केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

JAGATSINGHPUR DISTRICT, ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

South Eastern Region, Bhubaneswar

Government of India

MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

NATIONAL AQUIFER MAPPING & MANAGEMENT

HYDROGEOLOGICAL FRAMEWORK, GROUND WATER DEVELOPMENT & AQUIFER MANAGEMENT PLAN OF JAGATSINGHPUR DISTRICT, ODISHA STATE

By

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CENTRAL GROUND WATER BOARD
South Eastern Region, Bhubaneswar
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AQUIFER MAPPING OF JAGATSINGHPUR DISTRICT, ODISHA

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1. INTRODUCTION

Jagatsinghpur is one of the most natural disaster-prone districts of costal Odisha. The district came into existence on 1st April 1993 vide Government Notification. Before that, it was a part of the erstwhile Cuttack district, subsequently which divided into four different districts for administrative convenience. The district is surrounded by the districts namely Kendrapara, Cuttack, Khurda, Puri and Bay of Bengal. Cyclone and natural calamities regularly devastate the economy of the district. The district has a geographical area of 1668 sq. km and the smallest district in Odisha. Jagatsinghpur district has only one subdivision namely Jagatsinghpur. There are 8 Blocks, 8 Tahasils, 1320 villages, 194 Gram Panchayats and 13 Police stations functioning in the district. Agriculture is the mainstay of the people and economy of the district is mainly based on agricultural production. The district spreads over alluvial deposits of river Mahanadi and its distributaries that resulted fertile agricultural land. Besides the seasonal main occupation is fishing. Jagatsinghpur occupies a pivotal position in the agrarian & industrial economy, sea trade and fishing commerce. 70 percent of the total population depends upon agriculture & agro-based industries. There are two numbers of municipalities i.e. Jagatsinghpur & Paradeep. Paradeep is a port city with access to sea route. Paradeep is the cradle of series of industries. The PPL, the IFFCO, the IOCL, the ESSAR are noteworthy. Large scale, small scale and village industries are sufficiently crop up.

1.1 Location

Jagatsinghpur district lies between 860 03’ E to 86045’ East longitude and between 19058’ N to 20023’ North latitude falling in survey of India toposheet no. 73L in 1:2,50,000 scale. The headquarter is located at a distance of 45 kms away from Cuttack and 65 kms from Bhubaneswar, the State Capital.
It is bounded in north by Kendrapara district, in the north and northwest by Cuttack district and Puri district in the south west and in the east by the Bay of Bengal (Fig.1).

The river Mahanadi flowing from west to east and forming the northern boundary of the district forms the main drainage system in the district. Besides the river Devi, a tributary to Kathajori and flowing north-northwest to south-southeast with a meandering course also forms a drainage system in the district.

1.2 Population

Jagatsinghpur district is one of the thickly populated coastal districts of Odisha in the eastern part. This district has got a total population of 11,36,971 including 577,865 male and 559,106 females as per 2011 census. The total SC population of the District is 2,48,152 and ST population is 7,862 as per 2011 census. The density population of the district is 634 persons per sq km as per 2011 census against the state figure of 236 persons per sq km. 90% of the total population live in rural areas.

The average literacy rate of the district is 86.6 percent comprising of 92.4 percent male literacy and 80.6 percent female literacy.

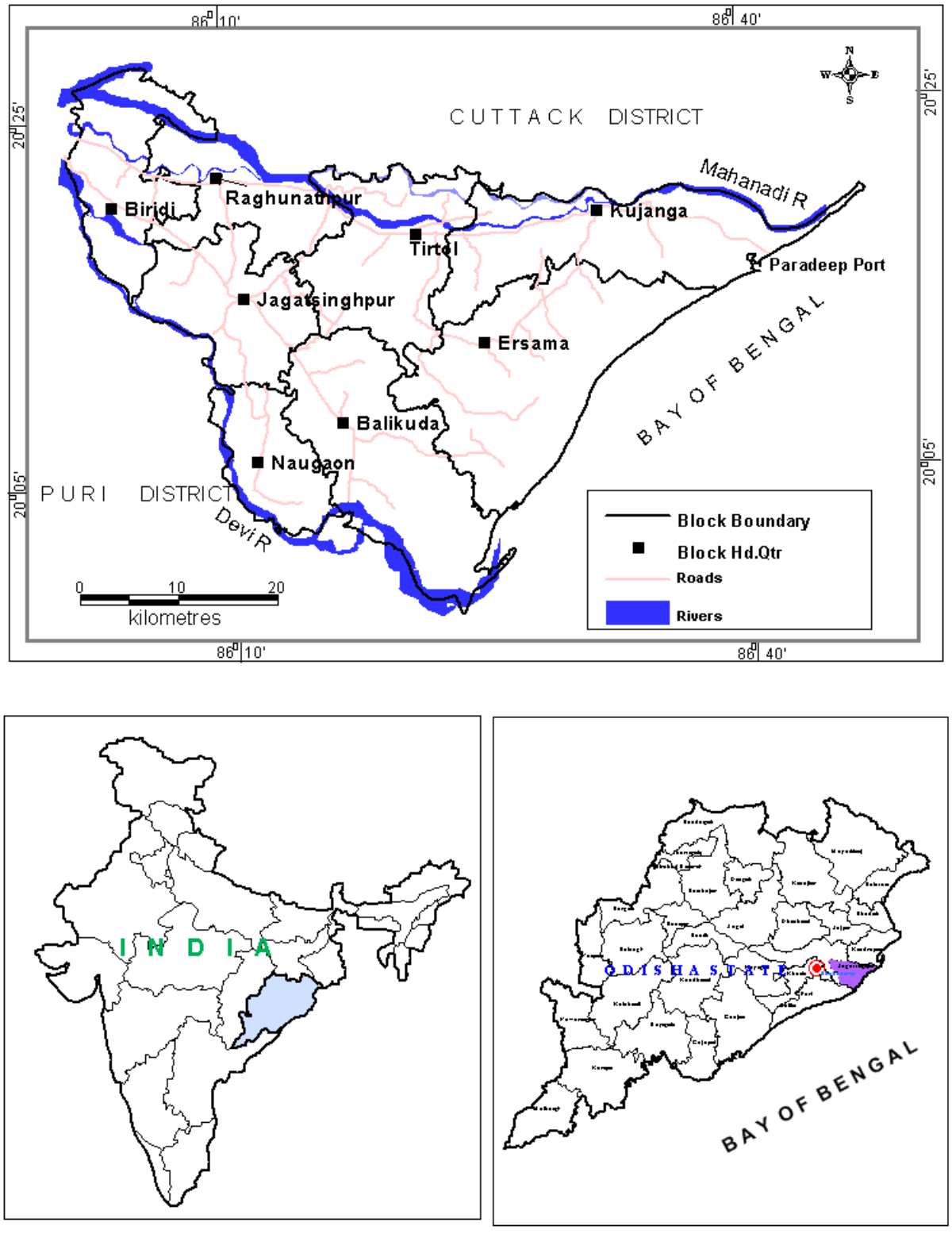


Fig.1: Location of Jagatsinghpur District

Table 1: Block-wise population of the district

Sl. No	General						Population(As per the 2011 Census)				
	Block	Villages		No.of Revenue Villages	Area (ha)	No.GPs	Male	Female	Total	S.C	S.T
		Inhabited	Un-inhabited								
1	Jagatsinghpur	161	5	166	18388	29	89068	86530	175598	41976	994
2	Raghunathpur	82	5	87	9769	19	42463	41183	83646	20664	1421
3	Biridi	80	1	81	10642	21	42227	40568	82795	26882	522
4	Balikuda	225	12	237	28520	30	83801	81474	165275	33078	260
5	Naugaon	87	3	90	11576	16	38943	38691	77634	14437	263
6	Tirtol	243	6	249	22543	27	80443	80657	161100	33247	387
7	Kujanga	155	19	174	27421	27	127327	117323	244650	48354	3386
8	Ersama	194	16	210	37111	25	73593	72680	146273	29514	629
	District(Total)	**1227**	**67**	**1294**	**165970**	**194**	**577865**	**559106**	**1136971**	**248152**	**7862**

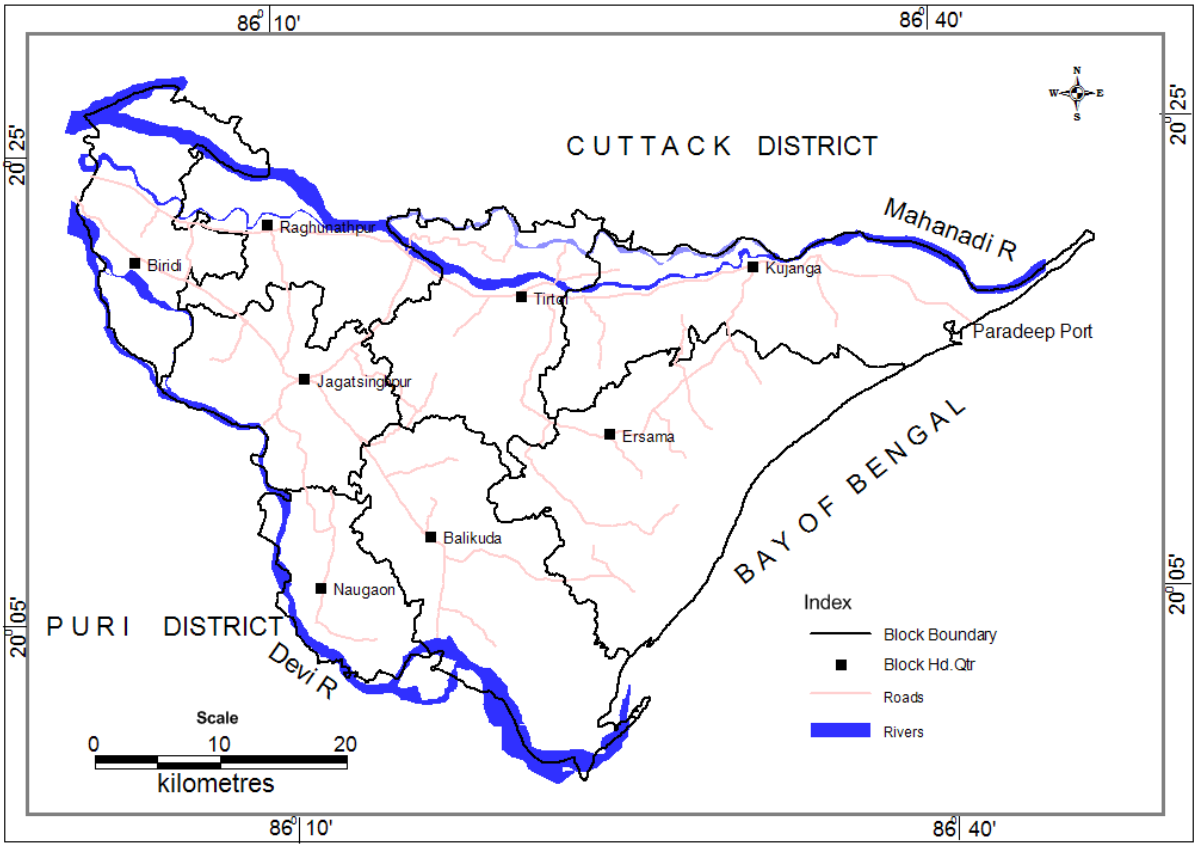


Fig.2: Administrative Map of the district

1.3 Physiography

Jagatsinghpur lies over alluvial plains of the river Mahanadi, Kathajodi, Devi, their tributaries and distributaries. Physiographically the district can broadly be divided into two distinct units, viz

1.The saline marshy and swampy strips along with the coast covered with wild growth of reeds and tropical jungle.

2.The very gently sloping fertile plain land.

The saline marshy tract forms a long and narrow strip along the coast. The width of this tract varies from 3 to 15 km and is intersected by tidal streams and shrubby vegetation. Sand dunes of varied relief extend continuously for kilometers parallel to the coast. These sand dunes usually forming 5 to 6 chains are gently sloping on the bay side and steeply sloping on the inland side. Due to creation of swamp at the meeting places with the sea, dense jungles have grown up.

The gently sloping alluvial plain occurs to the west of the saline marshy tract and forms the most fertile land of the district. The general slope of this tract is towards east and southeast and varies from 0.50 to 1.60 m/km.

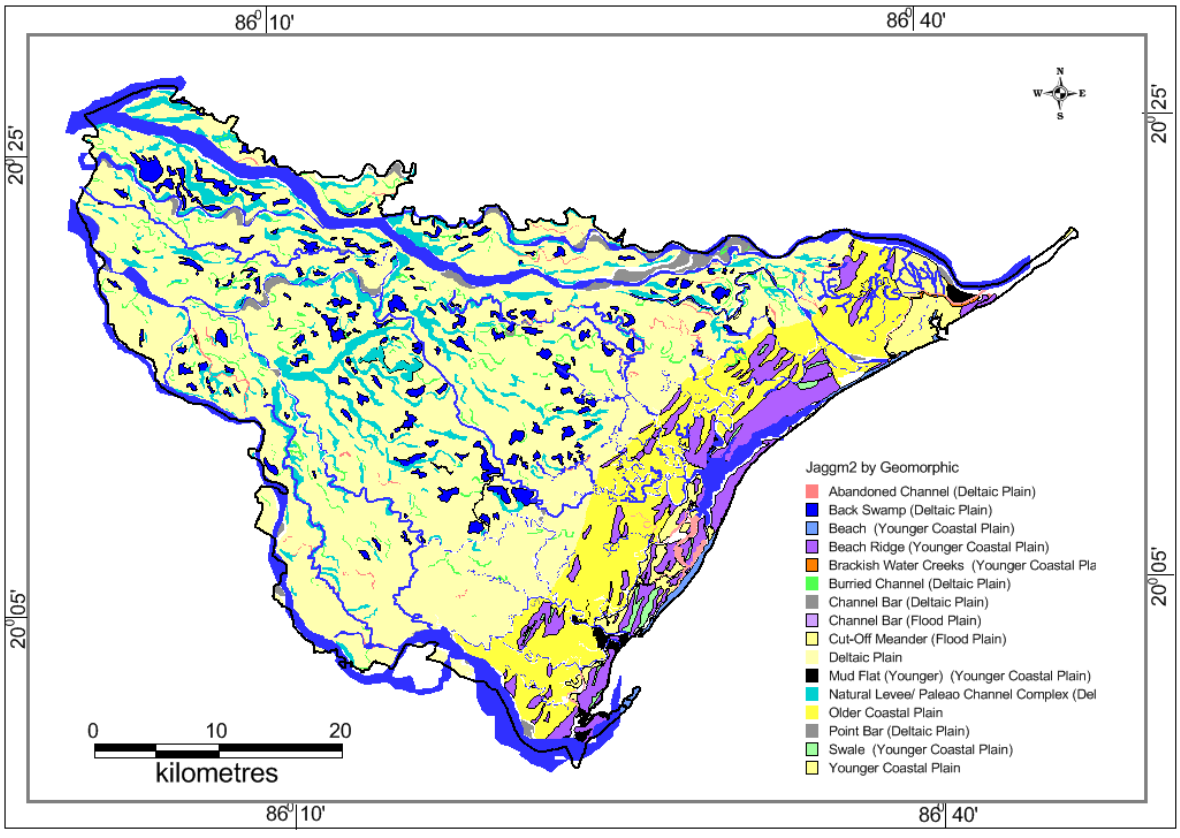


Fig.3: Physiography of the district

1.4 Drainage

The river Mahanadi flowing from west to east and forming the northern boundary of the district forms the main drainage system in the district. The river Devi, a distributary to river

Kathajori flows north-northwest to south-southeast with a meandering course drains southern part of the district. Both the rivers meet the Bay of Bengal in the east.

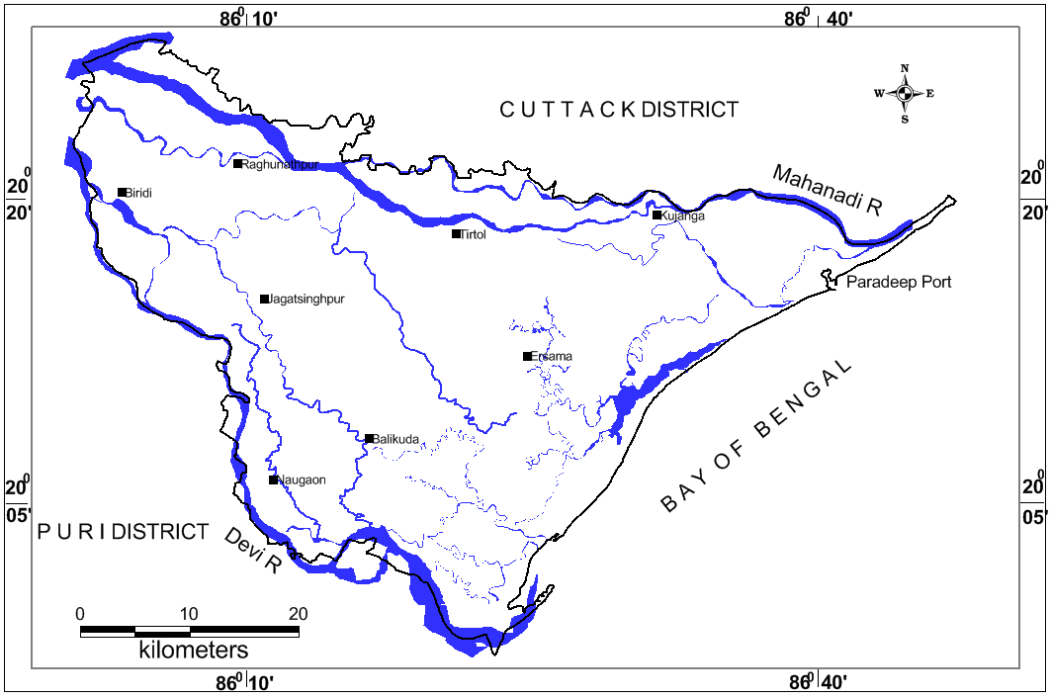


Fig.4: Drainage map of the district

1.5 Soil

The distribution of different soil types in the district depends much on its physiographic and lithologic variations. Based on the physical and chemical characteristics, mode of origin and occurrence, soils of the district may be classified into three groups namely Alfisols, Aridisols and Entisols.

i. Alfisols: This includes deltaic alluvial soils and this type of soils occupies nearly 90% of the entire district area. The deltaic alluvial soils are generally deficient in phosphate (P2O5) and nitrogen (N). Both the total and available potassium are fairly adequate and P^H varies between 7.38 and 8.16.

ii. Aridisols: These are saline and saline alkali soils and occur in small pockets in the north eastern and south eastern corner of the district near coast. These are rich in calcium, magnesium and also consist of half decomposed organic matter.

iii. Entisols: This includes coastal sandy soils and occurs as narrow elongated ridge along the coastline. The soils are deficient in nitrogen, phosphoric acid and humus, but not in potash and lime.

