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Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

SAMBALPUR DISTRICT, ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

South Eastern Region, Bhubaneswar

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1. INTRODUCTION:

Central Ground water Board, South Eastern Region has taken up National Aquifer Mapping (NAQUIM) programme during the Annual Action Plan of 2022-2023 to carry out integration of hydrogeological, geophysical, hydrochemical data and on the basis of existing information on geology, geomorphology, soil, hydrometeorology, hydrology, landuse, cropping pattern etc., block - wise Ground Water Management Plan have been prepared on a GIS platform for the whole Sambalpur district. The formulation of 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.

Objectives: To establish the disposition of aquifers up to 200-meter depth. To know the ground water quality of the shallow and deep aquifers. To calculate the ground water resources up to 100-meter depth. To prepare a comprehensive ground water management plan (Supply side and Demand side) for the whole district.

Scope of the Study: Sambalpur District comprises of 50% forest areas and very few number of exploratory tube wells constructed before the NAQUIM study specially in Naxalite areas and forest areas. So to fill up the gap of scarcity of hydrogeological data, there is a good scope for work regarding details of aquifer mapping in this district and as per AAP 2022-23, this district has been chosen for aquifer mapping.

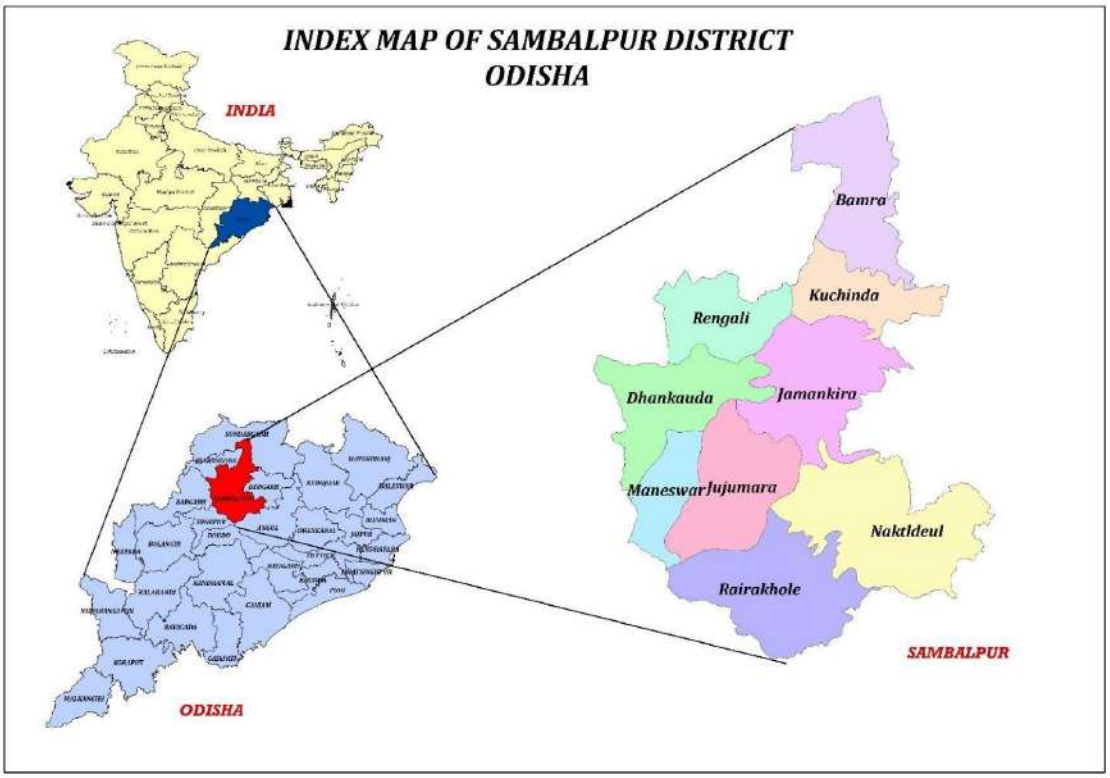
Approach and Methodology: The Sambalpur district is falling in parts of grid/sub grid area of the Toposheet number 64 O/14, 64 O/15, 64 O/16, 73 B/8, 73 C/1, 73 C/2, 73 C/3, 73 C/4, 73 C/5, 73 C/6, 73 C/7, 73 C/8, 73 C/9, 73 C/10, 73 C/11, 73 C/12, 73 D/1, 73 D/5. The data of all existing CGWB exploratory wells and NHS monitoring wells in the district are plotted on the Toposheets of 1:50000 scale with 5'X5'grid (9km x 9km). The exploration data shows that majority of tube wells falls in the Shallow aquifer (100 m depth) and Deep aquifer (from100 - 200 m depth). The grids/ formations devoid of SH/PZ/EW are

identified as data gaps and these are to be filled by data generation. Similarly, data gap established for ground water key monitoring wells (for collection of water level, quality etc.) in grids/sub grids and data generated for new established key wells. Similar methodology has been adopted for VES surveys. On the basis of aquifer disposition, decadal water level declining trend areas, availability of excess future ground water resources up to the year 2047 and surplus rainfall – runoff amount, a suitable supply side and demand side management plan for the whole Sambalpur district have been prepared.

Area details: Famous for its Sambalpuri Saree, the Sambalpur District is the western part of state of Odisha. The District is surrounded by Deogarh District in the East, Bargarh Districts in the West, Jharsuguda District in the North and Sonepur and Angul Districts in the South. The District of Sambalpur has a history full of events including Indian freedom struggle representing the different section of the society. Sambalpur is mentioned in the book of Ptomely as Sambalaka on the river Manada. Sambalpur District was subsequently divided into four separate Districts. Bargarh District was separated in 1993, and Jharsuguda and Deogarh Districts were separated in 1994.The District covering a geographical area of 6702 sq km lies between 20 degree 40’ to 22 degree 11’ North Latitude and 82 degree 39’ to 85 degree 15’ East Longitude.Total mappable area for NAQUIM study is taken as 4366 sq.km. Total population of the District as per 2011 census is 10,41,099. Total male population of the District is 5,26,877 whereas total female population is 5,14,222. Sambalpur is the 4th urbanised district in the state having 29.59 percent of its population live in urban areas as against 16.69 percent of state’s population living in urban areas (Fig-1). Many eminent personalities have taken birth on the soil of the Sambalpur District. Bir Surendra Sai (freedom fighter), Gangadhar Meher (Poet of nature), Bhama Bhoi (celebrated religious and poet), Satya Narayan Bohidar (Pioneer of Sambalpuri language and grammer), Swapneswar Das (accomplished poet and eminent journalist), Gokulanand Panda (Poet of extraordinary caliber), Sunil Mishra (renowned writer of humour and social satire), Braja Mohan Panda (Educationist of repute) and Laxmi Narayan Mishra (Eminent freedom fighter) are the famous personalities of this soil. The district is well connected by roads. The Administrative headquarter of the Sambalpur

District is located at Sambalpur City. As per the administration of the District is concerned, the District of Sambalpur has got 3 sub divisions namely Sambalpur, Kuchinda and Rairakhol. There are 9 Tehsils, 9 Blocks, 2 NAC's, 24 Police stations, 1349 Revenue Villages and 138 Gram panchayats functioning in the District. About 73.0 percent farmers in the district are having small and marginal holding and together they hold about 41.31 percent of available land. The large farmers (4.52 percent) hold about 20.29 percent of the land whereas semi-medium (15.20 percent) and medium farmers (7.89 percent) hold 21.09 percent and 17.25 percent of the available land respectively (District Irrigation Plan, Sambalpur, 2016) .

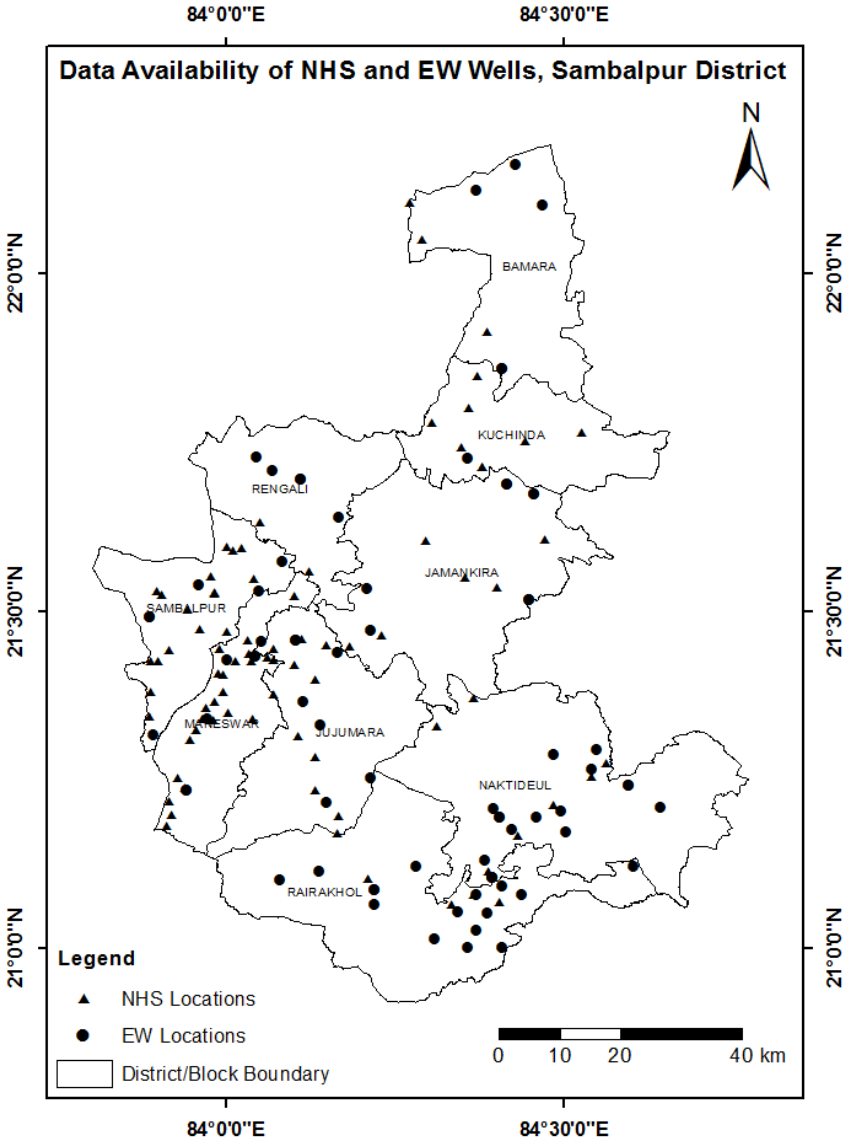
Fig.1. Location Map of Sambalpur District, Odisha



Brief Description (Data Availability, data adequacy, data gap and data generation):

a. **Data Availability**: Status of exploratory wells (only 72) and NHS monitoring wells (only 47) are plotted in the Fig.2.

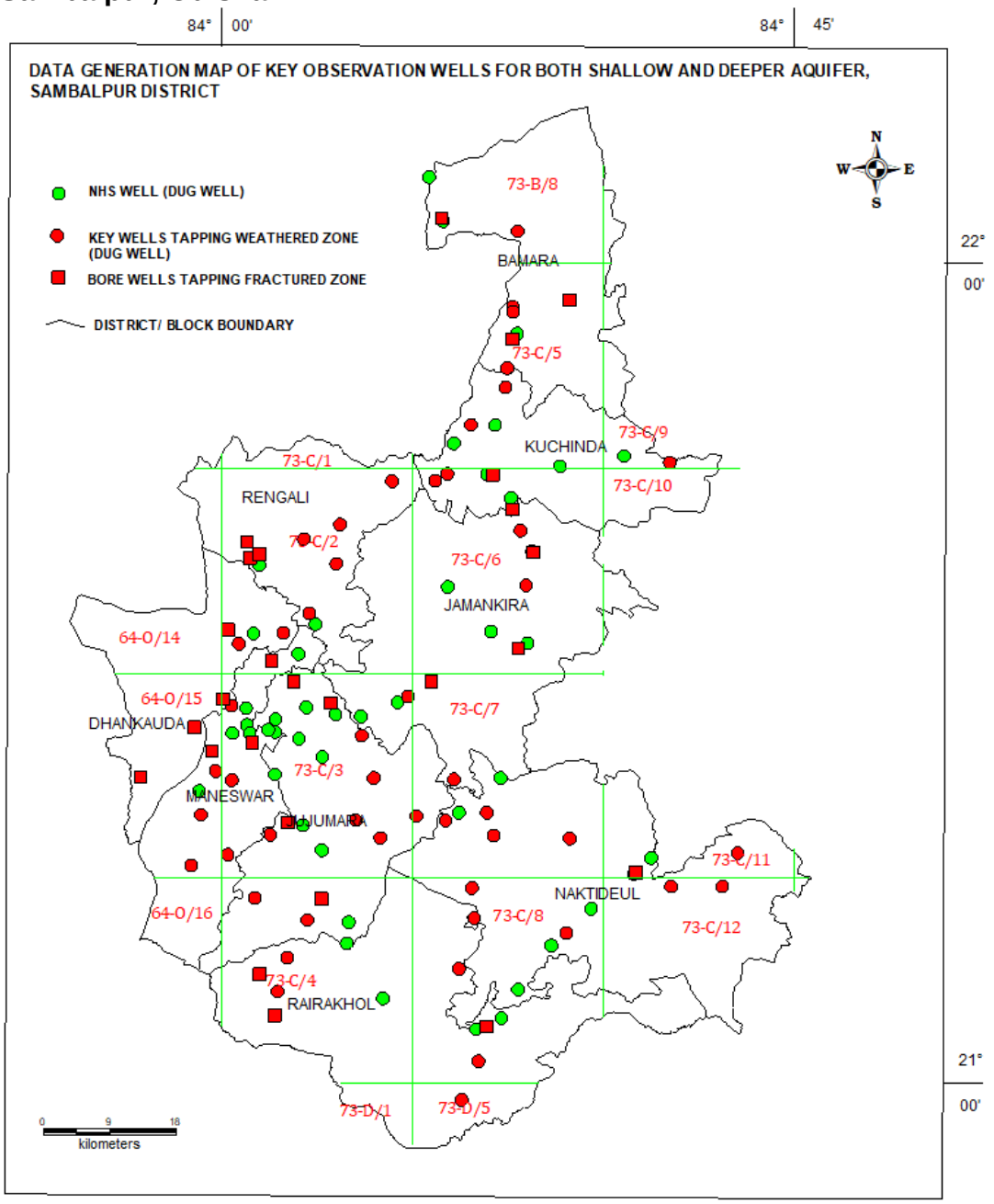
Fig.2. Availability of exploratory wells and NHS monitoring Wells, Sambalpur District.



b. **Data Adequacy and data gap analysis**:

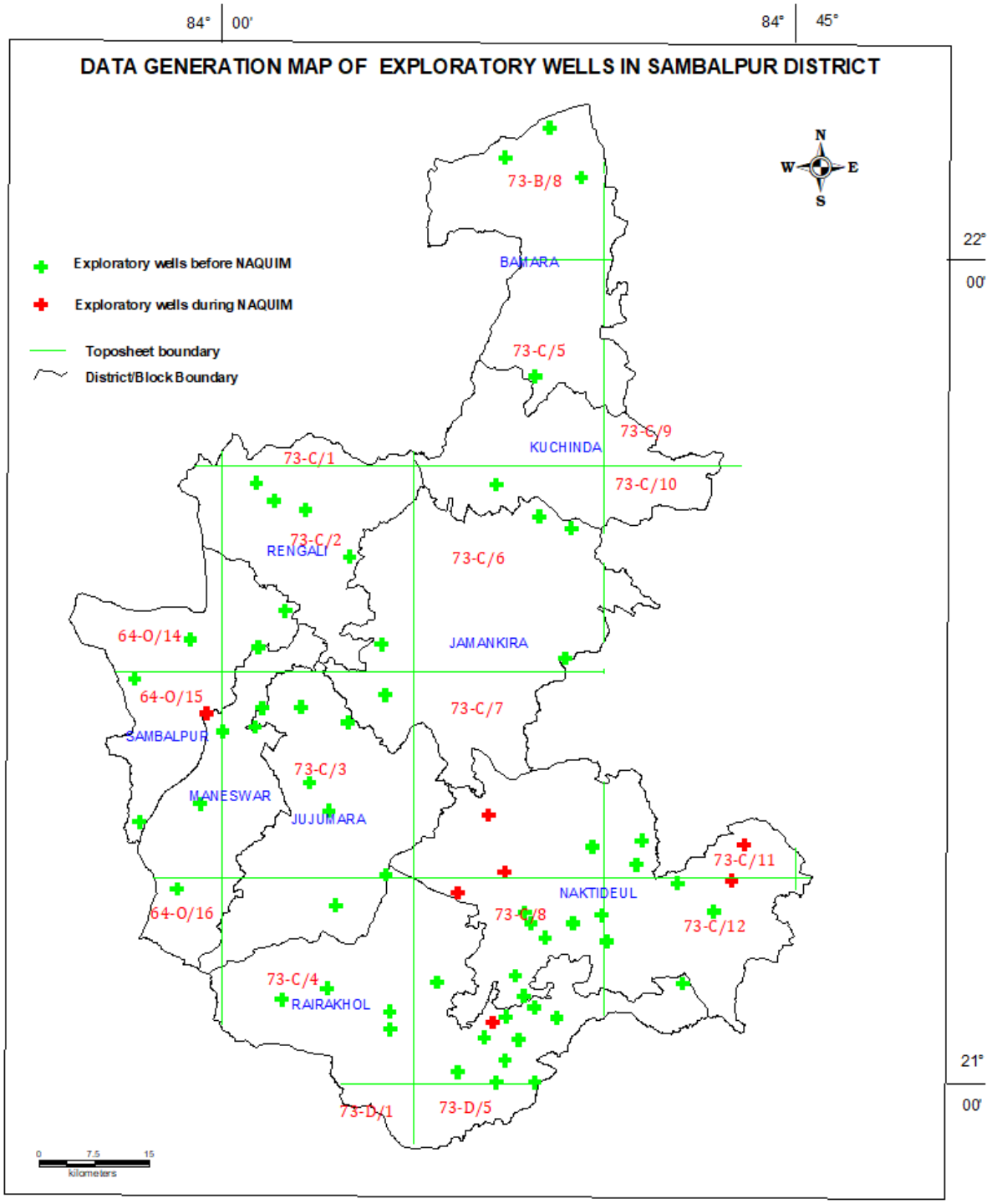
1. Monitoring Wells: On the basis of data adequacy of only 47 NHS monitoring wells data additional 50 key well have been selected to find the gap of water level monitoring and water quality analysis for shallow aquifer (mainly weathered zone and 26 additional bore well constructed witihin fractured zone for deeper aquifers are also considered for monitoring(Fig.3).

Fig.3. Data generation map after data gap analysis of Monitoring Wells, Sambalpur, Odisha



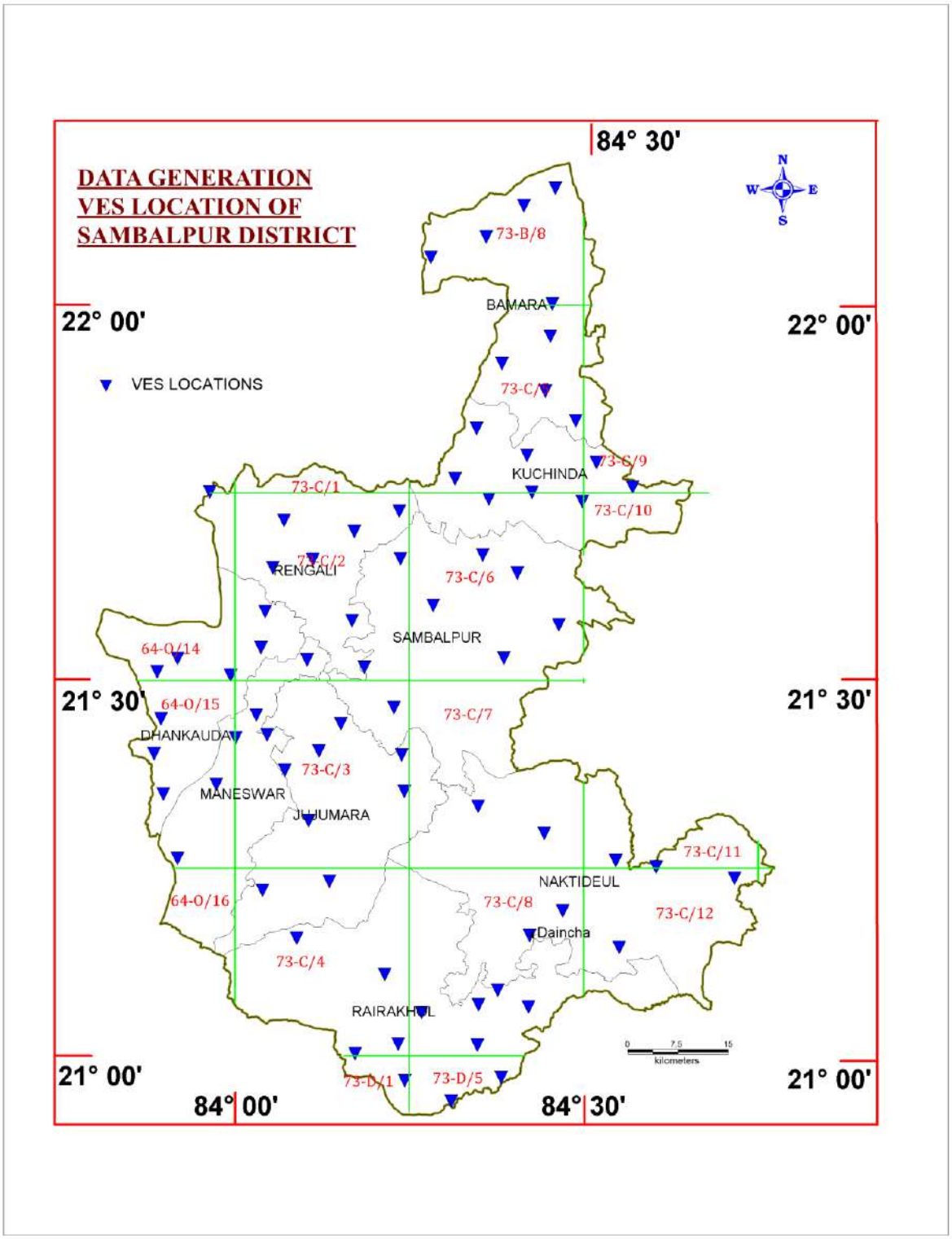
2. **Exploratory Wells:** On the basis of data adequacy of only 72 exploratory wells data additional 7 exploratory wells (EW) have been selected to find the gap of different aquifer disposition (Fig.4).

Fig 4. Data generation map after data gap analysis of Exploratory Wells, Sambalpur, Odisha



3. **VES Locations**: As Sambalpur district have been devoid of any VES surveys (as per previous reports) 75 uniformly distributed VES survey locations (Fig.5) have been selected to generated data up to 200 meter depth. Data generation interpretations are discussed in Annexure –II.

Fig.5. Data Gap and data generation analysis of VES surveys, Sambalpur District, Odisha



c. **Data Generation**: On the basis of construction of 79 exploratory wells a three-dimensional panel diagram and lithological sections in various

directions to show the disposition of weathered zone and fractured zone have been prepared. Similarly on the basis of data obtained from key wells, NHS wells and Bore Wells different types of water level map, decadal trend map, hydrograph, chemical quality parameters etc., are generated. Data generation points of Key wells, exploratory wells and VES locations are shown in Fig.3, 4 and 5.

Rainfall-spatial, temporal and secular distribution: Sambalpur District experiences extreme type of climate with 66 rainy days and 148.9 centimeters rainfall on an average per annum. Most of the rainfall is confined to the months from June to October visited by south west monsoon. Mercury rises upto 47^0C during May with intolerable heat wave and falls as low as 11.8^0C during December with extreme cold. Maximum rainfall has been observed in Jujumura block and minimum rainfall has been observed in Rairakhol block. The rainfall is highly uneven and irregular. Blockwise details of rainfall and yearwise rainfall of the whole district are given Table 1, 2 and 3 respectively. Rainfall distribution map is shown in Fig. 6.

Table 1 - Blockwise Normal Annual rainfall (mm), Average Annual rainfall (mm) and number of rainy days in Sambalpur District, Odisha

Name of Block	Normal Annual Rainfall (mm)	Average Monthly Rainfall (mm)	No. Of Rainy Days (number)
Bamra	1495.70	1476.40	59
Dhanakouda	1495.70	104.50	66
Jamankira	1495.70	1502.30	65
Jujumara	1495.70	13260	50
Kuchinda	1495.70	1657.2	57
Maneswar	1495.70	1092.20	53
Naktideula	1495.70	1381.30	58
Rairakhol	1495.70	1377.00	51
Rengali	1495.70	1099.00	50

Table 2- Year wise monthly rainfall (in mm) details of Sambalpur District (Source- Odisha Meteorological website)

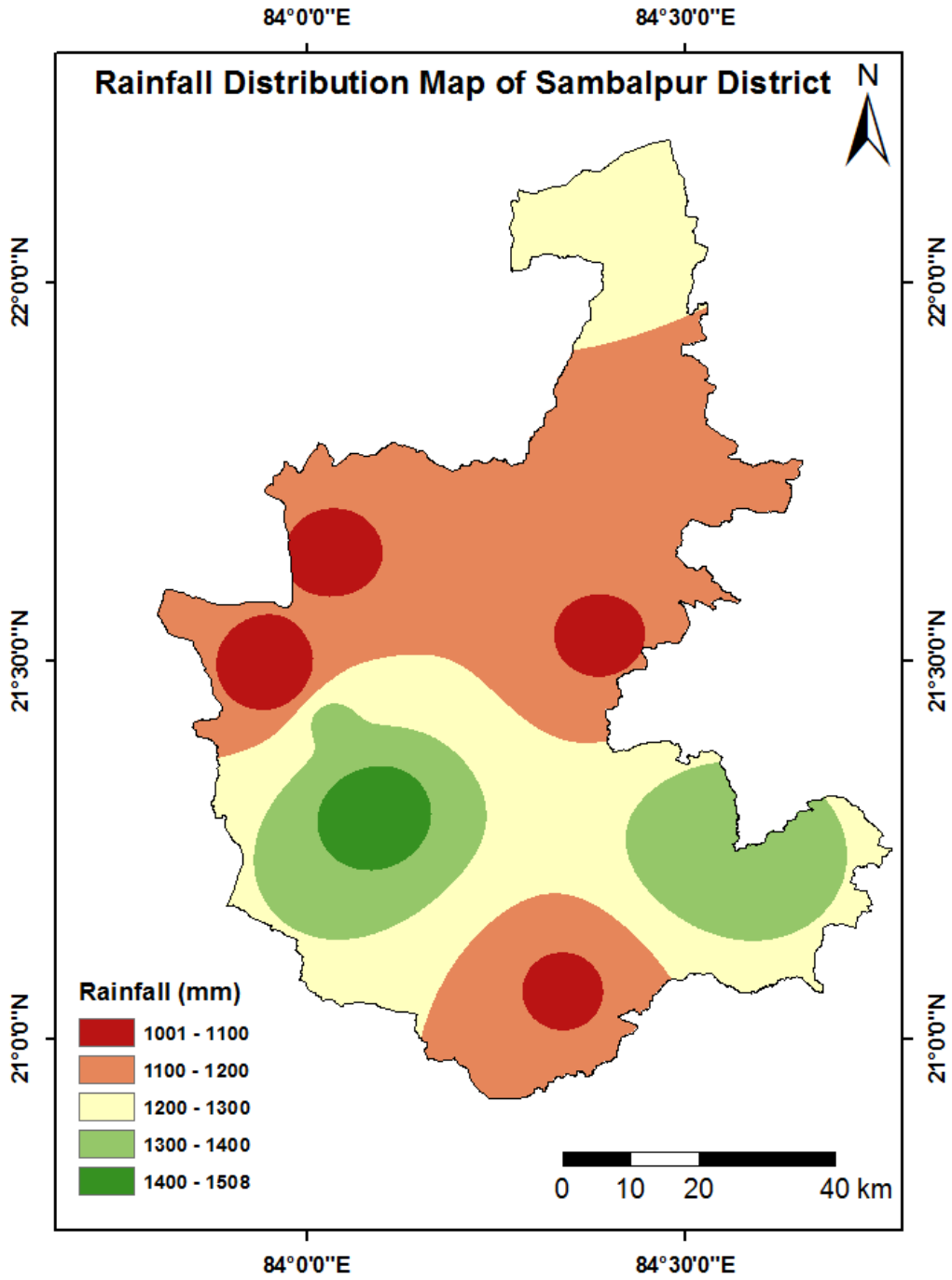
Sl. No.	Block Name	Total rainfall in 2017	Total rainfall in 2018	Total rainfall in 2019	Total rainfall in 2020	Total rainfall in 2021	Average rainfall (mm)
1	Jujumura	1291.6	1679.9	1676.6	1990	1507.8	**1629**
2	Dhankauda	1363.2	2181.4	1340.4	1567	1001	**1491**
3	Rengali	1127.9	1663.5	1611.1	1832	1075	**1462**
4	Maneswar	1279.9	1831.8	1607.6	1635.3	1327.6	**1536**
5	Kuchinda	1479.3	1717.7	1762	2258.6	1189.6	**1681**
6	Jamankira	1088.2	1638	1200.7	1460.4	1069.8	**1291**
7	Bamra	1323.6	1319.4	1505.9	1657.9	1231.7	**1408**
8	Rairakhol	1005.2	1615.7	2022.3	2000.7	1077.3	**1544**
9	Naktideul	1385.2	1296.2	1037	1695.3	1398	**1362**
10	**Average**	**1260**	**1660**	**1529**	**1788**	**1208.644**	**1489**

Table 3: Blockwise monthly rainfall (2021) in Sambalpur District, Odisha

Sl. No.	Block	January	February	March	April	May	June	July	August	September	October	November	December	Total
1	Jujumura	1.0	1.6	0.0	11.2	125.7	243.7	311.1	217.4	327.1	130.0	27.2	111.8	1507.8
2	Dhankauda	2.5	18.7	1.0	3.0	100.5	174.4	192.0	163.5	231.0	21.4	19.2	73.8	1001.0
3	Rengali	20.4	3.4	19.2	2.2	175.6	165.2	329.4	69.6	169.4	20.4	31.8	68.4	1075.0
4	Maneswar	10.4	2.8	10.6	4.6	112.2	238.8	322.6	89.2	377.0	39.4	6.8	113.2	1327.6
5	Kuchinda	9.0	8.5	18.0	5.6	127.6	391.4	275.6	44.4	147.6	9.0	82.8	70.1	1189.6
6	Jamankira	8.4	3.0	10.9	7.2	171.6	156.6	299.8	100.8	170.1	53.4	15.4	72.6	1069.8
7	Bamra	2.2	15.2	32.8	3.2	170.4	224.5	325.0	166.8	169.8	59.4	17.0	45.4	1231.7
8	Rairakhol	0.0	1.0	0.0	0.0	104.2	74.0	314.5	105.0	405.6	4.0	30.0	39.0	1077.3
9	Naktideul	4.0	0.0	0.0	8.0	128.0	121.0	421.0	239.0	357.0	35.0	28.0	57.0	1398.0
	Total	**57.9**	**54.2**	**92.5**	**45.0**	**1215.8**	**1789.6**	**2791.0**	**1195.7**	**2354.6**	**372.0**	**258.2**	**651.3**	10877.8
	Average	**6.4**	**6.0**	**10.3**	**5.0**	**135.1**	**198.8**	**310.1**	**132.9**	**261.6**	**41.3**	**28.7**	**72.4**	1208.6

Source: Meteorological Department, Odisha, 2021.

Fig.6. Rainfall Distribution map, Sambalpur District



Physiography and Geomorphology: Sambalpur district has three common geomorphological features comprising of denundational hills, pediments and pediplains and can be divided broadly in three units such

as (i) Northern hilly terrain of Bamra and Kuchinda, (ii) South eastern plateau and ridges of Rairakhol and (iii) South eastern valley and plains of Sambalpur Sadar sub-division. Average elevation of major parts of the district ranges from 100-300 meters above mean sea level with isolated hill peaks having height up to 772 meters above mean sea level. The highest and lowest topographic elevation of the district are 772 metre and 96 metres above mean sea level respectively. Elevation contour map is shown in Fig.7. Geomorphologically this district has been divided into several units and subunits (viz.,Buried pediment, plateau, gulley land, intermontane valley, paleochannel, pediment, structural hill,residual hill, linear ridge, valley fill). These units are shown in the Fig.8.

Fig.7. Elevation contour map, Sambalpur District

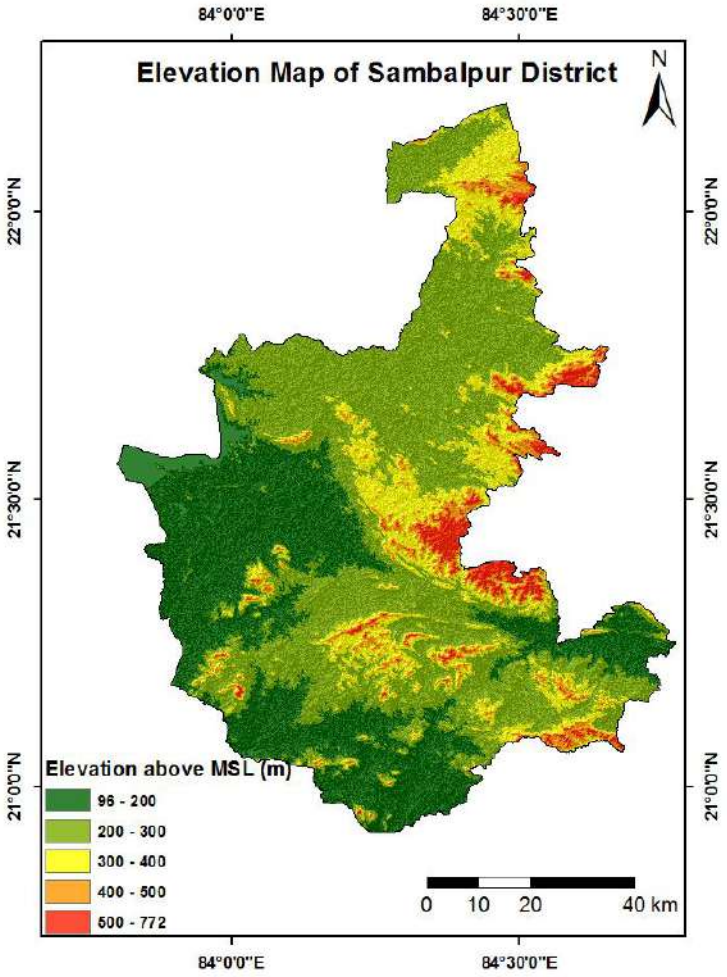
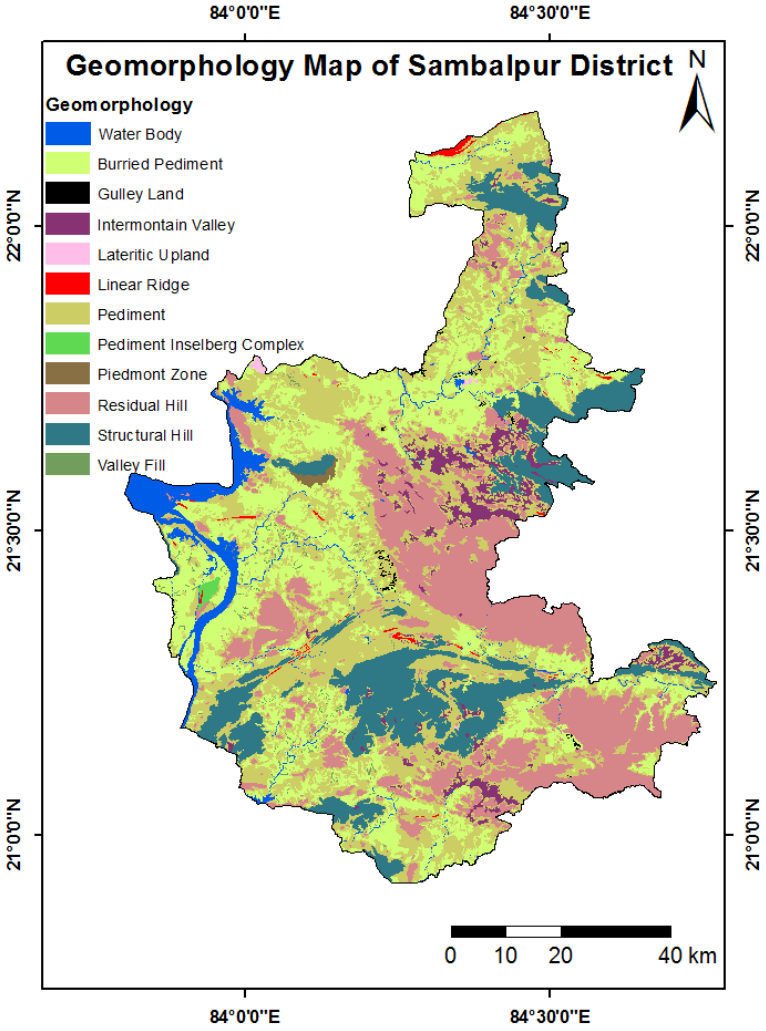


Fig.8. Geomorphology map, Sambalpur District, Odisha



Land use: Total geographical area of the district is about 6702 sq.km. The Net Area Sown is 26.88 percent of the total geographical area. Land under forest cover is highest in the district, i.e., 50 percent of the total geographical area. About 2.70 percent land of the district geographical area is barren and uncultivable waste land and 5.71 percent land is put to non-agricultural use. Miscellaneous tree groves and permanent pasture comprises 0.60 percent and 1.95 percent of the total geographical area of the district respectively (Fig.9). Block wise details of land use pattern are mentioned in Table-4.

