केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

DHENKANAL DISTRICT
ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

South Eastern Region, Bhubaneswar

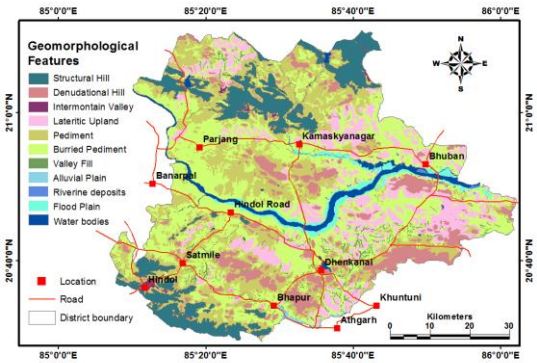
Government of India

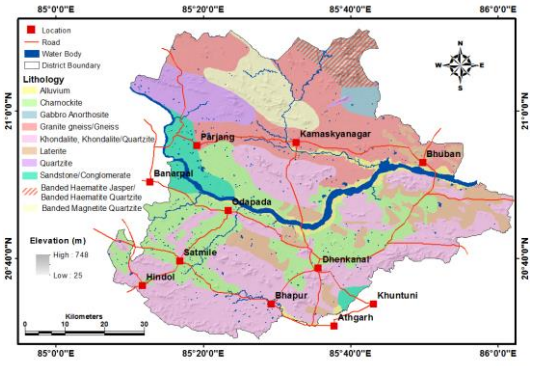
MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

REPORT ON

AQUIFER MAPPING AND MANAGEMENT PLAN IN DHENKANAL DISTRICT, ODISHA





CENTRAL GROUND WATER BOARD

South Eastern Region, Bhubaneswar

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CONTRIBUTORS PAGE

Data Acquisition	**:**	Shri S. K. Mohanty, Scientist-'B'
Data Processing	**:**	Shri S. K. Mohanty, Scientist-'B'
Data Compilation & Editing	**:**	Shri S. K. Mohanty, Scientist-'B'
Data Interpretation	**:**	Shri S. K. Mohanty, Scientist-'B'
GIS	**:**	Dr. Banaja Rani Panda, Young Professional Dr. Satyabrata Sahoo, Young Professional
Report Compilation	**:**	Shri S. K. Mohanty, Scientist-'B'
Technical Guidance	**:**	Dr. N. C. Nayak, Scientist-'D'
Overall Supervision	**:**	Shri P. K. Mohapatra, Regional Director Shri D. N. Mandal, Scientist-'D'

FOREWORD

Dhenkanal district, located in the central parts of the Odisha state, bears an agrarian economy. The agriculture in the district is inevitably exposed to the vagaries of rainfall. Erratic rainfall is quite frequent and also the irrigation facilities are inadequate in the district, affecting the agriculture production from year to year. The agrarian development of the district can be boosted by tapping the groundwater resources through dug wells and medium-deep bore wells.

Due to wide variation in hydrogeological set up in the district, the occurrence and distribution of aquifers are non-uniform and so also their yielding properties. The common modes of groundwater exploitation in the district are dug well, dug-cum-bore well, shallow tube well etc. The hard crystalline rocks of the district form two distinct aquifer systems. The shallow aquifers formed by the weathered mantle, stores groundwater under phreatic condition. The deeper aquifer is formed by fracture zones, joints, etc holds groundwater in semi-confined/confined conditions. Granitic hard-rock aquifers have water yielding fracture zones and have average success rate with 2-5 lps of discharge. The places where weathering thickness is more and condition is favourable, the phreatic aquifer attains good yield potential and large diameter dug wells are suitable structures to extract water from them.

Groundwater irrigation is currently an underutilized resource that could mitigate the effects of drought such as surface water scarcity and crop failure. Groundwater irrigation practices can insure increased agricultural production by enhancing the area irrigated and scope of irrigation. Apart from irrigation, drinking water scarcity can also be mitigated through judicious utilization of groundwater. The present stage of groundwater development is only 37.4%, leaving a vast scope for future groundwater development in the district. Groundwater irrigation practices can ensure increased agricultural production by enhancing the area irrigated and scope of irrigation.

Based on the available data and the earlier hydrogeological studies taken up in 08 blocks of the district viz. Dhenkanal Sadar, Odapada, Gandia, Hindol, Kamakshyanagar, Kankadahad , Bhuban and Parjang covering 4452 Sq. Km. of mappable area, an attempt has been made in this report to compile all relevant information, such as hydrogeological, agriculture, irrigation, land use, rain fall, chemical quality of water and other collateral data. Shri S. K. Mohanty, Scientist-'B' has compiled and prepared the present report on "Aquifer Mapping and Management Plan in Dhenkanal District, Odisha". Their sincere efforts in preparation of the report will no doubt be very useful and benefit the state. It is hoped that, it will be of immense help to different groundwater user agencies, administrators and planners in preparation of groundwater development plans and will be a handy tool in effective management of groundwater resources in the district.

(P. K. Mohapatra)
Regional Director

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1 INTRODUCTION

1.1 Objective

Central Ground Water Board (CGWB) has taken up National Aquifer Mapping and Management (NAQUIM) programme during the XIIth five year plan to carry out integration of micro level hydrogeological, geophysical, hydrochemical data and information on geology, geomorphology, soil, hydrometeorology, hydrology, landuse, cropping pattern etc on a GIS platform to formulate district, block or aquifer-wise Ground Water Management Plan. The formulation of a sustainable ground water management plan would help in achieving the demand for drinking, irrigation and industrial need for water with minimal stress on the aquifer.

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 ground water 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 hard rock terrain of Dhenkanal district in Odisha covering all eight blocks of the district.

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 ground water related problems and issues.

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

1.3 Approach and Methodology

Multi-disciplinary approach involving geological, geophysical, hydrological, hydrogeological and hydro-geochemical survey would be carried out to meet the aim and objectives listed above.

The Geological Survey of India has geologically mapped the entire Dhenkanal district. The systematic ground water survey programme was undertaken by central Ground water Board during 1970 decade. The programme of Exploratory Drilling to delineate deeper saturated fracture zones was carried out by CGWB. Besides, monitoring Ground Water regime is being done through 42 observation wells periodically in the districts, 4 times a year.

1.3.1 Compilation of Existing Data and Identification of Data Gaps

Preliminary work will consist of the collection and review of all existing data which relate to the area. This usually included the results of any previous hydrogeological studies and exploratory drilling carried out by CGWB and State agencies and compiled to identify the data gaps in the study area. After the data compilation all the data were integrated and analysed.

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 is to be carried out to strengthen the data base. The analysis of the data has to be carried out for preparation of thematic maps.

1.3.3 Geo -hydrochemical Investigations

Water Samples to be collected, analyzed and interpreted to bring out ground water 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
- Ground water quality

1.3.5 Development of Aquifer-Wise Management Plan

The dimension and disposition of the aquifer is figured out on the basis of 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 ground water 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) programme were taken up under Annual Action Plan (AAP) 2018-19 for detailed hydrogeological investigation and Aquifer Mapping in Dhenkanal district. The Dhenkanal district has its administrative headquarters in Dhenkanal town. In the present scenario of the administrative set up, there are 3 sub divisions, 8 tahsils and 8 CD blocks. There are total number of 198 gram Panchayat, 4 Urban Bodies (1.Dhenkanal Municipality 2.Bhuban NAC, 3.Kamakhyanagar NAC and 4.Hindol NAC) and 15 police stations running in the district of Dhenkanal.

Table-1.1: Block-Wise Demographic Details in Dhenkanal district.

Sl. No	Block	Geog. area (Sq. Km.)	Population
1	Dhenkanal Sadar	396.25	152932
2	Odapada	342.26	143482
3	Gandia	399.07	152180
4	Hindol	593.79	178145
5	Kamakshyanagar	386.08	113985
6	Kankadahad	589.23	110126
7	Bhuban	253.96	102087
8	Parjang	427.46	133450
9	Bhuban(NAC)	18.04	22200
10	Dhenkanal(M)	24.82	67414
11	Kamakshya Nagar(NAC)	11.15	168.10
Total	**Dhenkanal**	**4452.00**	**1192811**

As per 2011 Provisional Census the Dhenkanal district has 1237 villages having 11,92,948 population out of which 6,12,597 Male population and 5,80,351 Female Population. The

Dhenkanal district is having 79.41% literacy rate with total numbers of 4,71,681 male literates and 3,70,307 female literates The block-wise demographic details are shown in **Table-1.1**. The administrative map of the study area is presented in **Fig.1.1** and **Fig.1.2.**

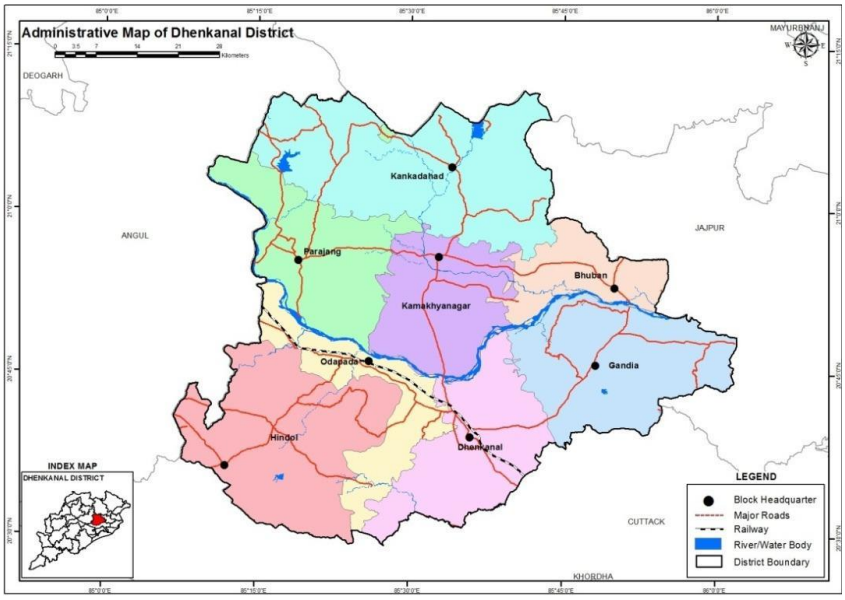


Fig. 1.1: Index Map of Study Area under NAQUIM in Dhenkanal district.

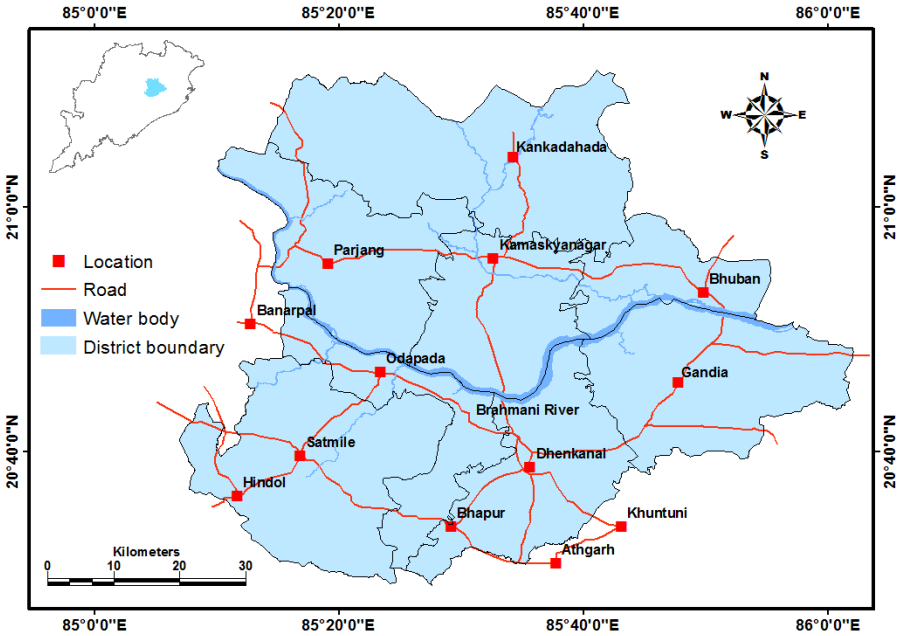


Fig. 1.2: Administrative Map of Dhenkanal district.

1.5 Rainfall and Climate

The district enjoys tropical climate characterized by hot and dry summer, cold winter and erratic rainfall in monsoon. The winter season extends from November to end of February, which is followed by summer season from March to the middle of June, and rainy season from middle of June to middle of October.

Southwest monsoon is the principal source of precipitation in the district. The normal annual rainfall of the district is 1048.0 mm, out of which about 85% is received during monsoon season (mid June to mid October). The month of July and August gets the heaviest rainfall of the year, though rainfall is not very regular throughout the season but fairly uniform throughout the district. There are on the average 60 – 85 rainy days in a year. Besides, the relative humidity varies between 30 % to 86%. The district faces occasional flash floods, which, because of the terrain, cause heavy damage to roads and crops. Drought is an almost constant feature that visits the district almost every alternate year. The rainfall data of Dhenkanal district is shown in **Table-1.2** and the isohyet map of Dhenkanal district is shown in **Fig.1.3**.

Temperature and Humidity: During summer months the maximum temperature rises up to 46.1^{o} C and May is the hottest month. December is the coldest month of the year when the average daily temperature drops down to 6.7 ^{o} C. Relative humidity is around 26-82% throughout the year. The highest and lowest monthly mean relative humidity so far recorded is 82% (Dec) and 26% (April). Humidity of the air is generally high during southwest monsoon season and decreases from the end of November due to cold wave.

Wind: Wind is generally light to moderate. During summer and southwest monsoon season, wind velocity increases. In the post-monsoon months and in winter, wind is mainly from the north and east. During summer wind direction is variable and in rainy season wind from southwest direction is very common. The southern part of the district is prone to cyclonic storms.

Table 1.2: Rainfall data of Dhenkanal district

Sl. No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total	year
1	0.0	0.0	0.5	96.8	115.9	171.2	422.4	265.3	359.0	154.6	0.0	34.3	1620.1	2018
2	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	2017
3	5.5	12.3	15.0	4.8	30.0	125.3	219.0	284.3	292.1	56.6	0.2	0.0	1045.1	2016
4	20.8	2.4	12.6	95.1	91.3	140.6	459.4	186.9	97.1	37.6	1.8	12.4	1158.0	2015
5	3.1	15.0	8.8	10.3	157.0	70.5	573.8	339.3	204.6	29.2	0.0	0.0	1411.6	2014
6	0.0	0.0	0.0	5.0	14.3	274.0	266.2	185.0	147.9	277.6	0.0	0.0	1170.2	2013
7	76.2	0.0	0.0	24.5	23.8	149.7	446.1	442.1	207.5	110.9	156.9	0.0	1637.5	2012
8	0.0	4.4	2.9	40.4	55.0	133.6	249.4	312.8	513.5	42.1	0.0	0.0	1354.0	2011
9	0.0	0.0	9.1	14.9	118.3	187.3	212.1	226.6	185.6	121.4	9.5	42.8	1127.4	2010
10	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	2009
11	3.8	11.6	21.5	19.4	61.9	192.3	225.6	275.0	303.4	27.5	19.9	0.0	1162.0	2008

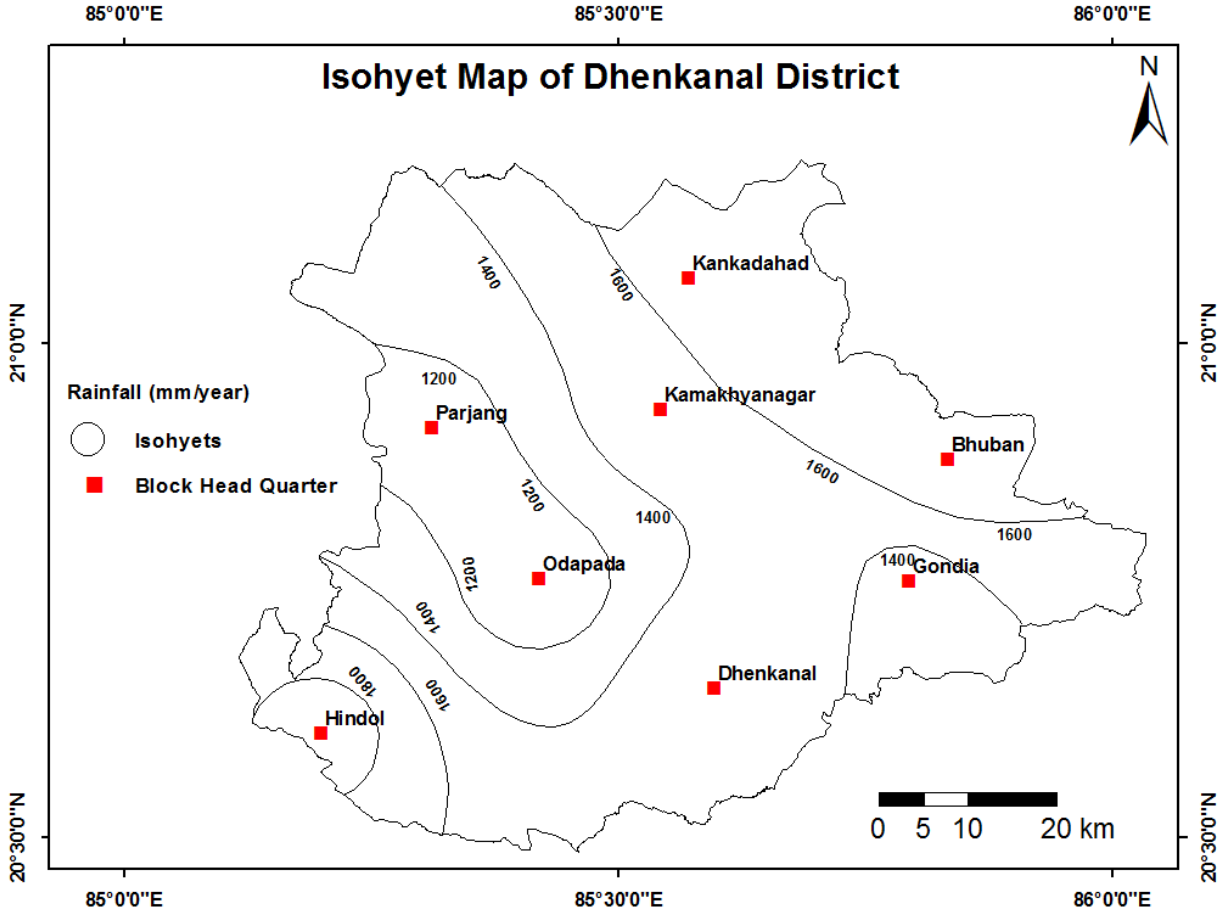


Fig. 1.3: Isohyet Map of Dhenkanal district.

1.6 Physiographic Setup

The Dhenkanal district is divided into four physiographical division –southern mountainous region, Eastern valley and plain, Central undulating plain and northern mountainous region. The district is characterized by rugged forest cladded mountainous terrain with narrow intermontane valleys. The elevation of the hills generally ranges from 300 m to 1100 m above mean sea level. The variation in land elevations above MSL is shown in **Fig. 1.4**. The details of the geomorphic unit as identified are as below:

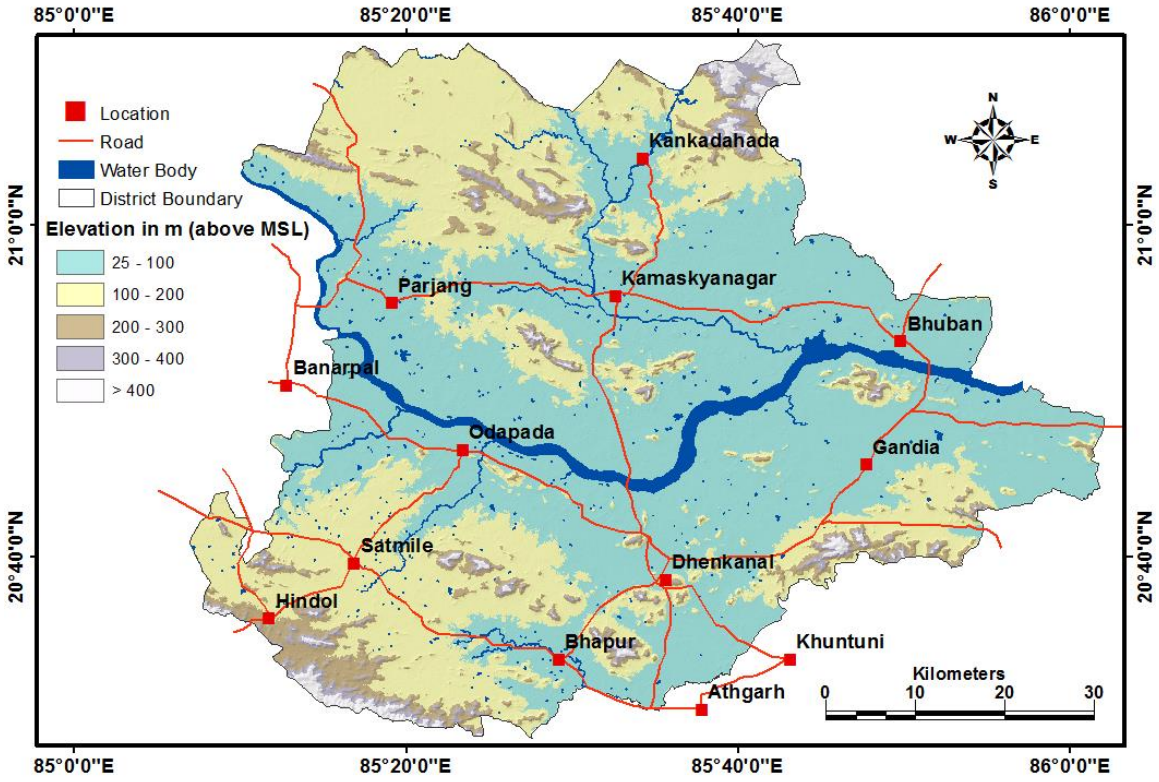


Fig. 1.4: Land surface elevations in Dhenkanal district.

Southern Mountainous Region: The hill ranges trend NNW-ESE and occupy parts of Hindol Block of Hindol Sub-division and parts of Gondia, Dhenkanal and Odapada blocks of Dhenkanal sub-division, it forms a watershed between the Brahmani and Mahanadi rivers. The elevation ranges from 60 to 971 mamsl. The hills are denudational to erosional in nature and covered with moderate to dense forest.

Eastern Valley and Plain: It occurs as small stripes along the curves of the Brahmani and its tributaries. It is characterized by residual hills and ridges. The elevation varies from 40 m to 630 m above mean sea level.

Central Undulating Plain: It spreads over Parjang block of kamakhya- nagar subdivision. The area is characterized by undulating to broad flat topography with low-lying hills with flattop.

Northern Mountainous Region: It spreads over Kankadahat, Kamakhyanagar and Bhuban block of Kamakhayanagar subdivision. This terrain is covered with dense forests. The hills are separated by broad valleys and low hilly regions.

1.7 Geomorphology

The study area comprises of the following geomorphic units. The geomorphology of the area is shown in **Fig. 1.5.**

1.7.1 Flood Plains

They occur along a narrow stretch with limited thickness and areal extent along the course of Mahanadi and its tributary Tel. They comprise of loose unconsolidated materials like sand, silt, clay, pebbles, boulders etc. Fine to coarse sand form potential aquifer zones and yield a good quantity of water. Ground water in these areas may be developed through dug wells 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 thick weathered zone with thickness varying from 10-15 m and forms potential phreatic aquifer. Ground water development can be through dug wells and dug-cum-bore wells.

1.7.3 Shallow Buried Pediment

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

1.7.4 Intermontane Valley

A number of Intermontane Valleys with major rivers and their tributaries have developed viz. Salki, Bagh, Kharag etc which have been formed by deep incise weathering of denudational hills.

1.7.5 Valley Fills

These hydromorphic units are confined to linear depressions which mostly contain fractured rock fragments and acts as very good area for storage and movement of ground water. Dug wells located in these areas yield fairly a good amount of water.

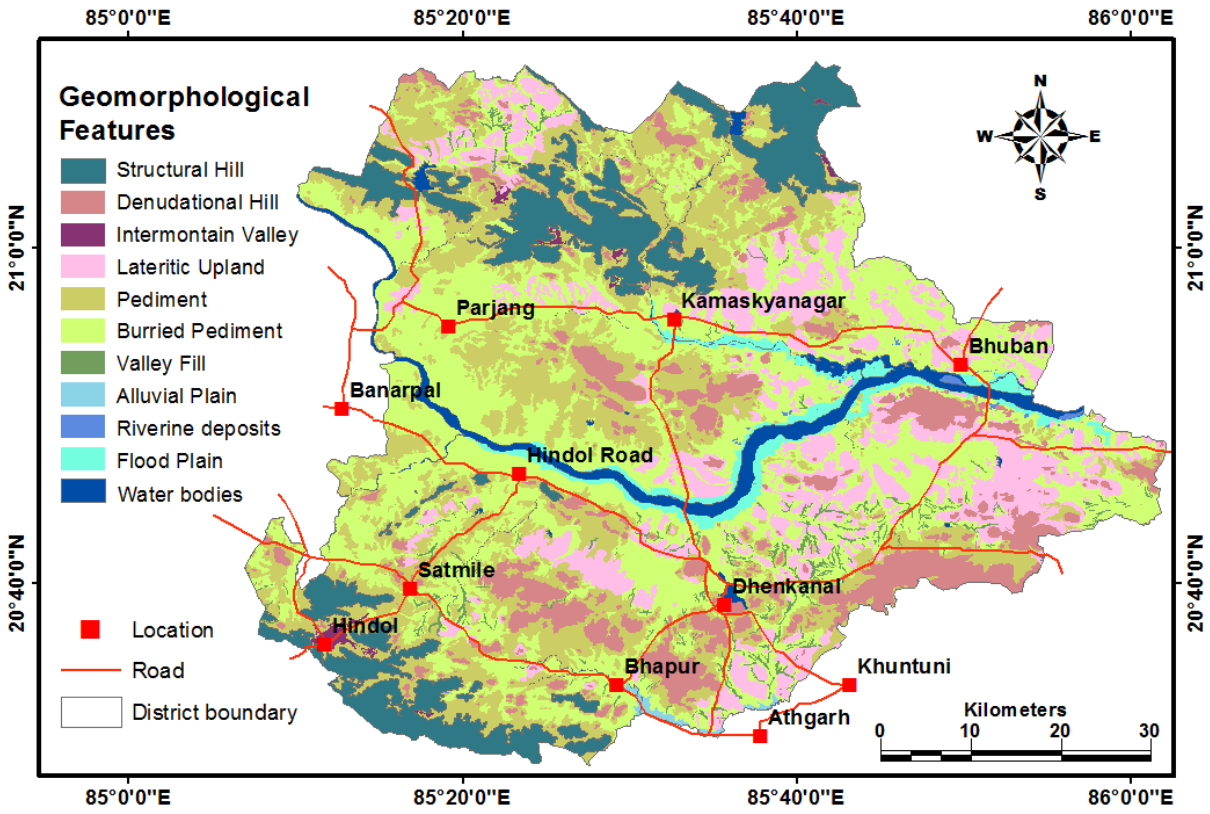


Fig. 1.5: Geomorphology of Dhenkanal district.

1.7.6 Inselbergs

This land form occurs as isolated hillocks. These are developed due to active weathering and denudation in a humid tropical climatic condition. This unit does not have any significance on occurrence and movement of ground water.

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. Rate of infiltration is very poor except along fractures/joints. These generally act as run-off zone.

1.8 Land use and Cropping Pattern

The study area shows wide variation in the pattern of land utilization. The forest area is 59% of total geographical area. The net sown area of the district is 132780 ha with maximum cropping intensity in Harbhanga block which is 169%. Agriculture is the main stay for the rural population of the district. The block-wise landuse pattern is shown in **Table 1.4,** a block-wise area under agriculture in **Table 1.5** and the thematic map on land use is shown in **Fig. 1.6**.

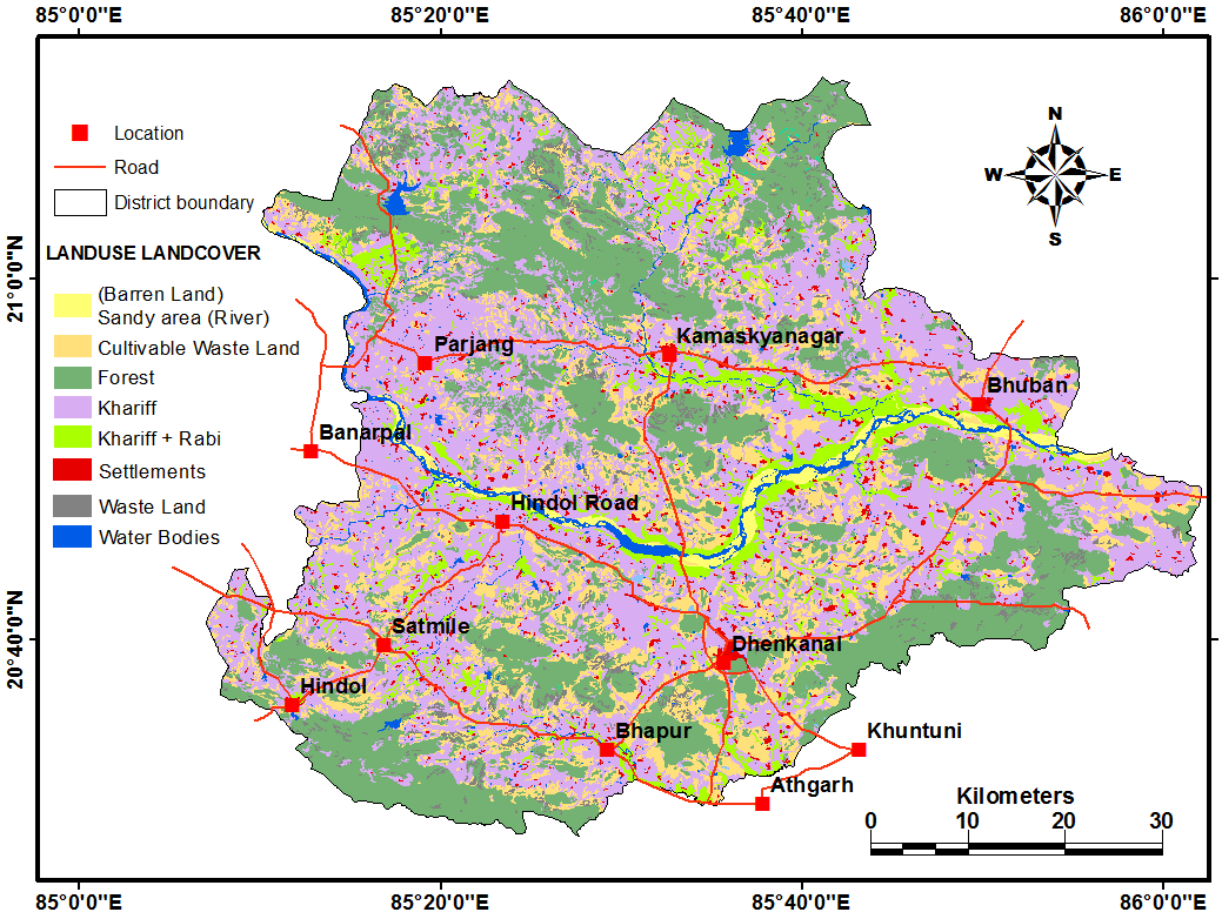


Fig. 1.6: Landuse in the NAQUIM Area in Dhenkanal district.

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, pulses (Arhar, Green and Black gram) and vegetables (potato, onion, garlic, turmeric, ginger and seasonal vegetables), fruits (mango, coconut, guava) etc. The major crop of the district is paddy. The paddy area in the district covers 59335 ha. The productivity of rainfed paddy and irrigated paddy in kharif season is 27.54 qt/ha and 41.75 qt/ha respectively. The productivity of irrigated paddy in rabi season is 45.37 qt/ha. The area under cereals, coarse cereals, pulses, oilseeds, fibres, vegetables, spices constitute 68270 ha, 610 ha, 37310 ha, 6880 ha, 250 ha, 17440 ha and 1900 ha respectively in the district.

Table 1.4: Land use pattern in Dhenkanal district

Sl. No.	Block	Geog. area in ha	Gross cropped area in ha	Net sown area in ha	Area sown more than once	Cropping intensity (%)	Area under forest in ha	Area under waste land in ha	Area under other uses in ha
1	Dhenkanal Sadar	46569	43729	30607	13122	143	10580	78	556
2	Odapada	34056	30632	21625	9007	142	6571	130	383
3	Gondia	47933	35638	23115	12523	154	16585	167	469
4	Hindol	81370	42600	31689	10911	134	41097	788	931
5	K. Nagar	46865	31420	19381	12039	162	21821	138	130
6	Bhubana	29216	32746	19757	12989	166	6000	678	290
7	Parjang	50497	33762	20771	12991	163	24319	511	145
8	Kankadahada	93971	31141	19341	11800	161	65726	1983	326
	Total	**430477**	**281668**	**186286**	**95382**	**153**	**192699**	**4473**	**3230**

1.8.1 Water Requirement

The water requirement of different crops grown in the district as worked out by Dept. of Agriculture and Food Production, Govt. of Odisha are enumerated in **Table 1.5**. The water requirements for live-stock and industries are produced in **Tables 1.6 and 1.7**. **Table 1.8** shows the total water requirement in the district.

Table 1.5: Crop water requirement in Dhenkanal district

Crops	Area Sown	Irrigated Area	Crop Water Demand(Mm)	Water Potential Required (Bcm)	Existing Water Potential (Bcm)	Potential To Be Created (Bcm)
Paddy	88776	50008	7200-9600	0.468	0.50008	-0.03208
Wheat	111	111	2800-3200	0.00002	0.00111	-0.00109
Maize	2644	1820	4000-4800	0.00824	0.0182	-0.00996
Ragi	34	0	3200-4800	0.00034	0	0.00034
Small Millets	172	0	4000-4800	0.00172	0	0.00172
Pulses	65232	10005	1600-2000	0.55227	0.10005	0.45222
OILSEEDS	35310	2492	2800-3200	0.32818	0.02492	0.30326
Fibres	740	0	0	0.0074	0	0.0074

Vegetables	61464	37178	4000-4800	0.24286	0.37178	-0.12892
Spices	10770	7592	4000-4800	0.03178	0.07592	-0.04414
Sugarcane	1365	1365	13600-16000	0	0.01365	-0.01365
TOTAL	**266618**	**110571**	47200-58000	**1.64081**	**1.10571**	**0.5351**

Table 1.6: Livestock water requirement

Sl. No.	Block	Total number of Livestock	Present Water Demand(BCM)	Water demand in 2020 (BCM)	Existing Water Potential(BCM)	Water Potential to be Created (BCM)
1	Dhenkanal	382929	0.0035	0.0042	0.0035	0.0007
2	Odapada	163324	0.0021	0.0025	0.0021	0.0004
3	Gondia	320727	0.0043	0.0051	0.0043	0.0008
4	Hindol	126055	0.003	0.0036	0.003	0.0006
5	K. Nagar	192944	0.0033	0.0039	0.0033	0.0006
6	Bhubana	93085	0.0006	0.0007	0.0006	0.0001
7	Parjang	288321	0.0033	0.004	0.0033	0.0007
8	Kankadahada	179984	0.0039	0.0047	0.0039	0.0008
	Total	**1747369**	**0.024**	**0.0287**	**0.024**	**0.0047**

Table 1.7: Industrial water requirement

Blocks	Name of the industry	Present water demand (BCM)	Water Demand In 2020 (BCM)	Existing Potential (BCM)	Water Potential To Be Created (BCM)
Odapada	GMR Kamalanga Energy, Kamalanga	0.26793	0.26793	0.26793	Nil
	Bhusan Steel, Narendrapur	0.41083	0.41083	0.41083	Nil
	BRG Iron & Steel, Kurunti	0.00848	0.00848	0.00848	Nil
	Lanco Babandha Power, Kurunti	0.35724	0.35724	0.35724	Nil
	Nav Bharat Venchures, Kharagprasad	0.03572	0.03572	0.03572	Nil

	Mangilal Runta, Tulasidiha	0.00268	0.00268	0.00268	Nil
	MGM Steel, Nimidha	0.01456	0.01456	0.01456	Nil
Dhenkanal Sadar	Shivananda Ferro Aloys, Gundichapada	0.00447	0.00447	0.00447	Nil
	Narbheram Steel, Gundichapada	0.02188	0.02188	0.02188	Nil

Table 1.7a: Total water demand in Dhenkanal district

Sl No.	Block	Components					Total (BCM)
		Domestic	Crop	Live-stock	Industrial	Power generation	
1	Dhenkanal sadar	0.01 059	0.33188	0.0042	0.02927		0.37594
2	Odapada	0.00 666	0.23408	0.0025	1.09744		1.34068
3	Gondia	0.00 735	0.26277	0.0051	0		0.27522
4	Hindol	0.00 896	0.28042	0.0036	0		0.29298
5	K Nagar	0.00 623	0.04341	0.0039	0		0.05354
6	Bhuvana	0.00 703	0.20307	0.0007	0		0.2108
7	Parjang	0.00 707	0.14219	0.004	0		0.15326
8	Kankadahada	0.0 095	0.14299	0.0047	0		0.15719
Total		**0.06 339**	**1.64081**	**0.0287**	**1.12671**		**2.85961**

1.9 Soil

Soil is the precious gift of nature to the mankind. All the plant family, animal kingdom and human society at large depend upon soil for their sustenance directly or indirectly. Ironically, soil is the most neglected commodity on the earth. Shifting cultivation on the hill slopes, non-adoption of soil conservation techniques, and over exploitation of land for crop production due to population stress, leads to enormous soil erosion. It will take hundreds of years to form an inch of soil, but in no time it gets washed away down the slope due to erosion.