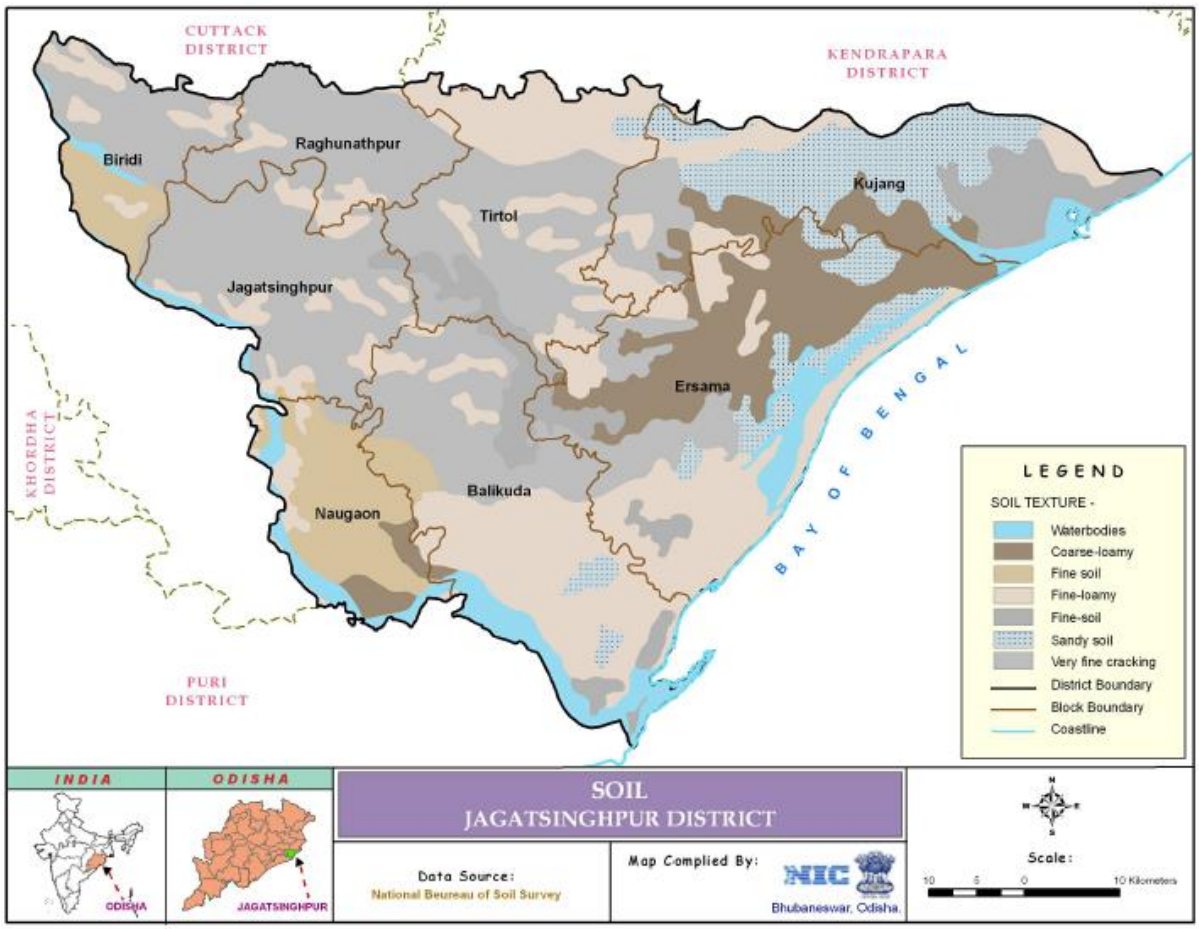


Fig.5: Soil Map of the district

1.6 RAINFALL AND CLIMATE

The south-west monsoon is the principal source of rainfall in the district. The district is characterized by a Topical monsoon climate having three distinct seasons in a year viz. winter, summer and rainy seasons. The Bay of Bengal, which forms the eastern boundary of the district, plays a vital role in controlling the climate of the district. The Normal rainfall of the district is 1501.3 mm. The block-wise annual rainfall from 1995 to 2016 is given in annexure No.1.The annual average rainfall in last seven years is 1436 mm. About 75% of the total rainfall occurs during the period from June to September. In the period between April and May 3 to 4 cyclonic rains generally occur in the district that causes a drop in the temperature. The temperature varies from 15 to 37^{o}C (Table 2). The relative humidity varies from 74 to 86 percent during the year (Table 3).

Fig.6: Block-wise rainfall

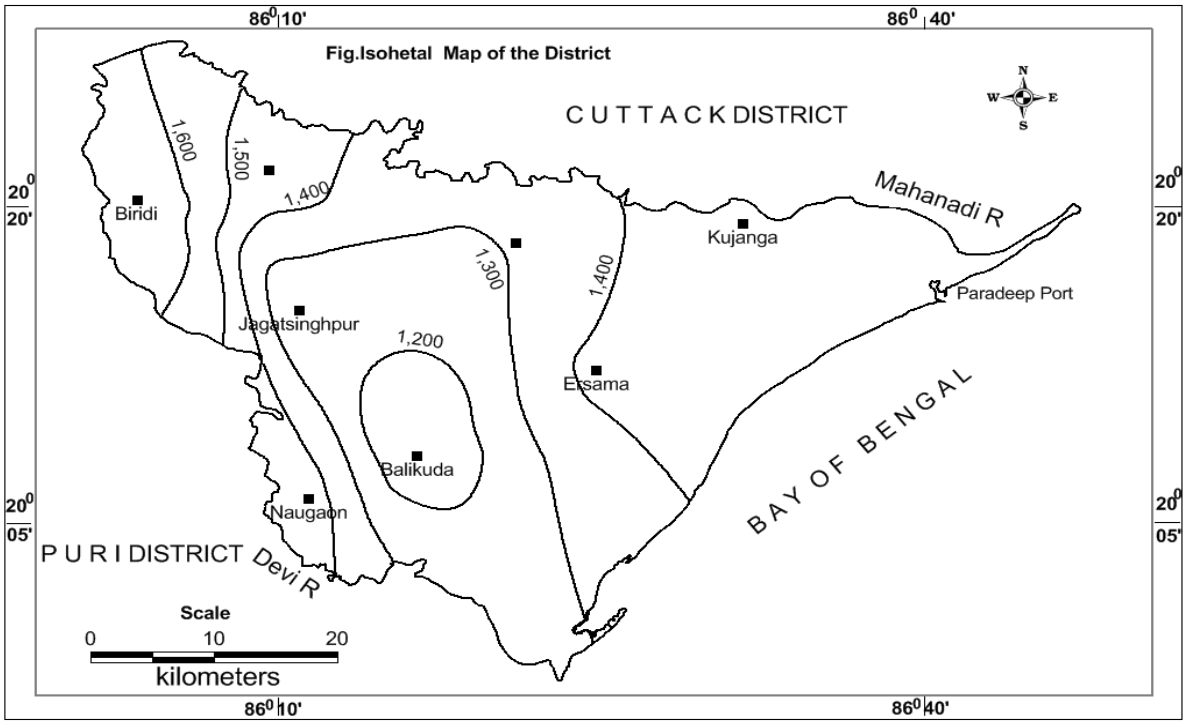
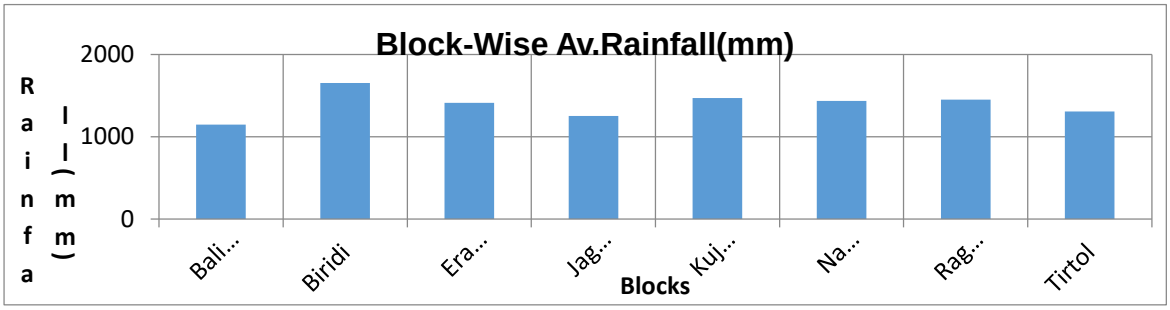


Fig.7: Isohyetal Map of the district

Table 2: Temperature of the district

Temp/Month	J	F	M	A	M	J	J	A	S	O	N	D
Temp.(max)	28.7	31.4	34.9	36.9	37.2	35.3	32.2	31.6	32.1	32.2	30.4	28.4
Temp.(min)	15.6	18.7	22.2	25	26.2	26.1	25.2	25.1	24.8	23	19.4	15.6



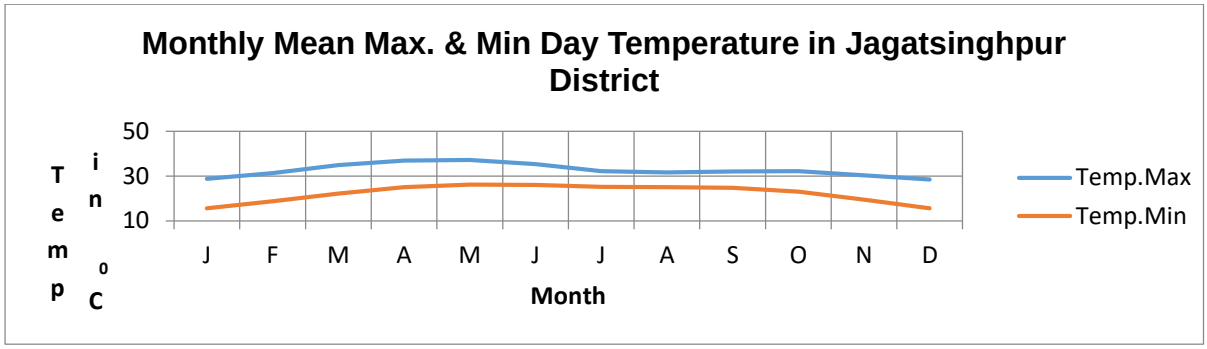


Fig.8: Mean Max & Min Temperature

Humidity

The district experiences tropical humid climate because of its close proximity to the Bay of Bengal. Humidity varies between 72 and 84 % at 0830 hrs and in between 68 and 84 % at 1730hrs (Table 3).Rainy months i.e. June to September experience max. Humidity. Morning humidity is relatively more than the evening.

Table 3: Relative humidity in the district

Humidity/Month	J	F	M	A	M	J	J	A	S	O	N	D
Humidity %(0830hrs)	83	81	79	77	80	84	81	84	84	77	72	76
Humidity % (1730 hrs)	70	70	75	78	81	84	81	83	82	73	68	67

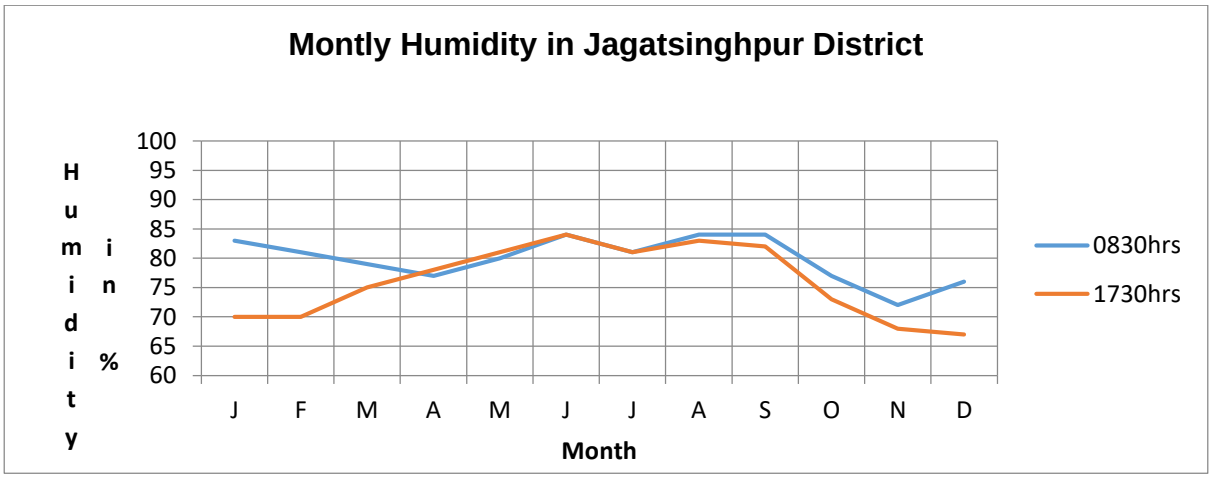


Fig.9: Humidity of the district

1.7 Agriculture

Agriculture and allied activities are the main occupation and backbone of the district economy. The rich fertile soils of the river Mahanadi make the region good for cultivation of different crops. Paddy is the subsistence crop and grown in 81,540 thousand ha across the district. Sugarcane, turmeric and cotton are the major commercial crops. Apart from paddy,

wheat, maize, green gram and black gram etc are grown in the district. Commercial crops like Jute and Sugar cane are grown in the district (in 2011-12, about 0.92 thousand MTs of Jute and 41.51 thousand MTs of sugarcane were produced). Pulses like green gram (mung) and black gram grown all most all areas except the saline track like Kujanga, Ersama and Balikuda. The district of Jagatsinghpur bounded by 80 km of coastline has ample scope for development of inland, brackish water as well as marine fisheries. Together with employment and income generation, the district is enriched with vast water resources. In addition, waterlogged area, the dead river and low-lying areas have scope for development of fisheries. The Fish Farmers Development Agency (FFDA) and Brackish Water Fisheries Development Agency (BFDA) have been working in the district. The State Agricultural Policy emphasizes development of fisheries and envisages greater participation of people in this sector. Pisciculture is an important sector for employment generation and supplementation of food. Abundance of water bodies including ponds, tanks, rivers, seashores provide a strong base for pisciculture in the district. Total fish production comes to 910567 MT out of which from Fresh water 5414 MT, Brackish water 3692 MT and Marine water 35655 MT during the year 2011-12.

1.8 Irrigation

The district enjoys irrigation facilities through major, medium, and lift irrigation projects. The major irrigation projects in the district are Taladanda and Machgaon canal irrigation system fed from the Mahanadi river at Jobra point near Cuttack. During kharif total irrigated area from all sources is only 66529 hectares against average net sown area of 94445 hectares in 2004-05. During Ravi season total area irrigated is around 31017 hectares.

Table 4: Status of Water Availability in area (hectare)

Sources	Kharif	Rabi	Total
Surface Irrigation			
Canal (Major & Medium Irrigation)	34770	1717	36487
Lift Irrigation/Diversion	4000	2	4002
Perennial Sources of Water	31742	31720	63462
Total Surface Irrigation	**70512**	**33439**	**103951**
Groundwater			
Open Well	0	0	0
Medium Tube Well	8383	4502	12885
Shallow Tube Well	823	0	823
Total Groundwater	**9206**	**4502**	13708
Grand Total	**79718**	**37941**	**117659**

(source: District Irrigation & Agriculture office)

Table 5: Status of Water Availability (in MCM)

Sources	Kharif	Rabi	Total
Surface Irrigation			
Canal (Major & Medium Irrigation)	985.182		985.182
Lift Irrigation/Diversion	50.49	25.2	75.69
Perennial Sources of Water	37.5	3.8	41.3
Total Surface Irrigation	**1073.17**	**29**	**1102.17**
Groundwater			
Open Well	3.6	0.9	4.5
Medium Tube Well	61.905	31	92.905
Shallow Tube Well	167.7	169.6	337.3
Total Groundwater	**233.205**	**201.5**	434.705
Grand Total	**1306.377**	**230.5**	**1536.88**

Table 6: Sources of water & cropping season

Sl.No	Block	Sources	Kharif	Rabi	Total
1	Jagatsinghpur	Surface Irrigation	195.507	0.3	195.807
		Groundwater Irrigation	30.72	35.21	65.93
		Total	226.227	35.51	261.737
2	Raghunathpur	Surface Irrigation	112.404	0.8	113.204
		Groundwater Irrigation	105.75	37.8	143.55
		Total	218.154	38.6	256.754
3	Balikuda	Surface Irrigation	179.268	3	182.268
		Groundwater Irrigation	37.575	30.81	68.385
		Total	216.843	33.81	250.653
4	Biridi	Surface Irrigation	111.258	0.2	111.458
		Groundwater Irrigation	22.155	24.48	46.635
		Total	133.413	24.68	158.093
5	Naugaon	Surface Irrigation	27.384	0.4	27.784
		Groundwater Irrigation	41.49	19.28	60.77
		Total	68.874	19.68	88.554
6	Tirtol	Surface Irrigation	214.493	8.7	223.193
		Groundwater Irrigation	33.45	23.92	57.37
		Total	247.943	32.62	280.563
7	Kujang	Surface Irrigation	170.787	6.8	177.587
		Groundwater Irrigation	27.915	13.4	41.315
		Total	198.702	20.2	218.902
8	Ersama	Surface Irrigation	62.057	8.7	70.757
		Groundwater Irrigation	20.52	33.73	54.25
		Total	82.577	42.43	125.007
		Grand Total SurfaceWater	**1073.158**	**28.9**	**1102.058**
		Grand Total Ground Water	**319.575**	**218.63**	**538.205**

Table 7: Water availability, demand & gap

Sl.No	Blocks	Existing Water Availability (MCM)			Water Demand (MCM)		Water Gap (MCM)	
		Surface Water	Ground Water	Total	Present	Projected (2020)	Present	Projected (2020)
1	Jagatsinghpur	195.822	65.9325	261.754	337.553	383.7979	75.799	122.0434
2	Raghunathpur	113.244	143.55	256.794	207.991	236.4864	-48.802	-20.3075
3	Balikuda	182.223	68.385	250.608	370.267	420.9931	119.659	170.3851
4	Biridi	111.483	46.635	158.118	198.839	226.0797	40.721	67.9617
5	Naugaon	27.744	60.7725	88.516	209.393	238.0801	120.877	149.5636
6	Tirtol	223.215	57.3675	280.582	367.109	417.4028	86.526	136.8203
7	Kujanga	177.582	41.31	218.892	412.6	469.1261	193.708	250.2341
8	Ersama	70.786	54.2475	125.034	405.14	460.6442	280.106	335.6102
	Total	**1102.099**	**538.2**	**1640.298**	**2508.892**	**2852.6103**	**868.594**	**1212.3109**

1.9 Drinking Water Supply

Groundwater is the main source of water for drinking and domestic uses as well as for animal feed. Rural Water Supply & Sanitation (RWS & S), Govt. of Odisha is responsible for supply of safe drinking fresh water in the rural villages and Municipalities in urban area. RWS & S has constructed 12997 number of hand pumps (mark-2) covering all most all villages (Table 8). Besides hand pumps, RWS&S is supplying piped water covering maximum villages. In blocks i.e. Biridi, Raghunathpur and Jagatsinghpur where phreatic aquifer is fresh, individual household have their own means of ground water extraction through dug wells and hand pumps.

