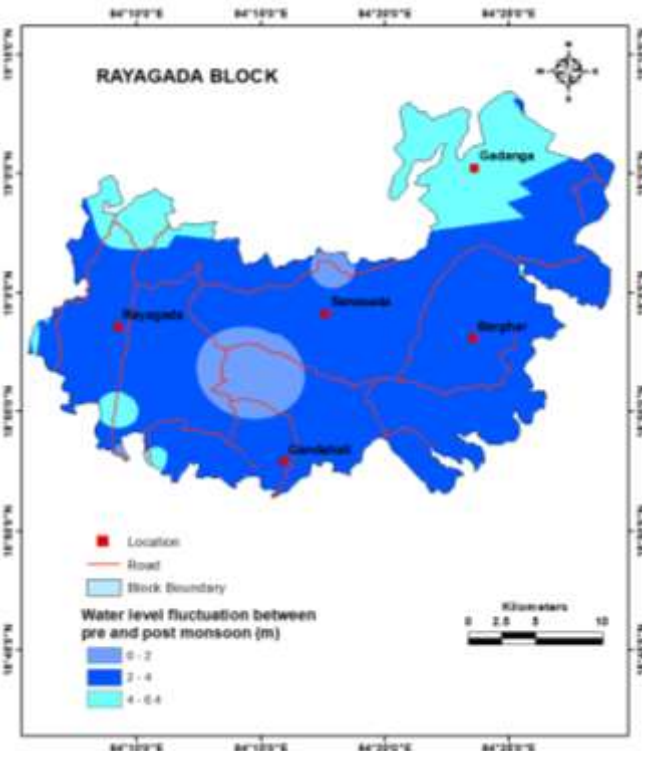

Figure 7.32 Elevation Map, Rayagada, Gajapati

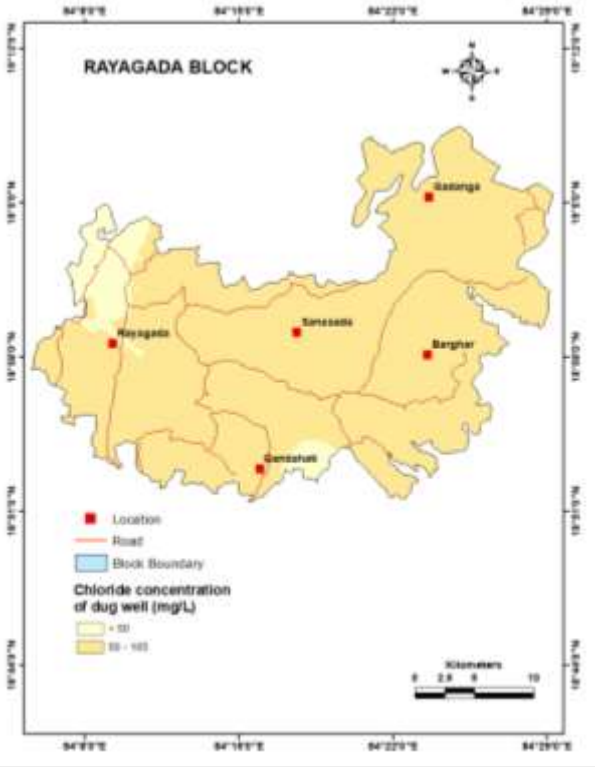

Figure 7.33 Administrative Map, Rayagada, Gajapati

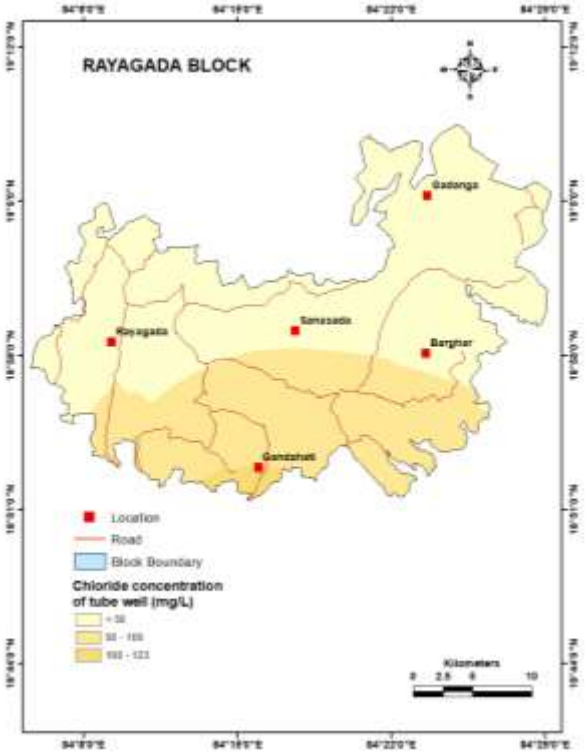

Figure 7.34 Geomorphology Mp, Rayagada, Gajapati

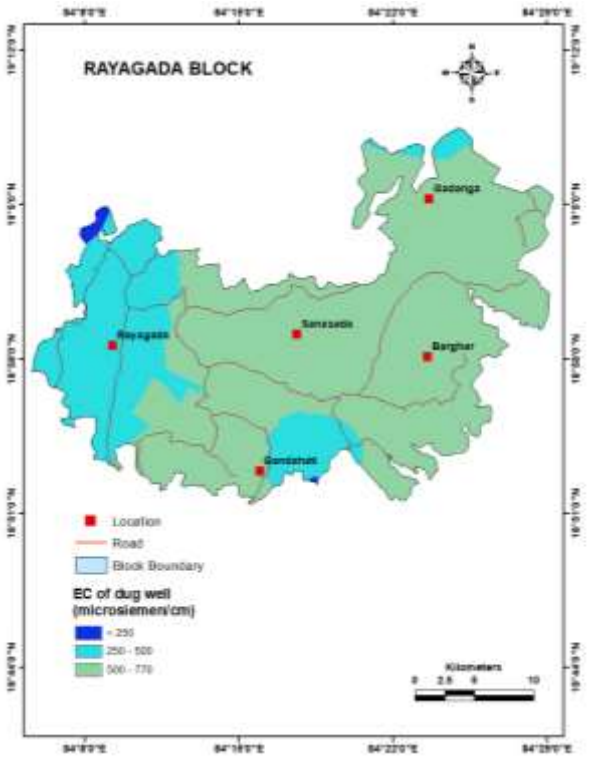

Figure 7.35 Lithology Map, Rayagada, Gajapati

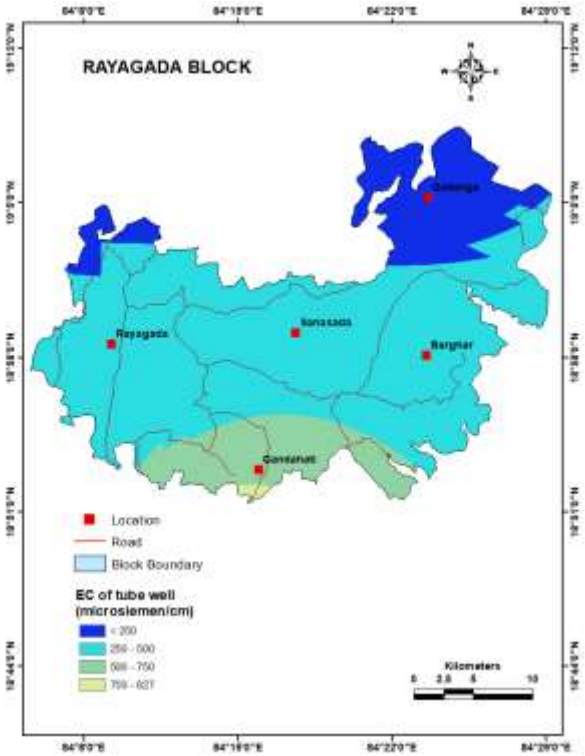

Figure 7.36 Elevation Map, Rayagada, Gajapati

7.4 BLOCK NUAGADA

1. SALIENT INFORMATION	
Name of the Block and Area (in Sq.Km)	**Nuagada** **Area**: 510 sq.km. **Gram Panchayats**: 19 **Villages**: 188
Population	54,696 as per 2011 census
Rainfall	Average Annual Rainfall 1675 mm
Agriculture and Irrigation	**Principal crops:** Paddy, Maize, Cereal, Pulses, Oil Seeds, Vegetable Crops **Gross cropped area:** 121.8 sq.km **Net sown area:** 100.04 sq. km. **Cropping intensity:** 122 % **Area under forest:** 402.61 Sq.Km **Area under waste land:** 152.32 Sq.km **Total irrigated area:** 20.39 Sq.km **Net irrigated area:** 11.59 Sq.km **Partially protective irrigation:** 4.8 Sq.km **Total Rainfed area:** 96.04 Sq.km
Major River and Soil Types	Mahendratanaya, Rato nadi and tributaries Red Sandy soil, Red Loamy soil and Alluvial soil
Major Rock Types	Eastern Ghat Super Group, Khondalite, Granite and Granite Gneisses, metabasics and veins of quartz and pegmatite
Groundwater resource availability and extraction (Dynamic)	**Total extractable GW resource (Dynamic**): 1416 Ham **Total Groundwater extraction**: 458 Ham **Allocation for Domestic use**: 176.6 Ham **Net availability for future use**: 941.5 Ham **Stage of GW extraction**: 32.46 %
Groundwater resource availability and extraction (In-storage) Aquifer-I and II	Aquifer-I (Instorage+ Dyanmic) 4521 +1416 =5937 Ham Aquifer-II 5273 Ham
Water level behaviour	Pre monsoon water level: 5.60 bgl to 10.0 mbgl Post monsoon water level: 2.04 mbgl to 7.50 mbgl Water level fluctuation: 2.85 mbgl to 3.56 mbgl

2. AQUIFER DISPOSITION	
Number of aquifers	Aquifer-I (Dynamic+Instorage) up to a depth of 30m Aquifer-II up to the depth of 150m fractured aquifer.
Exploration	1 no of EW by WAPCOS up to the depth of 200m, 0.8 lps discharge, 0.47 m^2/day Transmissivity
3-D aquifer disposition and basic characteristics of each aquifer	Refer to the panel diagram
3. CHEMICAL QUALITY OF GROUNDWATER AND OTHER ISSUES	
Chemical quality	Electrical Conductivity (µS/cm): 65-226 TDS (mg/l): 45-147 Ca^{++}(mg/l): 5.91-25.56 Mg^{++}(mg/l): 2.36-5.92 Na^{+}(mg/l): 5.37-15.93 K^{+}(mg/l): 2.63-3.34 HCO_3(mg/l): 17.4-87.1 $SO_4^{=}$ (mg/l): 7.43-9.17 Cl (mg/l)- 9.3-23.25 F (mg/l): 0.07-0.02 NO_3^{-}(mg/l): 0.59-41.77
Other issues	Total Water Demand-24.5MCM Total Water Vaialability-54.9 MCM Demand supply Gap: -30.4MCM The surface water availability is 52.9MCM, the groundwater situation is though not very good so to augment the GW situation structures are proposed keeping in view that the overall water gap will be minimised for the whole district.
4. GROUNDWATER RESOURCE ENHANCEMENT	
Management Plan for the block	**Surplus GW** available at 60% stage of extraction: 3.91 MCM **No of additional borewells proposed:** 88 **No of additional Dugwells proposed:** 752 **Total number of Farm ponds proposed:** 1000 & Total Annual recharge will be 2.131 MCM **Total number of RTRWH proposed:** 1136 & Total Annual recharge will be 0.194 MCM

	Total number recharge structures proposed to accommodate the volume of unsaturated zone- 22.17 MCM Percolation Tank-44 Sub-surface dyke-22 Nala bunding-22 Check dams-44