The soil types of the district are dominated by Mixed Grey Soil (Inceptisols) which covers 237834.28 i.e 55.24 %of the total area (430477ha). Unaltered Soils with Coarse Parent Materials (Entisols) covers an area about 111022.43 ha i.e 25.79 %of the total area. Matured,Red, Lateritic

Soil (Alfisols) covers an area about 36286.21ha i.e 8.4 % of the total area& Unclassified soilscover an area about 22324.53 ha i.e 5.18% of the total area. The soil map of the Dhenkanal districts is shown in **Fig. 1.7**.

The soil characteristics of the district show wide variation depending upon their occurrence, physical and chemical properties. The soil of the district is broadly grouped into1) Ultisols and 2) Alfisols 3) Entisols.

Alfisols or Red Soil:

The Alfisols, in the district, include red sandy soils and red loamy soils. These soils predominantly occupy high and medium land throughout the Dhenkanal district. Alfisols are neutral to slightly acidic in nature (pH varies from 5.5 to 6.9). 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.

Ultisols:

The ultisols comprises mainly of lateritic soils and red and yellow soils. These soils are mildly acidic in nature and deficient in nitrogen, phosphorous and potassium and organic matters.

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

Entisols:

These are younger alluvial soil occur along the Brahmani river on the eastern part of the district. The soils are deficient in nitrogen, phosphoric acid and humus but are not generally in potassium and lime. The PH of the soil is alkaline. The texture varies from sandy and loamy sand. The soils are most fertile and are suitable for variety of crops like paddy, wheat, sugarcane, cotton, banana and tobacco.

Soil Classes	Area_Ha
Matured, Red & Lateritic Soil (Alfisols)	36286.21
Mixed Grey Soil (Inceptisols)	237834.28
Unaltered Soils With Coarse Parent Materials (Entisols)	111022.43
Unclassified Soil	22324.53
Settlement	12339.68
Waterbody	10669.87
Total	**430477.00**

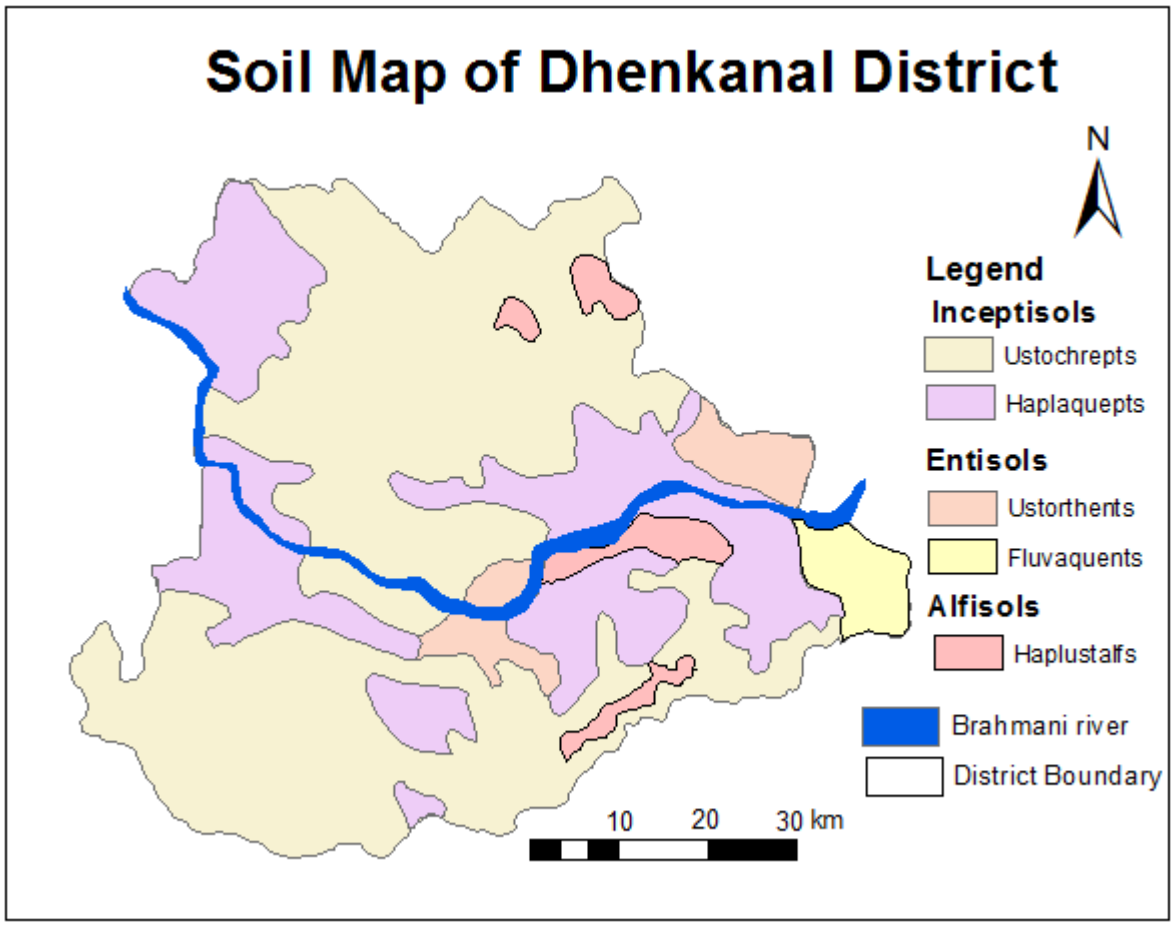


Fig. 1.7: Soil Map of Dhenkanal district.

1.10 Drainage and Hydrology

The drainage in the area is controlled by Brahmani River and its tributaries. The Brahmani River divides the area into two halves. Initially the river flows in a N-S direction then follows a NW-SE course and changes to NE-SW direction. Its important tributaries are Ramiala nadi, Nigre Nadi, Purajhor Nadi. The smallest stream shows dendritic pattern, while the major river and its tributaries show sub parallel while the major river shows sub parallel drainage indicating structural control. All the streams are of effluent in nature. The drainage map of the area is shown in **Fig. 1.8**.

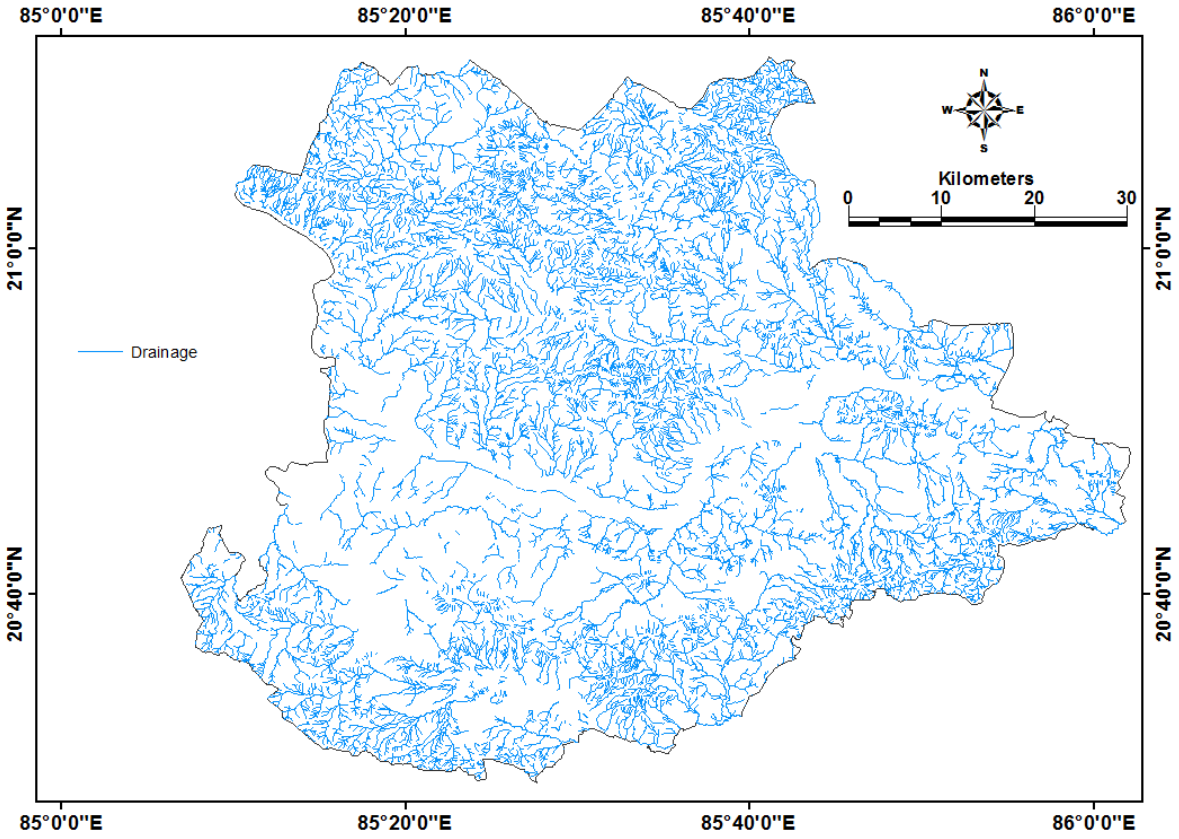


Fig. 1.8: Drainage Map of Dhenkanal district.

Though agriculture in this district mainly depends on rain, irrigation facilities are provided through major/medium irrigation, minor irrigation and lift irrigation projects both for Kharif and Rabi crops. The district has about 35% land are irrigated. The total irrigation potential is 46570Ha.

1.10.1 Major and Medium Irrigation Projects

The block-wise details of Minor Irrigation Projects in the study area are given in **Table 1.8.**

Table 1.8: Details of MIPs in Dhenkanal district.

SL. NO	Name of the M.I.P	Name of the Block	Name of G P	TYPE	Latitude	Longitude	catchment area(sq. Km)	Designed Ayacut (Ha)		Canal length in Mtr.
1	2	3	3	4	6			KHARIF	RABI	
1	Badabandha	Bhuban	Kuninda	D/W	20°-55'-30"	85°-18'-30"	35.3	364		L-2100,R-11200
2	Balibo	Bhuban	Balibo	RES	20°-54'-20"	85°-52'-48"	1.5	42		
3	Baunskana	Bhuban	Bhuban (NAC)	RES	20°-55'-10"	85°-49'-10"	1.3	61		R-360
4	Damasal	Bhuban	Baruan	D/W	20°-00'-00"	85°-43'-05"	182.3	2000	810	L-64350
5	Khurusia	Bhuban	Khurusia	RES	20°-52'-42"	85°-40'-34"	2.6	81		
6	Mathakargolla	Bhuban	Mathakargolla	RES	20°-48'-15"	85°-41'-30"	2.6	41		R-305
7	Solapokhari	Bhuban	Jiral	RES	20°-52'-22"	85°-42'-35"	1.6	81		
8	Tananali (Anal)	Bhuban	Anal	RES	20°-58'-00"	85°-16'-00"	9.1	162		LINK CHAN-1035 L-705
9	Tangarpada	Bhuban	Mathakargolla	RES	20°-54'-52"	85°-40'-34"	1.1	49	8	R-600
10	Tipilai	Bhuban	Surapratap Pur	RES	20°-55'-10"	85°-43'-56"	2.6	81		
11	Biradia	Dhenkanal	Kaimati	Res	20°-40'-00"	85°-42'-30"	3.4	162		L-1550
12	Gahamkhunti	Dhenkanal	Kaimati	D/W	20°-39'-20"	85°-40'-00"	5.2	81		R-1000
13	Gohirakhal	Dhenkanal	Kankadahad	Res	20°-36'-45"	85°-32'-00"	1.8	41		
14	Kaintaliabandha	Dhenkanal	Bhapur	Res	20°-33'-10"	85°-33'-00"	1.3	41	8	
15	Khalibandha	Dhenkanal	Tarava	Res	20°-43'-30"	85°-37'-00"	1	41		R-300
16	Parbatia	Dhenkanal	Sankarpur	Res	20°-32'-30"	85°-35'-15"	7.8	162		R-1500
17	Patrabhaga	Dhenkanal	Saptasajya	D/W	20°-35'-15"	85°-36'-00"	13.45	211		R-3000
18	Mahulapada	Dhenkanal	Baladiabandha	RES	20°-36'-30"	85°-41'-20"	1.2	41		L-800
19	Badajore	Dhenkanal	Chandrasekharprasad	D/W	20°-31'-05"	85°-28'-15"	13	202		

20	Dalibandha	Dhenkanal	Bhapur	RES	20°-32'-30"	85°-27'-00"	1.8	56		
21	Jhumpudia	Dhenkanal	Chandrasekharprasad	D/W	20°-31'-10"	85°-28'-10"	4.2	61		L-900
22	Khinda	Dhenkanal	Kankadahad	D/W	20°-39'-00"	85°-33'-10"	8.2	121		
23	Mankira	Dhenkanal	Chandrasekharprasad	RES	20°-30'-45"	85°-30'-40"	16.8	520	240	
24	Namichira	Dhenkanal	Kankadahad	RES	20°-37'-30"	85°-33'-00"	2.1	41		
25	Similibandha	Dhenkanal	Kakudibhaga	RES	20°-34'-10"	85°-29'-30"	2.6	41		
26	Talbarkote	Dhenkanal	Talbarkote	RES	20°-34'-00"	85°-37'-15"	10.4	162		R-200
27	Chaulia	Dhenkanal	Chaulia	D/W	20°-48'-50"	85°-39'-30"	67.85	810	100	
28	Sunajhari	Dhenkanal	Dhirapatna	RES	20°-32'-40"	85°-33'-10"	2.58	90	25	
29	Bunglow	Gondia	Santhapur	D/W	20°-48'-00"	85°-55'-45"	7.2	113		R-400
30	Daluasuni	Gondia	Sadangi	RES	20°-49'-37"	85°-49'-35"	2.3	73		L-6150
31	Dhanianali	Gondia	Sadangi	RES	20°-42'-30"	85°-15'-00"	18.1	243	121	L-7110
32	Durgabandha	Gondia	Deogan	D/W	20°-42'-30"	85°-42'-25"	14.4	202		L-970
33	Gundurapasi	Gondia	Bidharpur	RES	20°-43'-40"	85°-48'-40"	22	1012	182	L-5850,R-6960
34	Jaribandha	Gondia	Neulapoi	RES	20°-43'-36"	85°-41'-00"	2.6	81		
35	Jhumpan	Gondia	Bega	D/W	20°-45'-48"	85°-55'-40"	1.3	145		L-1570
36	Khandiabandha	Gondia	Khandibandha	D/W	20°-48'-28"	85°-55'-35"	3.3	53		R-1600
37	Madhapur	Gondia	Kabera	D/W	20°-45'-48"	85°-55'-48"	2.6	81		L-1180,R-570
38	Pinguabhusabandha	Gondia	Pingua	RES	20°-47'-45"	85°-56'-20"	2.6	81		R-1500
39	Ramei (Archua)	Gondia	Sorisiapada	RES	20°-43'-30"	85°-51'-45"	4.5	42		R-2200
40	Sibasagar	Gondia	Deogan	RES	20°-41'-50"	85°-44'-45"	1	41		
41	Sorisiapada	Gondia	Sorisiapada	D/W	20°-41'-25"	85°-51'-05"	7.5	108		L-1000,R-1610
42	Jharanabandha-II	Gondia	Mandar	RES	20°-51'-30"	85°-52'-10"	1.6	50		L-650,R-500

43	Alhachua	Gondia	Sadangi	D/W	20°-43'-30"	85°-51'-30"	5.2	81		
44	Aliapada	Gondia	Bidharpur	D/W	20°-44'-20"	85°-46'-25"	5.2	81		R-900
45	Archua	Gondia	Sorisipada	RES	20°-46'-20"	85°-52'-45"	3.9	121		
46	Badapokhari	Gondia	Bega	RES	20°-44'-35"	85°-59'-35"	2.6	81		
47	Baidakateni	Gondia	Laulae	D/W	20°-50'-40"	85°-58'-15"	5.8	72		L-600
48	Balusua	Gondia	Bega	D/W	20°-51'-30"	86°-00'-00"	2.6	41		
49	Bankianala	Gondia	Bega	D/W	20°-53'-10"	85°-59'-30"	5.2	81		
50	Binjarinalla	Gondia	Laulae	D/W	20°-44'-00"	85°-58'-45"	45.4	900		
51	Dadhisinga	Gondia	Kabera	D/W	20°-46'-50"	85°-44'-15"	2.6	81		
52	Deogaon	Gondia	Deogaon	RES	20°-42'-05"	85°-44'-55"	1.3	41		
53	Dhaneibandha	Gondia	Mathatentulia	D/W	20°-46'-20"	85°-50'-45"	7.2	100		L-700
54	Dhehuritotajharan	Gondia	Santhapur	RES	20°-49'-00"	85°-45'-15"	2	41		
55	Gunduribandha	Gondia	Kabera	RES	20°-46'-55"	85°-44'-30"	1.3	41		
56	Jharanabandha-I	Gondia	Mandar	RES	20°-49'-20"	85°-51'-20"	1.3	41		
57	Kolibandha	Gondia	Mandar	RES	20°-50'-25"	85°-51'-55"	3.9	81		
58	Kurangia	Gondia	Bega	D/W	20°-43'-00"	85°-59'-25"	2.6	81		
59	Lahada(Ankul)	Gondia	Kasipur	D/W	20°-49'-30"	85°-54'-15"	1.3	41		
60	Nuabandha	Gondia	Kasipur	RES	20°-48'-00"	85°-54'-05"	2.6	81		
61	Panaslikata	Gondia	Kasipur	RES	20°-49'-35"	85°-53'-15"	1.3	41		
62	Saharpokhari	Gondia	Kasipur	RES	20°-49'-50"	85°-53'-30"	1.3	41		
63	Sankeibandha	Gondia	Mathatentulia	RES	20°-46'-30"	85°-50'-30"	2.4	60		
64	Talibandha	Gondia	Kasipur	RES	20°-50'-10"	85°-33'-50"	1.3	41		
65	Worinalla	Gondia	Kasipur	D/W	20°-49'-05"	85°-55'-00"	2.6	41		

66	Bhuasunibandha	Gondia	Mathatentulia	D/W	20°-45'-30"	85°-55'-40"	6.6	89		L-700
67	Darh	Gondia	Chhotatentulia	D/W	20°-50'-00"	86°-00'-00"	33.7	216		R-1500
68	Saupajhar	Gondia	Deogan	D/W	20°-44'-30"	85°-47'-05"	47	350	100	L-2500
69	Badibahal	Hindol	Rasol	RES	20°-36'-58"	85°-14'-48"	1.3	41		R-100
70	Baradapal	Hindol	Baunsapokhari	D/W	20°-00'-41"	85°-00'-10"	54.1	715	202	L-820
71	Baradapal (Badabandha)	Hindol	Baunsapokhari	RES	20°-00'-39"	85°-00'-10"	1.3	42		R-480
72	Baunsapokhari	Hindol	Baunsapokhari	D/W	20°-00'-37"	85°-00'-16"	10.4	271	61	R-4632
73	Bedapada	Hindol	Badabandha	RES	20°-00'-44"	85°-00'-25"	13.7	386	130	L-7316
74	Beruanpal	Hindol	Paikapurunakote	RES	20°-45'-32"	85°-47'-10"	18.4	248	129	L-361,R-762
75	Champamunda	Hindol	Kantamilla	RES	20°-43'-50"	85°-16'-15"	1.4	41		L-883
76	Dudurkote	Hindol	Dudurkote	RES	20°-41'-30"	85°-20'-00"	1.3	41		R-245
77	Ektali	Hindol	Nizigarh	RES	20°-36'-10"	85°-11'-50"	6.7	206	81	L-5882
78	Kalijodi	Hindol	Kunua	RES	20°-00'-35"	85°-00'-50"	13	405	405	
79	Kamarbeda	Hindol	Dudurkote	RES	20°-41'-45"	85°-15'-19"	3	89		
80	Kansara	Hindol	Kansara	RES	20°-42'-00"	85°-08'-10"	2.6	81		L-2743,R-793
81	Kharidali	Hindol	Bompa	RES	20°-41'-50"	85°-26'-35"	3.9	121		R-883
82	Kukupangi	Hindol	Nuabag	D/W	20°-36'-26"	85°-16'-30"	17.4	134	24	R-3322
83	Kurumitha	Hindol	Hatura	RES	20°-41'-20"	85°-12'-10"	2.6	81		R-92
84	Nuaghai	Hindol	Babandha	RES	20°-42'-40"	85°-26'-35"	12.9	101		R-2205
85	Panaspal	Hindol	Baunsapokhari	RES	20°-33'-00"	85°-10'-00"	14.2	486	219	R-9297
86	Rampal	Hindol	Rasol	RES	20°-37'-10"	85°-19'-10"	2.6	81		R-457
87	Sanjapada	Hindol	Sanjapada	RES	20°-41'-18"	85°-13'-25"	1.2	41		L-300
88	Sarpa	Hindol	Karanda	RES	20°-44'-33"	85°-21'-30"	31.7	810	405	L-6305,R-9723

89	Brahmanipal	Hindol	Bumpa	RES	20°-39'-05"	85°-26'-10"	1.8	43		
90	Gandanali	Hindol	Gandanali	RES	20°-35'-30"	85°-20'-25"	2.6	41		R-420
91	Gulei	Hindol	Dudurkote	RES	20°-41'-45"	85°-15'-10"	13	405		R-1067
92	Kantamila	Hindol	Kantamila	RES	20°-40'-35"	85°-07'-08"	11.6	243		L-244
93	Khajuriakata	Hindol	Ranjagola	RES	20°-41'-30"	85°-18'-40"	2.6	81		
94	Nuabandha	Hindol	Kunua	RES	20°-38'-30"	85°-21'-50"	0.6	81		
95	Thengamunda	Hindol	Jarada	RES	20°-40'-10"	85°-20'-15"	11.6	162		L-152,R-450
96	Bankidibandha	Hindol	Patala	RES	20°-43'-28"	85°-15'-50"	0.6	81		
97	Diarpasi	Hindol	Baunsapokhari	RES	20°-39'-15"	85°-08'-15"	2.6	81		
98	Gadabandha	Hindol	Godipokhari	RES	20°-41'-30"	85°-20'-00"	11.6	364		
99	Jharanabandha	Hindol	Purunakot	RES	20°-38'-00"	85°-10'-05"	2.6	81		
100	Kalanda	Hindol	Hatura	RES	20°-40'-25"	85°-14'-45"	2.6	81		
101	Kalangabandha	Hindol	Jarada	RES	20°-39'-55"	85°-20'-40"	1.3	41		
102	Kusumbandha	Hindol	Jarada	RES	20°-41'-00"	85°-20'-20"	10.4	324		
103	Madhusagar	Hindol	Jiridaprasad	RES	20°-41'-30"	85°-21'-35"	2.6	41		
104	Paikpali	Hindol	Jarada	RES	20°-40'-07"	85°-19'-53"	1.2	41		
105	Kapasia	Hindol	Dudurkote	D/W	20°-41'-40"	85°-13'-30"	35.95	380	30	
106	Anlaberini	Kamakshyanagar	Kusumjodi	RES	20°-50'-05"	85°-33'-10"	2.6	81		L-1800,R-1200
107	Baligorada	Kamakshyanagar	Baligoruda	RES	20°-55'-45"	85°-36'-30"	1.4	41		L-3300,R-1200
108	Bankual	Kamakshyanagar	Bankual	RES	20°-52'-30"	85°-39'-05"	1	41		L-120,R-1050
109	Bhairapur	Kamakshyanagar	Bhairapur	RES	20°-50'-30"	85°-37'-00"	3.2	101		R-8070
110	Galukateni	Kamakshyanagar	Kadua	RES	20°-54'-42"	85°-30'-20"	4.1	41		L-12480,R-1200
111	Hadgudi	Kamakshyanagar	Kadua	RES	20°-54'-35"	85°-31'-05"	2.6	41		L-800,L-3800

112	Jodabadia	Kamakshyanagar	Tumusinga	RES	20°-48'-00"	85°-28'-00"	15	445	324	L-1300
113	Kankadajhar	Kamakshyanagar	Kantiokateni	RES	20°-50'-28"	85°-30'-05"	5.2	263	81	L-2200
114	Kantajharia	Kamakshyanagar	Budhibili	RES	20°-50'-30"	85°-35'-25"	7.2	41		R-950
115	Kantapal	Kamakshyanagar	Kantapal	RES	20°-47'-47"	85°-28'-35"	2.6	81		L-510
116	Kantiokateni	Kamakshyanagar	Kantiokateni	RES	20°-47'-40"	85°-30'-15"	3.6	42		L-420,R-850
117	Khatakhura	Kamakshyanagar	Baligorada	RES	20°-56'-50"	85°-36'-30"	1	41		R-300
118	Lokanathpur	Kamakshyanagar	Badasuanala	RES	20°-55'-20"	85°-33'-30"	2.3	73		L-3800
119	Machhia	Kamakshyanagar	Rainarasinghpur	RES	20°-46'-50"	85°-33'-45"	2.1	65		
120	Nahakani	Kamakshyanagar	Mahulpal	RES	20°-53'-30"	85°-32'-30"	1	41		
121	Rankia	Kamakshyanagar	Bhairapur	RES	20°-02'-25"	85°-28'-15"	2.8	81		
122	Indrajitnalla	Kamakshyanagar	Kusumjodi	D/W	20°-48'-17"	85°-32'-10"	30	486	121	L-5850,R-6140
123	Kakudia	Kamakshyanagar	Mahulpal	RES	20°-54'-00"	85°-33'-00"	1.4	41		L-2820
124	Bhagirathipur	Kamakshyanagar	Kadua	RES	20°-54'-10"	85°-31'-30"	1.3	41		
125	Jantakhola	Kamakshyanagar	Kanapura	D/W	20°-57'-30"	85°-32'-00"	2.4	81		
126	Kusumjodi	Kamakshyanagar	Kusumjodi	D/W	20°-40'-30"	85°-31'-20"	5	80		
127	Motta	Kamakshyanagar	Mahulpal	RES	20°-53'-22"	85°-35'-02"	1.3	41		R-1200
128	Rajakulkateni	Kamakshyanagar	Kanapura	RES	20°-56'-05"	85°-49'-50"	1.4	41		
129	Saradhapur	Kamakshyanagar	Kanapura	RES	20°-56'-40"	85°-31'-00"	1.3	41		
130	Jhamujhar	Kamakshyanagar	Baruan	RES	20°-50'-00"	85°-30'-00"	5.2	190	20	L-420,R-3400
131	Bandania	Kankadahad	Birasal	RES	21°-00'-25"	85°-41'-49"	4.1	65		R-1200
132	Birasal (Combined)	Kankadahad	Birasal	D/W	21°-00'-42"	85°-40'-30"	14.2	408	40	R-7200
133	Damsal	Kankadahad	Maruabil	RES	21°-03'-34"	85°-43'-49"	63.7	1215	405	L-6400,R-12650 PICK
134	Gurujanguli	Kankadahad	Dasipur	RES	21°-07'-00"	85°-20'-00"	1	41		L-2668,R-1370

135	Pangatira	Kankadahad	Pangatira	RES	20°-07'-30"	85°-21'-45"	2.6	73		L-450
136	Khandahata	Kankadahad	Kantol	D/W	21°-07'-15"	85°-38'-45"	2.1	61		
137	Barabahalia	Odapada	Gundei	RES	20°-44'-00"	85°-27'-00"	2.6	60		R-1500
138	Kalika Prasad	Odapada	Kalanga	RES	20°-31'-30"	85°-24'-55"	19	364		L-2750
139	Lowerbaga	Odapada	Kasidiha	D/W	20°-42'-30"	85°-27'-30"	4.5	121	20	R-10070
140	Ranipal	Odapada	Gobindprasad	RES	20°-30'-50"	85°-26'-50"	25.1	393		L-300
141	Tinimuhani	Odapada	Indipur	D/W	20°-40'-00"	85°-32'-00"	10.3	162		L-2000,R-7000 MIDDLE
142	Upperbega	Odapada	Balarampur	D/W	20°-41'-00"	85°-28'-00"	1.4	80		R-2600
143	Bhagirathisagar	Odapada	Dinabandhupur	RES	20°-30'-00"	85°-25'-00"	1.3	41		
144	Jadabandha	Odapada	Kalanga	RES	20°-46'-10"	85°-17'-57"	10.3	162		
145	Khandiabandha-I	Odapada	Kalanga	D/W	20°-31'-00"	85°-28'-00"	1.3	41		
146	Panchagochhia	Odapada	Kalanga	RES	20°-32'-40"	85°-26'-30"	2.3	90		
147	Nuabandha	Odapada	Ghatipiri	RES	20°-33'-30"	85°-27'-05"	2.3	41		R-1500
148	Badajhara	Parjang	Badajhara	RES	20°-56'-30"	85°-24'-00"	2.6	81		R-650
149	Barabank	Parjang	Parjanga	RES	20°-55'-30"	85°-20'-10"	1.4	41		R-1700
150	Kumusikata	Parjang	Kumusi	RES	20°-52'-00"	85°-22'-00"	1.3	41		R-1065
151	Vereniakata	Parjang	Saanda	RES	20°-50'-00"	85°-25'-30"	5.4	110		L-900
152	Kankadasoda (Similibahal)	Parjang	Kankadasoda	RES	20°-57'-30"	85°-21'-30"	0.8	41		R-2250
153	Baigania	Parjang	Saanda	RES	20°-51'-50"	84°-35'-00"	4.35	41		L-795
154							1.3	41		
155	Anladihikata	Parjang	Kumushi	RES	20°-52'-25"	85°-22'-28"	1.3	41		
156	Badakata	Parjang	Kankadasoda	RES	20°-59'-45"	85°-21'-00"	5.2	162		
157	Bahalabandha	Parjang	Basoi	RES	20°-53'-30"	85°-23'-10"	1	41		

158	Chandandeipur	Parjang	Chandandeipur	RES	20°-48'-40"	85°-24'-10"	1.3	41		
159	Jayapura	Parjang	Jayapura	RES	20°-57'-40"	85°-27'-30"	5.2	162		
160	Kamarda	Parjang	Muktaposi	RES	20°-59'-30"	85°-24'-30"	2.6			
161	Kantur	Parjang	Kantur	RES	20°-57'-15"	85°-20'-30"	5.2	41		
162	Muktaposi	Parjang	Muktaposi	RES	20°-56'-20"	85°-25'-10"	1.3	41		R-2200
163	Panigengutia	Parjang	Panibhandar	RES	20°-49'-15"	85°-22'-00"	5.2	162		
164	Saranga	Parjang	Saranga	RES	20°-55'-45"	84°-15'-30"	1.3	41		
165	Siarimalia	Parjang	Panibhandar	RES	20°-49'-20"	85°-24'-00"	1	41		
166	Patuapalli	Parjang	Manikmara	RES	21°-04'-00"	85°-11'-38"	2.26	75	30	

Source: Dept. of Water Resources, Minor Irrigation Projects, Odisha 2014

2 DATA COLLECTION AND GENERATION

2.1 Geology

The major parts of the district are underlain by Archean crystalline of the Eastern ghat group, Precambrian metasedimentaries, Gondwana sedimentaries and recent alluvium. The Archean occurring in the major parts of the district include granite, granite gneisses and khondalites. The Precambrian occur in small patches as phyllites and micaschist. The Gondwana occupy the northwestern parts of the district and comprise a sequence of sandstone, shale and carbonaceous shale. The recent alluvium occurs in limited patches along the river courses. The generalized stratigraphic sequence is given in **Table 2.1** and the geological map of the study area is shown in **Fig. 2.1.**

Table.2.1 Generalized stratigraphic sequence in Dhenkanal district.

Era	Group/Super group	Lithology
Quaternary Recent to sub-recent		Alluvium Sand, silt and clay in varying proportions
		Laterites and lateritic gravels
	Unconformity	
Upper Paleozoic to Mesozoic		Sandstone, shale , carbonaceous shale
	Unconformity	
Precambrian	Precambrian	Phyllite, Mica schist
Archean		Granite, granite gneisses, Khondalite

Archeans and Precambrian: The Archean formation belonging to the Eastern Ghats group are the oldest rocks exposed in the district. Khondalites are the common rock type consisting of quartz, feldspar, sillimanite and garnet with graphite and biotite as accessories. The abundance of garnet and sillimanite in the rocks indicates a high-grade metamorphism. Granite and gneisses occur wide spread on either side of the Brahmani River including variants like hornblends gneiss, biotite gneiss

with vein of pegmatite and quartz. Precambrian rocks exposed in the northwestern part of the district, consist of phyllites and mica schist.

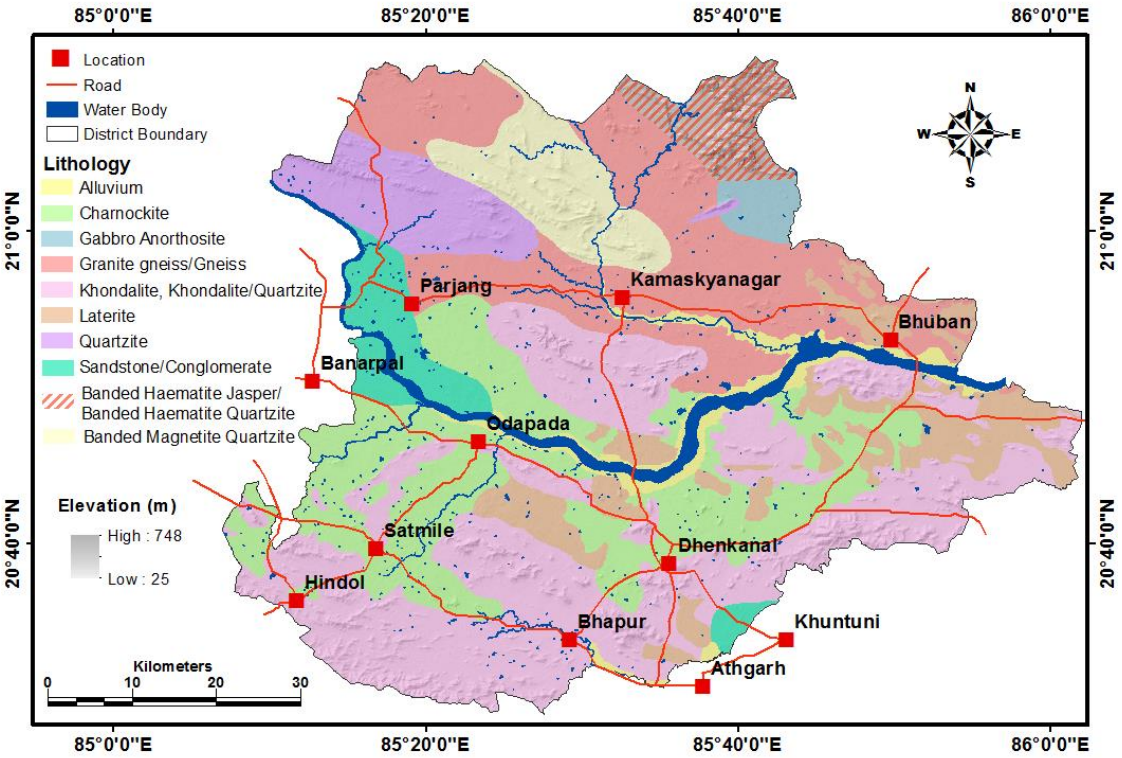


Fig. 2.1: Geological Map of Dhenkanal district.