Local body such as the Municipality is responsible for supply of piped water in Jagatsinghpur and Paradeep urban area.

Table 8: Nos. of Groundwater abstraction structures block-wise

No.	Blocks	No. of Hand pumps (Mark-2)	Public Water Supply (Tubewell)
1	Balikuda	1537	31
2	Jagatsinghpur	2105	35
3	Naugaon	947	21
4	Biridi	1497	25
5	Ersama	1384	31
6	Kujanga	1630	31
7	Tirtol	2167	34

8	Raghunathpur	1730	25
	Jagatsinghpur NAC		9
	Paradeep NAC	110	4
	Total	**12997**	**246**

1.10 Industrial Water Requirement

Paradeep city is the only industrial hub in the district which houses industries i.e. Paradeep Port Trust, Paradeep Phosphate Limited, IFFCO, IOCL, ESSAR etc. Industrial as well as domestic water need of these industries is based on surface water.

2. GEOLOGY

Geologically the district is covered by soft Quaternary sediments overlain by Baripada beds of Tertiary age. A total five Quaternary formations are identified namely, 1). Older beach deposit, 2). Lower delta deposit, 3). Upper delta deposit,4). Younger beach deposit and 5). Present day coastal & flood plain deposit.

Older Beach deposit consists of compact sand & silt of Late Pleistocene to early Holocene age occurs as small patches (mainly as small ridges within lower delta deposit.

Lower & upper delta consists of clay with fine sand & silt and alternating layers of sandy silt & silty clay respectively. Major difference between them is that lower delta is a marine deposit whereas upper delta is typically fluvial deposit.

Areas near the Bay of Bengal seashore are mainly occupied by younger beach deposit consisting of very fine sand and silt. This is a marine-aeolian deposit & occurs as small ridges. Present day coastal deposit occurs within narrow zone & consists of medium grained sand with heavy minerals. Present day fluvial deposit consists of sand & silt occurs at the bank of the rivers. Both younger beach deposit & present day coastal & fluvial deposits are of late Holocene age.

Table 9: Stratigraphical Succession of Jagatsinghpur District

Lithology	Morphology	Age
Sand & silts (flat surface with Occasional dunes/point & lateral bars & meander Scrolls	Present day coastal/flood Plain deposit	Late Holocene
Very fine sand, silt & clay (Older dunes)	Younger beach deposits	
Sandy silt & silty clay	Upper Delta Deposit	Middle to Lower
Clay with fine sand & silt	Lower Delta Deposit	Holocene
Compact Sand & Silt	Older Beach Deposit	Late Pleistocene To Early Holocene

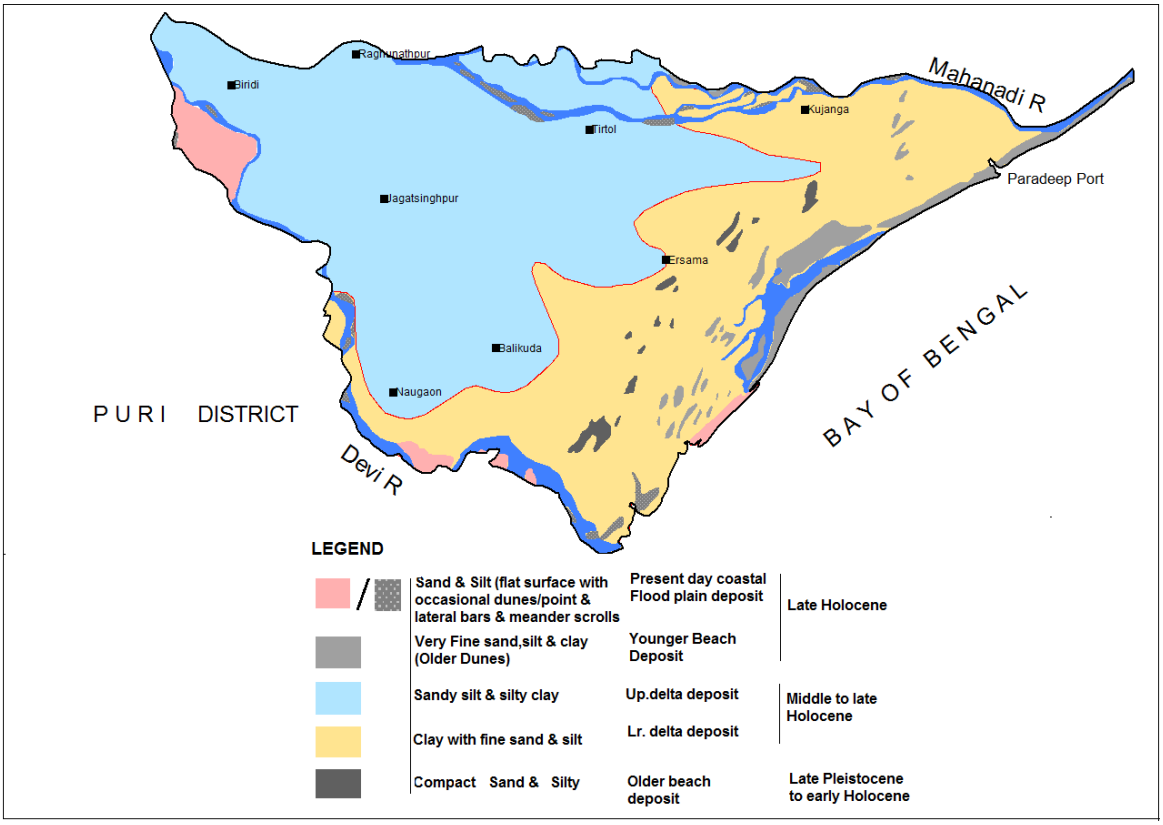


Fig.10: Geology of the district

3. AQUIFER SYSTEM

In Jagatsinghpur district, the ground water occurs in the intergrannular pore spaces. Sand, silt and gravel layers act as repository of ground water. Ground water occurs under unconfined condition in the shallow aquifer zone and perched water table condition within sand dunes underlain by clay beds. The ground water is found under confined condition in the deeper aquifer zones. The deltaic plain has potential for large-scale development of ground water. The coastal tract is beset with salinity problems both in shallow to medium in coastal Kujanga and Ersama blocks as well as in deeper aquifers in coastal Balikunda block. Salinity problem also persists in eastern part of deltaic plain.

Central Ground Water Board has drilled 7nos. of exploratory wells during 1974-75, 4 nos. of Slime holes during 1984-1989, 1 no. of deposit well and constructed 6 no. of piezometers during 1986-2000 (Fig.11). Exploratory drilling was carried out upto maximum depth of 612m. Wells were electrically logged and packer tests were carried out to ascertain the quality of formation water. Borewells were converted into production wells and pumping tests were conducted to determine aquifer parameters. Some of the slime holes and piezometers were electrically logged and zone tests were also carried out. The detail of exploratory wells is shown in annexure No.2.

Based on the behavior and occurrence of ground water, the regional ground water flow system of the district has been described under two distinct categories viz. i.) Shallow aquifer zone: from surface upto a depth of 50m and ii.) Deeper aquifer zones: between 50 and 300 m or more.

3.1 Shallow Aquifers : The shallow aquifers occurring within a depth of 50m from land surface consist of a mixture of sand and clay with little gravel at places. The thickness of the saturated sediments varies from 10 to 35m. Ground water in these sediments usually occurs under water table condition, where as in coastal tract it occurs under perched water table condition in sand dunes underlain by clay beds.

There is variation in quality of groundwater in shallow aquifers over the district. In the eastern part of the district i.e. Biridi, Raghunathpur, Jagatsinghpur,Naugaon and part of Tirtol & Balikuda block shallow aquifers yield fresh water. Even in fresh shallow aquifers in Balikuda block there remain patches of saline aquifers which are difficult to map .where as in coastal tract i.e. in Kujanga , Ersama blocks shallow aquifers are saline. But in coastal tract of Kujang and Ersama blocks wells lying on Paleo-beach ridge yield fresh water.

Open wells and shallow tube wells are used to develop ground water from this aquifer mainly for domestic and minor purposes. The open wells receive their recharge mainly from the local precipitation. There are many shallow tube wells for domestic use in the area particularly in the eastern part by tapping 3 to 6 m zone within 30 to 50 m depth.

3.2 Deeper Aquifers: The occurrence of water bearing deeper aquifers is identified from available bore hole data down to a maximum depth of 612m by CGWB. CGWB has drilled 17 nos. of wells (7 EWs, 4 SH & 6 Pz) within the depth range between 74.6m (Jagatsinghpur) and 612m (Machhagaon). Hydrogeological detail of exploratory borewells is given in annexure-2. Deep borewells were drilled in the Eastern part of the district and shallow to medium depth borewells were drilled in the western part of the district. Borewell drilled at village Arilo has encountered crystalline formation (quartzites) at 473m and rest of borewells were ended in sedimentary deposits. Production wells have been constructed upto maximum depth of 291m at Ersama and piezometer upto depth of 290m at Paradeepgarh by tapping freshwater aquifers. Borewells were electrically logged and zone tests were carried out in some wells to ascertain the quality of formation water. Attempts have been taken to establish disposition of aquifer system with the help of lithologs, e-logs and result of zone tests. In establishing the disposition of aquifer system, help has been taken from the wells drilled by Odisha Lift Irrigation Corporation and Rural Water Supply & Sanitation Department, Govt. of Odisha. Aquifer disposition map and sections have been prepared which are described below.

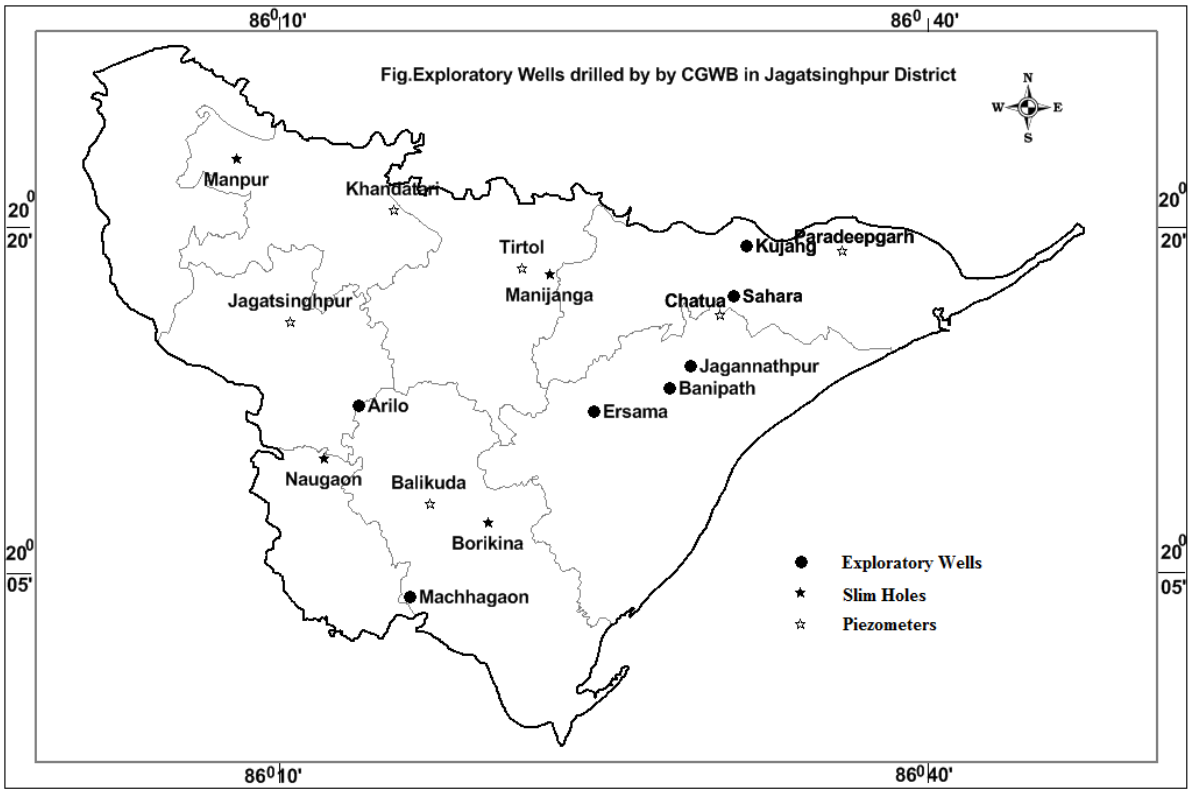


Fig.11: Location of exploratory wells in the district

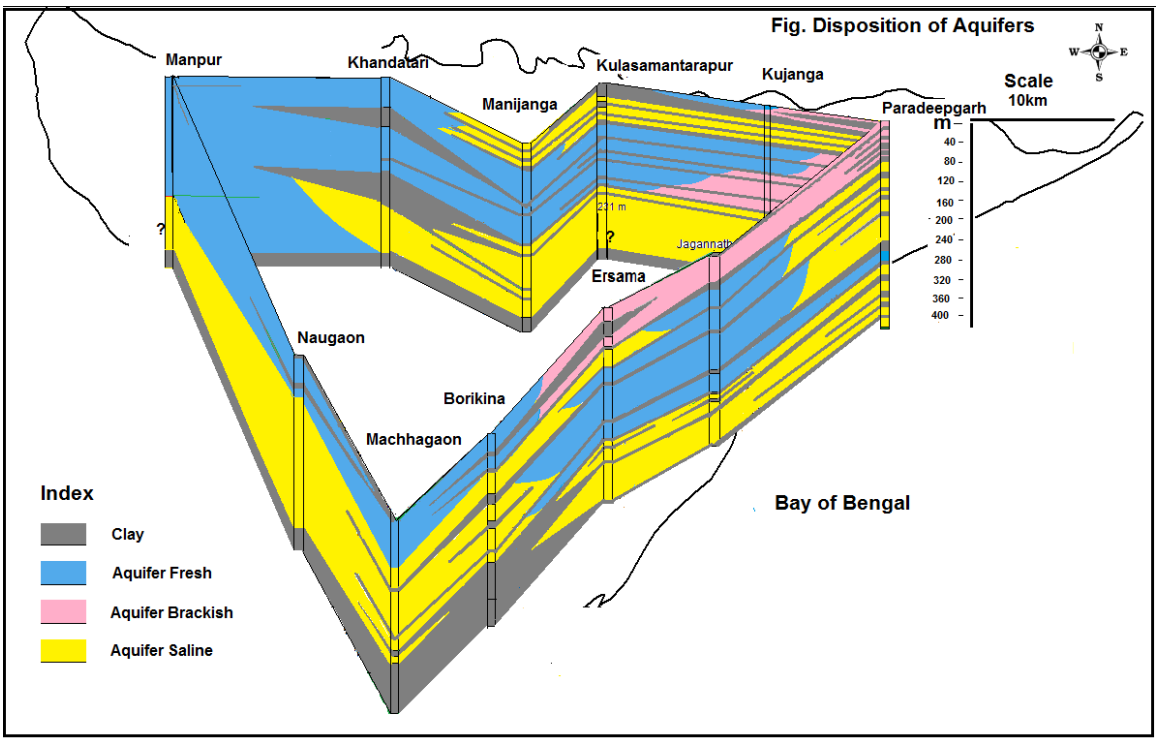


Fig. 12 A Disposition of aquifers

Aquifer disposition map for entire district is made upto depth of maximum 400m based on the exploratory Hydrogeological data of borewells drilled by CGWB. The entire district is underlain by thick sediments. The sediments got deposited on a north-west to south-east sloping platform of semi-consolidated rocks of the Gondwana Super Group or crystalline rocks of the Eastern Ghat Super Group. The source for the sediments lied on the west. Thickness of sediments increases towards east (Bay of the Bengal). There is a variation in the size of the sediments over the stretch. Finer sediments increased towards east. Western part of the district such as in Biridi, Raghunathpur and parts of Jagatsinghpur blocks is underlain principally by coarse sediments (sand & gravel). Borewell drilled at village Manpur shows that entire section upto 250m is sand and gravel except 3m thick clay at 20 to 23m below ground. Which indicates presence of a single aquifer upto drilled depth of 250m. Towards east clay got deposited and forming different layers within the single sandy aquifer separating the aquifer into multiple layers. On the west aquifer contains fresh water and towards east quality of water becomes brackish and saline. Salinity starts from Tirtol (Manijanga) at shallow levels and from Khandatari at deeper level. At places Naugaon and Machhagaon freshwater floats over saline water. Whereas in eastern part in Kujanga and Ersama blocks freshwater aquifers are overlain by saline aquifers. In these area phreatic aquifers are either brackish or saline except fresh at pockets. At Padadeep within 400m only one fresh water aquifer exists in the depth range between 270m and 290m.