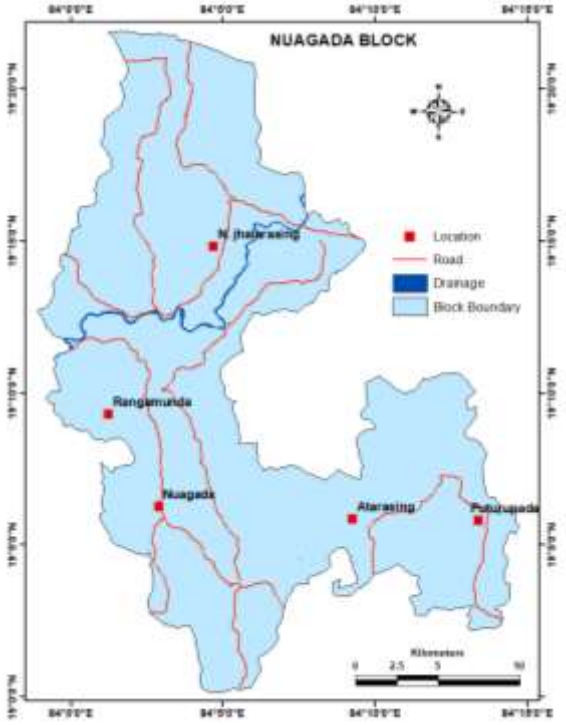

Figure 7.37 Administrative Map, Nuagada, Gajapati

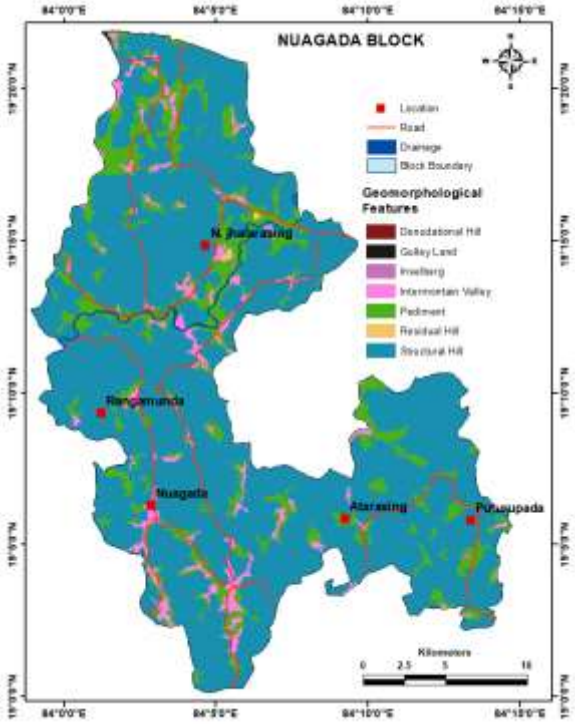

Figure 7.38 Geomorphology Map, Nuagada Gajapati

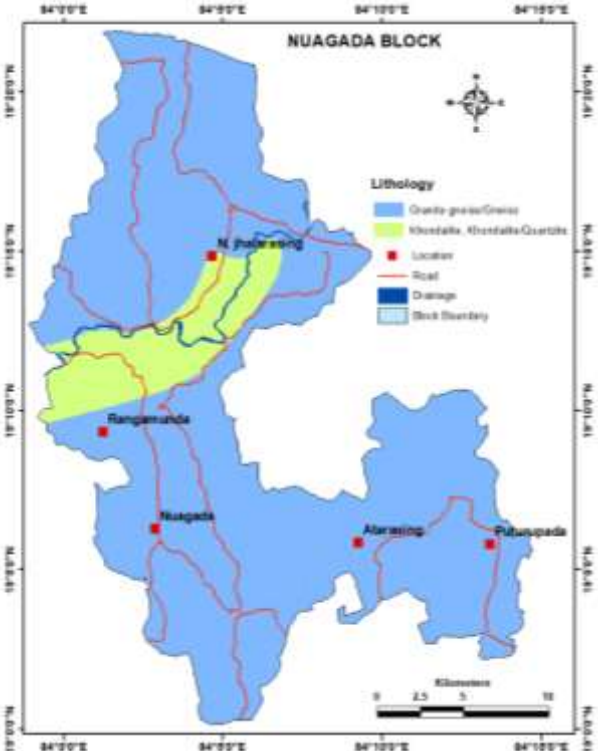

Figure 7.39 Lithology Map, Nuagada, Gajapati

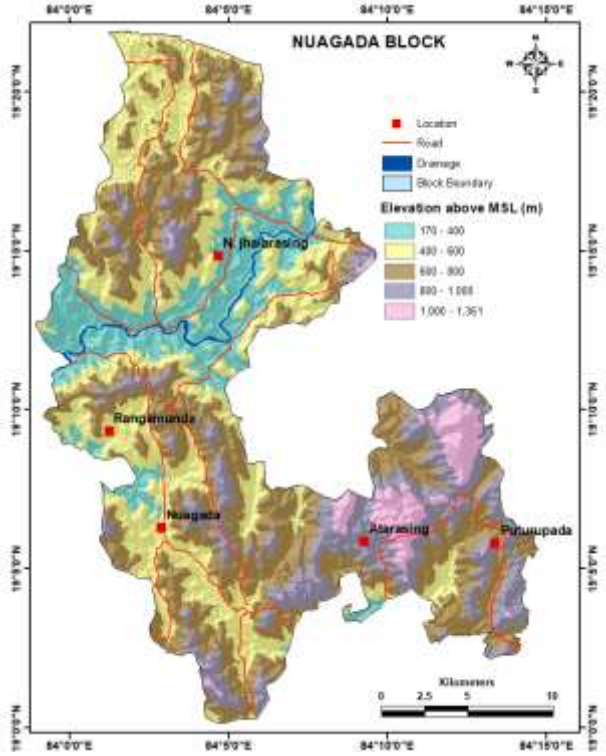

Figure 7.40 Elevation Map, Nuagada, Gajapati

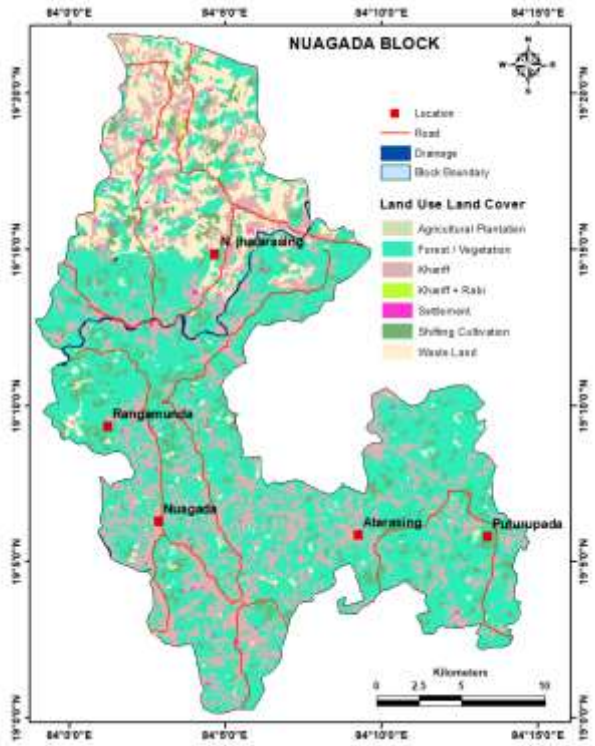

Figure 7.41 Administrative Map, Nuagada, Gajapati

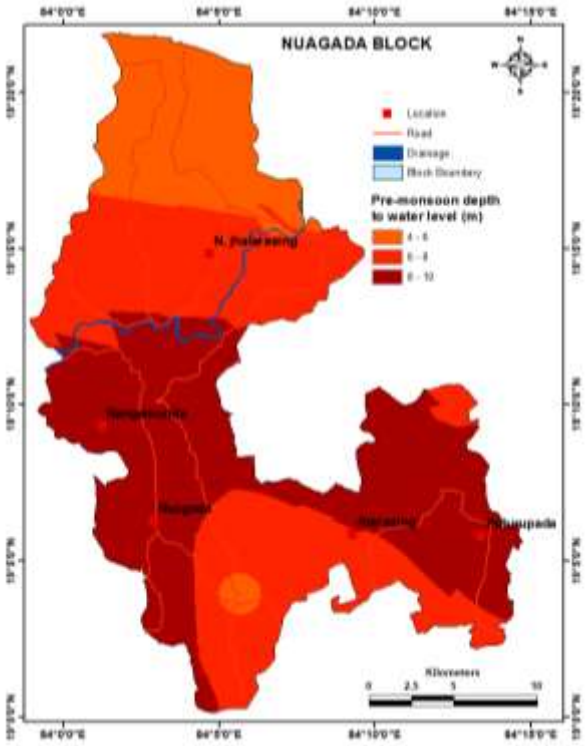

Figure 7.42 Geomorphology Map, Nuagada, Gajapati

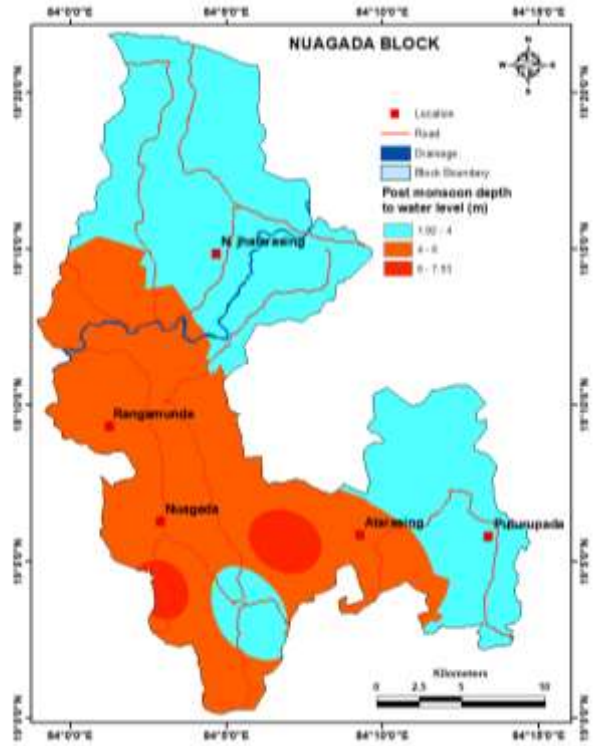

Figure 7.43 Lithology Map, Nuagada, Gajapati

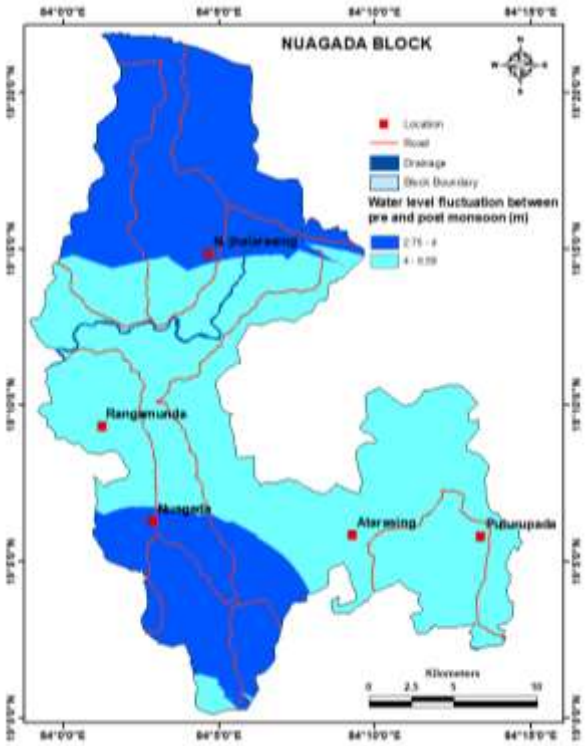

Figure 7.44 Elevation Map, Nuagada, Gajapati

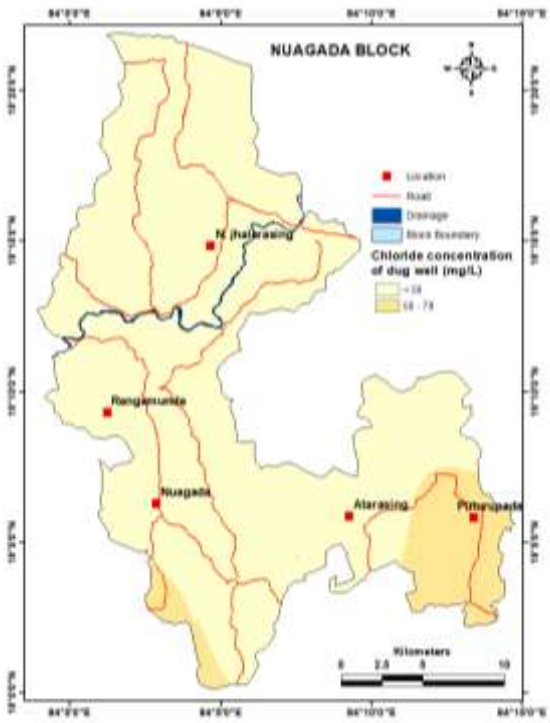

Figure 7.45 Administrative Map, Nuagada, Gajapati

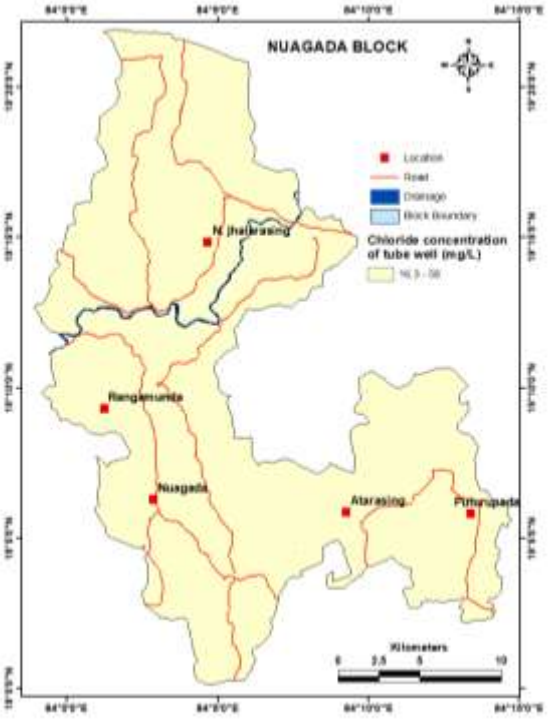

Figure 7.46 Geomorphology Map, Nuagada, Gajapati

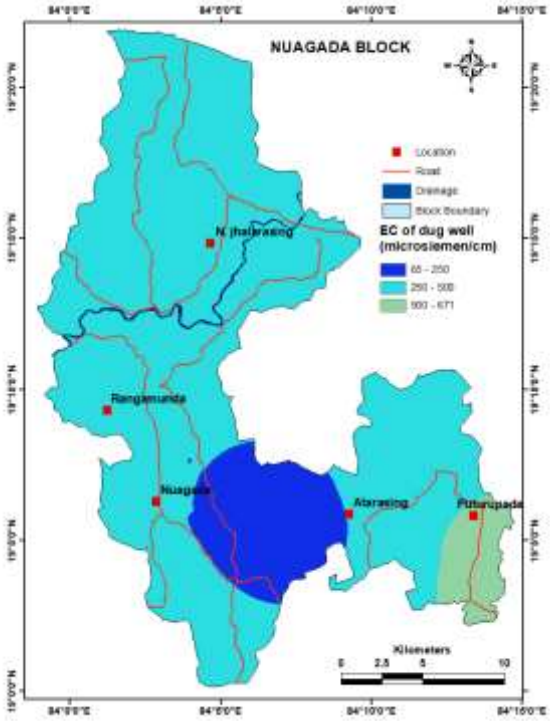

Figure 7.47 Lithology Map, Nuagada, Gajapati

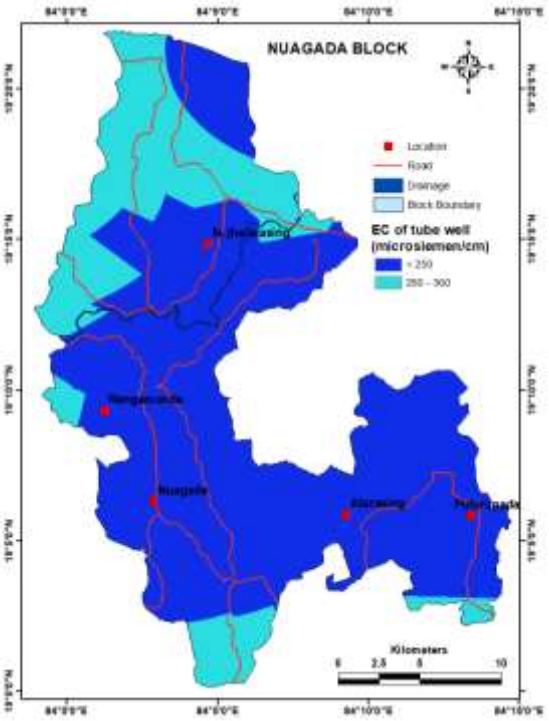

Figure 7.48 Elevation Map, Nuagada, Gajapati

7.5 BLOCK GUMMA

1. SALIENT INFORMATION	
Name of the Block and Area (in Sq.Km)	**Gumma** **Area**: 461 sq.km. **Gram Panchayats**: 20 **Villages**: 220
Population	79,520 as per 2011 census
Rainfall	Average Annual Rainfall 1451 mm
Agriculture and Irrigation	**Principal crops:** Paddy, Maize, Cereal, Pulses, Oil Seeds, Vegetable Crops **Gross cropped area:** 196.74sq.km **Net sown area:** 104.27 sq. km. **Cropping intensity:** 189 % **Area under forest:** 339.38 Sq.Km **Area under waste land:** 123.66 Sq.km **Total irrigated area:** 37.18 Sq.km **Net irrigated area:** 37.18 Sq.km **Partially protective irrigation:** 7.46 Sq.km **Total Rainfed area:** 149.15 Sq.km
Major River and Soil Types	Bansadhara and its tributaries Red Sandy soil, Red Loamy soil and Alluvial soil
Major Rock Types	Eastern Ghat Super Group, Khondalite, Granite and Granite Gneisses, metabasics and veins of quartz and pegmatite
Groundwater resource availability and extraction (Dynamic)	**Total extractable GW resource (Dynamic**): 2078 Ham **Total Groundwater extraction**: 976 Ham **Allocation for Domestic use**: 276 Ham **Net availability for future use**: 1068 Ham **Stage of GW extraction**: 46.99 %
Groundwater resource availability and extraction (In-storage) Aquifer-I and II	Aquifer-I (Instorage+ Dyanmic) 2104 +2078 =4182 Ham Aquifer-II 4810 Ham
Water level behaviour	Pre monsoon water level: 6.0 mbgl to 9.3 mbgl Post monsoon water level: 1.25 mbgl to 5.17 mbgl Water level fluctuation: 4.2 mbgl to 5.12 mbgl
2. AQUIFER DISPOSITION	