Gondwana: Lower Gondwana sedimentaries are exposed in parts of parjang and Kamakhya nagar blocks in the northwestern part of the district. These formations uncomfortably overlie the Precambrian or Archean Basements. This group consists of sandstone, shale and carbonaceous shale belonging to Talcher series. The sand stones at places are massive in nature.

Recent to Sub-recent: The lateries occur extensively as capping over the khondalite in topographic lows as also over granite gneiss. These are ferruginous in nature and highly porous having a spongy look and at places form a nodular mass. The recent to sub recent alluvium occurs as flood plains and channel deposits of the Brahmani river and its tributaries. It comprises of sand, gravel, silt and clay. The areal extent of this formation is limited and the maximum thickness is about 25m.

Structure: The Archean trend NE-SW to E-W and are steeply dipping. The rock types are jointed with joint directions varying form NE-SW to NW-SE. The Gondwana sediments were deposited in

the faulted troughs. The Gondwana have a gentle dip of 6 to 10 $^{O.}$ towards north. The faults detected in this formation trends NE-SW, N-S and NW-SE.

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 schistosity of the rock units. The rocks strike ENE-WSW with subvertical dip. These have been extensively weathered with the depth of weathering varying from 8.5 to 30m depending on the topography.

Charnockite Suite of Rocks: These occupy most of hilly areas of the district and 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 15m depending on the topographic situation.

Granite Gneiss: These are extensively found throughout the district occupying the low gradient plateau region towards the north. These include garnetiferous granite gneiss, biotite gneiss, medium to coarse grained porphyritic to porphyroblastic varieties. These rocks exhibit 3 sets of joints and are exposed in the hill ranges, in deep valleys as well as undulating plains. The depth of weathering is quite extensive and the thickness of weathered zone may be up to 32 m depending on the topographical situation.

Pegmatite, Quartz veins, Anorthosites, Amphibolites: Occurrence of small veins of quartz and pegmatite traversing the granite gneisses, charnockites and khondalites is an important feature. These exhibit criss-cross cutting relationship with the country rocks and are limited in occurrence. The quartz veins have been sheared and fractured at places. The anorthosites and amphibolites have very isolated and limited occurrence. Due to limited extent and occurrence they have of least significance from the ground water point of view.

Lower Gondwana: This comprises of gritty sandstone, felspathic sandstone and carbonaceous shale and conglomerates and found as two isolated patches in the Kantamal block. The shales are greenish and highly friable and the sandstones are brownish and are medium to coarse grained. The formations have low easterly dips of 10° to 30°.

Laterite: The laterites occur as a cap rock over all kind of formations like granite gneisses, charnockites and khondalites in the undulating plains and low lying area as small patches. These are found below the soil cover with the depth ranging from 1 to 3.5 m. They are highly porous and permeable.

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

Alluvium: These comprise of various grades of sand, gravel with subordinate silt and clay and occur in the northern part of Dhenkanal district, on the southern bank of river Mahanadi. The thickness of the alluvium varies from less than a metre 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 are also encountered along the major streams.

Structure: Granite gneisses and Khondalites exhibit well developed foliations while in Charnockites, it is less pronounced. Banding is prominent in the Gneisses and Khondalites. Various sets of joints occur in different rock formations. Granite gneiss exhibit prominent parallel joints. The Khondalites in addition to high angle joints show prominent sub-horizontal joints. The rocks have been sheared and mylonitised at places. Joints in granite gneiss are sub-vertical striking (i) along the trend of the rock, (ii) N55°E-S55°W and (iii) S40°W-N40°E. Sandstones and shales of lower Gondwana have fissile bedding planes and open joints. Carbonaceous shales are highly jointed.

2.2 Hydrogeology

Hydrogeologically the district can be divided into consolidated formations belonging to Eastern Ghats, semi consolidated formations belonging to Lower Gondwana and shallow unconsolidated alluvial formations occupying the southern bank of Mahanadi and course of Tal and other major rivers. The hydrogeological map of the area is presented in **Fig. 2.2**.

In the major part of district groundwater occurs under phreatic and semiconfined conditions, the water being stored in the secondary conduits viz. weathered mantle, fractures and

joint planes etc. Infiltration of atmospheric precipitation is the principal source of ground water 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 where as in the moderately undulating plains and valley areas, rainfall contributes significantly to the ground water recharge to form potential aquifers under favourable conditions.

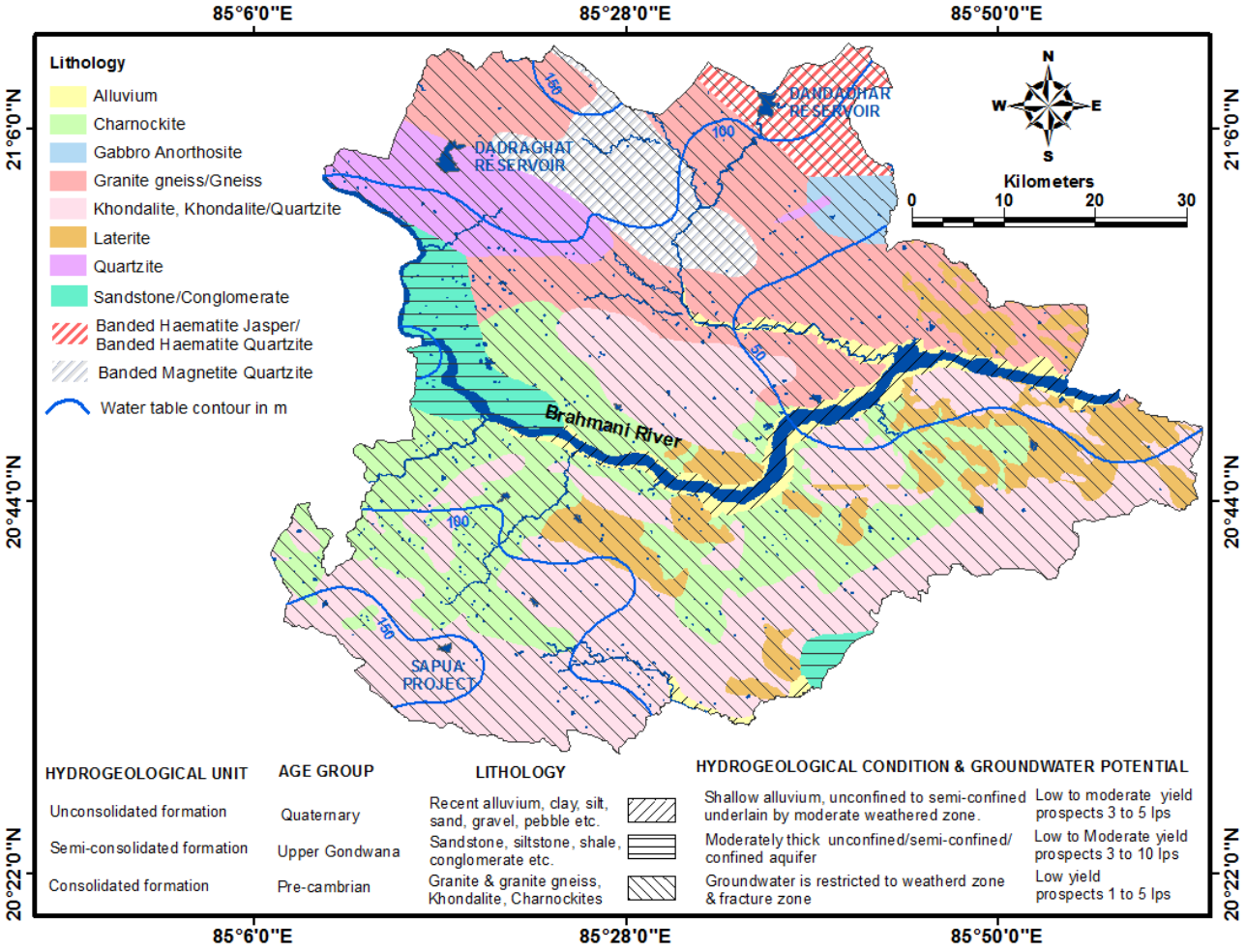


Fig. 2.2: Hydrogeological Map of Dhenkanal district.

2.2.1 Water Bearing Formations

A. Consolidated and Fissured Formation

Major part of the study area is occupied by crystalline rocks comprising of granite gneiss, charnockites and khondalites. These rocks lack primary porosity. Weathering plays an important

role in ground water occurrence and movement in these rocks. Under favourable conditions the weathered residuum forms potential phreatic aquifer. The fissures and joints, when interconnected depending on the extent, size, openness, continuity and interconnection form potential ground water repositories at favourable locales. Ground water 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 occurrence, storage and movement of ground water in the consolidated formations. Community dug wells 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 column of water which prelude heavy drawal of water.

Granite Gneiss and Its Variants: Granite Gneiss constitutes one of the major hydrogeological unit in the district forming undulating terrain dotted with hills, typically of Eastern Ghat topography. The weathered zone acts as good repository of groundwater. These rocks are weathered to form a heterogenous mixture of clayey and granular materials ranging in depth from 5 to 30m depending upon the mineralogical composition and topography. The well foliated and jointed nature of these rocks have largely controlled and accentuated the weathering process. Ground water potential of this unit is quite significant because of open nature of joints and porous nature of the weathered residuum. The irrigation wells are constructed with a large diameter in the topographic lows. The specific capacity of the wells varies from 5 lpm/m to 100 lpm/m. Bore wells generally yield within 2 lps and occasionally higher upto 5 lps.

Charnockites: This is one of the predominant rock types occurring extensively in the southern hilly parts of the district mostly in the Harbhanga 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 4m to 18m depending upon the topographic setup. The ground water potential of this litho unit is poor. The specific capacity of dug wells varies from 10 lpm/m to 37 lpm/m. Bore wells yield less than 1 lps.

Khondalites: These rocks generally form undulating hilly terrains. Moderately weathered rocks exhibit development of porosity with moderate water yielding capacity. Intensive weathering

results in the formation of kaolin reducing permeability. The depth of weathering varies from 8m to 30m. The specific capacity of the only tested dug well is 11 lpm/m. The yield of bore wells is poor and less than 1 lps.

B. Semi-Consolidated Formations

The exposures of rock units of Lower Gondwana occur as isolated patches comprising of gritty and felspathic sandstone, conglomerate and carbonaceous shale. These generally form undulating plains interspersed with low hills. The sandstones are friable and exhibit well developed bedding planes and open joints. Ground water occurs under water table conditions at shallow depth and at deeper depth under semiconfined to confined conditions. The yield potentials of dugwells range from 9 m^3/day to 20 m^3/day. The shallow tubewells constructed within 45 m depth have poor yield potential which is generally less than 1 lps.

C. Unconsolidated Formation

They generally comprise alluvium and valley fill deposits.

Alluvium: It is the derivative of the Mahanadi, the Tel rivers and their tributaries like Bagh, Salki etc. The thickness varies from less than a metre to 10 m while width varies from a few metres to half a km at places. Thick alluvial patches occur along major nalas. These comprise of coarse sand with gravels and pebbles mixed with silt and clay. The specific capacity index of the dugwells in this formation varies from 4 lpm/m/m^2 to 9 lpm/m/m^2.

Valley Fill Deposit: They occur as narrow strips along present and old river channels in the rugged topography. These are essentially coarse sediments comprising of pebble, gravel and sand which are highly permeable in nature. The thickness of the sediments varies from a few meters to 15m whereas the same extends laterally from a few meters to upto 1 km. The pumping tests conducted on the dug wells indicate that the specific capacity index varies from 3 lpm/m/m^2 to 40 lpm/m/m^2.

2.3 Ground Water Exploration

In order to decipher the aquifer system of the area, CGWB has constructed numerous exploratory wells and observation wells which are shown in **Fig. 2.3**. The details of data generated from this exploration are given in **Table 2.2**.

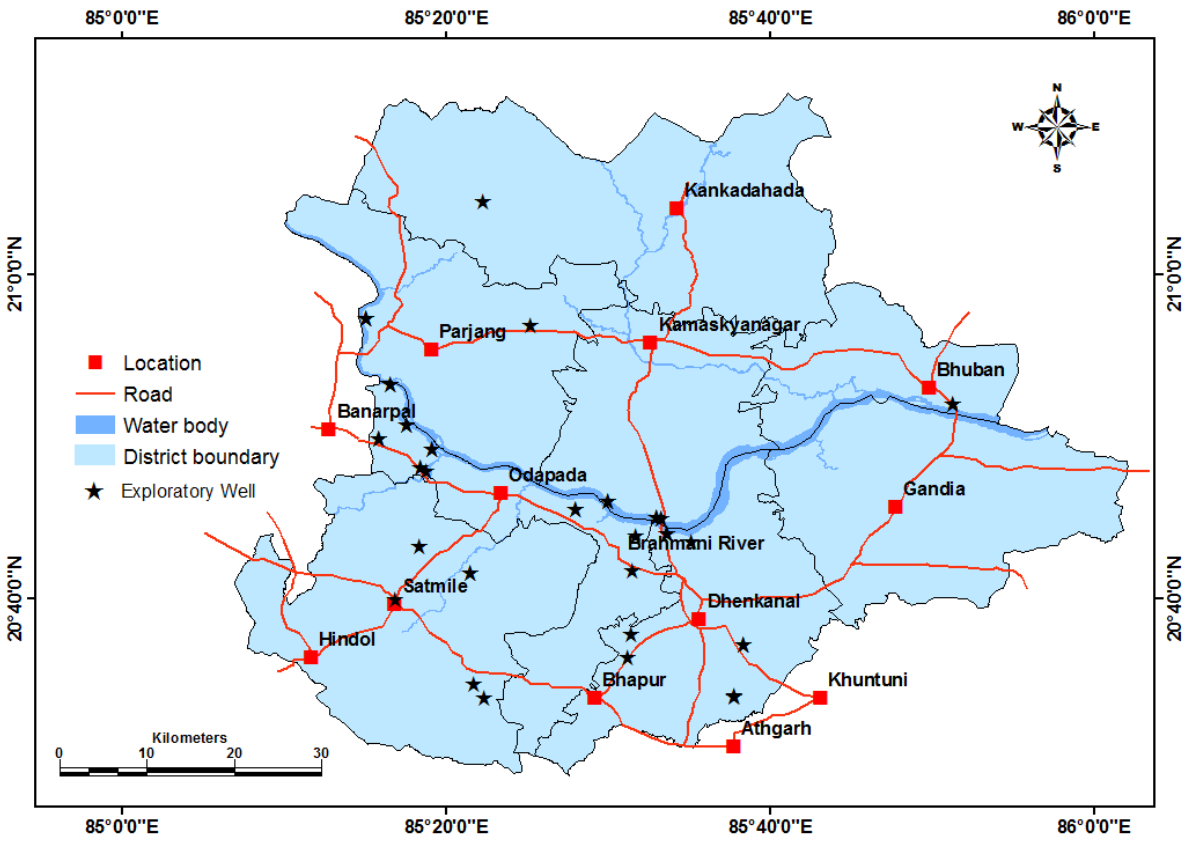


Fig. 2.3: Locations of Exploratory Wells Drilled by CGWB in Dhenkanal district.

2.4 Monitoring of Ground Water Regime

Under NAQUIM, the ground water regime of the phreatic aquifer was monitored during pre- and post-monsoon periods in 2018-19 in 45 National Hydrograph Network Stations (NHNS) and 77Key Observation wells (dug wells). The details of the monitoring wells are shown in **Table 2.3** and the locations of the monitoring stations are shown in **Fig. 2.4**. The chemical quality of ground water in the district is monitored annually on a routine basis by CGWB through its National Hydrograph Network Stations. During the NAQUIM programme, 145 water samples were collected from the monitoring wells and results of their chemical analysis is given in **Table 2.4.** Quality of ground water from deeper aquifers is assessed during the drilling and pumping tests. 55 nos of water samples were collected from the industrial cluster for heavy metal analysis during pre-monsoon period and 12 nos of water samples were collected from the industrial cluster for heavy metal analysis during post-monsoon period. The figures and tables are as follows. The chemical data of water samples collected during the exploration is given in **Table 2.5.**

Table 2.2: Basic Data of Exploratory Wells drilled by CGWB in Dhenkanal district

SL NO	Location	Block	Type of well	Depth (m)	Geological Formation	S.w.l (mbgl)	Discharge	Drawdown (m)	length of casing	Depth of Fracture(m)
DEPOSIST WELLS										
1	Gengutia1	Dhenkanal	DW	26.28	Recent Alluvium	6.19	6	0.67	26.70	12-25.20
2	Gengutia ii	Dhenkanal	DW	24.60	Recent Alluvium	6.11	5	0.31	24.90	10.50-23.80
3	Gengutia iii	Dhenkanal	DW	24.21	Recent Alluvium	7.01	35.2	5.11	24.26	8.63-23.96
4	Gengutia iv	Dhenkanal	DW	28.39	Recent Alluvium	6.87	33	7.45	26.64	10.17-25.34
5	Gundei	Odapada	DW	24.82	Charnokite	2.82	3.66	7.03	10.50	16,18
6	Kamalang	Odapada	DW	12.05	Biotite gneiss	5.71	0.23			
7	Kusponga	Odapada	DW	28.24	Gondwana shale, sandstone	5.87	0.90	9.43	12.40	22,25
8	Hindol Road	Odapada	DW	36.20	Charnokite, granite gneiss	3.54	1.46	6.26	18.95	18.50,20.00
9	Barjhara	Parjang	DW	26.32	Biotite gneiss	4.68	1.58	9.12	26.48	9.34,10.59
10	Bhuban		DW	26.55	Recent Alluvium	5.87	5.62	0.51	27.05	16-26.30

EXPLORATORY BORE WELL										
1	Khalpal	Parjang	SH	202.06	Gondwana shale, sand stone	5.15	2.58	10.90	52.50	18.00-25 42-52 screened temporarily for yield test
2	Meramandali	Odapada	EW	166.05	Granite gneiss	2.50	2.8	20	7.95	10.45-12.45,123-123.5
3	Narendrapur Gopalpur	Odapada	EW	56.25	Fractured granite gneiss	2.87	5.5	9.1	6.00	20-21,41-42,52-56
3b	Narendrapur Gopalpur	Odapada	OW	74.65	Fractured granite gneiss	2.95	3.5	8.59	6.00	46-47,59-60
4	Kharagaprasad	Odapada	EW	129.45	Fractured granite gneiss	7.5	5.538	6.5	16	23.65-24.65,73.45-74.5598.95-99.95
5	Motanga	Odapada	EW	80.7	Fractured granite gneiss	6.75	12	-	8.85	73.5-74.6,79.6-80.7

Table 2.2 contd..: Basic Data of Exploratory Wells drilled by CGWB in Dhenkanal district

Sl No	Block / ULB	Location	Lat.	Long.	Depth Drilled (m bgl)	Casing m	M.P. (M agl)	Formation/ Aquifer	yield (lps)	Cum. Disch. (lps)	SWL (M bgl)	PYT/ Pumping test duration (mins)	Drawdown /RDD (m)	T (m^2/d)
1	Hindol	Kharchuli	20-34-42	85-21-44	150	19.5	0.5	granite gneiss	0.5	0.5	2.33	60	32.61	0.293
2	Hindol	Nabakishorepur	20-33-49	85-22-22	150	15.5	0.5	granite gneiss	0.6	0.6	2.28	60	28.17	0.499
3	Hindol	Giridhari Prasad	25-41-34	85-21-31	150	14.7	0.53	granite gneiss	5.5	5.5	2.12	100	3.95	66.98
4	Hindol	Giridhari Prasad	25-41-34	85-21-31	150	12.5	0.56	granite gneiss	7.6	7.6	2.21	100	7.13	80.216
5	Hindol	Satmile	20-39-54	85-16-53	150	18.5	0.36	granite gneiss	1.2	1.2	5.57	60	27.58	0.688
6	Hindol	Babandha	20-42-46	85-26-07	150	14.35	0.5	granite gneiss	meagre	meagre	4.82	0	0	0
7	Kankadahada	Mahabirod	21-04-30.5	85-22-18.7	140	30	0.82	biotiteschist	1.75	1.75	4.4	300	5.88	0.14335
8	Adahada	Toradanali	21-06-17	85-3-48.8	151	15	0.82	biotiteschist	1.75	1.75	4.56	300	92.94	-

Table 2.2 contd..: Basic Data of Exploratory Wells drilled by CGWB in Dhenkanal district (wells where well assembly lowered)

Sr. No	district	Block	Location	Latitude	Longitude	Latitude in decimal	Longitude in decimal	Depth drilled (mbgl)	Lithology	Depth to Bed rock (mbgl) Casing Pipe Lowered	Granular zones/ deciphered (mbgl)	BAILPLUG	SWL (mbgl) / Date	Discharge (lps)	Drawdown (m)
1	Dhenkanal	Parjang	Khalpal	20°57 ’17”	85°15 ’05”	20.9547	85.2514	202.06	Gondwana Shale, Sand Stone	0.00-18.00,25.00-42.00	18.00 – 25.00 42.00 – 52.00	42.00-202.06 uncaesd	5.15	2.58	10.9
2	Dhenkanal	Bhuban	Bhuban	20°52 ’00”	85°51 ’19”	20.8667	85.8553	26.55	Recent alluvium	0.00-16.00	16.00 – 26.30	26.30-26.55	5.87	5.62	0.51
3	Dhenkanal	Parjang	Ekdal	20°59 ’15”	85°08 ’15”	20.9875	85.1375	164.947	Gondwana Shale, Sand Stone	0.00-41.00	41.00-50.00	50.00-164.947			
4	Dhenkanal	Odapada	Hindol Road	20°46 ’ 00	85°30 ’00	20.7667	85.5000	36.2	Charnockite, Granite Gness.	18.45	uncased		3.54	1.46	6.26
5	Dhenkanal	Odapada	Kusponga	20°50 ’40”	85°17 ’35”	20.8444	85.2931	28.24	Gondwana shale, sandstone	12.4	uncased		5.87	0.9	9.43
6	Dhenkanal	Odapada	Kamalang	20°53 ’13”	85°16 ’38”	20.8869	85.2772	12.05	Biotite gneiss				5.71	0.23	
7	Dhenkanal	Odapada	Gundei	20°45 ’30”:	85°28 ’00	20.7583	85.4667	24.82	Charnockite	10.5	uncased		2.82	3.66	7.03
8	Dhenkanal	Dhenkanal Sadar	Gengutia i	20°44 ’00”:	85°33 ’38”	20.7333	85.5606	26.28	Recent alluvium	0.00-12.00	12.00 – 25.20	25.20-26.20	6.19	6	0.67
9	Dhenkanal	Dhenkanal Sadar	Gengutia ii	20°44 ’00”:	85°33 ’38”	20.7333	85.5606	24.6	Recent alluvium	0.00-10.50	10.50 – 23.80	23.80-24.40	6.11	5	0.31
10	Dhenkanal	Dhenkanal Sadar	Gengutia iii	20°44 ’57”:	85°33 ’00”	20.7492	85.5500	24.21	Recent alluvium	0-8.63	8.63 – 22.96	22.96-23.76	7.01	35.2	5.11

11	Dhenkanal	Dhenkanal Sadar	Gengutia iv	20°44’56”:	85°33’17”	20.7489	85.5547	28.39	Recent alluvium	0.0-10.17	10.17 – 25.34	25.34-26.14	6.87	33	7.45

Table 2.3: Details of monitoring wells in Dhenkanal district.

slno	block	location	latitude	longitude	POST-WL	PRE-WL	well
1	BHUBAN	Mathakaragola	20.09444	85.68639	6.2	8.2	NHS
2	BHUBAN	Goda	20.0975	85.76667	4.47	8.17	NHS
3	BHUBAN	Bhuban	20.09167	85.83417	4.38	6.23	NHS
4	BHUBAN	Samole	20.09583	85.79861	2.56	4.56	NHS
5	BHUBAN	Bhuban-Ii	20.09167	85.83667	2.15	3.25	NHS
6	GANDIA	Mandar	20.08444	85.85722	4.19	6.19	NHS
7	GANDIA	Joranda	20.08444	85.725	3.45	6.25	NHS
8	GANDIA	Sading	20.08972	85.83833	1.77	3.02	NHS
9	GANDIA	Deogaon	20.07056	85.74833	1	3	NHS
10	GANDIA	Gondia1	20.08194	85.80167	0.89	2.14	NHS
11	HINDOL	Hindol1	20.06722	85.19667	4.95	6.15	NHS
12	HINDOL	Balmi	20.07278	85.32583	4.02	8.32	NHS
13	HINDOL	Rasol	20.07083	85.31722	1.84		NHS
14	HINDOL	Karanda	20.07361	85.33778	1.02	5.22	NHS
15	HINDOL	Babandh	20.07528	85.42972	0.78	4.38	NHS
16	KAMAKSHAYA NAGAR	Baisingha-Ii	20.09583	85.59333	5.9	8.55	NHS
17	KAMAKSHAYA NAGAR	Alnaberini 1	20.08972	85.54028	5.2	10.3	NHS
18	KAMAKSHAYA NAGAR	Kamakyanagar-Ii	20.09833	85.54444	3.8	3.75	NHS
19	KAMAKSHAYA NAGAR	Baisingha	20.09583	85.59306	3.45	8.55	NHS
20	KAMAKSHAYA NAGAR	Kamakyanagar	20.09861	85.54917	3.3	3.49	NHS
21	KAMAKSHAYA NAGAR	Hatwari	20.09528	85.63333	3.26	5.61	NHS
22	KAMAKSHAYA NAGAR	Badasuanlo-Hatwari	20.09528	85.83667	2.7	5.5	NHS
23	KAMAKSHAYA NAGAR	Mahulpal	20.09278	85.54056	2.13	6.03	NHS
24	KANKADA HAD	Kankadahad	21.17806	85.57194	6.23	7.23	NHS

25	KANKADA HAD	Batgaon	20.10944	85.5875	2.76	5.31	NHS
26	ODAPADA	Hindol Road	20.08167	85.42444	5.5	10.6	NHS
27	ODAPADA	Motanga	20.08889	85.31194	3.89	5.5	NHS
28	ODAPADA	Motanga-Ii	20.0875	85.31389	2.45	5.5	NHS
29	ODAPADA	Dhaulpur	20.08722	85.35694	1.5	5	NHS
30	ODAPADA	Balrampur	20.06806	85.49667	0.82	1.87	NHS
31	PARAJANG	Badajhara	20.10056	85.39194	2.19	5.89	NHS
32	PARAJANG	Parjang1	20.0975	85.31806	2.09	3.79	NHS
33	PARAJANG	Singhada	20.10111	85.30694	1.5	6.05	NHS
34	PARAJANG	Kandarsingha	20.08889	85.31667	1.36	5.06	NHS
35	PARAJANG	Muktaposi	20.10028	85.4125	1.22	5.42	NHS
36	SADAR	Baldiabandh	20.06528	85.6525	5.44	6.74	NHS
37	SADAR	Gangutia	20.075	85.56167	4.57	5.22	NHS
38	SADAR	Mahulpunja	20.05833	85.47583	2.32	4.77	NHS
39	SADAR	Saptasaja	20.06222	85.59667	2.26		NHS
40	SADAR	Samacharanapur	20.0725	85.61639	2.2	6.5	NHS
41	SADAR	Kaimati	20.06694	85.67639	2.04	5.04	NHS
42	SADAR	Shankarpur	20.06694	85.545	2.01	3.86	NHS
43	SADAR	Bandhnuagaon	20.07333	85.69722	1.88	4.68	NHS
44	SADAR	Dhenkanal	20.07528	85.59889	1.54	2.24	NHS
45	SADAR	Bhapur2	20.05944	85.49306	1.3	4.5	NHS
46	ODAPADA	GOBINDAPRASAD	20.58514	85.46275	2.44	4.07	KW
47	HINDOL	KUNUAN	20.6195	85.35289	3.43	7.36	KW
48	HINDOL	DANDIRI	20.57708	85.29844	3.15	4.85	KW
49	HINDOL	PANCHAMAIL CHHAK	20.63933	85.26906	1.31	2.72	KW
50	KAMAKSHYANAGAR	JIRIDAMALI	20.93606	85.55903	3.82	4.67	KW
51	KANKADAHADA	KANTOL	21.12158	85.62761	3.15	4.71	KW
52	KANKADAHADA	BUDHIBILI	21.09697	85.60186	5.26	4.82	KW
53	KANKADAHADA	KARAGOLA	21.08769	85.44578	5.69	6.08	KW
54	KANKADAHADA	KANTAPADA	21.08014	85.54103	1.89	1.47	KW

55	KANKADAHADA	DOLIA	21.11367	85.48569	2.31	4.8	KW
56	KANKADAHADA	JARADA	21.13522	85.44008	5.12	6.28	KW
57	KANKADAHADA	BADASAHI	21.14631	85.44008	4.05	4.3	KW
58	KANKADAHADA	TORADAMALI	21.10464	85.39681	3.44	6.27	KW
59	KANKADAHADA	PANGATIRA	21.13425	85.35439	1.98	2.7	KW
60	KANKADAHADA	MAHABIROD	21.07264	85.376	3.21	5.15	KW
61	KANKADAHADA	KUTURIA	21.02669	85.36889	3.2	4.41	KW
62	KAMAKSHYANAGAR	ALUAJHARANA	20.85331	85.52083	4.88	6.07	KW
63	KAMAKSHYANAGAR	TENTULISINGHA	20.75981	85.57236	4.61	5	KW
64	KAMAKSHYANAGAR	BAHADA	20.91747	85.51181	1.86	3.25	KW
65	KAMAKSHYANAGAR	SAMATANGI	20.89722	85.49147	1.04	5.41	KW
66	KAMAKSHYANAGAR	BAUNSHAPAL	20.94469	85.51489	4.57	5.95	KW
67	PARJANG	JAIPURAKATENI	20.96675	85.4455	1.02	2.7	KW
68	PARJANG	PATHARKHAMBA	20.91961	85.44528	2.38	4.5	KW
69	PARJANG	KANAKPURA	20.90181	85.39092	3.66	6.18	KW
70	PARJANG	KANKILI	20.88192	85.43008	3.36	7.67	KW
71	PARJANG	KANKADASODA	20.96356	85.34131	2.12	4.67	KW
72	PARJANG	PARAMHANSPUR	20.96003	85.2865	2.88	6.71	KW
73	PARJANG	JHARANABAHAL	21.01069	85.28236	3.05	7.9	KW
74	KANKADAHADA	BHEJIA	21.08617	85.28569	1.55	3.75	KW
75	PARJANG	PITIRI	20.94611	85.27678	1.13	2.2	KW
76	KAMAKSHYANAGAR	SOGOR	20.76311	85.59619	6.05	6.2	KW
77	KAMAKSHYANAGAR	BALIPADA	20.84514	85.64186	1.43	1.38	KW
78	KAMAKSHYANAGAR	BARUAN	20.79269	85.58433	3.22	3.81	KW
79	KAMAKSHYANAGAR	JAKA	20.78769	85.52403	5.05	6.55	KW
80	KAMAKSHYANAGAR	TUMUSINGHA	20.79458	85.47406	1.58	5.1	KW
81	PARJANG	CHANDPUR	20.80956	85.41325	1.83	3.58	KW
82	PARJANG	SIARI MALIA	20.81794	85.39006	10.68	9.9	KW
83	KAMAKSHYANAGAR	DADHIKHAI	20.78275	85.54089	4.85	10.41	KW
84	SADAR	MAHUL PADA	20.61453	85.67686	4.82	6.19	KW

85	SADAR	REGEDA	20.55606	85.65086	5.02	6.95	KW
86	SADAR	KRUSHNAKUMARPUR	20.67069	85.70822	1.8	2.9	KW
87	GONDIA	BANIA	20.70139	85.81728	5.25	6.84	KW
88	GONDIA	SORISIAPADA	20.70772	85.85789	5.23	7.34	KW
89	GONDIA	CHATIGHARA	20.69586	85.90628	6.17	9.29	KW
90	GONDIA	JHILI	20.73164	85.76928	2.97	5.25	KW
91	GONDIA	MATHATENTULIA	20.77425	85.83814	1.08	2.6	KW
92	GONDIA	TOLARPARI	20.80031	85.94256	9.77	10.7	KW
93	BHUBAN	MAHULPALA	20.86781	85.88956	3.66	4.3	KW
94	BHUBAN	ANANTAPUR	20.93117	85.84989	3.96	4.7	KW
95	BHUBAN	SURAPRATAPPUR	20.91483	85.73578	1.68	1.8	KW
96	HINDOL	GANJARA	20.65286	85.44756	2.82	5.54	KW
97	ODAPADA	KOCHILAMARA	20.79219	85.28	3.09	1.08	KW
98	ODAPADA	KURUNTI	20.83156	85.29039	2.27	2.1	KW
99	ODAPADA	ITAPA	20.82033	85.27136	2.82	8.05	KW
100	HINDOL	SARAPA	20.78022	85.25594	1.89	2.92	KW
101	ODAPADA	PANDARAVARANIA	20.87731	85.25542	1.98	1.55	KW
102	ODAPADA	KANTABANIA	20.82861	85.25694	2.36	5.96	KW
103	HINDOL	KOTHALU	20.77169	85.295	2.89	7.23	KW
104	ODAPADA	PASSASINGHA	20.74453	85.49317	3.76	7.29	KW
105	HINDOL	BEDAPADA	20.72569	85.40414	2.12	4.24	KW
106	HINDOL	GIRIDHARI PRASAD	20.69572	85.35047	1.7	3.68	KW
107	HINDOL	KHAJURIAKATA	20.69503	85.30692	8.53	13.09	KW
108	HINDOL	DUDURKOTE	20.68675	85.26256	6.2	8.38	KW
109	SADAR	LAMBODARPUR	20.60336	85.51867	8.02	10.4	KW
110	SADAR	GAHAMAKHUNTA	20.64753	85.65992	2.86	2.68	KW
111	GONDIA	CHHATIA	20.74069	85.69117	3.71	4.5	KW
112	GONDIA	KENDUPADA	20.80975	85.69906	3.68	6.38	KW
113	GONDIA	MAKUNDAPUR	20.84169	85.74278	6.71	7.86	KW
114	GONDIA	NABALINGA	20.85739	85.80444	7.84	13.35	KW

115	GONDIA	KIRTANPUR	20.88075	85.80464	2.27	4.21	KW
116	BHUBAN	KUMURSINGHA	20.95356	85.80386	5.36	7.16	KW
117	BHUBAN	DHALAPADA	20.94925	85.78417	3.07	4.4	KW
118	BHUBAN	ODISH	20.9685	85.74728	3.77	5	KW
119	BHUBAN	JAMUNAKOT	20.89144	85.71131	5.57	5.65	KW
120	BHUBAN	MARTHAPUR	20.86742	85.71989	5.38	6.22	KW
121	BHUBAN	DIGHI	20.847	85.67681	5.78	6.4	KW
122	SADAR	GAJAMARA	20.59986	85.59803	2.98	7.9	KW

Table-2.4: Ground Water Quality Data of Monitoring Wells in Dhenkanal district.