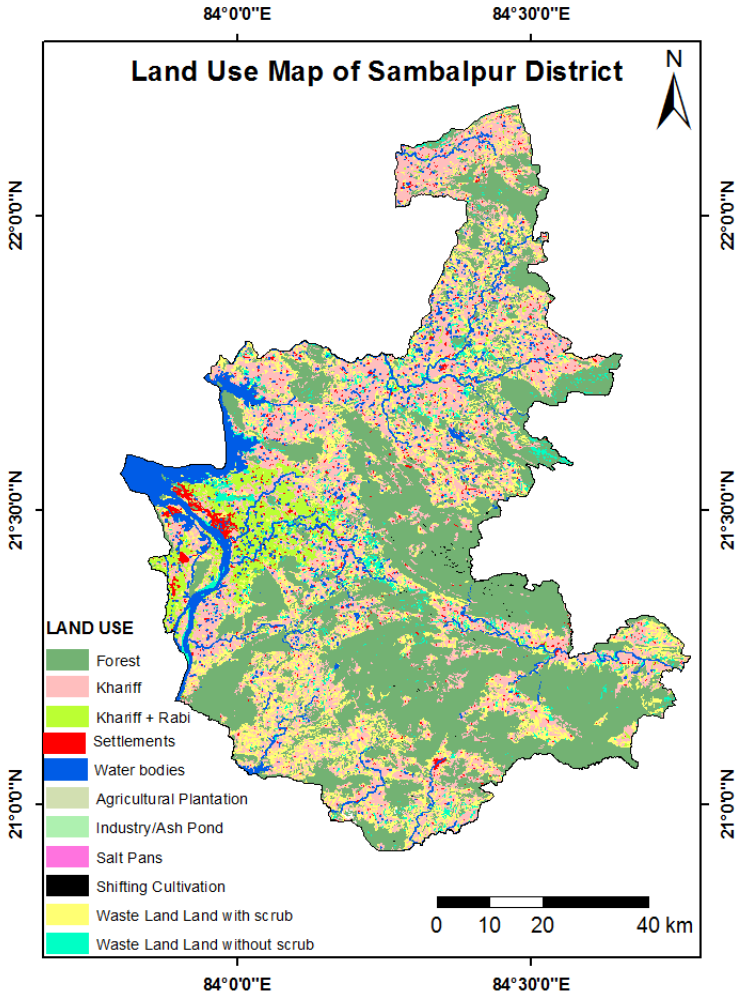
Table 4: Block wise Land use Pattern, Sambalpur District, Odisha

(Area in Ha)

Block	Geo. area	Forest Area	Misc. tree crops groves	Permanent pasture and other grazing land	Cultivable waste land	Land put to Non-agri. uses	Barren & un-culturable waste land	Current fallow	Other fallow	Net area sown
Bamra	51678	14339	242	406	1189	7254	345	0	117	27786
Dhankauda	28629	2247	48	4409	25	1830	60	0	533	19477
Jamankira	96866	62699	204	336	127	5267	6117	0	1334	20782
Jujomura	65280	19043	1214	2509	132	1085	975	0	17199	23123
Kuchinda	42178	6528	208	386	2254	4517	0	0	121	28164
Maneswar	29952	1914	324	545	1045	3412	665	0	270	21777
Naktideul	44796	18199	172	912	2325	5276	2254	0	1318	14340
Rairakhol	64766	23756	198	3365	8845	1728	4312	0	3315	19247
Rengali	36519	3849	764	346	4572	3654	1176	0	3180	18978
Block Total	**460664**	**152574**	**3374**	**13214**	**20514**	**34023**	**15904**	**0**	**27387**	**193674**

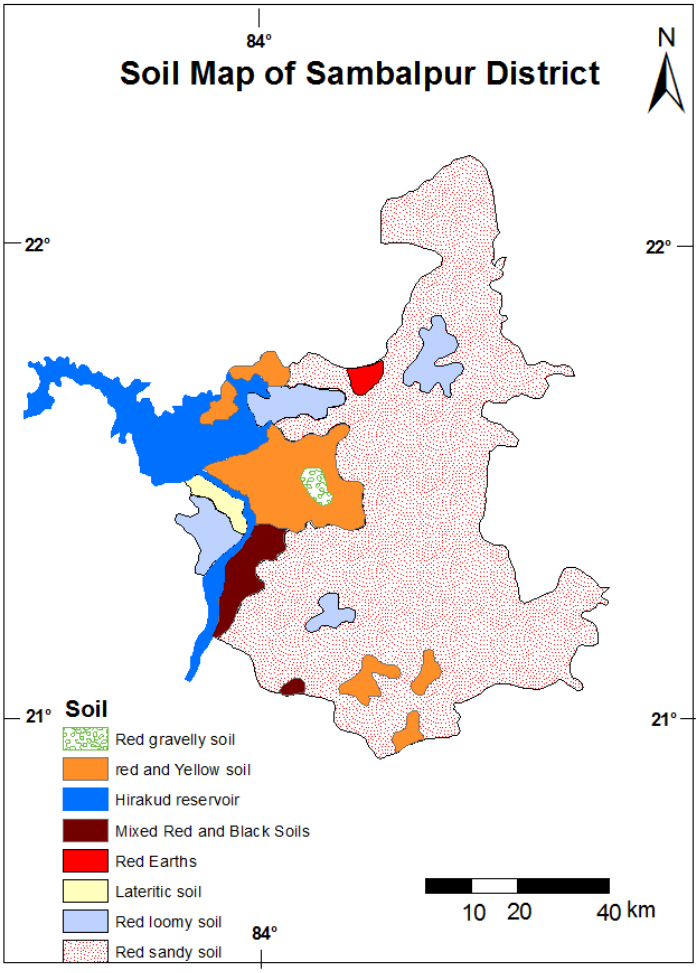
Source: ***District irrigation plan of Sambalpur, Odisha, PMKSY, 2016.***

Fig.9. Land use map, Sambalpur District, Odisha.



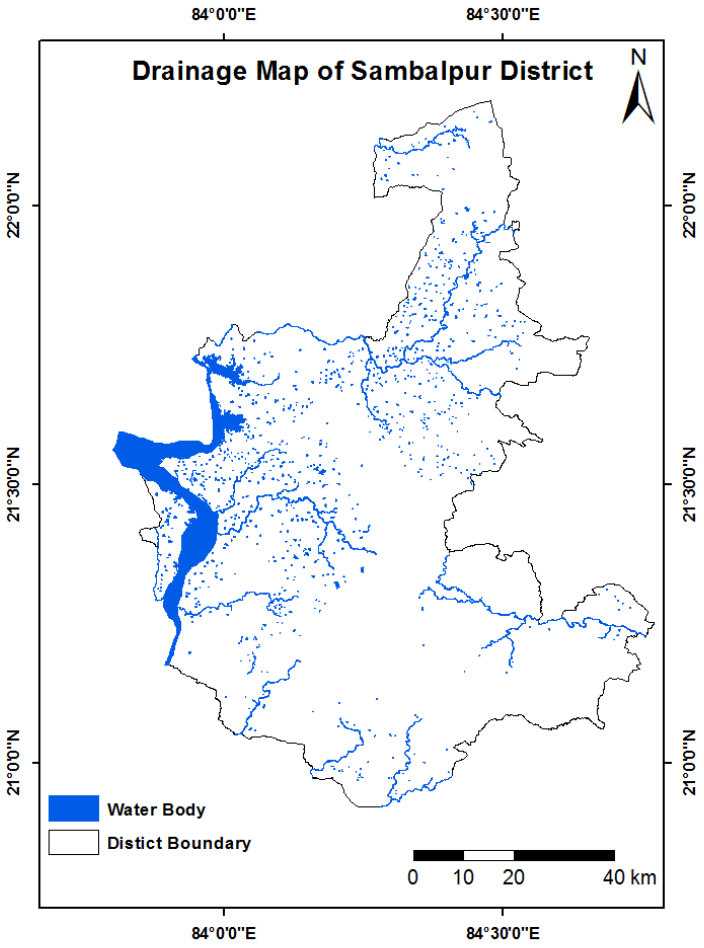
Soil: The soil type ranges from medium to deep black, red and yellow. Mainly two types of soils found in Sambalpur district, i.e., Ultisoils consisting of red, yellow and lateritic soils and mixed grey soil; Alfisoils predominantly include red gravelly, sandy, loamy, red earth mixed with black soils. The alfisoils cover about 60% of the area and are devoid of any lime concretions with pH ranging from 6.5-7.3. These soils are fertile and suitable for agriculture. (***District irrigation plan of Sambalpur, Odisha, PMKSY, 2016)***. Details of soil types are presented in Fig.10.

Fig.10. Soil distribution map, Sambalpur District, Odisha.



Drainage: The Mahanadi river basin forms an important part of the district geography. Apart from Mahanadi, the district is having important rivers like Maltijor, Harrad, Kulsara, Bheden and Phuljharan. (***District irrigation plan of Sambalpur, Odisha, PMKSY, 2016)***. The details of major drainages are shown in the Fig.11.

Fig.11. Major Drainage map, Sambalpur District, Odisha



Agriculture: In Sambalpur district crops are grown in khariff and rabi season. Crops are divided into cereals,pulses,oilseeds, vegetable, spices and sugarcane. Cereals crops are paddy , wheat, maize and ragi. Pulses crops are ground nut, til, sunflower and mustard. The major crop grown in the district are cereals and pulses in Kharif season. In Rabi season,

people grow cereals using available irrigation. Horticultural crops grown in both Rabi, Kharif and Summer season. Maneswar Block has the maximum growing area for cereals using available means of irrigation and Rengali block covers maximum pulses growing area using rain water in Kharif season. The Naktideul block has the lowest coverage of cereals production in Kharif and Rabi and Rengali block covers the lowest in Kharif cereals. Pulses are grown mostly by rain-fed conditions and followed by oilseeds and other horticultural and plantation crops. As rice is the staple food of the district, cultivation of Paddy is observed in both Kharif and Rabi. In an irrigated condition, productivity (yield) is observed higher than rain-fed area and blocks with higher irrigated area observed better production and productivity of Paddy in Kharif.

Cropping pattern and irrigation: During Kharif, major part of the irrigated area is used for growing cereals, followed by other crops. Further, major areas under rain-fed conditions are also used for growing cereals in Kharif. During Rabi season, major irrigated areas are used for other crops followed by cereals and pulses are majorly grown in rain-fed conditions during Rabi season. Crop wise area covered under irrigated and rain-fed conditions during Kharif and Rabi is presented in the table cereals, followed by other crops. Further, major areas under rain-fed conditions are also used for growing cereals in Kharif. During Rabi season, major irrigated areas are used for other crops followed by cereals and pulses are majorly grown in rain-fed conditions during Rabi season. Crop wise area covered under irrigated and rain-fed conditions during Kharif and Rabi is presented in the Table 5.

Table 5. Cropwise irrigated and rainfed area in Sambalpur District.

Crop Type	Kharif (in Ha.)			Rabi (in Ha.)			Total (in Ha.)		
	Irrigated	Rain-fed	Total	Irrigated	Rain-fed	Total	Irrigated	Rain-fed	Total
Cereals	51804	52996	104800	12928	0	12928	64732	52996	117728
Coarse Cereals	124	5404	5528	889	0	889	1013	5404	6417
Pulses	110	37265	37375	1534	15622	17156	1644	52887	54531
Oilseeds	109	15580	15689	6132	7783	13915	6241	23363	29604
Fibres	0	28	28	0	0	0	0	28	28
Other Crops	13365	18241	31606	22359	747	23106	35724	18988	54712
Total	**65512**	**129514**	**195026**	**43842**	**24152**	**67994**	**109354**	**153666**	**263020**

Source: ***District irrigation plan of Sambalpur, Odisha, PMKSY, 2016.***

Comparing the Net Sown Area vs Area Irrigated, it is observed that highest cultivated area in Dhankauda is having irrigation provision (83.71 percent) followed by Maneswar (79.16 percent). Lowest cultivated area having irrigation is in Rengali (11.70 percent), followed by Bamra (18.50 percent). Block wise total cultivated area and irrigated area is presented in the Table 6.

Table 6: Total Cultivated Vs Irrigated Area, Sambalpur District

Block	Net Sown Area (in Ha.)	Total Irrigated Area (in Ha.)	% Irrigated
Bamra	27,786	5,141	18.50
Dhankauda	19,477	16,305	83.71
Jamankira	20,782	5,713	27.49
Jujumura	23,123	8,197	35.45
Kuchinda	28,164	7,003	24.87
Maneswar	21,777	17,238	79.16
Naktideul	14,340	3,349	23.35
Rairakhol	19,247	3,641	18.92
Rengali	18,978	2, 220	11.70
Total	**1,93,674**	**68,807**	**35.53**

During Kharif the major source of irrigation is from Minor Irrigation tanks. During Kharif cropping season, irrigation through surface water is 74.35 percent and 25.65 percent is through ground water of the total area irrigated. So, use of surface water for irrigation during Kharif is more prevalent than ground water. Whereas, in Rabi cropping season, irrigation through ground water is maximum (64.04 percent of the total irrigated area) in comparison to surface water (35.96 percent of the total irrigated area). In total, including both Kharif and Rabi cropping season, irrigation through surface water is 63.64 percent and irrigation through ground water is 36.36 percent.

The district is having 100 numbers of Govt. canals which is having a command area of 19, 949 Ha. Apart from this, there are 119 Nos of Govt. reservoirs are there in the district under surface irrigation. For ground water irrigation, the district is having 29, 273 open wells of which 43.07 percent (12, 609 numbers) open wells are Govt. owned and 56.93 percent (16, 664 numbers) are private owned. Apart from open well, the district is also having 14, 393 bore wells which are used for irrigation in different

cropping seasons. Of the total 14393 bore wells, majority are Govt. owned (97.01 percent, 13962 numbers) and private ownership is limited to 2.299 percent (431 numbers). Blockwise existing type of irrigation sources, comprising both surface and ground water is presented in the table 7a.

Table-7a. Block wise details of Means of Irrigation, Surface and Ground Water, Sambalpur District

	Surface Irrigation			Ground water Irrigation			
Blocks	**Govt. Canals**	**Command area ha**	**Govt. Reservoir**	**Open well (Govt.)**	**Open well (Pvt.)**	**Bore Well (Govt.)**	**Bore Well (Pvt.)**
Bamra	8	2181	10	1276	2008	950	78
Dhankouda	2	295	5	421	1028	133	71
Jamankira	17	3799	18	1100	1398	687	101
Jujoumara	15	2199	18	1500	2115	1203	63
Kuchinda	6	2315	6	1363	1717	1271	118
Maneswar	9	1137	10	592	376	195	-
Naktideul	20	3868	24	1013	1404	1599	-
Raiakhol	12	3136	13	2376	3121	3065	-
Rengali	11	1019	15	2968	3497	4859	-
Total	100	19949	119	12609	16664	13962	431

Source: District irrigation plan of Sambalpur, Odisha, PMKSY, 2016.

Prevailing water conservation, recharge practices etc.: About 3788 Tanks/ponds and 634 water conservation structures are exists in Sambalpur District. These watersheds are being taken up for Run-off management, soil water conservation and improving soil-moisture regime (Dynamic Ground Water Resources Assessment of Odisha, 2020). The details of water conservation structures and recharge structures are shown in the Table-7b.

Table-7b. Block wise details of existing Tanks/Ponds and Water Conservation Structures, Sambalpur District, Odisha.

NAME OF BLOCK	**Number of Tanks/Ponds**		**Number of Water Conservation Structures**	
	Command Area	**Non Command Area**	**Command Area**	**Non Command Area**
JUJUMURA	45	447	7	77
DHANKAUDA	38	226	0	0
MANESWAR	329	251	40	31
KUCHINDA	29	497	5	92
RENGALI	0	293	0	69
JAMANKIRA	17	373	4	88
RAIRAKHOL	18	501	2	69
NAKTIDEOL	9	192	2	48
BAMRA	19	503	3	97
TOTAL	**505**	**3283**	**63**	**571**

2. DATA COLLECTION AND GENERATION

i. HYDROGEOLOGY: Previous study

Sambalpur district can be divided into two major hydrogeological units, viz (1) Consolidated formations comprising of hard rocks of Precambrian age occupying 85% of the area and (2) Semi-consolidated rocks of Gondwana Super Group occurring in pockets in northern and south eastern parts. Consolidated formations include Granite Gneisses, Khondalites, Charnockites, Schistose rocks and Epidiorites. Secondary porosity forms the conduits for movement of groundwater and also acts as reservoir of groundwater. Under phreatic condition, groundwater occurs in upper weathered residuum of rock masses at shallower depth. At deeper level, in fractured and jointed rocks, it occurs under semi-confined to confined condition.

A.Consolidated formations: This includes all the hard rocks of Precambrian age such as Granite gneiss, Khondalites, Charnockites, Schists, Phyllite, epidiorite. **Granite gneiss** occupy nearly 60% of the underlain by consolidated rock formation and mostly occurring in undulating plains and valley areas. The thickness of weathered zone in granitic rocks usually ranges from 10 to 15 m and occasionally extends beyond 25 m depth.The yield factor of the phreatic aquifer in granite gneiss ranges from 06 to 3.5 lpm/m^2 of the area/ m of drawdown with average value of 1 to 2 lpm/ m^2 / m drawdown.The yield factor is generally less in porphyritic granite gneiss than that of medium to coarse grained equigranular variety.The yield potentiality of deeper aquifer (upto 200 mbgl) varies from ne with average yield of 2 to 5 lps. The specific capacity of the well varies from 2.32 lpm/ m drawdown to 44 lpm/ m of drawdown with the average value of 10 to 20 lpm/ m drawdown.

Khondalites generally form hill ranges with narrow intermontane valleys.The weathered residuum and fracture zones constitute the main repository of ground water. The thickness of weathered zone ranges from 15 to 25 m. The yield factor of dug well zone ranges from 0.7 to 1.25 lpm/ m^2 / m drawdown. The highly schistose variety show less yield due to abundance of clay minerals. The characteristics of deeper aquifers have been ascertained from State government coupled with information of bore well data of other districts as in this district no

well has been drilled in khondalite,so far. The average yield of bore wells (100 m depth) is generally 1 to 2 lps with 25-30 m drawdown after running 4 to 5 hrs in a day.

Charnockites generally form hill ranges and narrow intermontane valleys.In generally the rocks are very hard and comapact.On an average thickness of weathered zones are restricted within 8 m depth in acid and intermediate variety while in pyroxene granulite it is around 10-12 m. The yield of existing wells in acid and intermediate variety is found to be 10-15 m^3/day and in pyroxene granulite it is around 25 - 30 m^3/day. The yield of deeper fractured aquifer upto a depth of 100 m varies from 1 to 2 lps. But maximum yield upto 10 lps have been observed in isolated patches from pyroxene granulite varieties. On an average the wells in acid and intermediate variety may be run for 3 – 4 hours in a day for a drawdown of pumping water levels around 30 m. While the wells in pyroxene granulite can run for 6-8 hours per day.The average values of specific capacity of the wells is around 4-6 lp/ m drawdown.

Schist and Phyllite occupy northern part of the district covering parts of Bamra and Kuchinda Block. Micaschist is the main rock types. Due to highly clay nature of weathered zone the yield of dug wells are less and varies from 12-15 m^3/day.The yield of bore wells are generally limited to 2 lps. The fracture zones are also restricted within 50-60 m depth. The little higher yield is observed from hard and fractured phyllitic rocks. As such these schists and phyllites donot form any potential aquifer either at shallow or deeper depth.

Metabasic rocks mainly includes epidiorites and amphibolites.These are found mainly in Jamankira block.The rocks are hard and compact but fractured.The thickness of weathered zone varies from 12 – 25 m depth. The yield characteristics of phreatic zone in this formation is more or less similar to granitic rocks. As per exploration results discharge ranges from 11 – 14 lps with a drawdown of 15 m. The fractures are observed within 80 m depth.

***B.Semi consolidated formation*:** These includes Gondwana sedimentaries and lateritic deposits. The laterite occur as capping over the country rocks with very limited thickness except in very isolated pockets where thickness around 4-5 m has been observed which form temporary shallow dug well zones.The yield from dug wells reported to be 30-35 m^3/day.

Gondwana group of rocks comprising mainly of shale, sandstone, siltstone, conglomerate etc. occur isolated pockets in the extreme south eastern part covering parts of Rairakhol subdivision and also in western and west central part as elongated bodies covering parts of Sambalpur sud-division. The rocks mostly belong to Talcher formation overlain by thin cover of Barakar formation at places with the maximum thickness of 30-35 lps. The weathered zone in sandstone extends down to 10-12 m while in shale it extends to 15 m depth. The thickness of the existing wells on an average is around 10-12 m and yield of these wells vary from 10-20 m^3/day. Few exploratory wells were drilled in Gondwana rocks mainly in Rairakhol, Jujumura and Rengali Block.The bore wells at Rairakhol and Kadaligarh revealed the extension of Gondwana rocks down to 120 and 143 m respectively. The yield of bore wells varies from negligible at Dongarpara to 4 lps at Laida. The bore wells at Laida and Kadaligarh encountered Barakar sandstone at 35 and 25 m depth respectively. The wells at rairakhol yieled 2.5 lps. The wells at Rairakhol, Laida and Kadaligarh may run for 5-6 hours in a day for a drawdown around 20-22 m.

***C.Unconsolidated formation*:** Alluvial deposits in the district occurs in very minor pockets along major rivers and stream courses with very limited thickness. The details of hydrogeological formations in Sambalpur District are summarized in Table-8.

Present Study: During the present NAQUIM study details of key 50 wells, 47 NHS wells (tapping weathered zone) and 26 Piezometers (Bore Wells tapping fractured aquifers) its depth, depth to water level (pre and post,2022), annual fluctuation etc., are summarized block wise in Table-9.

Table-8. Blockwise area in percent for different Hydrogeological Formations in Sambalpur District, Odisha

Name of Block	BHQ	Charnockite (Ch)	Granite gneiss/ Gneiss (Gr/Gn)	Khondalite, Khondalite/ Quartzite (Kh)(Kh/Q)	Micaceous Quartzite (MQtz)	Phyllite/ Limestone (Phy/Lst)	Quartzite (LR) (Q)	Quartzite/ Shale/ Sandstone (Q/Sh/Sst)	Sandstone/ Shale/ Conglomerate (Sst/Sh/Cgl)	Schist/ Quartzite/ Qt-schist (Sch/Q/Q.Sch)	Volcanics/ Lava Quartzite/ Volcanics (V) (Q/V)
Bamra	0	0	8.37	0	0	0.22	1.98	0	0	38.25	51.16
Kuchinda	33.82	0	62.51	0	0	0	0	0	0	0	3.66
Rengali	0	3.55	51.25	0	0	0	0	18	27.2	0	0
Jamankira	19.74	65.77	14.08	0	0	0	0	0.29	0.12	0	0
Dhankauda	0	0	40.59	0	0	0	0	34.11	25.29	0	0
Manesar	0	0	74.78	19.71	0	0	0	0.04	5.47	0	0
Jujumura	0	2.4	42.36	39.51	15.46	0	0	0.27	0	0	0
Naktideul	0	22	4.73	6.2	37.46	0	0	0	29.61	0	0
Rairakhol	0	1	13.47	31.69	43.75	0	0	0	10.08	0	0
District	**5.69**	**14.64**	**27.77**	**11.79**	**15.32**	**0.02**	**0.2**	**4**	**11.34**	**3.82**	**5.4**

Table 9a. Details of Key wells and NHS wells, its water level (pre and post monsoon, 2022), annual fluctuation in Sambalpur District.

Sl. No.	Block	Village	Lat Decimal	Long Decimal	Elevation in mamsl	Depth mbgl	Dia (m)	MP (magl)	SWL (Pre) (mbmp)	SWL (Post) (mbmp)	Annual Fluctuation (m)
1	Bamra	Amlikhaman	21.94	84.38194	297	7.23	6.4	0.48	6.41	2.05	4.36
2	Bamra	Bampei	22.10417	84.27194	236.7	11.35	NHS WELL	0.45	9.05	6	3.05
3	Bamra	Bamra	22.05056	84.29028	260.8	9.8	NHS WELL	0.8	7.45	4.25	3.2
4	Bamra	Kabribahal	21.8715	84.37436	259.1	5.04	5	GL	3.44	1.5	1.94
5	Bamra	Kesaibahal	21.91389	84.3875	277.3	6.88	NHS WELL	1.1	5.3	3	2.3
6	Bamra	Parimunda	21.946	84.38194	297.2	60	6.4	0.5	7.32	2.84	4.48
7	Bamra	Rangiatikira	22.0383	84.38792	323	30	2.5	0.2	8.34	4.3	4.04
8	Dhankauda	Rengali	21.63194	84.04944	206.9	8.5	NHS WELL	0.6	6.6	2.25	4.35
9	Dhankauda	Sason	21.54833	84.04167	169	11.78	NHS WELL	0.9	1.7	1.8	-0.1
10	Dhankauda	Bishalkinda	21.54929	84.08079	179.4	7.2	1.7	0.6	2.79	2.3	0.49
11	Dhankauda	Debaipali	21.53613	84.02266	168.4	10	1.2	GL	5.97	2.1	3.87
12	Dhankauda	Tumbesingha	21.46072	84.01311	153.9	7.07	1.2	0.9	3.64	1.1	2.54
13	Jamankira	Badmal	21.60708	84.39873	276	5.4	3.5	0.3	2.4	0.9	1.5
14	Jamankira	Bhojpur	21.64873	84.40701	277.1	100	0.25	0.5	16.63	15	1.63
15	Jamankira	Jamankira	21.53639	84.40111	159	9.7	NHS WELL	0.7	5.5	2.1	3.4
16	Jamankira	Kadalipali	21.46444	84.23056		9.25	NHS WELL	0.3	5	3	2
17	Jamankira	Katar Kela	21.43722	84.03306	151	8.25	NHS WELL	0.7	6	3.5	2.5
18	Jamankira	Khadiapali	21.67395	84.39206	265.5	6.53	4	0.3	3.44	0.92	2.52
19	Jamankira	Kuagola	21.55056	84.35333	279.7	10.3	NHS WELL	0.6	6.7	4.3	2.4
20	Jamankira	Patrapali	21.47138	84.2439	227.8	90	0.15	0.5	13.25	5.1	8.15
21	Jamankira	Phasimal	21.605	84.29639	241.7	8.45	NHS WELL	0.75	6.45		

22	Jamankira	Saraipali	21.37051	84.30483	212.6	6.6	2.5	0.3	3.5	2.1	1.4
23	Jamankira	Subarna Pali	21.71361	84.37944	230.6	6.65	NHS WELL	0.6	5.6	2.53	3.07
24	Jujumura	Amlipani	21.33	84.31139	227	9.4	NHS WELL	0.35	8.4	3.6	4.8
25	Jujumura	Badsahir	21.39833	84.13222	195	9.22	NHS WELL	0.7	6.2	3.8	2.4
26	Jujumura	Bhabanipali	21.37667	84.06944	196.3	10.6	NHS WELL	0.8	5.58	3.3	2.28
27	Jujumura	Gargarbahal	21.28472	84.13111	208.8	7.6	NHS WELL	0.6	6.25	1.55	4.7
28	Jujumura	Hathibari	21.315	84.10639	192.3	8.5	NHS WELL	0.85	5		
29	Jujumura	Jayantpur	21.44444	84.07083	188	7	NHS WELL	0.2	3.65	1.56	2.09
30	Jujumura	Jhargulanda	21.42056	84.10139	190.8	7.35	NHS WELL	0.6	5.3	3.1	2.2
31	Jujumura	Koakud	21.19667	84.16639	220.7	9.7	NHS WELL	0.65	5	3.5	1.5
32	Jujumura	Malgun	21.4475	84.1825	178	5.8	NHS WELL	0.7	1.9	1.65	0.25
33	Jujumura	Nildungri	21.45833	84.11111	181.7	15.96	NHS WELL	0.6	5.8	5	0.8
34	Jujumura	Padiabahal	21.45	84.14917	180	7.7	NHS WELL	0.4	5.76	3.57	2.19
35	Jujumura	Basiapada	21.30348	84.06378	179.2	6.2	0.9	0.2	5.4	2.5	2.9
36	Jujumura	Bhoipali	21.19926	84.1122	219.3	7.5	3.4	GL	3.66	2.1	1.56
37	Jujumura	Chamunda	21.32082	84.17567	227	8.88	3.7	0.4	8.24	4.3	3.94
38	Jujumura	Dangarpara	21.42375	84.18371	183.5	6.9	1.14	0.66	4.09	2.6	1.49
39	Jujumura	Kusamora	21.2995	84.20788	248	8	4.2	0.5	5.38	3	2.38
40	Jujumura	Ladaladi	21.37228	84.19933	217.6	7.3	3.9	GL	3.8	0.1	3.7
41	Jujumura	Rugripali	21.22622	84.04336	214.9	9.95	1.5	0.6	7.3	2.51	4.79
42	Jujumura	Tapopora	21.3259	84.25515	257.8	6.5	3.87	0.4	4.05	2	2.05
43	Kuchinda	Boxma	21.71361	84.37944	230.6	7.4	NHS WELL	0.2	5.67	2.15	3.52
44	Kuchinda	Kuchinda	21.7425	84.34833	243	10.2	NHS WELL	0.7	6.15	4.2	1.95
45	Kuchinda	Kusumi	21.76472	84.5275	279	10.5	NHS WELL	0.5	3.6	2.3	1.3
46	Kuchinda	Loiraguna	21.75222	84.44361	263.1	6.8	NHS WELL	0.3	7.58	2	5.58

47	Kuchinda	Nagadihi Chawk	21.84833	84.37222	251.3	7.35	NHS WELL	0.65	3.6	2.12	1.48
48	Kuchinda	Paruabhari	21.80194	84.35861	240.3	8.4	NHS WELL	0.8	6.2	2.8	3.4
49	Kuchinda	Telitiliamal	21.77972	84.30472	239.9	9.5	NHS WELL	0.6	7.58	2.7	4.88
50	Kuchinda	Hinjerkela	21.75655	84.58781	296.5	6.3	2.06	0.37	4.9	2.6	2.3
51	Kuchinda	Kutrachuan	21.74297	84.29596	244.7	8.46	2.1	0.38	8.40	2.25	6.15
52	Kuchinda	Nagadihi	21.8483	84.3721	251	7.4	4.2	0.6	3.9	1.9	2
53	Kuchinda	Puranapani	21.73424	84.28023	239.2	30		0.5	6.5	5.2	1.3
54	Kuchinda	Sahajbahal	21.80292	84.32718	248.2	70	4	GL	5.5	1.8	3.7
55	Manesar	Badmal	21.27892	84.00769	160.3	7.8	4.3	0.3	7.6	2.5	5.1
56	Manesar	Masuritikka	21.38076	83.99199	152	6.1	1.1	0.54	1.85	1.4	0.45
57	Manesar	Matisahi	21.36988	84.01343	168.8	7.29	3.2	GL	4.15	1.45	2.7
58	Manesar	Salesingh	21.32762	83.9731	160.4	7	2.3	0.2	1.8	1.4	0.4
59	Manesar	Subarnpur	21.266	83.96	147	6.36	6	GL	5.4	2.1	3.3
60	Manesar	Bhoipali	21.42861	84.07	161.7	7.2	NHS WELL	0.6	1.6	1.7	-0.1
61	Manesar	Dandeipalli	21.4575	84.03194		5.2	NHS WELL	0.6		2	
62	Manesar	Khunti	21.35667	83.97028	152.3	7.6	NHS WELL	0.42			
63	Manesar	Maneswar	21.42722	84.03694	158.7	8	NHS WELL	0.6	4.2	2.14	2.06
64	Manesar	Naxapali	21.42722	84.01417	153.7	8.75	NHS WELL	0.1	4.16	1	3.16
65	Manesar	Parmanpur	21.52333	84.10056	181.3	9.57	NHS WELL	0.7	5.3	2.15	3.15
66	Manesar	Talpali	21.43111	84.06083	163.3	8.25	NHS WELL	0.5	1	0.9	0.1
67	Natideul	Chandrapura	21.275	84.56306	178.7	13.5	NHS WELL	0.55	11.5	7.2	4.3
68	Natideul	Daincha	21.16861	84.43222	221.1	9	NHS WELL	0.4	5.5	3.8	1.7
69	Natideul	Majhipal	21.21306	84.48472	210.8	5.8	NHS WELL	0.8	4.1	3.2	0.9
70	Natideul	Naktideol	21.25556	84.54056	175.9	9.45	NHS WELL	0.6	7.95	4.2	3.75
71	Natideul	Simlipal Chawk	21.3725	84.36583	464	7.2	NHS WELL	0.55	4.35	2.9	1.45
72	Natideul	Terebera	21.11472	84.38861	207.3	8.3	NHS	0.2	5.75	3.5	2.25

							WELL				
73	Natideul	Balikiari	21.20187	84.33144	246.2	6	1.2	GL	4.6	2.4	2.2
74	Natideul	Batagaon	21.24026	84.65622	168.9	30	1.2	GL	6.1	2.7	3.4
75	Natideul	Goudpali	21.30248	84.35621	221.1	7.85	3.5	GL	6.5	2.9	3.6
76	Natideul	Hiraloi	21.32077	84.29353	250.7	6.5	1.6	0.46	4.5	2.22	2.28
77	Natideul	Kello	21.29852	84.45621	238.4	6.27	2.3	GL	4.2	2.9	1.3
78	Natideul	Keuntberni	21.28076	84.67627		4.79	4.05	GL	4.39	2.2	2.19
79	Natideul	Kisinda	21.3302	84.34748	229.5	8.53	1.6	0.25	3.33	1.9	1.43
80	Natideul	Paikamal	21.18382	84.45184	203.3	10	1.2	0.5	8	2.1	5.9
81	Natideul	Sahebi	21.2406	84.58946	176.9	7	6	GL	7	2.7	4.3
82	Natideul	Teleimal	21.23845	84.32824	271.5	4.74	2.92	GL	2.75	1.2	1.55
83	Rairakhol	Badbahal	21.02763	84.33652	139.9	7.8	1.4	0.4	6.6	2.8	3.8
84	Rairakhol	Badmal	21.11215	84.07313	166.1	8.12	0.9	0.54	6.68	3.3	3.38
85	RAIRAKHOL	Bhaluchuan	21.08	84.36667	157	6.6	NHS WELL	0.3	4.5	2.65	1.85
86	Rairakhol	Burda	21.14002	84.31119	205.6	8.4	2	0.4	7.15	2.8	4.35
87	RAIRAKHOL	Charmal	21.10417	84.21111	168	12.1	NHS WELL	0.7	9.98	5.2	4.78
88	RAIRAKHOL	Mochibahal	21.17083	84.16389	216.3	8.94	NHS WELL	0.7	6	3	3
89	Rairakhol	Pandakimal	20.98047	84.31469	119.9	6.52	2.3	0.2	5.38	2.7	2.68
90	RAIRAKHOL	Rairakhol	21.06667	84.33333	142	9.5	NHS WELL	0.7	7	4.1	2.9
91	Rairakhol	Satasama	21.15386	84.08581	183.3	7.7	4.8	GL	6.4	3.9	2.5
92	RENGALI	Barodungri (Orampara)	21.55972	84.12278	185.2	9.2	NHS WELL	0.65	5.25	2.65	2.6
93	Rengali	Kentigira	21.63353	84.15044	162.4	10.8	2.5	0.37	10.8	1.92	8.88
94	Rengali	Laida	21.73363	84.22356	230.4	5.76	2	0.66	4.3	3.1	1.2
95	Rengali	Luhakhandi	21.68098	84.15531	237.9	8.89	2.5	0.5	5.75	2.1	3.65
96	Rengali	Mohultikra	21.66336	84.10772	224.8	9.33	1	0.52	7.66	2.06	5.6
97	Rengali	Tabadabahal	21.57285	84.1151	192.3	10.3	2.7	0.6	7.15	1.9	5.25

Table 9b. Details of Piezometer wells (BW), its water level (pre and post monsoon, 2022), annual fluctuation in Sambalpur District.