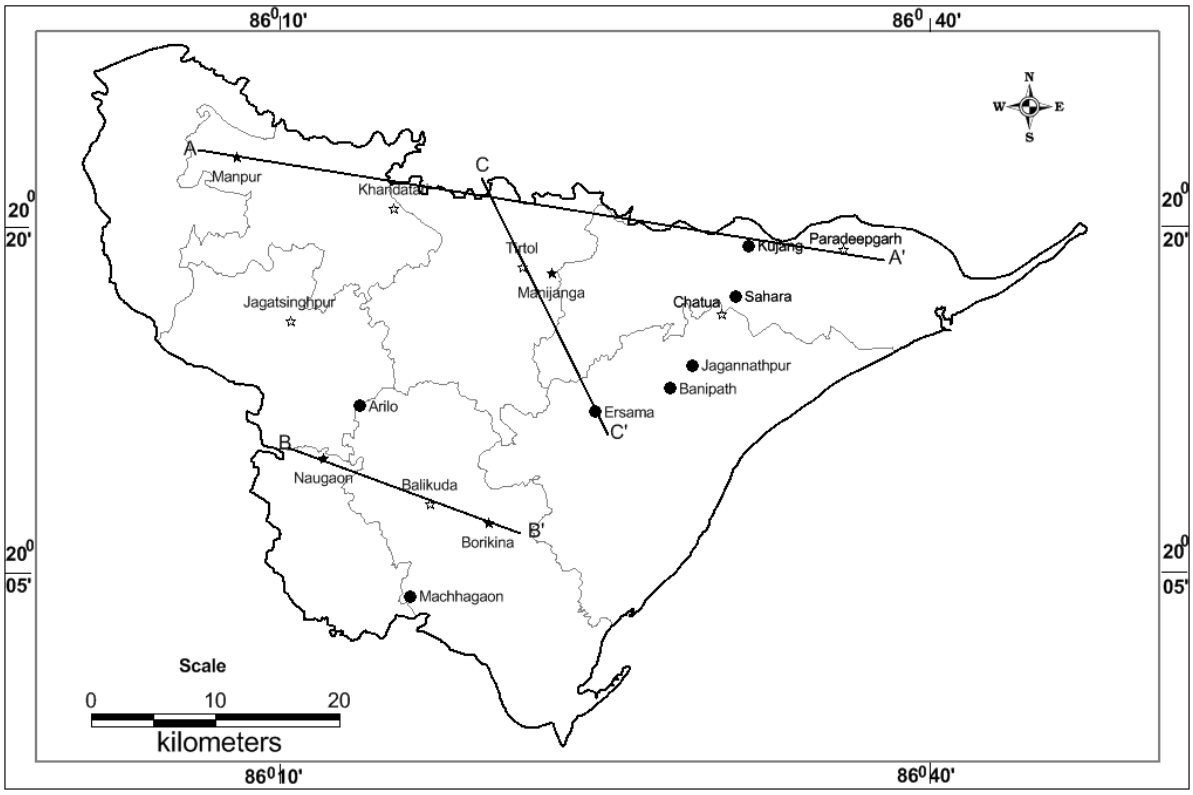


Fig.12 B: Sections along A-A'

Section Along A-A'

Section A-A' stretching a distance of 50km from Manpur and Paradeepgarh has been drawn taking the data of exploratory wells Manpur, Khandatari, Kujang and Paradeepgarh drilled by CGWB. Wells drilled by State Govt. Deptt at Narijang and Kulasamantarapur are also taken. Aquifers within depth range of 300m (Paradeepgarh being at the east, sea side) and 250m (Manpur in the west) were correlated. 7 nos. aquifers have been established within the depth range of 300m at Paradeep and 250m at Manpur. The aquifers are dipping towards east.

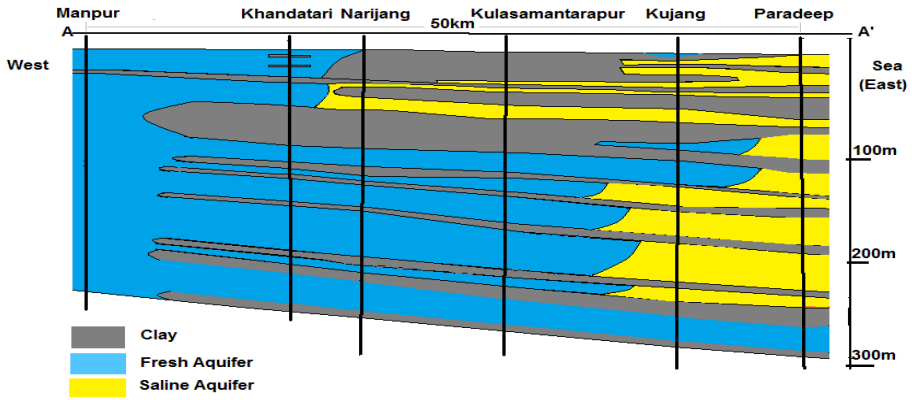


Fig.13: Section along AA'

Section Along B-B'

Along Behedpur-Titol and Ersama section in between 50m and maximum depth of 360m (Ersama) and 228m (Behedpur), At Ersama 9 nos. of aquifer exist within the depth of 60 and 360m depth. Topmost aquifer which is saline extends upto Tirtol and pinched out in clay at Behedpur. At Ersama aquifers within depth range between 125m and 288m are fresh and underlying aquifers are brakish. These fresh water aquifer extend through Tirtol and Behedpur. At Tirtol aquifers within depth range of 165m and 252m are fresh and at Behedpur these are fresh between 124m and 228m.

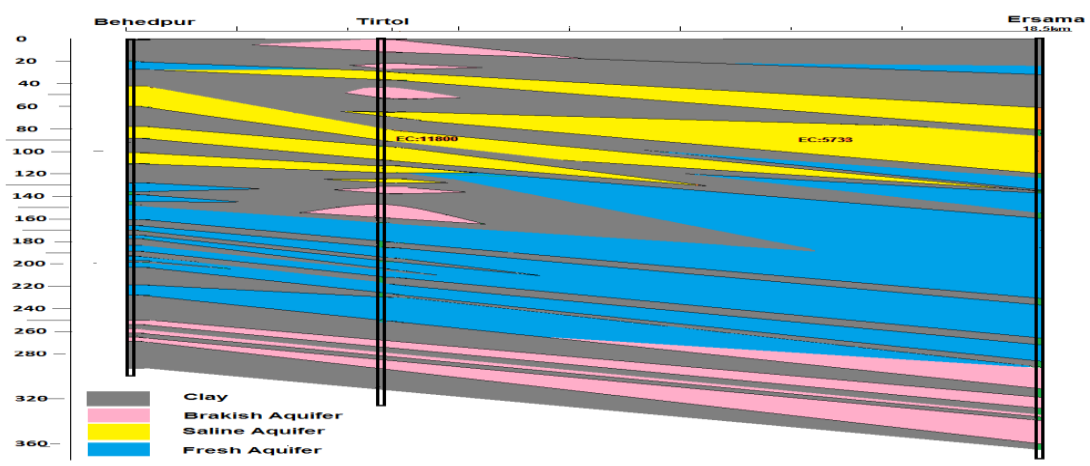


Fig.14: Section along BB'

Section Along C-C'

Section drawn along Naugaon to Borikina covering distance of 14km shows the existence of 4nos of aquifer systems in between depth range of 50m to 250m .Aquifers below 80m are saline. At Borikina cumulative 30m thick fresh water aquifers exist between 50m and 80m depth. Throughout the section below 96m(at Borikina) and 94m at Naugaon only one saline aquifer exist with a thickness of around 160m and within this aquifer only clay lenses occurs at Borikina.

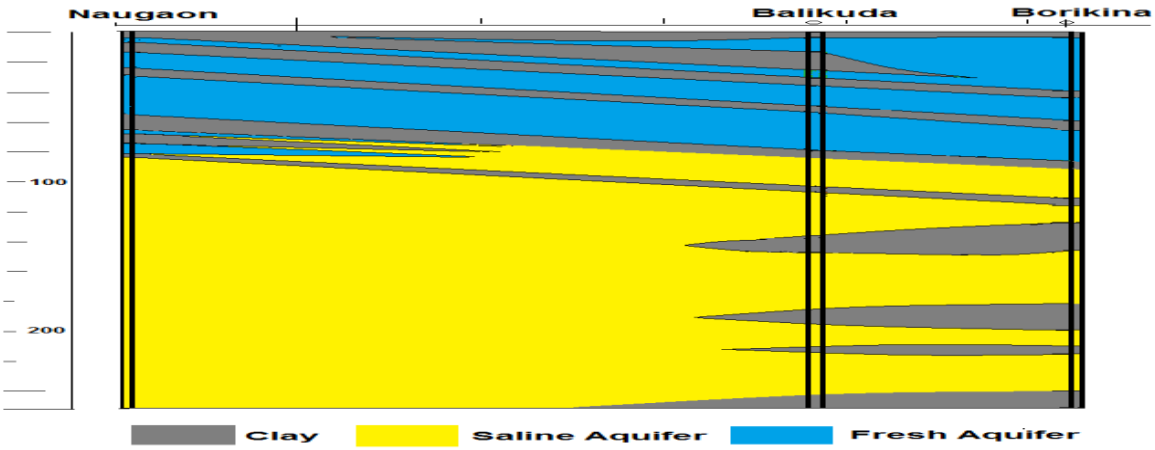


Fig.15: Section along CC'

3.3 Hydraulic characteristics of Aquifers

The alluvial deposit is a good repository of ground water. The thickness of sediments increases towards coast and is high as 600m in south-eastern part of the district (Mahanadi delta region). The deep aquifers are confined by extensive clay beds.

The wide range of permeability and storativity values indicates that the aquifer in the area is heterogeneous laterally. There is a sequence of alternating clayey and sandy layers with occasional presence of thin arenaceous materials. The wells tapping fresh water-bearing zones in coastal alluvial tracts yield copious quantities water. Tube well tapping 30 to 45m thick aquifer within depth of 300m yields water in the range between 75 and 270 m3/hr (1267lpm to 4500lpm) for draw down of 4 to 13m. The transmissivity value varies from 936 to 5673 m2/day, whereas Storativity varies from 1.918 × 10-4 to 4.68 × 10-4. The hydraulic conductivity values ranges from 44 to 253 m/day.

3.4 The distribution of Saline/freshwater Aquifers: From salinity point of view the entire district can be broadly divided in to three sectors. In eastern part in Kujanga, Ersama and part of Tirtol blocks, fresh aquifer is overlain by saline aquifers. In the south, in Balikuda and Naugaon blocks the case is just reverse, here fresh aquifer is underlain by saline aquifers. In Biridi, Raghunathpur and Jagatsinghpur blocks aquifers down to drilled depth of 260m is fresh.

Saline zones in the east close to the coastline restrict the occurrence of fresh water aquifer. The coastal saline tract is about 10 km wide in outfall areas of Mahanadi but expands to a maximum width of 45 km in Ersama block.

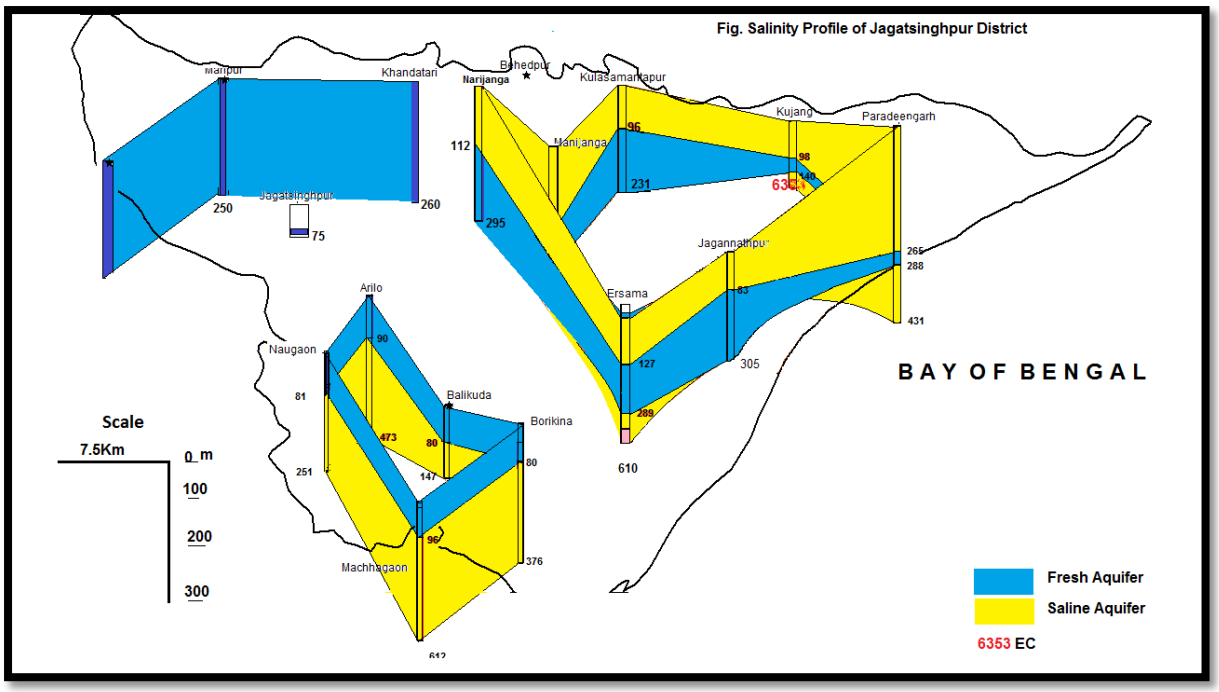


Fig.16: District salinity Profile

The block wise description of fresh and saline water bearing granular zones is described as follows:

Kujang-Ersama Blocks:

In the coastal saline tract in Kujang & Ersama blocks all the aquifers down to about 20 m below ground level contain brackish to saline water. The salinity of the water in the shallow granular zone in the low lying swampy coastal areas may be attributed to the tidal effects of the meandering nalas due to the poor drainage conditions. At places fresh phreatic aquifer exists in old coastal sand & sand dunes which is not mappable. Away from the coast in Kujang block shallow fresh water aquifers occurs within 20 mbgl on the top of the bore hole.

Saline water bearing granular zones occur at several depths close to the coast line extending right from Paradeepgarh to the extreme south eastern part of Ersama block in the district. In eastern part of Kujang block i.e. in Paradeep area granular zones down to a depth of 265 m are saline to brackish in nature and fresh water granular zones occur below this depth. Away from coast towards north-west i.e. in Kujang area fresh aquifer occurs in the depth range of 80m to 120m. Farther west fresh aquifer occurs in the depth range from 76-90m to 147-180m.

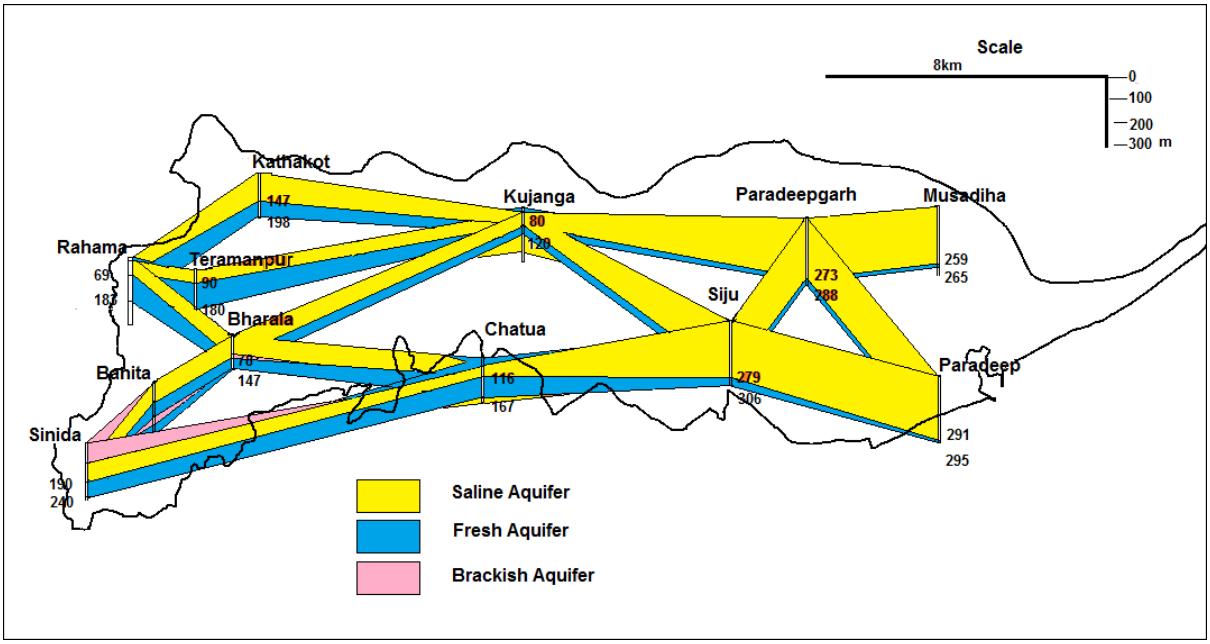


Fig.17: Salinity Profile in Kujanga Block

In entire Ersama block disposition of fresh aquifer id deep. In northern part of the block fresh aquifer lies beyond 140m to 204m depth and in the southern part even upto 300m depth aquifers are saline. Isolated fresh phreatic aquifers exist in old coastal sand and in old sand dunes.