SL NO.	Village	pH	EC	TDS	TH	Alkalinity	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	F^{-}
			µs/cm at 25°C	mg/L	mg/L as $CaCO_3$		<----------mg/L---------->								
1	Hindol1	7.65	610	302	255	185	34	41	20	3.5	0	226	61	31	0.24
2	Balmi	7.82	460	224	190	180	46	18	17	1	0	220	32	2	0.37
3	Bhapur2	7.92	520	238	185	200	30	27	30	3.9	0	244	26	2	0.27
4	Jhumpuria	7.66	580	298	235	180	22	44	20	8.2	0	220	59	38	0.29
5	Rasol	7.6	1020	487	460	105	56	78	20	2.5	0	128	221	47	0.22
6	Bhagabanpur	7.74	1350	735	450	195	28	92	100	2.8	0	238	290	105	0.43
7	Babandh	7.86	1030	500	415	230	34	80	44	2.9	0	281	159	43	0.65
8	Bompa	7.77	500	248	205	185	38	27	18	1.2	0	226	35	18	0.2
9	Balrampur	7.92	290	140	110	115	28	10	13	2.8	0	140	15	2	0.24
10	Bandhnuagaon	7.74	440	220	175	110	30	24	19	0.8	0	134	72	8	0.22
11	Joranda	7.67	230	122	70	55	24	2	18	1.6	0	67	38	5	0.22
12	Shyamchandrapur	7.81	370	177	140	105	26	18	20	1.2	0	128	32	17	0.21
13	Kaimati	7.91	540	245	205	205	24	35	28	1.1	0	250	32	2	0.81
14	Deogaon	8.23	450	231	175	205	38	19	20	3.9	0	250	20	7	0.99

15	Gondia	7.73	550	273	220	145	32	34	20	6.2	0	177	72	22	0.44
16	Sarangi	7.68	440	220	175	125	38	19	19	1.8	0	153	55	12	0.22
17	Mandar	7.63	830	425	285	200	76	23	57	4.2	0	244	130	16	0.28
18	Bhuban	7.76	510	267	210	210	62	13	20	1.2	0	256	32	13	1.6
19	Samole	8.01	440	216	175	125	28	26	18	1.9	0	153	45	23	0.38
20	Goda	7.64	160	80	65	60	20	4	5	3.2	0	73	10	3	0.18
21	Mathakaragola	7.22	140	67	60	40	20	2	2	1.9	0	49	17	0	0.13
22	Hatwari	7.58	630	306	275	240	56	33	16	2.8	0	293	43	12	0.23
23	Kankadahad	7.95	400	197	135	130	26	17	28	0.8	0	159	43	5	0.8
24	Muktaposi	7.86	1080	554	415	150	106	36	56	1.5	0	183	192	72	0.4
25	Badajhara	7.75	540	253	220	120	42	28	20	1.6	0	146	78	12	0.5
26	Parjang1	8.03	580	303	175	155	50	12	49	2.8	0	189	61	35	0.91
27	Kandarsingha	7.31	4420	2335	1945	85	497	171	118	2.9	0	104	1410	85	0.75
28	Motanga	8.3	1480	798	495	440	54	87	110	3.2	0	537	187	93	1.34
29	Dhaulpur	8.2	1300	710	465	240	110	46	83	0.8	0	293	184	142	0.67
30	Dhenkanal	8	930	466	295	200	42	46	62	25.8	0	244	146	24	1.26
31	Baldiabandh	7.41	320	155	115	95	18	17	18	1.8	0	116	43	0	0.13

Table-2.5: Ground water quality (Pre-Monsoon) data of key wells in Dhenkanal district.

Sl No	Block	Location	Lat.	Long.	pH	EC	TDS	Hardness	Alkalinity	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	F^{-}
						µs/cm at 25°C	mg/L	mg/L as $CaCO_3$		<----------mg/L---------->								
1	Odapada	Gobindaprasad	20.58514	85.46275	8.21	950	538	253	280	73	17	46	94.7	0	342	77	62	0.62
2	Hindol	Kunuan	20.6195	85.35289	7.72	1350	649	525	235	63	89	68	1.7	0	287	245	41	0.76
3	Hindol	Dandiri	20.5770	85.2984	7.6	260	129	101	95	24	10	8	5.7	0	116	20	4	0.1

			8	4	1													6
4	Hindol	Panchamail chhak	20.63933	85.26906	7.92	810	384	253	290	32	42	67	2.2	0	354	35	32	0.81
5	Kamakshyanagar	Jiridamali	20.93606	85.55903	7.55	170	80	66	60	14	8	7	0.4	0	73	15	0	0.08
6	Kankadahada	Kantol	21.12158	85.62761	6.91	250	128	96	89	22	10	5	11.3	0	109	12	14	0.18
7	Kankadahada	Budhibili	21.09697	85.60186	6.98	140	64	56	60	6	10	4	1.4	0	73	5	2	0.09
8	Kankadahada	Karagola	21.08769	85.44578	6.86	160	77	61	65	8	10	3	6.9	0	79	10	0	0.09
9	Kankadahada	Kantapada	21.08014	85.54103	6.99	160	78	60	65	16	5	6	1.9	0	79	10	0	0.08
10	Kankadahada	Dolia	21.11367	85.48569	8.06	740	374	258	210	55	29	24	44.3	0	256	67	29	0.02
11	Kankadahada	Jarada	21.13522	85.44008	7.81	290	145	111	108	20	15	6	15	0	132	22	2	0.11
12	Kankadahada	Badasahi	21.14631	85.44008	7.8	190	93	71	60	14	9	7	5.6	0	73	22	0	0.08
13	Kankadahada	Toradamali	21.10464	85.39681	7.3	190	96	65	70	22	2	10	4.1	0	85	15	1	0.09
14	Kankadahada	Pangatira	21.13425	85.35439	7.45	740	396	237	160	55	24	29	52	0	195	100	40	0.19
15	Kankadahada	Mahabirod	21.07264	85.376	8.03	210	101	91	70	16	12	5	0.9	0	85	25	0	0.06
16	Kankadahada	Kuturia	21.02669	85.36889	7.44	370	194	132	115	40	8	14	13.2	0	140	30	20	0.02
17	Kamakshyanagar	Aluajharana	20.85331	85.52083	7.58	250	123	91	84	14	14	11	5.5	0	103	27	1	0.08
18	Kamakshyanagar	Tentulisingha	20.75981	85.57236	7.76	740	371	283	266	55	35	36	7.8	0	324	67	11	0.24
19	Kamakshyanagar	Bahada	20.91747	85.51181	7.99	1340	687	449	355	36	87	85	27.6	0	433	165	74	0.65
20	Kamakshyanagar	Samatangi	20.89722	85.49147	7.85	190	97	66	63	18	5	10	4.8	0	77	17	4	0.16
21	Kamakshyanagar	Baunshapal	20.94469	85.51489	8.1	460	220	182	165	40	20	19	1.2	0	201	32	9	0.32

22	Parjang	Jaipurakateni	20.96675	85.4455	8.12	910	495	303	284	59	38	40	48.5	0	346	85	55	0.25
23	Parjang	Patharkhamba	20.91961	85.44528	7.79	940	491	323	302	51	48	38	45.6	0	369	80	47	0.49
24	Parjang	Kanakpura	20.90181	85.39092	7.81	1110	554	475	220	79	67	34	3.4	0	268	215	24	0.34
25	Parjang	Kankili	20.88192	85.43008	8.11	340	177	101	111	28	8	30	1.2	0	135	32	11	1.05
26	Parjang	Kankadasoda	20.96356	85.34131	7.92	740	380	208	280	45	23	72	1.5	0	342	37	33	1.03
27	Parjang	Paramhanspur	20.96003	85.2865	8.23	680	345	268	165	59	29	29	5.3	0	201	95	29	0.29
28	Parjang	Jharanabahal	21.01069	85.28236	8.28	830	462	278	250	81	18	33	51.5	0	305	85	44	0.46
29	Kankadahada	Bhejia	21.08617	85.28569	7.58	210	107	81	85	32	0	8	5.9	0	104	10	0	0.18
30	Parjang	Pitiri	20.94611	85.27678	7.82	460	228	167	163	40	16	24	6.2	0	199	42	2	0.36
31	Kamakshyanagar	Sogor	20.76311	85.59619	7.65	610	344	167	148	38	17	39	40.2	0	181	95	26	0.11
32	Kamakshyanagar	Balipada	20.84514	85.64186	7.45	160	71	66	50	12	9	5	0.5	0	61	15	0	0.07
33	Kamakshyanagar	Baruan	20.79269	85.58433	7.02	270	141	101	120	24	10	7	11.1	0	146	12	5	0.13
34	Kamakshyanagar	Jaka	20.78769	85.52403	7.21	200	95	81	80	18	9	4	4.2	0	98	12	0	0.08
35	Kamakshyanagar	Tumusingha	20.79458	85.47406	7.81	1190	598	480	205	93	60	51	3.2	0	250	195	73	0.71
36	Parjang	Chandpur	20.80956	85.41325	8.19	1710	854	571	405	59	103	119	16.2	0	494	232	82	0.85
37	Parjang	Siari malia	20.81794	85.39006	7.82	470	247	182	152	43	18	18	7.9	0	185	62	7	0.17
38	Kamakshyanagar	Dadhikhai	20.78275	85.54089	7.65	140	70	61	60	16	5	3	0.6	0	73	10	0	0.07
39	Sadar	Mahul pada	20.61453	85.67686	6.96	190	89	81	79	14	11	4	2.6	0	97	10	0	0.08
40	Sadar	Regeda	20.5560	85.6508	7.4	240	115	91	75	18	11	7	9.6	0	92	20	4	0.0

			6	6	4													8
41	Sadar	Krushnakumarpur	20.67069	85.70822	7.17	210	111	62	53	20	3	13	7.8	0	65	22	13	0.13
42	Gondia	Bania	20.70139	85.81728	7.08	220	101	86	86	12	14	7	3.7	0	105	12	1	0.08
43	Gondia	Sorisiapada	20.70772	85.85789	6.8	190	87	82	84	12	13	4	0.8	0	102	7	0	0.05
44	Gondia	Chatighara	20.69586	85.90628	7.42	370	197	133	148	33	12	11	22.5	0	180	22	8	0.13
45	Gondia	Jhili	20.73164	85.76928	7.52	1050	534	419	208	65	62	47	1.8	0	254	212	22	0.19
46	Gondia	Mathatentulia	20.77425	85.83814	7.25	210	94	84	74	12	13	7	1.8	0	90	15	1	0.06
47	Gondia	Tolarpari	20.80031	85.94256	7.62	350	168	149	138	39	13	7	3	0	168	17	7	0.12
48	Bhuban	Mahulpala	20.86781	85.88956	8.01	440	246	117	181	30	10	28	31.4	0	221	22	16	0.69
49	Bhuban	Anantapur	20.93117	85.84989	7.32	320	171	101	84	19	13	21	9.3	0	102	55	4	0.06
50	Bhuban	Surapratappur	20.91483	85.73578	7.17	100	47	40	43	7	5	4	0.4	0	52	5	0	0.06
51	Hindol	Ganjara	20.65286	85.44756	7.24	180	86	66	59	8	11	8	4.9	0	72	15	4	0.07
52	Odapada	Kochilamara	20.79219	85.28	7.65	910	483	262	272	48	35	87	0.7	0	332	75	74	0.89
53	Odapada	Kurunti	20.83156	85.29039	7.82	930	496	307	261	51	44	70	2.8	0	318	117	54	0.9
54	Odapada	Itapa	20.82033	85.27136	8.23	1390	758	327	405	65	40	166	4.9	0	494	165	74	1.49
55	Hindol	Sarapa	20.78022	85.25594	8.15	570	279	203	229	26	34	35	2	0	279	17	27	1.2
56	Odapada	Pandaravarania	20.87731	85.25542	7.98	600	300	215	213	27	36	36	1.2	0	260	25	46	1.2
57	Odapada	Kantabania	20.82861	85.25694	8.07	940	503	281	234	65	29	85	2	0	285	120	62	0.8
58	Hindol	Kothalu	20.77169	85.295	7.84	350	172	151	133	30	18	10	0.7	0	162	17	17	0.2

59	Odapada	Passasingha	20.74453	85.49317	8.22	980	478	345	383	21	71	66	0.6	0	467	57	32	1.56
60	Hindol	Bedapada	20.72569	85.40414	7.67	930	450	375	288	27	75	39	1.8	0	351	102	32	1.2
61	Hindol	Giridhari prasad	20.69572	85.35047	7.85	1690	882	500	501	84	70	146	19.4	0	611	200	63	0.23
62	Hindol	Khajuriakata	20.69503	85.30692	7.62	460	228	201	80	29	31	12	1.4	0	98	100	6	0.14
63	Hindol	Dudurkote	20.68675	85.26256	8.03	690	356	277	144	50	37	26	5.4	0	176	122	29	0.14
64	Sadar	Lambodarpur	20.60336	85.51867	8.14	190	91	73	64	8	13	8	3	0	78	20	1	0.12
65	Sadar	Gahamakhunta	20.64753	85.65992	7.78	200	104	69	59	8	12	7	10.2	0	72	20	11	0.09
66	Gondia	Chhatia	20.74069	85.69117	7.89	180	91	65	64	13	8	6	5.9	0	78	10	10	0.07
67	Gondia	Kendupada	20.80975	85.69906	7.37	470	261	138	69	19	22	25	32.9	0	84	100	21	0.06
68	Gondia	Makundapur	20.84169	85.74278	7.72	620	338	211	122	18	40	33	20.5	0	149	77	76	0.05
69	Gondia	Nabalinga	20.85739	85.80444	7.92	360	170	149	160	33	16	12	1.5	0	195	12	0	0.13
70	Gondia	Kirtanpur	20.88075	85.80464	6.76	330	167	117	107	12	21	14	11.2	0	131	27	17	0.18
71	Bhuban	Kumursingha	20.95356	85.80386	7.14	100	47	32	37	7	4	5	1.8	0	45	7	0	0.32
72	Bhuban	Dhalapada	20.94925	85.78417	7.2	170	89	42	32	6	7	15	5.5	0	39	35	1	0.08
73	Bhuban	Odish	20.9685	85.74728	8.16	1190	666	365	309	56	55	42	104.4	0	377	135	89	0.06
74	Bhuban	Jamunakot	20.89144	85.71131	8.01	610	336	205	133	46	22	22	36.5	0	162	77	53	0.26
75	Bhuban	Marthapur	20.86742	85.71989	7.86	790	521	90	170	19	10	67	123.5	0	207	112	88	0.13
76	Bhuban	Dighi	20.847	85.67681	7.66	220	109	68	64	18	6	14	4.6	0	78	22	6	0.11
77	Sadar	Gajamara	20.5998	85.5980	7.6	240	120	87	85	20	9	8	9.8	0	104	20	2	0.0

			6	3	8													9

Table-2.6: Ground water quality (post-monsoon) data of key wells in Dhenkanal district.

Sl. No.	Block	Location	pH	EC	TDS	Hardness	Alkalinity	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	F^{-}
				µs/cm at 25°C	mg/L	mg/L as $CaCO_3$		<----------mg/L---------->								
1	Odapada	Gobindaprasad	7.96	1240	677	286	458	29	51	52	172.8	0	500	76	51	0.38
2	Hindol	Kunuan	8.09	1710	807	658	252	14	148	95	2.3	0	275	366	46	0.69
3	Hindol	Dandiri	8.3	340	169	122	129	18	18	12	17.3	0	141	24	10	0.19
4	Hindol	Panchamail chhak	8.3	760	383	235	366	16	46	67	3.6	0	399	29	25	0.85
5	Kamakshyanagar	Jiridamali	7.94	90	46	26	21	8	1	8	0.5	0	22	17	0	0.86
6	Kankadahada	Kantol	8.1	240	120	87	82	20	9	8	10	0	90	19	10	0.11
7	Kankadahada	Budhibili	7.8	190	87	82	72	8	15	4	0.9	0	79	17	3	0.1
8	Kankadahada	Karagola	7.61	80	44	20	15	6	1	3	8.8	0	17	14	3	0.09
9	Kankadahada	Kantapada	7.65	80	44	20	21	6	1	7	3.8	0	22	12	3	0.08
10	Kankadahada	Dolia	8.22	250	140	87	36	22	7	11	11.8	0	39	57	12	0.15
11	Kankadahada	Jarada	8.04	200	111	66	57	18	5	9	10.5	0	62	33	5	0.12
12	Kankadahada	Badasahi	7.83	170	90	46	57	14	2	11	11.7	0	62	17	4	0.09
13	Kankadahada	Toradamali	7.78	140	74	41	46	10	4	10	4.6	0	51	17	3	0.8
14	Kankadahada	Pangatira	8.3	750	412	189	237	25	30	38	82.8	0	259	76	33	0.23
15	Kankadahada	Mahabirod	7.41	140	65	51	52	12	5	7	1.1	0	56	12	0	0.06
16	Kankadahada	Kuturia	8.3	370	191	117	67	6	24	17	23.5	0	73	67	17	0.29
17	Kamakshyanagar	Aluajharana	7.7	240	120	71	103	12	10	15	9.4	0	112	14	5	0.08
18	Kamakshyanagar	Tentulisingha	8.3	580	282	189	155	10	39	43	7.8	0	169	86	13	0.31
19	Kamakshyanagar	Bahada	8.25	1620	809	449	458	10	101	137	55.3	0	500	195	65	0.61
20	Kamakshyanagar	Samatangi	8.29	250	138	66	88	20	4	13	22.2	0	96	21	10	0.35

21	Kamakshyanagar	Baunshapal	8.3	530	249	163	221	12	32	46	2	0	242	24	14	0.69
22	Parjang	Jaipurakateni	8.3	730	406	204	206	14	40	38	64.5	0	225	76	63	0.33
23	Parjang	Patharkhamba	8.3	830	451	224	299	12	46	44	77.5	0	326	81	30	0.42
24	Parjang	Kanakpura	7.91	4140	2050	1490	530	147	267	268	15.5	0	579	994	75	0.19
25	Parjang	Kankili	8.25	400	235	143	98	41	10	2	40	0	107	64	25	0.87
26	Parjang	Kankadasoda	8.3	770	426	265	335	10	57	4	88.5	0	365	55	32	0.85
27	Parjang	Paramhanspur	8.3	670	355	209	180	18	39	23	60	0	197	95	23	0.26
28	Parjang	Jharanabahal	8.3	650	347	102	263	18	13	78	44.3	0	287	43	10	0.45
29	Kankadahada	Bhejia	8.29	240	125	102	98	31	6	2	9	0	107	19	5	0.22
30	Parjang	Pitiri	8.3	410	220	153	155	18	26	6	29.5	0	169	36	21	0.3
31	Kamakshyanagar	Sogor	8.06	650	355	128	165	25	16	67	37.7	0	180	107	14	0.11
32	Kamakshyanagar	Balipada	7.43	90	44	31	36	10	1	5	0.5	0	39	7	1	0.06
33	Kamakshyanagar	Baruan	7.95	170	99	41	67	8	5	9	17.2	0	73	12	12	0.2
34	Kamakshyanagar	Jaka	7.82	160	94	31	62	8	2	6	29.8	0	67	14	1	0.01
35	Kamakshyanagar	Tumusingha	8.15	1710	825	566	366	31	117	127	13.6	0	399	290	50	0.65
36	Parjang	Chandpur	8.3	1600	784	439	520	41	80	158	17.3	0	568	147	62	0.85
37	Parjang	Siari malia	8.05	440	224	138	113	20	21	25	20.5	0	124	69	8	0.17
38	Kamakshyanagar	Dadhikhai	7.4	240	121	82	82	14	11	14	6.3	0	90	31	1	0.07
39	Sadar	Mahul pada	7.79	100	51	31	36	6	4	5	3.7	0	39	10	3	0.1
40	Sadar	Regeda	8.22	300	150	102	98	12	17	13	16.4	0	107	31	8	0.15
41	Sadar	Krushnakumarpur	7.95	170	89	46	52	10	5	10	11.1	0	56	17	8	0.21
42	Gondia	Bania	7.88	140	75	46	46	8	6	9	3.8	0	51	19	4	0.11
43	Gondia	Sorisiapada	7.44	80	40	31	31	10	1	4	1.1	0	34	7	0	0.05
44	Gondia	Chatighara	7.7	130	72	31	41	8	2	6	15.6	0	45	14	4	0.08
45	Gondia	Jhili	8.3	1530	783	449	376	37	85	140	10.9	0	410	264	45	0.5
46	Gondia	Mathatentulia	7.95	220	113	66	46	10	10	16	5.2	0	51	38	9	0.09
47	Gondia	Tolarpari	7.9	240	115	97	98	14	15	8	2	0	107	19	4	0.18
48	Bhuban	Mahulpala	7.5	1860	996	464	551	88	58	128	150.5	0	602	212	64	0.45
49	Bhuban	Anantapur	7.71	240	131	61	77	8	10	21	10.3	0	84	33	7	0.09
50	Bhuban	Surapratappur	7.8	70	31	26	31	8	1	3	0.5	0	34	2	0	0.08

51	Hindol	Ganjara	8.03	180	91	56	67	18	2	12	6.6	0	73	14	3	0.12
52	Odapada	Kochilamara	8.3	1070	547	235	402	31	38	137	1.6	0	439	64	59	0.89
53	Odapada	Kurunti	8.3	860	433	240	216	8	52	87	2.3	0	236	126	41	0.99
54	Odapada	Itapa	8.3	1360	733	184	474	16	34	224	7	0	517	136	61	1.25
55	Hindol	Sarapa	8.3	1490	702	622	716	94	92	43	29.3	0	781	52	9	0.22
56	Odapada	Pandaravarania	7.54	490	234	163	201	29	22	35	1.4	0	219	17	21	1.06
57	Odapada	Kantabania	8.3	850	425	214	258	22	38	96	2.6	0	281	90	38	0.84
58	Hindol	Kothalu	8.3	380	177	153	160	27	21	15	0.9	0	174	14	14	0.33
59	Odapada	Passasingha	8.3	1630	814	291	577	35	49	239	1.1	0	630	138	41	2.03
60	Hindol	Bedapada	8.3	890	425	306	314	35	52	65	1.7	0	343	69	33	1.04
61	Hindol	Giridhari prasad	8.3	1920	997	393	587	41	69	214	84.3	0	641	216	57	1.23
62	Hindol	Khajuriakata	8.25	480	245	158	134	39	15	34	2.5	0	146	71	12	0.32
63	Hindol	Dudurkote	8.11	1070	537	378	278	76	45	57	25.7	0	304	155	29	0.24
64	Sadar	Lambodarpur	8	330	165	117	93	25	13	19	4.9	0	101	50	3	0.13
65	Sadar	Gahamakhunta	7.27	200	102	51	67	14	4	15	9.4	0	73	19	5	0.13
66	Gondia	Chhatia	7.45	140	72	41	57	14	1	9	5	0	62	7	5	0.13
67	Gondia	Kendupada	7.57	520	294	148	129	41	11	36	25	0	141	90	22	0.37
68	Gondia	Makundapur	7.59	860	440	270	211	57	30	59	24.8	0	231	117	39	0.26
69	Gondia	Nabalinga	7.97	270	135	87	124	22	7	20	3.5	0	135	14	2	0.22
70	Gondia	Kirtanpur	7.86	750	373	265	263	55	30	48	5	0	287	69	25	0.67
71	Bhuban	Kumursingha	7.39	130	66	36	46	8	4	10	2.6	0	51	14	2	0.11
72	Bhuban	Dhalapada	7.17	160	90	31	31	8	2	20	4.8	0	34	36	2	0.28
73	Bhuban	Odish	7.99	990	554	245	299	51	28	57	96.8	0	326	128	33	0.33
74	Bhuban	Jamunakot	7.84	730	404	235	216	51	26	30	50	0	236	95	36	0.17
75	Bhuban	Marthapur	7.93	830	482	179	242	43	17	74	56.3	0	264	102	60	0.15
76	Bhuban	Dighi	7.53	450	224	138	113	29	16	35	5	0	124	74	4	0.22
77	Sadar	Gajamara	7.1	150	77	46	52	8	6	10	5	0	56	19	1	0.08

Table-2.7: Ground water quality (heavy metals-pre-monsoon) data of key wells in Dhenkanal district.

Sl No	Block	Village	Source	Lat Decimal	Long Decimal	F^-	Cu mg/L	Fe mg/L	Mn mg/L	Zn mg/L	Cd mg/L	Pb mg/L	As mg/L
1	Odapada	Near railway bridge	PZ	20.81539	85.26433	0.681	0	0.142	0	0.044	0	0	BDL
2	Odapada	Etp	ETP WATER	20.81117	85.25456	0.742	0	0.294	0.069	0.17	0	0	BDL
3	Odapada	Reservoir	RIVER WATER	20.81214	85.25492	0.202	0	1.284	0.022	0.122	0	0	BDL
4	Odapada	Near gate no-10	HP	20.81092	85.26258	0.678	0.009	0.531	0.271	0.131	0.0034	0	0.008
5	Odapada	Waste water reservoir	4-WASTE WATER	20.81431	85.28828	0.850	0	0.139	0.273	0.172	0.0038	0	BDL
6	Odapada	Etp/stp-outlet	ETP WATER	20.86803	85.26925	0.869	0.006	5.004	0.222	0.163	0	0	BDL
7	Odapada	Bw-4	HP	20.85972	85.26517	3.260	0	0.163	0.008	1.503	0	0.026	BDL
8	Odapada	Handpump-1,near boundary	HP	20.85731	85.25933	0.598	0	0.175	0	0.702	0	0	BDL
9	Odapada	Handpump-2,near simplex office	HP	20.86594	85.25797	4.420	0	0.233	0	1.244	0	0.044	BDL
10	Odapada	Handpump-3,near raxa barrack	HP	20.8715	85.26214	0.282	0.042	2.28	0	1.092	0	0.062	BDL
11	Odapada	Maniabeda	POND WATER	20.871	85.27667	0.978	0.228	1.331	0.397	0.02	0	0	BDL
12	Odapada	Kalia taila	HP	20.87708	85.28236	0.611	0.01	0.526	0.084	0.161	0.0046	0	BDL
13	Odapada	Barasahi	DW	20.87397	85.28389	0.164	0	0.377	0.031	0.09	0	0	BDL
14	Odapada	Pandaravarania	DW	20.87731	85.25542	0.648	0.016	1.062	0.041	2.258	0	0	BDL
15	Odapada	Pandaravarania	HP	20.87711	85.256	0.753	0	0.056	0	0.041	0	0	BDL
16	Odapada	Maniabeda	STREAM WATER	20.86525	85.27472	0.988	0	0.205	0.022	0.049	0	0	0.003
17	Odapa	Manpur	DW	20.84628	85.27522	1.060	0	0.146	0	0.01	0	0	BDL

	da												
18	Odapada	Manpur	HP	20.84825	85.27511	0.856	0	0.789	0	0.169	0.0038	0	BDL
19	Odapada	Kantabania	DW	20.82861	85.25694	0.728	0	0.134	0	0.048	0	0	0.003
20	Odapada	Kantabania	HP	20.82864	85.25697	0.548	0	0.588	0.032	0.078	0	0	BDL
21	Odapada	Near gas plant	STREAM WATER	20.81869	85.28642	2.170	0	0.184	0.105	0.032	0	0	0.002
22	Odapada	Kurunti	RIVER WATER	20.81972	85.28172	23.900	0.015	0.561	0.835	0.061	0	0	BDL
23	Odapada	Kurunti	DW	20.83156	85.29039	0.700	0	0.155	0	0.058	0	0	BDL
24	Odapada	Kurunti	HP	20.8315	85.29028	0.785	0	1.557	0.064	0.082	0	0	BDL
25	Odapada	Badalo	DW	20.73928	85.36369	1.140	0	1.201	0.086	0.069	0	0	BDL
26	Odapada	Badalo	HP	20.73931	85.36386	1.550	0	0.181	0.053	0.136	0	0	BDL
27	Odapada	Nimidha	DW	20.76094	85.33947	0.374	0	0.419	0.012	0.116	0	0	BDL
28	Odapada	Nimidha	HP	20.76444	85.33867	0.245	0.031	14.844	0.246	0.64	0	0	BDL
29	Hindol	Khaliberana	DW	20.78225	85.23972	0.615	0	0.059	0.017	0.054	0.0038	0	BDL
30	Hindol	Khaliberana	HP	20.78347	85.23819	0.925	0	0.72	0.033	0.123	0.004	0	BDL
31	Hindol	Sarapa	DW	20.78022	85.25594	0.497	0	0.209	0.011	0.054	0.004	0	BDL
32	Hindol	Sarapa	HP	20.78011	85.25622	0.520	0.012	1.537	0.062	0.872	0.0046	0	BDL
33	Hindol	Raghunathpur	SW	20.777	85.26236	0.463	0	2.702	0.238	0.031	0	0	BDL
34	Hindol	Balisahi-nuagaon	SW	20.78108	85.26917	6.390	0	0.469	0.293	0.183	0	0	BDL
35	Hindol	Nuagaon	DW	20.78547	85.27364	2.010	0	0.049	0	0.02	0.004	0	BDL
36	Hindol	Nuagaon-talasahi	HP	20.78533	85.27372	1.440	0.008	0.596	0.023	0.101	0	0	BDL
37	Hindol	Shivpur	SW	20.80375	85.27117	0.461	0	0.068	0.023	0.016	0	0	BDL
38	Hindol	Shivpur	DW	20.80447	85.27183	0.680	0	0.35	0.532	0.042	0	0	0.007

39	Hindol	Shivpur	HP	20.80461	85.27169	0.801	0.011	0.463	0.022	0.044	0	0	BDL
40	Odapada	Ashanbani	DW	20.82033	85.27136	1.120	0	0.689	0.185	0.062	0	0	BDL
41	Odapada	Ashanbani	HP	20.82039	85.27153	0.880	0	1.395	0	1.164	0	0	BDL
42	Odapada	Kurunti	SW	20.81853	85.27975	5.140	0	0.719	0	0.124	0	0	0.004
43	Odapada	Charadagadia	DW	20.79608	85.28478	1.170	0	0.18	0	0.039	0	0	0.004
44	Odapada	Charadagadia	HP	20.79642	85.28469	1.510	0.009	0.128	0	0.972	0	0	0.003
45	Odapada	Kochilamara	DW	20.79219	85.28	1.130	0	0.071	0.019	0.102	0	0	0.003
46	Odapada	Kochilamara	HP	20.79169	85.27983	0.880	0.009	0.344	0.078	0.297	0	0	BDL
47	Odapada	Khadagprasad	DW	20.82153	85.31542	0.365	0	0.175	0.013	0.198	0	0	BDL
48	Odapada	Khadagprasad	HP	20.82164	85.31486	0.377	0.076	7.692	1.059	47.4	0	0	BDL
49	Odapada	Meramundali	DW	20.80244	85.31039	0.684	0	0.102	0.021	0.094	0	0	BDL
50	Odapada	Meramundali	HP	20.80236	85.30939	1.560	0	1.085	0.126	11.48	0	0	BDL
51	Odapada	Meramundali	SW	20.79172	85.31028	0.739	0.008	3.308	0.159	0.197	0	0	BDL
52	Hindol	Kothalu	DW	20.77169	85.295	0.471	0	0.133	0	0.093	0	0	BDL
53	Hindol	Galapada	HP	20.77511	85.29311	0.400	0.015	1.43	0.295	0.13	0	0	BDL
54	Odapada	Narendrapur	DW	20.82472	85.25892	0.714	0	0.129	0	0.145	0	0	BDL
55	Odapada	Narendrapur	HP	20.82531	85.25917	1.600	0	0.489	0	0.273	0	0	0.001

Table-2.8: Ground water quality (heavy metals-post-monsoon) data of key wells in Dhenkanal district.

Sl	Block	Village	Source	Lat Decimal	Long Decimal	Cu mg/L	Fe mg/L	Mn mg/L	Zn mg/L	Cd mg/L	Pb mg/L	As mg/L

No												
1	Odapada	Pz-4	HP	20.85972222	85.26516667	BDL	7.526	0.081	2.93	BDL	0.088	BDL
2	Odapada	Handpump-1,Near Boundary	HP	20.85730556	85.25933333	0.131	0.7488	0.083	2.112	BDL	0.071	BDL
3	Odapada	Handpump-2,Near Simplex Office	HP	20.86594444	85.25797222	BDL	1.7184	0.073	2.232	BDL	BDL	BDL
4	Odapada	Handpump-3,Near Raxa Barrack	HP	20.8715	85.26213889	BDL	0.1614	0.08	1.308	0.003	BDL	BDL
5	Odapada	Manpur	DW	20.84627778	85.27522222	BDL	0.329	0.054	1.068	BDL	BDL	BDL
6	Odapada	Manpur	HP	20.84825	85.27511111	BDL	0.2954	BDL	0.648	0.004	BDL	BDL
7	Odapada	Kurunti	RIVER WATER	20.81972222	85.28172222	BDL	0.7278	0.062	0.134	BDL	BDL	BDL
8	Odapada	Badalo	DW	20.73927778	85.36369444	BDL	0.1216	BDL	BDL	0.003	BDL	BDL
9	Odapada	Badalo	HP	20.73930556	85.36386111	BDL	0.131	0.269	BDL	0.005	0.066	BDL
10	Odapada	Charadagadia	DW	20.79608333	85.28477778	BDL	0.3236	BDL	0.417	0.006	BDL	BDL
11	Odapada	Charadagadia	HP	20.79641667	85.28469444	BDL	0.0794	BDL	BDL	0.004	BDL	BDL
12	Odapada	Meramundali	HP	20.80236111	85.30938889	BDL	0.1478	BDL	0.161	BDL	BDL	BDL

Table-2.9: Ground water quality data of exploratory wells in Dhenkanal district.

SL. NO	Location	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F
1	Govindapur	7.8	900	458	295	295	36	50	66	6.6	0	360	78	41	0.38
2	Kantio Putasahi	6.85	1900	1039	430	135	58	69	233.5	5.8	0	165	518	72	0.19
3	Chulia	7.89	870	490	160	230	36	17	123.8	4.1	0	281	131	37	0.58
4	Chulia	8.08	920	506	185	245	44	18	124.6	3.7	0	299	128	37	0.5

5	Kharchuli	7.68	700	326	230	265	30	37.665	45.7	0.1	0	323	43	8	0.51
6	Nabakishnanpur	7.48	850	419	330	190	48	51.03	44	0.2	0	232	138	21	0.49
7	Giridhari Prasad	8.09	570	274	255	240	48	32.805	13.4	0.2	0	293	21	12	0.32
8	Giridhari Prasad	7.68	630	311	290	245	62	32.805	19.4	0.1	0	299	32	15	0.345
9	Satamile	8.14	350	173	165	150	48	10.935	4.5	0.6	0	183	14	3	0.78
10	Babandha	7.41	330	162	135	95	28	15.795	11.3	0.2	0	116	46	2	0.33
11	Bangurusingha	7.82	480	231	200	175	26	32.805	16.9	0.6	0	214	36	11	0.47
12	Bangurusingha	7.71	480	239	160	150	28	21.87	35.4	0.1	0	183	36	25	1.32
13	Meramunduli	7.75	400	207	170	135	36	19.44	13.9	0.2	0	165	32	23	0.25
14	Gangariya	7.96	900	477	255	205	44	35.235	85.5	0.5	0	250	117	70	0.19
15	Giridhari Prasad	6.91	540	263	235	30	39	16.2	0.1	0	226	50	14.5	0.33	0.546
16	Bdajhara	7.9	1070	552	465	110	46	29.6	1	0	256	213	23.5	0.44	0.317
17	Banguru Singh	7.72	680	359	200	44	22	63.3	0.8	0	275	57	33	1.06	0.24
18	Badagharia	7.35	1200	635	575	174	34	23	3	0	275	238	24.8	0.23	0.25
19	Mahabirod	7.38	230	118	120	114	28	12	0	0	0	139	10	0	0.26
20	Toradanali	8.47	650	295	254	269	28	45	26	8	13	301	22	5	0.05
21	Gadapalasuni	7.92	450	226	128	196	22	17	36	8	0	214	24	5	1.04
22	Jarada	8.53	540	237	215	238	46	24	0	0	15	260	12	3	0.32
23	Mahabirod	7.55	380	174	167	146	36	18	9.39	1.87	0	178	21	0.2	0.05
24	Toradanali	7.65	540	258	230	241	51	25	17	1.2	0	294	17	3	0.06
25	Sanda	7.38	230	118	120	225	28	12	0	0	0	139	10	0	0.05

3 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Shallow Aquifer

Ground water occurs in phreatic condition in shallow aquifers and is utilized by means of dug wells or shallow tube wells. The depth of the dug wells used as observation points vary from 4.5 to 11.25 mbgl and their diameter ranges from 0.8 m to 4.60 m. The wells are generally lined to the total depth.

3.1.1 Pre-monsoon Depth to Water Level

A perusal of the water table data for the year 2018-19 indicates that the depth to water level in the district ranges from 4.1 to 9.98 m below ground level during pre-monsoon period and from 1.19 to 6.99 m below ground level during post monsoon period respectively. It is observed that during the premonsoon period the depth to water table values are more than 6m in nearly fifty two percent of the NHS station. Baulpur, Dhenkanal, Saptasaja, Shankarpur are the area where water level is below 4m during premonsoon period .In post monsoon period water level is generally found below 4m in most parts of the district. Areas like Kankadahad, Joranda, Baisingha and Lambodarpur have water level more than 6 m below ground level during post monsoon period.

The pre-monsoon depth to water level map is shown in **Fig. 3.1**.