Number of aquifers	Aquifer-I (Dynamic + Instorage) up to a depth of 30m Aquifer-II up to the depth of 150m fractured aquifer.
Exploration	2 nos of EW by WAPCOS up to the depth of 200m, 1.4 lps discharge, 13.31 m^2/day Transmissivity
3-D aquifer disposition and basic characteristics of each aquifer	Refer to the panel diagram
3. CHEMICAL QUALITY OF GROUNDWATER AND OTHER ISSUES	
Chemical quality	Electrical Conductivity (µS/cm): 122-468 TDS (mg/l): 78-329 Ca^{++}(mg/l): 7.8-39.4 Mg^{++}(mg/l): 2.36-11.83 Na^{+}(mg/l): 4.95-37.32 K^{+}(mg/l): 1.75-25.58 HCO_3(mg/l): 29-151 $SO_4^{=}$ (mg/l): 7.33-20.68 Cl (mg/l)- 9.3-63 F (mg/l): 0.048-0.303 NO_3^{-}(mg/l): 0-54.3 Marginally high value of Nitrate is reported at Dahajanga, Abarsingh, Gumma and Kesapur due to Anthropogenic causes
Other issues	Total Water Demand: 45.0 MCM Total Water Vaialability-16.7 MCM Demand supply Gap: 28.8 MCM
4. GROUNDWATER RESOURCE ENHANCEMENT	
Management Plan for the block	**Surplus GW** available at 60% stage of extraction: 2.7 MCM **No of additional borewells proposed: 61** **No of additional Dugwells proposed: 520** **Total number of Farm ponds proposed:** 1043 & Total Annual recharge will be 2.223 MCM **Total number of RTRWH proposed:** 1730 & Total Annual recharge will be 0.295 MCM **Total number recharge structures proposed to accommodate the volume of unsaturated zone**- 17.42 MCM Percolation Tank-35 Sub-surface dyke-17 Nala bunding-17 Check dams-35