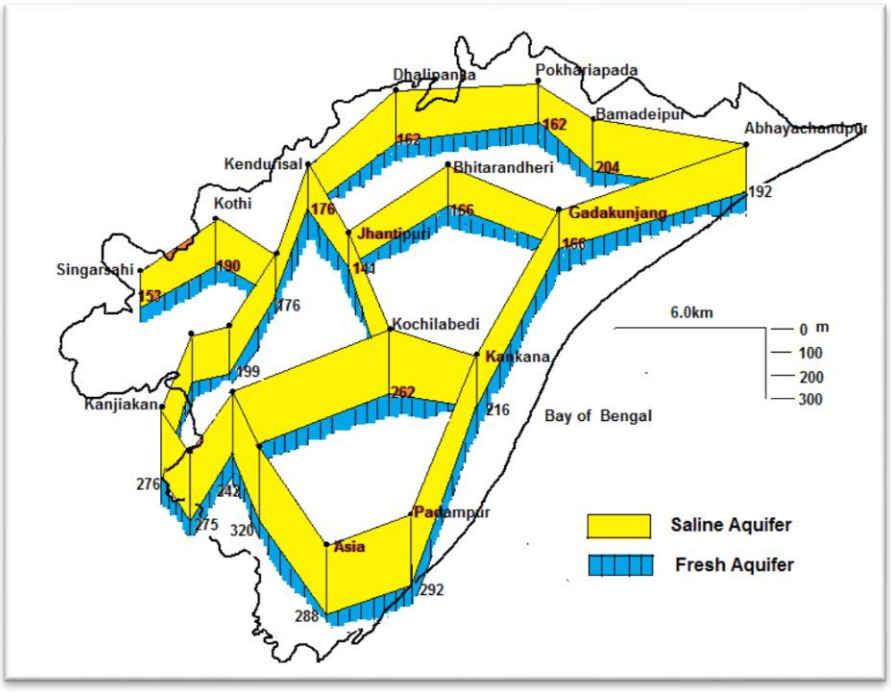


Fig.18: Salinity Profile in Ersama Block

Balikuda-Naugaon Blocks:

There is variation in disposition of fresh aquifers in these blocks. In area adjacent to Erasama blocks aquifers upto 197m to 324m depth are saline. But in other parts i.e. western part of Balikuda block and entire Naugaon block aquifers upto 96m from surface are fresh and underlain by saline aquifers. In southern part of Balikuda block aquifer upto 22m from surface is fresh.

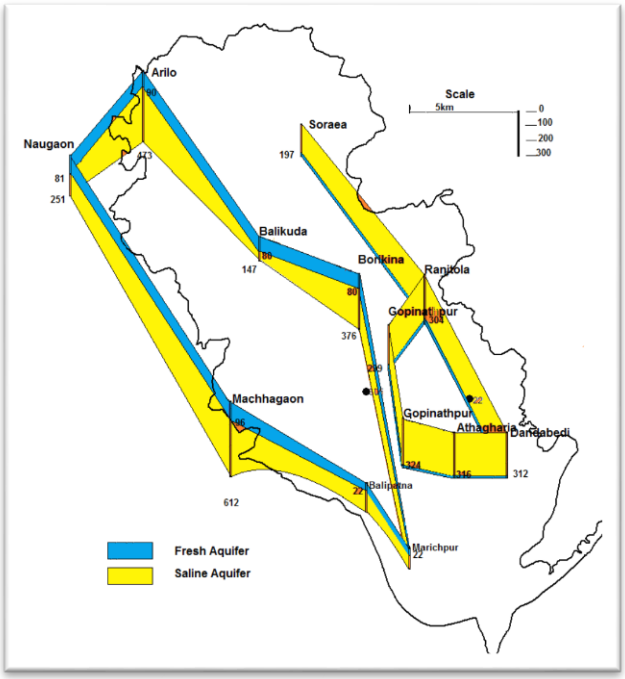


Fig.19: Salinity Profile in Balikuda-Naugaon Blocks

Tirtol Block

In northern part of Tirtol block aquifers upto depth of 72m(Manijanga) to 165m (Tirtol) depth are saline but in southern part disposition of saline aquifers extend much deeper i.e. upto 159m at Salabhanga and 213m at Kotapur.

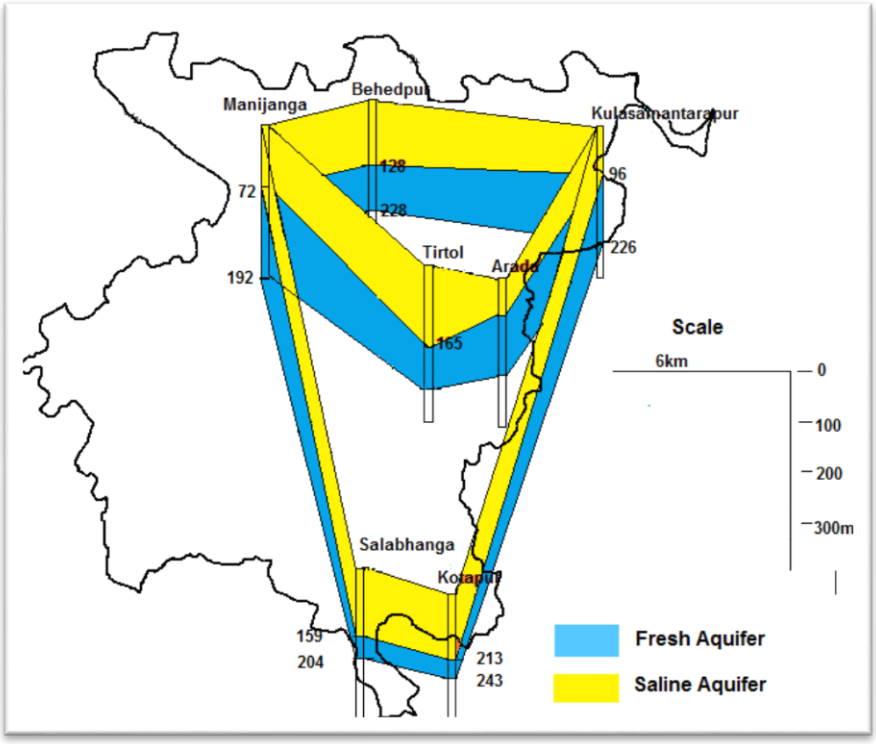


Fig.20: Salinity Profile in Tirtol Block

Jagatsinghpur-Biridi-Raghunathpur Blocks:

Only three (3nos.) of exploratory borewells have been drilled by CGWB in these three blocks. At Khandatari (Tritol block) borewell was drilled upto depth of 260m, at Manpur (Biridi) drilled upto 249m and at Jagatsinghpur ,Piezometer has been drilled upto 75m. At Manpur entire section consists of sand and gravel only 3m clay zone exist within the depth range of 20 to 23m. Cummulative thickness of grannular zones is more in the eastern part and finer sediments (clay) content increases gradually towards east i.e. Coast. Various departments of Govt.of Odisha have drilled wells in these blocks but these borewells are within the depth of 100m due to reasons of availability of sufficient potential fresh aquifers within shallow depth. There is no requirement of tapping deeper aquifers. Drilling data infer the existence of fresh aquifers upto drilled depth of 260m.

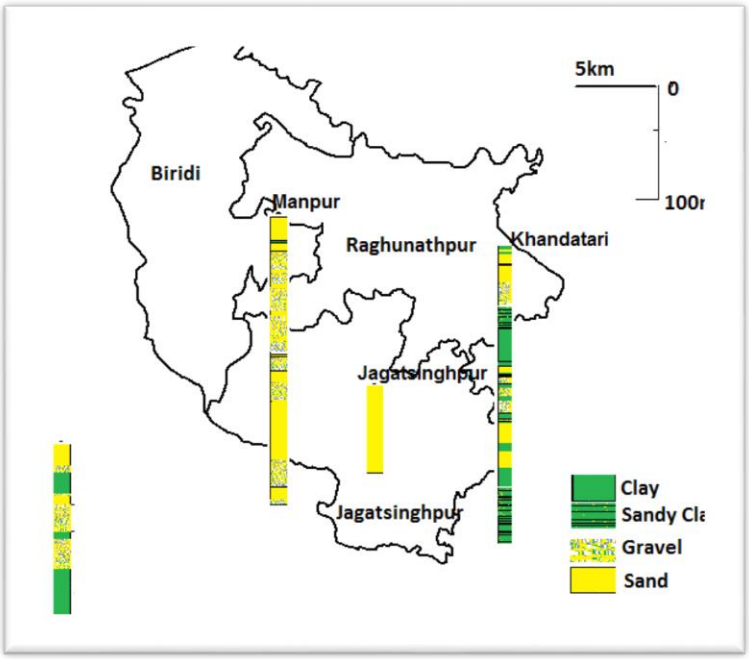


Fig.21: Salinity Profile in Tirtol Block

3.5 Water Level Regime

To know the water level regime of the district, wells were established both for phreatic as well deep aquifers. Water level was measured during Pre-monsoon and Post-monsoon,2017. Annexure-3 & 4 show the water level data for phreatic and deep aquifers.

Phreatic Aquifer

During pre-monsoon 2017, depth to water level varies between 1.1m and 5.3m below ground level(Fig.22). In major area, water level lies between 2 and 4m. Coastal area shows relatively shallow water level.

During post-monsoon 2017, depth to water level varies between 0.45m and 3.97m below ground level (Fig.23). In major area, water level lies between 0.0 and 2m. Coastal area shows relatively shallow water level.

During pre to Post-monsoon, all wells show rise in water level. Water level rose in between 0.35 and 3.5m (Fig.24). North-western part of the district shows high rise in water level relatively to other part.

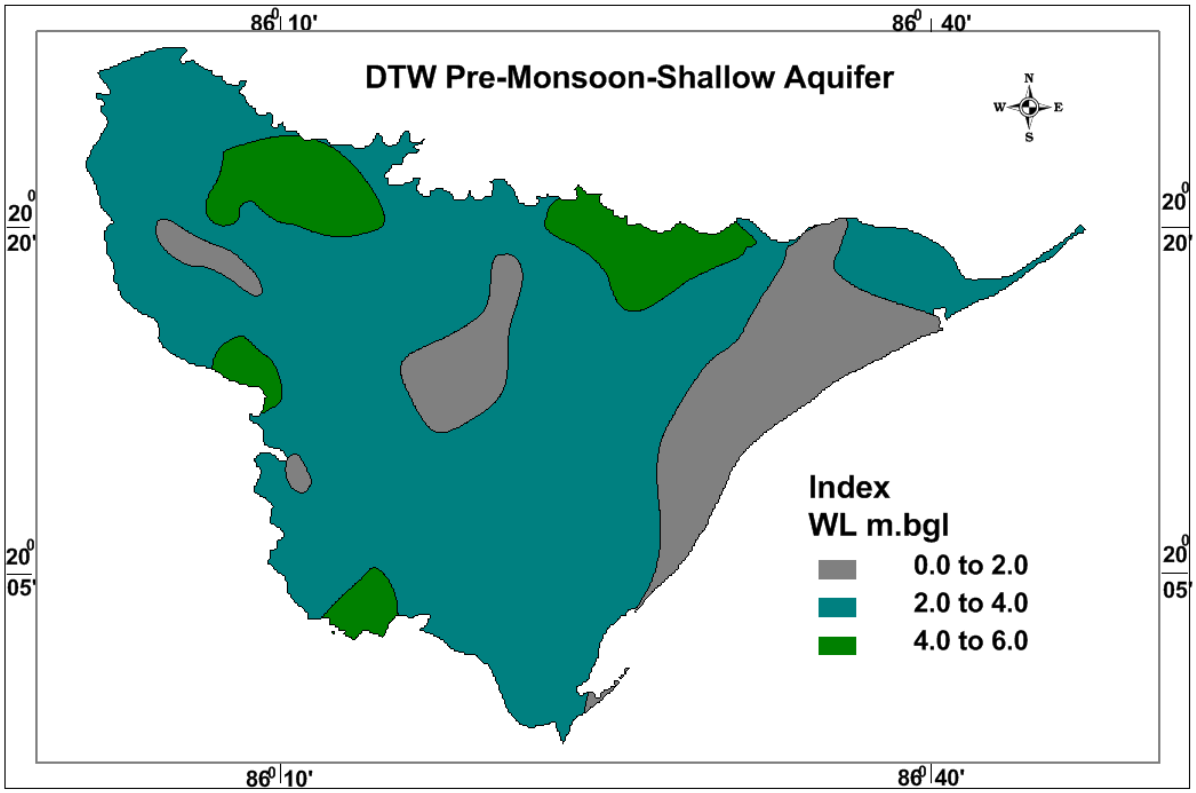


Fig.22:DTW Pre-Monsoon Shallow Aquifer

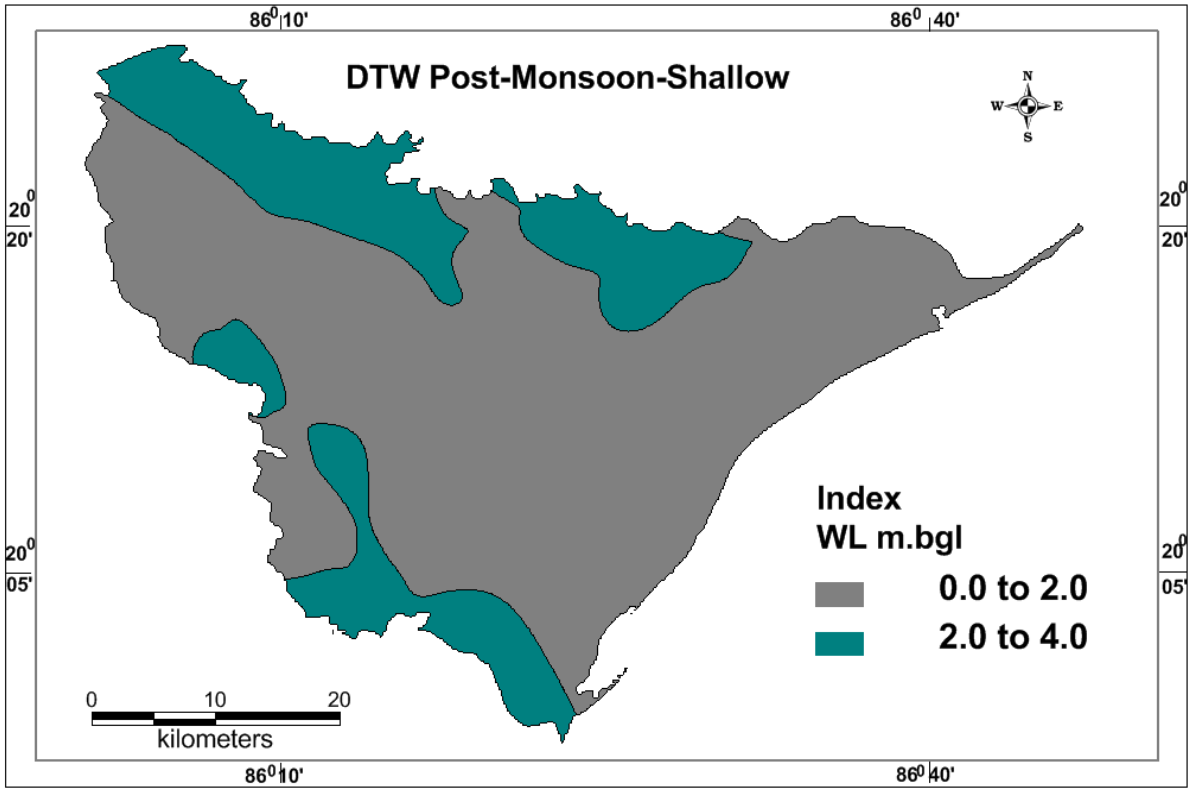


Fig.23:DTW Post-Monsoon Shallow Aquifer

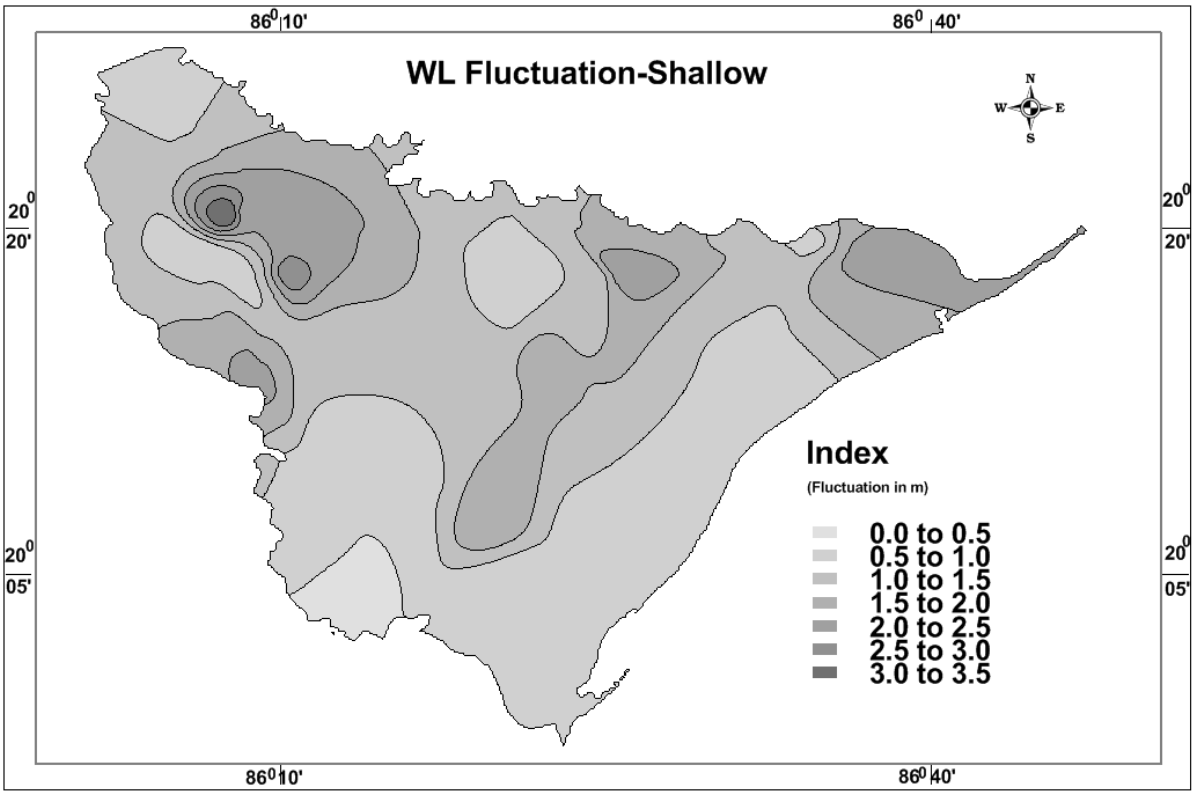


Fig.24:Water Level Fluctuation Pre to Post-Monsoon (Shallow Aquifer)

Water Level (Piezometric head) of Deep Aquifers

During pre-monsoon,2017, piezometric head varies between 1.67m and 8.18m below ground level. In major area, water level lies between 2 and 6m(Fig.25). Coastal area shows relatively shallow water level.

During post-monsoon,2017, piezometric head varies between 0.78m and 6.83m below ground level(Fig.26). In major area, water level lies between 2 and 6m. Coastal area shows relatively shallow water level which lies between 0 and 2m.