3.1.2 Post-monsoon Depth to Water Level

Depth to water level in post-monsoon period (Nov 2018) varies from 0.45 mbgl (Dholpur) to 6.73 (Tileswar) mbgl, the average being 2.80 m bgl. The depth to water level of the study area during Nov 2018 is in general within 3 mbgl. The areas around Dhenkanal on bank of Mahanadi and the valley fill areas between the highway and Salki river show shallow water level of less than 3.0 mbgl. In Harbhanga block, the valley areas within Charichhak, harbhanga and Kusang have shallow water level of less than 3 mbgl. Southern parts of Dhenkanal block, mainly the medium high land areas south of Dhenkanal canal, Eastern parts of Kantamal block and one or two patches in Harbhanga block show relatively deeper water level of 3 to 6 mbgl. The locations where the depth to water level is more than 4.5 m bgl are Kusang (4.66), Tileswar (6.6 & 6.73) in Harbhanga block and Jaimumal (4.5) and Dopla (4.95 mbgl) in Kantamal block. The post-monsoon depth to water level map is shown below in **Fig. 3.2**.

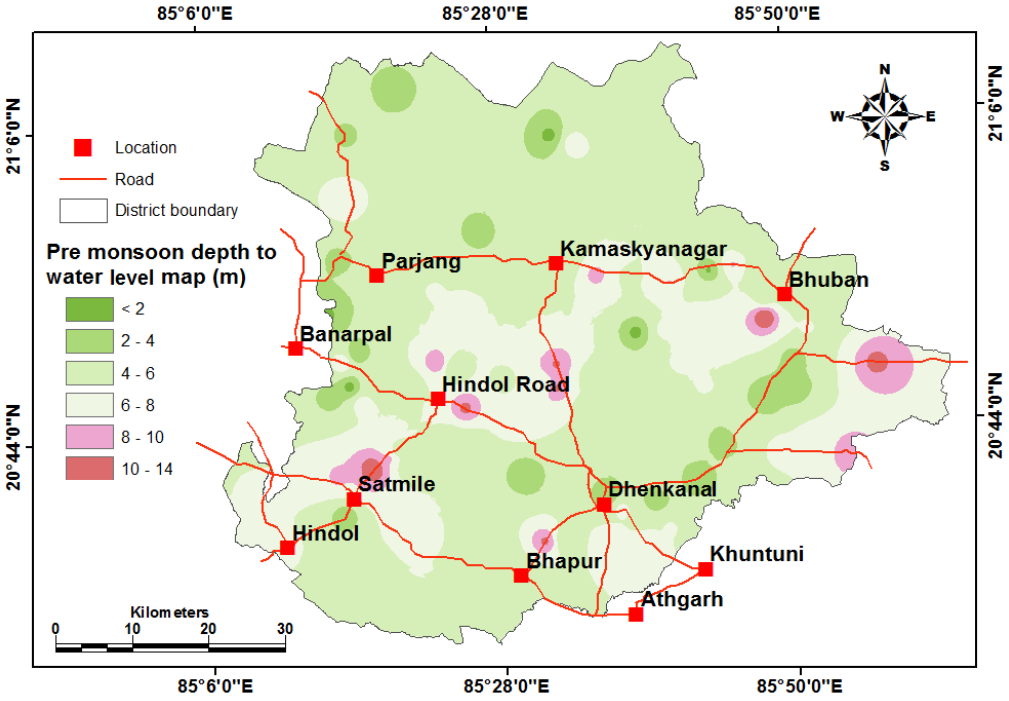


Fig. 3.1: Depth to water level in phreatic aquifer during pre-monsoon.

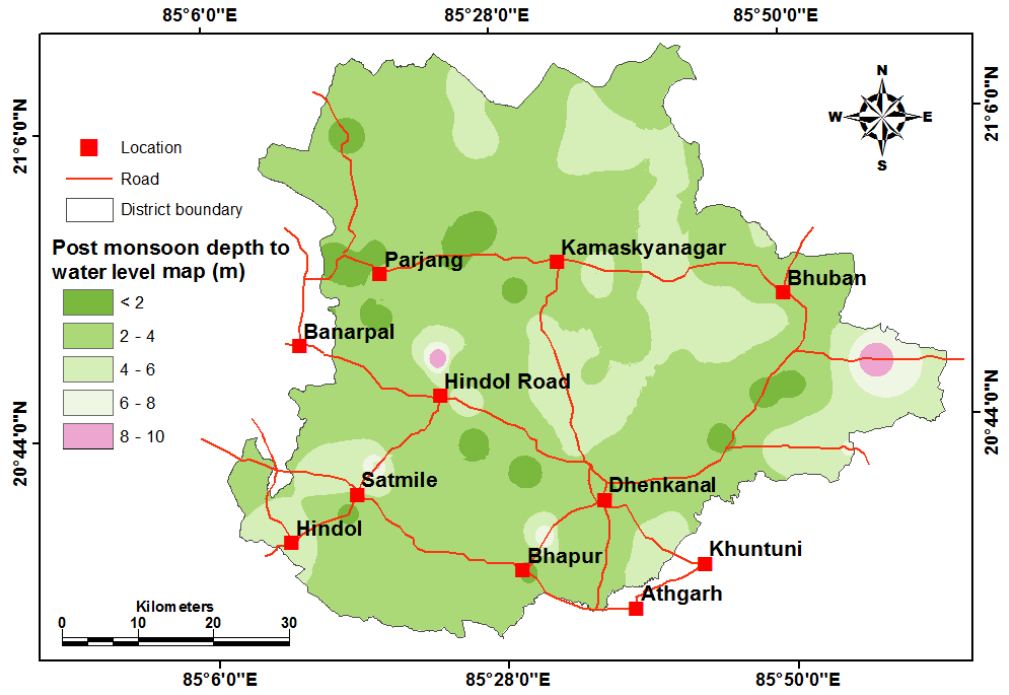


Fig. 3.2: Depth to water level in phreatic aquifer during post-monsoon.

3.1.3 Seasonal Fluctuation of Water Level

The seasonal fluctuation of water table has been depicted in plate-6. A study of the map reveals that in the major parts of the district fluctuation of the water table is in the range of 2 m to 4 m. Some areas like Kankadahad, saptasaja; Lambodarpur, Baulpur and Kaimati have fluctuation less than 2m. Long-term hydrographs of monitoring stations (15 nos.) in the district for which continuous data are available .

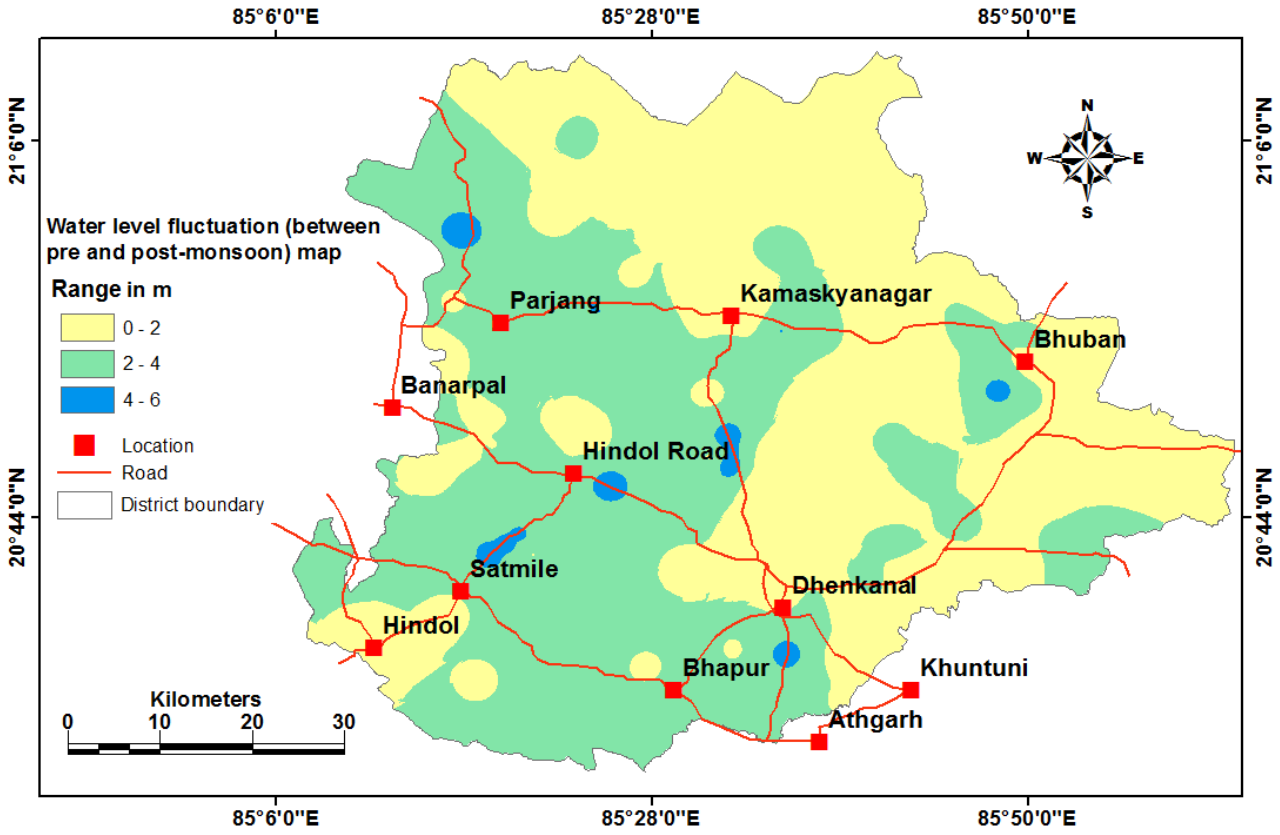


Fig. 3.3: Seasonal fluctuation in water level in phreatic aquifer

3.1.4 Decadal Water Level Trend

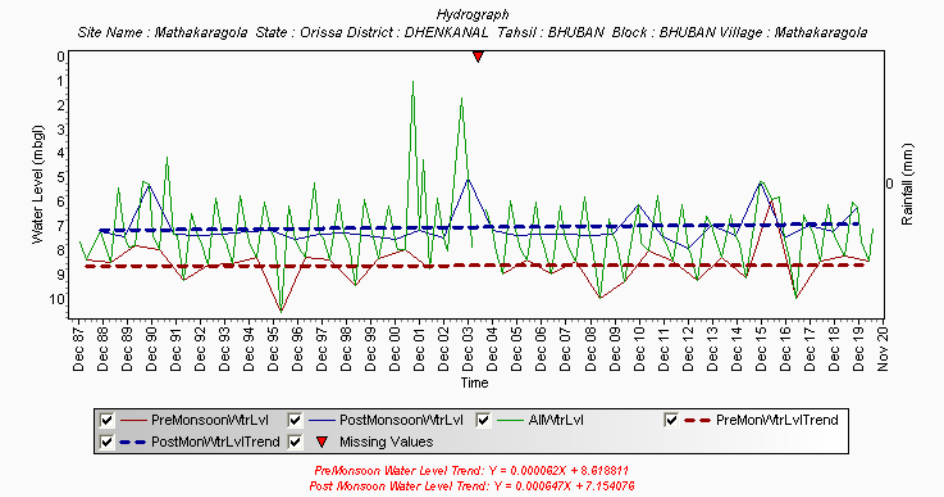
Ground water regime in the district is monitored through 43 numbers of observation wells (National Hydrograph Network Stations) established by CGWB, monitored four times in a year i.e. in the months of January, April, August and November. The decadal water level trends during pre monsoon period indicate that 62 % of the NHS station shows rising trend of water level, the maximum being 0.375 m/yr. In most of the cases the rise is less than 0.1m/ yr, which has not much significance. The rest 38% stations show a falling trend and maximum fall recorded is 0.208m/yr.

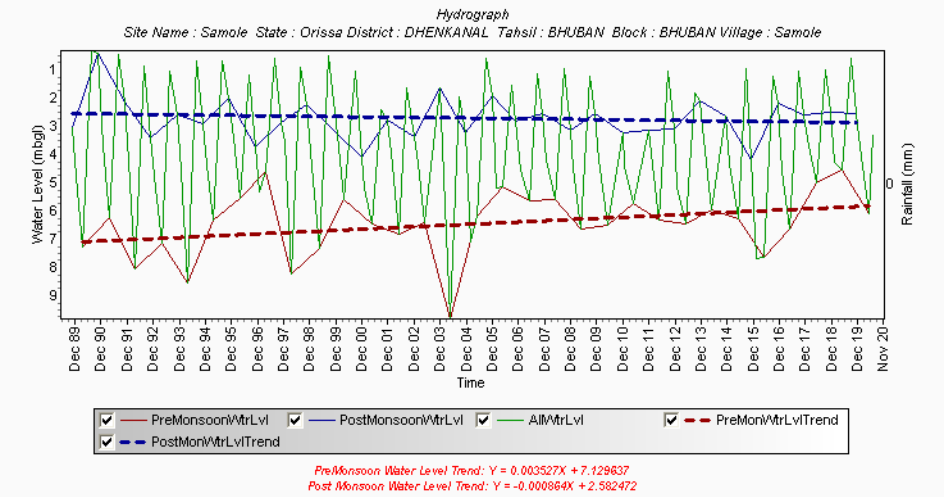
However, the majority of cases the magnitude of fall is less than 0.1m/yr.

The decadal water level trend analysis data of post-monsoon period (2008-2018) indicate that there is a rising trend of water level in 67% cases and rest 33% shows falling trend. The maximum rise recorded is 0.198m/yr with the majority of values being less than 0.10m/yr. The maximum fall is around 0.102m/yr with most values being less than 0.1m/yr.

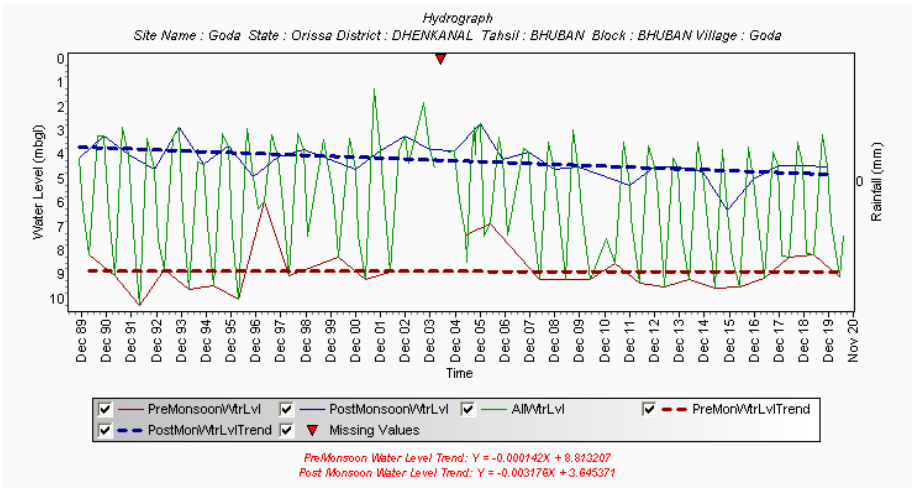
Considering the minor magnitude of rise and fall of water level over a period of 10 years both the rise and fall values can be ignored in both the cases. From the long-term trend data there is no significant variation in ground water level in the area.

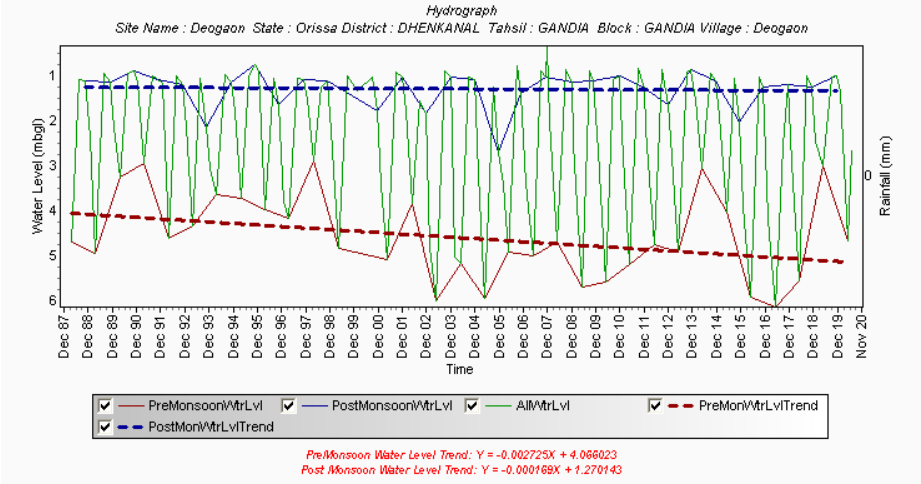
Hydrographs in Dhenkanal district.

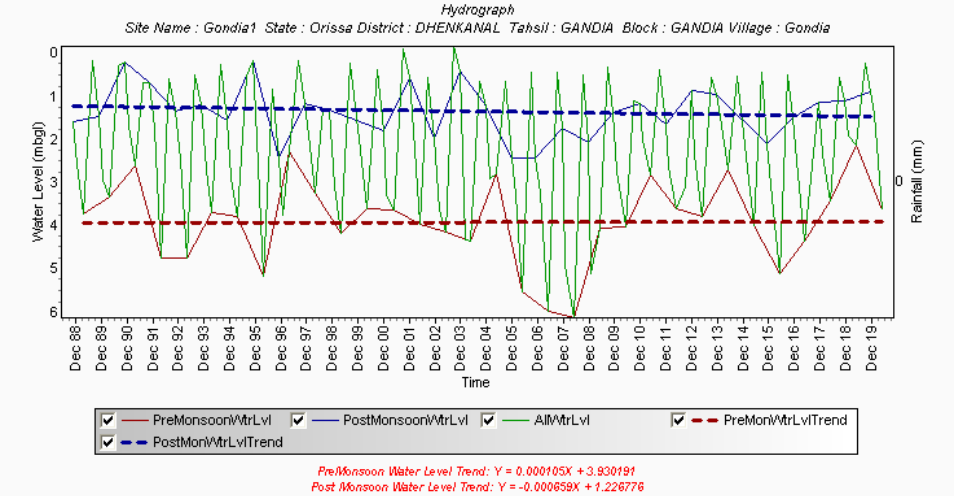




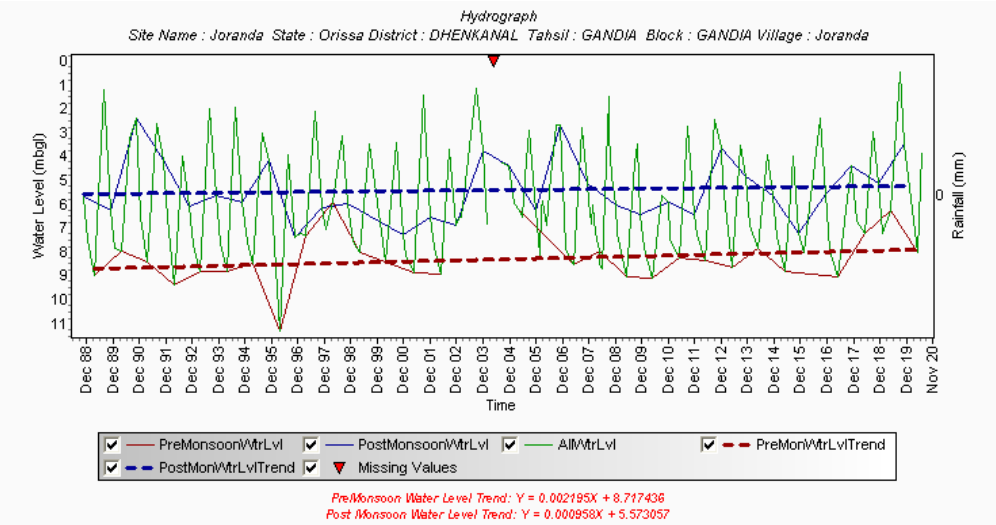
Hydrographs in Dhenkanal district.

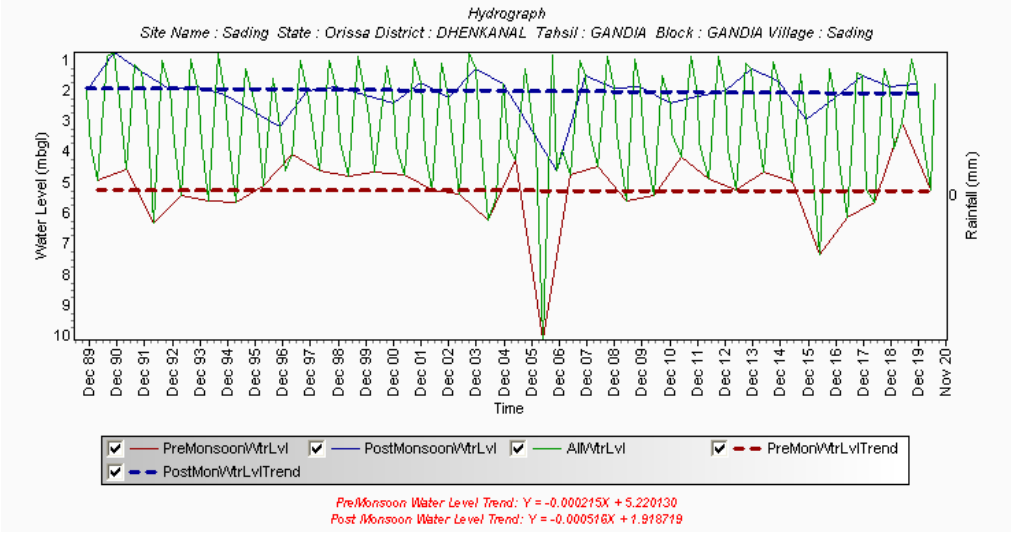

Hydrograph
Site Name : Goda State : Orissa District : DHENKANAL Tahsil : BHUBAN Block : BHUBAN Village : Goda
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.000142X + 8.813207
Post Monsoon Water Level Trend: Y = -0.003176X + 3.645371

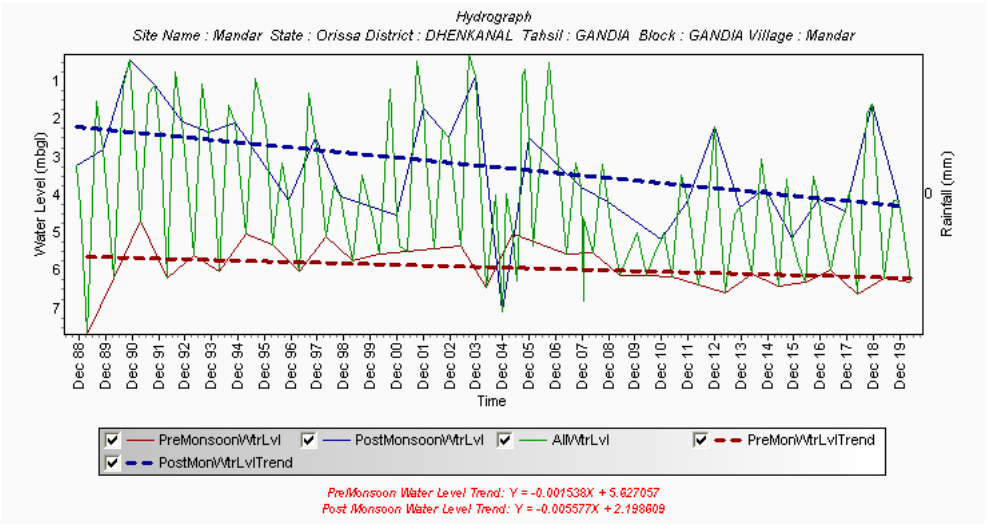

Hydrograph
Site Name : Deogaon State : Orissa District : DHENKANAL Tahsil : GANDIA Block : GANDIA Village : Deogaon
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.002725X + 4.066023
Post Monsoon Water Level Trend: Y = -0.000169X + 1.270143


Hydrograph
Site Name : Gondia1 State : Orissa District : DHENKANAL Tahsil : GANDIA Block : GANDIA Village : Gondia
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.000105X + 3.930191
Post Monsoon Water Level Trend: Y = -0.000659X + 1.226776

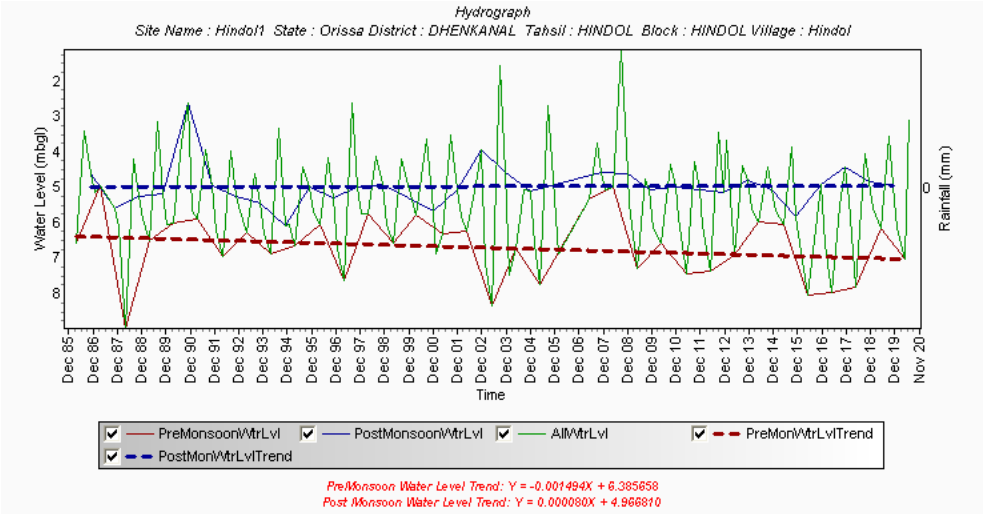
Hydrographs in Dhenkanal district.

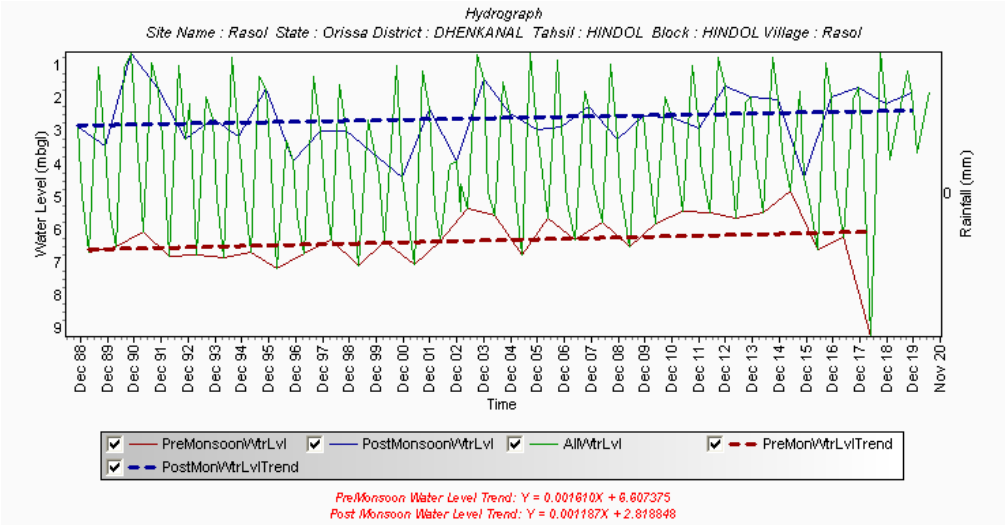


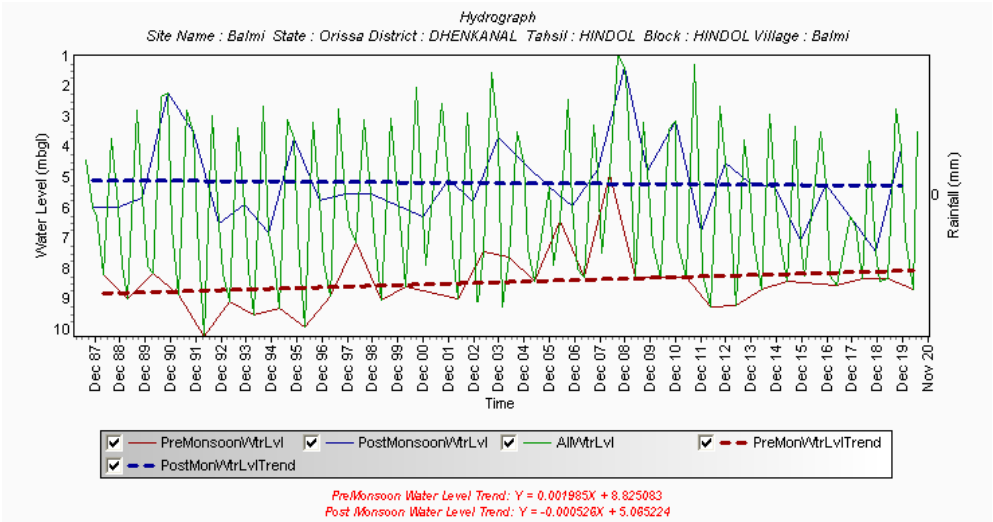




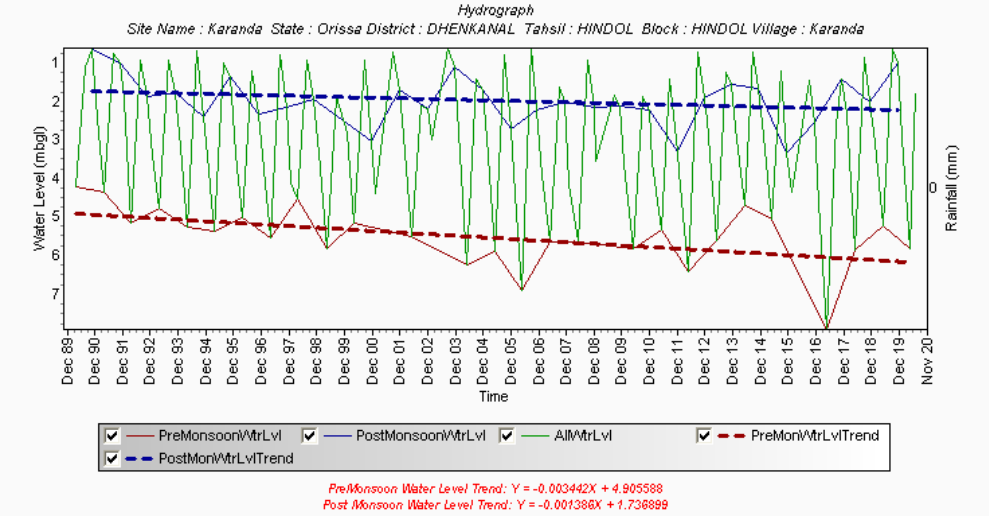
Hydrographs in Dhenkanal district.

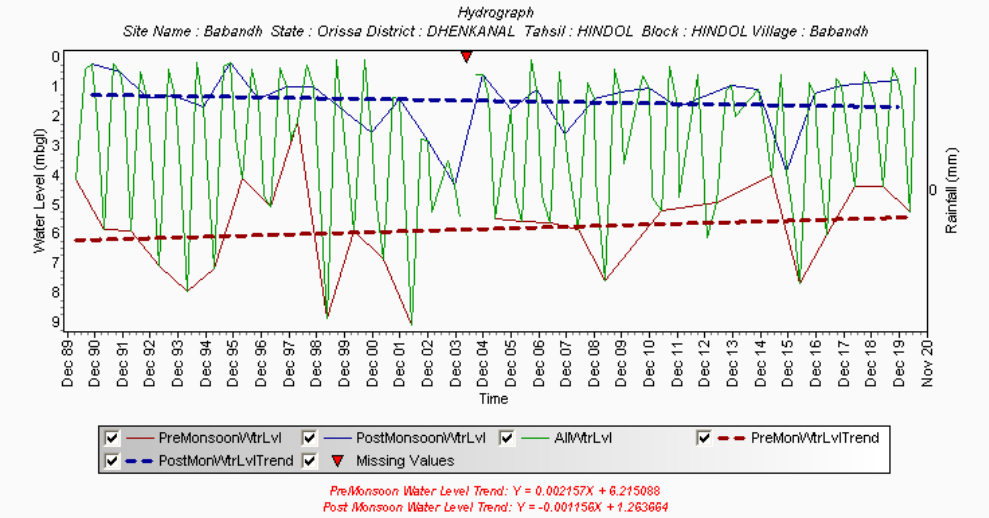


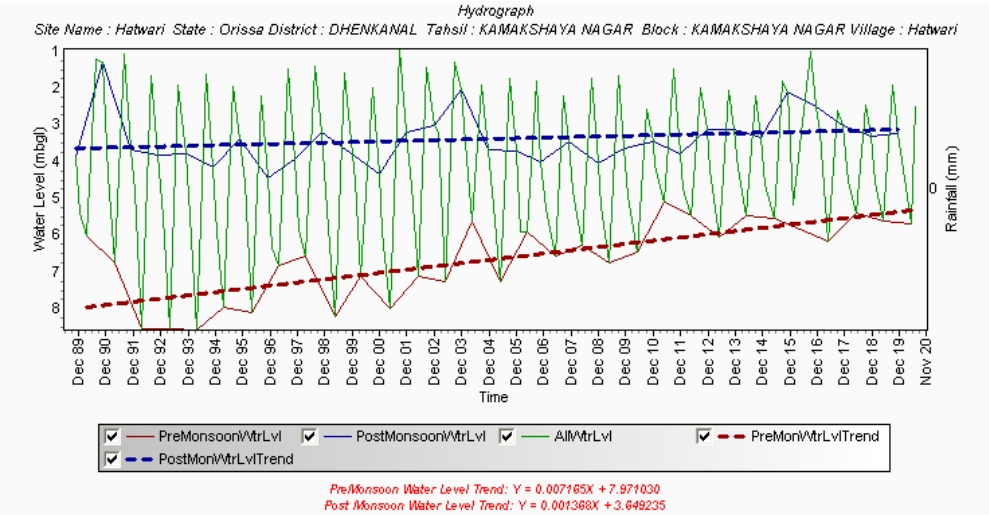




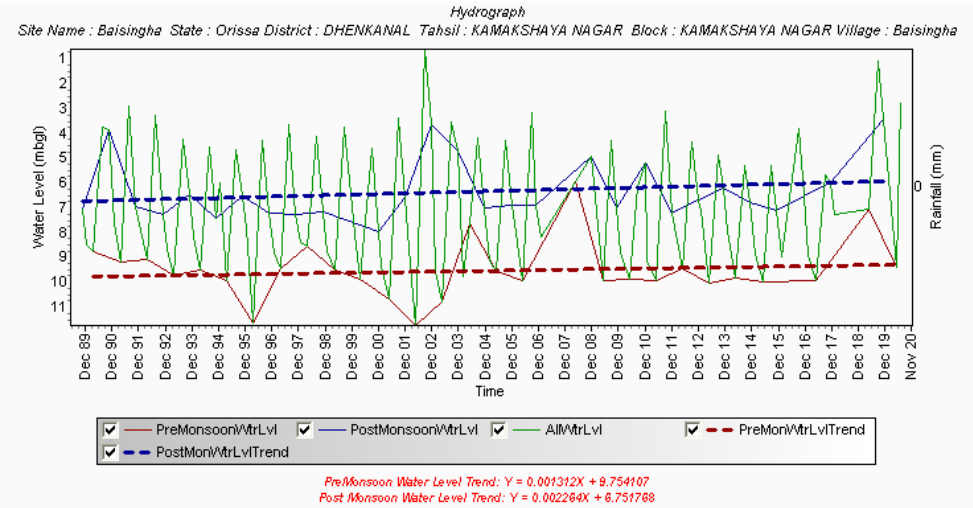
Hydrographs in Dhenkanal district.