Sl. No.	Block	Location of Piezometer (BW)	Depth (mbgl)	Lat	Long	WL Pre (mbgl)	WL Post (mbgl)	Fluctuation (m)
1	Bamra	Bamra; RI Office campus	39.63	22.0542	84.2889	4.40	2.04	2.36
2	Bamra	Jurabaga; GP Office campus	43.20	21.9542	84.4556	7.06	4.93	2.13
3	Bamra	**Keseibahal; Junior College Campus**	**60.97**	21.9064	84.3808	6.90	2.53	4.37
4	Dhankauda	Chanarpur; GP Office campus	49.50	21.4339	83.9642	2.91	0.88	2.03
5	Dhankauda	Chiplima; KVK (OUAT) Campus	49.20	21.3739	83.8939	3.98	1.03	2.95
6	Dhankauda	**Dhankauda; Block Office Campus**	**48.60**	21.4686	84.0019	3.59	0.79	2.80
7	Dhankauda	Talab; GP Office campus	**59.12**	21.5528	84.0083	2.69	2.29	0.40
8	Jamankira	Jamankira; Block office campus	42.00	21.5306	84.3889	5.74	2.42	3.32
9	Jamankira	Badrama; GP Office Campus	60.97	21.4897	84.2747	8.72	4.17	4.55
10	Jamankira	Bhojpur; GP Office campus	43.40	21.6472	84.4083	7.49	2.72	4.77
11	Jujumura	Jujumara; MI Office campus	40.24	21.2250	84.1306	6.68	2.44	4.24
12	Jujumura	Baham; GP Office campus	48.77	21.4633	84.1431	6.54	3.14	3.40
13	Jujumura	Kukudapali; GP Office campus	49.38	21.4894	84.0947	8.01	2.97	5.04
14	Jujumura	Hatibari; PHC Campus	49.80	21.3181	84.0867	5.81	1.78	4.03
15	Kuchinda	Kuchinda; MI Office campus	40.24	21.7417	84.3556	5.96	2.41	3.55
16	Kuchinda	Boxma; GP Office Campus	60.97	21.6997	84.3811	5.53	2.39	3.14
17	Manesar	Maneswar; Irrigation Canal colony	40.24	21.4153	84.0403	4.41	2.53	1.88
18	Manesar	M. Gunderpur; Block Office Campus	49.30	21.4050	83.9875	3.29	1.59	1.70
19	Manesar	Tabla; GP Office campus	48.77	21.5152	84.0658	3.49	2.46	1.03
20	Naktideul	Naktideol; MI office campus	40.24	21.2569	84.5431	7.26	3.54	3.72
21	Rairakhol	Rairakhol; NH Sub-Division Office Campus	50.10	21.0694	84.3469	5.1	0.92	4.18
22	Rairakhol	Badamal GP office campus	48.20	21.0833	84.0694	5.49	2.82	2.67
23	Rairakhol	Bhaliakata GP Office campus	48.80	21.1333	84.0500	6.79	3.57	3.22
24	Rengali	Rengali; Block office campus	40.24	21.6403	84.0375	5.86	4.64	1.22
25	Rengali	Nishanbhanga GP Office Campus	39.00	21.6596	84.0333	4.36	1.31	3.05
26	Rengali	Rengali GP Office Campus	45.00	21.6443	84.0500	4.49	2.96	1.53

ii.Hydrochemical: For water sample collection from shallow aquifers (mainly weathered zone) 127 number of water samples collected for basic analysis (only for major elements in mg/l) only during pre monsoon time and 18 samples collected during post monsoon time. Another set of 33 water samples collected during construction of Exploratory wells are also summarized. All samples are analysed in CGWB Lab as well as NABL accredited lab.The details are summarized in Table 10a,10b and 10c.

Table-10a. Chemical quality analytical results of major elements from all key wells (Shallow aquifer), Sambalpur District.

SL NO.	LABSAMPLE ID	BLOCK	VILLAGE	pH	EC µS/cm	TDS	Hardness	Alkalinity	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	SO_4	NO_3	F^{-}	U
				at 25 °C	at 25°C	mg/l	as $CaCO_3$ mg/l		mg/l										
Identification of method used: APHA, 23rd Ed. 2017				4500H B	2510 B		2340C	2320B	3500Ca B	35000Mg B	3500Na-B	3500K-B	2320B		4500-Cl B			4500 F C	
1	2022-23/459	Natideul	Terebeda	8.34	397	236	216.92	177.45	49.4	22.7	11	2.99	6.08	212	17.32	10.41	15.64	0.23	0.001
2	2022-23/460	Natideul	Paikamal	8.04	714	400	266.22	202.8	55.3	31.1	55.67	2.15	0	246	79.17	34.51	20.24	0.37	0.006
3	2022-23/461	Natideul	Kunjamura	8.36	379	207	192.27	152.1	37.5	23.94	13.27	1.39	6.08	185.56	19.79	17.64	1.78	0.25	BDL
4	2022-23/462	Natideul	Keuntberni	7.85	165	107	54.23	40.56	11.8	6.01	16.74	2.04	0	44	24.74	14.36	6.23	0.25	BDL
5	2022-23/463	Natideul	Batagaon	7.71	132	86	44.37	30.42	7.9	5.98	8.62	4.19	0	32	12.37	12.29	16.44	0.06	BDL
6	2022-23/464	Natideul	Sahebi	8.14	218	149	73.95	60.84	11.8	10.8	14.24	18.9	0	69	32	16.85	7.19	0.17	BDL
7	2022-23/465	Natideul	Balikiari	8.02	187	102	29.58	20.28	7.9	2.39	25.12	2.46	0	24.74	37.11	9.65	4.8	0.12	BDL
8	2022-23/466	Jamankira	Patrapali	8.33	663	370	207.06	197.73	41.5	25.1	68.34	2.24	9.13	235.05	96.49	11.31	5.86	0.28	0.001
9	2022-23/467	Jamankira	Chepotam	8.57	472	251	128.18	96.33	31.6	11.95	37.84	8.48	12.17	117.52	56.9	39.37	6.32	0.31	BDL
10	2022-23/468	Jamankira	Kadalimunda	8.44	721	399	251.43	172.38	55.3	27.5	69.88	2.57	12.17	210.3	103.91	35.71	0.22	0.16	0.001
11	2022-23/469	Jamankira	Badmal	8.29	523	314	285.94	228.15	51.3	38.32	19.43	2.2	0	272.16	29.69	34.46	1.35	0.18	0.001
12	2022-23/470	Jamankira	Bhojpur	8.33	479	274	187.34	131.82	47.4	16.73	40.23	4.46	9.13	160.82	59.38	22.5	3.63	0.25	0.009
13	2022-23/471	Jamankira	Kkhadiapali	8.51	548	339	177.48	126.75	47.4	14.33	72.79	1.29	9.13	148.45	111.33	11.52	2.66	1.22	0.007
14	2022-23/472	Kuchinda	Kuchinda	8.44	315	175	147.9	116.61	31.6	16.74	16.8	4.4	12.17	142.26	24.74	10.04	0.94	0.23	0.001
15	2022-23/473	Kuchinda	Tainsar	7.92	118	66	29.58	20.28	7.9	2.39	11.96	0.67	0	24.74	17.32	9.89	3.38	0.25	BDL
16	2022-23/474	Kuchinda	Teletilimal	8.39	358	195	123.25	96.33	35.5	8.38	28.97	3.98	15.21	117.52	42.06	16.55	0.95	0.31	0.001
17	2022-23/475	Dhankauda	Debaipali	8.14	214	124	78.88	60.84	13.8	10.78	15.29	2.91	0	68.04	22.27	21.88	0.05	0.53	0.041
18	2022-23/476	Dhankauda	Bishalkinda	8.47	1212	700	369.75	370.11	77	43.07	87.8	83.68	9.13	445.35	133.6	7.38	44.97	0.33	0.001

19	2022-23/477	Rengali	Tabadabahai	8.02	1492	868	438.77	283.92	90.8	51.46	165.24	10.24	0	340.2	242.45	89.89	46.76	0.34	0.001
20	2022-23/478	Rengali	Gumlai	8.2	639	353	256.36	197.73	51.3	31.13	31.39	12.3	0	235.05	47.01	35.34	25.34	0.33	0.005
21	2022-23/479	Rengali	Kentigia	8.33	408	223	64.09	40.56	13.8	7.19	53.12	12.04	6.08	43.3	76.69	25.3	9.69	0.39	0.004
22	2022-23/480	Rengali	Mohultikra	7.77	98	60	19.72	10.14	5.9	1.21	12.64	0.96	0	6.19	19.79	8.7	4.91	0.12	BDL
23	2022-23/481	Rengali	Luhakhandi	8.38	105	61	39.44	20.28	5.9	6	9.24	0.65	9.13	18.56	12.37	11.36	2.68	0.44	BDL
24	2022-23/482	Rengali	Laida	8.16	1057	568	256.36	197.73	61.2	25.12	100.24	8.73	0	235.05	153.39	55.34	45.48	0.15	0.001
25	2022-23/483	Kuchinda	Puranapani	8.32	1274	693	379.61	228.15	84.9	40.67	130	1.16	3.04	278.34	202.87	51.67	44.98	0.27	0.001
26	2022-23/484	Kuchinda	Kutrachuan	8.33	938	496	221.85	172.38	65.2	14.3	88.52	6.57	6.08	204.12	128.65	43.93	45.56	0.18	BDL
27	2022-23/485	Kuchinda	Sahajbahal	8.2	238	125	34.51	20.28	5.9	4.8	33.36	2.2	0	24.74	49.48	16.16	0	0.84	0.002
28	2022-23/486	Bamra	Kabribahal	8.33	127	74	29.58	20.28	7.9	2.39	15.98	2.25	6.08	18.56	24.74	6.52	2.16	0.26	BDL
29	2022-23/487	Bamra	Amlikhaman	7.78	172	102	29.58	10.14	9.9	1.17	24.47	1.36	0	12.37	37.11	12.19	9.24	0.4	BDL
30	2022-23/488	Bamra	Parimunda	7.89	307	175	128.18	106.47	23.7	16.75	21.38	1.95	0	123.71	32.16	11.6	3.36	0.61	0.001
31	2022-23/489	Bamra	Ghunghuti	8.37	335	182	123.25	86.19	31.6	10.75	23.41	0.98	9.13	105.15	34.64	17.08	11.25	0.15	BDL
32	2022-23/490	Bamra	Rangiatikira	8.35	530	283	182.41	106.47	41.5	19.11	27.24	1.74	9.13	129.89	39.58	52.97	37.09	0.25	BDL
33	2022-23/491	Kuchinda	Nagadihi	7.92	93	50	14.79	10.14	3.9	1.22	10.17	1.54	0	6.19	14.84	11.41	0.54	0.32	BDL
34	2022-23/492	Dhankauda	Tumbesingha	8.12	1425	871	414.12	329.55	96.7	41.89	187.3	3.65	0	402.05	277.09	56.64	9.22	0.43	0.002
35	2022-23/493	Jujumura	Dangarpara	8.49	1004	571	290.87	172.38	69.1	28.7	102.24	8.2	12.17	210.3	145.97	105.2	6.51	1.2	0.011
36	2022-23/494	Jujumura	Ladaladi	6.94	63	38	14.79	15.21	3.9	1.22	6.4	2.71	0	13.6	9.9	5.3	1.83	0.264	0.001
37	2022-23/495	Jujumura	Tapopora	6.75	55	39	9.86	10.14	2	1.18	9.94	1.19	0	6.19	14.84	4.3	0.56	0.14	BDL
38	2022-23/496	Natideul	Kisinda	8.33	585	300	128.18	96.33	23.7	16.75	56.34	7.49	9.13	111.34	81.64	20.01	35.98	0.34	BDL
39	2022-23/497	Jamankira	Saraipali	7.97	195	99	54.23	30.42	11.8	6.01	10.45	2.33	0	37.11	14.84	16.66	18.5	0.16	BDL
40	2022-23/498	Natideul	Kello	8.16	263	145	69.02	40.56	11.8	9.6	29.33	0.77	0	43.3	39.58	27.88	1.17	0.15	BDL
41	2022-23/499	Natideul	Goudpali	7.48	136	80	73.95	60.84	13.8	9.59	4.87	0.4	0	74.22	7.42	5.14	1.57	0.66	BDL
42	2022-23/500	Natideul	Teleimal	7.99	140	81	54.23	40.56	9.9	7.16	9.97	1.3	0	43.3	14.84	12.43	1.22	0.22	BDL

43	2022-23/501	Natideul	Hiraloi	8.39	285	166	128.18	106.47	21.7	17.96	18.53	3.93	6.08	129.89	27.21	11.37	0	1.58	0.001
44	2022-23/502	Manesar	Matisahi	8.36	356	199	69.02	30.42	13.8	8.39	55.19	2.21	9.13	30.93	84.12	15.4	1.23	0.52	0.001
45	2022-23/503	Manesar	Masuritikka	8.49	528	279	24.65	76.05	5.9	2.41	27.6	96	12.17	86.6	42.06	56.66	1.65	0.6	BDL
46	2022-23/504	Manesar	Salesingh	8.19	656	338	177.48	131.82	31.6	23.93	62.31	2.83	0	154.64	89.06	46.89	1.42	0.54	0.002
47	2022-23/505	Manesar	Huma	7.89	1432	706	522.58	415.74	82.9	76.63	87.89	7.33	0	501.02	128.65	27.98	44.85	0.39	0.003
48	2022-23/506	Manesar	Sabarnpur	8.27	425	211	138.04	106.47	23.7	19.15	28.16	1.73	0	129.89	44.53	17.39	11.81	0.47	BDL
49	2022-23/507	Manesar	Badmal	8.45	494	229	147.9	86.19	25.7	20.33	30.94	1.35	12.17	98.97	49.48	32.04	17.2	0.24	BDL
50	2022-23/508	Jujumura	Basiapada	8.15	1196	573	290.87	162.24	75	25.12	90.74	1.78	0	197.93	141.02	93.82	48.36	0.09	0.002
51	2022-23/509	Jujumura	Rugripali	8.29	180	89	39.44	20.28	7.9	4.78	17.18	2.8	0	24.74	27.21	15.95	0.86	0.32	BDL
52	2022-23/510	Jujumura	Chamunda	8.07	450	245	49.3	10.14	9.9	5.97	60.03	14.38	0	12.37	86.59	33.09	28.86	0.19	BDL
53	2022-23/511	Jujumura	Kujamora	7.94	121	75	9.86	10.14	2	1.18	21.87	3.46	0	6.19	32.16	2.24	6.27	0.15	BDL
54	2022-23/512	Jujumura	Bhoipali	8.03	256	137	44.37	50.7	9.9	4.77	12.83	25.58	0	55.67	19.79	10.23	23.02	0.18	BDL
55	2022-23/513	Rairakhol	Satasama	8.16	362	183	59.16	40.56	15.8	4.78	23.19	21.99	0	49.48	34.64	24.27	33.69	0.15	BDL
56	2022-23/514	Rairakhol	Badmal	8.33	380	177	128.18	86.19	25.7	15.53	18.38	1.12	9.13	98.97	27.21	24.22	12.69	0.4	BDL
57	2022-23/515	Rairakhol	Burda	8.21	529	238	197.2	152.1	41.5	22.71	17.45	1.1	0	185.56	19.79	24.98	18.37	0.39	0.006
58	2022-23/516	Rairakhol	Badbahal	8.3	718	367	177.48	116.61	37.5	20.35	67.04	0.09	0	142.26	101.43	31.49	37.97	1.43	0.001
59	2022-23/517	Rairakhol	Pandakimal	8.33	346	150	123.25	60.84	27.6	13.18	14.41	0.21	12.17	74.22	22.27	29.86	5.93	0.45	BDL
60	2022-23/518	Kuchinda	Hinjekela	7.86	95	48	24.65	10.14	5.9	2.41	5.58	0.18	0	12.37	7.42	8.83	10.39	1.05	BDL
61	2022-23/519	Natideul	Keuntberni	8.36	395	192	103.53	60.84	21.7	11.98	41.25	0.45	9.13	74.22	61.85	15.43	1.22	1.61	0.001
62	2022-23/1749	Natideul	Batagaon	6.99	114	64	39	32	10	4	6	3	<5	37	9	12	1	0.03	BDL
63	2022-23/1750	Kuchinda	Teleimal	7.18	88	50	34	32	8	4	6	1	<5	35	9	1	2	0.05	BDL
64	2022-23/1751	Dhankauda	Bishalkinda	7.64	1096	667	378	303	84	41	63	75	<5	365	95	44	84	0.20	0.004
65	2022-23/1752	Kuchinda	Puranapani	6.70	1136	530	383	278	86	41	56	2	<5	339	85	44	48	0.19	BDL
66	2022-23/1753	Kuchinda	Nagadihi	7.07	78	31	19	19	4	2	3	1	<5	20	5	3	1	0.83	BDL

67	2022-23/1754	Bamra	Rangiatikira	7.33	520	375	291	215	47	42	38	4	<5	262	59	36	20	0.21	BDL
68	2022-23/1755	Dhankauda	Tumbesingha	7.73	920	471	306	259	64	35	67	5	<5	316	95	5	44	0.53	BDL
69	2022-23/1756	Jujumura	Dangarpara	7.75	1203	665	403	322	62	60	102	22	<5	393	145	17	64	0.89	0.004
70	2022-23/1757	Jamankira	Patrapali	7.80	740	369	267	215	51	34	53	2	<5	271	76	7	17	0.21	0.003
71	2022-23/1758	Manesar	Badmal	7.67	402	193	146	120	27	19	22	1	<5	146	31	2	19	0.16	BDL
72	2022-23/1759	Jamankira	Khadiapali	8.01	283	136	97	82	18	13	16	3	<5	100	24	5	8	0.17	0.005
73	2022-23/1760	Manesar	Masuritikka	7.32	720	410	257	208	55	29	49	38	<5	254	76	3	55	0.34	BDL
74	2022-23/1761	Manesar	Subarnpur	7.84	435	208	175	145	37	20	19	2	<5	177	28	1	13	0.49	0.003
75	2022-23/1762	Jujumura	Basiapada	7.44	905	538	364	297	74	44	67	11	<5	362	104	34	26	0.19	BDL
76	2022-23/1763	Jujumura	Chamunda	7.32	506	359	189	152	35	25	58	21	<5	185	88	24	17	0.11	BDL
77	2022-23/1764	Jujumura	Bhoipali	6.81	286	225	136	114	27	16	23	21	<5	139	33	31	14	0.15	BDL
78	2022-23/1765	Rairakhol	Burda	7.21	460	245	155	126	29	20	33	9	<5	154	50	18	10	0.12	BDL
79	2022-23/1766	Rairakhol	Pandakimal	7.36	472	246	165	133	31	21	38	2	<5	162	54	3	16	0.30	BDL

Table-10b. Chemical quality analytical results of major elements from all NHS wells (Shallow aquifer), Sambalpur District.

Concentration in mg/l except EC (µmhos/cm at 25^{0}C) and pH

SL NO.	Block	Village	Sampling Date	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3=	HCO3-	Cl-	SO4=	NO3-	F -
1	Jujumura	Amlipani	Apr-22	7.77	325	174	120	125	40	4.86	21	1.3	0	153	25	4	3	1.360
2	Jujumura	Badsahir	Apr-22	7.91	1600	791	560	165	100	75.33	81	9.6	0	201	300	65	62	0.630
3	Bamra	Bampei	Apr-22	8.05	450	246	185	115	50	14.58	12	1.2	0	140	32	30	38	0.250
4	Bamra	Bamra	Apr-22	8.04	1681	804	485	145	158	21.87	102	7	0	177	275	106	47	0.390
5	Rengali	Barodungri	Apr-22	8.28	478	252	160	140	44	12.15	25	7.6	0	171	45	17	17	0.380
6	Jujumura	Bhabanipali	Apr-22	7.87	968	526	380	265	114	23.085	39	1.9	0	323	100	72	18	1.770
7	Rairakhol	Bhaluchuan	Apr-22	8.04	722	380	240	255	76	12.15	51	4.9	0	311	42	24	18	1.570
8	Manesar	Bhoipali	Apr-22	8.21	990	523	200	370	34	27.945	130	3.9	0	451	45	59	2	2.290
9	Kuchinda	Boxma	Apr-22	7.97	939	504	335	230	88	27.945	57	5.2	0	281	117	70	1	0.330
10	Naktideul	Chandrapura	Apr-22	8.07	607	309	235	125	62	19.44	23	1.8	0	153	70	16	42	0.620
11	Rairakhol	Charmal	Apr-22	8.07	335	179	140	95	44	7.29	14	2.2	0	116	32	0	23	1.670
12	Naktideul	Daincha	Apr-22	7.9	605	288	270	130	66	25.515	10	1.5	0	159	90	13	3.8	0
13	Jujumura	Gargarbahal	Apr-22	8.13	426	222	170	175	58	6.075	18	5.3	0	214	25	4	1	0.350
14	Jujumura	Hathibari	Apr-22	8	1132	581	305	310	44	47.385	103	2.9	0	378	100	81	17.7	1.650
15	Jamankira	Jamankira 1	Apr-22	8.07	528	285	180	135	44	17.01	40	1.7	0	165	60	34	7	0.760
16	Jujumura	Jayantpur	Apr-22	8.04	550	282	230	150	42	30.375	21	1	0	183	47	41	9.6	0.580
17	Jujumura	Jhargulanda-1	Apr-22	7.88	1677	724	530	195	58	93.555	83	8.8	0	238	322	41	1	1.510
18	Jamankira	Kadalipali	Apr-22	8.08	591	280	250	250	40	36.45	20	4.5	0	305	25	5	0	0.080
19	Jamankira	Katarkela	Apr-22	7.87	349	189	135	75	44	6.075	14	1	0	92	35	13	31	0.000
20	Jamankira	Kasaibahal	Apr-22	8.08	952	480	340	135	76	36.45	41	2.8	0	165	165	44	33.8	0.180
21	Jujumura	Koakud	Apr-22	8.05	221	120	110	105	26	10.935	2.5	1	0	128	10	4	2.5	0.160
22	Jamankira	Kuagola	Apr-22	8.26	340	176	115	115	30	9.72	23	4.7	0	140	35	4	1	0.220
23	Kuchinda	Kuchinda	Apr-22	7.99	232	122	75	60	20	6.075	16	2.7	0	73	27	2	12	0.350
24	Kuchinda	Kusumi	Apr-22	8.18	1060	541	290	160	52	38.88	95	6.7	0	195	145	72	35.7	0.430

25	Kuchinda	Loiraguna	Apr-22	8.21	440	226	210	190	38	27.945	11	1.6	0	232	22	9	3	0.030
26	Naktideul	Majhipal	Apr-22	7.99	130	68	55	50	12	6.075	2	4.8	0	61	10	3	0	0
27	Manesar	Manesswar	Apr-22	8.06	967	546	320	200	46	49.815	78	1	0	244	95	120	37	0.780
28	Rairakhol	Mochibahal	Apr-22	8.03	727	359	265	220	42	38.88	38	5.6	0	268	67	35	1.5	0.160
29	Kuchinda	NagadihiChawk	Apr-22	8.12	186	94	75	70	18	7.29	8	1	0	85	12	5	1	0.550
30	Naktideul	Naktideol	Apr-22	8.28	570	293	260	225	40	38.88	19	1	0	275	47	11	1	0.050
31	Manesar	Naxapalli	Apr-22	8.11	1418	729	470	250	52	82.62	99	4.7	0	305	177	120	44	1.040
32	Jujumura	Nildungri	Apr-22	8.29	662	381	175	255	30	24.3	82	13.8	0	311	57	17	4.5	0.280
33	Jujumura	Padiabahal	Apr-22	8.01	886	452	255	150	54	29.16	69	4.2	0	183	115	49	42	0.880
34	Manesar	Parmanpur	Apr-22	8.26	593	301	100	210	22	10.935	86	1	0	256	45	5	6	**2.490**
35	Kuchinda	Paruabhari 1	Apr-22	7.91	1326	683	225	220	58	19.44	169	6.4	0	268	197	65	37	0.540
36	Jamankira	Phasimal	Apr-22	8.02	258	137	105	90	40	1.215	11	1.3	0	110	22	4	3.5	0.070
37	Rairakhol	Rairakhol	Apr-22	8.02	850	462	375	195	84	40.095	24	1	0	238	97	44	55	0.340
38	Rengali	Rengali	Apr-22	8.15	560	301	240	200	56	24.3	25	3.5	0	244	47	21	4.7	0.740
39	Dhankouda	Sason 1	Apr-22	8.13	390	202	150	145	48	7.29	17	4.6	0	177	17	21	0	1.250
40	Naktideul	Simlipal Chawk	Apr-22	8.1	372	185	160	145	40	14.58	11	1.4	0	177	25	6	0	0
41	Jamankira	Subarnapali	Apr-22	8.17	313	165	90	115	24	7.29	27	6.7	0	140	22	7	2.7	0.270
42	Manesar	Talpali	Apr-22	8.2	438	225	190	195	48	17.01	18	3.1	0	238	15	7	0	0.060
43	Kuchinda	Telitiliamal	Apr-22	8.01	623	318	220	200	42	27.945	38	6.4	0	244	57	22	5.4	0.470
44	Naktideul	Terebera	Apr-22	8.04	536	267	225	225	44	27.945	25	1	0	275	32	1	1	0.830
45	Manesar	Baduapali	Apr-22	7.64	561	270	195	245	24	32.805	38	2.8	0	299	22	1.3	3	0.58
46	Manesar	Baragoan	Apr-22	8.19	441	237	190	160	68	4.86	11	6.5	0	195	20	26	5	0.39
47	Manesar	Batemura	Apr-22	7.77	533	280	215	165	32	32.805	27	3.2	0	201	30	10.7	46	0.34
48	Manesar	Bausenmura	Apr-22	8.02	2006	1103	570	550	94	81.405	143	101	0	671	225	103	26.5	0.29
49	Manesar	Chhachanpali	Apr-22	7.54	710	371	200	170	32	29.16	70	2.9	0	207	117	18	1	0.36
50	Manesar	Chiplima	Apr-22	7.88	326	168	125	125	32	10.935	14	4.4	0	153	17	14.5	0	0.19
51	Dhankouda	Christianpara	Apr-22	7.84	477	258	170	170	50	10.935	25	11.4	0	207	30	11	18.6	1.46
52	Manesar	Deogaon	Apr-22	8.14	377	191	150	145	36	14.58	16	1.6	0	177	22	11	2.6	0.29
53	Manesar	Dhama	Apr-22	7.6	625	314	195	255	42	21.87	54	2	0	311	32	8.5	1	0.36

54	Manesar	Gainpura	Apr-22	7.9	776	409	290	250	52	38.88	30	25.4	0	305	62	41.7	9.5	0.33
55	Dhankouda	Goudapali	Apr-22	7.85	476	291	95	70	30	4.86	62	10.9	0	85	70	25.6	46	0.12
56	Dhankouda	Gunchamal	Apr-22	7.6	646	343	125	270	32	10.935	88	5.7	0	329	22	13.9	9	0.33
57	Dhankouda	Hirakud	Apr-22	7.77	508	265	190	170	58	10.935	31.4	3.6	0	207	37	21.9	1	0.26
58	Manesar	Hotapala	Apr-22	8.04	617	309	145	275	26	19.44	76.8	1.2	0	336	17	2.7	1	1.09
59	Dhankouda	Jamadarpali	Apr-22	8.02	627	314	220	225	24	38.88	45.3	4.2	0	275	27	33.2	6.4	0.94
60	Dhankouda	Jugipali	Apr-22	7.96	614	341	105	175	32	6.075	92.6	2.98	0	214	60	39.9	2.2	1.25
61	Manesar	Jhankarbahli	Apr-22	7.69	738	383	235	250	44	30.375	60.1	2.1	0	305	52	39.9	5.5	1.25
62	Manesar	Khunti	Apr-22	7.96	834	429	305	220	56	40.095	51.5	2.1	0	268	120	11.9	16.2	0.16
63	Manesar	Larasara	Apr-22	7.76	1117	574	360	345	48	58.32	85.8	13.5	0	421	112	43.7	6.2	0.24
64	Manesar	Remerha	Apr-22	7.84	614	312	235	240	52	25.515	29.3	4.9	0	293	30	21.5	4.8	0.49
65	Manesar	Sahaspur	Apr-22	8.07	939	509	340	220	66	42.525	62.2	1.9	0	268	95	78.5	32	1.14
66	Dhankouda	Sambalpur	Apr-22	7.93	542	289	145	180	42	9.72	55.7	5	0	220	50	16	2.3	1.7

Table-10c. Chemical quality analytical results of major elements from few exploratory wells (Deeper aquifer), Sambalpur District.

Concentration in mg/l except EC (µmhos/cm at 25^{0}C) and pH

Sl.No.	Location	Lat	Long	Ec	Ph	HCO_3	Cl	SO_4	NO_3	F	Na	K	Ca	Mg	TH	SAR
				µS/cm		In mg/l										
1	Kuchinda Ward II	21.74139	84.345	515	7.82	171	79	12	19	0.5	39	6.45	48	17	190	1.1
2	Irbanpur			470	8.06	214	35	6.5	3.9	0.66	12	1	50	19	205	0.37
3	Hawamaiden			522	7.9	220	40	8.3	10	0.53	33	4.1	54	9.7	175	0.64
4	Baniagaon	21.25	84.66	1288	7.7	262	296	0.2	0.07	1.52	58	6.1	60	85	500	1.1
5	Pandikimal	21.1953	84.4589	668	7.95	336	44	23	8.8	0.56	28.8	2	64	24	260	0.78
6	Kadligarh	21.66	84.41	263	7.42	146	12	13	1.7	0.63	30.9	3.9	8	9.7	60	1.74
7	Batagaon	21.3403	83.9718	385	7.7	220	19	5.1	1.3	0.29	7.86	19	30	19	155	0.27

8	Kuchinda	21.74444	84.34944	759	7.36	165	101	45	32	0.2	27.2	5.2	70	19	255	0.74
9	Saida	21.2433	84.595	374	7.9	195	24	8.6	0	0.26	21.3	2.9	30	17	145	0.76
10	Khandakota	21.0283	84.37	364	8.15	207	23	4.6	0	1.06	34.8	4.1	23	9.1	95	1.5
11	Rengali	21.6965	84.1095	688	7.66	336	55	14	0.04	1	54.4	6.3	38	23	190	1.7
12	Kulundi	21.84	84.49	607	7.59	256	57	11	20	0.52	18.4	2	57	25	245	0.5
13	Basantpur			164	7.4	92	8.9	4.6	1.5	0.4	13.6	1.1	9	5.5	45	0.67
14	Paharsrigidi			334	7.83	177	21	11	1.3	0.33	12.3	4.2	39	12	145	0.24
15	Rengali	21.72	84.51	418	8.18	201	30	7	1.3	0.76	31	11.2	28	17	140	1.13
16	Laira	21.2083	84.3958	182	7.52	76	12	1.9	4.5	1.03	20	4.3	15	0	38	1.4
17	Chaurpur	21.04	84.23	458	7.94	207	34	2.4	11	0.43	14	7.7	51	16	193	0.43
18	Gunderpur	21.4275	84.0009	509	7.44	220	41	1.1	8.7	19	55	4.3	39	11	143	2.17
19	Bhishalkhinda	21.63	84.27	969	7.54	445	60	0.87	0.56	0.8	173	16	16	13	95	7.7
20	Mohulmunda	20.96	84.34	558	7.9	287	28	4.68	0	0.1	105	8.5	13	3.6	48	6.6
21	Kayakud	21.05	84.11	399	7.85	268	14	0.41	0	0.1	20	6	29	27	185	0.63
22	Rairakhol	21.06	84.35	490	8.17	262	7	33	0.3	0.62	31	11	40	22	190	0.97
23	Pamdikmal	21.2	84.06	634	8.08	250	43	40	0.5	0.96	42	5	54	19	215	1.23
24	Mantrimunda	21.74	84.39	137	8.11	67	14	3.75	0	0.29	13	8.9	14	4.9	55	0.75
25	Parmanpur	21.8282	84.4072	442	8.25	238	16	1.71	0	0.32	30	25	24	23	155	0.8
26	Phasimal	21.13	84.11	175	7.55	37	7	ND	6.6	0.3	10	3.2	8	1.2	25	0.86
27	Barpali	21.11	84.12	499	7.6	92	74	17	22	0.42	22	3.5	50	12	175	0.71
28	Agaipur			950	7.69	262	131	25	19	1.2	58	17	62	34	295	1.45
29	Laira	21.74	84.23	98	7.33	37	7	ND	6.6	0.3	10	3.2	8	1.2	25	0.86
30	Kunjamara	21.25	84.67	487	7.92	244	25	9	2	0.34	18	2	34	29.16	205	6.05
31	Salebhata	21.29	84.68	335	7.59	111	47	11	1	0.23	30	3	28	10	108	6.42
32	Rairakhaol	21.07	84.35	512	7.71	220	57	6.35	30.14	0.09	48.2	3.4	48	18.23	195	8.34
33	Phulkusum	21.26	84.37	320	7.32	165	12	3.47	2.1	0.21	21	4	38	4	110	8.29

iii.Geophysical Study: A total of 75 VES were carried out in Sambalpur district during AAP 2022-23.

All the 75 VES were interpreted in terms of layer parameters. The field curves were obtained as H, HK, KQ, KH, HKH and QH type. The long spread VES and Borehole logs spatially distributed were utilized for interpretation. VES analysis delineates that the true resistivity of the top Soil/Dry soil layer ranges from 15 to 250 Ω.m. This top layer varies in depth from 0.34 to 5.19 m. Next, the second layer has Clay/Sandy Clay having a resistivity range of 5 to 25 Ω.m. The thickness of this partially freshwater-bearing layer varies from 2.09 to 57.88 m. The mostly third and occasionally 2nd layer is Highly Weathered to Weathered Formation having a resistivity of 25 to 175 Ω.m, bearing good quality groundwater also. The depth of this layer varies from 5.25 to 84m. Mostly the 3rd or 4th geoelectric layer, occasionally the 2nd one with resistivities ranging from 175 to 600 Ohm m, occasionally exceeding to more than 800 Ohm m has been inferred as formation with fractures (Fractured granite). Wide range of the resistivities may be due to the variations in the degree of fracturing, nature of the formation, etc. The thickness of the geoelectric layer inferred formation with fractures varies between 27 and 106 m.Mostly the 3rd, 4th or 5th geoelectric layer, occasionally, the 2nd or 6th one with resistivities ranging above 800 Ohm m, has been inferred as Granite Formation. The depth to bottom of this layer is, in general, varying from 5.25 to 200 m. On the basis of geoelectrical layer parameters and the fractured zone analysis a few sites are recommended for borehole drilling or Shallow borehole or Dug well. Some of the representative VES curves are presented in Fig.3.In this study, resistivity VES data coupled with Litho Log data have been employed for the aquifer disposition/Sub surface lithology in the Sambalpur district. The data was incorporated into the vertical lithological distribution to demarcate the Weathered and Fractured zones governing the aquifer geometry. On the basis of geoelectrical layer parameters and the fractured zone analysis a few sites are recommended for borehole drilling or Shallow borehole or Dug well (ANNEXURE-II).

iv. Exploratory Drilling (Previous study): Ground water exploration by CGWB, SER in the district was initiated in the early nineties and till 2005, nearly 90 wells were drilled. Out of all these wells only four wells were drilled in Semi-

consolidated Gondwana rocks and rest wells in hard rock formations. Out of total wells in hard rock, 26 wells yielded less than 1 lps and 22 wells yielded more than 5 lps with maximum yield of 14 lps. The yield of 22 wells ranges between 1 to 3 lps and 18 wells yielded more than 3 to 5 lps. The potential saturated fractures were encountered in the south western part along Malatigunderpur- Bargaon-Dhama tract at close proximity of the Mahanadi river and in the Boxma-Bhojpur-Jamankira sector along the central part of eastern boundary of the district. Moderately good to very good discharges were recorded in pockets of Charmal, Jujumura, Naktideul, Kuchinda and Rairakhol blocks.

Present Study: During AAP 2022-23 a total number of 7 exploratory wells have been constructed within a depth ranges from 104.7 – 196.2 mbgl depth and discharge varying from 0.2 lps to 19 lps. Lithologs data, discharge data, chemical quality data etc. are also collected from the Basic data reports of 79 Exploratory wells constructed in Sambalpur District. Block wise details of exploratory wells are given in Table-11. Therefore, on the basis of 79 Exploratory well data composite cross section, panel diagram has been prepared.