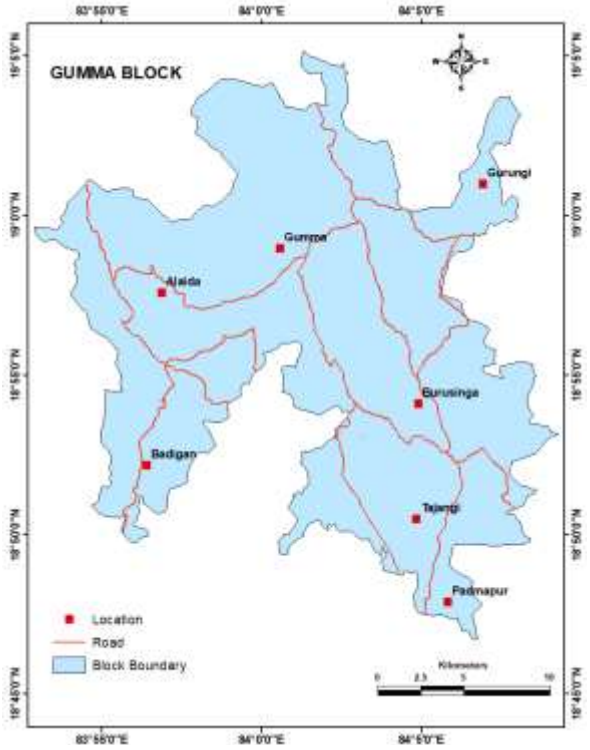

Figure 7.49 Administrative Map, Gumma, Gajapati

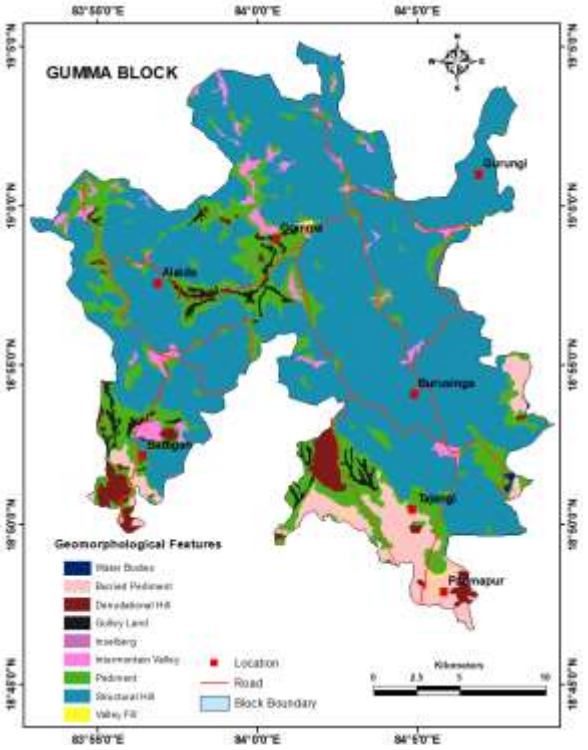

Figure 7.50 Geomorphology Map, Gumma, Gajapati

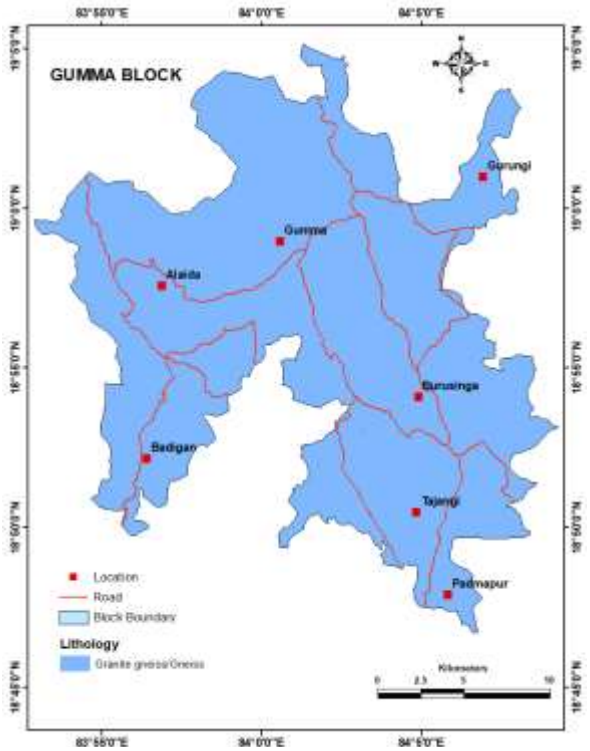

Figure 7.51 Lithology Map, Gumma, Gajapati

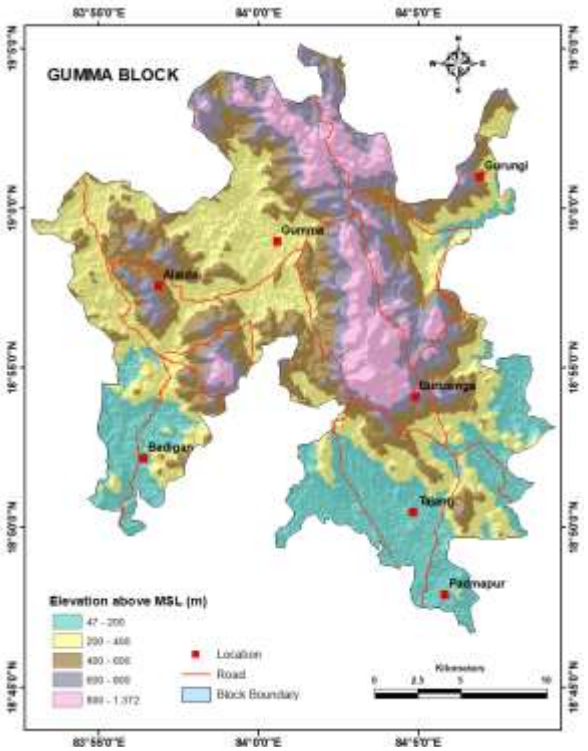

Figure 7.52 Elevation Map, Gumma, Gajapati

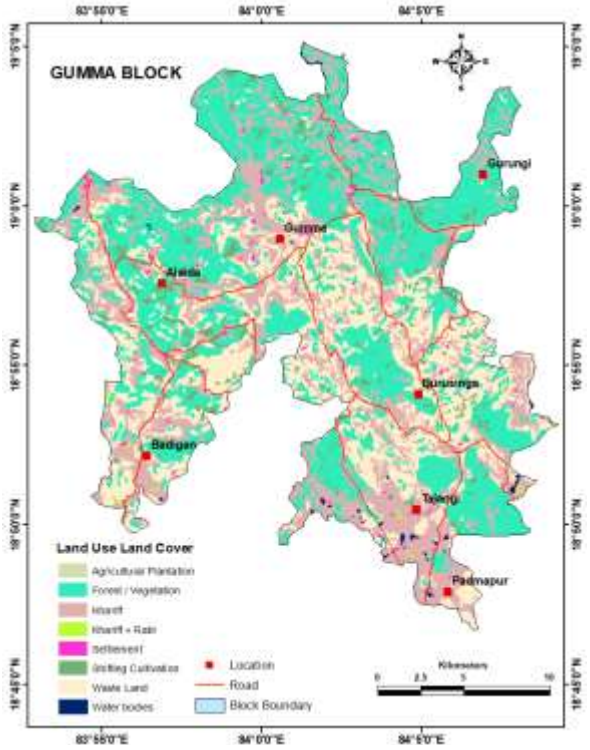

Figure 7.53 Administrative Map, Gumma, Gajapati

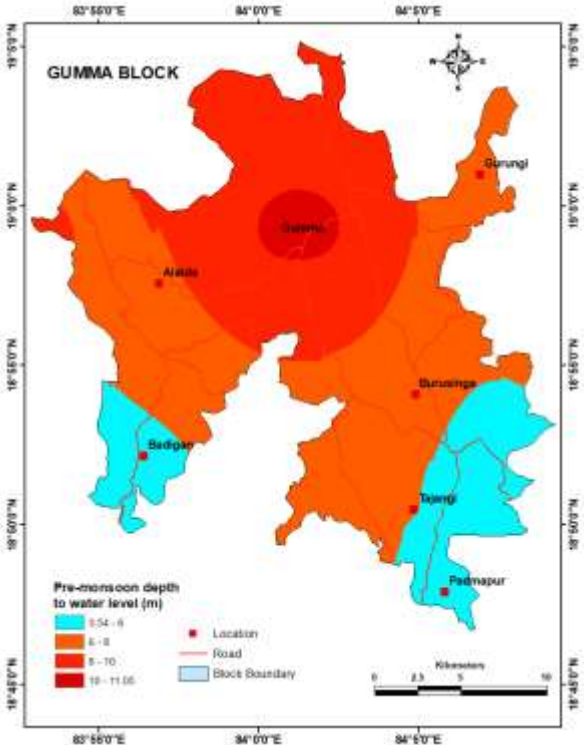

Figure 7.54 Geomorphology Mp, Gumma, Gajapati

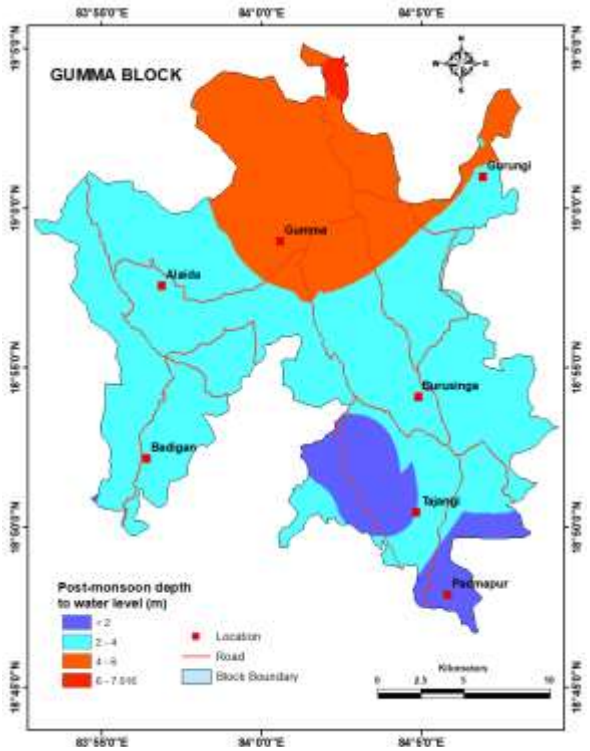

Figure 7.55 Lithology Map, Gumma, Gajapati

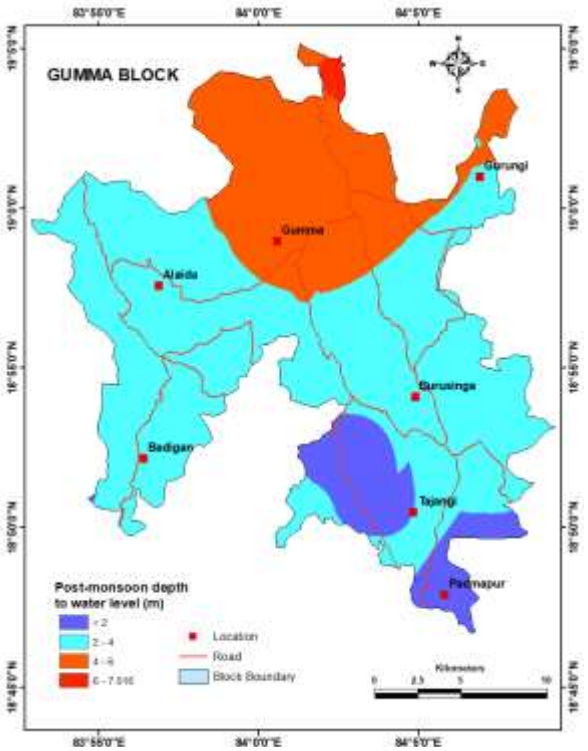

Figure 7.56 Elevation Map, Gumma, Gajapati

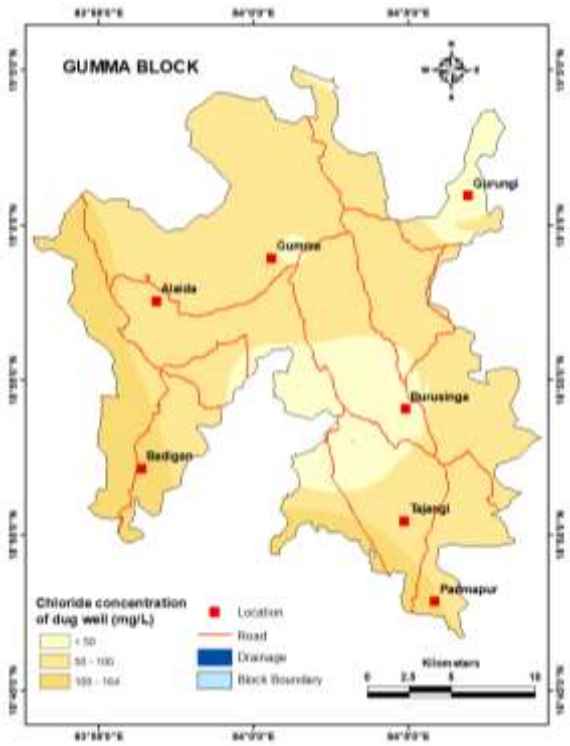

Figure 7.57 Administrative Map, Gumma, Gajapati

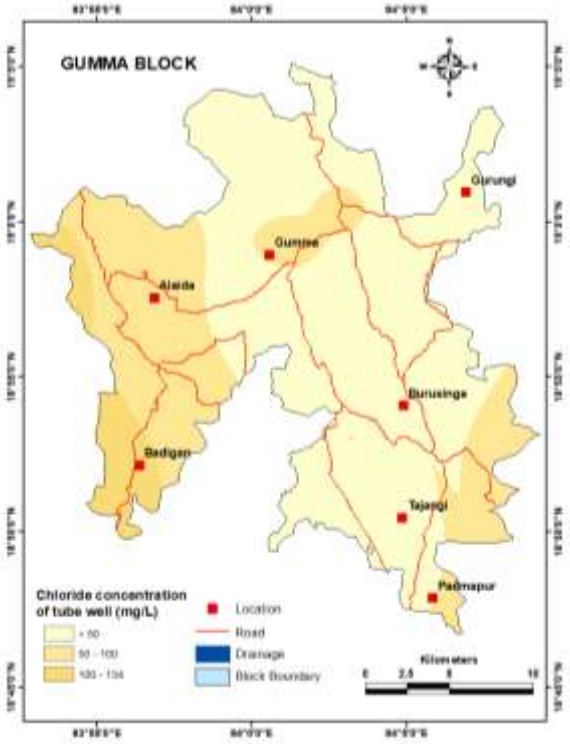

Figure 7.58 Geomorphology Map, Gumma, Gajapati

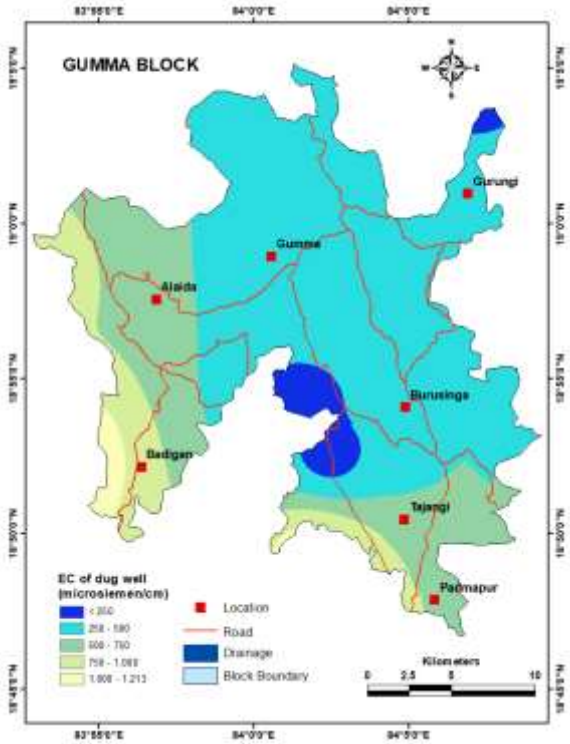

Figure 7.59 Lithology Map, Gumma, Gajapati

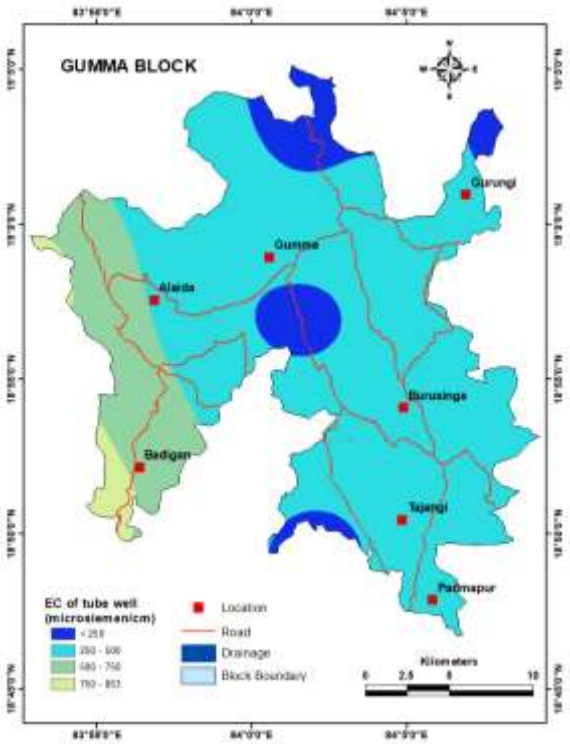

Figure 7.60 Elevation Map, Gumma, Gajapati

7.6 BLOCK PARALAKHEMUNDI (GOSANI)

1. SALIENT INFORMATION	
Name of the Block and Area (in Sq.Km)	**Gosani** **Area**: 241 sq.km. **Gram Panchayats**: 21 **Villages**: 136
Population	1,13,916 as per 2011 census
Rainfall	Average Annual Rainfall 1178 mm
Agriculture and Irrigation	**Principal crops:** Paddy, Maize, Cereal, Pulses, Oil Seeds, Vegetable Crops **Gross cropped area: 271.65** sq.km **Net sown area:** 124.96 sq. km. **Cropping intensity: 217** % **Area under forest:** 341.11 Sq.Km **Area under waste land:** 124.24 Sq.km **Total irrigated area:** 115.24 Sq.km **Net irrigated area: 117** Sq.km **Partially protective irrigation: 5.79** Sq.km **Total Rainfed area:** 115.73 Sq.km
Major River and Soil Types	Bansadhara and its tributaries Red Sandy soil, Red Loamy soil and Alluvial soil
Major Rock Types	Eastern Ghat Super Group, Khondalite, Granite and Granite Gneisses, metabasics and veins of quartz and pegmatite
Groundwater resource availability and extraction (Dynamic)	**Total extractable GW resource (Dynamic**): 3355 Ham **Total Groundwater extraction**: 1686 Ham **Allocation for Domestic use**: 323 Ham **Net availability for future use**: 1659 Ham **Stage of GW extraction**: 50.25 %
Groundwater resource availability and extraction (In-storage) Aquifer-I and II	Aquifer-I (Instorage+ Dyanmic) 3839 +3355 =7194 Ham Aquifer-II 2455 Ham
Water level behaviour	Pre monsoon water level: 1.86 mbgl to 6.55 mbgl Post monsoon water level: 1.05 mbgl to 4.65 mbgl Water level fluctuation: 0.76 mbgl to 4.76 mbgl

2. AQUIFER DISPOSITION	
Number of aquifers	Aquifer-I (Dynamic + Instorage) up to a depth of 30m Aquifer-II up to the depth of 150m fractured aquifer.
Exploration	2 nos of EW and 1no of OW by CGWB whining a depth of 160m, 14 lps discharge, 26 m^2/day Transmissivity
3-D aquifer disposition and basic characteristics of each aquifer	Refer to the panel diagram
3. CHEMICAL QUALITY OF GROUNDWATER AND OTHER ISSUES	
Chemical quality	Electrical Conductivity (µS/cm): 225-1009 TDS (mg/l): 152-663 Ca^{++}(mg/l): 21.6-65 Mg^{++}(mg/l): 2.36-28.4 Na^{+}(mg/l): 10-110 K^{+}(mg/l): 13.72-35.06 HCO_3(mg/l): 87-331 $SO_4^{=}$ (mg/l): 10.9-43.41 Cl (mg/l)- 16.28-142 F (mg/l): 0.146-0.707 NO_3^{-}(mg/l): 0-06-49.33 Marginally high value of Nitrate is reported at Adagaon due to Anthropogenic causes
Other issues	Total Water Demand: 131.2 MCM Total Water Vaialability-46.7 MCM Demand supply Gap: 84.5 MCM
4. GROUNDWATER RESOURCE ENHANCEMENT	
Management Plan for the block	**Surplus GW** available at 60% stage of extraction: 3.27 MCM **No of additional borewells proposed: 74** **No of additional Dugwells proposed: 629** **Total number of Farm ponds proposed:** 1250 & Total Annual recharge will be 2.664 MCM **Total number of RTRWH proposed:** 1765 & Total Annual recharge will be 0.471 MCM **Total number recharge structures proposed to accommodate the volume of unsaturated zone**- 2.18 MCM Percolation Tank-4 Sub-surface dyke-2 Nala bunding-2 Check dams-4