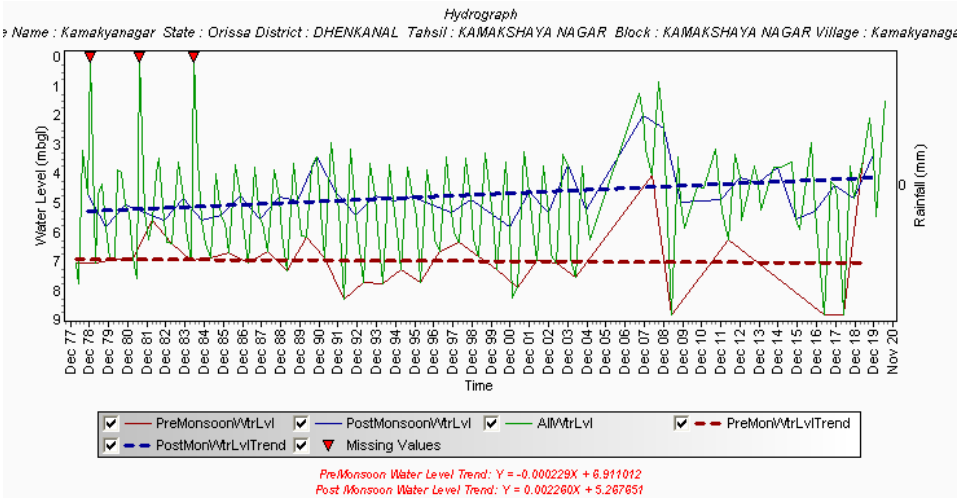


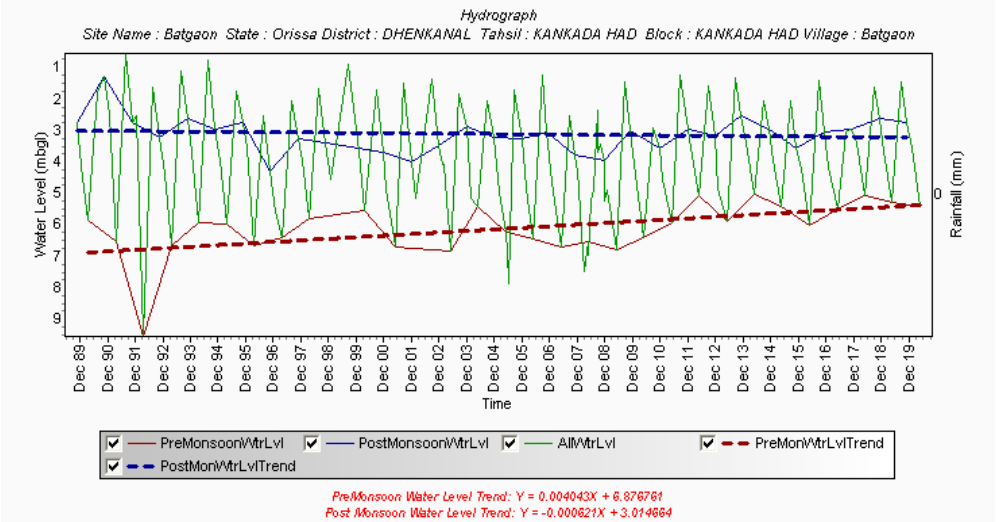




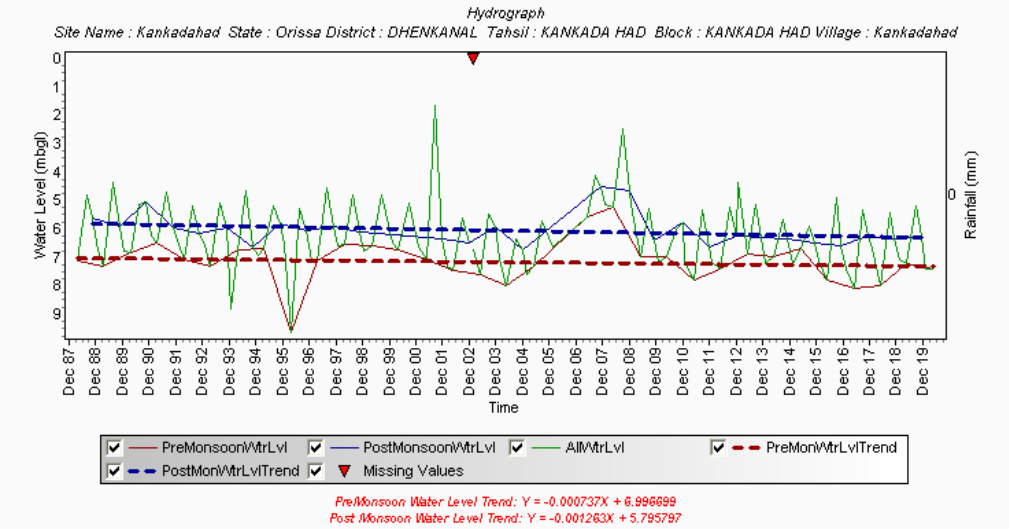
Hydrographs in Dhenkanal district.

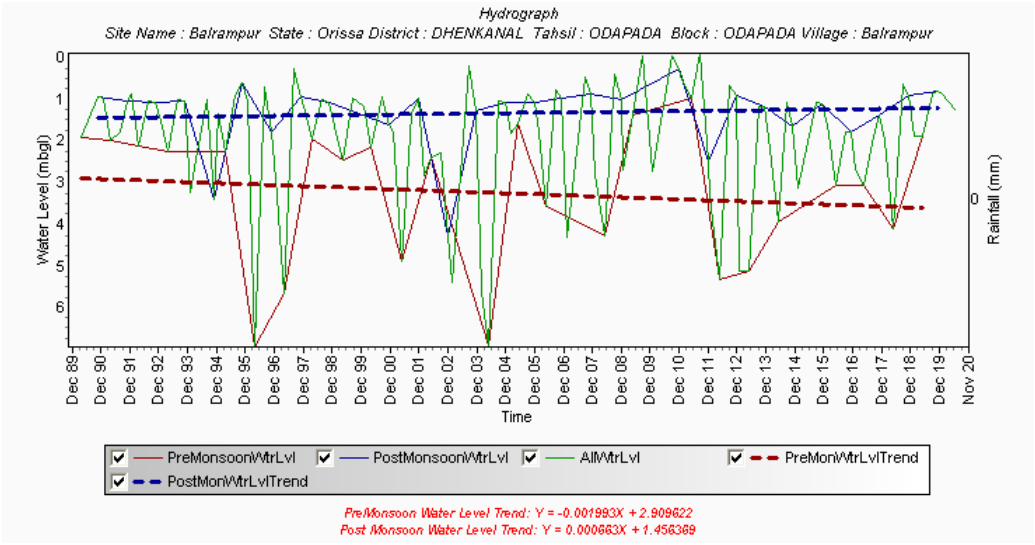


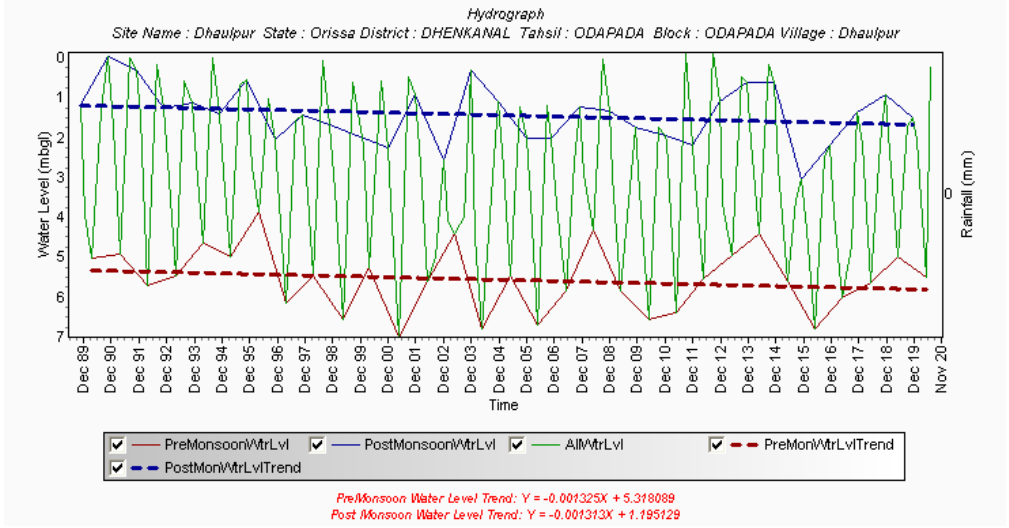




Hydrographs in Dhenkanal district.







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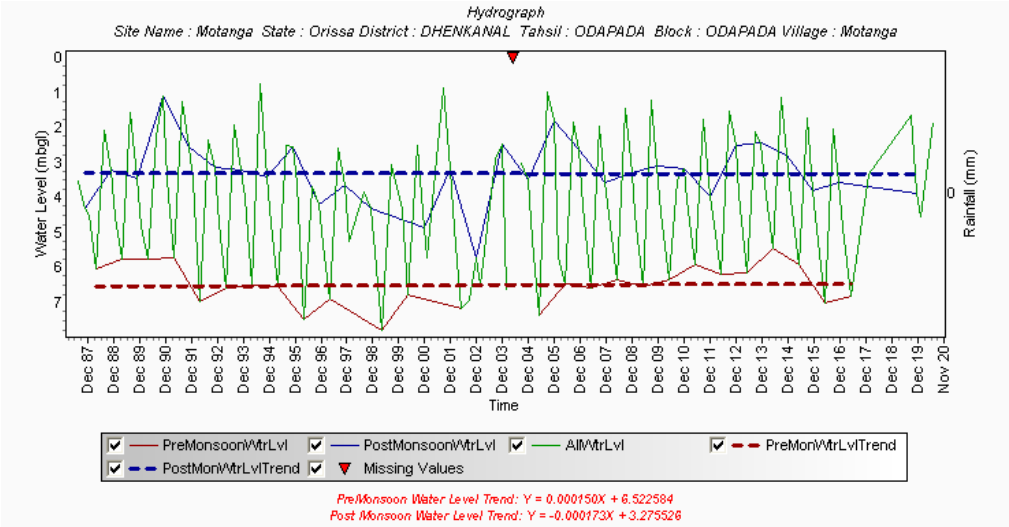
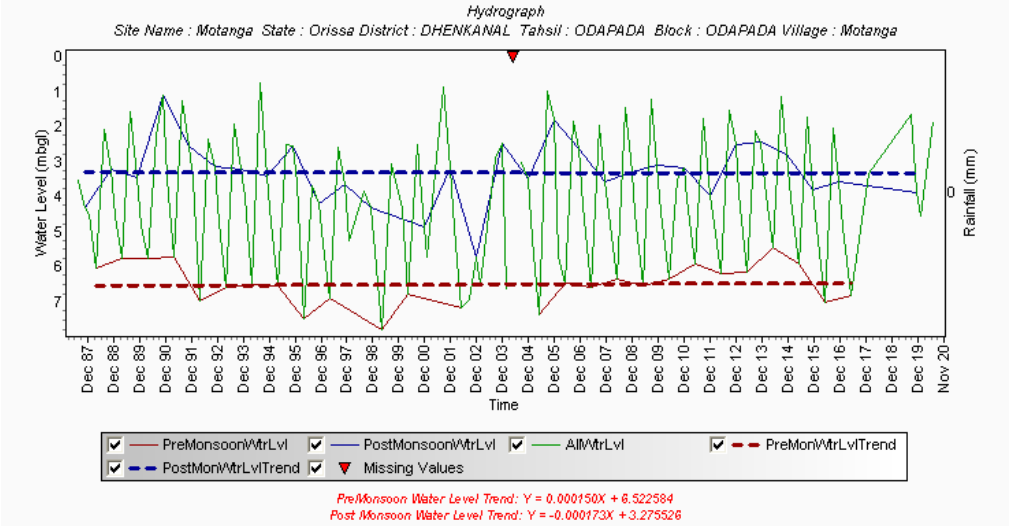
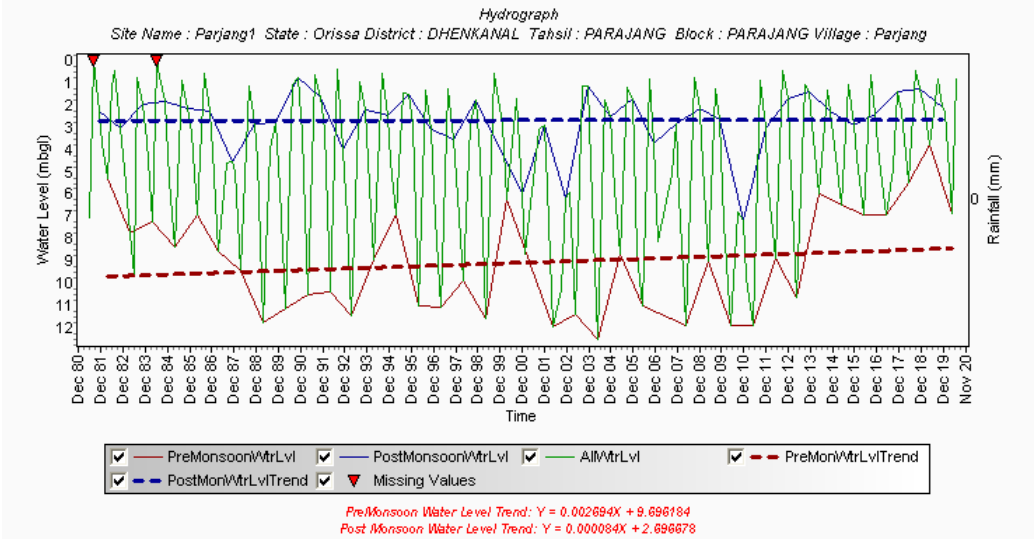
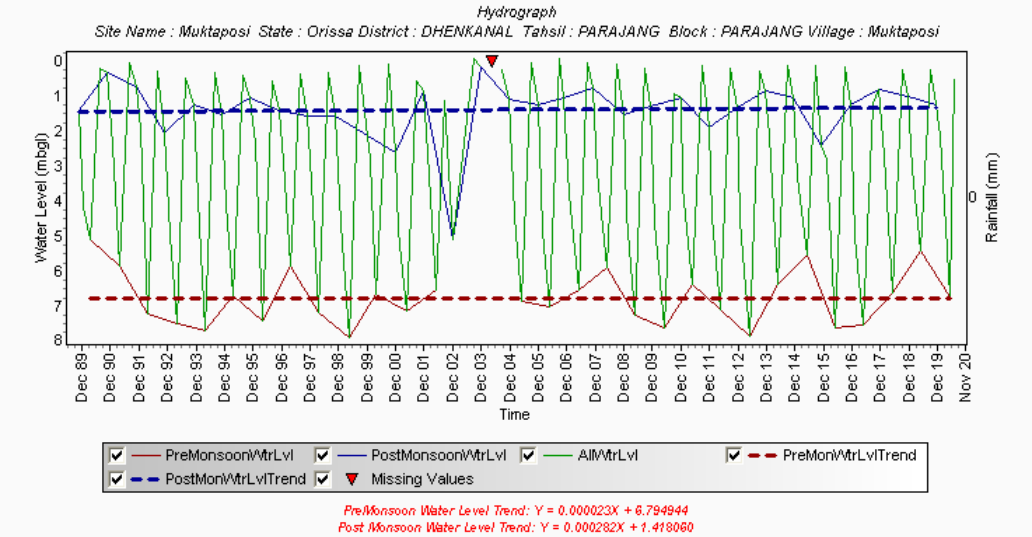
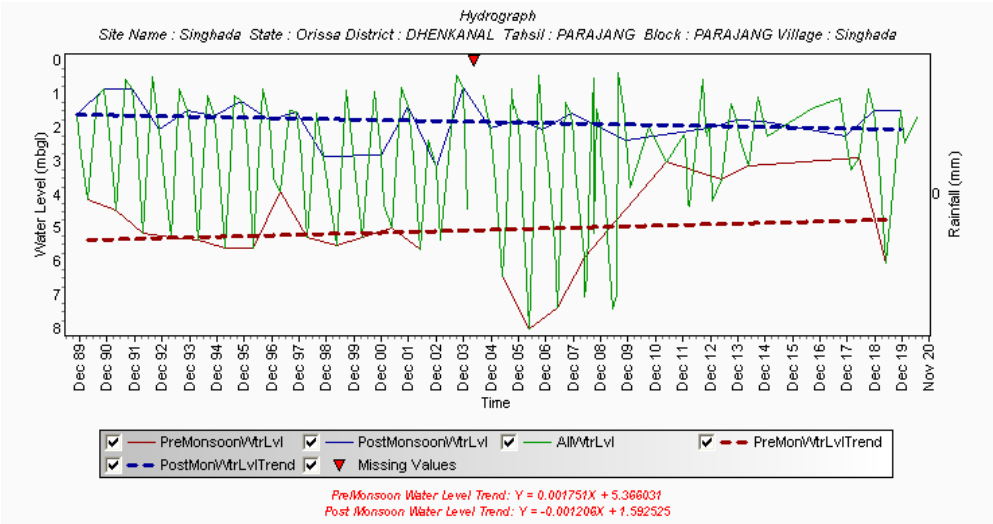


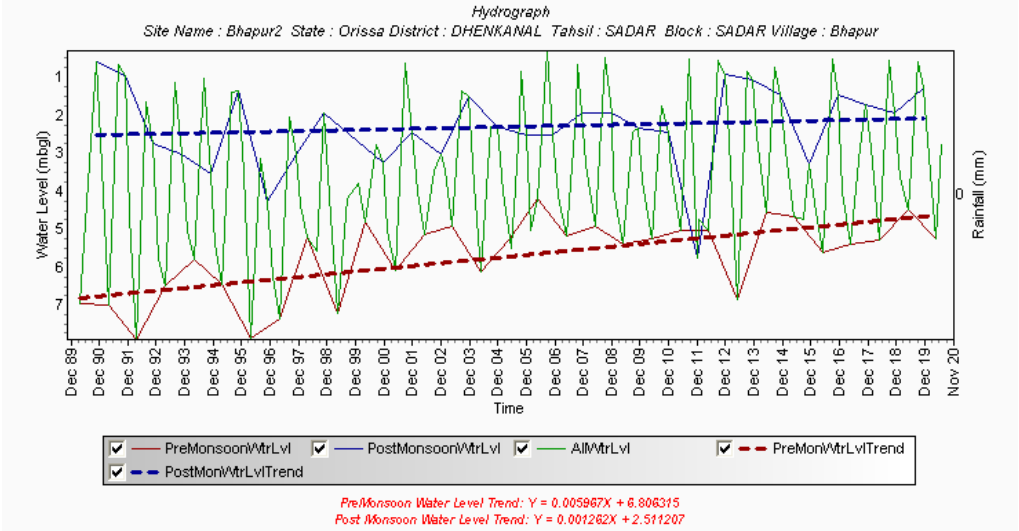




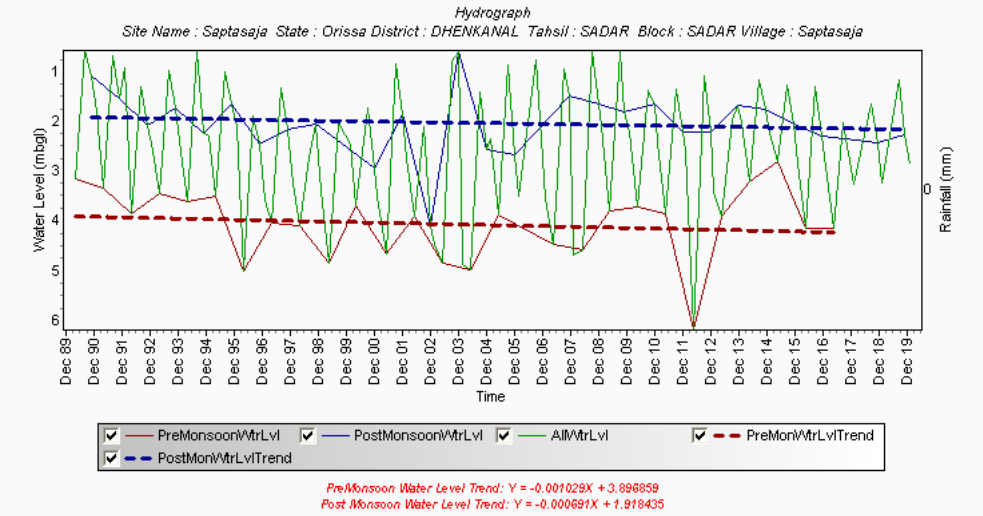
Hydrographs in Dhenkanal district.

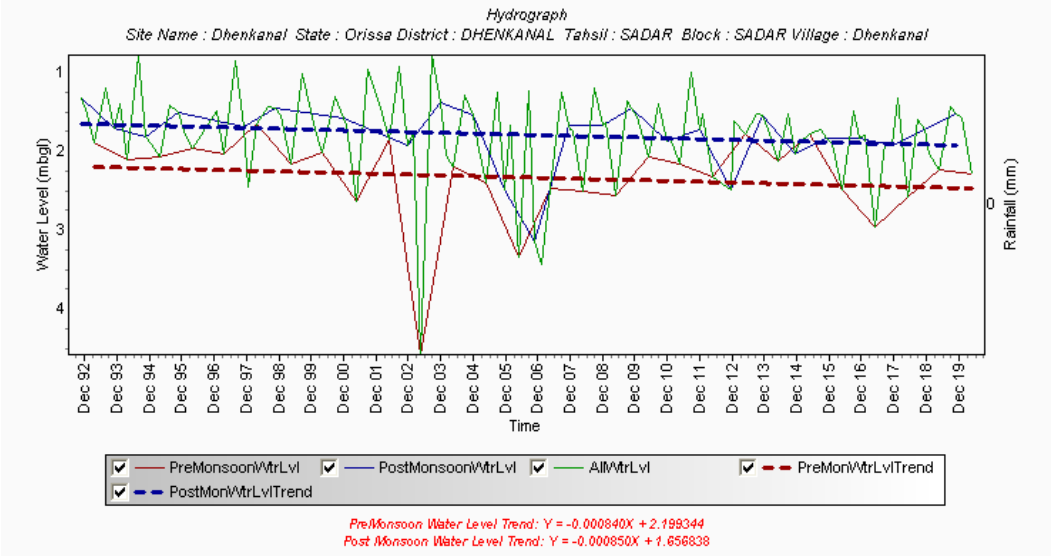




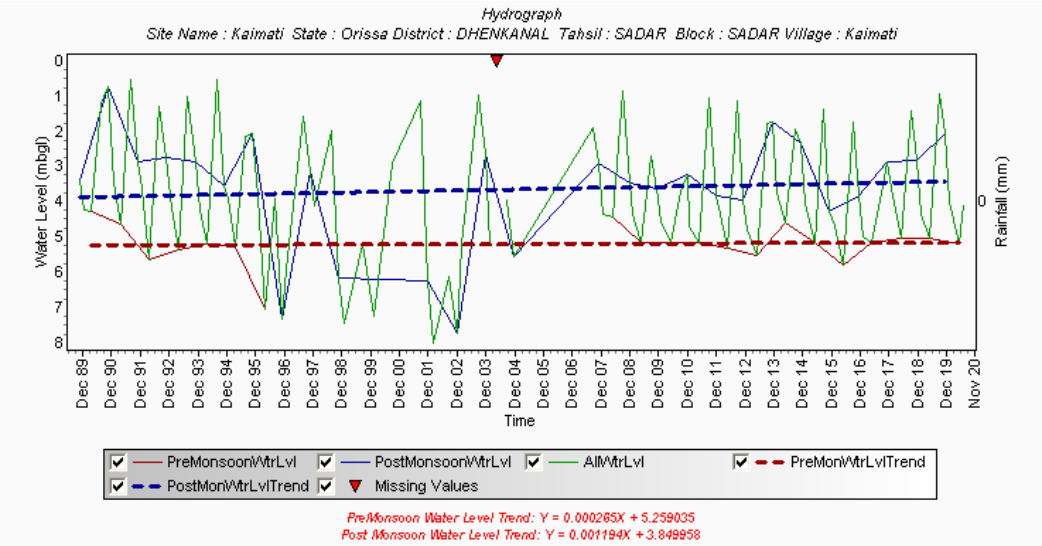


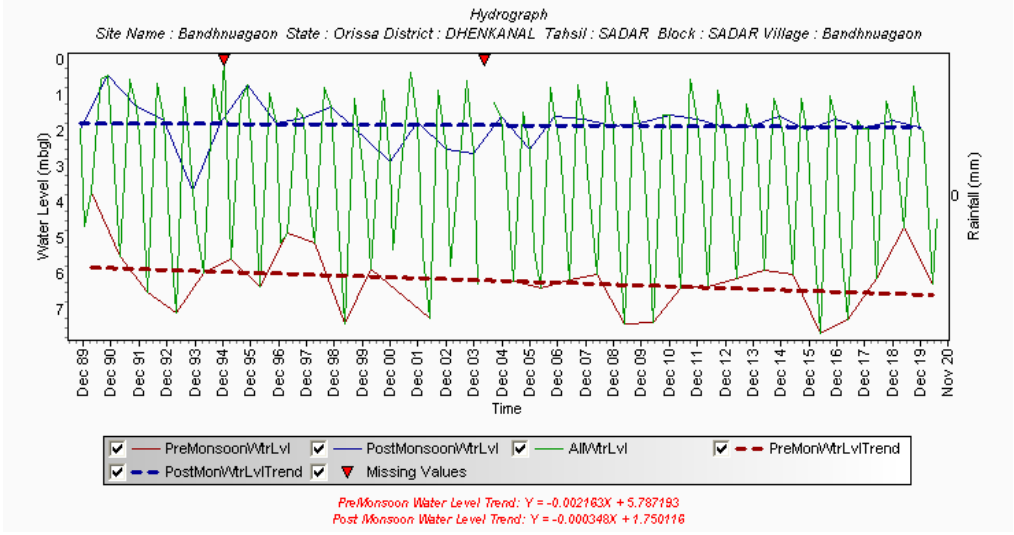
Hydrographs in Dhenkanal district.

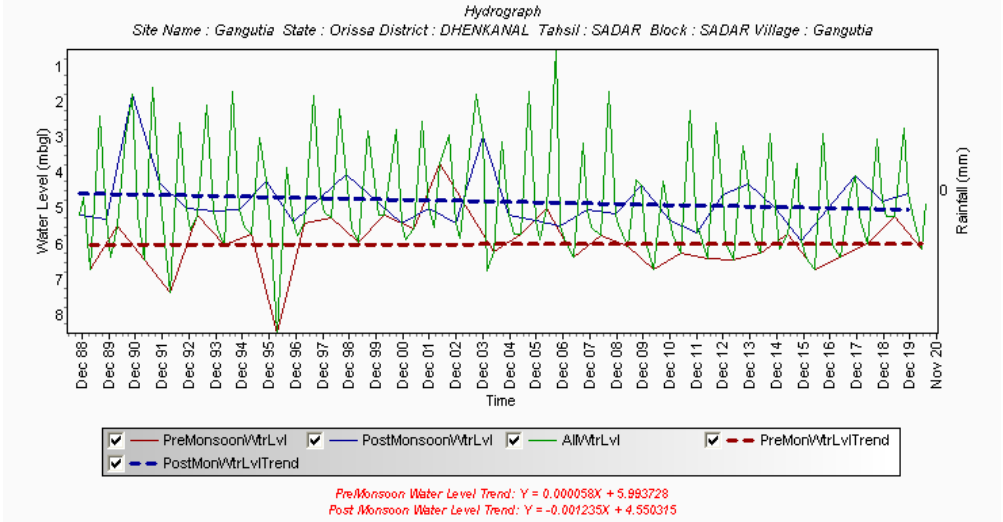




Hydrographs in Dhenkanal district.


Hydrograph
Site Name : Kaimati State : Orissa District : DHENKANAL Tahsil : SADAR Block : SADAR Village : Kaimati
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = 0.000265X + 5.259035
Post Monsoon Water Level Trend: Y = 0.001194X + 3.849958


Hydrograph
Site Name : Bandhnuagaon State : Orissa District : DHENKANAL Tahsil : SADAR Block : SADAR Village : Bandhnuagaon
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.002163X + 5.787193
Post Monsoon Water Level Trend: Y = -0.000348X + 1.750116


Hydrograph
Site Name : Gangutia State : Orissa District : DHENKANAL Tahsil : SADAR Block : SADAR Village : Gangutia
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.000058X + 5.983728
Post Monsoon Water Level Trend: Y = -0.001235X + 4.550315

3.1.5 Aquifer characteristics of phreatic aquifer

The pumping tests were conducted on selected dugwells representing different hydrogeological units and the aquifer characteristics was evaluated in terms of Specific Capacity Index i.e. flow of ground water per metre depression of head over unit cross sectional area of inflow offered by the aquifer. The **Table-3.2** summarises the aquifer characteristics of the phreatic aquifers. The wide range of yield and specific capacity is due to very much heterogeneous nature of the weathered zone in lateral extension as well as variation of thickness of this zone.

Table-3.2: Aquifer characteristics of major hydrogeological units in Dhenkanal district,

Sl. No	Hydrogeological Unit	Specific Capacity Index (lpm/m/m^2)
1	Weathered Granite Gneiss	0.50 to 4
2	Weathered Charnockite	1 to 3
3	Khondalites	0.80 to 4
4	Lower Gondwana (Sandstone)	2.3
5	Valley Fills	3.0 to 40.0
6	Alluvium	4 to 9

3.2 Deeper Aquifer

Unlike phreatic aquifer, ground water occurs under confined to semi-confined condition in the deeper aquifer. The deeper aquifer comprises of the jointed and fractured consolidated or crystalline formations as well as the semi-consolidated formations such as Gondwanas. In general it's confined on top by weathered formations and bottom by massive rocks.

Exploratory drilling has been taken up by the Central Ground Water Board in the Dhenkanal district with the objective to delineate deeper water bearing fractures in the consolidated formation and their yield potentiality within a maximum depth of 202.06m. 5 nos of exploratory wells, 1 no of observation well and 10 nos of deposit wells has been drilled under the ground water exploration programme. The depth of the wells drilled ranges from 12.05 to 202.06 m and the yield varies from 0.23 lps to a maximum of 35.2 lps. On an average 2 to 3 sets of saturated fracture zones are encountered which are generally restricted to about a maximum of 80 m depth. The summarized hydrogeological data of the exploratory wells are presented in Annexure-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 30 m, acts as a single aquifer system occurring under phreatic or near phreatic condition. The deeper aquifers are hydraulically inter-connected with shallow weathered zones.

3.3 Ground Water Quality

The chemical quality of ground water in the district is monitored annually on a routine basis by CGWB through its national Hydrograph Network Stations. Quality of ground water from deeper aquifers was assessed during the exploration activities like drilling and pumping tests. The suitability of ground water 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.**

Table 3.3: Aquifer-wise ranges of chemical constituents in Dhenkanal district

Parameter	Unit	Shallow (Aquifer-I)		Deep (Aquifer-II)	
		Minimum	Maximum	Minimum	Maximum
pH	-	7.37	8.3	6.9	8.3
EC	µS/cm	290	2760	290	1190
TDS	mg/L	143	1477	194	476
TH	mg/L	110	970	120	410
TA	mg/L	94	558	-	-
Ca^{++}	mg/L	20	263	10	112
Mg^{++}	mg/L	5	151	4.9	77
Na^{+}	mg/L	2	172	12	193
K^{+}	mg/L	0.3	89.4	0.4	49
$CO_3^{=}$	mg/L	0	0	0	0
HCO_3^{-}	mg/L	115	681	88	421
NO_3^{-}	mg/L	0.23	120	0.3	65
Cl^{-}	mg/L	10	490	10.6	220
$SO_4^{=}$	mg/L	0	114	0	80.5
F^{-}	mg/L	0.13	3.3	0	1.58
Fe	mg/L	-	-	0	1.04
SAR	-	0.1	3.7	7	153

Based on the chemical analysis of water samples from different sources, it was observed that, almost all chemical parameters lie within permissible limit for drinking and irrigation purpose

except few samples of some isolated pockets. For example, fluoride in excess of permissible limit has been found certain villages, which is discussed in detail in Chapter-5.

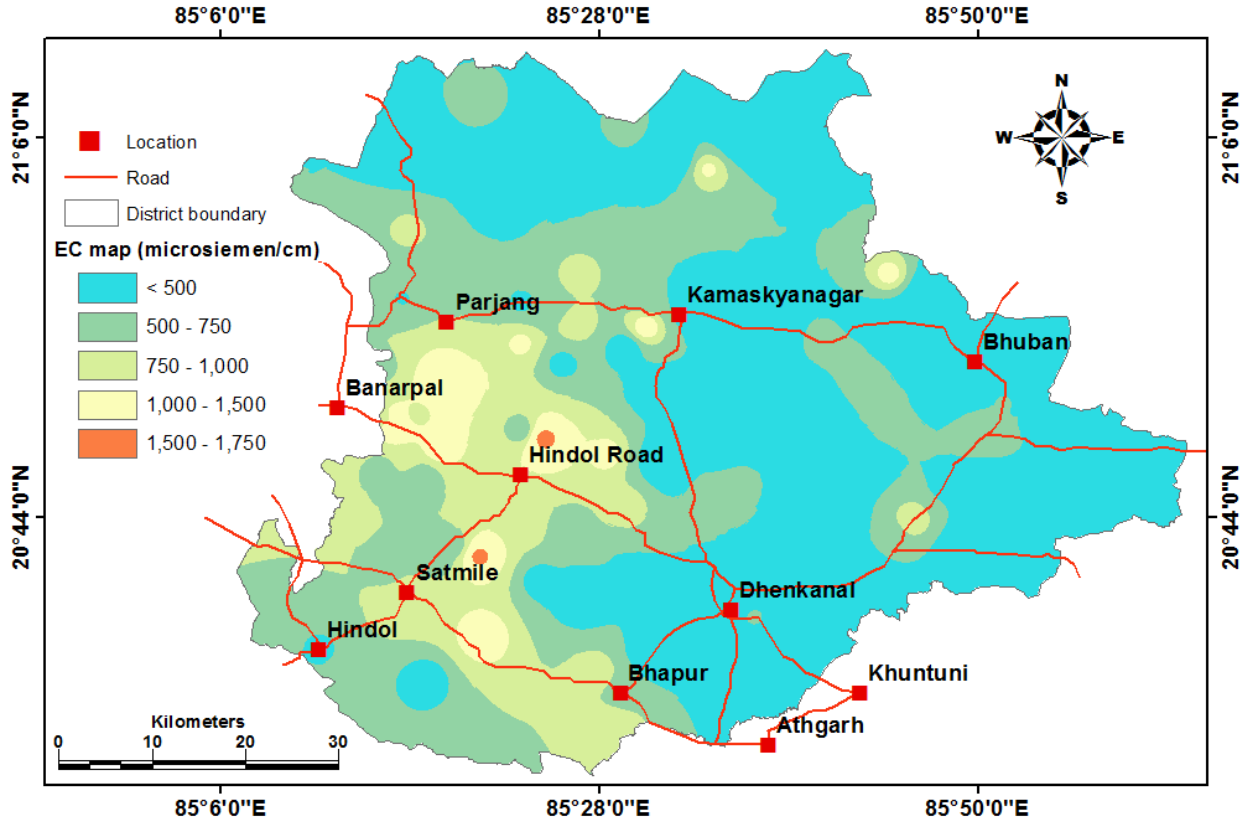


Fig. 3.4: Iso-conductivity map of phreatic aquifer.

The iso-conductivity map of phreatic and deeper aquifers of the district has been prepared and presented as **Fig. 3.4** and **3.5** respectively. The quality of ground water is generally good with EC ranging from 290 to 2760 µs/cm. The SAR value of the samples of Aquifer-I ranges from 0.1 to 3.7. The suitability of the ground water for the purpose of irrigation analysed in the US-Salinity diagram as shown in **Fig. 3.6** and **3.7**. The predominant USSL classes of the water samples fall within C2S1 and C3S1 classes. The water samples represent Mg-HCO_3 type to mixed facies of Ca-Mg-Na-HCO_3-Cl types as shown in the Piper diagram in **Fig. 3.8**. This indicates a transitional or mixing environment between the younger water and resident water.