Table-11: Block wise details of exploratory wells in Sambalpur District, Odisha

Sl. No.	Block	Location	Latitude in decimal	Longitude in decimal	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	Depth to Bed rock (mbgl) Casing Pipe Lowered	Granular zones/ deciphered (mbgl)	SWL (mbgl)	Discharge (lps)	Drawdown (m)	T (m^2/day) and S (if any)
1	Jamankira	Jamankira I	21.52	84.45	80.40	80.40	Basic intrusives	18.00	18,52,68, 78	3.76	11.00	4.96	
2	Jamankira	Jamankira II	21.52	84.45	75.80	75.80	Basic intrusive	52.10	38,58,63, 76	1.93	14.00	12.12	
3	Kuchinda	Kuchinda	21.73	84.36	196.20	196.20	Bio.Gr. Gneiss	15.20	27,129	6.00	1.20	-	
4	Kuchinda	Boxama	21.69	84.42	131.20	131.20	Gr. Gneiss	19.30	47,54,129,131	5.50	9.20	18.50	
5	Kuchinda	Boxama	21.69	84.42	192.20	192.20	Gr. Gneiss	16.30	52,93,122,146	5.37	6.0	17.09	
6	Kuchinda	Bhojpur	21.67	84.46	82.00	82.00	Gr. Gneiss	8.20	48,65	4.21	11.50	22.66	
7	Kuchinda	Bhojpur	21.67	84.46	172.40	172.40	Gr. Gneiss	12.0	50,85	4.30	5.0	11.30	
8	Jamankira	Podiabahal	21.47	84.21	171.90	171.90	Bio Gr. Gneiss	5.85	20,172	4.00	Nil	-	
9	Maneswar	Sindurpank	21.46	84.05	190.10	190.10	Bio Gr. Gneiss	12.20	15,190	2.00	Nil	-	
10	Dhankauda	Parmanpur	21.57	84.08	196.20	196.20	Bio Gr. Gneiss	9.30	124	7.46	Nil	-	
11	Maneswar	Maneswar	21.53	84.05	200.30	200.30	Bio Gr. Gneiss with Basic	4.10	178	6.30	0.30	-	
12	Dhankauda	Gosala	21.49	83.89	158.60	158.60	Gr. Gneiss	31.50	45,78,135	4.29	7.0	11.91	
13	Dhankauda	Gosala	21.49	83.89	196.80	196.80	Gr. Gneiss	28.10	51,69,94,103	5.49	7.0	11.72	

14	Rengali	Rengali	21.70	84.11	166.30	166.30	Gr. Gneiss	16.40	15,44,50,155	5.94	7.0	19.51	
15	Rengali	Rengali	21.70	84.11	172.40	172.40	Gr. Gneiss	16.90	26	6.50	1.40	-	
16	Rengali	Sasan	21.71	84.07	200.00	200.00	Gr. Gneiss	38.52		38.52	Nil	-	
17	Rengali	Lapanga	21.73	84.04	188	188	Granite	21		4.6	0.2		
18	Maneswar	Naxapali	21.43	84.04	118.40	118.40	Gr. Gneiss	17.5	28,106		7.00	32.65	
19	Maneswar	Naxapali	21.43	84.04	109.00	109.00	Gr. Gneiss	16.8	28,106		4.50	-	
20	Jujumura	Hatibari	21.33	84.14	50.4	50.4	Gr. Gneiss		32	6.8	6	10.79	
21	Jujumura	Jojumura	21.22	84.15	191.00	191.00	Gr. Gneiss		48.0		1.50		
22	Maneswar	Maltigunderpur	21.43	84.00	191.	191.	Gr. Gneiss	12.8	43,51	4.02	0.8		
23	Jujumura	Charmal	21.09	84.22	146.00	146.00	Gr. Gneiss	19.6	21	4.5	1.50	23.0	
24	Jujumura	Charmal	21.09	84.22	62.60	62.60	Gr. Gneiss	16.1	18	4.7	0.2		
25	Jujumura	Mundher	21.37	84.11	200.00	200.00	Gr. Gneiss	18.3	20	5.6	0.3		
26	Rairakhol	Sundhimunda	21.06	84.34	184.60	184.60	Gr. Gneiss	26		4.6	Ngl	24.59	
27	Rairakhol	Rairakhol (Biswanathpur)	21.11	84.39	200.00	200.00	Gr. Gneiss	19.1	21,73,109,129,156	4.8	5.00	27.60	4
28	Rairakhol	Rairakhol (Biswanathpur)	21.11	84.39	197.00	197.00	Gr. Gneiss	18.6	21,73,109,129,156	5	3.00	24.59	
29	Naktideol	Daincha	21.21	84.64	80.90	80.90	Gr. Gneiss	19.6	25,33	8.00	8.00	23.10	
30	Naktideol	Naktideule	21.12	84.60	191.00	191.00	Gr. Gneiss	18.6		2.30	3.00	20.70	
31	Rairakhol	Rairakhol	21.11	84.39	190.70	190.70	Gondwana SST & Shale upto 120m the Granite gneiss	21.0	15,44,50,155	1.80	2.50	2.0	
32	Maniswar	Dhama	21.24	83.94	105.70	105.70	Gr. Gneiss	12.34	14,20,23,27,73,76,85,87	2.44	11.0		
33	Maneswar	Dhama	21.24	83.94	99.60	99.60	Gr. Gneiss	12.60	23,52,88	2.46	8		
34	Maneswar	Bargaon	21.34	83.97	192.20	192.20	Gr. Gneiss	6.85	23,27,88, 92	2.72	1.50		
35	Bamra	Garposh	22.16	84.43	184.40	184.40	Gr. Gneiss	1.90	51,81	5.24	1.80		

36	Bamra	Taldihi	22.10	84.47	178.80	178.80	Gr. Gneiss	19.0	80	3.88	1.0		
37	Bamra	Kasaibahal	22.12	84.37	180	180	Gr. Gneiss	9.4	163.5,166.5	12.35	6		
38	Dhankavda	Sambalpur	21.54	83.96	200	200	Quartzite & Granite	10.8	15.9, 164.3	0.49	0.88	23.54	
39	Maneswar	Mura	21.53	84.21	125	125	Gr. Gneiss	7.0	11, 44.5	6.55	3.4		
40	Rengali	Katarbaga	21.64	84.17	169	169	Granite	11.5	12.0	4.2	0.5		
41	Jujumura	Dongarpada	21.44	84.16	173	173	Gondwana Shale		12.3	4.2	Neg		
42	Jujumura	Jaintpur	21.46	84.10	106	106	Granite gneiss & Amphibolite	6.5	21, 45, 52, 56	5.28	9		
43	Jujumura	Jaintpur	21.46	84.10	106	106	Granite gneiss & Amphibolite	6.1	21, 56, 62	5.07	3		
44	Bamra	Tangarpai	21.86	84.41	105	105	Granite Gneiss	6.2	61,86, 104, 84,110	2.57	7		
45	Bamra	Tangarpai	21.86	84.41	111.5	111.5	Granite Gneiss	6.6	-	254	3		
46	Dhankauda	Chiplima	21.32	83.89	200	200	Granite Gneiss	14.8			Ngt		
47	Rairakhol	Khutasingha	21.08	84.44	170	170	Granite Gneiss	21.35	83	5.35	0.5	-	
48	Rairakhol	Bansajal	21.07	84.22	165	165	Granite	21.30	62, 100, 109	5.6	3.3		
49	Rairakhol	Badmal	21.10	84.08	145	145	Granite Gneiss	14.20	70	7.9	0.2	-	
50	Rairakhol	Rairakhol	21.08	84.37	167	167	Pink Granite	7.40	92, 130	8.31	1.5	-	
51	Rairakhol	Kukuda Bahal	21.00	84.41	160	160	Granite Gneiss	16.60	68, 100	6	0.5	-	
52	Rairakhol	Loindamal	21.01	84.31	160	160	Shale & Granite	20.70	80	3.8	1.5		
53	Naktideul	Saraipalli	21.27	84.54	151	151	Granodiorite with Amphibolite	24.50	60, 82	Seasonal - Autoflow	5	10.96(1min)	

54	Naktideul	Gogua	21.20	84.40	115	115	Granodiorite	24.00	82-83	-	5	-	87.898
55	Naktideul	Gogua	21.20	84.40	20	20	Weathered zone	0.00	-	-	-	-	
56	Naktideul	Paikmal	21.20	84.46	51	51	Granodiorite	7.70	42, 63, 89	4.98	0.2	-	
57	Naktideul	Khunjamura	21.25	84.21	152	152	Sandstone & Pebbly Grit	22.40	62, 80	1.8	5.5	6.80(1)	
58	Naktideul	Shaibi	21.24	84.60	120	120	Sandstone & Quartzite	18.40	63, 82	1.95	3.3	-	17.39
59	Naktideul	Shaibi	21.24	84.60	100	100	Sandstone & Shale	24.20	70	5.1	0.5	-	
60	Naktideul	Simalipal	21.20	84.50	148	148	Granite Gneiss	19.40	23-24	2.45	6	-	
61	Naktideul	Girishchandrapur	21.29	84.48	24	24	Siltstone	14.30	128	4.46	2	25.04(1)	
62	Naktideul	Balam	21.30	84.55	148	148	Sandstone & Shale	18.40	72	5.9	1	-	2.43
63	Naktideul	Lusura	21.17	84.50	125	125	Granite Gneiss	9.50	72	1.74	1.5	-	
64	Naktideul	Terabeda	21.13	84.38	150	150	Shale	17.70	-	-	Negl	-	
65	Naktideul	Chatrapur	21.18	84.42	151	151	Granite	12.40	76	1.7	1	-	
66	Rairakhol	Kantakatta	21.03	84.37	150	150	Granite	11.90	72, 99	5.67	3	-	
67	Rairakhol	Hatibahal	21.00	84.36	138.8	138.8	Granite Gneiss	17.30	98-99	9.75	3	16.80(1)	2.64
68	Rairakhol	Nuapara	21.12	84.28	125.4	125.4	Granite	12.20	92	6.8	0.5	-	
69	Rairakhol	Charpatti	21.05	84.39	150	150	Granite	6.50	72	8.2	0.2	-	
70	Rairakhol	Pitanali	21.09	84.41	150	150	Granite	17.20	79	4.29	1	-	
71	Rengali	Laida	21.21	84.40	150	150	Shale, sandstone, siltstone	24.00		8.5	4	-	
72	Jujumura	Charmal	21.12	84.14	150	150	Biotite granite gneiss	19.60	21	4.5	4.5		

73	Naktideul	Kunjamura	21.25	84.67	190.2	190.2	Granite	15.2	30, 47, 48, 68, 77, 130, 168	3.98	6.64	14.87	24.6/ $2.00*10^{-4}$
74	Naktideul	Salebhata	21.29	84.68	196.2	196.2	Granite gneiss	28.5	34,42,48,89, 92,102,121,124	5.77	10.3	24.69	26.43/ $1.46*10^{-4}$
75	Rairakhol	Rairakhol	21.07	84.35	104.7	104.7	Granite	16	62, 76	6	3.35		
76	Naktideul	Phulkusum	21.26	84.37	159.6	159.6	Granite gneiss	24.9	37,38,39,42, 46,48,57,61, 73,84,90	5	18.96	10.50	43.19/ $1.2*10^{-4}$
77	Sambalpur City	Sambalpur	21.45	84.98	104.7	104.7	Granite	9.5		6	0.23		
78	Naktideul	Kisinda	21.33	84.35	104.7	104.7	Granite	23.5	75,80	20	0.44		
79	Naktideul	Sahajbahal	21.23	84.31	196.2	196.2	Granite gneiss	23.5	40, 43.7, 52, 53.9, 68, 108, 110	5	6.88		

3. DATA INTREGATION, INTERPRETATION AND AQUIFER MAPPING

A. GEOLOGY: Major parts of this district is underlained by hard rocks of Precambrian age. Lower Gondwana sediments of Paleozoic-Mesozoic age occur as isolated patches occupying small areas. Recent alluvium occur as thin and discontinuous patches limited along prominent drainage channel. The laterite occur as thin capping over the country rocks in isolated pockets particularly in upland areas. The generalized stratigraphic sequence is given in the Table 12.

Table 12: General Geological sequence in Sambalpur District

Geological age	Rock types	Description
Recent to sub-Recent	Alluvium	Sand, silt, clay in varying proportion
	Laterite	Laterites and lateritic gravels
Paleozoic to Mesozoic	Lower Gondwana rocks	Mainly shale, sandstone sequence with minor coal seams
Precambrian	Quartz & pegmatite veins, dykes eic. Meta basics (Epidiorite, amphibolite etc.) Granite gneisses Quartz-micaschist, phyllite, Carbon phyllite etc. Charnockite and khondalite suits of rocks.	

Khondalite: These comprise quartz-garnet-sillimanite schists and gneisses and calc-silicate rocks. The rocks usually form hills in the south western part and is mostly associated with charnockite suite of rocks. The rocks are greyish brown to pinkish brown in colour, and well foliated. The calcsilicates occur as minor bands. The quartzites occurs prominently with khondalites in Sambalpur Town forming hills.

Charnockite: This suite of rocks comprises of pyroxene granulite, hypersthene granite and granodiorite etc. The acid and intermediate group of rocks are more common than other varieties.The charnockites are found mostly in south western part of the district covering parts of Jujumura, Rairakhol and Manesar Blocks and mostly forms rugged hill ranges. The charnockites are fine to coarse grained, greenish grey coloured having greasy lutture. Texture is mostly granulitic and having gneissic structure.

Granite gneiss: Granite gneisses are the most predominant rock types in the district occupying nearly 60% area of the hard rock terrain. The rocks generally occur in the undulating plains and sometimes form low hills and mounds also. These rocks are mostly represented by biotite gneiss, porphyritic granite gneiss etc. Light grey to grey in colour and mostly medium to coarse grained and sometimes form well developed gneissic structure.

Phyllitic and Schistose rocks: These rocks are confined to northern and north eastern parts covering parts of Bamra blocks. The rocks comprises of phyllites, carbon phyllites, mica schist and quartzites. These rocks belongs to Iron ore Group of rocks.

Meta-Basic: These basic meta-volcanics occur as intrusive bodies within the granitic rocks in Jamankira Blocks. The rock are mainly occur as linear bodies.

Minor intrusive bodies: These rocks include quartz and pegmatite veins and also basic intrusive bodies (other than epidiorite) as dykes and sills etc. The occurances of these bodies are found throughout the district. Pegmatites are usually coarse grained comprising mainly of quartz, feldspar and minor amount of mica. Quartz veins are more common in the northern part of the district. The basic intrusives are mostly doletite dykes.

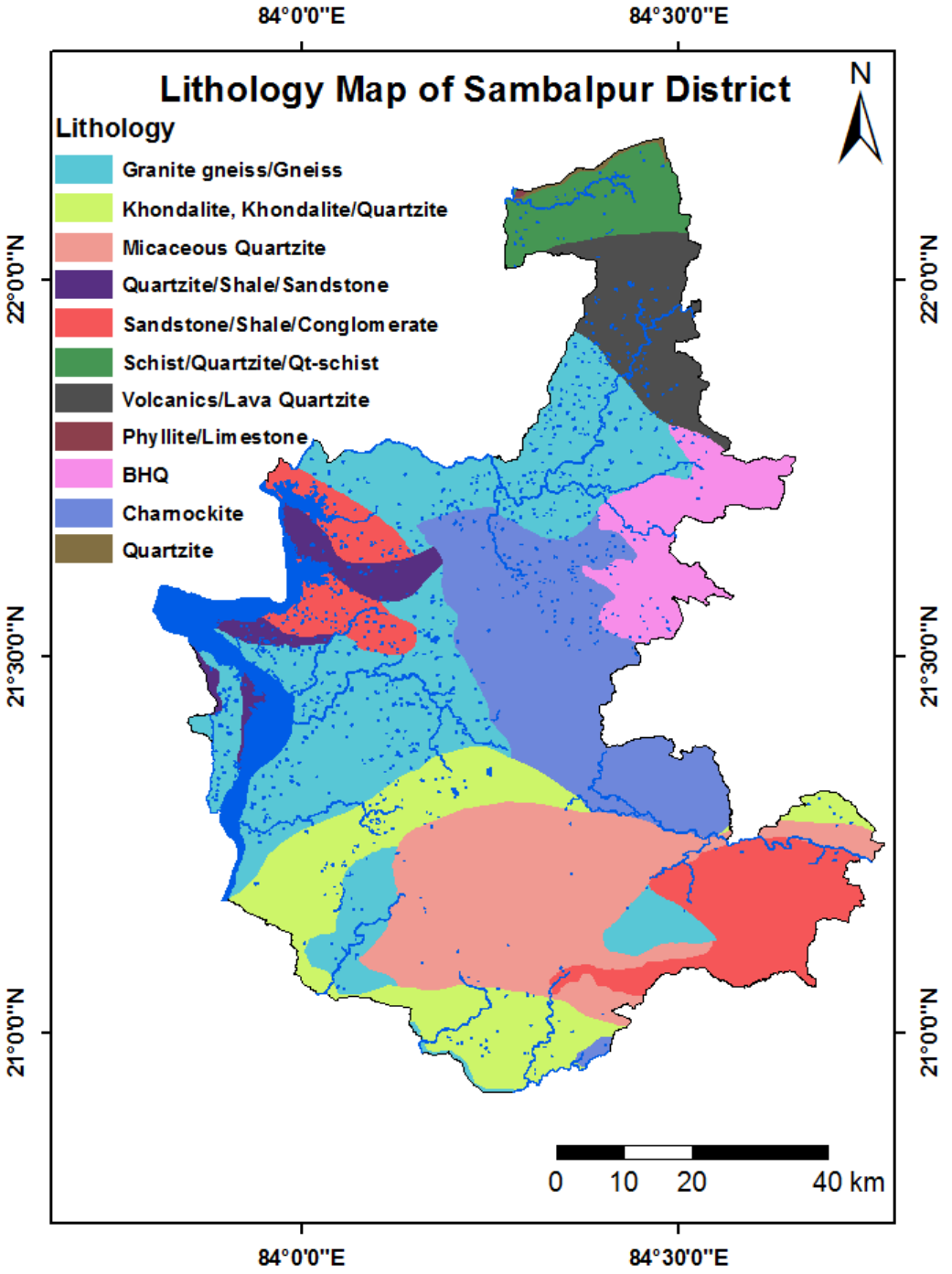
Lower Gondwana Sedimentaries: This group of rocks occur in extreme south eastern part covering parts of Rairakhol and Naktideul blocks also occur as linear bodies in the west central and north western parts covering parts of Sambalpur Sadar Subdivision. The rocks comprises of mainly shale-sandstone sequences alongwith siltstone, clay stone, conglomerate and non-mineable occurrences of coal seams.

Laterites: Laterite occur as a capping over the country rock particularly in local upland areas with limited thickness. The thickness upto 4 to 5 m has been observed in Jamankira block in association with epidiorite rocks..

Alluvium: The alluvium of Recent origin comprising of sand, silt and clay of limited extension and thickness occurs in pockets along major drainage channels.

Structure: The most important fault is the North Orrisa Boundary fault running E-W and passing north of Sambalpur town. The Gondwana rocks occur along this fault zone. The regional trend of foliation in the area located south of North Orrisa Boundary fault is generally NE-SW,NNE-SSW while it is in the north of Boundary fault is generally E-W.

Fig.12. Geological map of Sambalpur District, Odisha



B. HYDROGEOLOGY: As discussed earlier the district comprises with 85 % consolidated formation and 15% semi-consolidated formation and mintute presence of unconsolidated formations. From the water table contour map it is observed the ground water flow direction is from NE to SW direction and N-S direction (Fig.13a,b).

Fig.13a. Hydrogeological Map of Sambalpur District

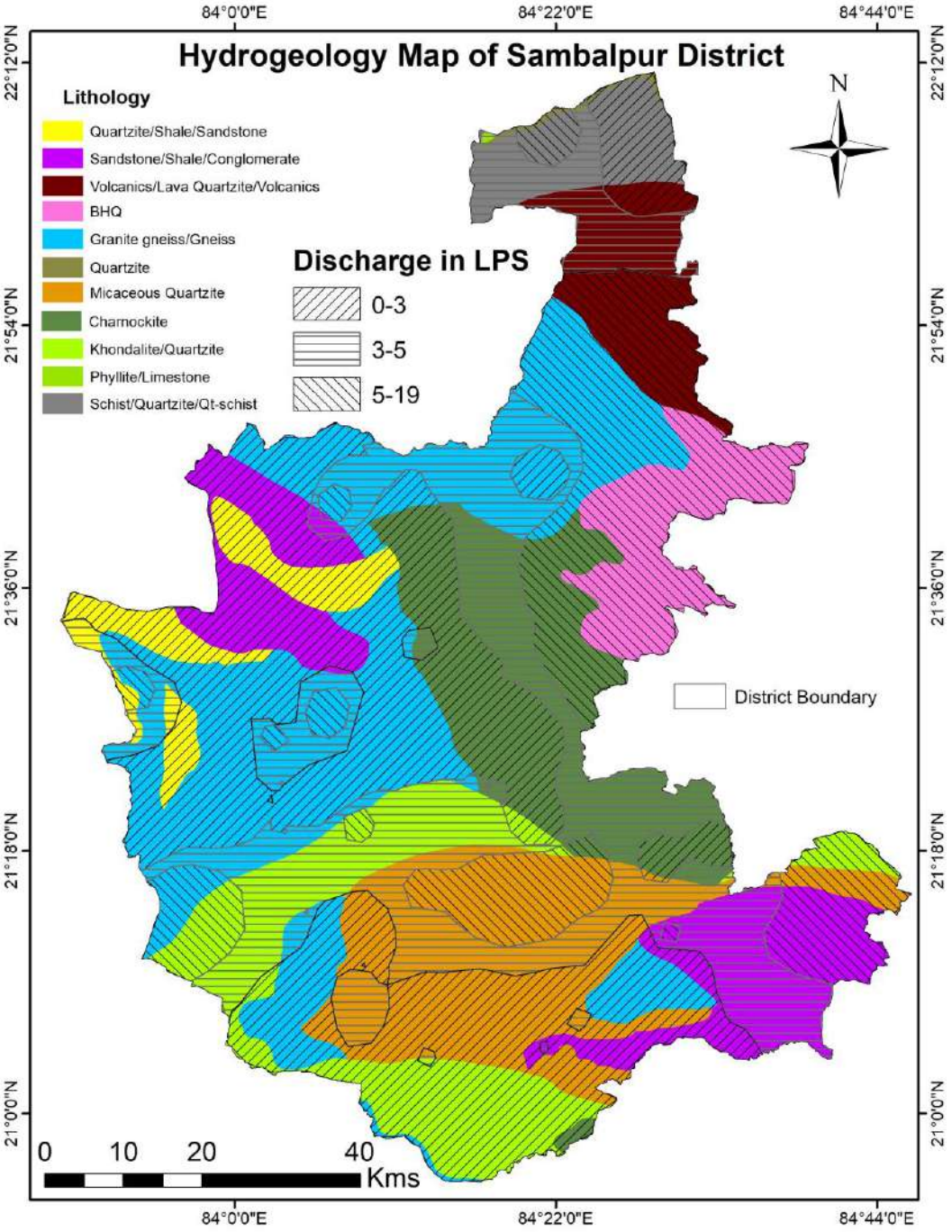
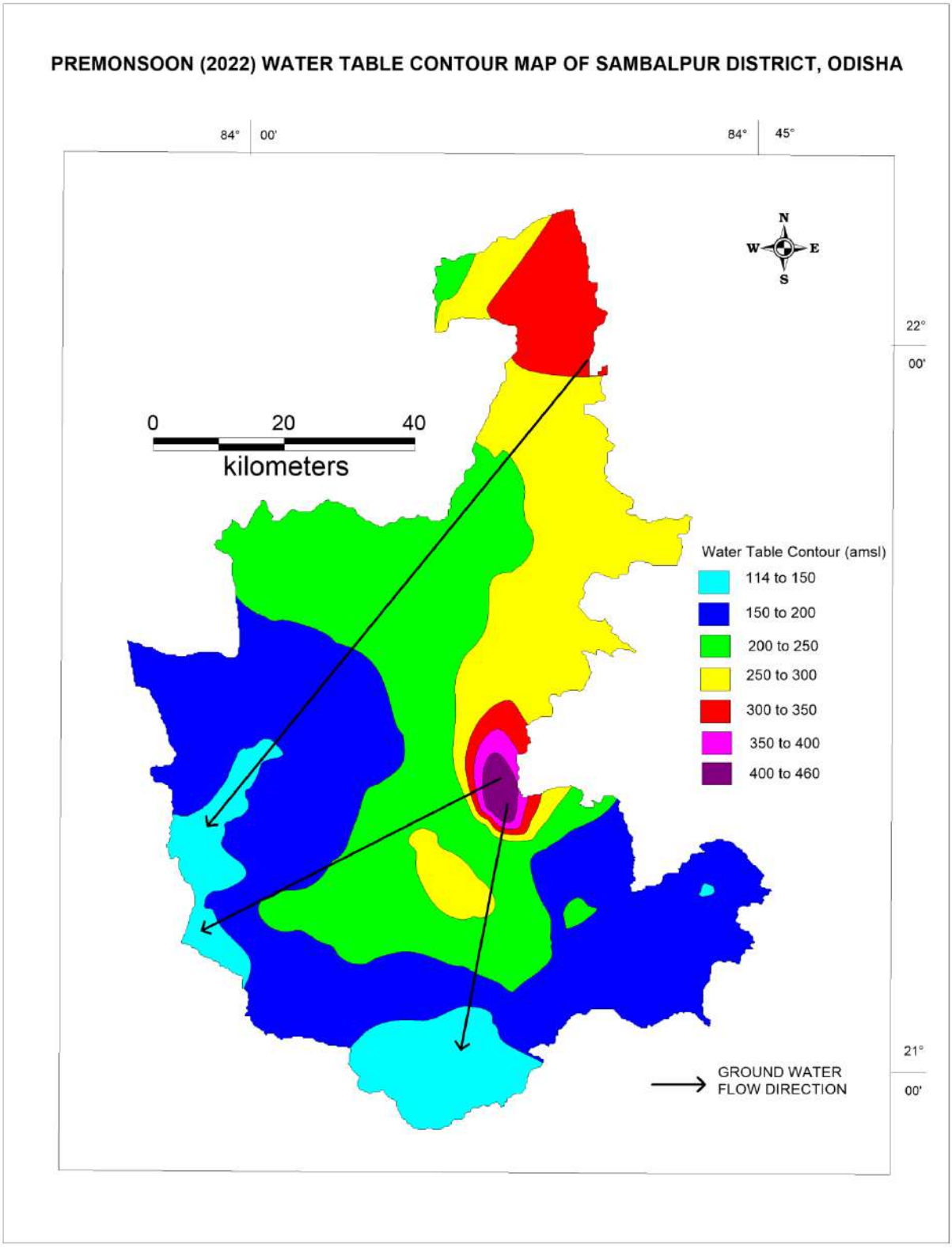


Fig.13b. Premonsoon (2022) Water Table Contour Map of Sambalpur District



C. SUBSURFACE DETAILS:

Nearly 85% of the total geographic area is occupied by crystalline rocks (Consolidated Formation) comprising of granite gneiss, charnokites, khondalites, schists, phyllites, quartzite, volcanics, intrusives. Aquifer is unconfined within weathered zone and semiconfined within fracture zone. Majority of fracture zones are confined within 100 meter depth and very few are beyond 100 meter depth upto a drilling depth of 200 mbgl. Fracture zones are generally discontinuous upto a drilling depth of 200 mbgl. From the depthwise fracture frequency analysis (Fig.14) for all 79 exploratory wells it is observed that maximum number of fractures are located within 20-30m, 40-50m, 70-80m, 80-90 m depth ranges in granite gneiss, at 40-50m, 70-80 m in Gondawan sedimentaries and from 50-80 m depth ranges in basic intrusives.Discharge of 67 selected bore wells in granite gneiss ranges from negligible to 19 lps.Out of 67 wells in granite/granite gneiss 58.20% wells having discharge varies from 0 to 3 lps, 13.43% wells having discharge ranges from 3 to 5 lps and 28.36% wells having discharge ranges from 5 to 19 lps.During the current NAQUIM year drilling at three sites (Kunjamar,Salebhata, Phulkusum) upto 196.2 near the fold hinge/limb in Naktideul block shows high yielding wells having yield ranges from 12-19 lps with drawdown of 10.5-24.69 m during 500 to 1000 minutes of aquifer performance test. T values in granite gneiss ranges from 2.64 to 87.89 m^2/day. Storativity value obtained as **$1.20*10^{-4}$** to **$2.0*10^{-4}$**. This denotes fractured aquifer is semiconfined type. But here also fracture zones are observed within 100 mbgl depth.The wells are recovered within 2 hours after stoppage of pump. Discharge of 10 selected bore wells in Gondwana sedimentaries ranges from negligible to 5.58 lps.Out of 10 wells in Gondwana sedimentaries 70% wells having discharge varies from 0 to 3 lps, 20% wells having discharge ranges from 3 to 5 lps and 10% wells having discharge ranges from 5 to 5.58 lps. T values in gondwana sedimentaries ranges from 2.43 to 17.39 m^2/day. Only two wells in ultrabsics rocks in Jamankira Block shows discharge ranges from 11 to 14 lps. (Three dimensional and two dimensional aquifer dispositions are shown in Fig.15).

Fig.14: Depthwise Fracture frequency analysis in Sambalpur District

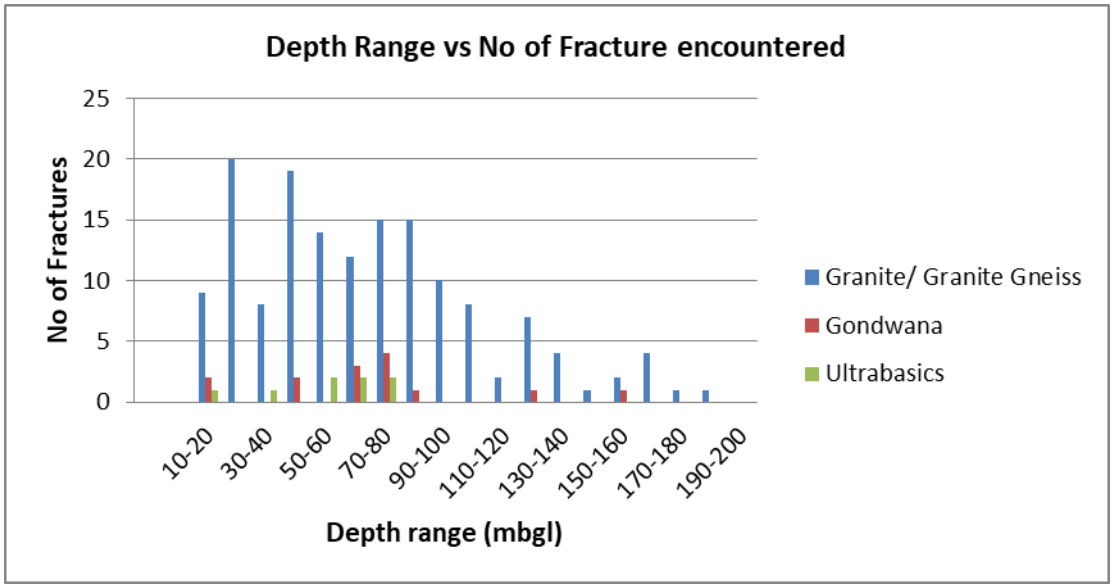


Fig.15a.Three-dimensional aquifer disposition model, Sambalpur District

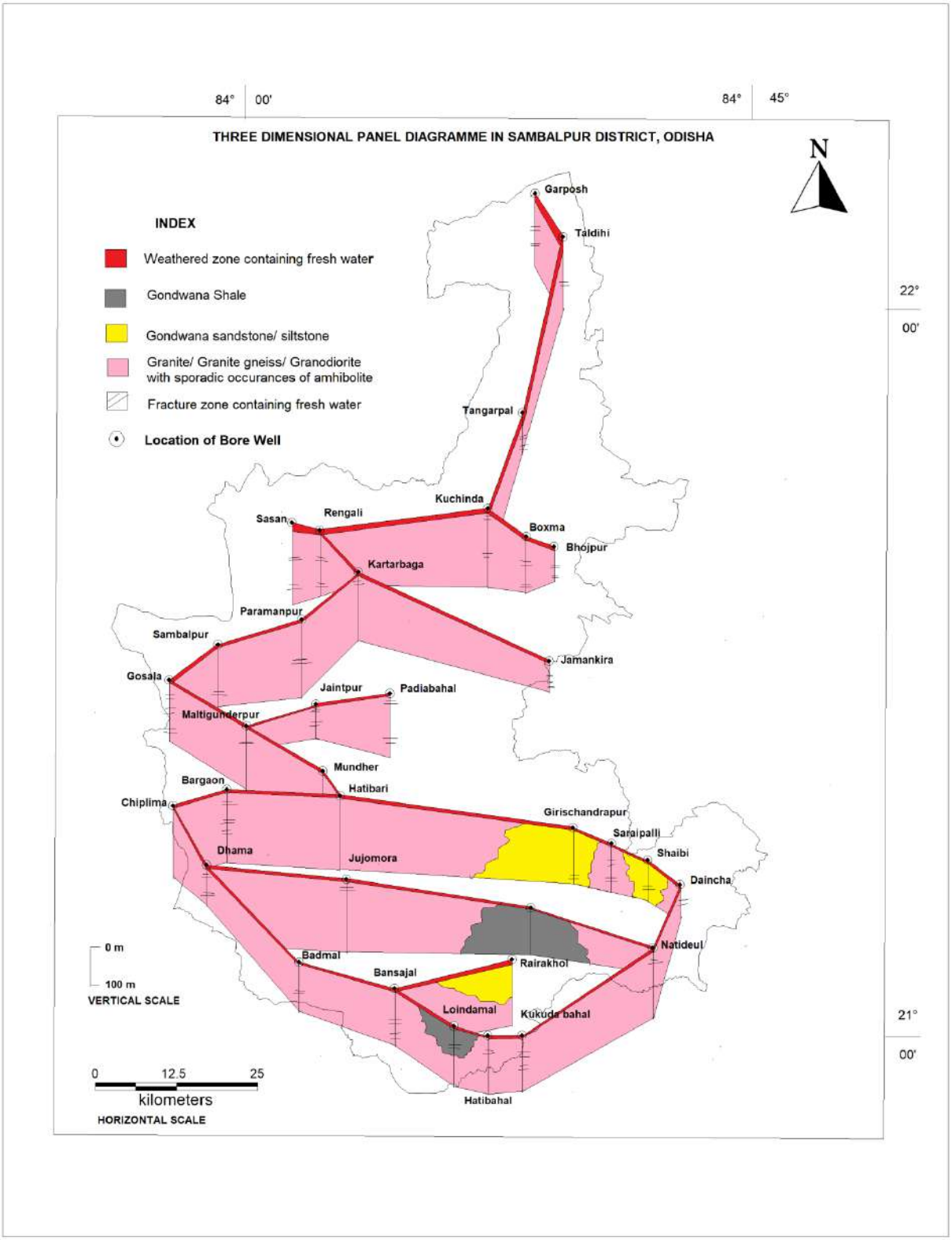


Fig.15b.Cross section lines in different direction, Sambalpur District

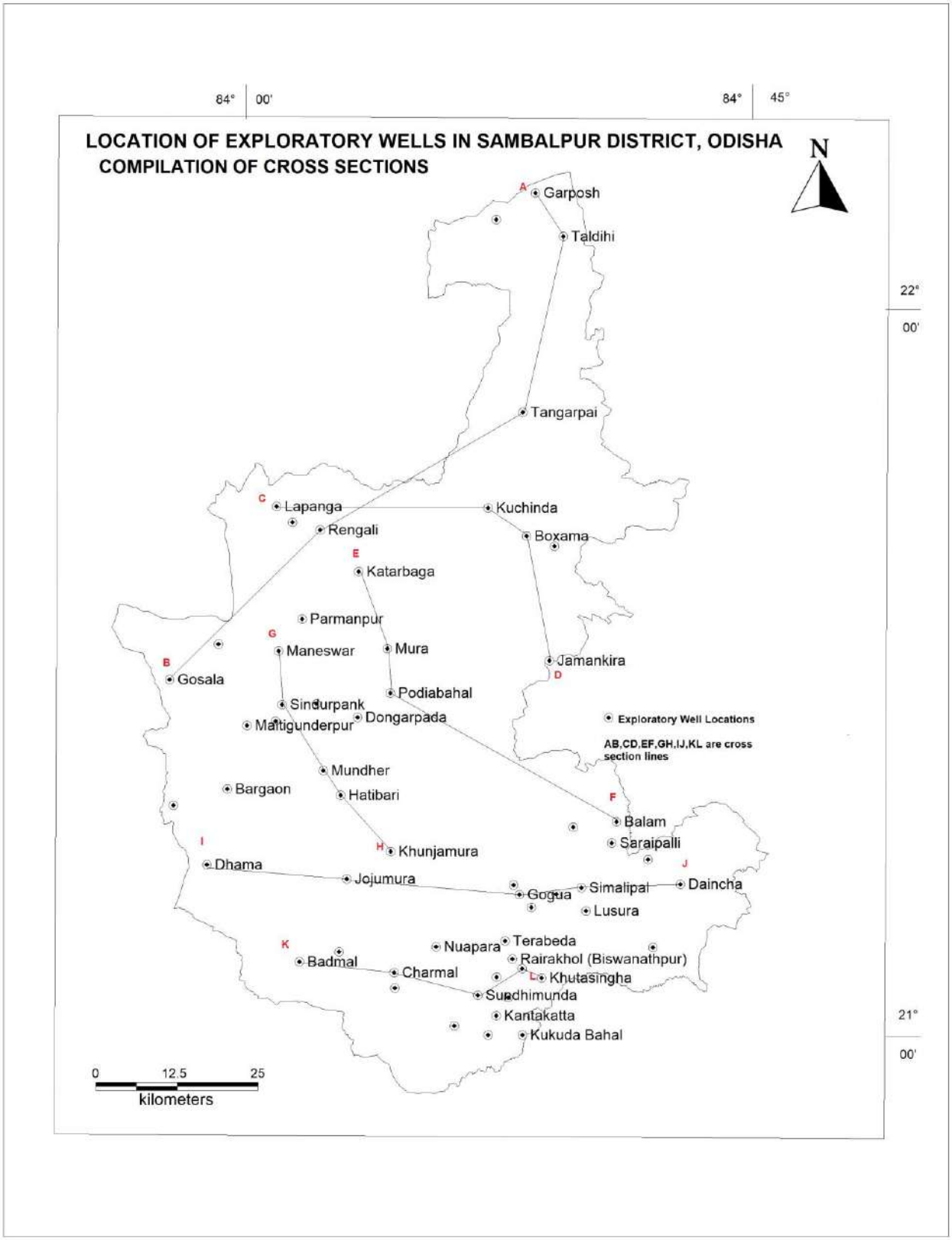


Fig.15c.Two-dimensional aquifer disposition model along AB and CD direction, Sambalpur District