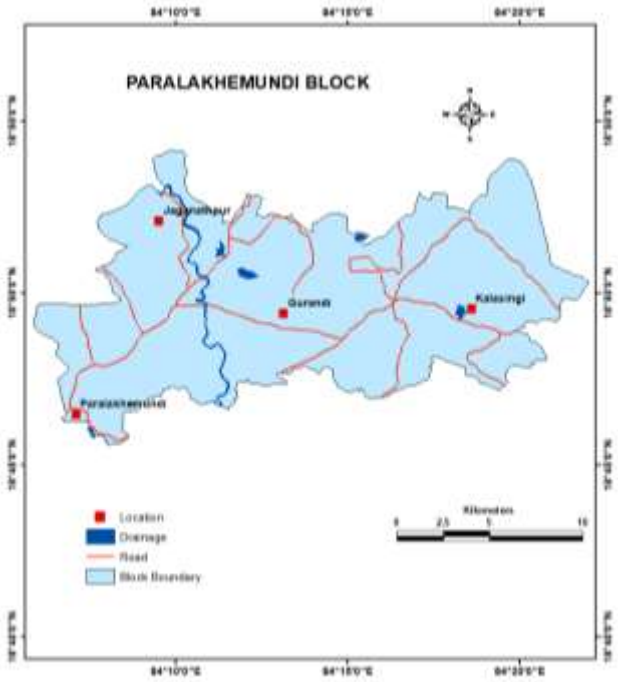

Figure 7.61 Administrative Map, Paralakhemundi, Gajapati

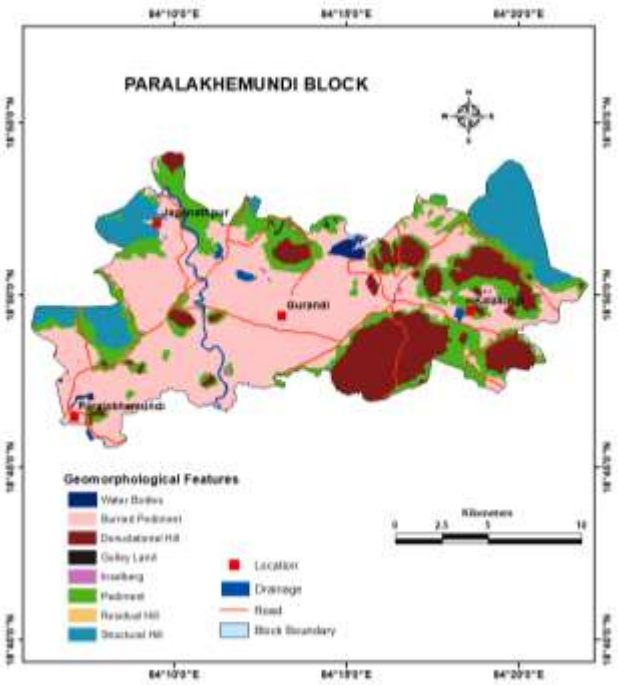

Figure 7.62 Geomorphology Map, Paralakhemundi Gajapati

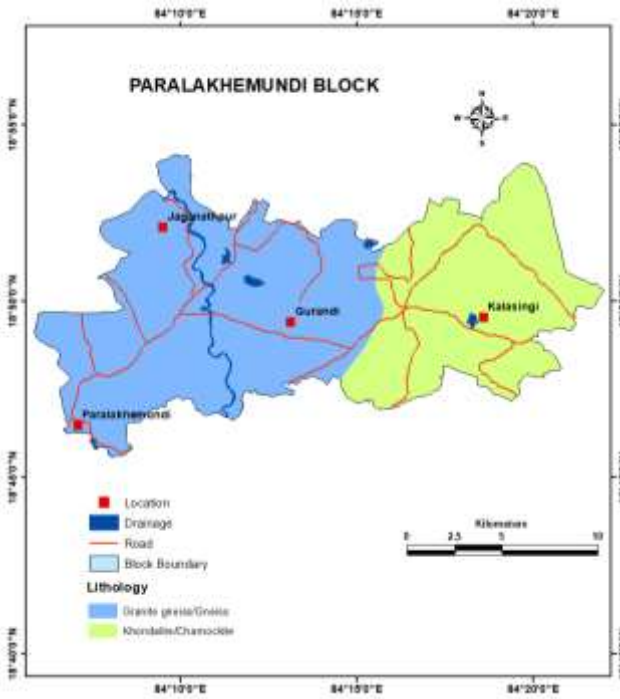

Figure 7.63 Lithology Map, Paralakhemundi, Gajapati

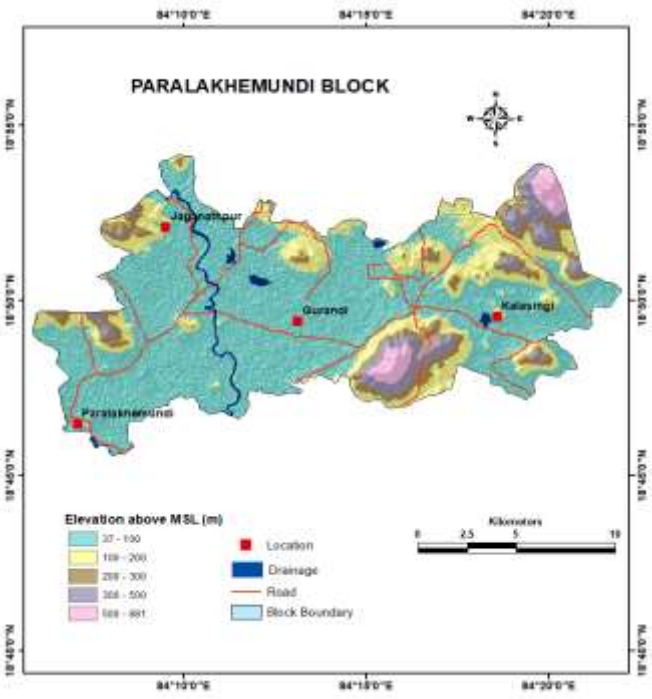

Figure 7.64 Elevation Map, Paralakhemundi, Gajapati

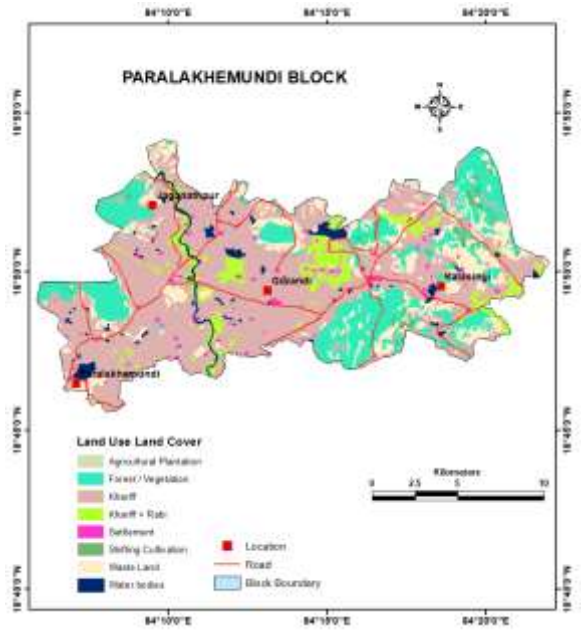

Figure 7.65 Administrative Map, Paralakhemundi, Gajapati

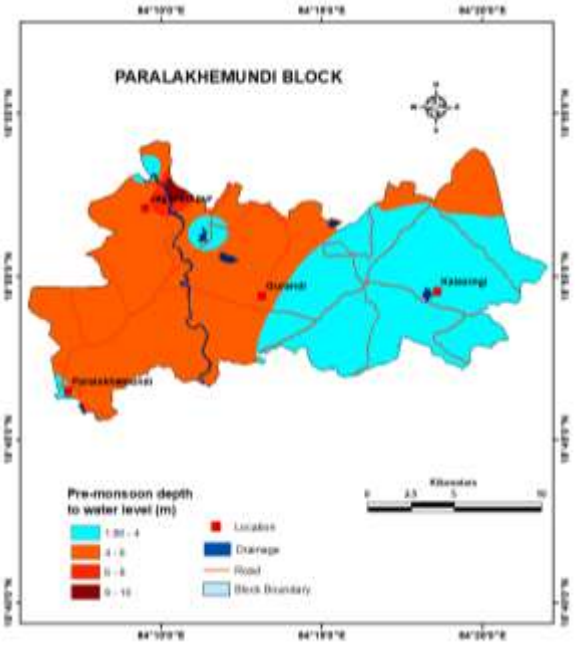

Figure 7.66 Geomorphology Map, Paralakhemundi, Gajapati

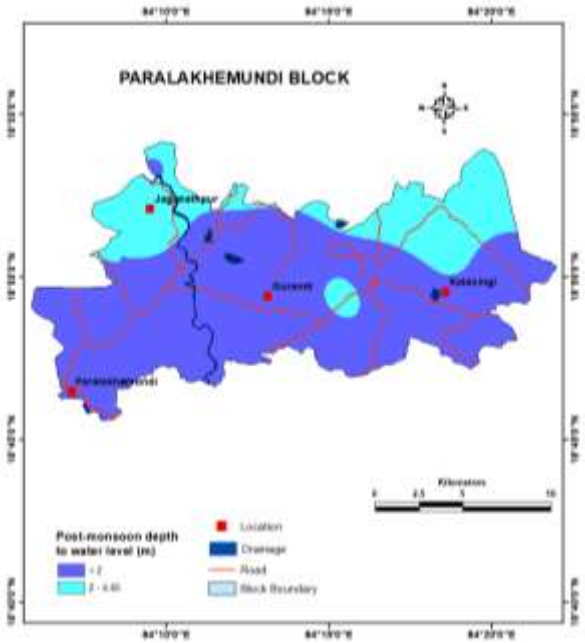

Figure 7.67 Lithology Map, Paralakhemundi, Gajapati

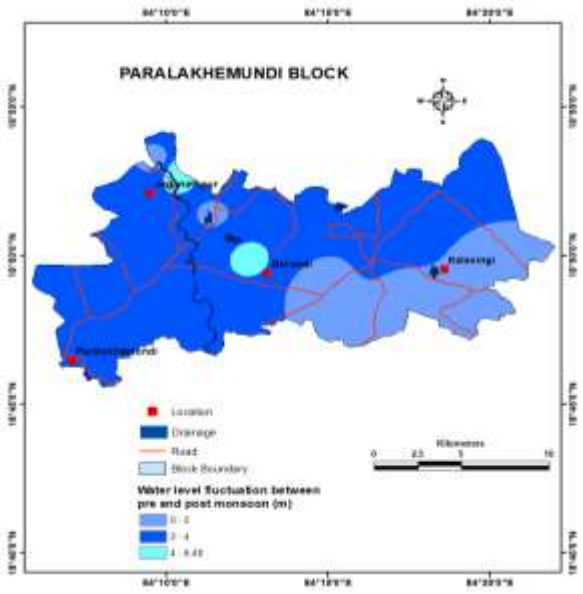

Figure 7.68 Elevation Map, Paralakhemundi, Gajapati

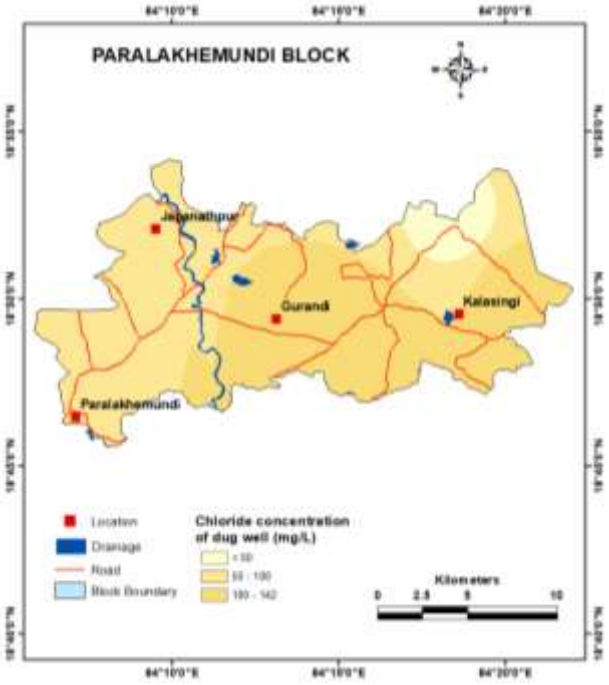

Figure 7.69 Administrative Map, Paralakhemundi, Gajapati

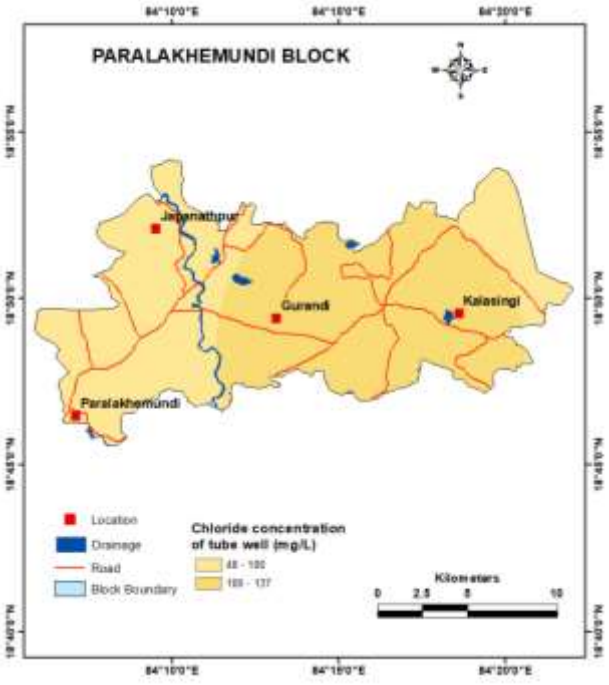

Figure 7.70 Geomorphology Map, Paralakhemundi, Gajapati

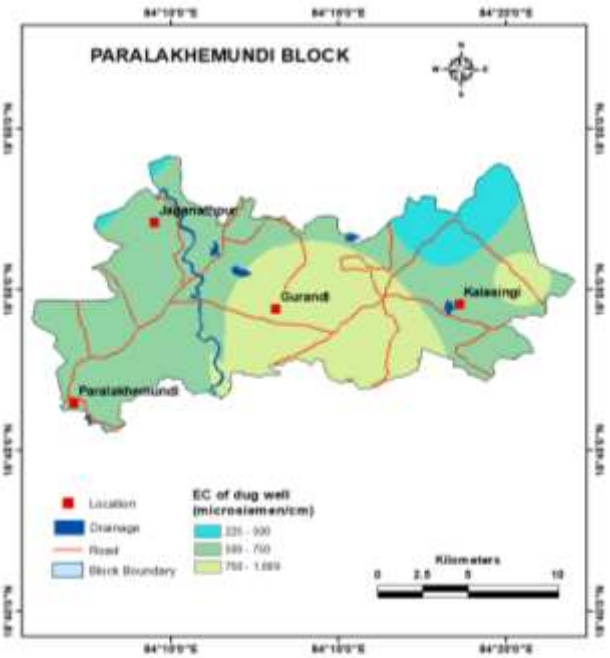

Figure 7.71 Lithology Map, Paralakhemundi, Gajapati

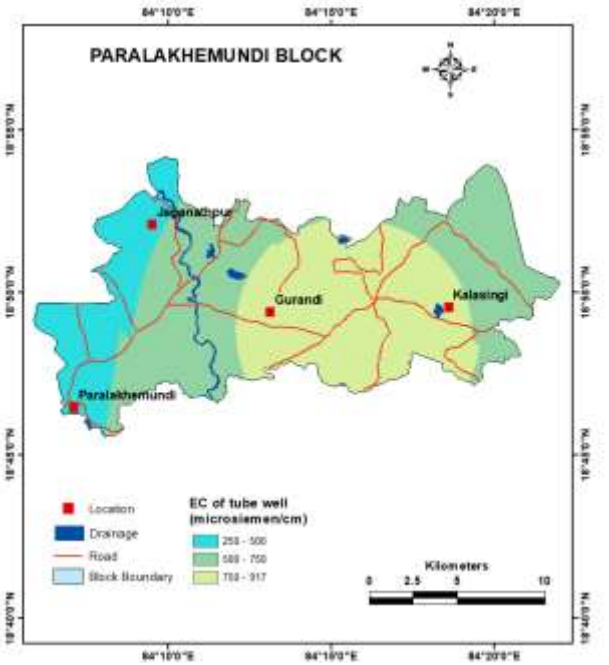

Figure 7.72 Elevation Map, Paralakhemundi, Gajapati

7.7 BLOCK KASINAGAR

1. SALIENT INFORMATION	
Name of the Block and Area (in Sq.Km)	**Kasinagar** **Area**: 272 sq.km. **Gram Panchayats**: 12 **Villages**: 103
Population	61,098 as per 2011 census
Rainfall	Average Annual Rainfall 1207 mm
Agriculture and Irrigation	**Principal crops:** Paddy, Maize, Cereal, Pulses, Oil Seeds, Vegetable Crops **Gross cropped area: 286.5** sq.km **Net sown area:** 125.81 sq. km. **Cropping intensity: 223** % **Area under forest: 417.43** Sq.Km **Area under waste land:** 152.10 Sq.km **Total irrigated area:** 104.67 Sq.km **Net irrigated area: 69.43** Sq.km **Partially protective irrigation: 7.29** Sq.km **Total Rainfed area:** 145..87 Sq.km
Major River and Soil Types	Bansadhara and its tributaries Red Sandy soil, Red Loamy soil and Alluvial soil
Major Rock Types	Eastern Ghat Super Group, Khondalite, Granite and Granite Gneisses, metabasics and veins of quartz and pegmatite
Groundwater resource availability and extraction (Dynamic)	**Total extractable GW resource (Dynamic**): 2010 Ham **Total Groundwater extraction**: 1128 Ham **Allocation for Domestic use**: 192 Ham **Net availability for future use**: 876.5 Ham **Stage of GW extraction**: 56.14 %
Groundwater resource availability and extraction (In-storage) Aquifer-I and II	Aquifer-I (Instorage+ Dyanmic) 4198 +2010 =6208 Ham Aquifer-II 2774 Ham
Water level behaviour	Pre monsoon water level: 4.0 mbgl to 9.12 mbgl Post monsoon water level: 1.25 mbgl to 2.89 mbgl Water level fluctuation: 2.21 mbgl to 7.11 mbgl
2. AQUIFER DISPOSITION	
Number of aquifers	Aquifer-I (Dynamic + Instorage) up to a depth of 30m

	Aquifer-II up to the depth of 150m fractured aquifer.
Exploration	1 no of EW and 1 no of OW by CGWB whining a depth of 108m, 7 lps discharge,
3-D aquifer disposition and basic characteristics of each aquifer	Refer to the panel diagram
3. CHEMICAL QUALITY OF GROUNDWATER AND OTHER ISSUES	
Chemical quality	Electrical Conductivity (µS/cm): 484-1677 TDS (mg/l): 112-1021 Ca^{++}(mg/l): 23.6-108.46 Mg^{++}(mg/l): 3.55-34.3 Na^{+}(mg/l): 11.04-151.5 K^{+}(mg/l): 0.8-33.66 HCO_3(mg/l): 75.5-424 $SO_4^{=}$ (mg/l): 7.6-56 Cl (mg/l)- 16.28-223 F (mg/l): 0.082-2.01 NO_3^{-}(mg/l): 0.77-56.19 Marginally high value of Nitrate is reported at Siali, Singipur due to Anthropogenic causes and High fluoride is found at Madhusudhanpur due to geogenic causes.
Other issues	Total Water Demand: 109 MCM Total Water Vaialability-34.8 MCM Demand supply Gap: 74.3 MCM
4. GROUNDWATER RESOURCE ENHANCEMENT	
Management Plan for the block	**Surplus GW** available at 60% stage of extraction: 0.78 MCM **No of additional borewells proposed: 17** **No of additional Dugwells proposed: 149** **Total number of Farm ponds proposed:** 1284 & Total Annual recharge will be 0.251 MCM **Total number of RTRWH proposed:** 1474 & Total Annual recharge will be 0.471 MCM **Total number recharge structures proposed to accommodate the volume of unsaturated zone**- 2.18 MCM Percolation Tank-24 Sub-surface dyke-12 Nala bunding-12 Check dams-24