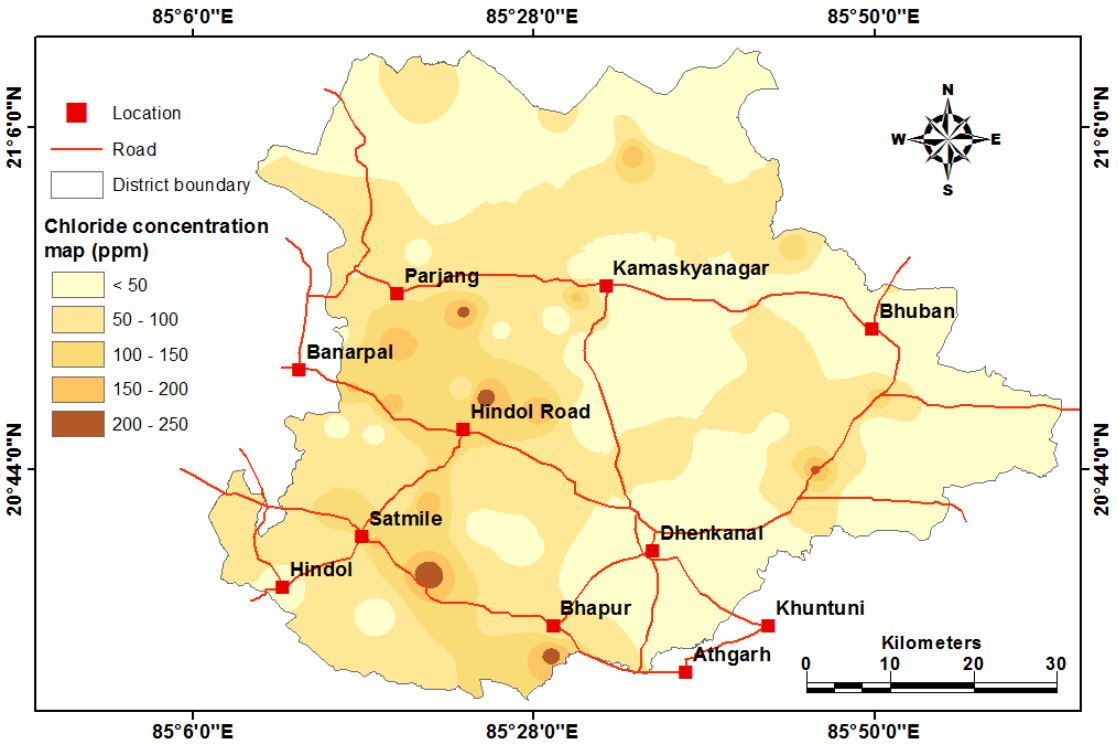


Fig. 3.5: Chloride map of phreatic aquifer.

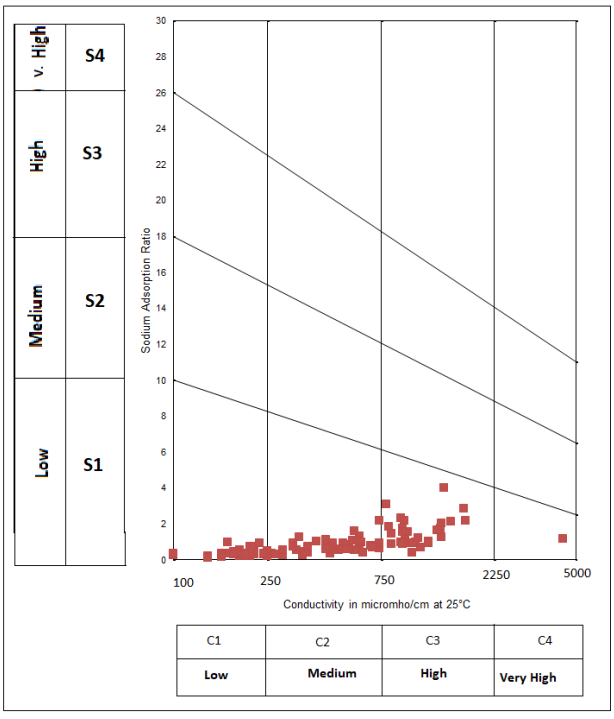


Fig. 3.6: US-Salinity diagram, phreatic aquifer (pre-monsoon) in Dhenkanal district.

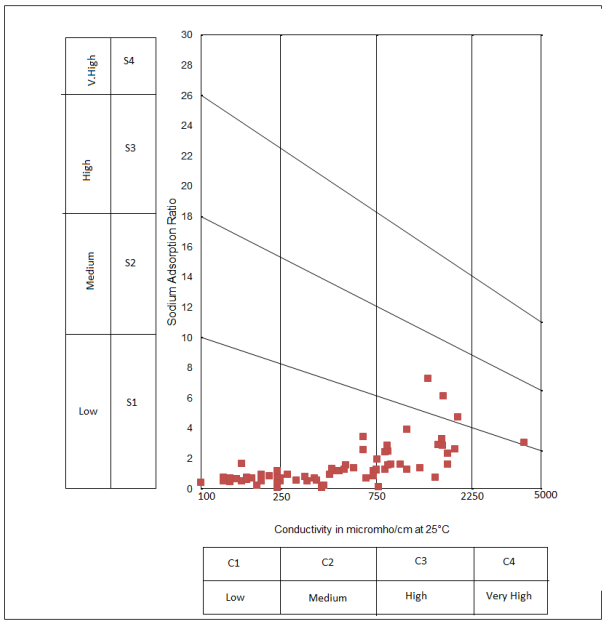


Fig. 3.7: US-Salinity Diagram, post-monsoon period, Dhenkanal district.

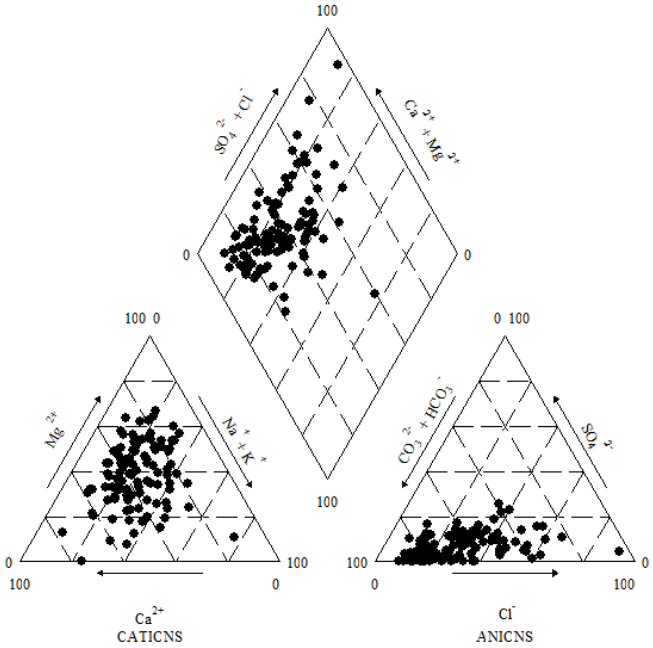


Fig. 3.8: Piper Diagram of water samples, Dhenkanal district

3.3.1 Ground water Pollution in Dhenkanal district

The water pollution due to vast expansion of thermal power generation and associated industrial activities are expected to increase pollution load to the river system. Major source of pollution are industrial & mining activities, urban storm and surface runoffs. Runoff from waste dumps and ash ponds contains a high quantity of toxic dissolve pollutant and suspended solids.

Non point source (NPS) pollution is typically associated with storm water runoff in either urban or mining areas. Surface runoff can transport significant amounts of contaminants--including sediment, nutrients, pathogens, pesticides, heavy metals, oil and grease from multiple sources into the water body.The major polluting industries in Dhenkanal District is given in Table No-3.4.

Table:3.4 Major Polluting Industries in Dhenkanal District.

Sl.No.	Name of the Industry	Public/Private Sector	Category	Effluent Receipent concerned River
5	Bhusan (TATA) Steel & Power Ltd.	Private	Thermal Power &Steel Plant Industrial effluent and ash pond over flow	Kisinda Nalah
6	GMR Energy	Private	Thermal Power and ash pond over flow	Kisinda Nalah
7	B.R.G Steel	Private	Steel Plant Industrial effluent	Kisinda Nalah
8	Navabharat Alloys	Private	Alloys industries and waste water	Kisinda Nalah
9	JITPL	Private	Thermal Power &Steel Plant Industrial effluent and ash pond over flow	Tikira tributary of Brahmani

Heavy metals (like Iron, fluride, lead, zinc, arsenic and cadmium) in the sources of groundwater and at some locations of surface water around the Angul-Talcher-Meramunduli Pollution Cluster, as detected in the study are produced in the Figs 3.9 – 3.21.

The drainage channels such as Tikra &Kisinda flowing in the pollution cluster area of Dhenkanal District show high Alkalinity in pre-monsoon period. The concentration of soluble salts of drainage channels are within the permissible limit in pre &post monsoon period. There is a slight variation in soluble salt content in upstream and downstream. The F concentration in Kisinda channel decreased in post monsoon period. The concentrations of Heavy metals are observeved to be decreased in Tikra &Kisinda channnel in post monsoon period. Thus the F concentration is above the permissible limit due to leaching effect of ash water from nearby ashpond of Thermal plants.

Maximum value of F is observed at GMR PZ- 2, may be due to leaching effect of nearby ash pond. The content of Fe varied from BDL to 5.004 mg/L and maximum value observed at GMR ETP water. The concentration of Cd varied from BDL to 0.0034 mg/L and maximum value observed at inside Navabharat alloys of waste water reservoir. The concentration of Zn varied from BDL to 0.197 mg/L and maximum value observed at Meramundalli of Kisinda Nallah. All are within permissible limit. The concentration of Cd observed to be BDL. The concentration of Pb varied from BDL to 0.023 mg/L and maximum value observed in upstream of Kisinda drainage channel at Talabahal.

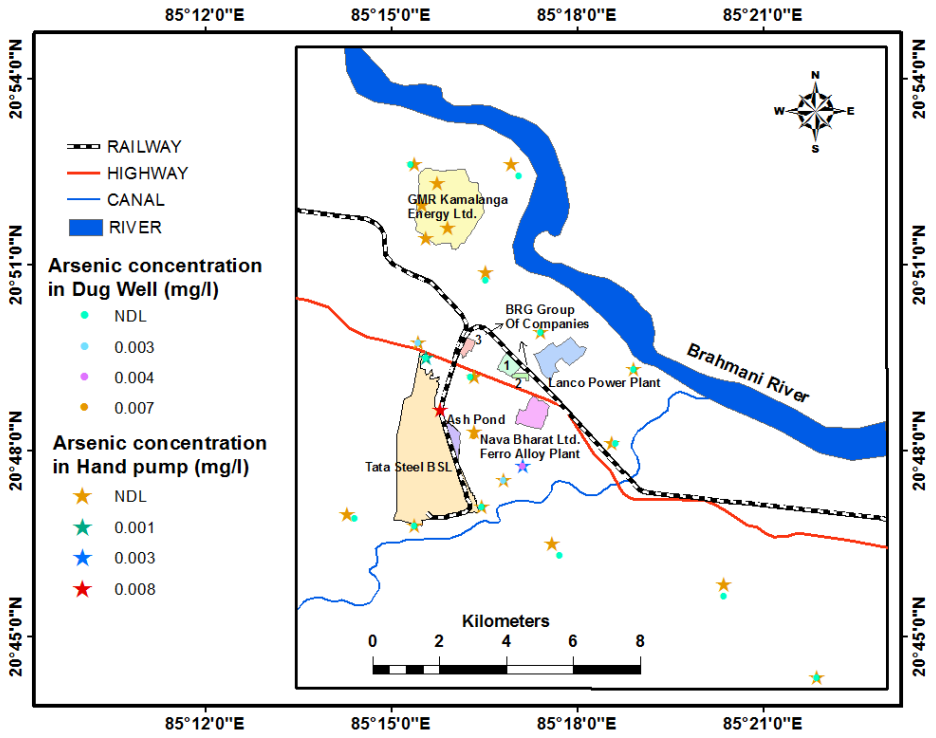


Fig.3.9: Arsenic in HP map in Dhenkanal district

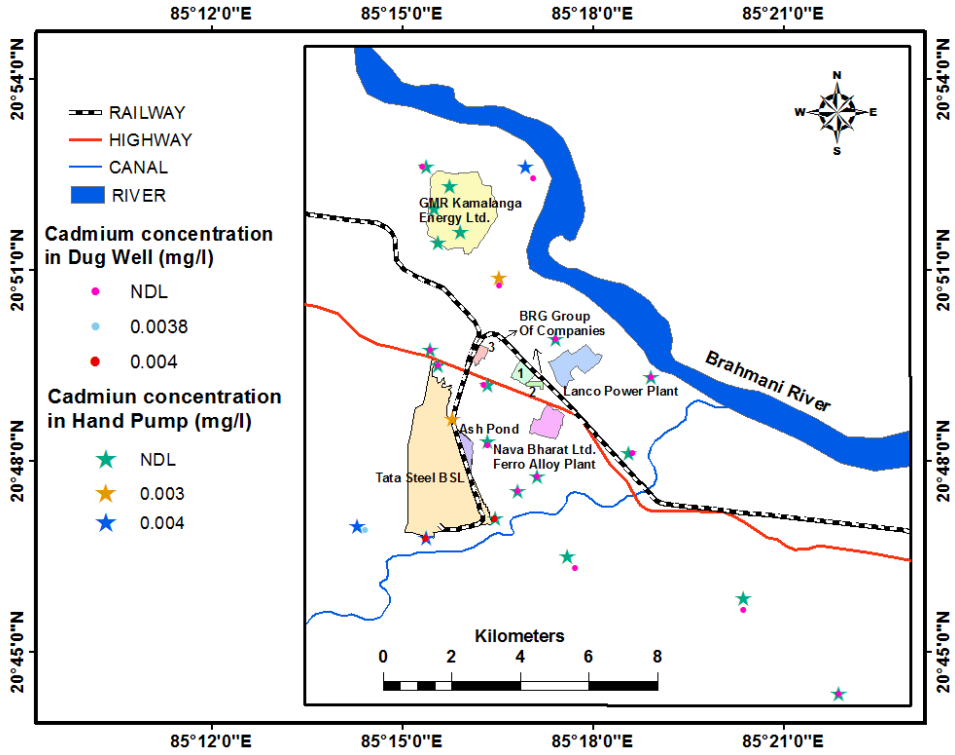


Fig.3.10: Cadmium in HP map in Dhenkanal district

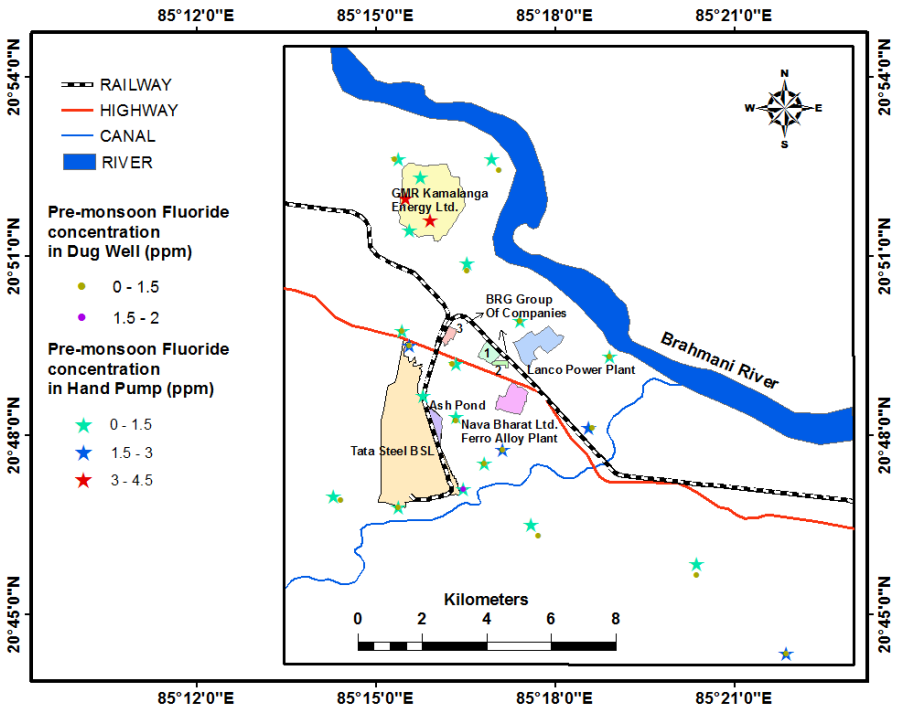


Fig.3.11: Fluoride in DW map in Dhenkanal district

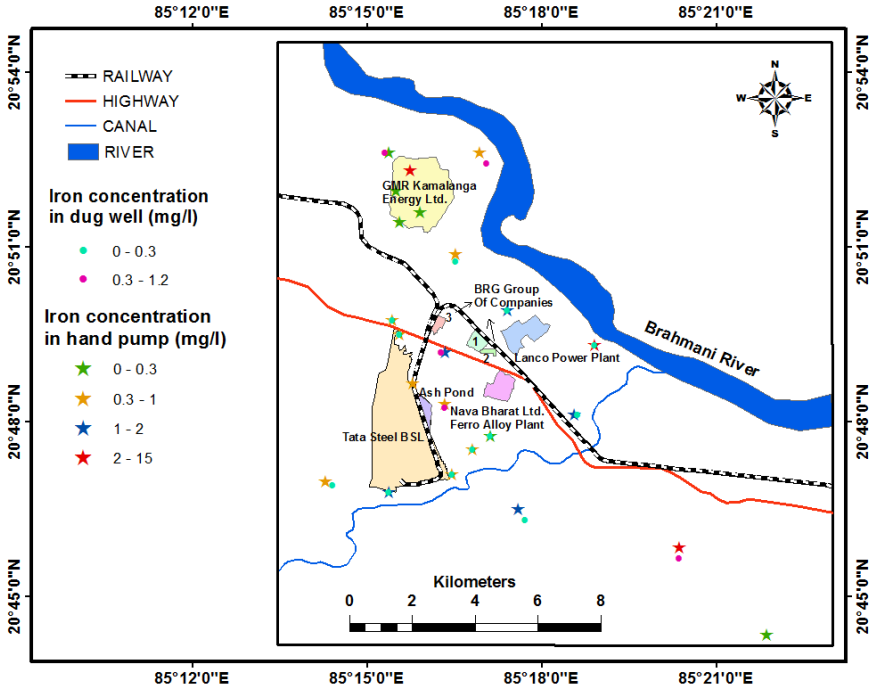


Fig.3.12: Iron in DW map in Dhenkanal district

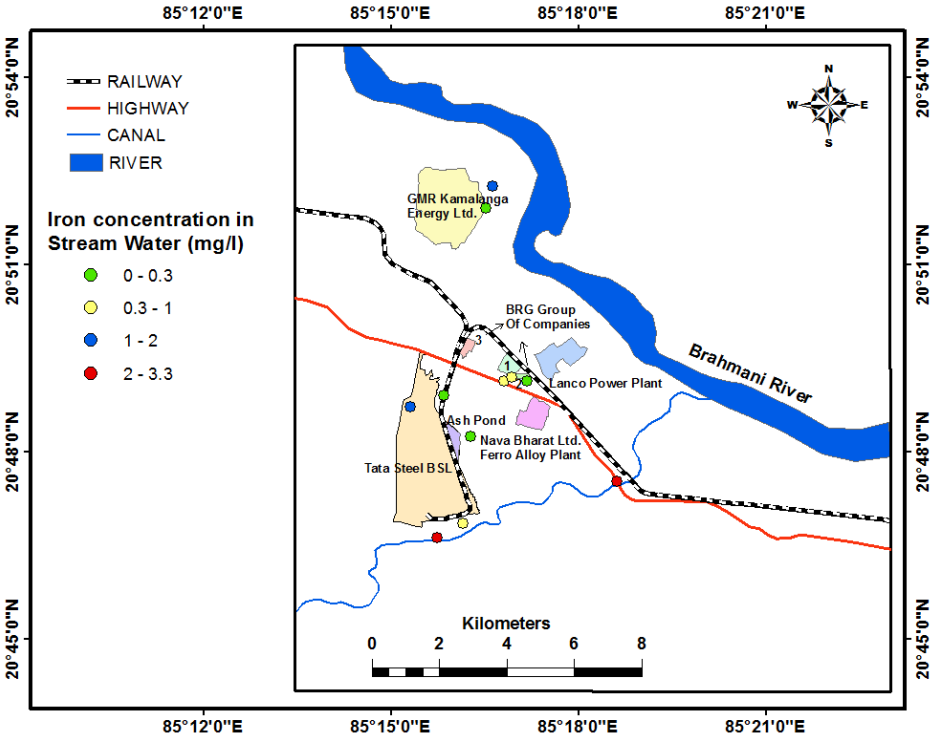


Fig.3.13: Iron in stream water map in Dhenkanal district.

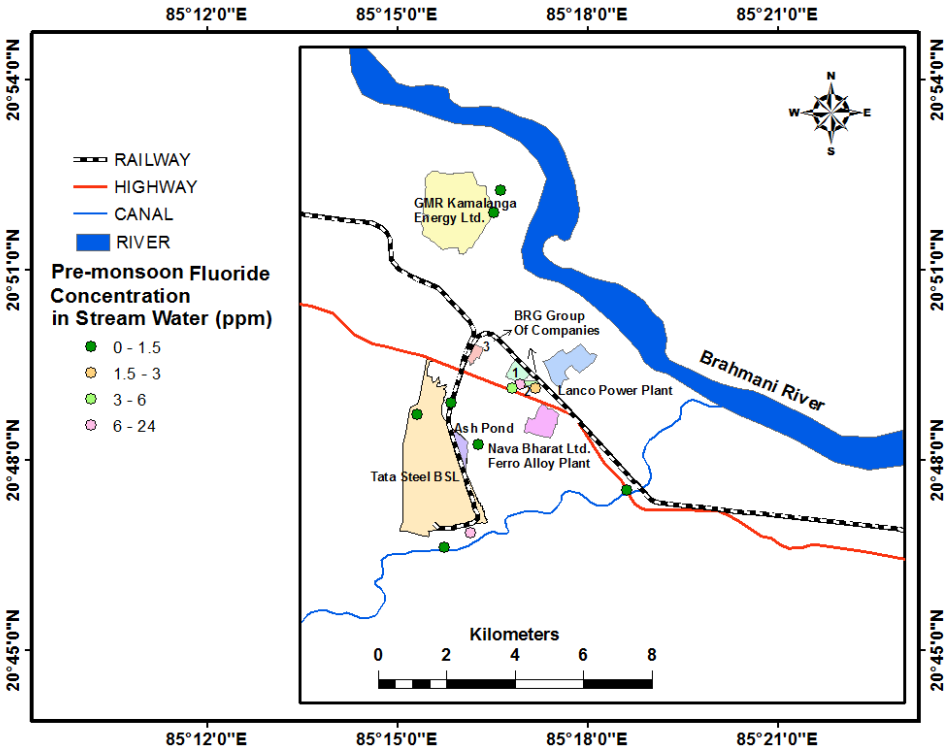


Fig.3.14: Fluoride in SW map in Dhenkanal district

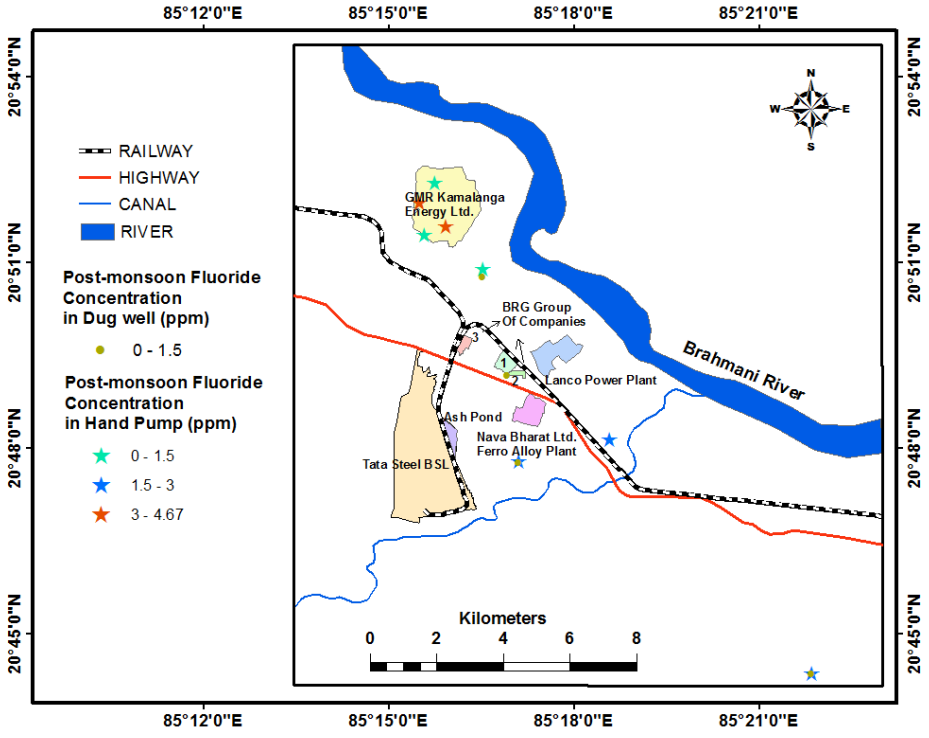


Fig.3.15: Post monsoon Fluoride in DW and HP map in Dhenkanal district.

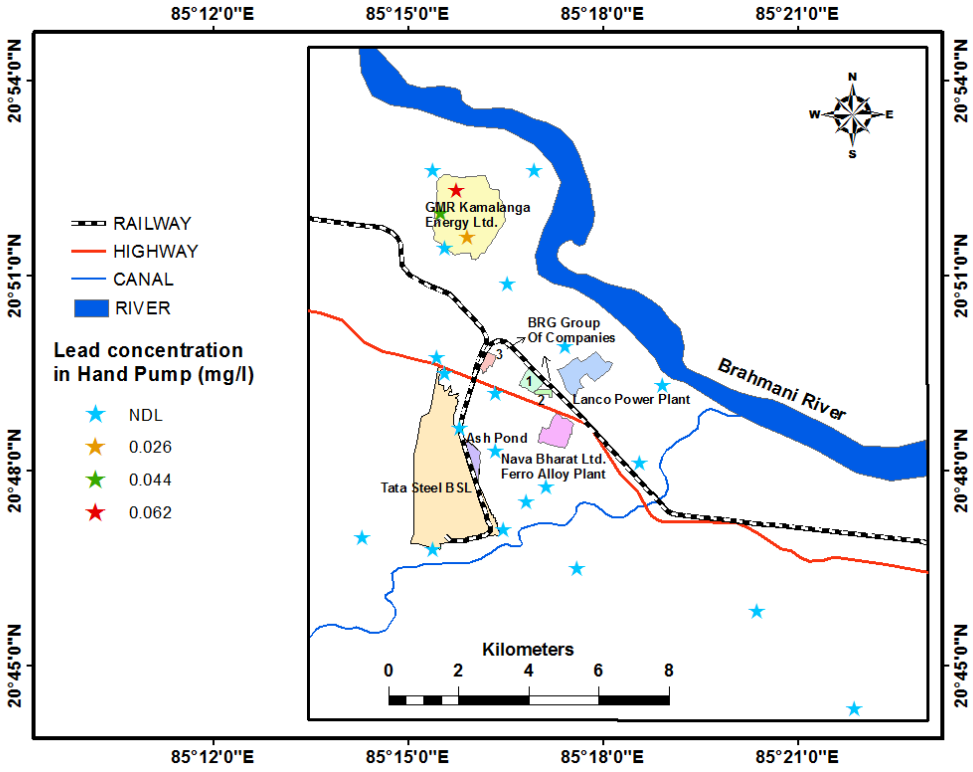


Fig.3.16: Lead in HP Map in Dhenkanal district

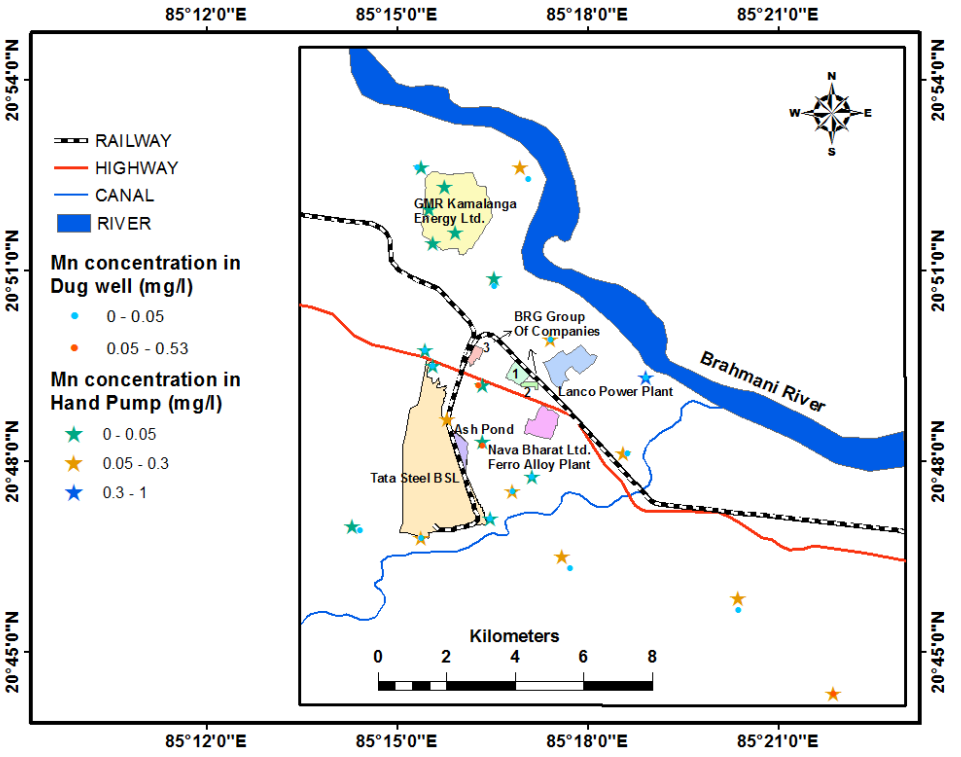


Fig.3.17: Mn in DW map in Dhenkanal district

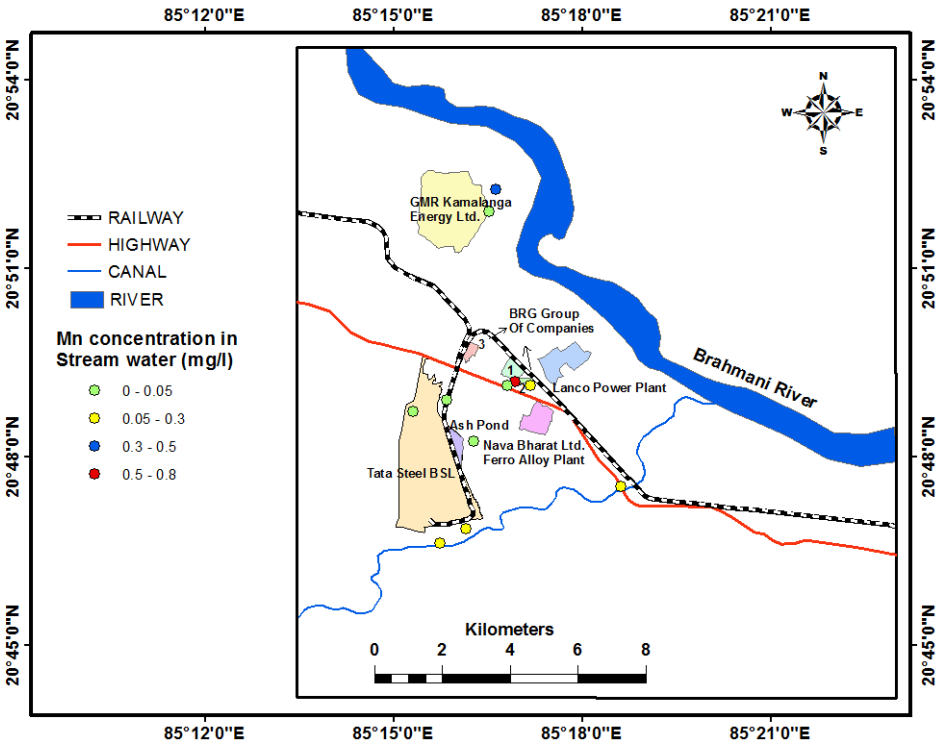


Fig.3.18: Mn in SW Map in Dhenkanal district

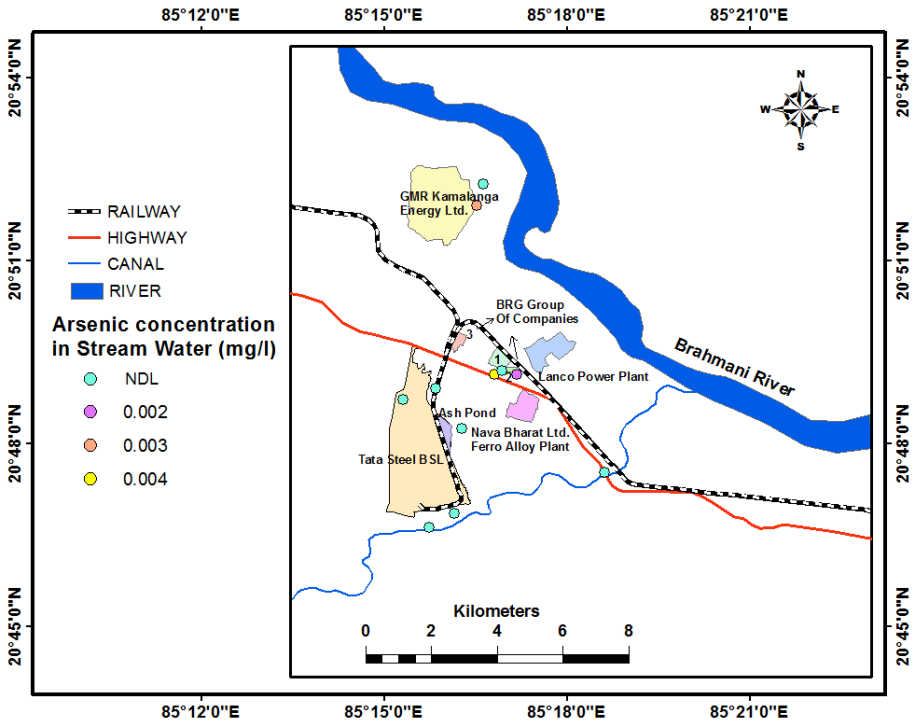


Fig.3.19: Arsenic in SW map in Dhenkanal district

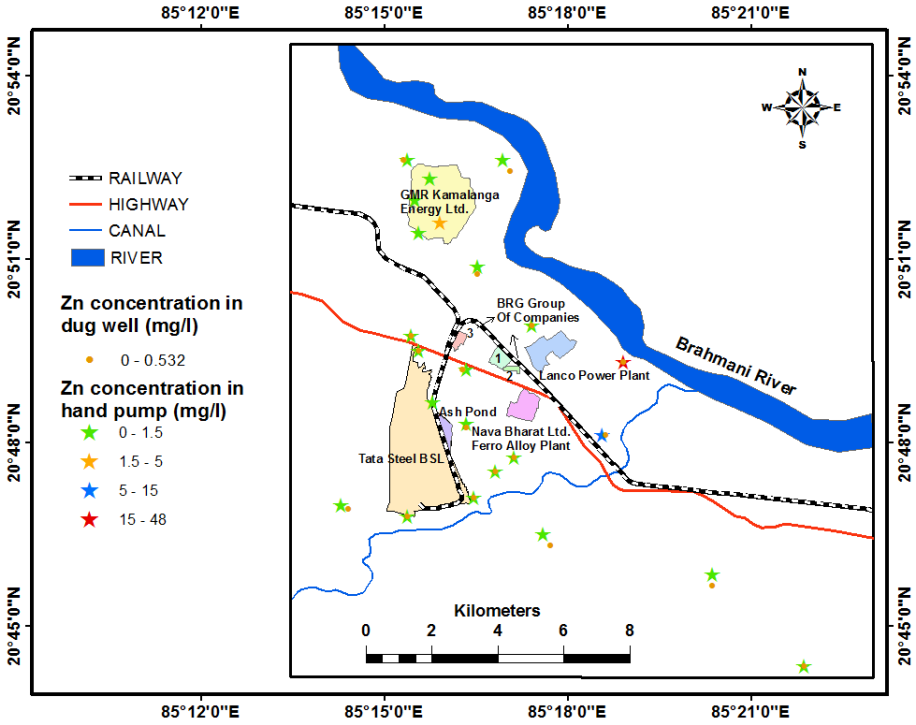


Fig.3.20: Zn in DW map in Dhenkanal district.