During pre to Post-monsoon, all wells except two well show rise in water level. Water level rose in between 0.11 and 3.15m(Fig.27). Relatively high rise in water level observed in area in patches in south, eastern and west central part of the district.

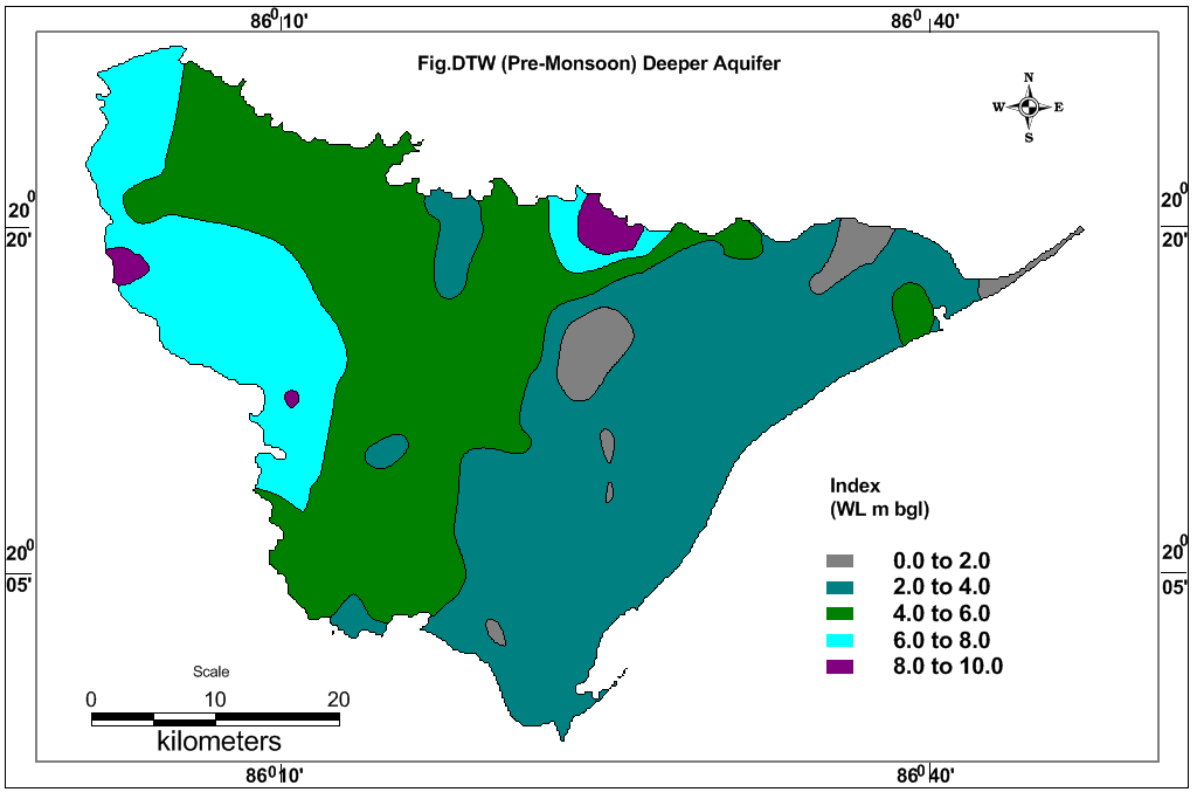


Fig.25:DTW Pre-Monsoon (Deeper Aquifer)

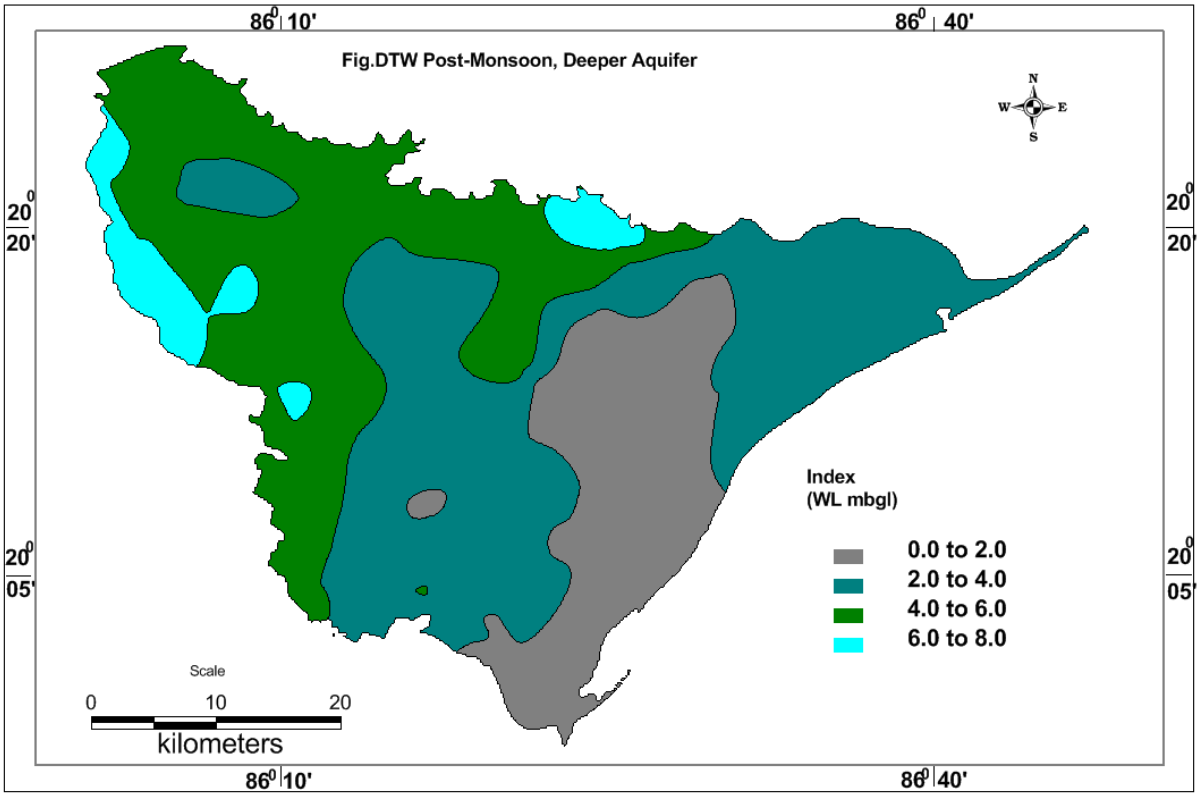


Fig.26:DTW Post-Monsoon (Deeper Aquifer)

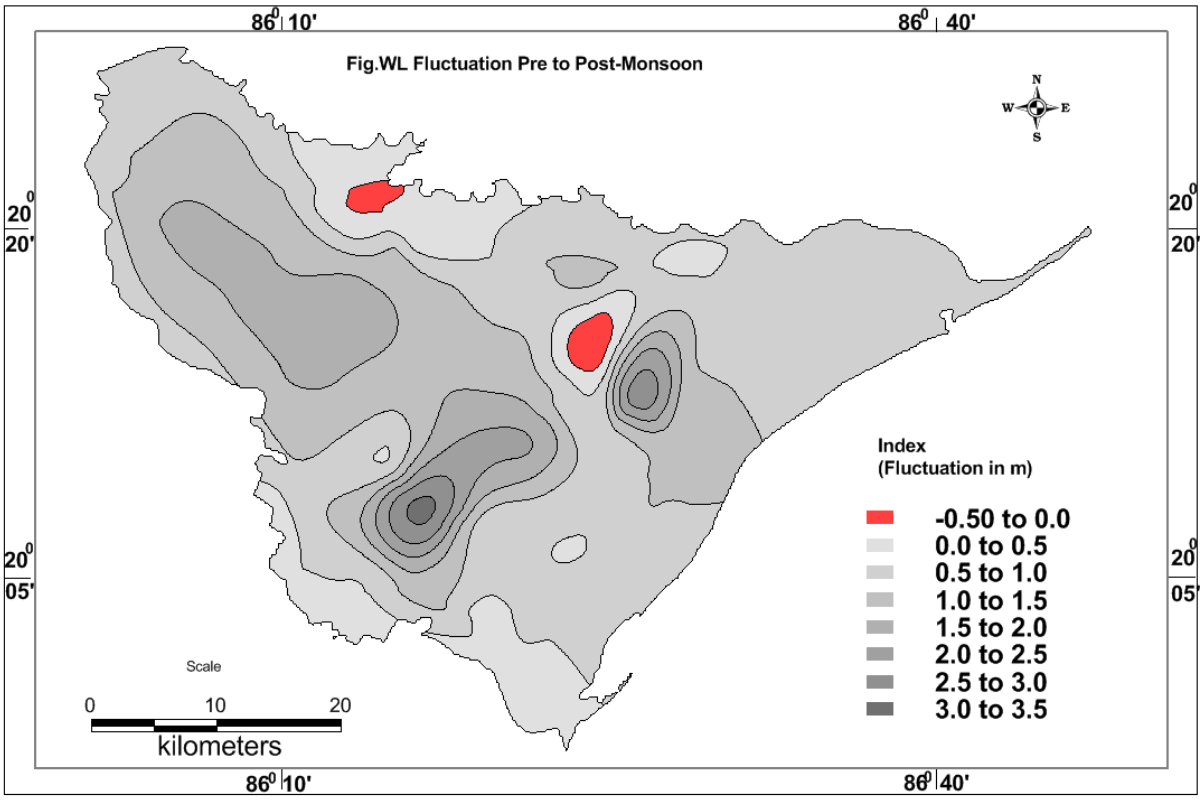
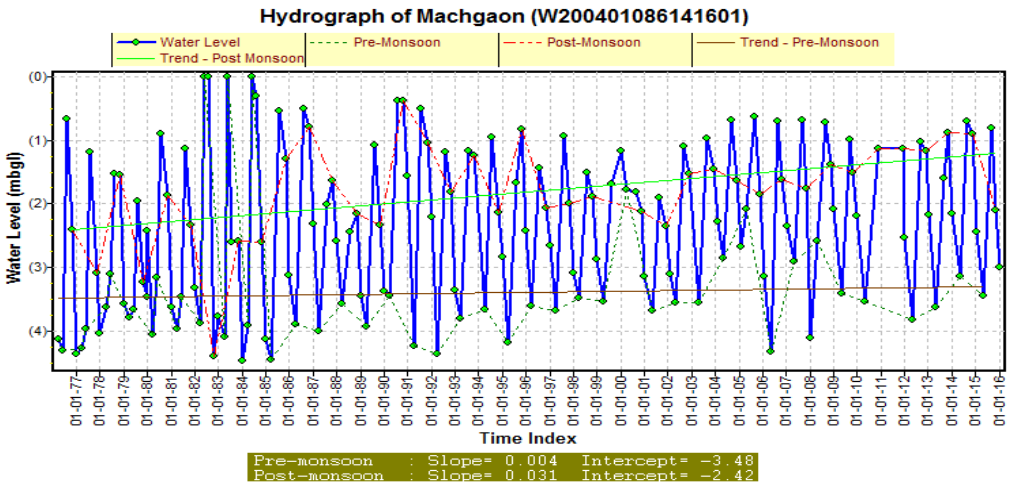
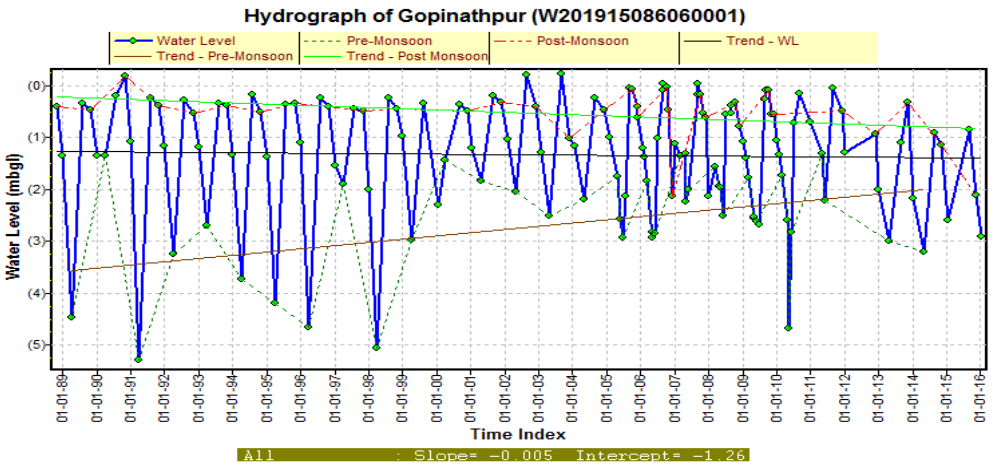


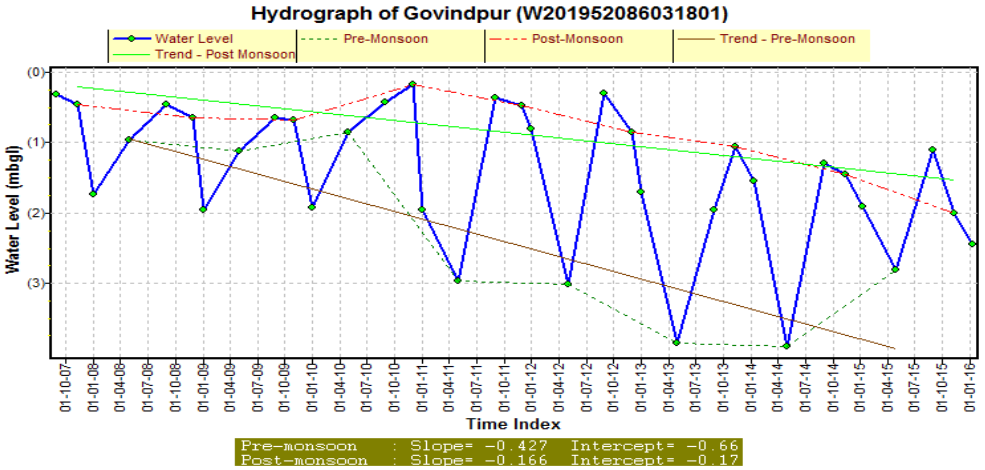
Fig.27:Fluctuation Pre to Post-Monsoon (Deeper Aquifer)

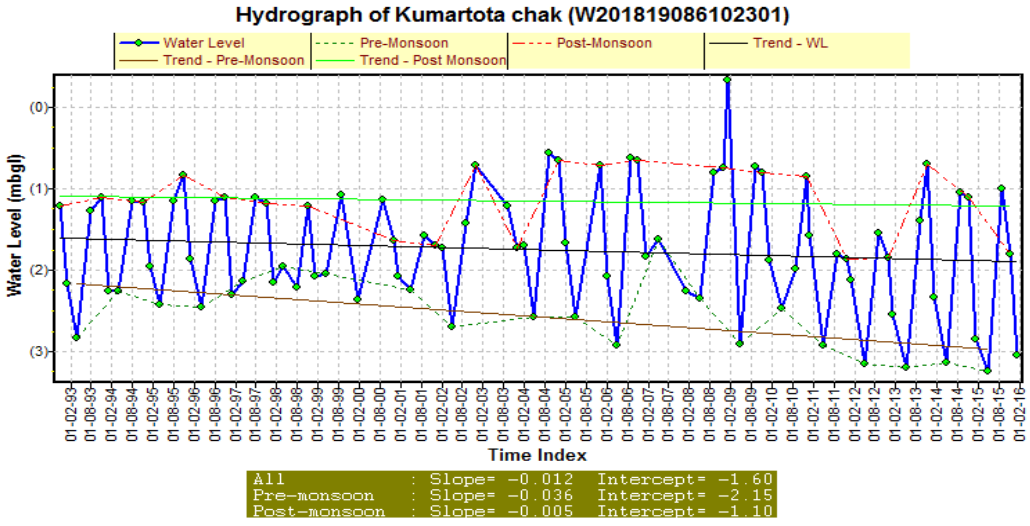
Long term Water Level Trend

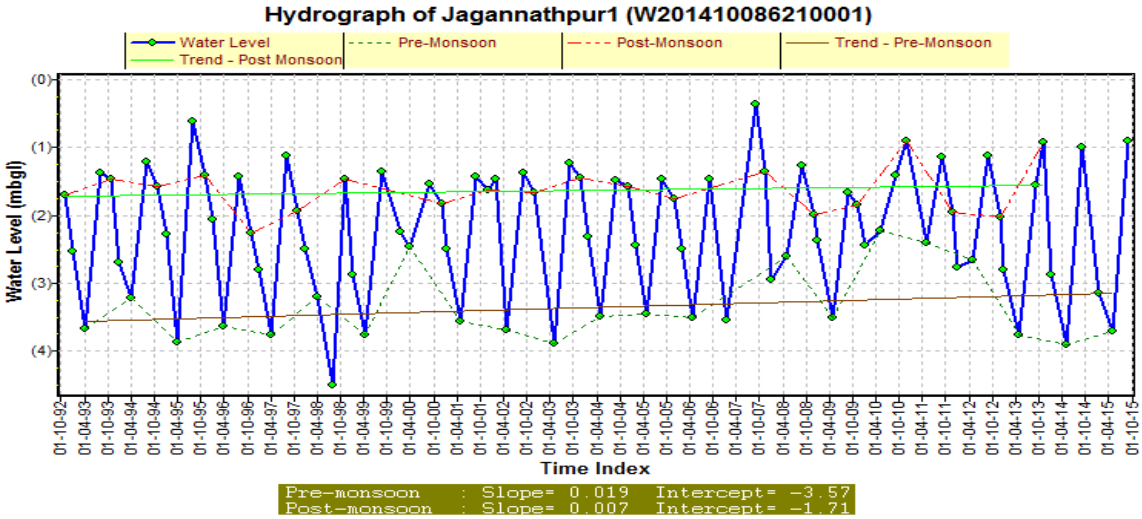
Longterm trend of water level of some of national hydrograph stations are shown in the fig.28.