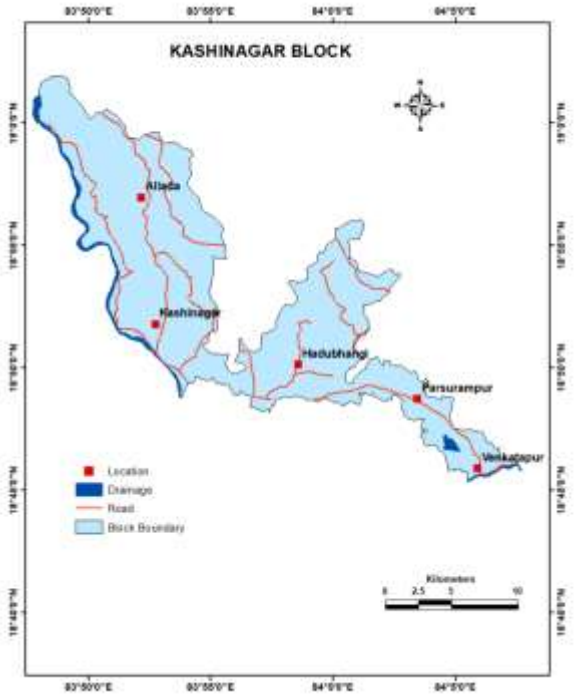

Figure 7.73 Administrative Map, Kasinagar, Gajapati

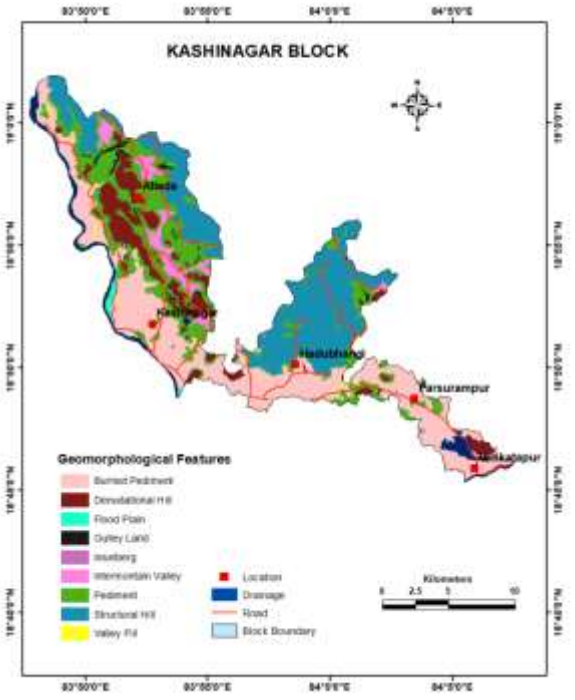

Figure 7.74 Geomorphology Map, Kasinagar, Gajapati

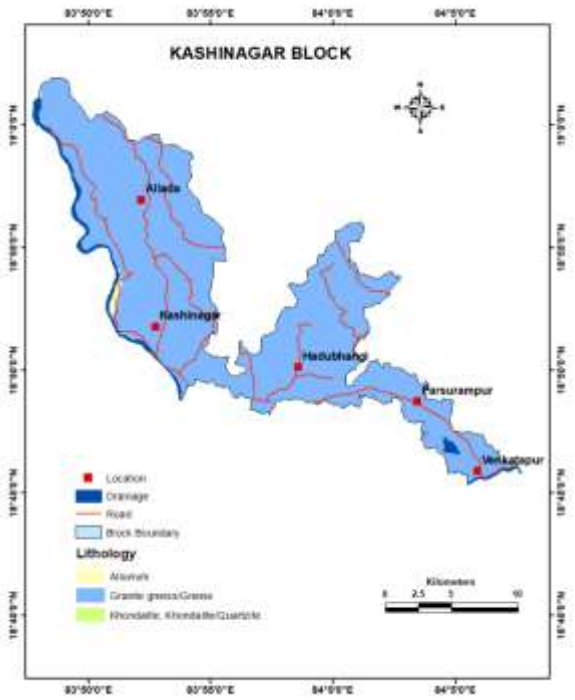

Figure 7.75 Lithology Map, Kasinagar, Gajapati

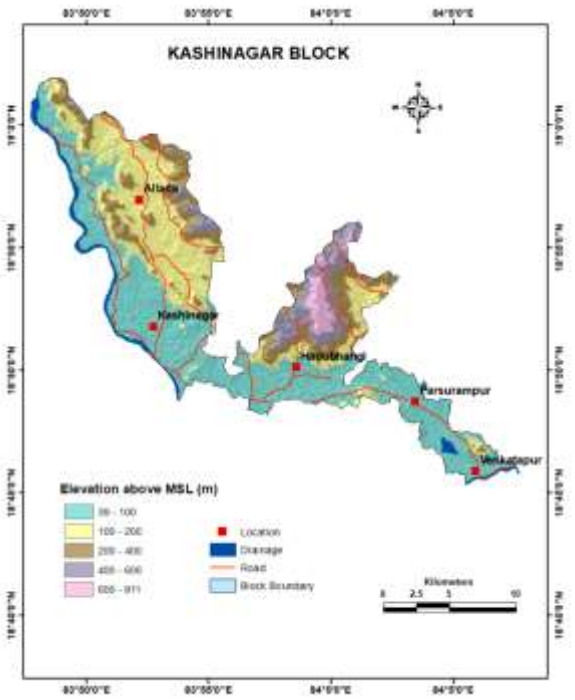

Figure 7.76 Elevation Map, Kasinagar, Gajapati

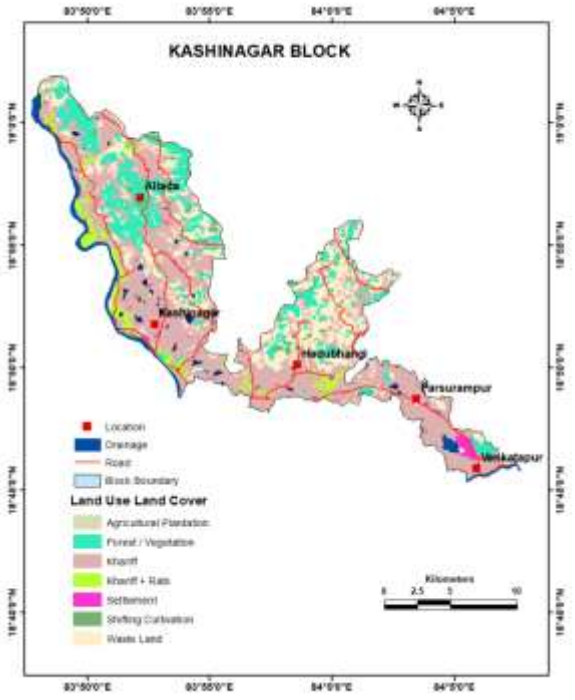

Figure 7.77 Administrative Map, Kasinagar, Gajapati

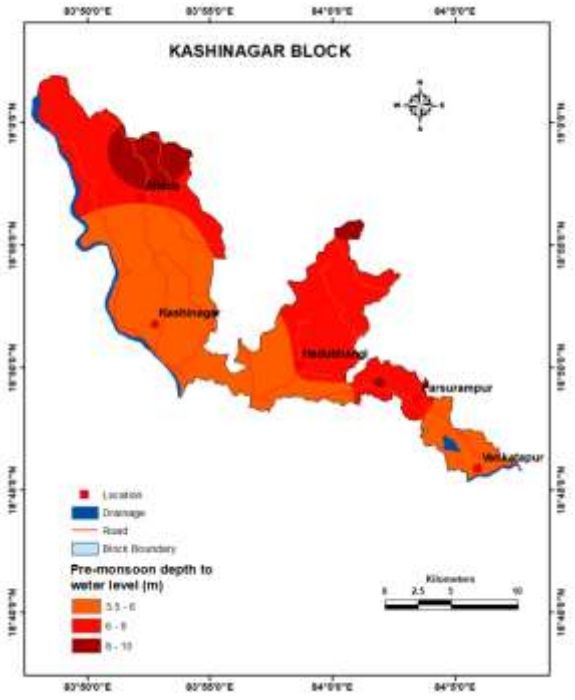

Figure 7.78 Geomorphology Map, Kasinagar, Gajapati

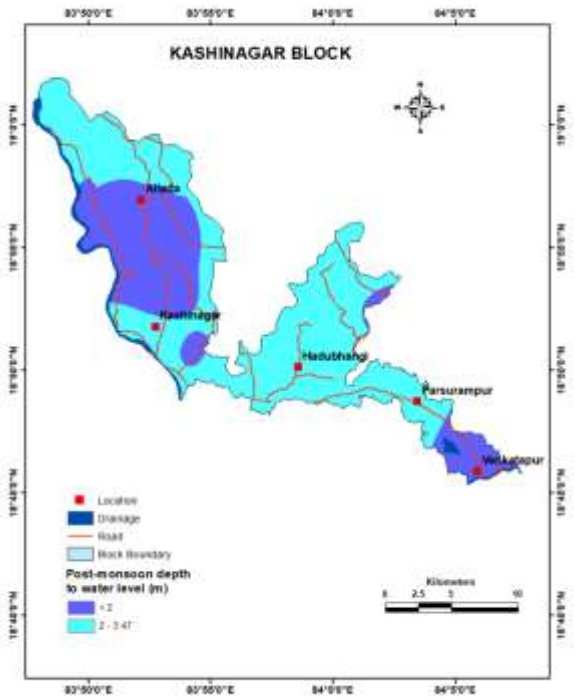

Figure 7.79 Lithology Map, Kasinagar, Gajapati

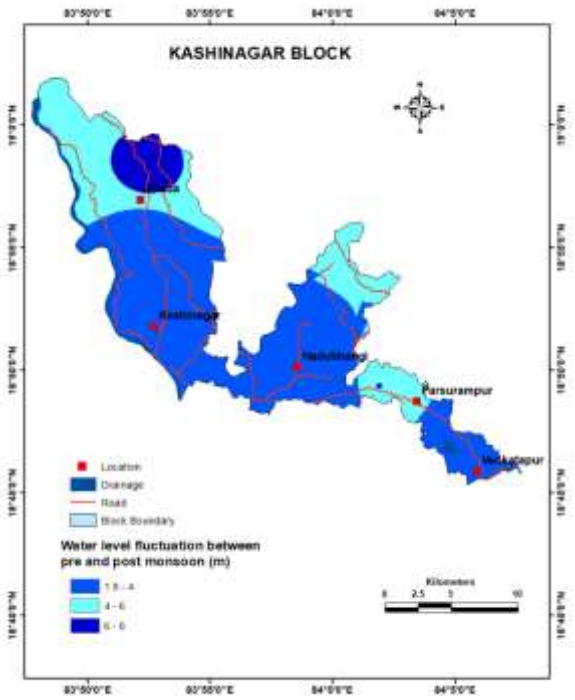

Figure 7.80 Elevation Map, Kasinagar, Gajapati

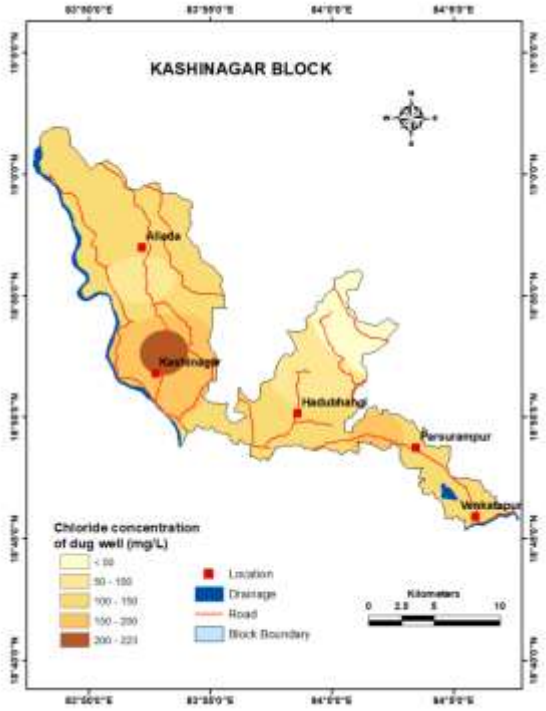

Figure 7.81 Administrative Map, Kasinagar, Gajapati

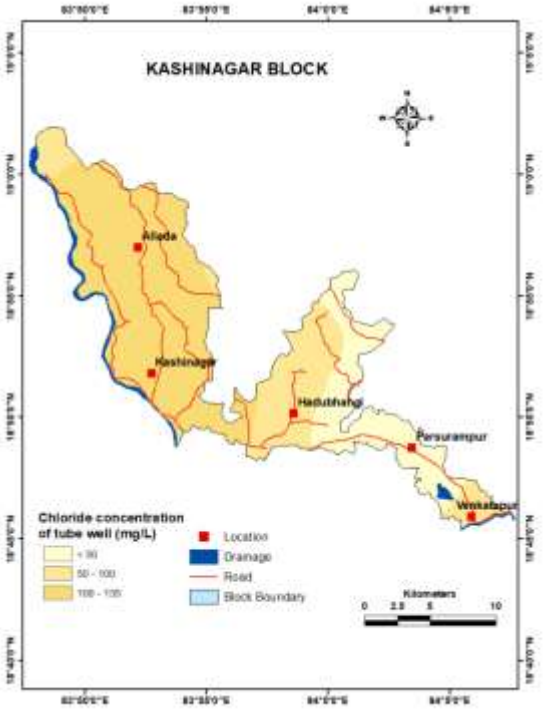

Figure 7.82 Geomorphology Map, Kasinagar, Gajapati

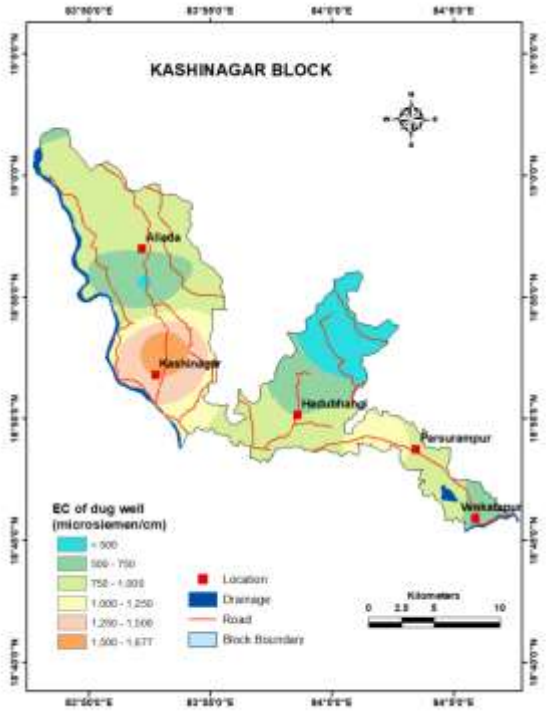

Figure 7.83 Lithology Map, Kasinagar, Gajapati

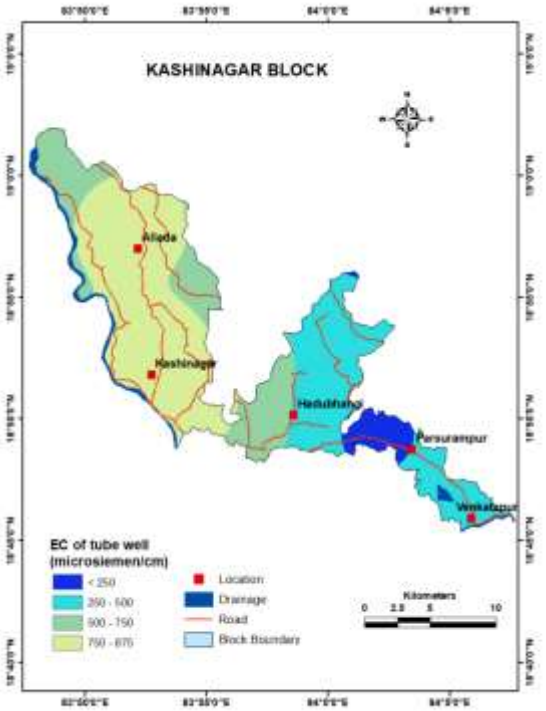

Figure 7.84 Elevation Map, Kasinagar, Gajapati

Annexures I Exploratory Details for the wells constructed by Central Ground Water Board, WAPCOS and Rural Water Supply and Sanitation, in Gajapati District, Odisha

S.No	Location	Block	Type	Latitude	Longitude	Depth	Lithology	Casing Depth (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Disch-	Draw-down (m)	T	S
						Drilled (mbgl)					arge (lps)		(m^2/day)	
DEPARTMENTAL														
1	Paralakhemundi	Paralakhemundi	EW	20.7625	84.2333	80.2	Granite	36	41, 45, 71, 80	8.42	14	17.62		
2	Paralakhemundi	Paralakhemundi	OW	20.7631	84.2334	81.3	Granite	32	41, 45, 51, 70, 80	9.75	14	6.8		
3	Paralakhemundi	Paralakhemundi	EW	20.7345	84.2341	185.6	Granite	31.7	91, 101, 110, 162	2.19	2	26		
4	Kashinagar	Kashinagar	EW	20.7666	84.325	136.2	Granite	23.8	26, 35, 95	3.94	4	17.86		
5	Kashinagar	Kashinagar	OW	20.7666	84.325	108	Granite	24.5	45, 70, 108	3.61	7	17.57		
6	Rayagada	Rayagada	EW	20.7666	84.325	155	Granite	22	40, 81	7.7	2.3	29		
WAPCOS														
1	Deraba EW	R.Udayagiri	EW	19.22933	84.30533	200	Granite	36.5	-	4.8	Dry			
2	Chelliguda EW	R.Udayagiri	EW	19.19609	84.23947	117	Granite	12	106- 1.4, 112- 13 lps	11.03	13	15.09	176.8	
3	Chelliguda OW	R.Udayagiri	OW	19.19609	84.23947	134	Granite	12	76- 2.3, 106- 6.2, 121- 8lps	13.35	10.2	7.78	105.33	$S= 6.80x10^{-4}$
4	Khajuripada EW	Nuagada	EW	19.06116	84.08376	200	Granite	23.5	76- 0.1 , 109- 0.4, 152- 0.8 lps	6.37	0.8		0.43	
5	Kumalsingh EW	Rayagada	EW	18.98417	84.0968	200	Granite	20	30- 0.1, 52- 0.1, 83- 0.8 lps	9.4	0.8		0.74	