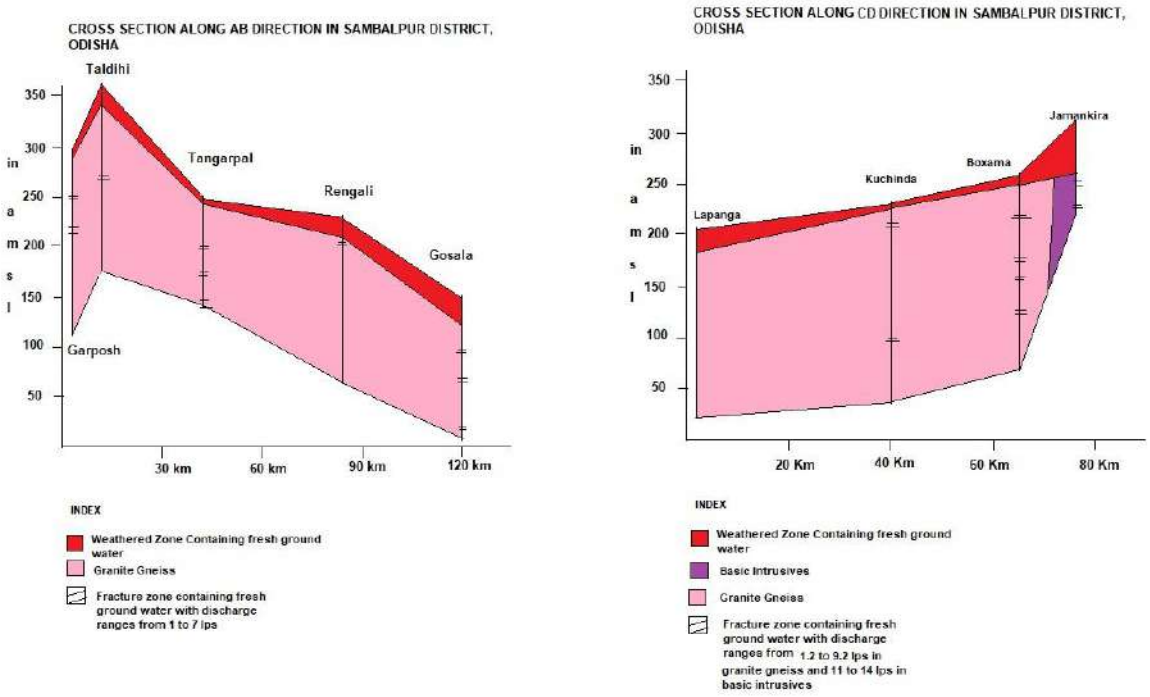


Fig.15d.Two-dimensional aquifer disposition model along EF and GH direction, Sambalpur District

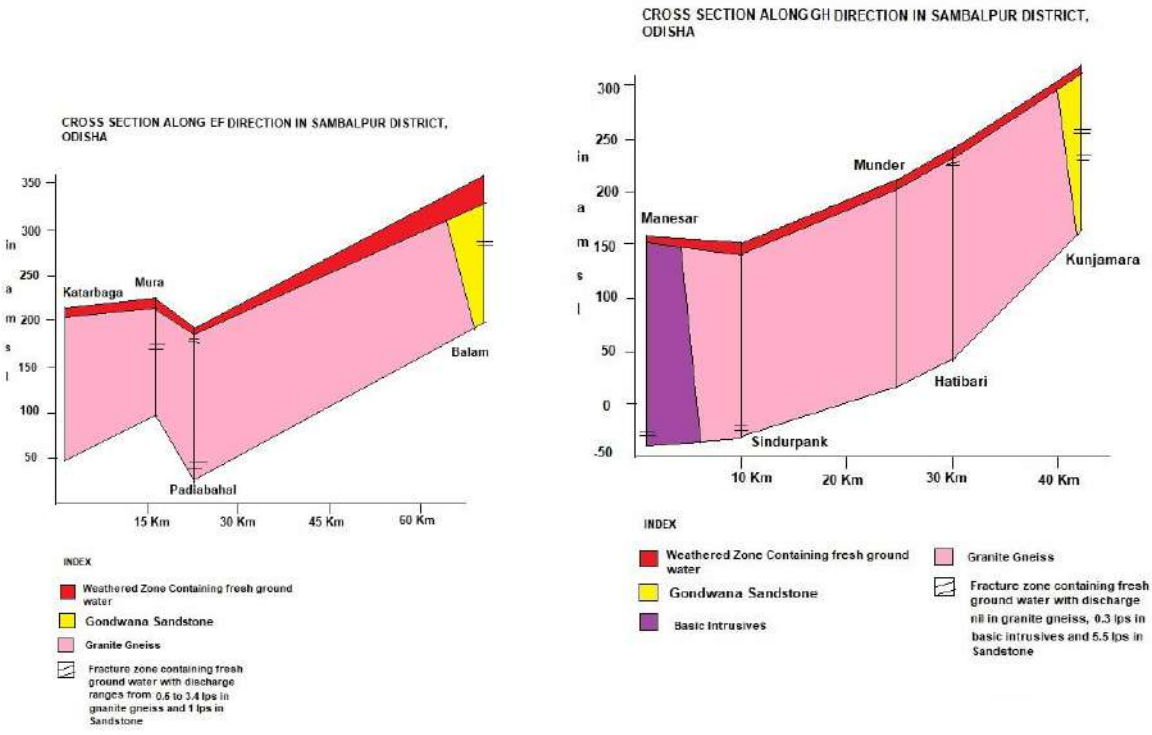
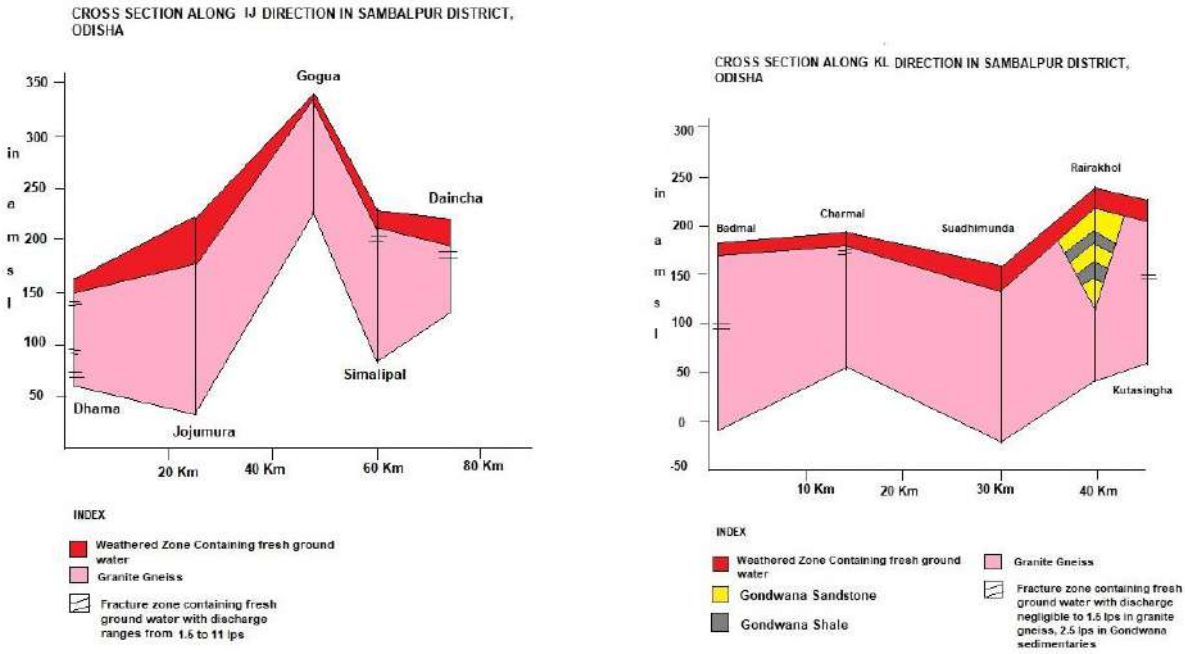


Fig.15e.Two-dimensional aquifer disposition model along IJ and KL direction, Sambalpur District



D. AQUIFER GROUPING: On the basis of data collection of exploratory wells it has observed that 5 tube well constructed within 100 mbgl depth and 74 tube wells constructed between 100-200 mbgl depth. Discharge of the tube wells having fracture zones within 100 meter depth varies from 0.2- 6.0 lps and discharge of the tube wells having fracture zones upto 200 meter depth varies from 0.2 – 18.96 lps. On the basis of weathered zone and fracture zone details, aquifer grouping is summarized in the Table 13:

Table 13: Aquifer Grouping in Sambalpur District, Odisha

Aquifer Group		Depth Range (mbgl)		Thickness (m)	
		From	To	Min	Max
Aquifer I (Within 100 m)	(Weathered Zone)	6.50	38.52	1.5*	33.52*
	(Fracture Zone)	11	100	0.5	1.5
Aquifer II (100-200 m) (Fracture zone)		103	190	0.5	1.5

***Depth of mean water level, i.e., 5.0 mbgl will be considered as depth of unsaturated zone. Hence it will be subtrracted from the total depth of weathered zone**.

E. WATER LEVEL, WATER TABLE, DECEDAL TREND AND HYDROGRAPH:

Pre-Monsoon Depth to Water Level of shallow aquifer (weathered zone) during 2022 ranges from 1.31 mbgl to 16.13 mbgl (Fig.16a). Post-Monsoon Depth to Water Level of shallow aquifer during 2022 ranges from 0.1 mbgl to 14.5 mbgl (Fig.16b). Annual fluctuation of water level ranges 0.1 to 8.88 m rise in 95 wells and 0.1m fall in 2 wells (Fig.16c).

Pre-Monsoon Depth to Water Level of deeper aquifer (Fracture Zone) during 2022 ranges from 2.69 mbgl to 8.72 mbgl (Fig.16a). Post-Monsoon Depth to Water Level of fracture zone during 2022 ranges from 0.79 mbgl to 4.93 mbgl (Fig.16b). Annual fluctuation of water level ranges 0.4 to 5.04 m rise in all the bore wells (Fig.16c).

Long Term water level fluctuation in 10 yrs (2013-2022) in m-----0.01 m to 7.30 m rise in 68.31% well, 0.03 m to 4.49 m falling in 29.70 % well (Pre-monsoon).

0.007 m to 3.24 m rise in 69% well, 0.018 m to 2.50 m falling in 31 % well (Post monsoon).

Ten years post monsoon mean (2013-22) ground water level ranges from 0.44 to 8.43 mbgl. Ten years pre monsoon mean (2013-22) ground water level ranges from 0.46 to 8.65 mbgl. As per availability of NHS data long term ten years trend is falling in 350 sq.km area of the district ranges from 0.68 cm/year to >7.00 cm/year and rising in 6352 sq.km area of the district (ranges from 0.44 cm/year to 1.57 cm/year) (Fig.17a, b). Few hydrographs are also shown in the Fig.18.

Fig.16a. Depth to water level map of Shallow aquifer (Pre monsoon, 2022), Sambalpur District

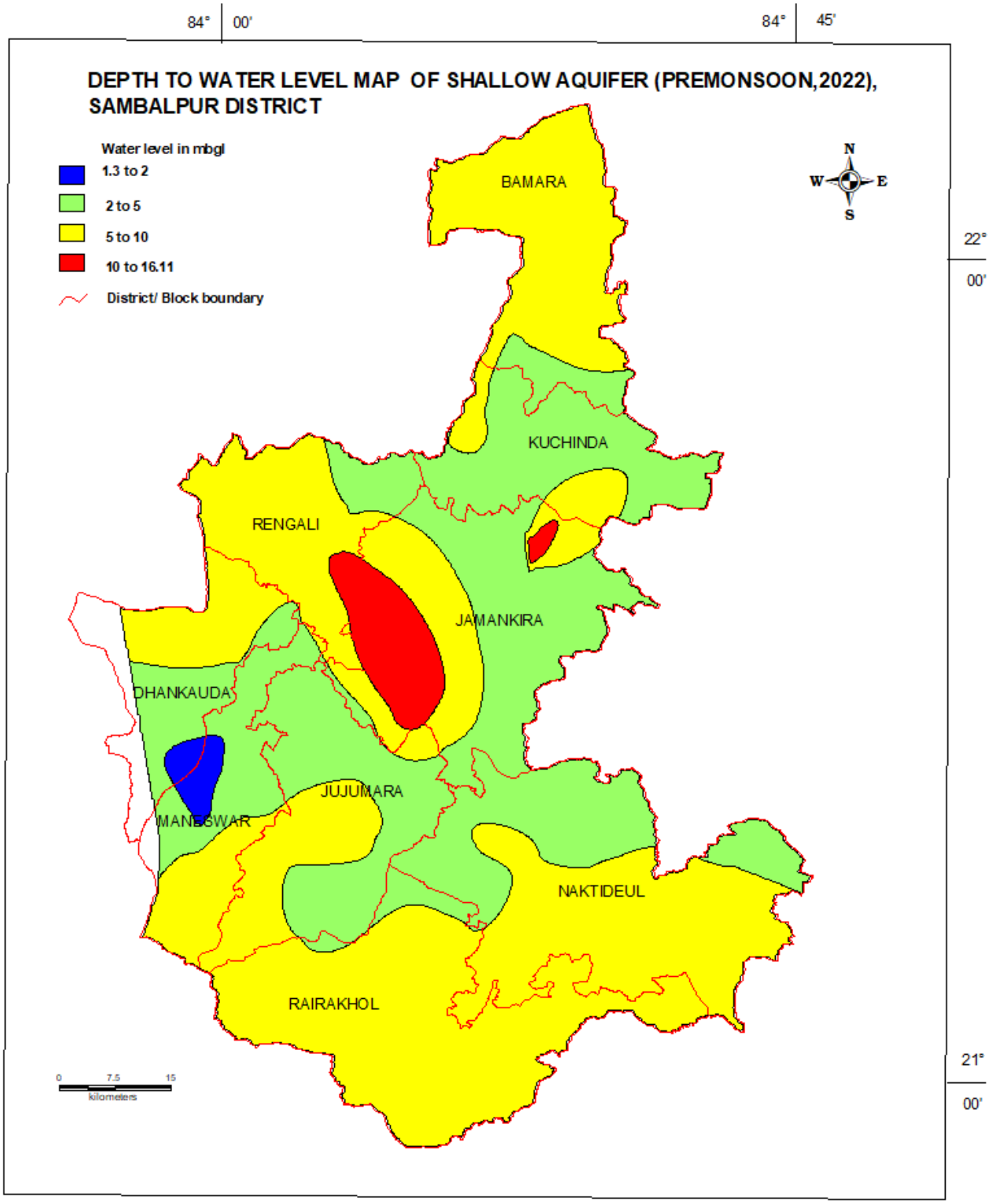


Fig.16b. Depth to water level map of Shallow aquifer (Post monsoon, 2022), Sambalpur District

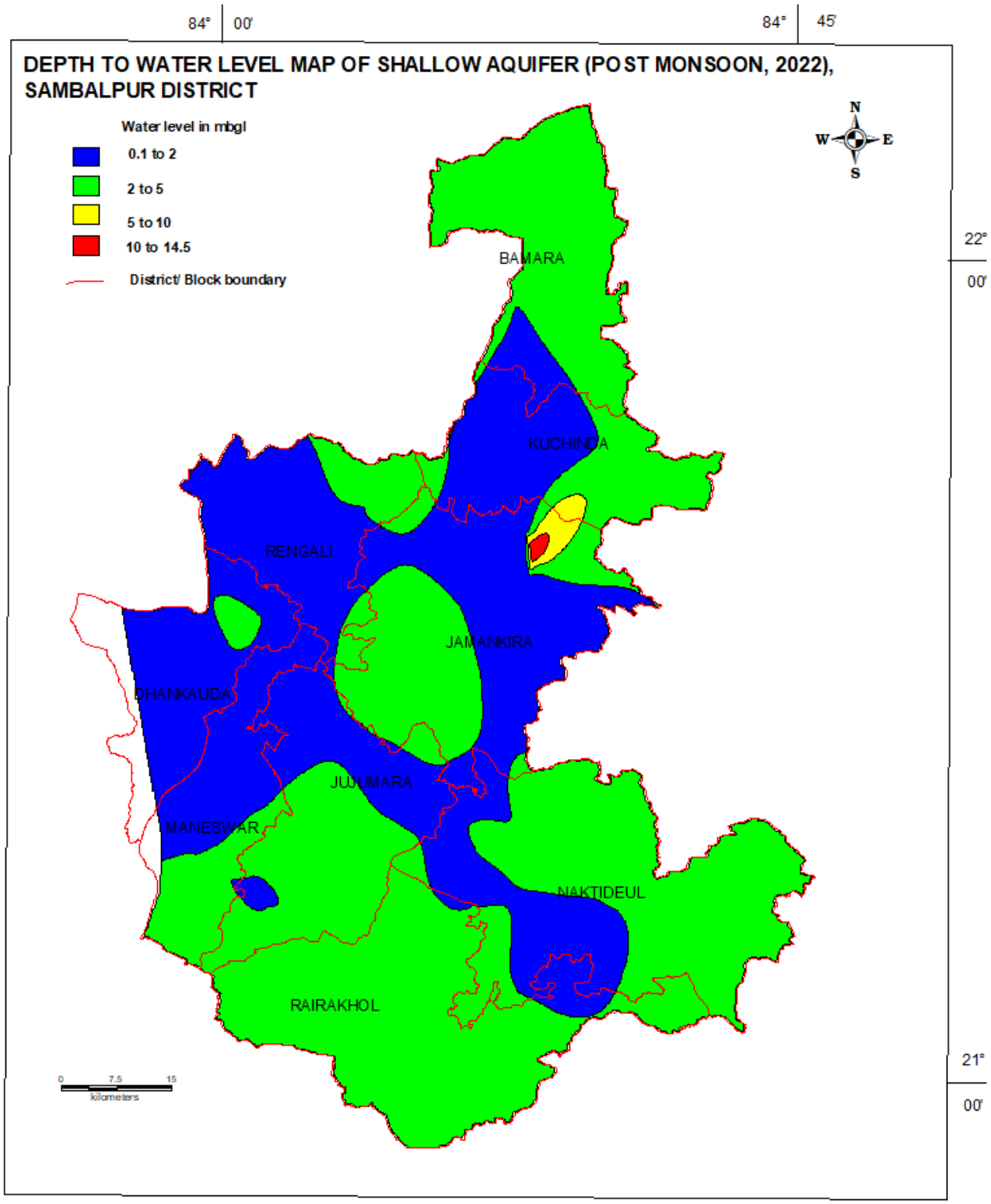


Fig.16c. Annual fluctuation of water level of Shallow Aquifer (Pre and postmonsoon- 2022), Sambalpur District

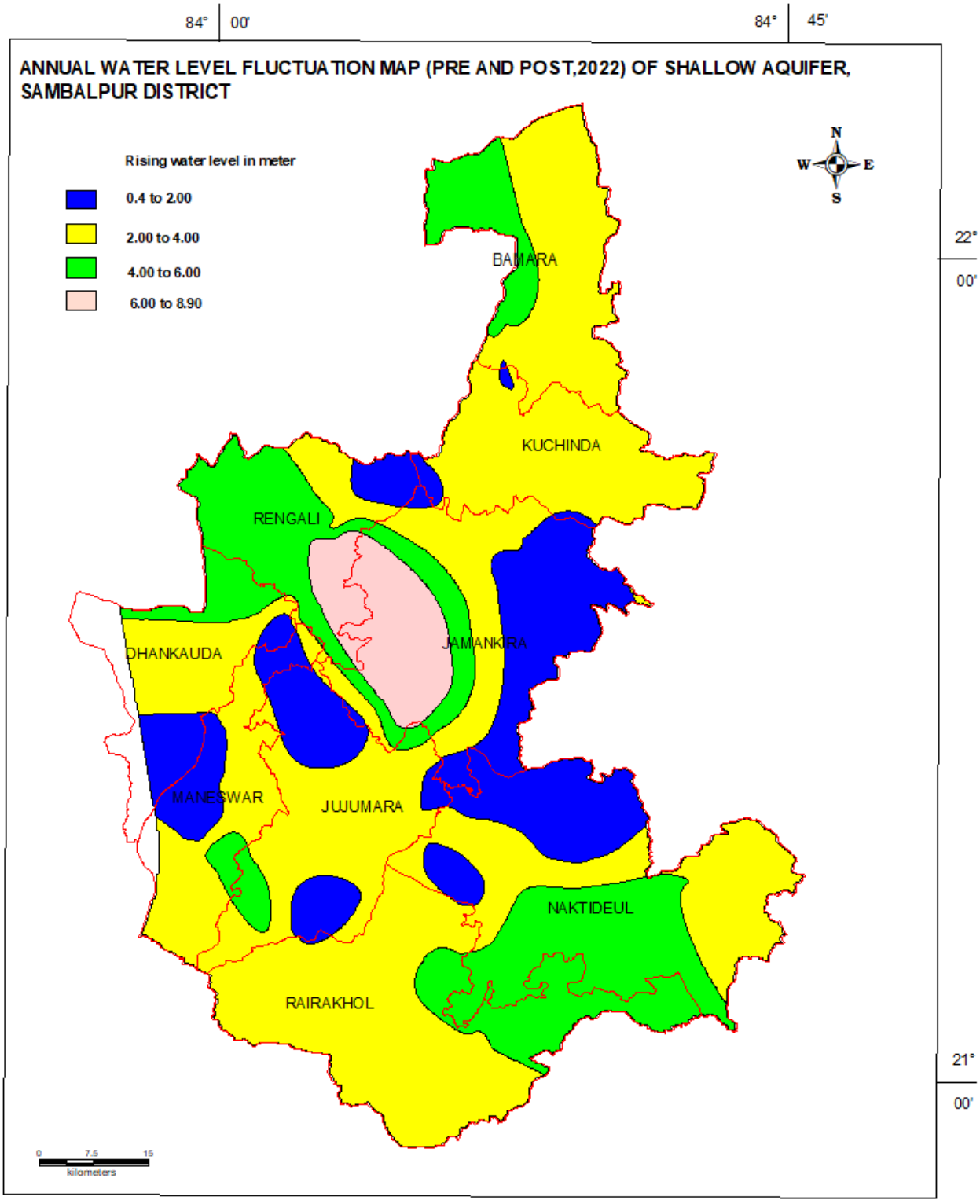


Fig.16d. Depth to water level map of Deeper aquifer (Pre monsoon, 2022), Sambalpur District

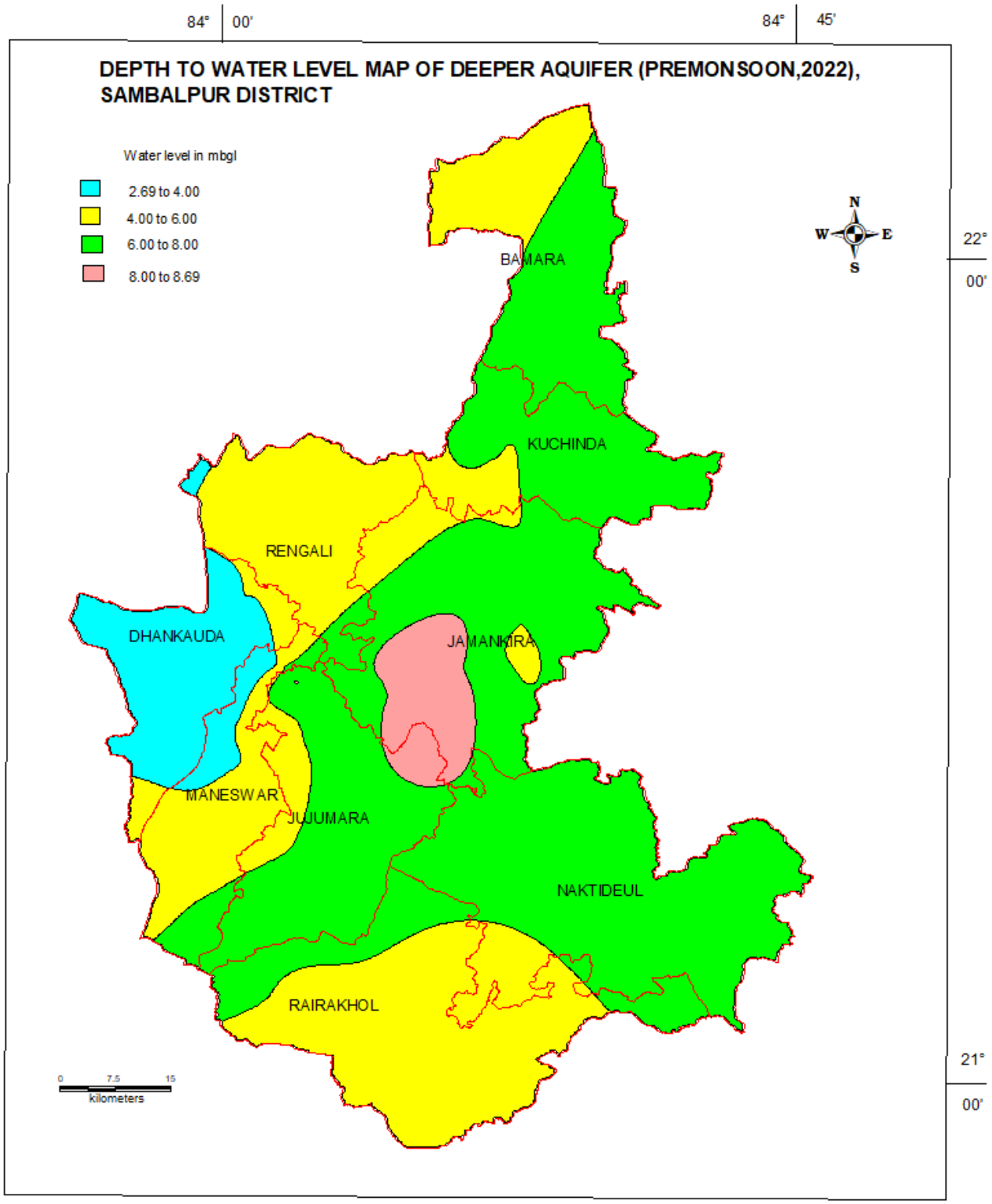


Fig.16e. Depth to water level map of Deeper aquifer (Post monsoon, 2022), Sambalpur District

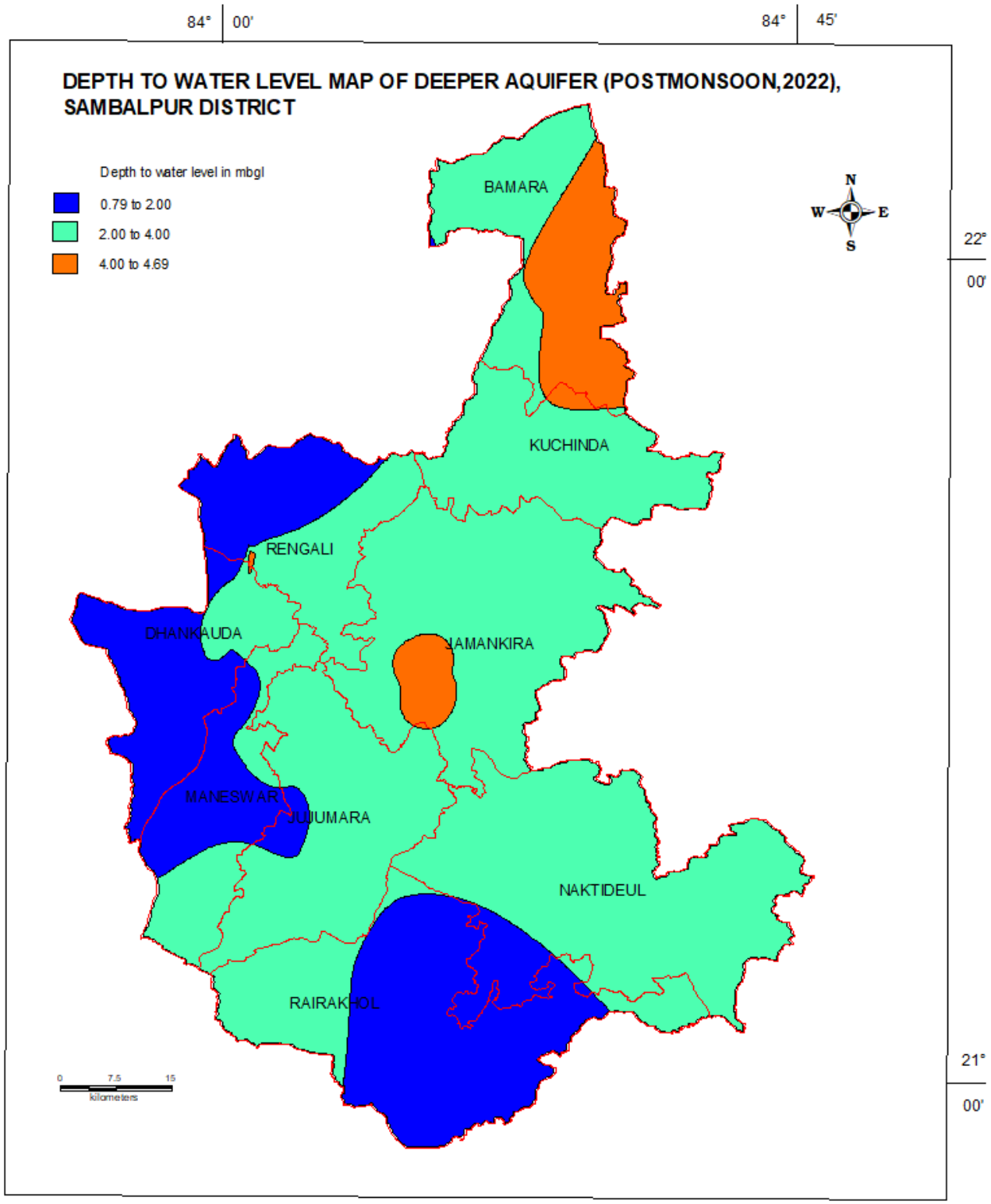


Fig.16f. Annual fluctuation of water level of Deeper Aquifer (Pre and postmonsoon- 2022), Sambalpur District

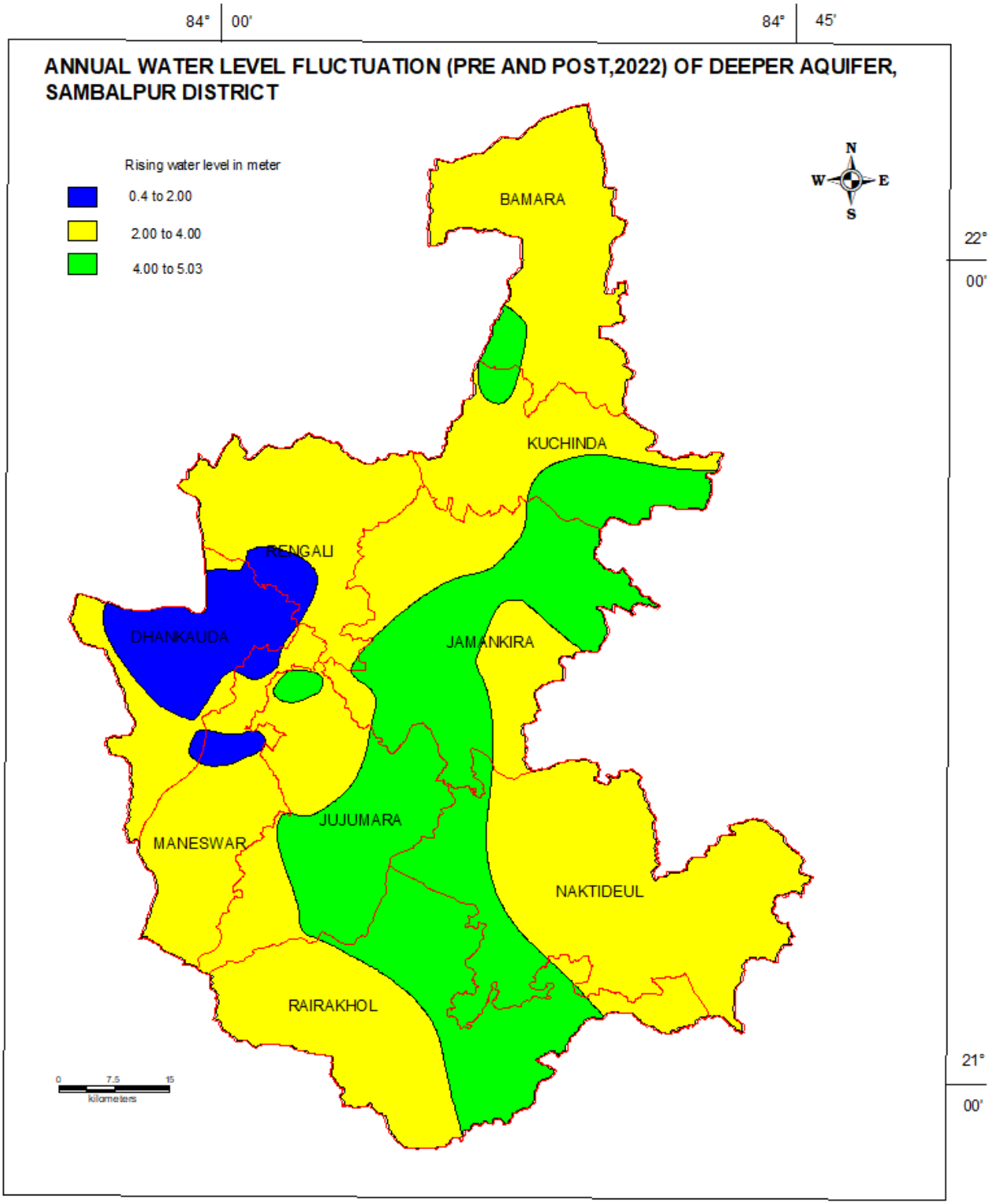


Fig.17a. Ten years Post monsoon (2013-2022) Mean water level, Sambalpur District, Odisha

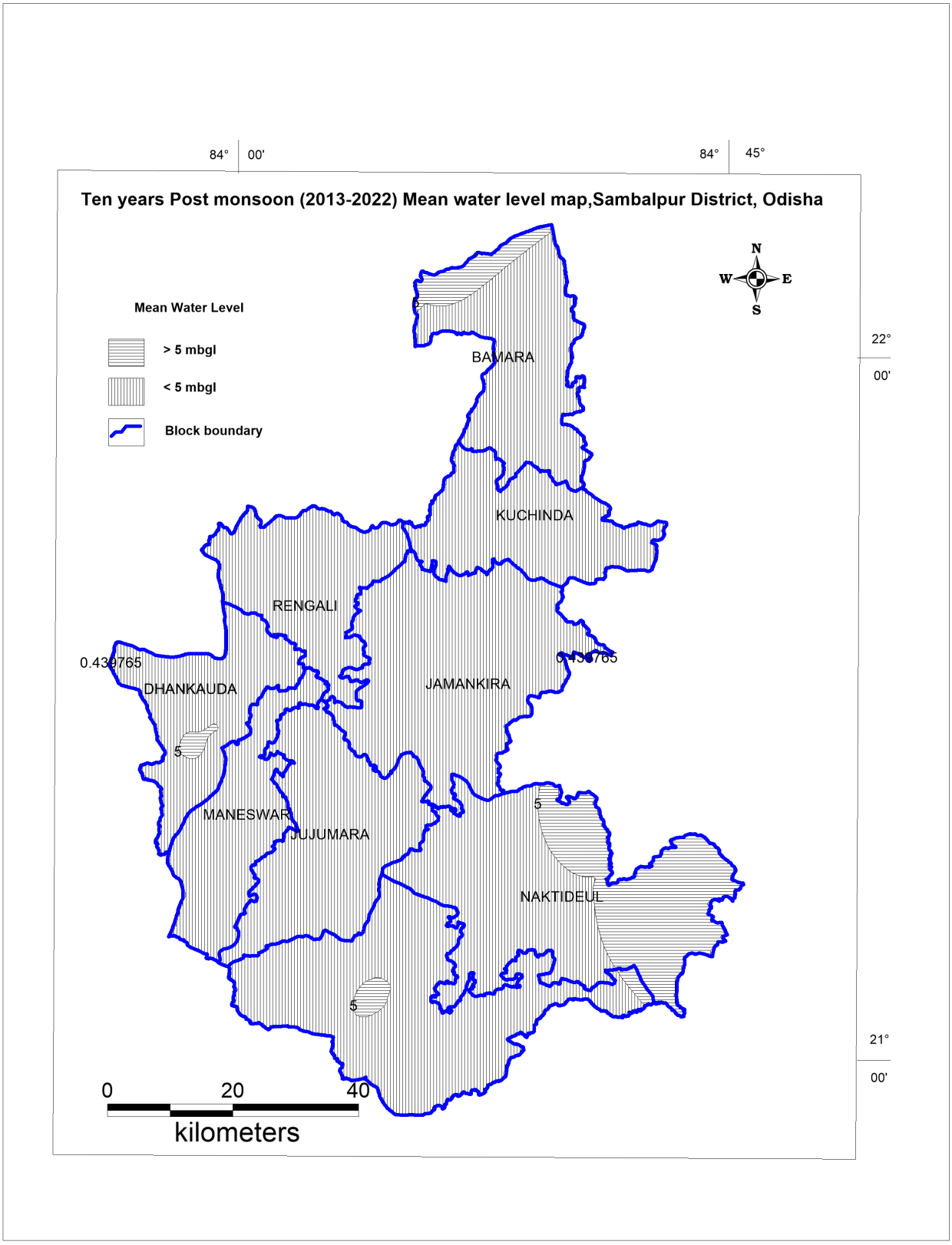


Fig.17b. Ten years Post monsoon (2013-2022) Mean water level vs. ten years water level trend map,Sambalpur District, Odisha