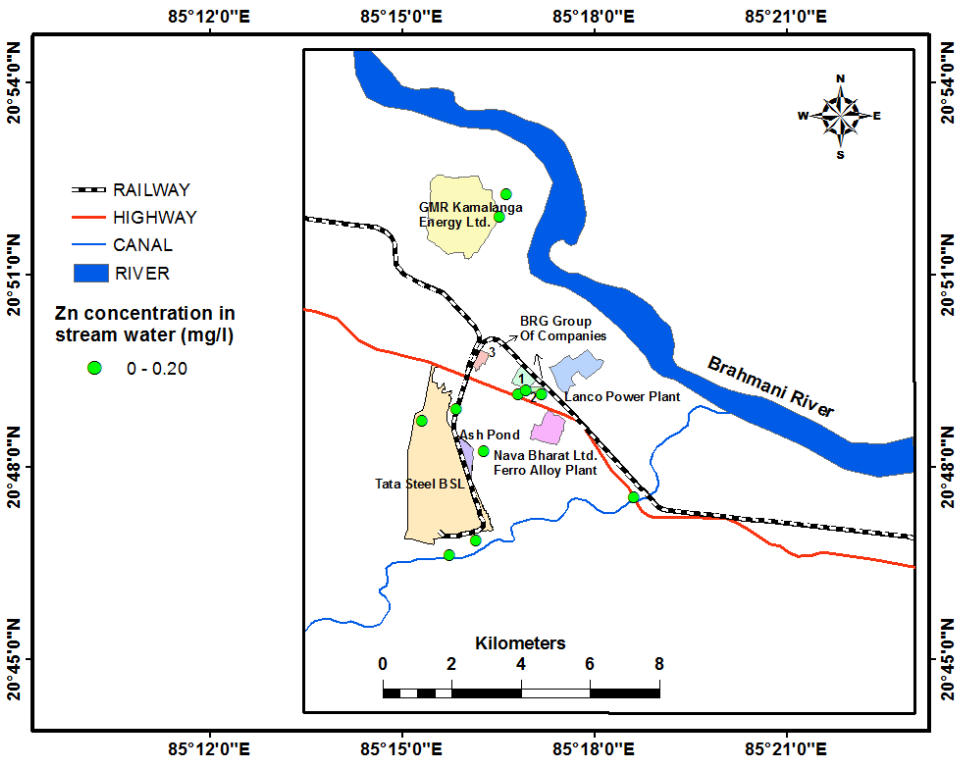


Fig.3.21: Zn in SW map in Dhenkanal district

3.4 Aquifer Groups and their demarcation

Based on extensive analysis of historical data, micro level hydrogeological survey data generated and ground water exploration carried out in the area, the following two types of aquifers can be demarcated and the details are given below:

Aquifer- I (Unconfined Aquifer): Unconfined aquifer, occurs in entire area except rocky outcrops, formed by the weathered mantle atop all crystalline as well as Gondwana formations and discontinuous alluvial tracts along major river channels. This aquifer generally occurs down to maximum depth of 30m bgl. Based on field observations, isopach map of Aquifer–I is generated and shown in **Fig. 3.9.**

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, the yield of bore wells constructed in them depends on the rock type. As per the ground water exploration, carried out by CGWB. Aquifer-II in Granitic rocks has better yield in comparison to Gondwanas, Charnockites and Khondalites. In general, most of the fracture zones are encountered within 0 to 150 mbgl and seldom beyond that. Thus the maximum depth for the Aquifer-II has been taken as 200 mbgl.

The characteristics of the aquifer groups are summarized in **Table 3.4**.

Table 3.5: Characteristics of Aquifer Groups in Dhenkanal 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 **Lower Gondwana**: Sandstone, Shale and conglomerate **Pre-cambrian**: Granite Gneiss, Charnockite, Khondalite,	0-30	10-50 m^3/day	Specific Capacity Index: 0.5-40 lpm/m/m^2	Yes for both
Aquifer-II (Semi-confined to Confined)	**Fractured** Granite Gneiss, Charnockite, Khondalite, Gondwanas	30-200	Negl.-2 lps	Transmissivity: 0.95-6	Yes for both

3.5 Aquifer Disposition

The ground water exploration data and VES data has been used to generate the 3D disposition of the aquifer system. It comprises of all existing litho-units and the zones tapped during the groundwater exploration, forming an aquifer. Based on the groundwater exploration and micro-level hydrogeological and geophysical survey data and aquifer delineation method, a 3-D schematic aquifer disposition and a fence diagram have been prepared and shown in **Figs. 3.22 and 3.23.** Three 2D schematic sections were drawn along lines A-A', B-B', and C-C', which are shown in plan view in **Fig.3.24** and the corresponding 2D schematic sections are shown in **Fig. 3.25**, **3.26 and 3.27**.

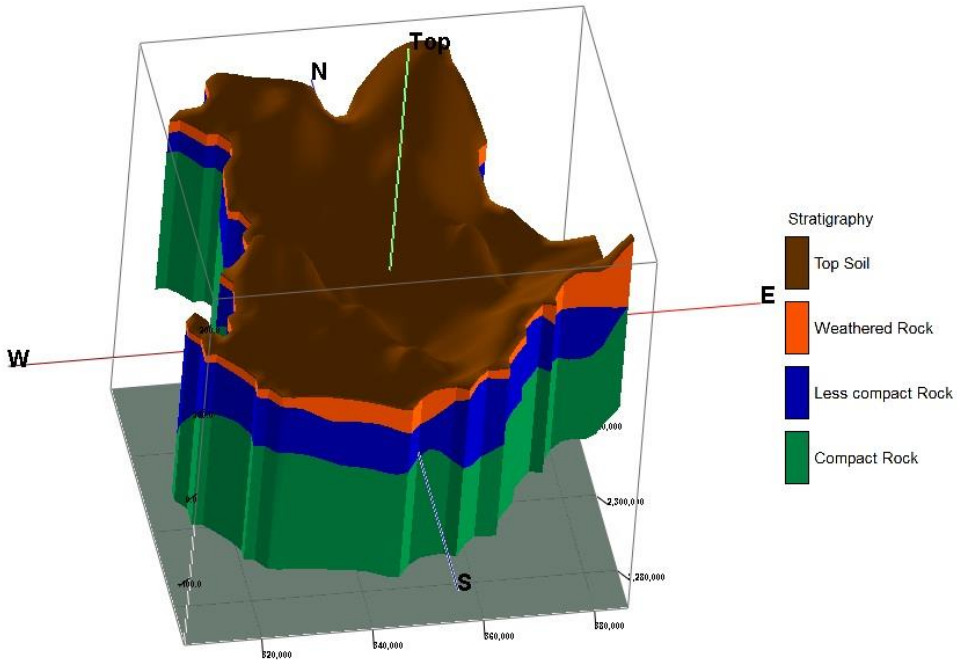


Fig. 3.22: 3D aquifer disposition of Dhenkanal District

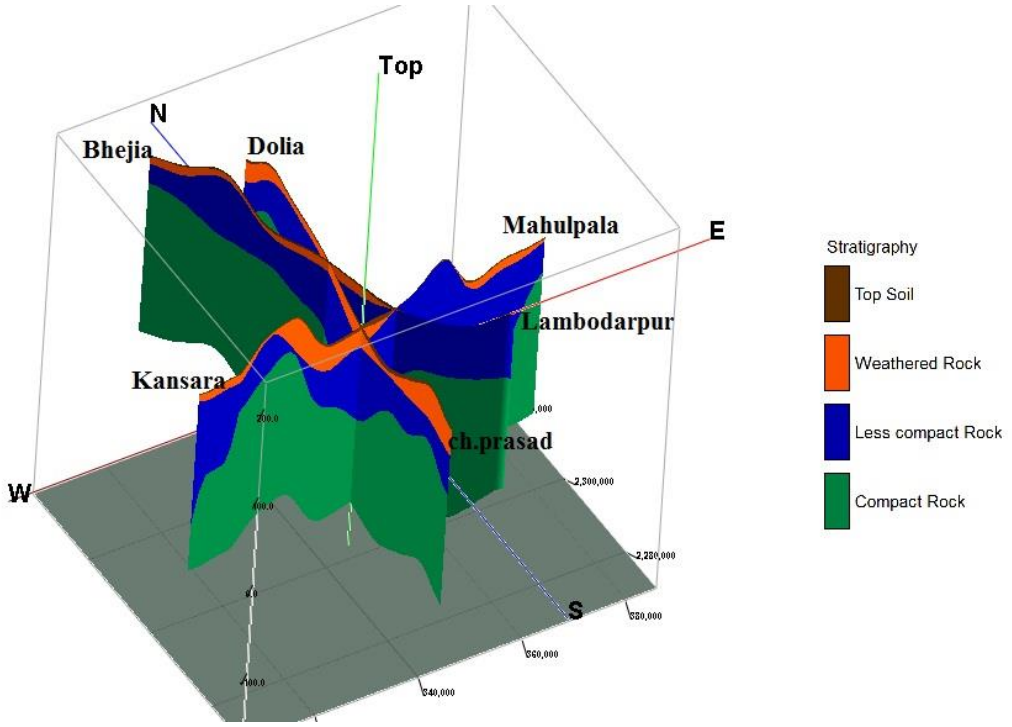


Fig. 3.23: Fence diagram depicting the aquifer disposition in Dhenkanal District

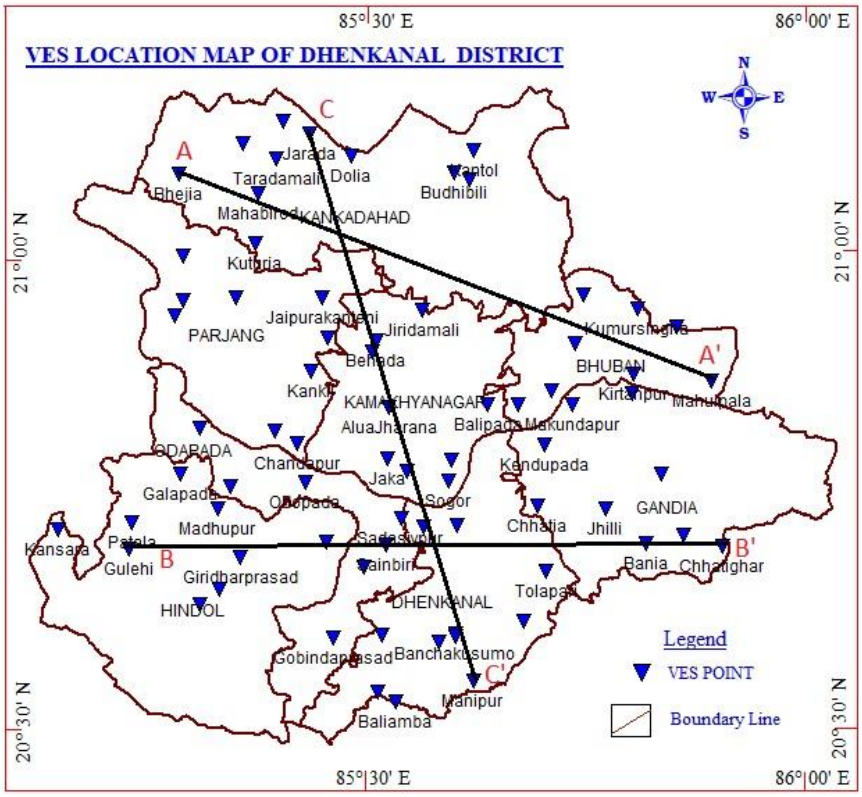


Fig. 3.24: Location and plan view of schematic hydrogeological cross-sections in Dhenkanal District

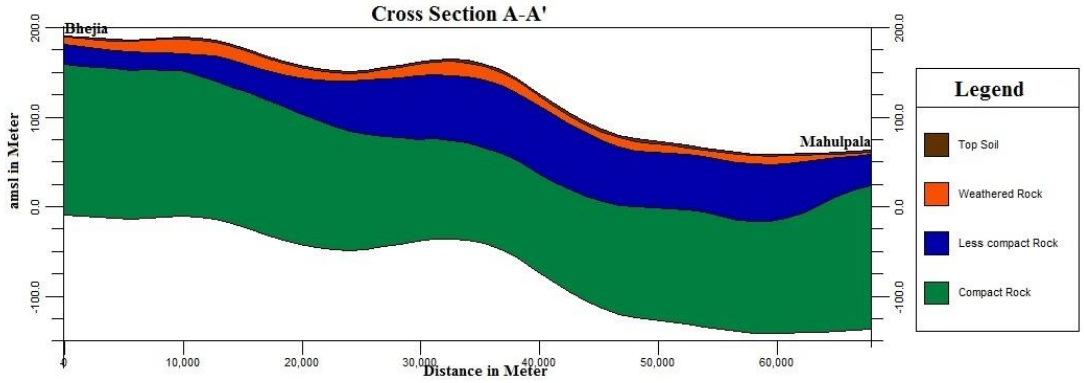


Fig. 3.25: Schematic aquifer cross-section A-A' in Dhenkanal district

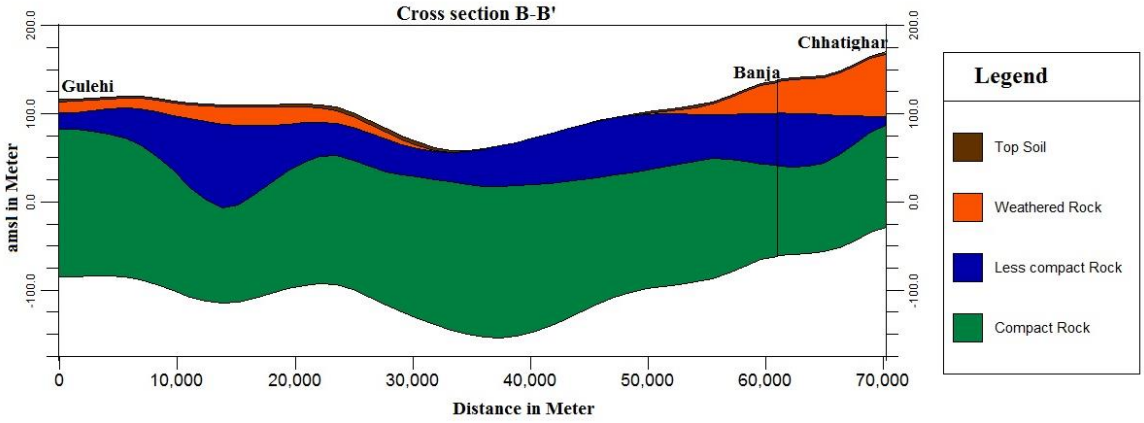


Fig. 3.26: Schematic aquifer cross-section B-B' in Dhenkanal district

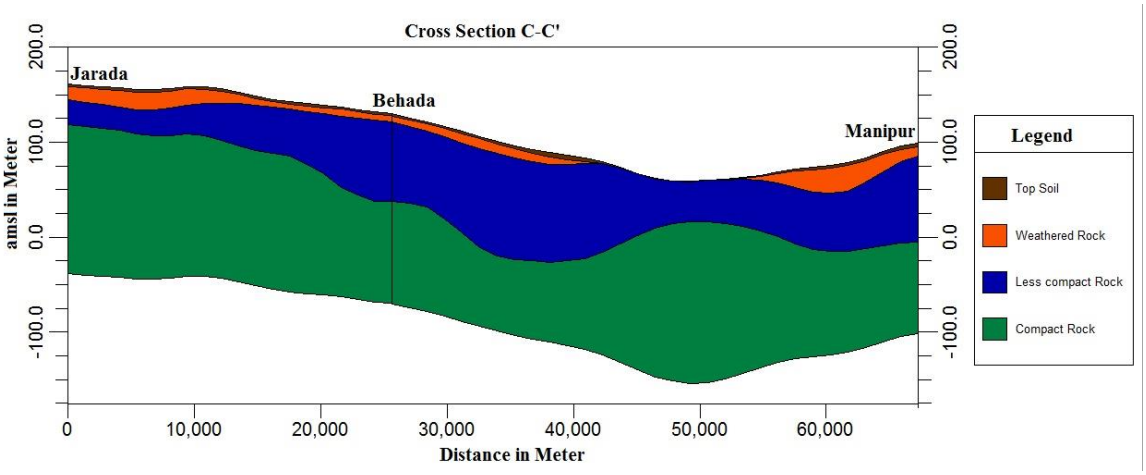


Fig. 3.27: Schematic aquifer cross-section C-C' in Dhenkanal district

4 GROUND WATER RESOURCES

The dynamic ground water resource of the district was jointly carried out in 2020 by Central Ground Water Board (CGWB) and Ground Water Survey and Investigation (GWS&I) adopting the methodology recommended by GEC 2015. The ground water resource can be aquifer wise divided into Dynamic and Static resource. 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 calculation of recharge. The block-wise resource of the aquifer mapping blocks as on 2020 is given below in **Table 4.1.**

Table 4.1: Dynamic Ground Water Resources of Aquifer-I in Dhenkanal district. (2020)

Sl No	Block	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for Irrigation	Existing Gross Ground Water Draft for domestic & Industrial Supply	Existing Gross Ground Water Draft for all uses	Annual ground water allocation for domestic water supply as on 2025	Net Ground Water Availability for future irrigation development	Stage of Ground Water Development
		(Ham)	(Ham)	(Ham)	(Ham)	(Ham)	(Ham)	(%)
1	Bhuban	2182.08	1416.05	406.3	1822.4	431.67	2182.08	45.22
2	Dhenkanal	1910.81	2443.48	911.0	3354.56	881.78	1910.81	62.89
3	Goundia	3595.99	1252.04	427.0	1679.13	453.08	3595.99	31.67
4	Hindol	5417.59	1395.41	514.7	1910.14	538.57	5417.59	25.94
5	Kamakshyanag	4692.45	797.51	427.8	1225.33	434.75	4692.45	20.62
6	Kankadahadaa	5081.15	924.41	319.0	1243.41	346.58	5081.15	19.57
7	Odapada	1441.26	1968.11	557.4	2525.56	428.19	1441.26	63.33
8	Parajang	3845.56	2173.8	381.9	2555.75	380.88	3845.56	39.86
	Total	28166.89	12370.8	3945.45	16316.28	3895.5	28166.89	36.48

The combined net ground water available is 28166.8 Ham and gross annual draft is 16316.28 Ham. The stage of ground water development is minimum for Kankadahada block which is 19.57 %. The highest ground water development is in Odapada block that is 63.33 %

and all the blocks are in Safe category.

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 continuous recharge. The In-storage ground water resources of Aquifer-I are given in **Table 4.2** and the total resources of Aquifer-I in **Table 4.3** below.

Table 4.2: In-Storage Ground Water Resources of Aquifer-I in Dhenkanal district

Sl No	Block	Assessment Area	Bottom Depth of Aquifer	Average Pre-monsoon Water Level	Total Effective Saturated Thickness 5% of (2-3)	Average Specific Yield	In Storage Ground Water Resources [(1)*(4)*(5)]
		(Ha) (1)	(mbgl) (2)	(mbgl) (3)	(m) (4)	(5)	(Ham) (6)
1	Bhuban	28004	100	5.18	4.741	0.03	3983.009
2	Dhenkanal	46907	100	4.78	4.761	0.03	6699.727
3	Goundia	55864	100	4.68	4.766	0.025	6656.196
4	Hindol	65362	100	5.69	4.7155	0.025	7705.363
5	Kamakshyanagar	41518	100	6.95	4.6525	0.03	5794.875
6	Kankadahad	75480	100	6.31	4.6845	0.025	8839.652
7	Odapada	34207	100	5.97	4.7015	0.03	4824.726
8	Parajang	50533	100	5.25	4.7375	0.03	7182.003
	Total						51685.549

Table 4.3: Total groundwater resources of Aquifer-I in Dhenkanal district (2020)

Sl No	Block	Dynamic Resource	In Storage Resource	Total Ground Water
1	Bhuban	2182.08	3983.009	6165.089
2	Dhenkanal	1910.81	6699.727	8610.537
3	Goundia	3595.99	6656.196	10252.19
4	Hindol	5417.59	7705.363	13122.95
5	Kamakshyanagar	4692.45	5794.875	10487.33
6	Kankadahad	5081.15	8839.652	13920.8
7	Odapada	1441.26	4824.726	6265.986
8	Parajang	3845.56	7182.003	11027.56
	Total	28166.89	51685.549	79852.44

The in-storage ground water resource in Aquifer- II i.e. the semi-confined to confined aquifer is shown in **Table 4.4**.

Table 4.4: In-Storage groundwater resources of Aquifer-II in Dhenkanal district (2020)

Sl No	Block	Assessment Area	Bottom Depth of Aquifer	Average Pre-monsoon Water Level	Total Effective Saturated Thickness 5% of (2-3)	Average Specific Yield	In Storage Ground Water Resources [(1)*(4)*(5)]
		(Ha) (1)	(mbgl) (2)	(mbgl) (3)	(m) (4)	(5)	(Ham) (6)
1	Bhuban	28004	200	5.18	9.741	0.03	8183.60892
2	Dhenkanal	46907	200	4.78	9.761	0.03	13735.7768
3	Goundia	55864	200	4.68	9.766	0.025	13639.1956
4	Hindol	65362	200	5.69	9.7155	0.025	15875.6127
5	Kamakshyanagar	41518	200	6.95	9.6525	0.03	12022.5748
6	Kankadahad	75480	200	6.31	9.6845	0.025	18274.6515
7	Odapada	34207	200	5.97	9.7015	0.03	9955.77631
8	Parajang	50533	200	5.25	9.7375	0.03	14761.9526
	Total						106449.149

5 AQUIFER MANAGEMENT PLAN

The highly diversified occurrence and considerable variations in the availability and utilization of groundwater makes 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.

5.1 Ground Water Related Issues

5.1.1 Fluoride and heavy metals in groundwater

Incidence of high concentration of fluoride in ground water of Dhenkanal district has been detected near Meramundali pollution cluster. Heavy metals like Fe, Zn, Mn, Cd , As are also reported in the same area. Since the ground water is not suitable in these areas, alternate sources to be provided to the public for drinking and daily use. The pollution in the quality of water in the Mearamundali pollution cluster is due to the steel, power industries present there.

5.1.2 Under utilization of groundwater resources

As per the ground water resource estimated jointly by CGWB and State Govt. in 2017, the t Ground Water use is less in all blocks except Dhenkanal and Odapada blocks of Dhenkanal. As the stages of ground water development are below 40%, thus there is ample scope exists for further ground water development.

5.1.3 Ground Water Problem in Hilly Areas

Dhenkanal district receives adequate rainfall and the normal annual rainfall is 1442 mm. The southern parts of the district are mainly of of hilly terrain and thus high run off zone. They act as recharge zones as well as good reservoir 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 there is scarcity of water in these areas in lean and summer season.

5.1.4 Less Productive Deeper Aquifer

The exploratory drilling in the district reveals that the deep fractured aquifer is less productive. Many of the bore wells drilled in the district has very poor discharge. The failure rate of bore wells is very high.

5.2 Aquifer Management Plan

5.2.1 Management plan for higher concentration of Fluoride and heavy metals

As the problem of Fluoride and heavy metals is restricted to surface water and phreatic aquifer in the Meramundali pollution cluster, alternate sources may be provided to the public. Hence deeper aquifers form a better alternative source for the domestic use in this area.

5.2.2 Management plan for under-utilization of groundwater

Proposed Interventions: There is very little scope for the demand side interventions as the district experiences acute shortage of water during the lean seasons. However to meet the irrigation requirement in relatively water deficient areas, efficient irrigation techniques such as drip and sprinkler should be practised. No other demand side intervention is feasible.

For the supply side intervention, further development of ground water resource is possible as there is sufficient scope for this is available in the district as the present ground water development ranges from 19% to 69 % in the district. The quantum of water available for extraction from the phreatic aquifer is thus calculated, keeping the percentage of ground water development within 60%. The same is shown in the **Table 5.3**.

Structures Feasible: The feasible ground water structures and probable yield in different geological units in Dhenkanal district is given below:

Granite and Granite Gneiss: Ground water occurs in weathered horizon in unconfined condition, yield of dug well upto 50 m3/day; Deeper fracture zones - yield of bore wells within 2.0 lps, occasionally upto 5 lps.

Charnockites: Ground water in weathered zone in unconfined condition, yield of dug wells up to 30 m^3/day; Deeper fracture zones- yield of bore wells less than 1 lps

Khondalites: Ground water in weathered zone in unconfined condition, yield of dug wells upto 50 m^3/day; Deeper fracture zones- yield of bore wells less than 1 lps

Lower Gondwana: The semi-consolidated sandstones are friable and exhibit well developed bedding planes and open joints. The yield potentials of dug wells up to 20 m^3/day. Shallow tube wells yield less than 1 lps.

Table 5.3: Ground water development potential of Dhenkanal district

Block	Net Ground Water Availability (Ham)	Stage of Ground Water Development (% in 2017)	Present Ground Water Draft (Ham)	Ground Water draft at 60% Stage of development (Ham) (1)*0.6	Surplus Ground Water at Present Stage of development (Ham) (4)-(3)	Number of BW/ STW Recommended in Each block (assuming unit draft as 2.21 ham per structure per year) 50%	Number of DW Recommended in Each block(assuming unit draft as 0.26 ham per structure per year) 50%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Goundia	3595.99	31.67	1679	2157.594	478.464	108	416
Hindol	5417.59	25.94	1910	3250.554	1340.414	303	1166
K Nagar	4692.45	20.62	1225	2815.47	1590.14	360	1384
Kankadahad	5081.15	19.57	1243	3048.69	1805.28	408	1571

5.2.3 Management Plan for Scarcity of Water

Due to uneven and hilly terrain and lower ground water recharge and storage capacity, there are many areas where the phreatic aquifer quickly de-saturates causing water scarcity during non-monsoon periods. To enhance the ground water availability, suitable measures for augmentation of monsoon recharge, should be taken up. In the foot hill 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**.

5.2.4 Management Plan for less productive deeper aquifer

Selection of proper site for drilling of bore wells, based on the favourable hydrogeological conditions has to be done. As discussed earlier, a lot of scope exists for ground water development. Priority should be given to the phreatic aquifer for extraction of ground water through large diameter dugwells and dug cum borewells at hydrogeologically suitable locations.

5.2.5 Management Plan for depleted water level in phreatic aquifer

The problem of water level depletion in the phreatic aquifers can be addressed through artificial recharge and through various water conservation structures. As the deeper aquifer is usually less productive, injection wells are less feasible. Rather surface spreading techniques will

be useful in these areas. During the canal running days the phreatic aquifer gets adequate recharge from the canal water. Thus the foot hill areas to the Main Canals 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. 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.
3. Construction of percolation tanks, check dams can be done.

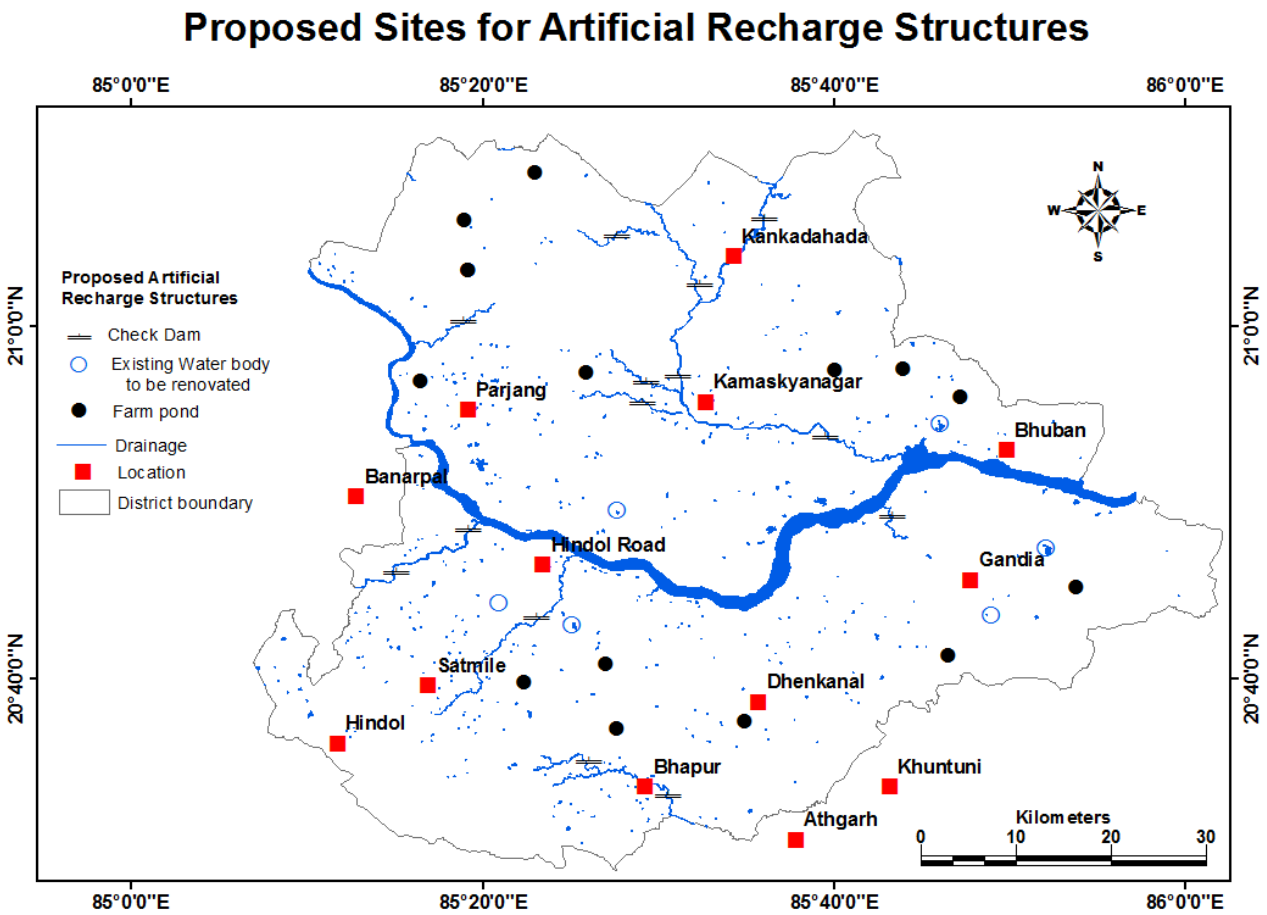


Fig. 5.2: Proposed sites for artificial recharge Structures.

6 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 aspirational district of Dhenkanal, covering the blocks of Bhuban, Dhenkanal, Gondia, Kamakshyanagar, Kankadahada, Prjanga, Hindol and Odapada covering an area of 4552 sq. km., during the period 2018-2019. The following are the summarised details.

Dhenkanal district has a total geographical area of 4,452 sq. km with 3 subdivisions and 8 administrative blocks. The total population of the district as per 2011 census is 11,92,948.

Physiographically, Dhenkanal district is characterized by rugged forest cladded mountainous terrain with narrow intermontane valleys. The district has three sub-divisions, Dhenkanal, Bhuban and Kamakyshyanagar. The area falling in Dhenkanal are dotted with isolated hills of considerable height in contrast to Bhuban and Kamakyshyanagar sub-division, which has a mostly a flat topography. The drainage in the area is controlled by river Brahmani and its tributaries.

About 15.09 % of the total geographical area constitutes forest area. The net shown area is only 257927 Ha. Irrigation potential created in the district (2004-05) is 36770 Ha during Kharif and 7127 Ha during Rabi season, through surface water sources. Paddy is the principal crop grown in the district. Other crops grown in the district during autumn, winter and summer seasons are Pulses, Maize, Vegetables, Ragi, Sugarcane and Jute etc.

A major part of Dhenkanal district is underlain by Precambrian crystalline. Khondalite are the common rock type consisting of quartz, feldspar, sillimanite and garnet with graphite and biotite as accessories. Areas like Parjang and Kamakhanagar blocks are occupied by the lower Gondwana sedimentaries consisting of sandstone, shales, grits, conglomerates and laterite. Alluvium occurs as thin narrow patches. Depending upon the distribution of major lithounits, physiographic setup, extent of weathering and fracturing of hard rock the ground water development potential vary widely.

Depending upon geology, water bearing and water yielding properties, two major

Hydrogeological units have been identified in the district such as (i) Consolidated formations and (ii) Semi-consolidated formations. Major parts of the district are underlain by consolidated formations. Lithology and structure controls the occurrence and movement of ground water. The weathered residuum constitutes the shallow aquifer, while fractured and fissured hard rocks constitute the deeper aquifers. Ground water occurs under phreatic condition in weathered residuum and under semi-confined to confined condition in the deeper fractured rock. The semi-consolidated and unconsolidated formations form only shallow aquifers in which groundwater occur under unconfined conditions.

On an average 2 to 3 potential fracture zones are encountered which are generally restricted to about a maximum of 100 m depth. The quality of ground water from the shallow as well as deeper aquifers, in general, is good and water is suitable for drinking and irrigation purposes. However, in a few patches higher occurrences of iron and high total hardness and total dissolved solids have been observed where suitable precaution in their use and management are needed.

The principal source of groundwater recharge in the district is the rainfall infiltration. Other sources of recharge are seepage from surface water bodies, tanks, reservoirs etc and return seepage from applied irrigation.

The net ground water availability in the district is estimated to be 28166.8 hectare metre and for domestic and Industrial use (based on population projections up to 2025) is 3895.5 hectare metre. The annual draft through existing ground water extraction structures for irrigation use has been worked out to be only 12370.8 hectare metre and the gross annual draft for all uses is 16316.28 hectare metre leaving a balance ground water resource of 11850.52 hectare metre for further development for irrigation use. The present stage of groundwater development has been worked out to be 36.48 % only.

It is also observed that there is increase in soluble salts, heavy metals(Pb) & F concentration in peizometers installed around the ash pond or waste disposal site of industries such as GMR Energy Ltd , TATA-Bhusan Ltd. The Confined/Semi confined aquifer highly polluted due to leaching effect of nearby ash pond &waste disposal from phreatic aquifer.

6.2 Recommendations

For a sustainable ground water 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 ground water management strategy is suggested.

- Large scale planning for ground water resources development should be preceded by remote sensing studies and followed by intensive hydrogeological and geophysical surveys. Since the stage of ground water development in the district is only 37.40%, there is vast scope for development of available ground water resources for irrigation.

- Both old and defunct wells may be renovated by deepening down to the fresh rocks. For optimal utilization of ground water potential, the existing wells should be energized.

- In the hard rock areas, dug and bore and dug-cum-bore wells are feasible. Exploratory drilling aided by remote sensing studies followed by intensive hydrogeological and geophysical surveys may be carried out to delineate deep potential fracture zones in crystalline rocks.

- In areas where irrigation facility is available, three-crop season such as Kharif, Rabi-I and Rabi-II should be followed to make irrigation economically viable. The farmers should be educated through agricultural extension services, mass awareness and water management training programmes to adopt suitable cropping pattern, conservation of ground water and irrigation practices especially for drought tolerant crops for optimal utilization of available ground water resources.

- As the erratic and uneven pattern of rainfall sometimes causes mild drought in the district, ground water resources may be augmented through adoption of different artificial recharge techniques such as percolation tanks, nalla/contour bunding, small check dams, renovation of old tanks, sub-surface dykes, gully plugging, etc. in areas where deeper water levels coupled with high water level fluctuation are observed.

- The excess runoff in hilly and forest areas can be stopped by construction of percolation tanks in the higher reaches to enable the recharge of shallow aquifer.
- In case of shallow water table (3 to 5m) during post monsoon, surface water bodies like local ponds and small earthen dams may be constructed to hold water for longer duration.
- Conjunctive use of surface and ground water is recommended to ensure irrigation facility in all seasons in tail end areas of canal command and also to increase gross irrigation potential.
- For augmentation of drinking water supply to the major towns and villages near the major rivers, infiltration galleries or collector wells should be constructed in suitable locations to harness the base flow.
- Growing sugarcane and cash crops may be encouraged along the alluvial patches adjacent to rivers and streams flowing through the district.
- Rapid industrialisation (fly ash and waste generation) and Urbanisation has resulted in increase in the content of fluoride,heavymetals such as Pb,Mn,Fe,As with variation of time in drainage channels & ground water (Phreatic aquifer and confined/semi-confined aquifer) in industrial cluster of Angul-Talcher-Meramundali in the state of Odisha.
- The Industries should treat their effluents before discharging these in to connecting drainage channels, otherwise the content of F, heavy metals may increase in due course of time.
- All major industries should be asked to have wastewater treatment plant mandatory to minimize water pollution.
- The State Ground Water Organisation should render expert guidance for selection of ground water structures as well as should ensure conjunctive use of surface and ground water in the canal command areas in order to supplement irrigation in water scarcity areas.

- The financial institutions should generally come forward for financing ground water development schemes.