6	Kurlundagud a EW	Gumma	EW	18.84957	84.04016	200	Granite	50	88 - 0.1, 129 - 0.4 lps	6.6	0.4			
7	Gumma EW	Gumma	EW	18.9776	84.02084	200	Granite	30	32, 86, 96 & 109	0.2	1.4		13.31	
8	Aliganda EW	Mohana	EW	19.54688	84.17489	200	Khondalite	12.5	52- 0.4 lps	3.5	0.8			
9	Antaraba EW	Mohana	EW	19.37948	84.17746	200	Granite	14	91- 0.1, 155- 0.4 lps	1.5	0.8			
10	Majhi Kirimba	Mohana	EW	19.57178	84.17684	200	Granite	34.4	-	0.7	Dry			
11	Birikot	Mohana	EW	19.47662	84.10926	200	Granite	12	47, 106, 183	1.3	0.8		0.41	
RWSS														
1	Adagaon	Paralakhem undi		18.82021	84.25532		Granite	24.6		4.5	0.4	66		
2	Garabandha	Paralakhem undi		18.83043	84.27332		Charnockite	30.9		6.5	0.86	72.6		
3	Kalasing Banjiri	Paralakhem undi		18.82815	84.28995		Charnockite	53.55		12.5	0.86	64.8		
4	Burujhali	Paralakhem undi		18.83971	84.35285		Charnockite	21.6				79		
5	Andharijhola	Paralakhem undi		18.86014	84.26868		Charnockite	39.1		5	0.86	70		
6	Padmapur	Paralakhem undi		18.87451	84.28177		Charnockite	38.25		5.4	0.86	51.2		
7	Badadeula	Paralakhem undi		18.86637	84.17229		Granite	46.6		4.5	0.85	74		
8	Janglow	Gumma		18.93938	84.03593		Granite	32.15		23.2	0.3	60		
9	Sargyasaing	Gumma		18.92421	83.93912		Granite	34.15		13.4	0.2	73.4		
10	Alaida	Gumma		18.9695	83.941		Granite	25		3	0.2	70		
11	Kitumba	Gumma		18.97199	84.03566		Granite	32.3		6.3	0.45	63.5		
12	Bhalery	Gumma		18.87675	83.96564		Granite	40.4		7.5	0.2	60		
13	Kulanga	Gumma		19.02432	83.99597		Granite	39.55		dry	dry	75		

14	Gantara	Gumma		18.90032	84.03226		Granite	25.5		15	0.2	74.5		
15	Ullabhadra	Kashinagar		19.00529	83.8413		Granite	32.8		7	0.42	74		
16	Baliaguda	Kashinagar		18.97002	83.8719		Granite	22.5		6	0.86	71		
17	Allada	Kashinagar		18.96856	83.87407		Granite	32.5		6	0.865	72		
18	Ranipentha	Kashinagar		18.80462	84.06803		Granite	35.5		6	0.45	73		
19	Lenthaguda	Kashinagar		18.96683	83.86998		Granite	35.5		6	0.42	73		
20	Ankarada	Kashinagar		18.94815	83.87727		Granite	32.2		7	0.42	74		
21	Banjeriguda	Kashinagar		18.94593	83.88919		Granite	42.6		9	0.86	53		
22	Birikote	Mohana		19.47621	84.09973		Granite	12.4		13	0.15	66.4		
23	Tiama	Mohana		19.45054	84.38052		Granite	24.9		10	0.17	60		
24	Narangi	Mohana		19.41913	84.02857		Granite	29				75		
25	Mahakupa	Mohana		19.40635	84.03105		Granite	26.1		5	0.45	61		
26	Buduring	Mohana		19.43315	84.01971		Granite	32		8	0.16	65		
27	Kalapanka	Mohana		19.48022	84.03985		Granite	26.5				75		
28	Mohana	Mohana		19.44296	84.25949		Granite	23.5		6	0.45	58		
29	Baluma	Nuagada		19.20845	84.06105		Khondalite	31.8		6	2.36	62		
30	Tandrang	Nuagada		19.20047	84.06812		Khondalite	10.6		8	0.45	61		
31	Partipanka	Nuagada		19.22047	84.06812		Khondalite	26.7		5	2.4	27		
32	Hatiruda	Nuagada		19.3217	84.04123		Granite	23.6		8	0.17	55.5		
33	Ambajhari	Nuagada		19.32813	84.03596		Granite	17.6		8	0.86	60		
34	Jamusahi	Nuagada		19.30905	84.03541		Granite	39.6		7	0.16	60		
35	Jaypur	Nuagada		19.30509	84.03541		Granite	35		6	0.16	47		
36	Musadoli	R.Udayagiri		19.20082	84.30025		Charnockite	34.1		7	0.45	64		
37	Durango	R.Udayagiri		19.19962	84.37051		Charnockite	30.5				75		
38	Tamula	R.Udayagiri		19.20477	84.38562		Charnockite	34.7		6	0.15	44		
39	Lanja	R.Udayagiri		19.20279	84.38384		Charnockite	20.5		4	0.42	73.2		
40	Kurudamba	R.Udayagiri		19.21331	84.33095		Charnockite	16.4		5	0.16	72.4		

41	Mahendragada	R.Udayagiri		19.22191	84.26088		Granite	40.5		6	0.16	74		
42	Dabaraguda	R.Udayagiri		19.26849	84.18571		Granite	34.1		7	0.42	68.1		
43	Pekata	Rayagada		19.0536	84.1481		Granite	28.6		6	0.43	72.2		
44	M.Laupur	Rayagada		18.87948	84.29627		Granite	41.6		18	0.45	73		
45	Munigabada	Rayagada		18.88221	84.2807		Charnockite	59.4		10	0.45	75		
46	Gandahati	Rayagada		18.87667	84.2606		Granite	29.6		10	0.45	35		
47	Parida	Rayagada		18.8744	84.21678		Granite	39		10	0.45	75		
48	Badamasingh	Rayagada		18.94921	84.37756		Charnockite	41.5				75		
49	Badamasingh	Rayagada		18.94771	84.34766		Charnockite	43		5	0.45	61		

Annexures II Details of Monitoring wells in Gajapati District, Odisha

SLNO	BLOCK NAME	SITE NAME	SOURCE	LATITUDE	LONGITUDE	PRE-MONSOON WL IN mbgl	POST-MONSOON WL IN mbgl	FLUCTUATION IN mbgl
1	GUMA	Parasamba	NHS	18.84472	84.05333	6	1.8	4.2
2	GUMA	U Abasingh	Keywells	18.90781	84.02289	-	2.85	-
3	GUMA	Sindiba	Keywells	19.04117	84.03488	-	4.67	-
4	GUMA	Kesapur	Keywells	18.95444	84.02351	-	4.01	-
5	GUMA	Gumma	Keywells	18.98613	84.02124	-	5.17	-
6	GUMA	Dahajanga	Keywells	18.87534	84.04075	-	1.25	-
7	GUMA	Kesapur	Keywells	18.95444	84.02351	9.13	4.01	5.12
8	KASHINAGARA	K Sitapur	NHS	18.81750	84.00361	5.1	2.89	2.21
9	KASHINAGARA	Madhusudhanpur	Keywells	18.88034	83.88511	-	1.75	-
10	KASHINAGARA	Kainthapadar	Keywells	18.84701	83.90626	-	1.86	-
11	KASHINAGARA	Kasinagar	NHS	18.85611	83.88000	5.7	2.4	3.3
12	KASHINAGARA	Singipur	Keywells	18.82279	84.03142	8.15	2.11	6.04
13	KASHINAGARA	Siali	Keywells	18.92660	83.87166	4	1.25	2.75
14	KASHINAGARA	Allada	Keywells	18.96836	83.87474	9.12	2.01	7.11
15	MOHANA	Luhaguda	NHS	19.45944	84.36250	8.1	2.8	5.3
16	MOHANA	Dantarinalo	NHS	19.44722	84.36028	7.15	3.98	3.17
17	MOHANA	Suklipadar	NHS	19.40250	84.34111	4.37	2.87	1.5
18	MOHANA	Chandiput 1	NHS	19.36500	84.30056	5.3	2.76	2.54
19	MOHANA	Zubagaon	NHS	19.32667	84.30278	4.72	3.66	1.06
20	MOHANA	Lillygada	NHS	19.42861	84.28417	3.3	2.6	0.7
21	MOHANA	Adaba	NHS	19.48944	84.18222	4.91	2.46	2.45

22	MOHANA	Mohana	NHS	19.43833	84.26833	11.28	1.78	9.5
23	MOHANA	Kirama	NHS	19.43778	84.31139	4.65	2.65	2
24	MOHANA	Damadua	NHS	19.55611	84.16000	4.5	1.18	3.32
25	MOHANA	Chandragiri 1	NHS	19.30583	84.28639	5.15	2.76	2.39
26	MOHANA	Madhura-Amba	NHS	19.44833	84.34806	3.25	2.75	0.5
27	MOHANA	Taramala	NHS	19.38667	84.30639	3.6	2.97	0.63
28	MOHANA	Raipanka	Keywells	19.39859	83.98311	-	5.05	-
29	MOHANA	Mandimera	Keywells	19.45402	84.01039	-	0.21	-
30	MOHANA	Kirting	Keywells	19.39646	84.23687	-	1.1	-
31	MOHANA	Birikote	Keywells	19.47605	84.09983	-	2.31	-
32	MOHANA	Bada Galama	Keywells	19.40511	84.21973	-	0.75	-
33	MOHANA	Santhi Nagar	NHS	19.45972	84.21722	2.25	1.75	0.5
34	MOHANA	Ladruma	NHS	19.45528	84.26528	8.45	2.85	5.6
35	MOHANA	Bada Khoni	NHS	19.48167	84.29083	4.9	3.31	1.59
36	MOHANA	Kirimasahi	Keywells	19.38005	84.18062	3.12	0.92	2.2
37	MOHANA	Jubagaon	GWD	19.32611	84.30194	4.37	1.85	2.52
38	NUAGADA	Khajuripara	NHS	19.06528	84.09278	5.6	2.04	3.56
39	NUAGADA	Tabarada	Keywells	19.09012	84.11218	-	7.53	-
40	NUAGADA	Sauri	Keywells	19.06469	84.04932	10	7.16	2.84
41	PARLAKHEMUNDI	Narayanpur	NHS	18.87361	84.19194	5.43	2.13	3.3
42	PARLAKHEMUNDI	Appalanaidupetta	NHS	18.84056	83.91917	3.93	2.13	1.8
43	PARLAKHEMUNDI	Parlakhemundi	NHS	18.77083	84.10417	3.5	1.6	1.9
44	PARLAKHEMUNDI	Lavanyagada	NHS	18.81972	84.28639	3.5	2	1.5
45	PARLAKHEMUNDI	Kattalakanita	NHS	18.81056	84.14278	4.93	1.83	3.1
46	PARLAKHEMUNDI	Tattipati	NHS	18.83167	84.21000	5.65	1.05	4.6
47	PARLAKHEMUNDI	Raygarh	NHS	18.88750	84.16111	2.56	1.8	0.76

48	PARLAKHEMUNDI	Gosani	NHS	18.81250	84.24556	1.86	1.06	0.8
49	PARLAKHEMUNDI	Kantragada	NHS	18.85806	84.19056	2.75	1.5	1.25
50	PARLAKHEMUNDI	Lingipur	Keywells	18.86953	84.30818	-	4.65	-
51	PARLAKHEMUNDI	Bhimpur	Keywells	18.84205	84.33838	-	1.63	-
52	PARLAKHEMUNDI	Adagaon	Keywells	18.82010	84.25527	-	2.48	-
53	PARLAKHEMUNDI	Lavanya Khotta	NHS	18.81639	84.33111	3.38	1.73	1.65
54	PARLAKHEMUNDI	Garabandh	NHS	18.83028	84.28222	3.8	1.1	2.7
55	PARLAKHEMUNDI	Minigaon	NHS	18.82806	84.00333	6.55	2.9	3.65
56	R.UDAYGIRI	Ramagiri	NHS	19.08667	84.29389	9.58	6.31	3.27
57	R.UDAYGIRI	R.udaygiri	NHS	19.15500	84.14583	8.95	2.13	6.82
58	R.UDAYGIRI	Tabarsingh	Keywells	19.12816	84.30243	5.12	1.5	3.62
59	R.UDAYGIRI	Randiba	Keywells	19.13907	84.25039	8.11	3.11	5
60	R.UDAYGIRI	Tabarsingh	Keywells	19.12816	84.30243	5	1.5	3.5
61	R.UDAYGIRI	Poipani	Keywells	19.18735	84.33697	-	1.45	-
62	R.UDAYGIRI	Mahendragada	Keywells	19.21288	84.25636	-	4.58	-
63	R.UDAYGIRI	Khamarisahi	Keywells	19.22289	84.27937	-	0.43	-
64	R.UDAYGIRI	Cheligada	Keywells	19.20039	84.24869	-	6	-
65	R.UDAYGIRI	Burupada	Keywells	19.15833	84.34075	-	0.6	-
66	R.UDAYGIRI	Ramagiri	Keywells	19.08535	84.29135	15	5.19	9.81
67	RAYAGADA	Tumbagarh	NHS	18.94111	84.23611	3.1	2.75	0.35
68	RAYAGADA	Marlaba	GWD	19.02028	84.29778	2.79	1.28	1.51
69	RAYAGADA	Sebakpur	NHS	18.87972	84.17472	10.1	3.7	6.4
70	RAYAGADA	Pegoda	NHS	18.91333	84.15528	7	2.4	4.6

Annexures III Analysis of Chemical Parameters of Keywells established in Gajapati District, Odisha