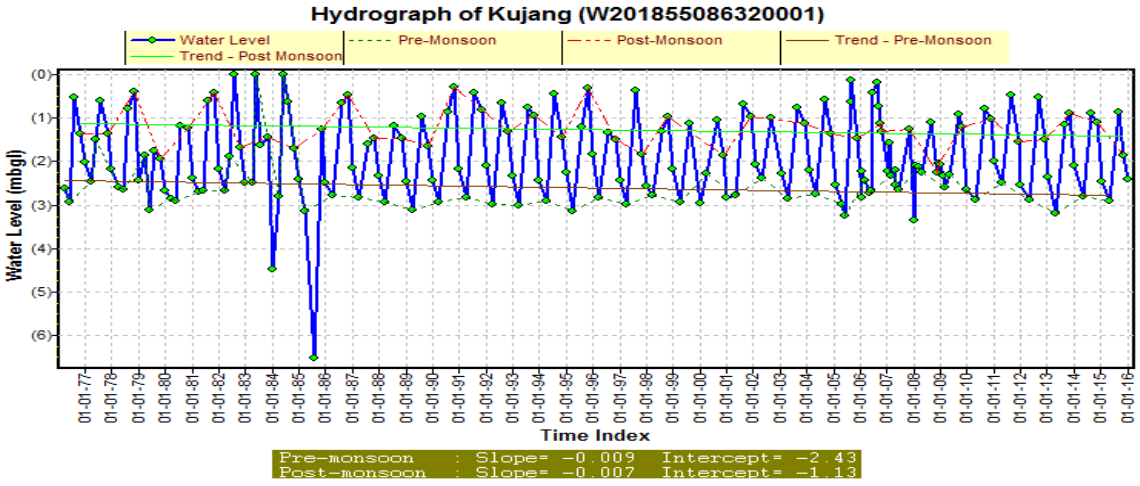


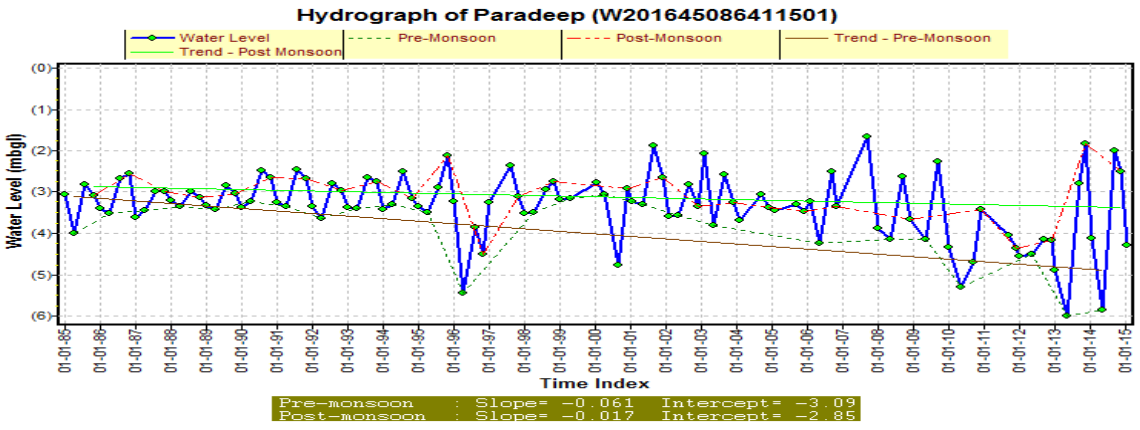

Hydrograph of Gopinathpur (W201915086060001)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - WL
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
All : Slope= -0.005 Intercept= -1.26

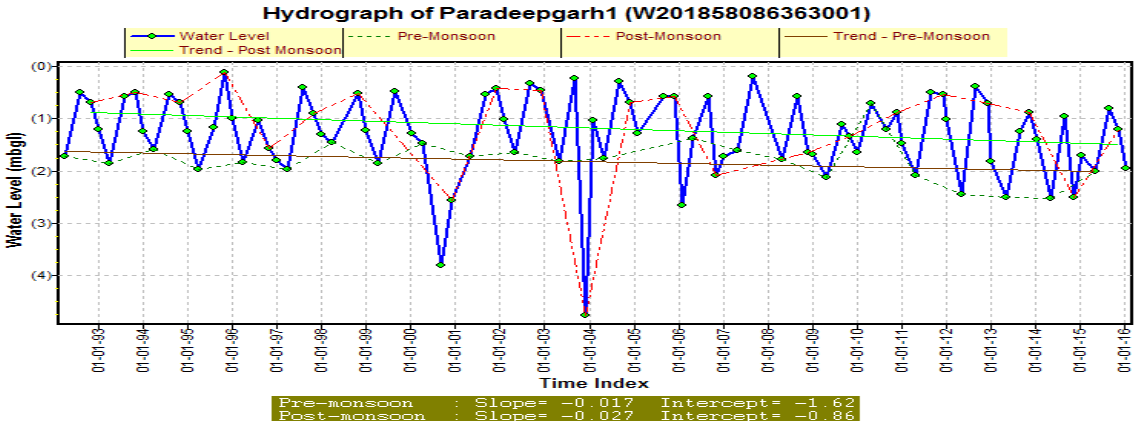

Hydrograph of Govindpur (W201952086031801)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
Pre-monsoon : Slope= -0.427 Intercept= -0.66
Post-monsoon : Slope= -0.166 Intercept= -0.17

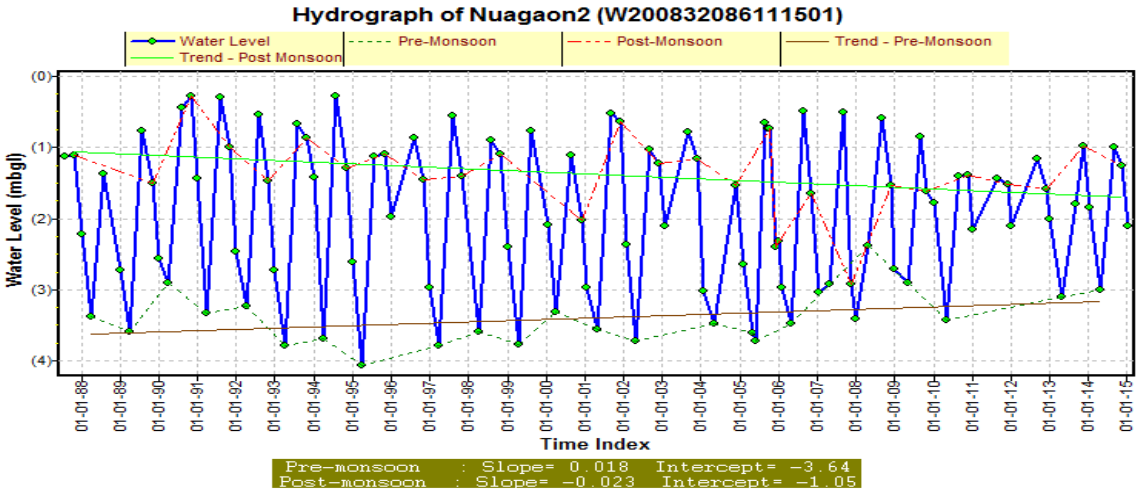

Hydrograph of Kumartota chak (W201819086102301)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - WL
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
All : Slope= -0.012 Intercept= -1.60
Pre-monsoon : Slope= -0.036 Intercept= -2.15
Post-monsoon : Slope= -0.005 Intercept= -1.10

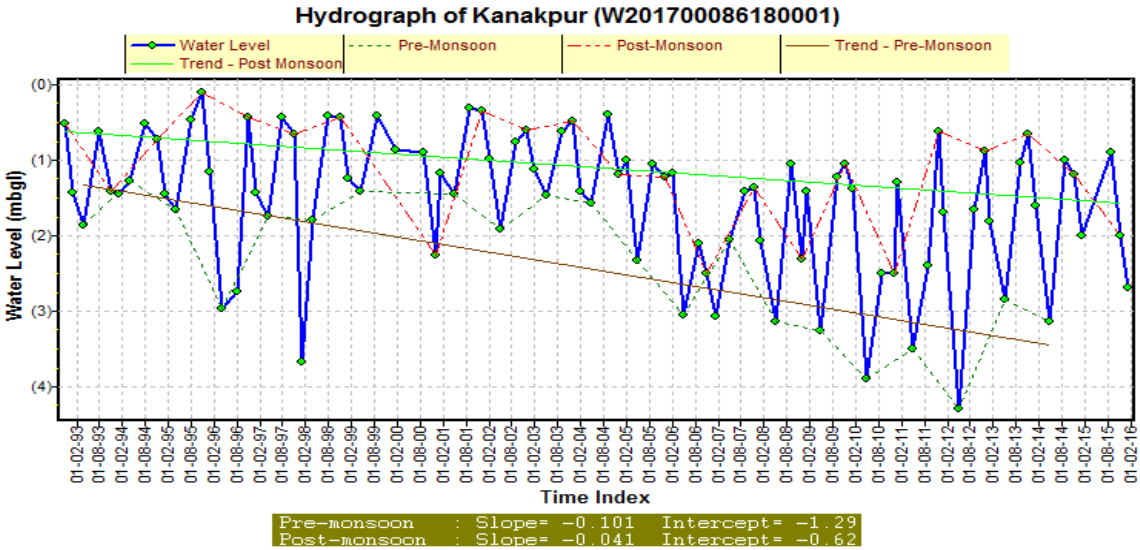

Hydrograph of Jagannathpur1 (W201410086210001)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
Pre-monsoon : Slope= 0.019 Intercept= -3.57
Post-monsoon : Slope= 0.007 Intercept= -1.71


Hydrograph of Kujang (W201855086320001)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
Pre-monsoon : Slope= -0.009 Intercept= -2.43
Post-monsoon : Slope= -0.007 Intercept= -1.13


Hydrograph of Paradeep (W201645086411501)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
Pre-monsoon : Slope= -0.061 Intercept= -3.09
Post-monsoon : Slope= -0.017 Intercept= -2.85


Hydrograph of Paradeepgarh1 (W201858086363001)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
Pre-monsoon : Slope= -0.017 Intercept= -1.62
Post-monsoon : Slope= -0.027 Intercept= -0.86


Hydrograph of Nuagaon2 (W200832086111501)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
Pre-monsoon : Slope= 0.018 Intercept= -3.64
Post-monsoon : Slope= -0.023 Intercept= -1.05


Hydrograph of Kanakpur (W201700086180001)
Water Level
Pre-Monsoon
Post-Monsoon
Trend - Pre-Monsoon
Trend - Post Monsoon
Water Level (mbgl)
Time Index
Pre-monsoon : Slope= -0.101 Intercept= -1.29
Post-monsoon : Slope= -0.041 Intercept= -0.62

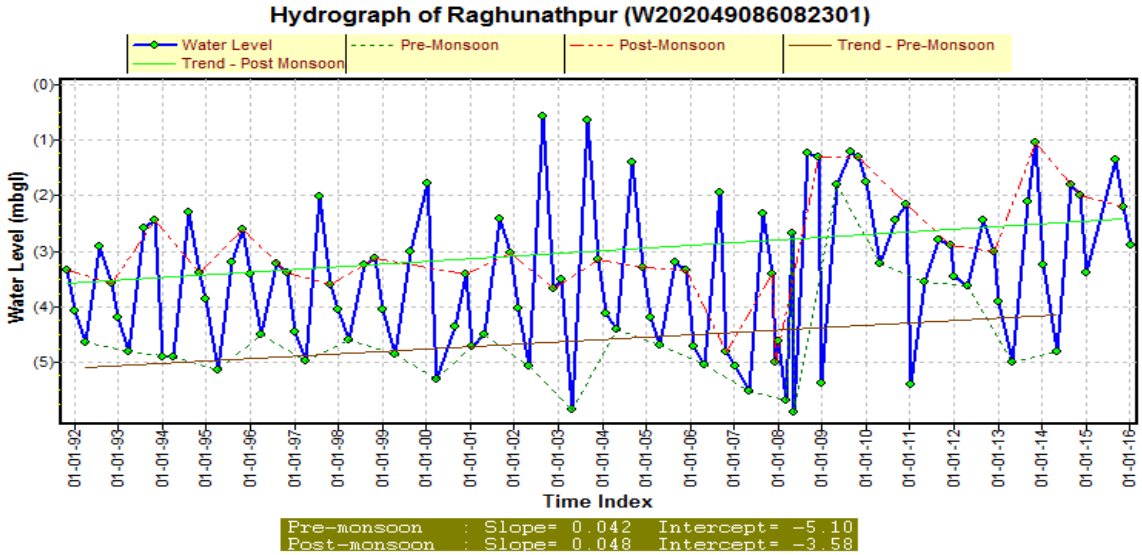


Fig.28: Hydrographs of selected NHS

4.0 GROUND WATER QUALITY

Groundwater samples from phreatic as well as deeper aquifers were collected for analysis. Water samples from existing in use hand pumps tapping fresh water aquifers were collected during study. Water samples from existing NHS were collected during regular monitoring and got analysed. The result of analysis is given below.

4.1 Quality of Phreatic Aquifer

Ground water from 10 nos. of NHS wells is being collected and analysed for 14 parameters. The wells tap the phreatic aquifers and depth of the wells is around 10m.The locations of wells quality of water measured during April 2018 is shown in annexure no 5.

The analysis data show that the concentration of all parameters lie within the permissible limit of Bureau of Indian Standards. Concentration of few parameters is described below.

Hydrogen ion concentration (pH) :

pH is the negative logarithm of the hydrogen ion activity in solution and it indicates the balance between acids and bases in water. In the study area, the pH of ground water samples varies from 8.17 to 8.72. The maximum permissible limit for pH as prescribed by B.I.S (1991) in drinking water supply is 6.50 to 8.50. However, in the study area, the ground water has pH values within desirable limits.

Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized or micro-granular suspended form. TDS is not generally considered a primary pollutant, it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the

presence of a broad array of chemical contaminants. TDS concentration of water samples varies between 190 and 714 mg/l which is well within the permissible limit.

Chloride: The major sources of chloride in ground water are from rainwater, evaporite deposits and seepage from sewage and industrial effluents containing common salt. The chloride concentration in ground water varies from 24 to 281 mg/l indicating the quality of water within this aquifer is portable.

Fluoride: The fluoride concentration in the area varies from 0.09 to 0.67mg/l. The fluoride concentration is less than the desirable limit as prescribed by BIS, 1991.

Suitability of Ground Water for Drinking Purposes: The ground water samples of the area show that water is fit for drinking as well as for domestic purposes.

4.2 Quality of Deeper Aquifer

Groundwater samples from hand pumps tapping fresh water aquifers in different depth ranges were collected during the study. The result of analysis is shown in annexure 5. Concentration of few parameters is described below.

Hydrogen ion concentration (pH): In the study area, the pH of ground water samples varies from 6.7 to 8.3. The ground water has pH values within desirable limits as prescribed by B.I.S (1991.

Total dissolved solids (TDS): TDS concentration of most water samples lie within permissible limit. Water samples from locations i.e. Trilochanpur (2328), Sampur(2077) and Ambiki(1644) show high TDS concentration. High TDS at Trilochanpur is due to defunct/faulty design of handpump tapping saline aquifer. High TDS at other places is due to brackish aquifer.

Chloride: The chloride concentration in ground water lies within permissible limit except few locations where TDS is high.

Fluoride: The fluoride concentration in groundwater is well within permissible limit except at Garh Bishnupur where it exceeds limit and has concentration of 2.1mg/l and marginally high at Machhagaon with concentration of 1.1 mg/l.

Suitability of Ground Water for Drinking Purposes: The ground water samples of the area show that water is fit for drinking as well as for domestic purposes.

Chloride to Carbonate-Bicarbonate Ratio

Chloride to Carbonate-Bicarbonate ration map shows that eastern part of the district is slightly to injuriously contaminated by saline water. The area surrounding village Trilochanpur shows highly contaminated that is due to faulty well construction.