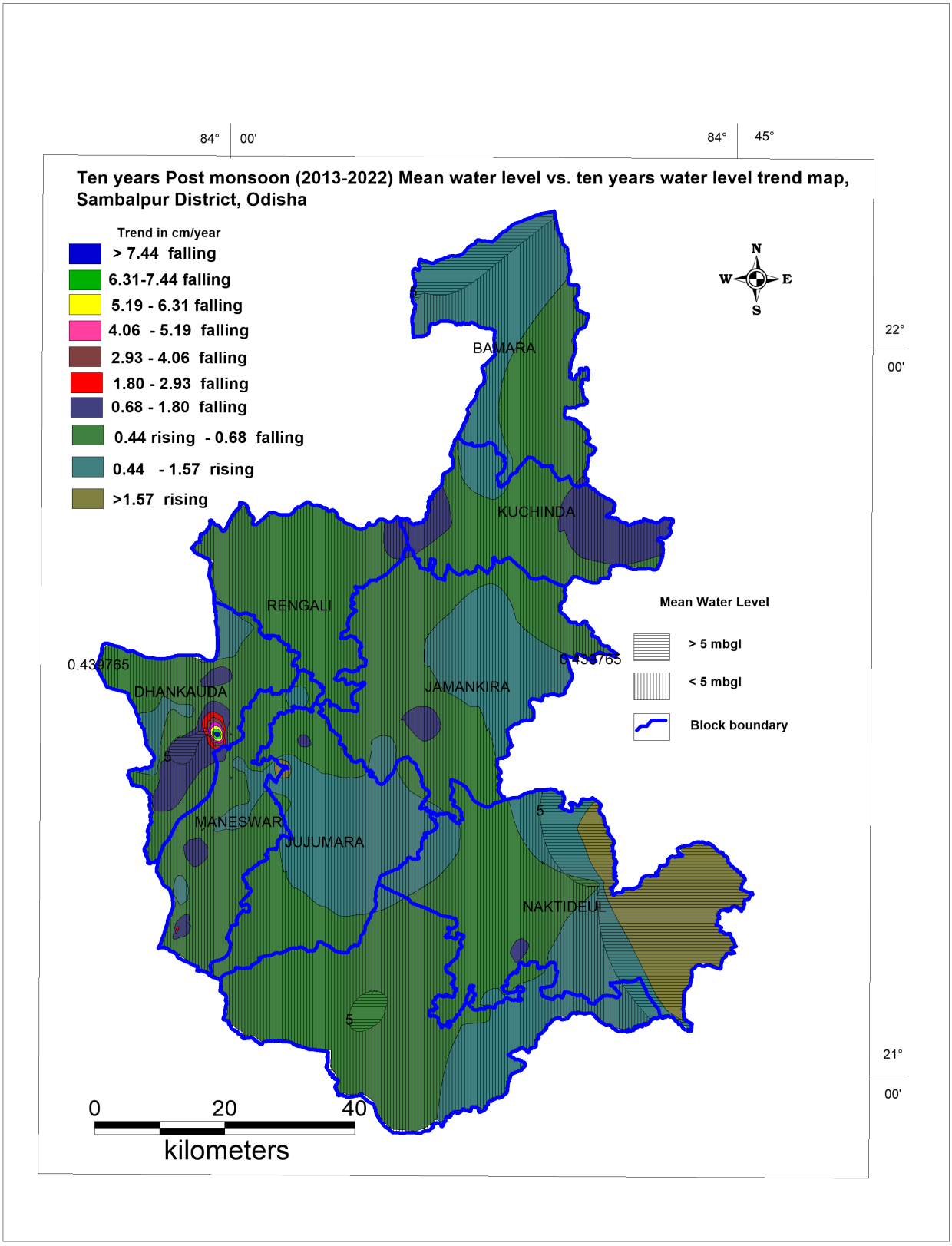
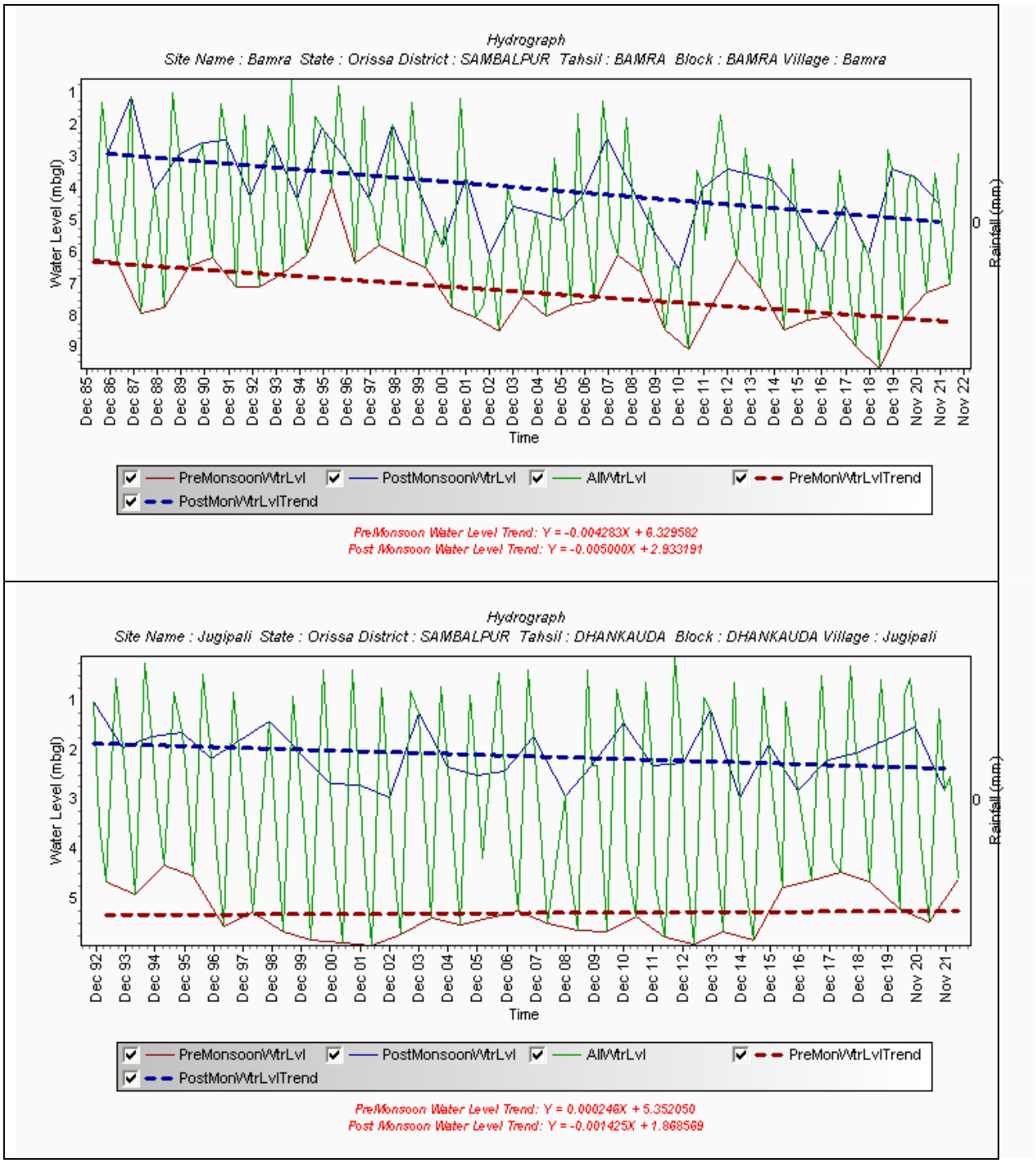
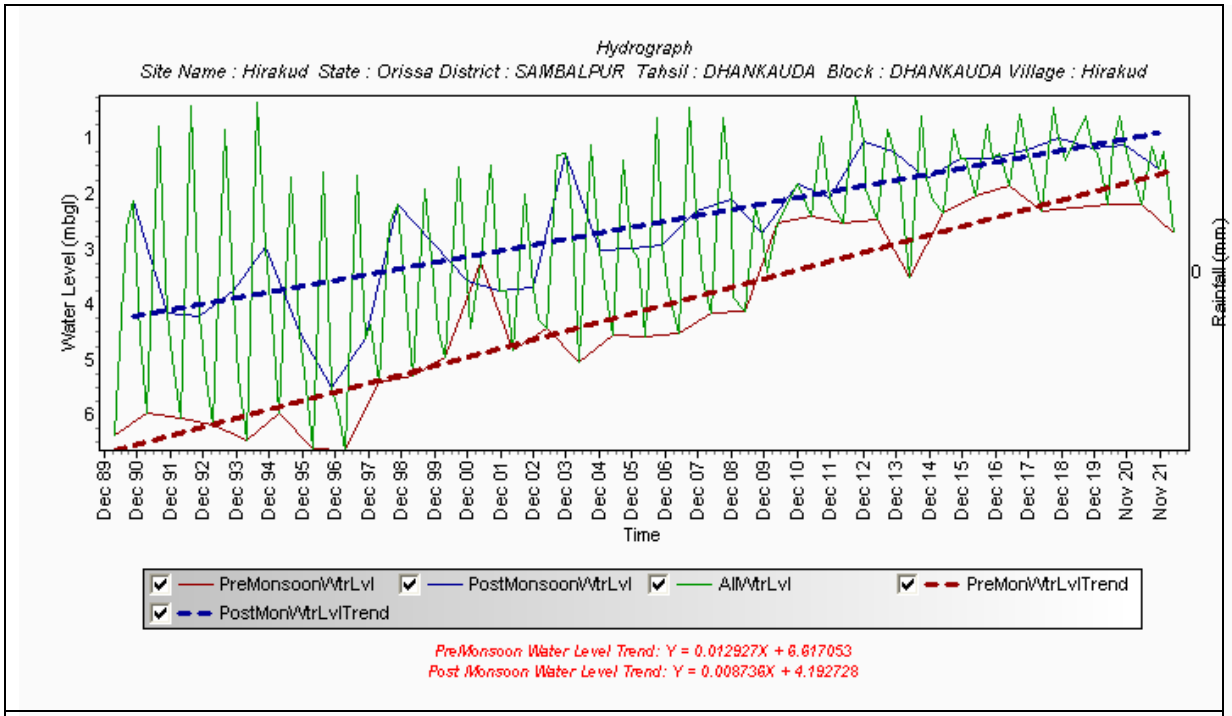
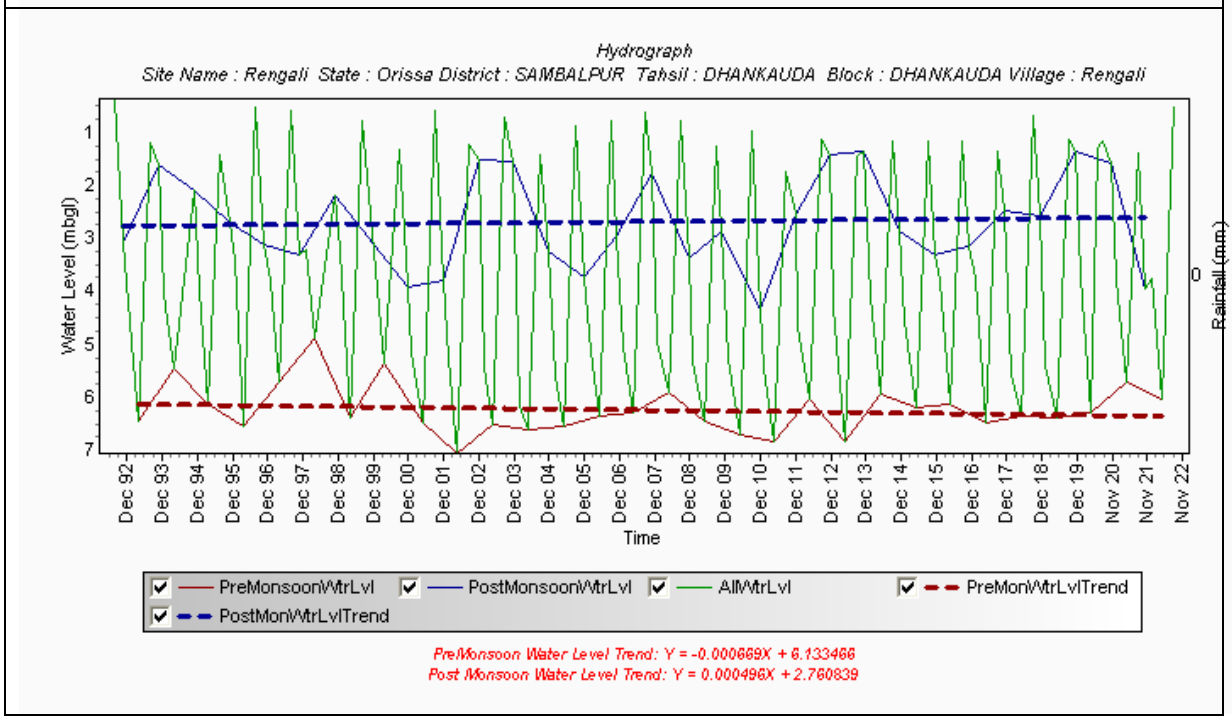
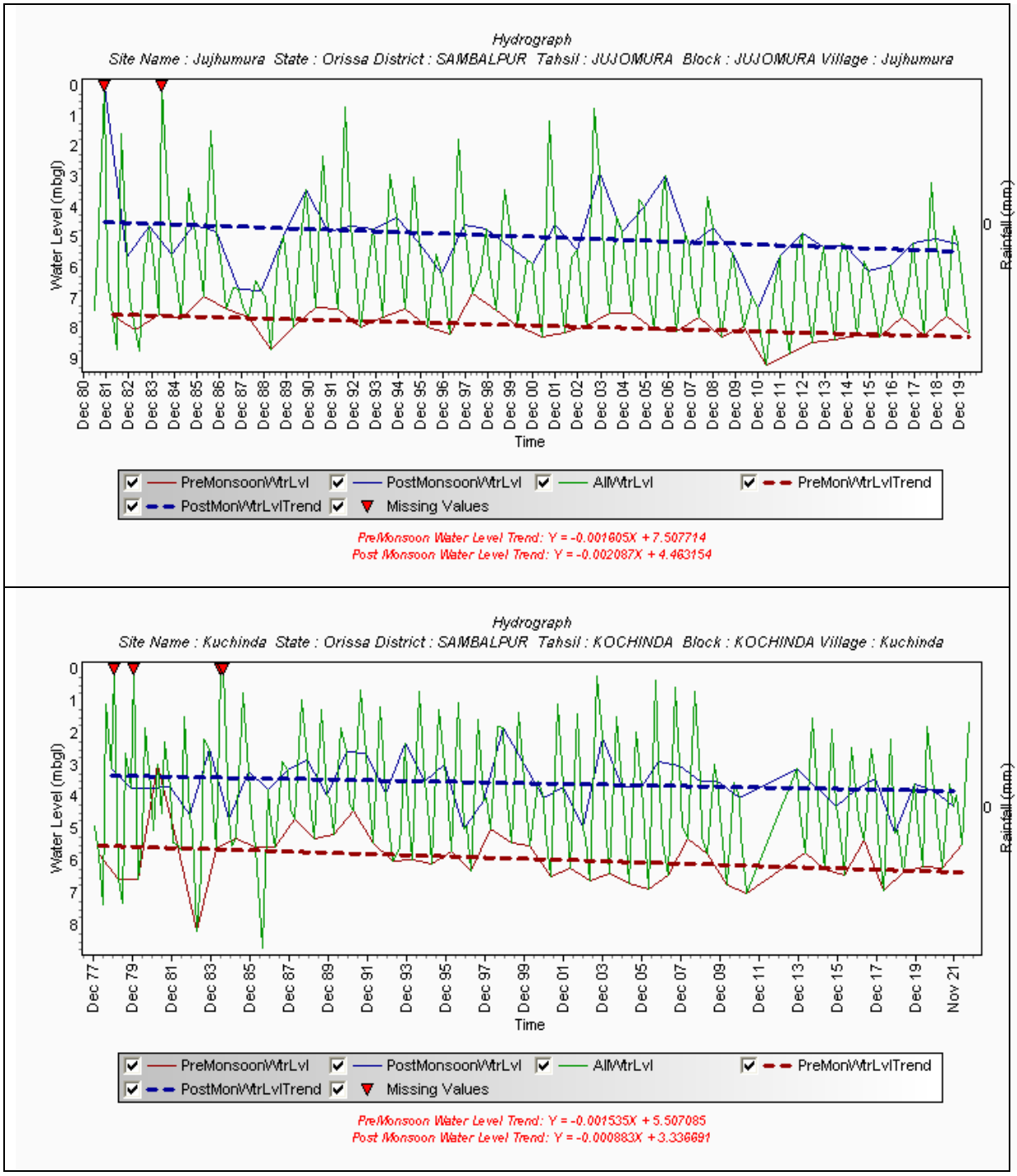


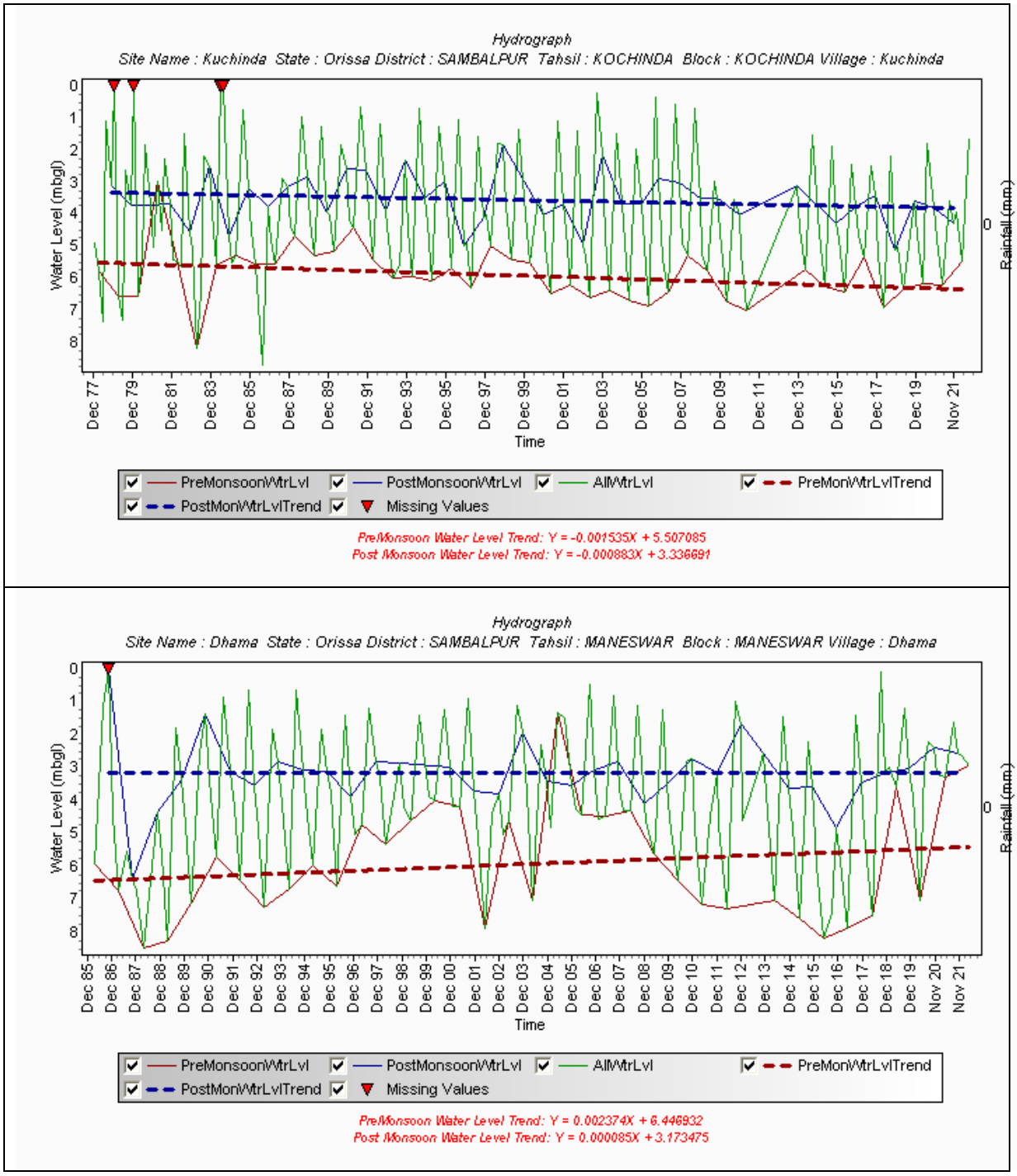
Fig.18. Hydrographs of selected NHS stations in Sambalpur District, Odisha

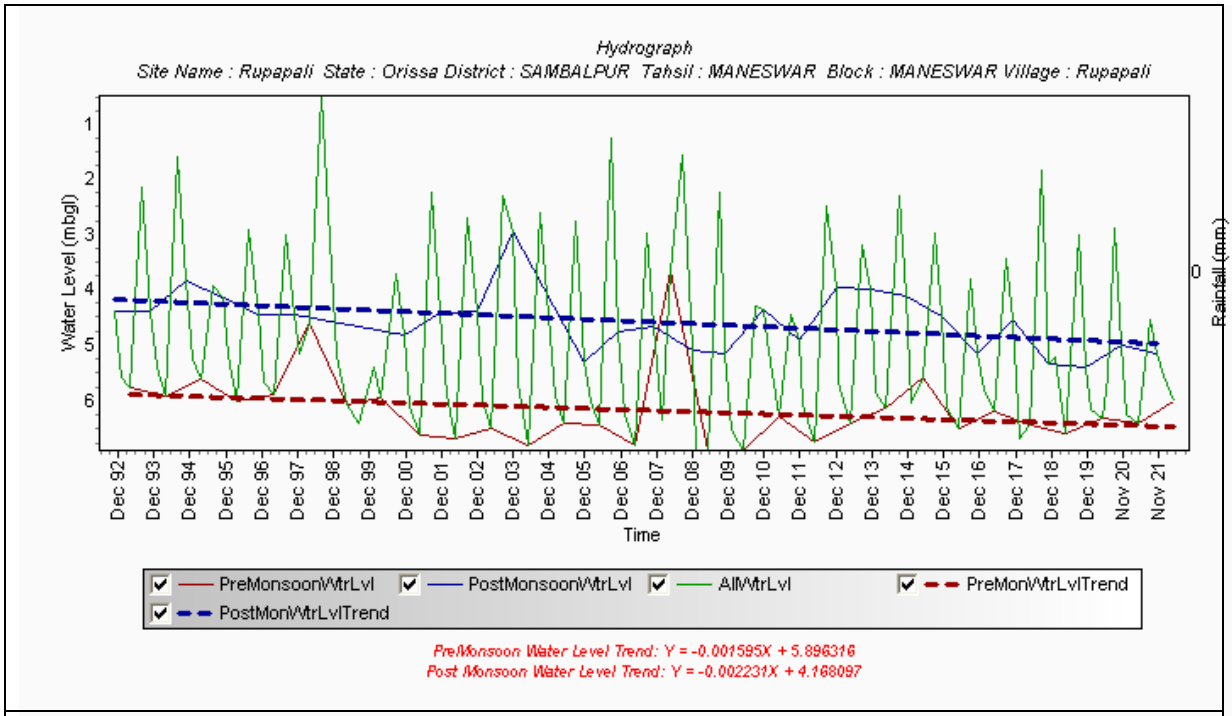


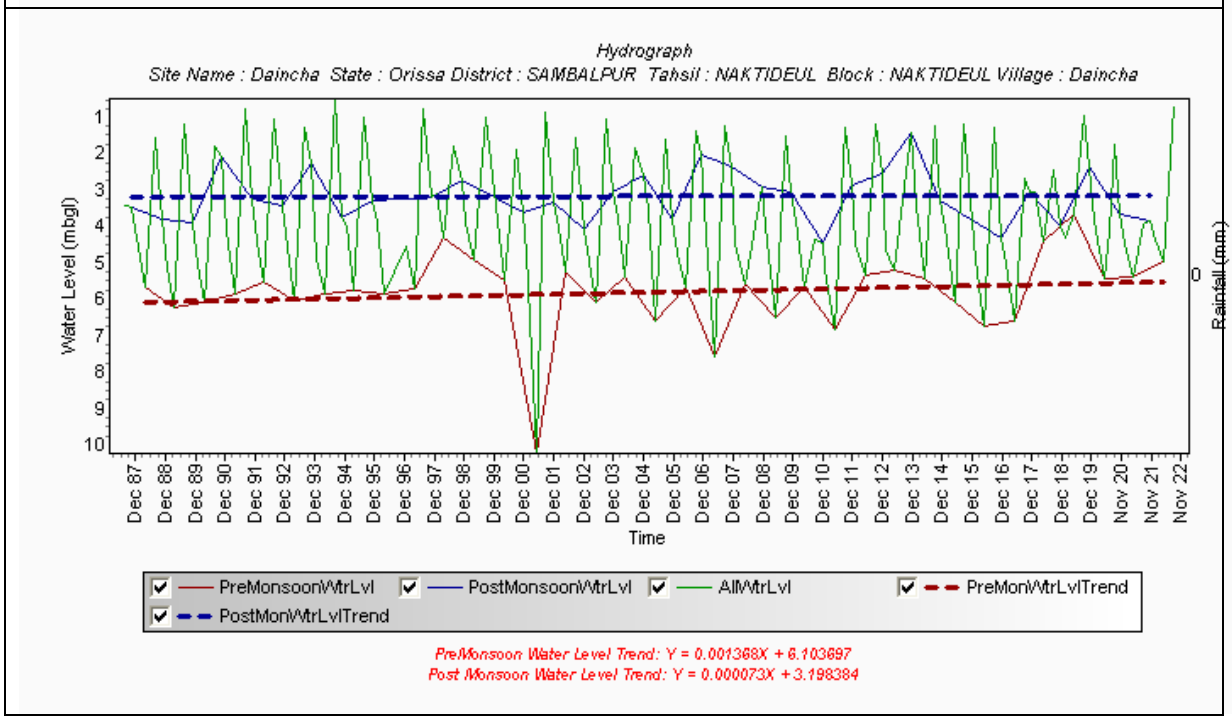

Hydrograph
Site Name : Hirakud State : Orissa District : SAMBALPUR Tahsil : DHANKAUDA Block : DHANKAUDA Village : Hirakud
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.012927X + 6.617053
Post Monsoon Water Level Trend: Y = 0.008736X + 4.192728

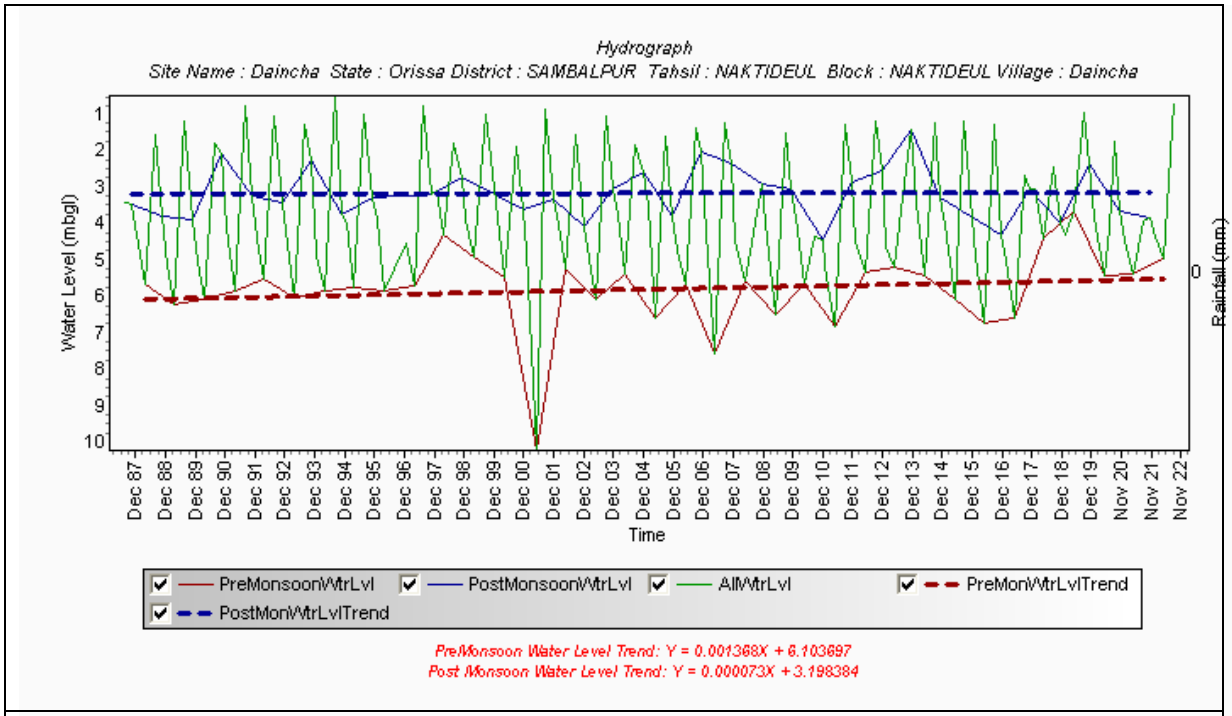

Hydrograph
Site Name : Rengali State : Orissa District : SAMBALPUR Tahsil : DHANKAUDA Block : DHANKAUDA Village : Rengali
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.000669X + 6.133466
Post Monsoon Water Level Trend: Y = 0.000496X + 2.760839

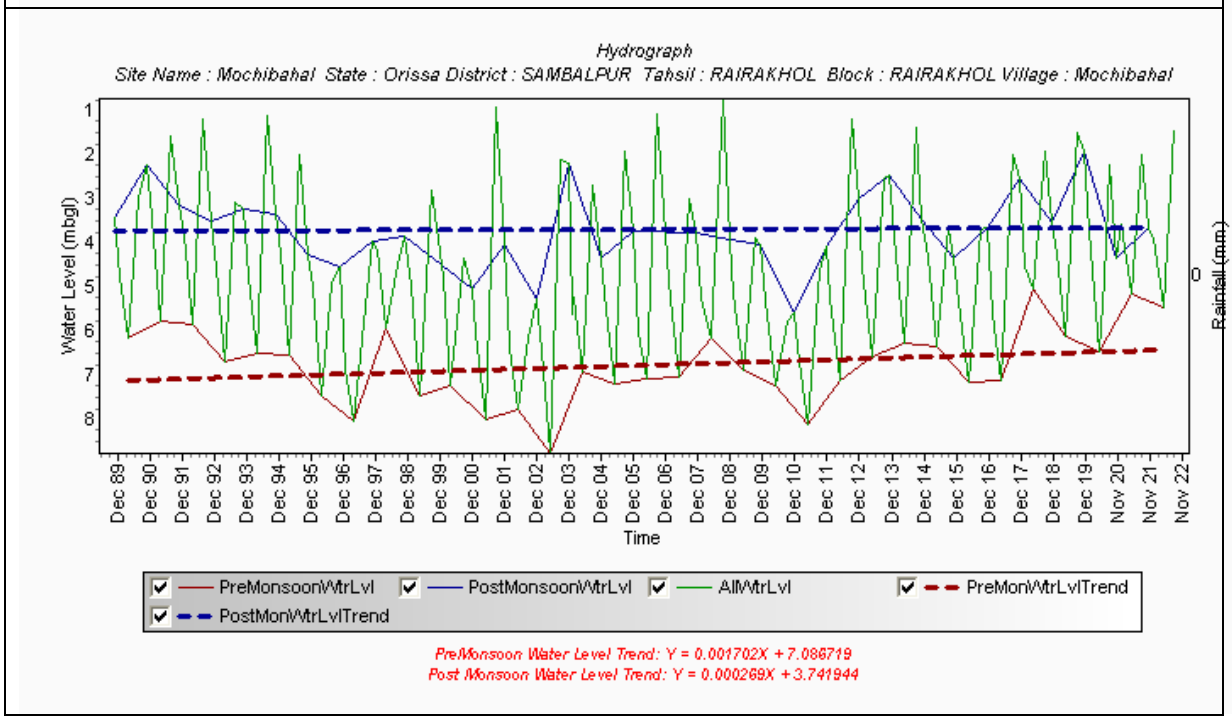

Hydrograph
Site Name : Jujhumura State : Orissa District : SAMBALPUR Tahsil : JUJOMURA Block : JUJOMURA Village : Jujhumura
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.001605X + 7.507714
Post Monsoon Water Level Trend: Y = -0.002087X + 4.463154
Hydrograph
Site Name : Kuchinda State : Orissa District : SAMBALPUR Tahsil : KOCHINDA Block : KOCHINDA Village : Kuchinda
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.001535X + 5.507085
Post Monsoon Water Level Trend: Y = -0.000883X + 3.336691


Hydrograph
Site Name : Kuchinda State : Orissa District : SAMBALPUR Tahsil : KOCHINDA Block : KOCHINDA Village : Kuchinda
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.001535X + 5.507085
Post Monsoon Water Level Trend: Y = -0.000883X + 3.336691
Hydrograph
Site Name : Dhama State : Orissa District : SAMBALPUR Tahsil : MANESWAR Block : MANESWAR Village : Dhama
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = 0.002374X + 6.446932
Post Monsoon Water Level Trend: Y = 0.000085X + 3.173475


Hydrograph
Site Name : Rupapali State : Orissa District : SAMBALPUR Tahsil : MANESWAR Block : MANESWAR Village : Rupapali
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.001595X + 5.896316
Post Monsoon Water Level Trend: Y = -0.002231X + 4.168097


Hydrograph
Site Name : Daincha State : Orissa District : SAMBALPUR Tahsil : NAKTIDEUL Block : NAKTIDEUL Village : Daincha
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001368X + 6.103697
Post Monsoon Water Level Trend: Y = 0.000073X + 3.198384


Hydrograph
Site Name : Daincha State : Orissa District : SAMBALPUR Tahsil : NAKTIDEUL Block : NAKTIDEUL Village : Daincha
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001368X + 6.103697
Post Monsoon Water Level Trend: Y = 0.000073X + 3.198384


Hydrograph
Site Name : Mochibahal State : Orissa District : SAMBALPUR Tahsil : RAIRAKHOL Block : RAIRAKHOL Village : Mochibahal
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001702X + 7.086719
Post Monsoon Water Level Trend: Y = 0.000269X + 3.741944

F. HYDROCHEMISTRY OF SHALLOW AQUIFER (Aquifer-I): All groundwater samples collected from key wells and NHS wells during pre and post monsoon 2022 are analysed in Chemical Laboratory of CGWB. The maximum and minimum value of analysed parameters are summarized in the Table 14a. Distribution of EC is shown in Fig.19. Out of 145 analysed samples only 8 samples shows fluoride concentrations, 13 samples show nitrate concentrations and only one sample shows uranium concentrations above permissible limit. But other elements are found within permissible limit.

Table-14a. Range of parameters in shallow aquifer ground water samples.

Parameter	Unit	Min	Max
pH		6.7	8.57
Ec	micromhos/cm	55	2006
Ca	mg/l	2	158
Mg	mg/l	1.22	93.55
Na	mg/l	2	187.3
K	mg/l	0.09	101
Cl	mg/l	5	322
HCO_3-	mg/l	6.19	671
SO_3^{4-}	mg/l	1	120
F^-	mg/l	0.03	2.49
NO_3^-	mg/l	0.05	84
TDS	mg/l	31	1103
Hardness	mg/l	9.86	570
Alkalinity	mg/l	10.14	550
U	mg/l	0.001	0.041

An attempt has been made to prepare a Piper diagram and Salinity diagram to know the type of water, its utilization of irrigation etc. All these are presented in Fig. 19. A comparison regarding type of water and water quality index are given in Table 13b,c,d,e,f.

Table-14b. Comaprison of Range of parameters and average values in shallow aquifer ground water samples during pre and postmonsoon.

	Premonsoon			Postmonsoon		
Parameters	**MIN**	**MAX**	**AVERAGE**	**MIN**	**MAX**	**AVERAGE**
pH	6.75	8.57	8.07	6.7	8.01	7.4
EC	55	2006	581.14	78	1203	575.78
TDS	38	1103	306.81	31	667	321.22
Hardness	9.86	570	186.24	19.4	402.55	211.24
Alkalinity	10.14	550	147.97	18.94	322.01	169.43
Ca++	2	158	39.95	3.9	85.6	41.51
Mg++	1.17	93.555	20.99	2.34	59.97	26.12
Na+	2	187.3	43.66	3.21	101.66	39.88
K+	0.09	101	6.43	0.84	75.1	12.46
CO3=	0	15.21	1.89	0	0	-
HCO3-	6.19	671	179.01	19.56	392.86	206.46
Cl-	7.42	322	65.39	4.74	144.51	59.23
SO4=	0	120	27.94	1.12	44.38	16.21
NO3-	0	62	13.67	0.73	84.4	25.58
F -	0	2.29	0.45	0.03	0.89	0.29

Table-14c. Comaprison of Water Quality Index for drinking in shallow aquifer ground water samples during pre and postmonsoon.

	Premonsoon (Number)			Postmonsoon (Number)		
Parameters	**SUITABLE**	**ACCEPTABLE**	**UNSUITABLE**	**SUITABLE**	**ACCEPTABLE**	**UNSUITABLE**
pH	125	0	2	18	0	0
TDS	105	22	0	14	4	0
Hardness	77	50	0	10	8	0
Alkalinity	92	35	0	10	8	0
Ca++	113	14	0	16	2	0
Mg++	98	29	0	11	7	0
Cl-	123	4	0	18	0	0
SO4=	127	0	0	18	0	0
NO3-	118	0	9	14	0	4
F -	106	11	10	18	0	0
OVERALL_DRINKING	61	45	21	10	4	4

Table-14d. Comaprison of SAR, % Na, RSC, PI and Magnesium Ratio (MI) in shallow aquifer ground water samples during pre and postmonsoon.

	Premonsoon			Postmonsoon		
Parameters	**MIN**	**MAX**	**AVERAGE**	**MIN**	**MAX**	**AVERAGE**
SAR (epm)	0.103637	4.898551	1.43	0.317033	2.203016	1.12
%Na	4.656383	76.88722	32.77	18.56356	36.80658	26.99
RSC(epm)	-7.90492	3.393443	-0.79	-2.10632	-0.06694	-0.84
PI(%)	35.12155	141.2286	69.42	47.54747	133.8935	68.7
MR(%)	4.761905	72.72727	43.99	37.52882	61.3082	50.04

Table-14e. Comaprison of Water Quality Index for irrigation in shallow aquifer ground water samples during pre and postmonsoon.