Sl No	Location		Block	Latitude	Longitude	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	F -	NO3	Uranium
							µS/cm	mg/L	as CaCO3 mg/L		mg/L										
1	Bhimpur	DW	Paralakhemundi	18.8421	84.3384	7.72	794	506	212.0	176	55.2	17.7	93.8	13.7	0.0	215.0	132.5	33.4	0.71	6.8	0.005
2	Lingipur	DW	Paralakhemundi	18.8695	84.3082	7.68	225	152	64.1	71	21.7	2.4	10.0	22.0	0.0	87.1	16.3	10.2	0.15	3.9	BDL
3	Adagaon	DW	Paralakhemundi	18.8201	84.2553	7.80	1009	663	281.1	271	65.1	28.4	110.2	35.1	0.0	331.1	141.8	43.4	0.31	0.1	BDL
4	Madhusudhanpur	DW	Kashinagar	18.8803	83.8851	8.19	1677	1021	414.2	348	108.5	34.3	151.5	8.8	0.0	424.1	223.2	51.4	2.01	9.1	0.002
5	Siali	DW	Kashinagar	18.9266	83.8717	7.65	484	339	143.0	100	29.6	16.6	46.0	7.5	0.0	122.0	74.4	13.7	0.16	49.4	BDL
6	Allada	DW	Kashinagar	18.9684	83.8747	7.72	952	651	251.5	186	59.2	24.9	97.6	9.2	0.0	226.6	141.8	36.9	0.08	29.8	BDL
7	Singipur	DW	Kashinagar	18.8228	84.0314	7.65	1178	780	212.0	205	63.1	13.0	132.8	33.7	0.0	249.8	172.1	55.8	0.39	17.7	0.003
8	Dahajanga	DW	Gumma	18.8753	84.0407	7.75	165	101	59.2	48	19.7	2.4	9.7	2.9	0.0	58.1	14.0	10.1	0.21	52.9	BDL
9	U Abasingh	DW	Gumma	18.9078	84.0229	7.77	122	78	39.4	24	7.8	4.7	5.0	4.8	0.0	29.0	9.3	10.3	0.07	52.9	BDL
10	Kesapur	DW	Gumma	18.9544	84.0235	7.53	442	305	138.1	81	39.4	9.5	33.0	9.8	0.0	98.8	62.8	8.9	0.10	4.0	BDL
11	Gumma	DW	Gumma	18.9861	84.0212	7.76	366	258	108.5	86	31.6	7.1	26.6	17.8	0.0	104.6	48.8	7.3	0.30	52.0	BDL
12	Sindiba	DW	Gumma	19.0412	84.0349	7.30	468	329	128.2	124	31.6	11.8	37.3	25.6	0.0	151.1	58.1	20.6	0.05	0.5	BDL
13	Tabarada	DW	Nuagada	19.0901	84.1122	7.65	65	45	24.7	14	5.9	2.4	5.4	2.6	0.0	17.4	9.3	9.2	0.15	1.5	BDL
14	Khamarisahi	DW	R.Udayagiri	19.2229	84.2794	7.80	250	148	83.8	71	27.6	3.6	14.6	5.2	0.0	87.1	23.3	11.0	0.15	4.3	BDL
15	Poipani	DW	R.Udayagiri	19.1873	84.3370	7.96	513	350	123.3	95	41.4	4.7	22.3	50.2	0.0	116.2	41.9	24.9	1.00	48.6	BDL
16	Burupada	DW	R.Udayagiri	19.1583	84.3408	8.03	105	73	44.4	33	9.6	4.7	5.4	1.9	0.0	40.7	9.3	8.3	0.02	6.3	BDL
17	Tabarsingh	DW	R.Udayagiri	19.1282	84.3024	7.89	1191	828	266.3	229	71.0	21.3	132.2	29.7	0.0	278.9	188.3	57.9	0.28	13.1	0.001
18	Ramagiri	DW	R.Udayagiri	19.0854	84.2913	8.03	1045	668	236.7	190	69.0	15.4	84.8	57.6	0.0	255.6	109.3	53.4	0.11	24.6	0.002
19	Randiba	DW	R.Udayagiri	19.1391	84.2504	8.00	289	197	78.9	76	21.7	5.9	20.4	13.7	0.0	75.5	30.2	22.0	0.03	21.1	BDL
20	Cheligada	DW	R.Udayagiri	19.2004	84.2487	8.13	205	142	69.0	38	17.7	5.9	18.1	2.6	0.0	46.5	25.6	16.7	0.16	17.0	BDL
21	Mahendragada	DW	R.Udayagiri	19.2129	84.2564	7.89	386	246	143.0	76	35.5	13.0	18.8	12.0	0.0	98.8	32.6	9.6	0.07	4.6	BDL
22	Kirting	DW	Mohana	19.3965	84.2369	7.89	235	155	74.0	67	17.7	7.1	20.4	4.8	0.0	81.3	27.9	17.5	1.23	1.7	BDL
23	Kirimasahi	DW	Mohana	19.3800	84.1806	7.65	465	276	123.3	90	41.4	4.7	26.0	18.4	0.0	110.4	44.2	25.0	0.40	2.9	0.001
24	Bada Galama	DW	Mohana	19.4051	84.2197	7.76	178	108	59.2	48	17.7	3.6	13.1	2.6	0.0	58.1	23.3	10.2	0.12	0.0	BDL

25	Birikote	DW	Mohana	19.4761	84.0998	8.04	945	558	226.8	181	65.0	15.4	85.8	14.2	0.0	220.8	120.9	54.6	0.15	1.5	0.001
26	Mandimera	DW	Mohana	19.4540	84.0104	8.10	231	139	83.8	71	19.7	8.2	14.0	1.4	0.0	87.1	18.6	10.9	0.15	2.2	BDL
27	Adagaon	TW	Paralakhemundi	18.8201	84.2553	7.70	917	520	236.7	176	57.2	22.5	91.4	14.2	0.0	215.0	137.2	42.2	0.27	49.3	BDL
28	Madhusudhanpur	TW	Kashinagar	18.8803	83.8856	7.78	851	592	226.8	186	53.2	22.5	92.5	0.8	0.0	226.6	130.2	23.6	1.72	0.8	0.013
29	Allada	TW	Kashinagar	18.9671	83.8739	7.84	875	601	246.6	181	61.1	22.5	93.0	0.9	0.0	220.8	130.2	43.6	0.50	2.2	0.001
30	Karatama	TW	Kashinagar	18.8462	83.9066	8.17	856	497	231.8	190	65.0	16.6	98.9	1.3	0.0	234.4	134.9	21.8	0.22	4.1	0.003
31	Singipur	TW	Kashinagar	18.8228	84.0316	7.88	195	112	74.0	62	23.6	3.6	11.0	2.0	0.0	75.5	16.3	7.6	0.16	56.2	BDL
32	Kesapur	TW	Gumma	18.9545	84.0235	7.65	161	104	54.2	33	11.8	5.9	10.3	2.1	0.0	40.7	16.3	14.4	0.13	54.3	BDL
33	Gumma	TW	Gumma	18.9860	84.0208	7.81	372	261	123.3	90	35.5	8.3	34.6	1.8	0.0	110.4	58.1	15.6	0.28	42.2	BDL
34	Seranga	TW	Gumma	19.0096	84.0463	7.64	442	299	118.3	90	33.6	8.3	35.6	12.3	0.0	110.4	55.8	20.7	0.09	21.2	BDL
35	Sindiba	TW	Gumma	19.0412	84.0349	7.48	185	116	59.2	43	15.8	4.7	10.3	4.1	0.0	52.3	18.6	10.2	0.15	2.0	BDL
36	Sauri	TW	Nuagada	19.0647	84.0494	7.46	118	82	49.3	29	9.9	5.9	9.3	3.3	0.0	34.9	16.3	8.4	0.22	41.8	BDL
37	Nuagada	TW	Nuagada	19.0988	84.0488	7.52	226	147	88.8	71	25.6	5.9	15.9	3.3	0.0	87.1	23.3	7.4	0.08	0.6	BDL
38	Khamarisahi	TW	R.Udayagiri	19.2229	84.2794	7.35	220	131	83.8	67	25.6	4.7	14.2	0.9	0.0	81.3	20.9	9.0	0.12	2.1	BDL
39	Poipani	TW	R.Udayagiri	19.3986	83.9831	8.01	632	408	152.9	152	51.2	5.9	88.7	3.8	0.0	185.9	125.6	17.7	0.08	53.1	0.002
40	Burupada	TW	R.Udayagiri	19.1582	84.3405	7.96	125	84	39.4	29	11.8	2.4	6.8	3.7	0.0	34.9	11.6	8.7	0.24	46.3	BDL
41	Cheligada	TW	R.Udayagiri	19.2005	84.2487	8.00	201	135	64.1	67	13.8	7.1	18.1	2.6	0.0	81.3	27.9	7.2	0.08	9.8	BDL
42	Sagada	TW	Mohana	19.2808	84.2684	8.05	89	55	29.6	19	7.9	2.4	6.4	2.8	0.0	23.2	11.6	7.6	0.12	5.0	BDL
43	Kirting	TW	Mohana	19.3962	84.2359	8.09	654	457	162.7	110	49.3	9.5	75.6	2.0	0.0	133.6	116.3	26.7	0.12	1.8	0.001
44	Kirimasahi	TW	Mohana	19.3796	84.1777	8.24	305	207	103.6	86	29.6	7.0	24.3	2.5	0.0	104.6	44.2	15.0	0.12	49.5	0.002
45	Budangapur	TW	Mohana	19.3617	84.1461	8.15	135	93	49.3	38	11.8	4.7	9.6	0.9	0.0	46.5	16.3	9.0	0.13	0.7	BDL
46	Sialilata	TW	Mohana	19.3626	84.0888	8.08	186	112	54.2	48	17.7	2.4	12.6	3.1	0.0	58.1	18.6	13.9	0.35	49.8	BDL
47	Bada Galama	TW	Mohana	19.4051	84.2197	7.92	402	280	152.9	95	37.4	14.2	16.5	7.6	0.0	116.2	27.9	19.8	0.17	3.1	BDL
48	Raipanka	TW	Mohana	19.4013	83.9832	8.04	225	142	69.0	67	15.7	7.1	12.8	9.1	0.0	81.3	20.9	14.5	0.33	2.8	BDL
49	Taptapani	Hotspring	Mohana	19.4847	84.3937	8.24	335	231	128.2	95	31.6	11.8	20.4	1.5	0.0	116.2	37.2	13.6	0.56	0.0	BDL

Annexures IV Analysis of Chemical Parameters of Exploratory Wells constructed by WAPCOS

Sl.no	Site Name	Well Depth	pH	EC	TDS	TH	F-	Cl-	SiO_2	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3	HCO_3	SO_4
		m		(µS/cm)	mg/l												
1	Birikote	**200**	7.54	614	392	150	0.58	25	4.4	7.2	40	12	68.3	2.5			28.1
2	Aligunda	**200**	6.98	920	584	220	0.6	85	5	8.8	48	24	106.8	2.9			53
3	Antaraba	**200**	7.73	482	318	160	0.52	20	4	6.3	36	16.8	33.5	2.3			4
4	Chelligada	**200**	7.81	414	266	150	0.48	15	5.3	36	14.4	22.7	2.1	Nil	Nil	160	15.7
5	Chelligada	**200**	7.68	482	313	180	0.5	15	5.9	40	19.2	24.1	2.5	Nil	Nil	180	28.2
6	Khajuripada	**200**	7.69	232	148	70	0.3	20	2.1	4	16	7.2	18.4	1.5			19.5
7	Kumalsingh	**200**	7.82	518	334	170	0.47	25	3.4	6.6	36	19.2	37.2	2.3			21.4
8	Gumma	**200**	7.74	608	392	130	0.58	45	4	7.5	28	14.4	76.3	2.3			26.5
9	Kurlunguda	**200**	7.63	714	453	120	0.62	50	4.6	8.2	28	12	104.8	2.7			31.2

Annexures V Analysis of Chemical Parameters of NHS Wells (2019)

Sl No	BLOCK_NAME	SITE_NAME	LAT	LONG	pH	EC	TDS	TH	ALKALINITY	Ca++	Mg++	Na+	K+	HCO3-	Cl-	SO4=	F -
1	GUMA	Parasamba	18°50'41" N	84°3'12" E	8	220	134	77	62	20	6.6	16	2	76	35	3	0.166
2	KASHINAGARA	Kasinagar	18°51'22" N	83°52'48" E	8.4	800	437	281	310	51	37.4	56	8	372	62	23	0.596
3	MOHANA	Adaba	19°29'22" N	84°10'56" E	8.2	250	156	102	103	31	6.0	15	2	126	15	5	0.131
4	MOHANA	Bada Khoni	19°28'54" N	84°17'27" E	8.3	700	360	194	233	47	18.7	19	80	284	45	26	0.39
5	MOHANA	Chandiput 1	19°21'54" N	84°18'2" E	8.1	300	168	102	134	31	6.0	21	8	164	12	12	0.182
6	MOHANA	Chandragiri 1	19°18'21" N	84°17'11" E	8.3	400	194	133	145	43	6.3	19	19	177	20	10	0.247
7	MOHANA	Dantarinalo	19°26'50" N	84°21'37" E	8.3	300	229	128	150	27	14.7	15	2	183	12	0	0.253
8	MOHANA	Kirama	19°26'16" N	84°18'41" E	8	550	276	189	130	49	16.2	37	5	158	92	9	0.121
9	MOHANA	Ladruma	19°27'19" N	84°15'55" E	8.2	250	141	102	98	37	2.4	15	2	120	-	25	0.112
10	MOHANA	Lillygada	19°25'43" N	84°17'3" E	8.3	850	456	306	305	61	37.4	26	52	372	47	26	0.389
11	MOHANA	Luhaguda	19°27'34" N	84°21'45" E	8.2	1250	641	423	373	90	48.3	59	63	455	147	52	0.33
12	MOHANA	Madhura-Amba	19°26'54" N	84°20'53" E	8.1	200	110	77	72	20	6.6	16	2	88	20	12	0.319
13	MOHANA	Mohana	19°26'18" N	84°16'6" E	8.3	400	209	112	150	29	9.6	44	1	183	32	7	0.935
14	MOHANA	Santhi Nagar	19°27'35" N	84°13'2" E	8	600	302	230	197	45	28.6	29	12	240	67	16	0.147
15	MOHANA	Suklipadar	19°24'9" N	84°20'28" E	8	450	258	168	109	43	14.8	21	6	133	80	3	0.101
16	MOHANA	Taramala	19°23'12" N	84°18'23" E	8.4	600	355	163	222	47	11.1	19	74	265	37	28	0.456
17	MOHANA	Zubagaon	19°19'36" N	84°18'10" E	8.2	120	88	36	47	12	1.5	11	3.5	57	10	2	0.069
18	GOSANI	Apalanaidupetta	18°50'26" N	83°55'9" E	8.4	750	409	204	212	37	27.2	56	41	253	95	25	0.889
19	GOSANI	Garabandh	18°49'49" N	84°16'56" E	8.1	3200	1756	694	93	162	70.5	431	13	114	995	68	0.273
20	GOSANI	Gosani	18°48'45" N	84°14'44" E	8.4	950	487	265	383	31	45.6	77	41	461	50	30	0.404
21	GOSANI	Kantragada	18°51'29" N	84°11'26" E	8.3	450	258	204	181	45	22.3	22	3	221	35	14	0.259
22	GOSANI	Kattalakanita	18°48'38" N	84°8'34" E	8.3	1200	624	230	197	51	25.0	161	19	240	242	39	0.682
23	GOSANI	Lavanya Khotta	18°48'59" N	84°19'52" E	8.1	500	261	199	181	43	22.3	31	3	221	50	1	0.281
24	GOSANI	Lavanyagada	18°49'11" N	84°17'11" E	8.4	1200	648	306	238	45	47.1	137	2	284	250	4	0.9
25	GOSANI	Minigaon	18°49'41" N	84°0'12" E	8.2	350	186	122	155	31	10.9	26	1	189	17	3	0.617
26	GOSANI	Narayanpur	18°52'25" N	84°11'31" E	8	190	100	66	78	18	5.1	12	3	95	12	3	0.162
27	GOSANI	Parlakhemundi	18°46'15" N	84°6'15" E	8.2	500	248	160	155	33	18.9	37	9.5	189	52	18	0.134
28	GOSANI	Raygarh	18°53'15" N	84°9'40" E	8.3	450	258	133	166	31	13.5	21	32	202	25	14	0.18
29	GOSANI	Tattipati	18°49'54" N	84°12'36" E	8.1	800	393	276	170	61	30.1	57	2.5	208	140	34	0.284
30	GOSANI	Pegoda	18°54'48" N	84°9'19" E	8.3	500	260	163	212	39	16.0	40	2	259	22	3	0.286
31	GOSANI	Sebakpur	18°52'47" N	84°10'29" E	8.4	1000	553	235	325	61	20.1	54	116	391	92	37	0.274