	Premonsoon (Number)		Postmonsoon (Number)	
Parameters	**SUITABLE**	**UNSUITABLE**	**SUITABLE**	**UNSUITABLE**
SAR (epm)	127	0	18	0
%Na	127	0	18	0
RSC(epm)	124	3	18	0
PI(%)	84	43	15	3
MR(%)	83	44	10	8
OVERALL_IRRIGATION	53	74	7	11

Table-14f. Comaprison of Type of Water in shallow aquifer ground water samples during pre and postmonsoon.

Type of water	Premonsoon (Number)	Post monsoon (Number)
Ca-HCO3	43	10
Mg-HCO3	29	7
Na-HCO3	16	1
Ca-Cl	3	0
Mg-Cl	3	0
Na-Cl	31	0
K-HCO3	2	0

G. HYDROCHEMISTRY OF DEEPER AQUIFER (Aquifer-I and II):

On the basis of chemical quality analysis of ground water samples from exploratory wells EC contour map (19), Piper Diagram (Fig. 19) and Salinity diagram (Fig. 19f) have been prepared. The analytical details are summarized in the Table- 15. Type of water is also bicarbonate type and is also suitable of irrigation. Out of 33 analysed samples only one sample show fluoride concentration above permissible limit. But other elements are found within permissible limit.

Table-15. Range of parameters in Deeper aquifer ground water samples.

Parameter	Unit	Min	Max
pH		7.32	8.25
Ec		98	1288
Ca	mg/l	8	70
Mg	mg/l	1.2	85
Na	mg/l	7.86	173
K	mg/l	1	25
Cl	mg/l	7	296
HCO_3-	mg/l	37	445
SO_3^{4-}	mg/l	0.2	45
F^-	mg/l	0.09	1.52
NO_3^-	mg/l	0.04	32
Hardness	mg/l	25	500

Fig.19a. Ec contour map of shallow aquifer, Sambalpur district

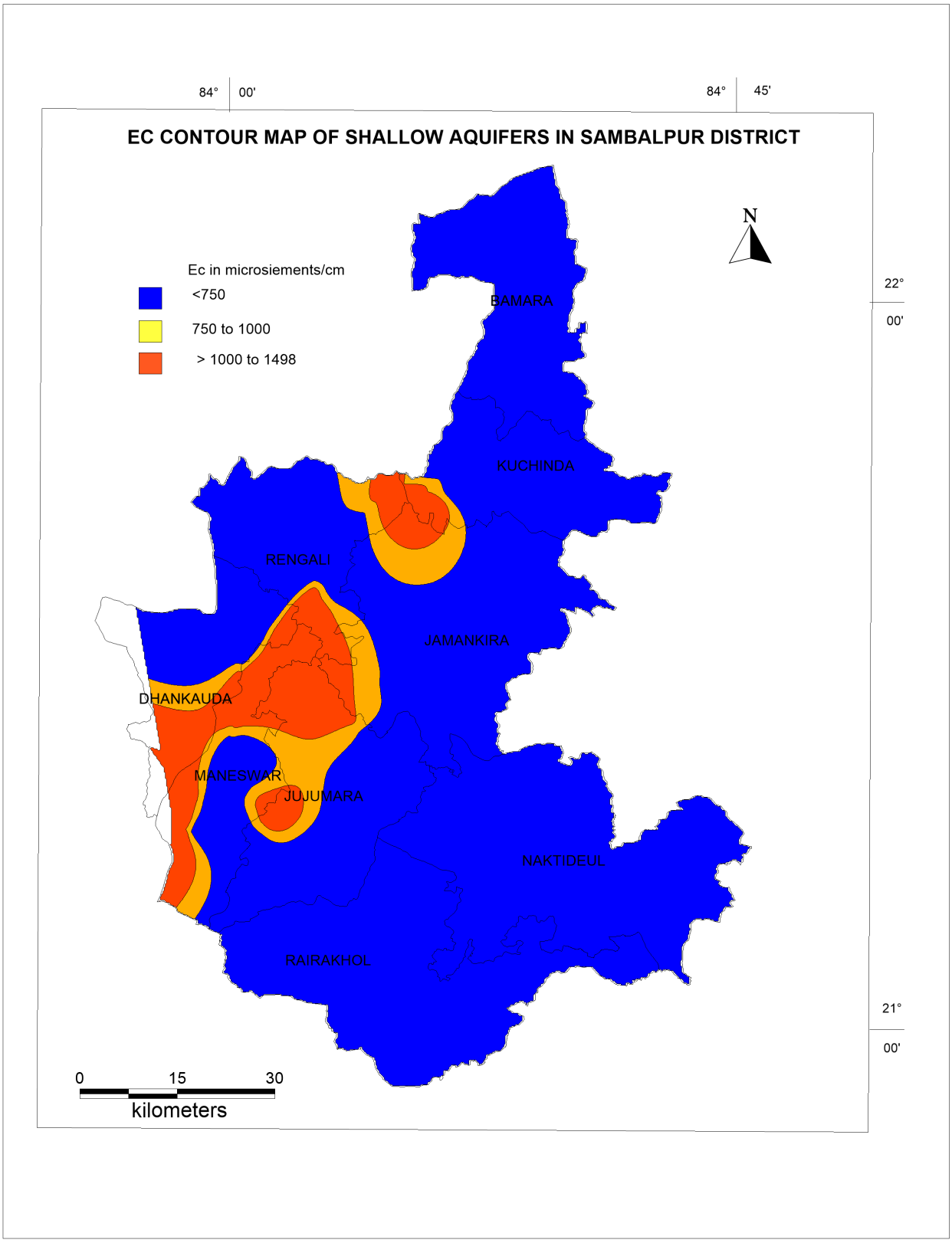


Fig.19b. Ec contour map of deeper aquifer, Sambalpur district

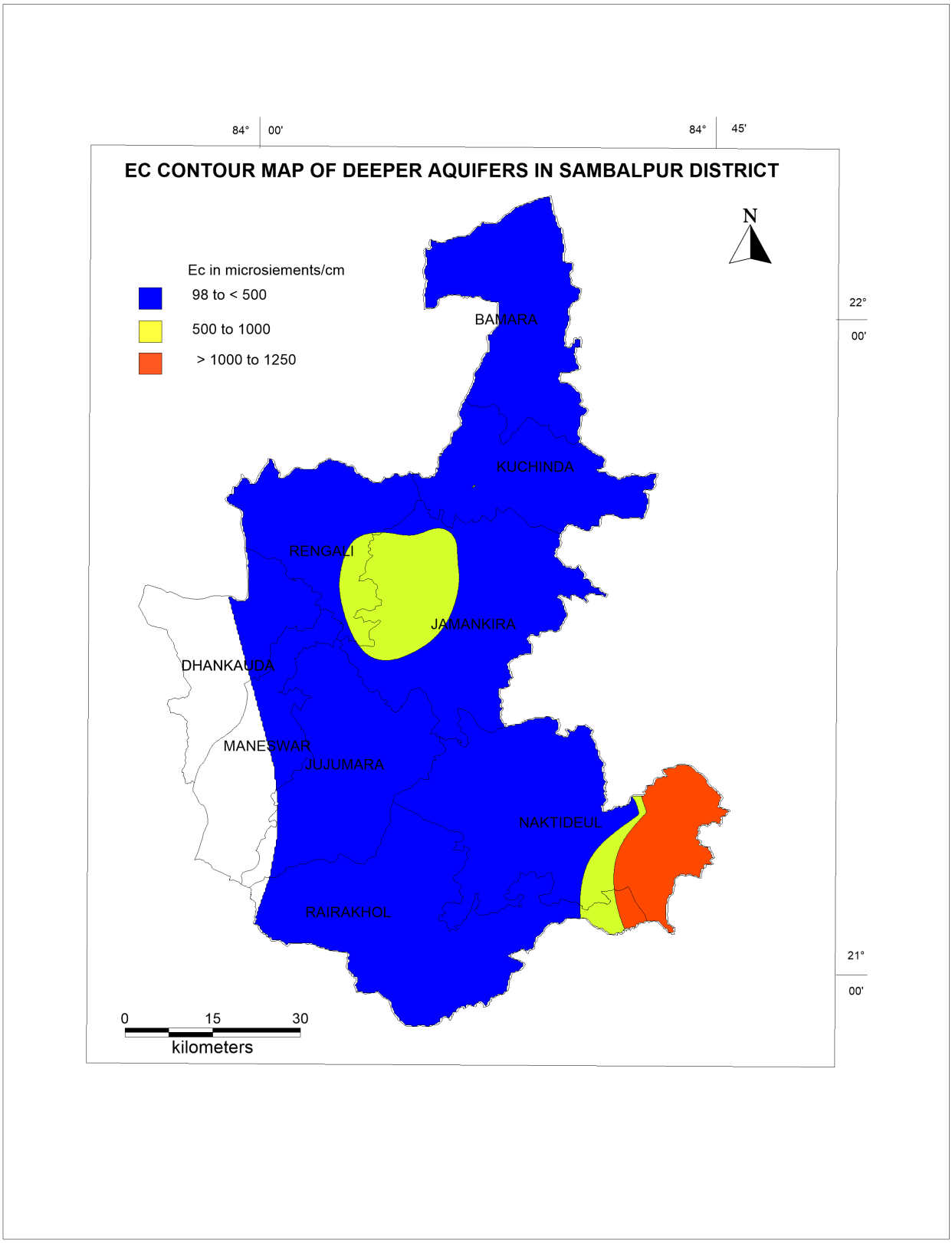


Fig.19c. Piper diagram for shallow aquifer (premonsoon), Sambalpur District

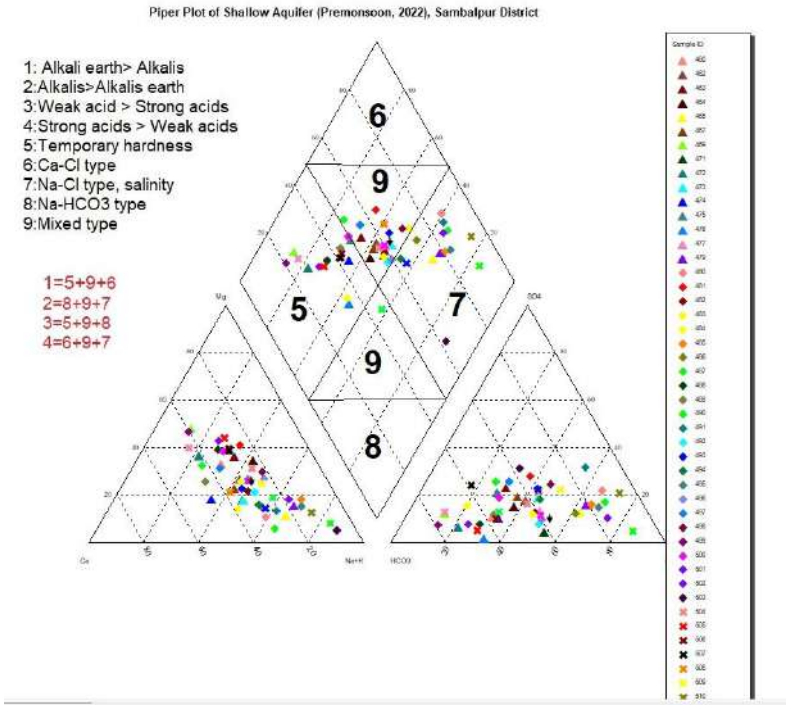


Fig.19d. Piper diagram for shallow aquifer (postmonsoon), Sambalpur District

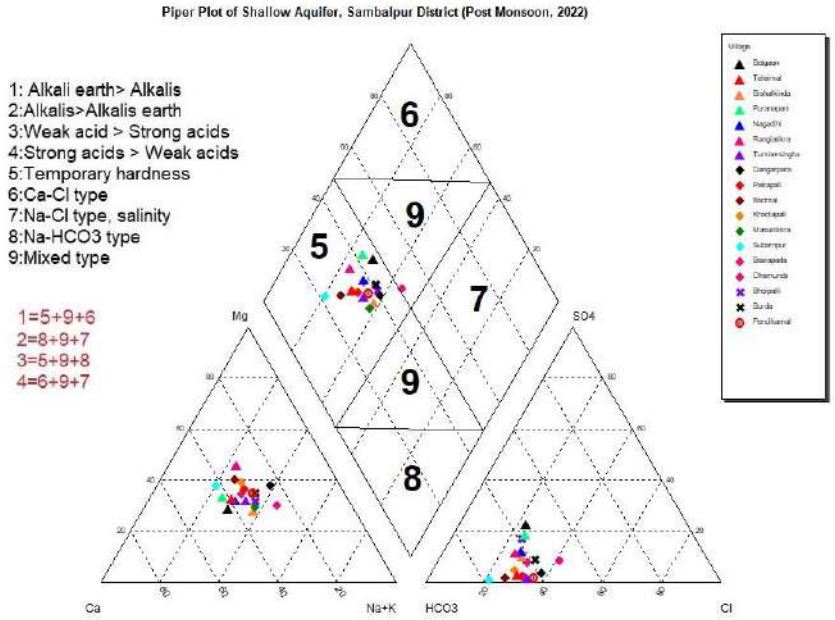


Fig.19e. Piper diagram for deeper aquifer, Sambalpur District

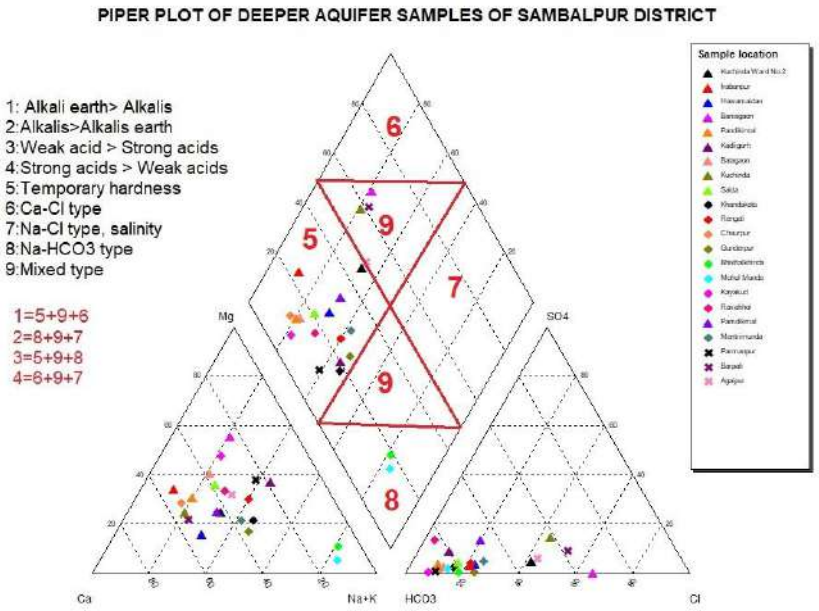


Fig.19f. Salinity diagram for shallow aquifer (premonsoon), Sambalpur District

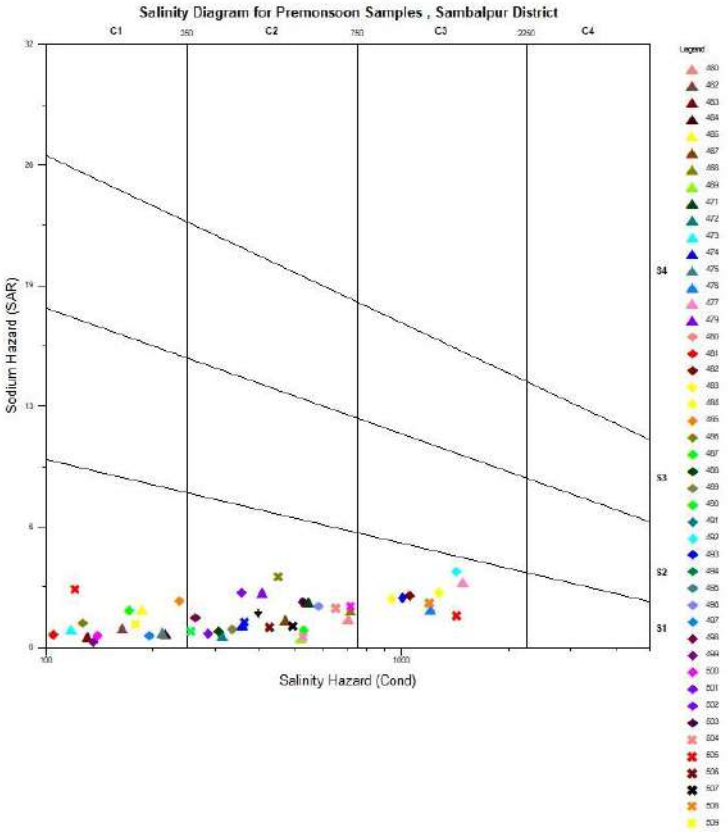
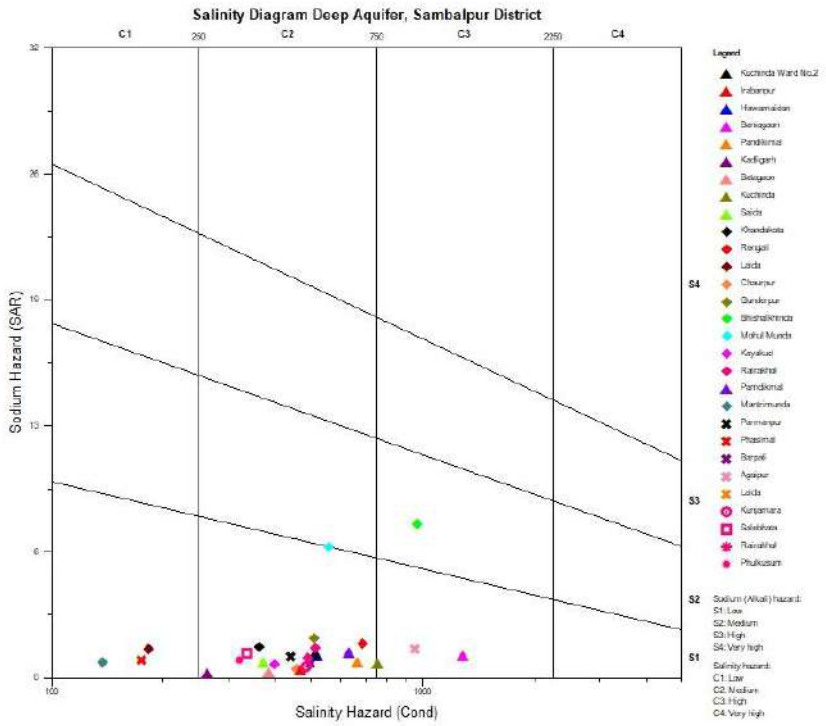


Fig.19g. Salinity diagram for deeper aquifer, Sambalpur District



From the analysis of water from shallow aquifer it is seen 74.5% water samples are bicarbonate type and 24.5% water samples belongs to chloride type, whereas from deeper aquifer it is seen 91% water samples are bicarbonate type and 9% water samples belongs to mixed type.

4. **GROUND WATER RESOURCES:** Stage of ground water development for Aquifer 1 estimated from year 1999 to year 2022 is summarized in the Table-16. Blockwise dynamic resources assesment (2022) of Aquifer-I of Sambalpur district have been summarized in Table-17. Blockwise static resources assessment of Aquifer-1 is also formulated in Table-18. From the above table it is observed that yearwise stage of ground water extraction of Aquifer-I increases from 7.86% to 28.96% for the whole district.

Table-16. Yearwise stage of ground water extraction percentage for Aquifer-I, Sambalpur District

Block/District	1999	2004	2009	2013	2017	2020	2022
BAMRA	11.28	13.99	22.41	26.53	36.16	37.43	38.58
DHANKAUDA	8.38	10.04	15.66	18.51	26.94	27.09	27.88
JAMANKIRA	5.53	9.38	17.74	20.90	18.76	21.99	23.00
JUJUMURA	5.86	10.27	13.57	15.58	23.26	30.03	30.56
KUCHINDA	14.37	17.29	19.67	23.74	43.31	46.88	47.01
MANESWAR	5.22	7.47	11.45	13.52	14.51	12.96	13.86
NAKTIDEOL	6.62	7.69	12.80	14.85	16.4	17.19	17.84
RAIRAKHOL	6.54	7.29	11.70	14.15	18.34	18.27	18.69
RENGALI	11.50	15.30	19.11	24.20	51.29	54.20	53.92
Sambalpur District	7.86	10.34	15.43	*18.35*	26.45	28.41	28.96

Table-17. Dynamic Ground Water Resources of Aquifer-1, Sambalpur District (2022)

Sl No	Block	Utilizable Ground Water Resources	Gross Ground Water Draft for all uses	Balance Ground Water Resources	Allocation for Domestic Requirement for next 25 years	Net Ground Water Availability for Future Development	Stage of Ground Water Development	Category
		Ha. M	Ha. M	Ha. M	Ha. M	Ha. M	%	
1	**BAMRA**	6847.44	2641.68	4205.76	278.13	4196.42	38.58	Safe
2	**DHANKAUDA**	7101.21	1979.97	5121.24	1286.89	5037.7	27.88	Safe
3	**JAMANKIRA**	7829.39	1800.72	6028.67	271.64	6019.45	23.00	Safe
4	**JUJUMURA**	8137.2	2487.08	5650.12	243.5	5641.85	30.56	Safe
5	**KUCHINDA**	5558.2	2613.18	2945.02	280.94	2938.04	47.01	Safe
6	**MANESWAR**	5804.84	804.7	5000.14	280.18	4990.87	13.86	Safe
7	**NAKTIDEOL**	6426.41	1146.48	5279.93	193.98	5270.81	17.84	Safe
8	**RAIRAKHOL**	7225.58	1350.74	5874.84	253.46	5864.65	18.69	Safe
9	**RENGALI**	4337.54	2338.86	1998.68	267.75	1995.65	53.92	Safe
District Total		**59267.81**	**17163.41**	**42104.4**	**3356.47**	**41955.44**	**28.96**	**Safe**

From Table -17, it can be understood that stage of ground water extraction is minimum in Manesar Block and maximum in Rengali Block.

Static groundwater resources (Table-18) have been calculated for Aquifer-I considering effective aquifer thickness of only 5%, as fracture zones are very thin and heterogeneously distributed throughout 100-meter depth (i.e., the bottom of aquifer-1).

Table-18. Static Ground Water Resources of Aquifer -1, Sambalpur District (As on 31.3.2017)

Name of the Assessment Unit	Static Resources Area (ha)	Pre-monsoon water level (m)	Bottom of unconfined aquifer (m)	Difference (3-2) (m)	Effective Aquifer Thickness (m) {= (4) *5%}	Specific Yield (%)	Total Static Resources (ham) (7) = (1) *(5) *(6)
	1	2	3	4	5	6	7
BAMRA	58969	6.45	100	93.55	4.6775	0.03	8274.82
DHANKAUDA	48744	4.14	100	95.86	4.793	0.02	4672.6
JAMANKIRA	85387	6.69	100	93.31	4.6655	0.03	11951.19
JUJUMURA	63087	7.52	100	92.48	4.624	0.02	5834.29
KUCHINDA	44940	5.87	100	94.13	4.7065	0.03	6345.3
MANESWAR	36093	4.99	100	95.01	4.7505	0.03	5143.79
NAKTIDEOL	87819	6.67	100	93.33	4.6665	0.03	12294.22
RAIRAKHOL	92130	6.31	100	93.69	4.6845	0.02	8631.66
RENGALI	49923	6.47	100	93.53	4.6765	0.02	4669.3
	567092						**67817.17**

Block wise total groundwater resources of Aquifer-1 have been summarized in Table-19. Total dynamic groundwater resources has been observed as **592.68** mcm and total static ground water resources has been seen as **678.17** mcm for the whole Sambalpur district. Therefore, total ground water resources=**1270.85** mcm.

Table-19. Total Ground Water Resources (2022), Sambalpur District

Name of the Assessment Unit	Annual Extractable Ground Water Recharge of Aquifer -1	In storage Ground Water Resources of Aquifer-1	Total Ground Water Availability of Aquifer 1
	Aquifer-1		
BAMRA	6847.44	8274.82	15122.26
DHANKAUDA	7101.21	4672.6	11773.81
JAMANKIRA	7829.39	11951.19	19780.58
JUJUMURA	8137.2	5834.29	13971.49
KUCHINDA	5558.2	6345.3	11903.5
MANESWAR	5804.84	5143.79	10948.63
NAKTIDEOL	6426.41	12294.22	18720.63
RAIRAKHOL	7225.58	8631.66	15857.24
RENGALI	4337.54	4669.3	9006.84
Total	**59267.81**	**67817.17**	**127085**

5. GROUNDWATER RELATED ISSUES:

a. Total number of irrigation dug well were decreases from 9134 during 1999 to 5388 during 2020.But irrigation bore wells have been increases from 10 during 1999 to 5213 during 2022. Block wise and yearwise details of irrigation dug well and tube well numbers are shown in Table 20. The data shows multifold increase (800-900%) of Bore Wells specially in Bamra, Kuchinda, Jujumura and Regnali Blocks. Minimum number of borewells is observed in Manesar and Dhankauda Block. But there is a substantial decrease of dug wells upto 40% over last 23 years and average 500% increase of borewell number have been observed over last 23 years.

Table-20: Block wise and yearwise details of irrigation dug well and tube wells in Sambalpur District

	Yearwise number of irrigation dug well and bore wells in Sambalpur District, Odisha									
Name of Block	**Total Dug Well 1999**	**Total TW 1999**	**Total Dug Well 2009**	**Total TW 2009**	**Total Dug Well 2013**	**Total TW 2013**	**Total Dug Well 2020**	**Total TW 2020**	**Total Dug Well 2022**	**Total TW 2022**
BAMRA	1565	0	1662	65	1010	78	805	930	805	953
DHANKAUDA	343	1	629	51	600	71	420	115	420	126
JAMANKIRA	843	0	1286	88	648	123	604	640	604	573
JUJUMURA	849	0	1822	61	1010	63	892	772	892	828
KUCHINDA	1681	0	1633	94	828	147	718	912	718	949
MANESWAR	474	3	968	61	708	75	319	155	319	204
NAKTIDEOL	1450	0	1494	44	806	53	494	329	494	368
RAIRAKHOL	1180	0	1363	38	747	48	698	372	698	410
RENGALI	749	6	1083	46	581	89	438	762	438	802
Total	**9134**	**10**	**11940**	**548**	**6938**	**747**	**5388**	**4987**	**5388**	**5213**

b. WATER DEMAND, AVAILABILITY AND GAP ANALYSIS:

For calculation of water demand, availability and gap analysis, surface water availability, projected domestic water demand, crop water demand, livestock water demand and industrial water demand data taken from District Irrigation plan of Sambalpur District (2016), Irrigation department, Odisha for the year 2020, 2025 and 2035. Then on the basis of interpolation technique future demand for the year 2047 have been extrapolated (Table 21). The ground water availability data taken from CGWB, Ground water resources assessment (2022).

Table-21: Various types of water demand in Sambalpur District

Domestic demand in mcm				Crop Water demand in mcm			Live stock demand in mcm			Industrial water demand in mcm		
Block	Year 2022	Year 2035	Year 2047	Year 2022	Year 2035	Year 2047	Year 2022	Year 2035	Year 2047	Year 2022	Year 2035	Year 2047
Bamra	2.37	2.72	3.04	25.9	28.17	30.26	0.31	0.23	0.15	0.17	0.56	0.92
Dhankouda	2.48	2.82	3.12	100.52	102.02	103.4	0.29	0.21	0.13	0.59	2.01	3.32
Jamankira	2.31	2.65	2.97	10.15	12.21	14.11	0.37	0.27	0.17	0.18	0.6	0.98
Jujumora	2.07	2.38	2.66	54.25	56	57.61	0.26	0.19	0.12	0.16	0.53	0.87
Kuchinda	1.76	2.02	2.26	25.65	28.2	30.56	0.37	0.27	0.17	0.18	0.59	0.17
Maneswar	2.42	2.78	3.1	97.25	98.52	99.7	0.26	0.18	0.11	0.18	0.61	1.00
Naktideula	1.57	1.8	2.02	82.84	97.49	111.02	0.45	0.31	0.18	0.11	0.38	0.64
Rengali	2.29	2.59	2.86	41.68	43.1	44.4	0.27	0.19	0.11	0.13	0.44	0.72
Rairakhol	1.38	1.58	1.77	13.91	17.01	19.87	0.43	0.3	0.18	0.16	0.54	0.88
Block Total	18.65	21.34	23.8	452.15	482.72	510.93	3.01	2.15	1.32	1.86	6.26	9.5

Total water availability in Sambalpur district is 576.55 mcm, out of which 157 mcm is surface water & 419.55 mcm (Dynamic Groundwater resources mentioned in Table-17) is ground water. Projected water demand for 2035, 2047 shall be 512.47 mcm, 545.55 mcm respectively. As per water availability of Sambalpur district there will be no gap exists during the year 2035 and 2047, but it is noticed that demand will be increasing over the years. Block wise water availability, demand have been elaborated in Table-22. From this table it is observed that **no demand-supply gap will exists for all the blocks in Sambalpur District except Dhankauda** Block.

c. On the basis of premonsoon dept to water level map of shallow aquifer it is observed water level in 62.22 sq.km. occupying parts of Manesar and Dhankauda block is within 0-2 mblg. But deeper aquifer water in that area is below 2.5 mbgl.So water logging area is identified in 62.22 sq.km . area.

d. Decadal water level trend vis-à-vis post monsoon mean water level map shows very small area in Dhankauda Block having both declining water level trend as well as post monsoon mean water level is > 5 mbgl.

e. From ground water exploration in the district it is observed that 60 to 70% bore wells area having negligible to 3 lps discharge upto the drilling depth of 200 mblg. Majority of fracture zones of the successful bore wells are also observed within 100 mbgl depth also.

Table-22: Water deamnd, availability and gap analysis , Sambalpur District

Block	Water Demand (mcm)		Water Availability (mcm)			Gap (Yes/No)	
	Year 2035	Year 2047	Surface water	Ground Water (2022)	Total	Year 2035	Year 2047
Bamra	31.68	34.37	7.7	41.96	49.66	No	No
Dhankouda	107.06	109.97	31.7	50.38	82.08	24.98	27.89
Jamankira	15.73	18.23	9.6	60.19	69.79	No	No
Jujumora	59.1	61.26	14	56.42	70.42	No	No
Kuchinda	31.08	33.16	10.9	29.38	40.28	No	No
Maneswar	102.09	103.91	69.6	49.91	119.51	No	No
Nakti Deula	99.98	113.86	5.2	52.71	57.91	No	No
Rengali	46.32	48.09	3	58.65	61.65	No	No
Rairakhol	19.43	22.7	5.3	19.96	25.26	No	No
Total	512.47	545.55	**157**	**419.55**	576.55		

f. Percentage of number of unlined water distribution channel in comparison to linned channel for irrigation is 88.38% (table-23).

Table-23: Schemewise distribution of unlined to lined channel, Sambalpur District.

Name of Ground water/ surface water scheme	Irrigation distribution channels (in number)		
	Unlined Channel (No.)	Lined Channel (No.)	Percent of Unlined to lined
Dug Well	4224	532	88.81
Shallow T/W	42	3	93.33
Medium Deep T/W	32	1	96.97
Deep T/W	338	26	92.86
Surface Flow	433	30	93.52
Surface Lift	128	91	58.45
Total	5197	683	88.38

g. Sporadic occurances of Fluoride above permissible limit have been observed in 3 locations of Jujumura, 2 locations of Rairakhol, 2 locations of Naktideul, 1 location each for Dhankauda and Manesar Blocks. Smilarly nitrate concentration above permissible limit have been observed in 2 each locations in Regali, Kuchinda, Dhankauda, Bamra Block and 3 locations in

Jujumura Block. Uranium concentration above permissible limit has been observed only in one location in Dhankauda Block (Table-10a,b,c).

h. Flat rate of electricity (Rs.1.5/ unit) for ground water irrigation through shallow and deep bore wells upto 100 mbgl depth in water scare areas in Sambalpur district may cause high drawdown value upto 50 – 70 metre.

6. MANAGEMENT STRATEGIES: As per water availability, water demand and gap analysis (Table-22) it is understand that water demand will gradually increasing from 475.67 mcm during 2022 to 545.55 mcm during the year 2047 for the whole Sambalpur District. This value came after considering existing dynamic groundwater resources (2022) of Aquifer-I and other surface water availability from the Irrigation Department, Govt. Of Odisha. Eight blocks out of nine blocks in Sambalpur District doesnot show any shortage of water resources during the year 2035 and 2047 respectively. But only one block, viz., Dhankauda is showing shortage of water resources during 2035 and 2047 respectively.

From the three-dimensional aquifer model, it can be seen that ground water present mostly in the weathered zone (avg. thickness 20 meter) and also in fracture zones within 100 mbgl depth in most of the consolidated formation areas.

From decadal five years water level trend and five years post monsoon mean water level map it is seen few area in part of Dhankauda Block is showing a ground water level falling trend as well as mean water level is more than 5 mbgl (Fig.17b). This is also supported by hydrgraph analysis of NHS station in Dhankauda Block. Similary Sambalpur City area is also seen a ground water declining trend from hydrograph analyisis.

i. **Ground Water Resources Enhancement:** On the basis of Census 2011 data, Village area, Block area, number of total households was taken. The whole block area except 20 sq.km water logging area in Dhankauda block, where demand-supply gap exists and falling decadal trend exists, have been selected for construction of farm pond (one pond per hector) to arrest the rainwater for recharge. Similarly, in whole Sambalpur city area where water level is declining , 10% household is considered(with average rooftop area 200 sq. Meter per house) for calculation of recharge from roof top rainwater. Average five years rainfall to the tune of 1489 mm (year 2017– year 2021) is taken for calculation. Coefficient of rainfall

taken 15% for farm recharge and 80% for roof top rainfall recharge. Block wise details are summarized in Table 24 and 25.

Table-24. Enhancement of Groundwater Resources by adoption of Farm Recharge, in Dahankauda block, Sambalpur District

Sr.No.	Name Block	Total area of the village (in hectares rounded up to one decimal place)	10%of village area taken for farm recharge(sq m)	Total number of recharge pits/farm pond (1 recharge pit / hector) for 10% area	Annual recharge/conservation (MCM)= (Area*Runoff 15%*Rainfall 1489mm/1000000)
1	2	3	4	5	6
1	Dhankauda	48594	48594000	4859	10.861

Table-25. Enhancement of Ground Water Resources by adoption of roof top rainwater harvesting structures in Sambalpur City,Sambalpur District

Sr.No.	Name of Urban area	Total area of the village (in hectares rounded up to one decimal place)	Number of households (2011 census)	No of Houses taken for Artificial Recharge (10% of total households)	Total No of AR Structures (one structure for 10 house holds)	Annual Rainfall runoff Available for recharge (MCM) (No of households x avg rooftop area(200 sqm) x runoff coefficient (80%) x rainfall, 1489mm)
1	2	3	5	6	7	8
1	Sambalpur City	4648	41553	4155	4155	0.991

So, after combining the total amount of annual recharge a composit table have been prepared to know the exact improvement of groundwater resources and future demand supply position. The details are given in Table-26.

So, 11.852 **mcm** amount of rainwater may be conserved annually after adoption of farm pond and roof top rainwater harvesting structure which can enhance the groundwater storage. Feasibility of water conservation structure can be understood from Slope map (Fig.20).

Table-26. Demand supply gap position after Ground water resources Improvement, in Sambalpur District

Block	Water Demand (mcm)		Water Availability (mcm)			Gap (Yes/No)		Gap after intervention	
	Year 2035	Year 2047	Surface water	Ground Water (2022)	Total	Year 2035	Year 2047	Year 2035	Year 2047
Bamra	31.68	34.37	7.7	41.96	49.66	No	No	No	No
Dhankouda	107.06	109.97	31.7	50.38	82.08	24.98	27.89	13.128	14.762
Jamankira	15.73	18.23	9.6	60.19	69.79	No	No	No	No
Jujumora	59.1	61.26	14	56.42	70.42	No	No	No	No
Kuchinda	31.08	33.16	10.9	29.38	40.28	No	No	No	No
Maneswar	102.09	103.91	69.6	49.91	119.51	No	No	No	No
Nakti Deula	99.98	113.86	5.2	52.71	57.91	No	No	No	No
Rengali	46.32	48.09	3	58.65	61.65	No	No	No	No
Rairakhol	19.43	22.7	5.3	19.96	25.26	No	No	No	No
Total	512.47	545.55	**157**	**419.55**	**576.55**				

From Table 26 it is clear that a cumulative gap of 14.762 mcm will still exists during the year 2047 in Dhankauda Block. This can only be managed by crop water diversification, like paddy to maize,millet, modernizing the irrigation distribution channels from unlined to lined (which can save upto 25% water consumption) and adoption of subsurface drip irrigation techniques.

Old abandoned dug wells may be rejuvenated and reuse as recharge structure may arrest the declining water level in a particular village.

ii. **Demand side Management:** For demand side ground water management, average crop water requirement for kharif and rabi season calculated on the basis of data obtained from District Irrigartion Plan, Sambalpur (2016). As per ground water resources assessment 2022, total additional water availability for future irrigation has been considered. As 50% area is under forest area, considering only 50% additional water for future irrigation, 34768 ha additional irrigation potential area calculated and on that basis 8692 number of bore well can be drilled upto 80 mbgl preferable at the low land area sites and site along lineaments may be suggested for irrigation during summer season. The details are given in the Table-27.

Fig.20. Slope map of Sambalpur District

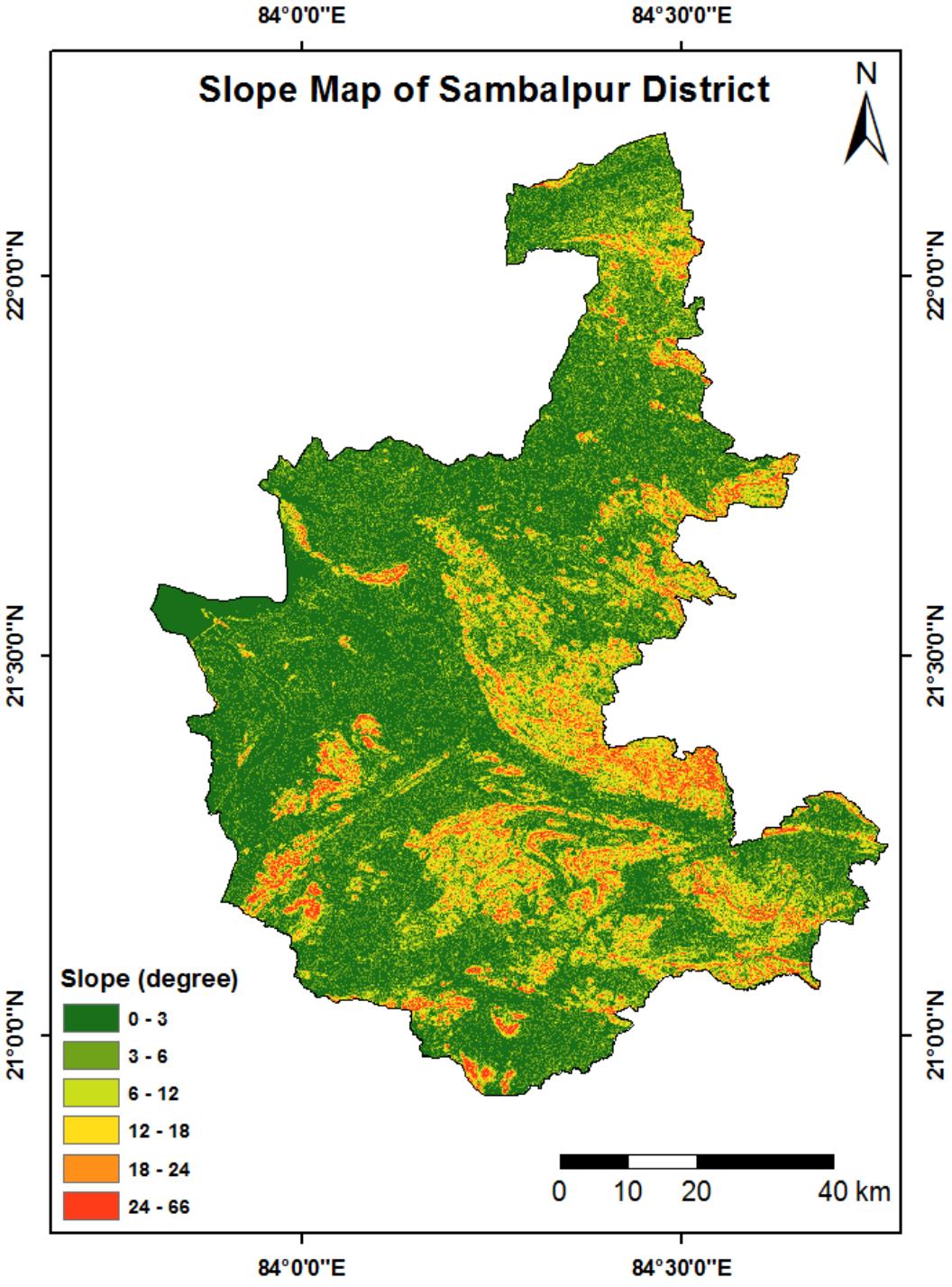


Table 27. Additional Irrigation potential that can be created and feasible number of additional irrigations Bore wells to be constructed, Sambalpur District

Block	Kharif crop area (ha*)	Average Water requirement @ 0.4 m/ha *(ham)	Rabi crop area (ha*)	Average Water requirement @ 0.8 m/ha* (ham)	Total Water requirement (ham)	Average crop Water requirement in a year (m)	Net GW Resources available for future irrigation (ham)**	Possible additional irrigation potential area that can be created with available resources (ha)	50% of the additional potential area taken for irrigation (ha)	Command area of one Bore Well (ha)	Number of Additional Shallow Bore Well to be constructed
1	2	3	4	5	6=(3+5)	7=[6/(2+4)]	8	9=(8/7)	10	12	13
Bamra	4604	1841.6	3595	2876	4717.6	0.58	1727.9	3003	1502	4	375
Dhankauda	15761	6304.4	12890	10312	16616.4	0.58	3918.29	6756	3378	4	845
Jamankira	5611	2244.4	2983	2386.4	4630.8	0.54	5611.19	10413	5207	4	1302
Kuchinda	4719	1887.6	4089	3271.2	5158.8	0.59	5076.83	8668	4334	4	1084
Manesar	16620	6648	9887	7909.6	14557.6	0.55	3750.81	6830	3415	4	854
Manesar	8033	3213.2	2689	2151.2	5364.4	0.50	5747.81	11488	5744	4	1436
Naktideul	3620	1448	2092	1673.6	3121.6	0.55	4710.69	8620	4310	4	1077
Rairakhol	3,846	1538.4	2093	1674.4	3212.8	0.54	2657.1	4912	2456	4	614
Rengali	1620	648	2689	2151.2	2799.2	0.65	5747.81	8848	4424	4	1106
Total	64434	25773.6	43007	34405.6	60179.2	0.56	38948.43	69537	34768	4	8692

Source: *District Irrigation Plan, Sambalpur District, 2016, **Ground water resources estimation of Orissa, 2022

From the cropping pattern in Sambalpur district, it has observed that during summer time crop production is very negligible. So, from the excess available water for future irrigation (Table-28) subsurface drip irrigation practices may be adopted which can reduce at least 60% water consumption. Crops suitable for drip irrigation are as follows:

i. Fruit crops: Grapes, banana, pomegranates, mango, orange, cashew nuts, papaya, litchi, watermelon.
ii. Vegetable plants: Onion, brinjal, bitter gourd, ridge gourd, cucumber, tomato, chilly, capsicum etc.
iii. Oil seeds: Sunflower, oil palm.
iv. Forest crop: Bamboo, teakwood

Therefore, after adopting this technique, 60% of future irrigation potential, i.e,60% of 38948 ham = 23368.8 ham ground water resources will be saved.

To mitigate the wastage of water specially for commercial activity Department of Water Resources, Govt. of Odisha notifies a separate water pricing policy vide letter dated 24.4.2020. Concerned District Administration should strictly follow the water pricing policy for sustainable development of ground water (Annexure-1).

7. CONCLUSION:

i. Sambalpur district comprises with two types of hydrogeological formations. Consolidated formations are occupying about 5697 sq. Km area, semi consolidated formations are occupying about 1005 sq.km area of the district.

ii. Ground water potentiality is very less in consolidated formation beyond 100-meter depth compared to shallow depth. Yield of tube wells is more in granite gneiss fracture zone in comparison to khondalite and charnockites as well as Gondwana sedimentaries.

iii. Aquifer consists of two groups: Aquifer I and Aquifer II. Aquifer I consists of weathered zone and fracture zone. Aquifer II consists of only fracture zone.Thickness of weathered zone ranges from 1.5 meter to 33.52 meter. Thickness of fracture zone varies from 0.5 to 1.5 meter.Most of the potential fractures are available within 100 mbgl depth.Recent ground water exploration along major lineament like fold hinges and limbs in granite/granite gneisses in Naktideul block shows 10-19 lps discharge with 10 to 20 m drawdown in bore wells constructed by CGWB. So these wells can be taken up for major water supply scheme in nearby villages.

iv. Long-term (5 years) post monsoon trend of water level is falling in 350 sq.km area and rising in rest of the area of the District. 611 sq.km. area is showing long term post monsoon mean water level more than 5 mbgl.

v. From CGWB hydrograph stations a remarkable decline of water level has been noticed at Bamra, Dhankauda, Jujumura, Kuchina, Manesar Block hydrograph stations.Water logged area is noticed only in 62 sq. Km. area which covering part of Dhankauda and Manesar block.

vi. Total number of irrigations dug wells reduced from 9134 during 1999 to 5388 during 2022 and number of irrigations bore wells also enhanced from 10 during 1999 to 5213 during 2022.

vii. Stage of ground water development for the whole district enhanced from 7.86% during 1999 to 28.96% during 2022.Present Dynamic ground water resources for the district is 592.68 mcm and in-storage ground water resources upto 100 mbgl depth is 678.17 mcm.

viii. Quality of ground water for the whole district is potable except sporadic occurrences of fluoride, nitrate and uranium above permissible limit. At one exploratory well fluoride concentration found above permissible limit have also been noticed. This polluted water should be avoided for drinking.The locations having the above pollution require further detailed study. Type of water is bicarbonate type in most of the cases and chloride type or mixed type in few cases.

ix. As per water demand-supply-gap analysis it is observed that a total amount of water demand will gradually increasing from 475.67 mcm during 2022 to 545.55 mcm during the year 2047 for the whole Sambalpur District. Only Dhankauda block is showing a gap between demand-supply.So to combat the situation ground water enhancement and demand side intervention have been planned.

x. In ground water enhancement category rainfall to be recharge by creating farm ponds in agricultural fields in Dhankauda Block and roof top rainwater harvesting structure only in Sambalpur City. By adoption of 4859 number of farm pond techniques annually 10.861 mcm water will be recharge/ conserve and by adoption of 4155 number of roof top rainwater harvesting structures techniques annually 0.991 mcm water will be recharge/ conserve. After adoption of all the above ground water enhancement techniques a cumulative gap of 14.762 mcm will still exists during the year 2047 in Dhankauda Block. This can only be managed by crop water diversification, like paddy to maize, millet, modernizing the irrigation distribution channels from unlined to lined (which can save upto 25% water consumption) and adoption of subsurface drip irrigation techniques.Old abandoned dug wells may be used as recharge structure to arrest the declining water level in a particular village.

xi. In Demand side management after taking average crop water requirement and 50% of additional future irrigation potential, 34768 ha area may be converted to additional irrigation potential area for subsurface drip irrigation during summer season and thereby construction of additional 8692 number of bore wells may be planned. Drip irrigation may be planned for minimum water utilization.Flat minimum rate of electricity by

the government may be enhanced for sustainaible ground water resources utilization.

xii. Special awareness campaign to be initiated at blocklevel only for farmers to adopt the water efficient irrigation practices and crop diversification from high water intensive crops to low water intensive crops.

ACKNOWLEDGEMENTS: The author is very much thankful to the Chairman, Sh Sunil Kumar, Member East, Sh T B N Singh, Member Head Quarter, Sh A K Agarwal and Sh P K Mohapatra , Regional Director, CGWB, SER, Bhubaneswar for their valuable suggestion for compilation of the report. The author is also thankful to Geophysical Section and chemical section of CGWB, SER, Bhubaneswar for their valuable contribution for compilation of the report. The author is also grateful to Ground Water Department, Sambalpur District for providing water level data of various bore wells.

REFERENCES:

i. Ground water resources and development potentials of Sambalpur District, Orissa; CGWB, SER, Bhubaneswar, 1992 and 2005.

ii. Ground water resources assessment of Odisha State; CGWB, SER, Bhubaneswar, 2017.

iii. Ground water resources assessment of Odisha State; CGWB, SER, Bhubaneswar, 2022.

iv. District irrigation plan of Sambalpur, Odisha, PMKSY; District level implementation committee, Sambalpur, 2016.

v. Well completion report of exploratory wells constructed by CGWB, Sambalpur District, CGWB, SER, Bhubaneswar, 2022.

vi. Basic data report of exploration in Sambalpur District by CGWB,SER,Bhubaneswar, 1987-2005.

vii. Irrigation census 2018 , Odisha, Ministry of Jal Shakti, Government of India.

ANNEXURE1

Government of Odisha
Department of Water Resources
*****

No. 8561 /WR.. Date: 21/4/2020
Irr.-II-WRC-92/20

From
Sri. R. N. Chinara
Under Secretary to Government.

To
The EIC, WR, Secha Sadan, Bhubaneswar.

Sub: Enhancement of licence fee & special water rate w.e.f 01.04.2020.

Sir,

In inviting reference to your Letter No. 8464 / WE dated 13.03.2020 on the subject noted above, I am directed to say that as per amendment made in Rule-23-A (2) (f) of Odisha Irrigation Rules, 1961vide Odisha Irrigation (Amendment) Rules, 2016, the licence fees / special water rate for drawal and use of water shall be enhanced @ 10% per annum w.e.f. 1st day of April.

Accordingly, the 4th annual enhancement @ 10% will be effective from 01.04.2020 to 31.03.2021. The enhanced rate chart of special water rate & licence fee are annexed vide Schedule-II & Schedule-III respectively.

It is, therefore, requested to circulate the above licence fees / special water rate among all Sub-Ordinate Officers under your administrative control for further follow up action.

Encl.:-As above.

Yours faithfully,

22/04/2020
Under Secretary to Government

Memo No. 8562 / **Dt.** 21/4/2020

Copy forwarded to the CE, Water Services, O/o the EIC, WR for information and necessary action.

22/04/2020
Under Secretary to Government

1404

SPECIAL WATER RATES UNDER SCHEDULE-II FOR THE PERIOD FROM 01.4.2019 TO 31.3.2020 AFTER THE ENHANCEMENT @ 10% PER ANNUM AS PER RULE-23A(2)(f) AND RULE 26 OF THE ODISHA IRRIGATION RULES, 1961 FOR THE PURPOSES OTHER THAN IRRIGATION(INDUSTRIAL/ COMMERCIAL USES OF WATER) FROM THE IRRIGATION WORKS

Item No	Purpose for which supply is given	Special water rates as per Schedule II from 01.10.2010 to 31.3.2017 (in Rupees) (Base Rate)	Enhanced special water rate (for the period from 01.4.2019 to 31.03.2020) (in Rupees)	Enhanced special water rate (for the period from 01.4.2020 to 31.03.2021) (in Rupees)	Quantity	Remarks
1	2	3	4	5	6	7
1	Bricks or tile making	30.00	39.00	42.00	1000 Bricks or Tiles	
2	(i)For water actually drawn or allocated whichever is higher for industrial or commercial purpose					
	Slab-I-Consumption not exceeding 5 cusecs	4.20	5.46	5.88	1000 liter (1 m^3)	
	Slab-II-Consumption of 5 cusecs or more	5.60	7.28	7.84	1000 liter (1 m^3)	
	(ii) For water used for Hydro Power Generation	0.01	0.013	0.014	1 KWH	
3	(i) For bulk supply to Municipalities and Notified Area Councils and other local authorities for drinking, washing etc.	0.25	0.325	0.35	1000 liter (1 m^3)	
	(ii) For bulk supply to Municipalities and Notified Area Councils and other local authorities and cluster of villages by industrial, commercial or other establishments actually drawn or allocated whichever is higher for drinking, washing etc.	0.50	0.65	0.70	1000 liter (1 m^3)	
4	Construction of commercial buildings	7.10	9.23	9.94	1000 liter (1 m^3)	
5	For filling tanks	0.10	0.13	0.14	1000 liter (1 m^3)	
6	For filling tanks mainly for drinking purposes	0.05	0.065	0.07	1000 liter (1 m^3)	

N.B:- The enhancement of licence fees and special water rates @ 10 per centum per annum with effect from the first day of April is as per the Odisha Irrigation (Amendment) Rules, 2016.

22/04/2020

Under Secretary to Government,
Department of Water Resources.

RATE OF LICENCE FEE UNDER SCHEDULE-III FOR THE PERIOD FROM 01.4.2019 TO 31.3.2020 AFTER THE ENHANCEMENT @ 10% PER ANNUM AS PER RULE-23A(2)(f) OF THE ODISHA IRRIGATION RULES, 1961

FOR INDUSTRIAL/ COMMERCIAL USES OF WATER FROM THE GOVERNMENT WATER SOURCES

Item No	Purpose for which supply is given	Licence fees as per Schedule III from 01.10.2010 to 31.3.2017(in Rupees)(Base Rate)	Enhanced Licence Fee for the period from **01.4.2019 to 31.3.2020** (in Rupees)	**Enhanced Licence Fee for the period from 01.4.2020 to 31.3.2021 (in Rupees)**	Quantity	Remarks
1	2	3	4	5	6	7
1	Bricks or tile making	25.00	32.50	**35.00**	1000 Bricks or Tiles	
2	(i)For water actually drawn or allocated whichever is higher for industrial or commercial purpose					
	Slab-I-Consumption not exceeding 5 cusecs	3.40	4.42	**4.76**	1000 liter (1 m^3)	
	Slab-II-Consumption of 5 cusecs or more	4.50	5.85	**6.30**	1000 liter (1 m^3)	
	(ii) For water used for Hydro Power Generation	0.01	0.013	**0.014**	1 KWH	
3	(i) For bulk supply to Municipalities and Notified Area Councils and other local authorities for drinking, washing etc.	0.20	0.26	**0.28**	1000 liter (1 m^3)	
	(II) For bulk supply to Municipalities and Notified Area Councils and other local authorities and cluster of villages by industrial, commercial or other establishments actually drawn or allocated whichever is higher for drinking, washing etc.	0.40	0.52	**0.56**	1000 liter (1 m^3)	
4	Construction of commercial buildings	5.30	6.89	**7.42**	1000 liter (1 m^3)	
5	For sub soil water actually used and consumed for industrial /commerical purpose					
	Slab I Consumption not exceeding 5 cusecs	6.80	8.84	**9.52**	1000 liter (1 m^3)	
	Slab II Consumption of 5 cusecs or more	9.00	11.70	**12.60**	1000 liter (1 m^3)	

N.B:- The enhancement of licence fees and special water rates @ 10 per centum per annum with effect from the first day of April is as per the Odisha Irrigation (Amendment) Rules, 2016.

22/04/2020

Under Secretary to Government,
Department of Water Resources.

ANNEXURE-2

SL NO.	LOCATION	BLOCK	VES NO.	Longitude	Latitude	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Charectristics		
						Layer	Resistivity(ohm.m)	Thickness(m)	Depth (m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
1.	Kalamati	Maneswar	04	83.88402	21.40307	1	85	1.34	1.34	Top Soil			
						2	11.6	7.87	9.2	Clay			
						3	VH			Granite Formation			
2.	Katapali	Maneswar	05	83.89383	21.44931	1	111.99	2.09	2.09	Top Soil			
						2	56.4	6.7	8.75	Highly Weathered Formation	Aquifer	2.09-8.75	potable
						3	1234			Granite Formation			
3.	khandual	Maneswar	06	84.00086	21.42379	1	20.9	2.52	2.52	Top Soil			
						2	22.7	2.73	5.25	Highly Weathered Formation			
						3	1314			Granite Formation			
4.	Khunti	Maneswar	07	83.97343	21.36172	1	22.6	2.51	2.51	Top Soil			
						2	158	8.26	10.8	Weathered Formation	Aquifer	2.51-10.8	potable
						3	2192			Granite Formation			
5.	Dhama	Maneswar	08	83.91765	21.26357	1	9.22	2.2	2.2	Top Soil			
						2	163.6	22.3	24.5	Weathered Formation	Aquifer	2.2-24.5	potable
						3	VH			Granite Formation			
6.	Rasanpur	Maneswar	09	84.04587	21.42796	1	11.2	1.15	1.15	Top Soil			
						2	29	5.29	6.45	Highly Weathered Formation			
						3	VH			Granite Formation			
7.	Bhabanipali	Jujumura	10	84.07145	21.38104	1	2.27	1.23	1.23	Top Soil			
						2	814	21.9	23.1	Fractured Granite	Aquifer	1.23-23.1	Potable
						3	VH			Granite Formation			
8.	NUAMAHULPALI	JUJUMURA	11	84.10561	21.3138	1	281	1.3	1.3	Top Soil			
						2	47.7	5.17	6.47	Highly Weathered Formation	Aquifer	1.3-11.7	Potable

						3	21.9	5.2	11.7	Highly Weathered Formation			
						4	1842			Granite Formation			
9.	JUJUMURA	JUJUMURA	12	84.13516	21.23259	1							
						2							
						3					Aquifer	1.647-10.78	Potable
						4					Aquifer	10.78-38.64	Potable
						5							
10.	GAHARIPALI	JUJUMURA	13	84.03915	21.22113	1	18.8	2.52	2.52	Top Soil			
						2	123	21.5	24	Weathered Formation	Aquifer	2.52-24	Potable
						3	5013			Granite Formation			
11.	ATASAMAL	RAIRAKHOL	14	84.08847	21.15713	1	649	0.4	0.4	Top Soil			
						2	13.4	5.56	5.9	Clay			
						3	VH			Granite Formation			
12.	PADIABAHAL	JUJUMURA	15	84.15147	21.44272	1	68.58	1.2	1.2	Top Soil			
						2	24.78	1.3	2.5	Top Soil			
						3	119.6	8.5	11.0	Weathered Formation	Aquifer	2.5-11	Potable
						4	2871			Granite Formation			
13.	BEHERAMAL	JUJUMORA	16	84.23859	21.40133	1	35.1	0.557	0.557	Top Soil			
						2	19	15.8	16.4	Highly Weathered Formation	Aquifer	0.5-16.4	Potable
						3	VH			Granite Formation			
14.	KADLIPAL	JAMUKAIRA	17	84.22772	21.46452	1	20.7	1.2	1.2	Top Soil			
						2	7.84	1.31	2.51	Clay			
						3	40.3	8.99	11.5	Highly Weathered Formation	Aquifer	1.2-11.5	Potable
						4	2341			Granite Formation			
15	GHENUHALI	JUJUMURA	18	84.12036	21.40635	1	21.5	2.63	2.63	Top Soil			
						2	195	15.4	18	Weathered Formation	Aquifer	2.63-18	Potable
						3	VH			Granite Formation			

16.	MEGHAPALI	JUJUMORA	19	84.24264	21.35277	1	25.7	1.26	1.26	Top Soil			
						2	43.4	5.88	7.14	Highly Weathered Formation			
						3	8000			Granite Formation			
17.	KISINDA	NAKTIDEUL	20	84.34846	21.33245	1	28.35	2.788	2.788	Top Soil			
						2	6.7	10.37	13.16	Clay			
						3	18.6	34.21	47.36	Sandy Clay	Aquifer	16.16-47.36	Potable
						4	204.1			Fractured Formation			
18.	SASAN	NAKTIDEUL	21	84.03731	21.54405	1	7.9	1.426	1.426	Top Soil			
						2	3.9	.77	2.2	Top Soil			
						3	9.9	8.7	11	Clay			
						4	15.83	46.89	57.88	Sandy Clay	Aquifer	11-57.88	Potable
						5	255.1			Fractured Formation			
19.	RENGALI	RENGALI	22	84.05427	21.65089	1	28.5	2.99	2.99	Top Soil			
						2	5.72	7.7	10.7	Clay	Aquifer	0.519-17.2	Potable
						3	222.8	70.2	80.9	Fractured Granite	Aquifer	10.7-80	Potable
						4	7609			Granite Formation			
20.	BADMAL	RENGALI	23	84.11148	21.66133	1	11.2	1.31	1.31	Top Soil			
						2	7.44	1.87	3.17	Clay			

						3	5762			Granite Formation			
21.	TAMPARKELA	RENGALI	24	84.16769	21.58009	1	110	0.9	0.95	Top Soil			
						2	33.78	4.2	5.154	Highly Weathered Formation			
						3	343.4	44.85	50.01	Fractured Granite	Aquifer	5-50	Potable
						4	VH			Granite Formation			
22.	PARMANPUR	MANESWAR	25	84.10347	21.52774	1	15.3	3.99	3.99	Top Soil			
						2	45.29	19.39	23.38	Highly Weathered Formation	Aquifer	4-23	Potable
						3	1235			Granite Formation			
23.	SINGHAPALI	SAMBALPUR	26	83.99385	21.50751	1	53.3	2.78	2.78	Top Soil			
						2	194	2.92	5.71	Weathered Formation	Aquifer	2-14	Potable
						3	13	8.23	13.9	Highly Weathered Formation			
						4	VH			Granite Formation			
24.	SINDURPANK	SAMBALPUR	27	84.03057	21.45473	1	267.5	1.2	1.2	Top Soil			
						2	92.7	9.7	10.99	Weathered Formation	Aquifer	1.2-11	Potable
						3	1407	11.9	22.93	Granite Formation			
						4	510.3	24.95	47.89	Fractured Granite	Aquifer	22-47	Potable
						5	VH			Granite Formation			
25.	Kuchinda	Kuchinda	110	84.36365	21.74258	1	344	4.42	4.42	Top Soil			

						2	38.4	15.2	19.7	Highly Weathered Formation	Aquifer	5-20	Potable
						3	23225			Granite Formation			
26	Bauriguda	Kuchinda	111	84.34639	21.836	1	613	1.41	1.41	Top Soil			
						2	76.6	8.3	9.71	Highly Weathered Formation	Aquifer	1.5-9	Potable
						3	1935	6.37	16.1	Granite Formation			
						4	187	26.2	42.3	Fractured Granite	Aquifer	16-42	Potable
						5	VH			Granite Formation			
27.	kesaibahal	Bamara	112	84.38258	21.92267	1	117	0.698	0.698	Top Soil			
						2	1034	1.2	1.89	Dry Soil			
						3	21	2.59	4.49	Highly Weathered Formation	Aquifer	2-35	Potable
						4	117	30.5	35	Weathered Formation			
						5	VH			Granite Formation			
28.	Daitaripali	Bamara	113	84.48851	21.84667	1	101	0.993	0.993	Top Soil			
						2	14.4	13	14	Highly Weathered Formation	Aquifer	1-14	Potable
						3	VH			Granite Formation			
29.	Belmunda	Bamara	114	84.44495	21.88581	1	32.1	0.92	0.92	Top Soil			
						2	7.88	1.6	2.52	Clay			
						3	2343			Granite Formation			
30.	Jarabaga	Bamara	115	84.45184	21.95887	1	407	1.41	1.41	Top Soil			
						2	74.5	3.64	5.05	Weathered Formation	Aquifer	2-10	Potable
						3	27.5	5.56	10.6	Highly Weathered Formation			
						4	3161			Granite Formation			

31	Lariapali	Bamara	116	84.45458	22.00195	1	285	1.7	1.7	Top Soil			
						2	44.6	5.5	7.21	Highly Weathered Formation			
						3	VH			Granite Formation			
32.	Ulanda	Kuchinda	117	84.41811	21.80014	1	35.4	2.39	2.39	Top Soil			
						2	9.35	6.72	9.11	Clay			
						3	VH			Granite Formation			
33.	Kuntara	Kuchinda	118	84.51814	21.79052	1	46.6	0.331	0.331	Top Soil			
						2	19.9	9.73	18.1	Highly Weathered Formation	Aquifer	1-18	Potable
						3	VH			Granite Formation			
34.	Tanmura	Kuchinda	119	84.56957	21.7578	1	619	0.789	0.789	Top Soil			
						2	90.3	2.12	2.91	Weathered Formation			
						3	14.7	2.76	5.67	Highly Weathered Formation			
						4	455	35.3	41	Fractured Granite	Aquifer	6-41	Potable
						5	VH			Granite Formation			
35.	Kukam	Kuchinda	120	84.49774	21.73879	1	12.9	0.636	0.636	Top Soil			
						2	3.02	2.28	2.91	Clay			
						3	1225			Granite Formation			
36.	Matamahul	Jamankira	121	84.40479	21.64337	1	69.55	1.064	1.064	Top Soil			
						2	25.92	1.428	2.492	Dry Soil			
						3	50.64	13.41	15.9	Highly Weathered Formation	Aquifer	3-15	Potable
						4	174	90.5	106.4	Fractured Granite	Aquifer	16-106	Potable
						5	VH			Granite Formation			

37	Baramundi	Jamankira	122	84.46377	21.57434	1	136	0.559	0.559	Top Soil			
						2	113	7.62	8.18	Weathered Formation			
						3	713	36.8	45	Fractured Granite	Aquifer	8-45	Potable
						4	1421			Granite Formation			
38.	Jamankira	Jamankira	123	84.38543	21.53049	1	145.3	1.621	1.621	Top Soil			
						2	9.609	1.763	3.374	Clay			
						3	22.95	14.71	18.1	Highly Weathered Formation	Aquifer	3-18	Potable
						4	302.2			Fractured Granite			
39.	Fasimal	Jamankira	124	84.28392	21.60055	1	8.7	2.53	2.53	Top Soil			
						2	161	44.4	46.9	Weathered Formation	Aquifer	3-46	Potable
						3	1586			Granite Formation			
40.	Ghodabandhini	Jamankira	125	84.35475	21.66771	1	148	1.46	1.46	Top Soil			
						2	40	7.19	8.65	Highly Weathered Formation			
						3	411	93.2	102	Fractured Granite	Aquifer	9-102	Potable
						4	VH			Granite Formation			
41.	Laida	Rengali	126	84.23519	21.72603	1	298	2.17	2.17	Top Soil			
						2	171	8.96	11.1	Weathered Formation			
						3	71.6	20.1	31.2	Highly Weathered Formation	Aquifer	11-31	Potable
						4	1322			Granite Formation			
42.	Junadihi	Rengali	127	84.17103	21.6988	1	369	1.77	1.77	Top Soil			
						2	198	3.49	5.26	Weathered Formation			

						3	16.6	5.64	10.9	Highly Weathered Formation			
						4	1935			Granite Formation			
43.	Bijaguda	Jamankira	128	84.23698	21.66278	1	1396	0.34	0.34	Top Soil			
						2	95.3	2.97	3.31	Dry Soil			
						3	25.6	3.67	6.97	Highly Weathered Formation			
						4	2333			Granite Formation			
44.	Kaputikara	Kuchinda	129	84.42564	21.75132	1	211	0.76	0.76	Top Soil			
						2	36.6	2.6	3.36	Highly Weathered Formation			
						3	8.42	5.38	8.74	Clay			
						4	VH			Granite Formation			
45.	Tileimal	Rengali	130	84.0703	21.71359	1	879	3.2	3.2	Top Soil			
						2	249	75.4	78.6	Fractured Granite	Aquifer	3-78	Potable
						3	3520			Granite Formation			
46.	Mura	Rengali	131	84.18544	21.5179	1	23	0.606	0.606	Top Soil			
						2	6.12	2.33	2.94	Clay			
						3	VH			Granite Formation			
47.	Budhiapali	Rengali	132	83.96395	21.75172	1	454	0.822	0.822	Top Soil			
						2	112	1.52	2.34	Dry Soil			
						3	2550	1.76	4.09	Granite Formation			
						4	162	27	31.1	Fractured Granite	Aquifer	4-31	Potable
						5	3872			Granite Formation			

48.	Kindira	Kuchinda	133	84.31547	21.76897	1	589	1.42	1.42	Top Soil			
						2	83	8.53	9.95	Weathered Formation			
						3	601	71.8	81.8	Fractured Granite	Aquifer	10-81	Potable
						4	VH			Granite Formation			
49.	Padhanpali	Sambalpur	134	84.04312	21.59233	1	17.2	1.27	1.27	Top Soil			
						2	5.22	1.67	2.94	Clay			
						3	VH			Granite Formation			
50.	Hirakud	Sambalpur	135	83.91737	21.52981	1	26.2	2.25	2.25	Top Soil			
						2	11.8	8.47	10.7	Highly Weathered Formation	Aquifer	2-10	Potable
						3	VH			Granite Formation			
51.	Chipilima	Sambalpur	136	83.89731	21.34918	1	221	1.16	1.16	Top Soil			
						2	97.6	4.12	5.27	Weathered Formation			
						3	30.8	14.1	19.3	Highly Weathered Formation			
						4	226	54.5	73.8	Fractured Granite	Aquifer	20-73	Potable
						5	VH			Granite Formation			
52.	Burla	Sambalpur	137	83.38719	21.48524	1	35.5	0.794	0.794	Top Soil			
						2	18.5	18.2	19	Highly Weathered Formation	Aquifer	1-19	Potable
						3	VH			Granite Formation			
53	Gadakhol	Rairakhol	138	84.26764	21.05797	1	134	1.65	1.65	Top Soil			
						2	32.6	16.3	17.9	Weathered Formation	Aquifer	2-17	Potable
						3	VH			Granite Formation			

54	Kusapali	Rairakhol	139	84.23366	21.01597	1	24.7	0.596	0.596	Top Soil			
						2	7.7	9.77	10.4	Clay			
						3	4931			Granite Formation			
55.	Tribanpur	Rairakhol	140	84.24309	20.96744	1	60.9	1.12	1.12	Top Soil			
						2	16.9	5.22	6.34	Clay			
						3	8747			Granite Formation			
56.	Bhatra	rairakhol	141	84.17194	21.00351	1	62.5	3.02	3.02	Top Soil			
						2	20.1	2.93	5.95	Highly Weathered Formation			
						3	224	28.9	34.8	Fractured Granite	Aquifer	6-34	Potable
						4	VH			Granite Formation			
57.	Charmal	Rairakhol	142	84.21473	21.10895	1	115	1.01	1.01	Top Soil			
						2	23.9	17.3	18.3	Highly Weathered Formation	Aquifer	1-18	Potable
						3	VH			Granite Formation			
58.	Daincha	Naktideul	143	84.42193	21.16065	1	83.5	1.7	1.7	Top Soil			
						2	17.4	8.89	10.6	Highly Weathered Formation			
						3	VH			Granite Formation			
59	Landimal	Naktideul	144	84.52253	21.14911	1	32.95	0.83	0.83	Top Soil			
						2	14.63	1.263	2.093	Clay			
						3	47.92	10.74	12.83	Highly Weathered Formation			
						4	342.1	90.15	103	Fractured Granite	Aquifer	12-103	Potable
							VH			Granite Formation			
						5							
60	Kadobahal	Naktideul	145	84.46967	21.19336	1	202	1.84	1.84	Top Soil			

						2	19.9	8.21	10.1	Highly Weathered Formation			
						3	VH			Granite Formation			
61	Naktideul	Naktideul	146	84.54579	21.26034	1	36.9	3.347	3.347	Top Soil			
						2	69.31	33.84	37.18	Highly Weathered Formation	Aquifer	4-37	Potable
						3	VH			Granite Formation			
62	Dimirikud	Rairakhol	147	84.37646	21.08782	1	191	1.15	1.15	Top Soil			
						2	34.2	3.55	4.7	Highly Weathered Formation			
						3	8.04	74.3	79	Clay			
						4	VH			Granite Formation			
63	Banjagola	Naktideul	148	84.44326	21.29703	1	98.87	0.87	0.87	Top Soil			
						2	85.75	11.3	12.17	Weathered Formation			
						3	39.88	72.11	84.28	Highly Weathered Formation	Aquifer	12-84	Potable
						4	4093			Granite Formation			
64	Banjagola 2	Naktideul	149	84.44326	21.29703	1	60.8	1.78	1.78	Top Soil			
						2	34.2	12.6	14.4	Weathered Formation			
						3	18.3	61.1	75.5	Highly Weathered Formation	Aquifer	14-75	Potable
						4	1706			Granite Formation			
						5							
65	Jharbeda	Naktideul	150	84.60322	21.252	1	9.79	1.2	1.2	Top Soil			
						2	6.14	4.06	5.26	Clay			
						3	61.4	19	24.3	Highly Weathered Formation	Aquifer	6-24	Potable
						4	1219			Granite Formation			
66	Baghabar	Naktideul	151	84.71564	21.23699	1	776	0.1936	0.1936	Top Soil			

						2	13.13	8.497	8.691	Highly Weathered Formation			
						3	170.3	86.7	95.39	Fractured Granite	Aquifer	9-95	Potable
						4	9089			Granite Formation			
67	Laindamal	Rairakhol	152	84.34739	21.01436	1	280	1.34	1.34	Top Soil			
						2	5.95	9.33	10.7	Clay			
						3	4852			Granite Formation			
68	Kandhara	Rairakhol	153	84.30985	20.93996	1	110	1.93	1.93	Top Soil			
						2	46	14.1	16	Highly Weathered Formation			
						3	176	70.3	86.3	Fractured Granite	Aquifer	16-86	Potable
						4	1700			Granite Formation			
69	Kudabahali	Rairakhol	154	84.38166	20.97137	1	105	0.946	0.946	Top Soil			
						2	46.9	5.71	6.66	Weathered Formation			
						3	16.7	7.96	14.6	Highly Weathered Formation	Aquifer	5-15	Potable
						4	VH			Granite Formation			
70	Rairakhol	Rairakhol	155	84.349	21.06829	1	32.6	1.2	1.2	Top Soil			
						2	15.5	3.86	5.06	Clay			
						3	55.5	48.2	53.3	Highly Weathered Formation	Aquifer	5-53	Potable
						4	3336			Granite Formation			
71	Kharsali	rairakhol	156	84.42042	21.06517	1	145	2.34	2.34	Top Soil			
						2	11.2	8.89	11.2	Clay			
						3	1.88	14.4	25.7	Highly Weathered Formation			
						4	849			Granite Formation			
72	Bamra	Bamra	224	84.28043	22.06386	1	59.1	0.679	0.679	Top Soil			

						2	16.6	1.67	2.34	Clay			
						3	60.2	9.18	11.5	Highly Weathered Formation			
						4	5051			Granite Formation			
73	Tangarmunda	Bamra	225	84.36012	22.09143	1	1976	0.319	0.319	Top Soil			
						2	42.1	6.6	6.91	Highly Weathered Formation			
						3	VH			Granite Formation			
74	Garposh	Bamra	226	84.41397	22.13284	1	40.2	0.758	0.756	Top Soil			
						2	13.2	16.8	17.5	Highly Weathered Formation	Aquifer	1-18	Potable
						3	8181			Granite Formation			
75	Sagar	Bamra	227	84.45896	22.15647	1	25.8	5.49	5.49	Top Soil			
						2	VH			Granite Formation			