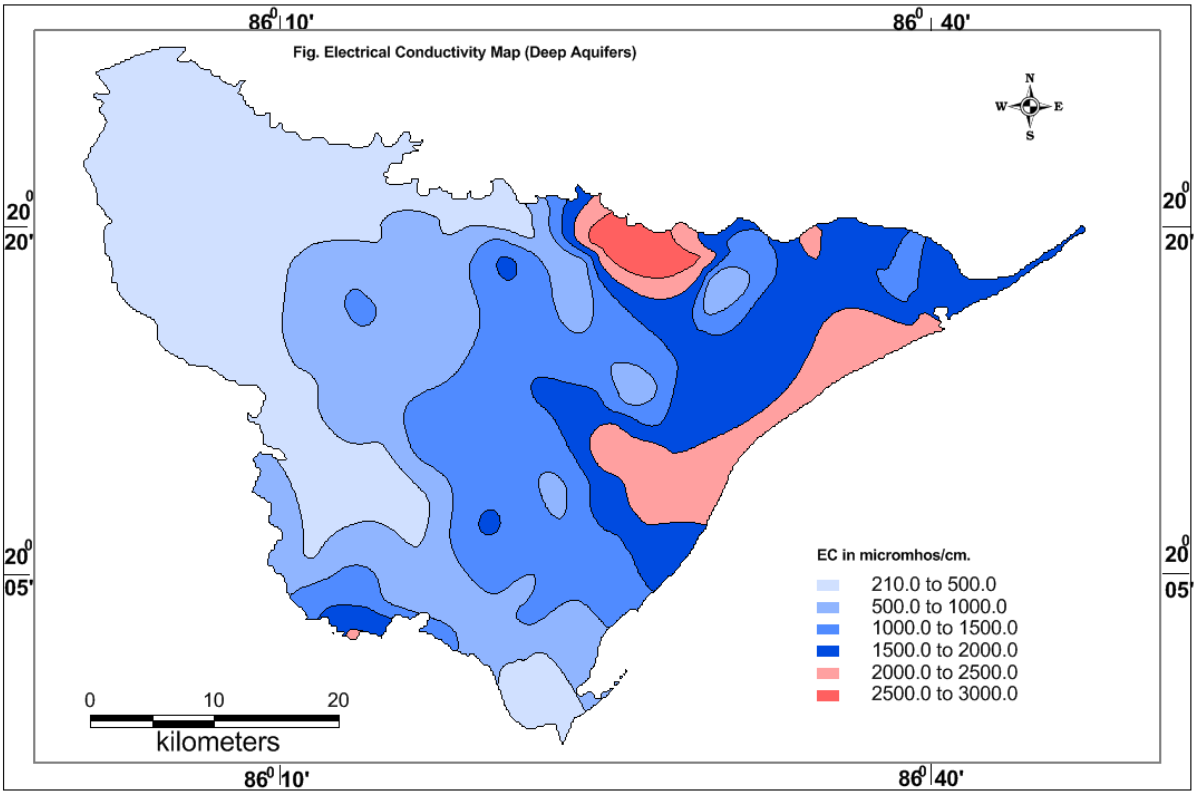


Fig.29.Electrical Conductivity (Deep Aquifers)

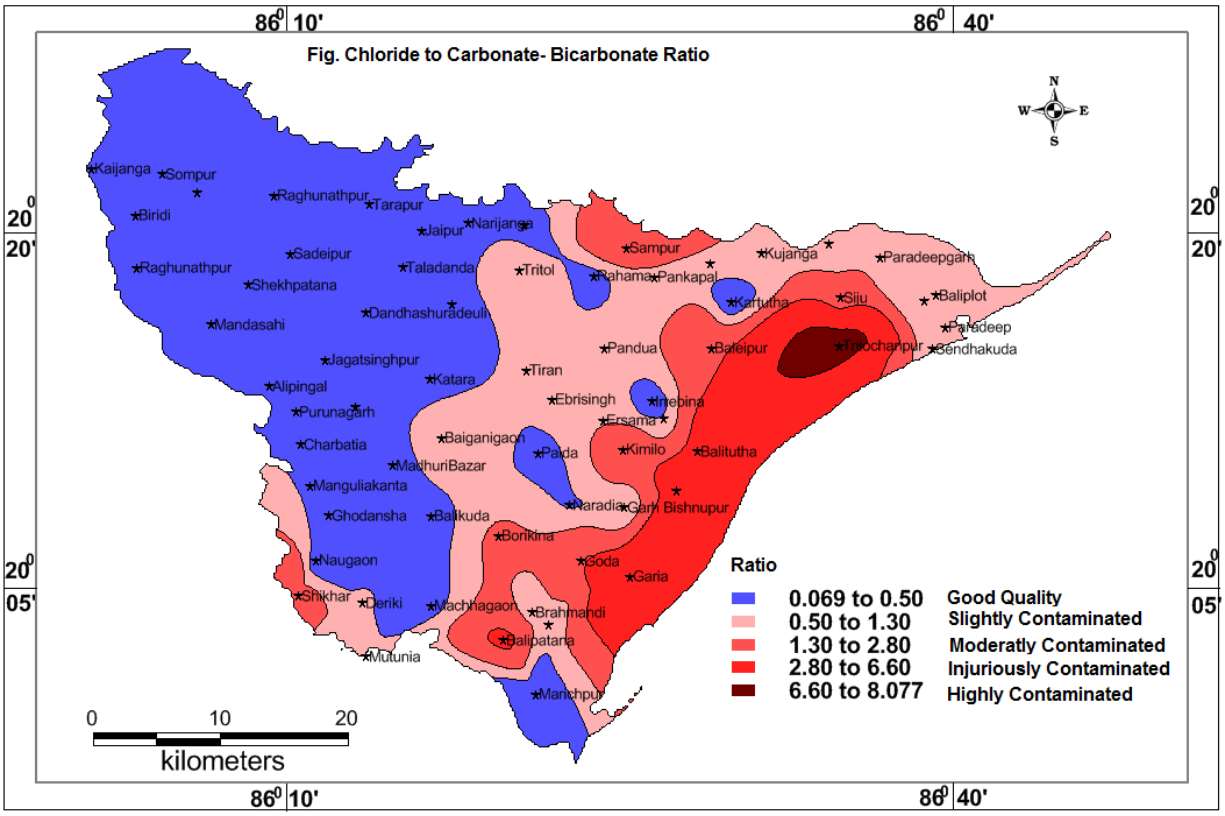


Fig.30: Chloride to Carbonate-Bicarbonate Ratio

5. WATER LOGGING

In the coastal tract, the elevation of around 238sq.km area lies in the range between 0 to 3m above mean sea level. The area is either inundated or prone to be inundated during high tides. During high tides the bunds of creeks overflow and submerge low lying area. Moreover, inundation of area is due to accumulation of surface irrigation excess water. Surface elevation map for the district has been prepared by using SRTM data and shown in the fig.31. Kujang and Ersama blocks are most affected water logging problems.

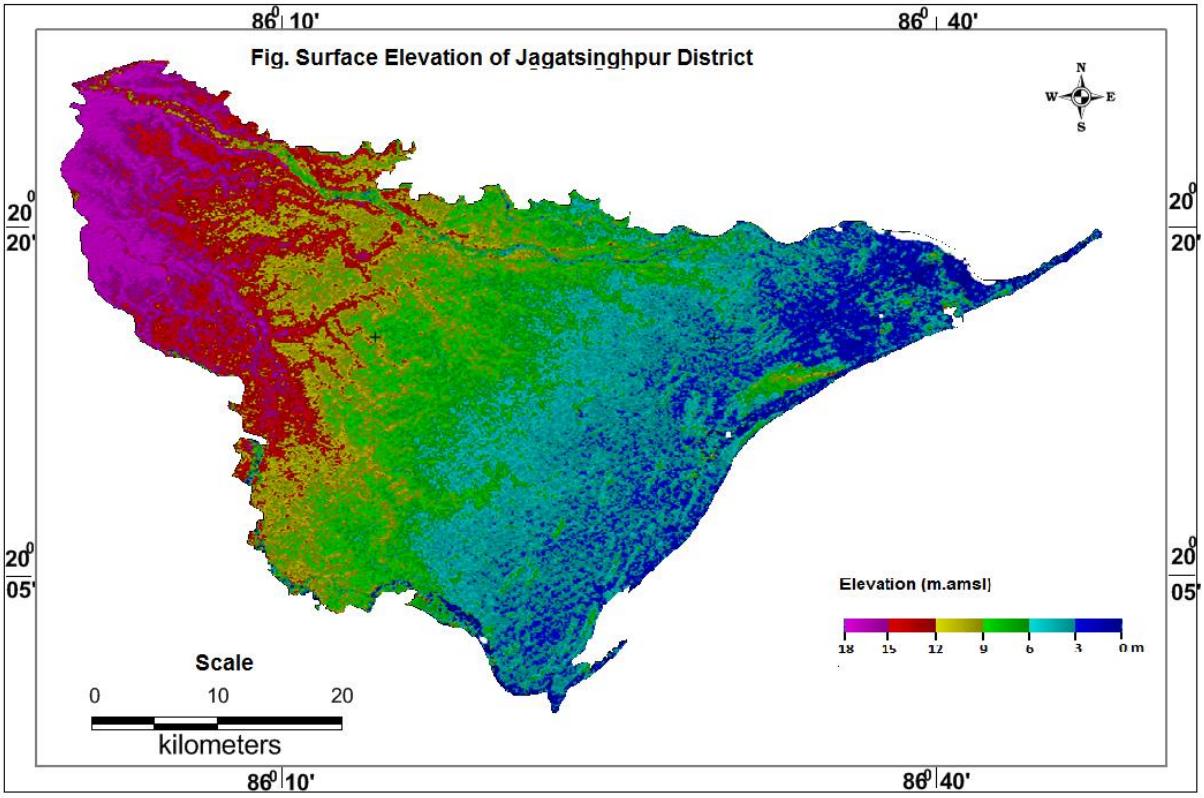


Fig.31: Surface elevation of Jagatsinghpur district

Low lying (poor drainage) in Ersama Block

Flooding through creek

Fig.32: Water logged area in Ersama Block

DTW & Water Logging

DTW Post-monsoon map (fig.23) shows that water level in area round 1380 sq.km lies between 0 and 2m below ground water level implying water logged conditions. Water level is show in all the blocks. The entire Ersama block is water logged and is due to saline phreatic aquifer.

Hydrographs (fig.33) of selected NHS show that water level is shallow and is almost steady over a long period.

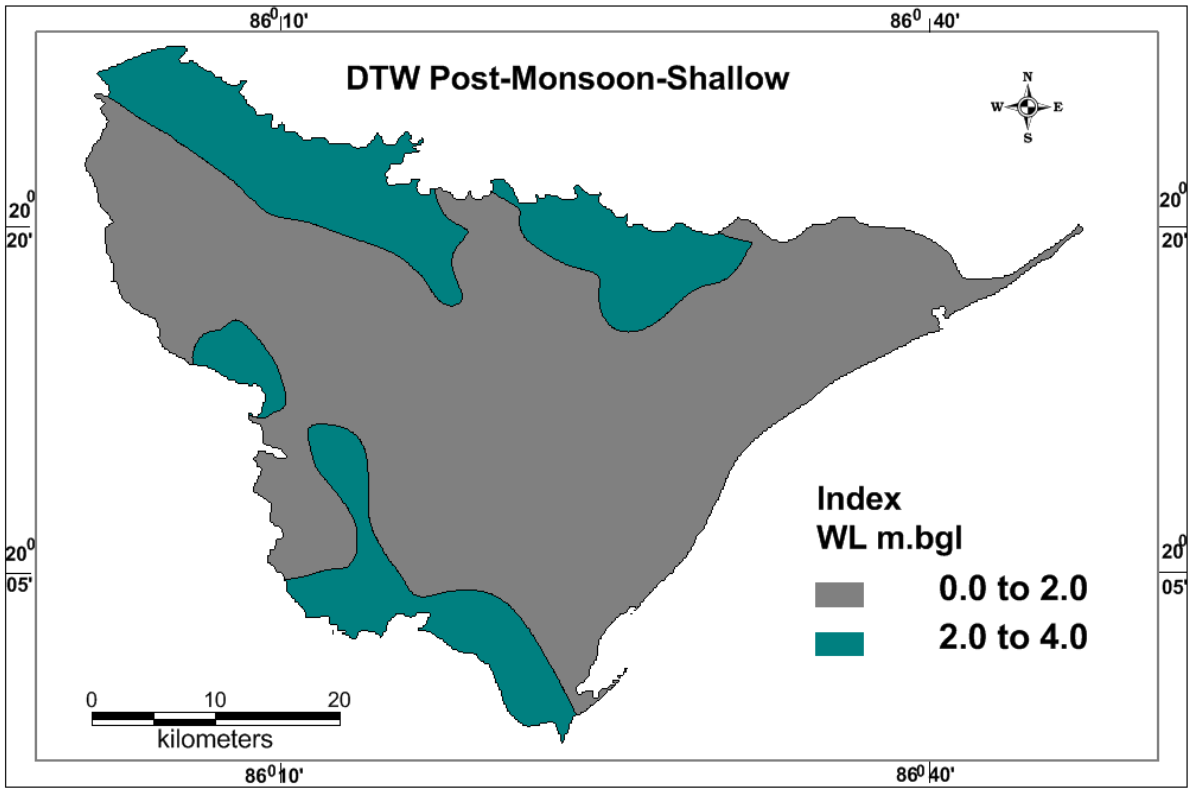
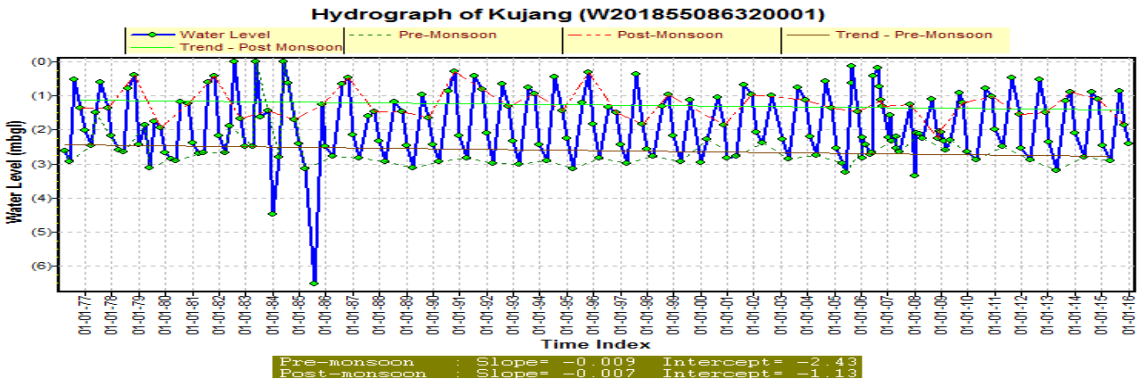
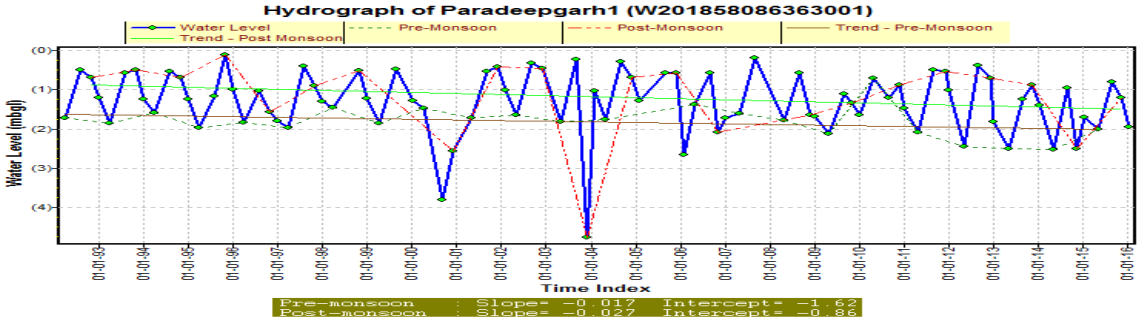
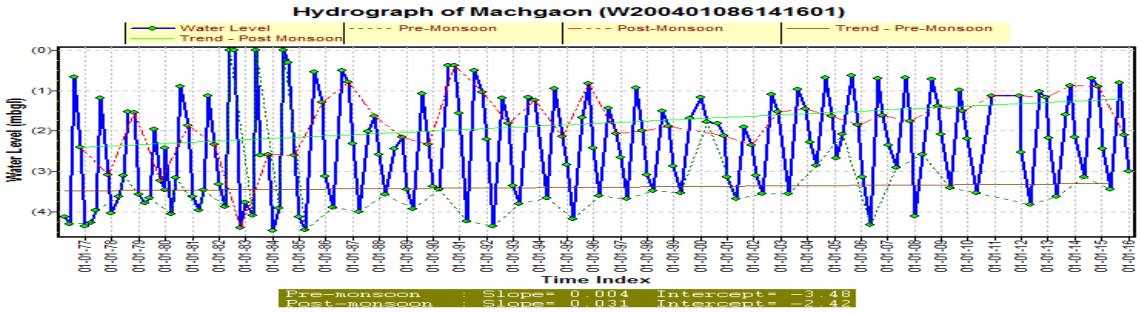


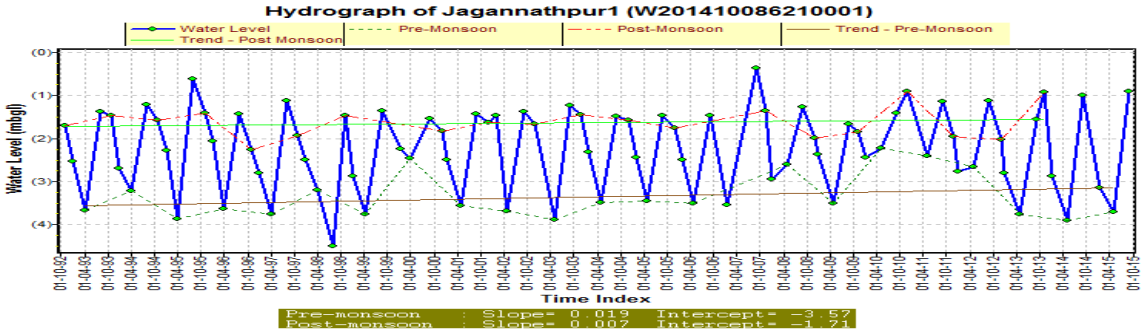
Fig.23:DTW Post-Monsoon Shallow Aquifer

Fig.33: Hydrographs of selected NHSs









6. GROUNDWATER RESOURCE

The dynamic ground water resource of the district was jointly estimated by CGWB and GWS & I adopting the methodology recommended by Ground Water Estimation Committee 1997. Mainly water level fluctuation method was adopted taking the pre-monsoon and post-monsoonal measurements of phreatic and shallow aquifers. The block-wise resource as on 2013 is given below:

Table 10: Ground water resources of the 1st aquifer (phreatic & shallow aquifers upto 50 m of epth), Jagatsinghpur District* Resources are in Hectare Meter (HaM)

Sl No	Block	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for all uses	Provision for domestic & industrial requirement supply for next 25 years	Net Ground Water Availability for future irrigation development	Stage of Ground Water Development	Category
		(ham)	(ham)	(ham)	(ham)	(%)	
1	Balikuda	5052.00	2610.93	360.00	2353.95	51.68	Safe

2	Biridi	6814.00	3541.99	233.00	3216.97	51.98	Safe
3	Ersama	0.00	0.00	0.00	0.00	0.00	-
4	Jagatsinghpur	8222.00	4048.97	579.18	3963.87	49.25	Safe
4	Kujanga	6409.00	4180.96	554.00	2107.84	65.24	Saline
6	Naugaon	2786.00	1890.00	162.00	855.86	67.84	Safe
7	Raghunathpur	7340.00	2762.00	239.00	4523.14	37.63	Safe
8	Tirtol	8406.00	4677.02	436.00	3631.08	55.64	Safe
	District Total	45029.00	23711.87	2563.18	20652.71	52.66	Safe

A vast replenishable ground water resource is available, mainly confined to the 4 western blocks i.e. Biridi, Raghunathpur, Jagatsinghpur & part of Tirtol of the district. However the ground water utilization in this part is also high to the tune of 55.64% of the ground water resources in Tirtol block. Thus there is a scope for further development of ground water resources to the tune of 90%, by keeping an eye on the ground water trend behaviour of the aquifer system.

The first 50 meters of unconfined and confined aquifers are either connected or gets recharge from nearby recharge areas and hence are taken as single aquifer. Most of the places they show similar water level and recharge. So the ground water resources estimated by GEC -97 methodology is applicable to the 1st aquifer system.

Attempts have been made to evaluate the ground water resource of confined aquifers upto 300m.depth for all blocks. Resource has been calculated by taking the fluctuation in piezometric head assuming that lowering in piezometric head can be allowed and safe. Resource has been calculated by multiplying the volume of fresh aquifer with fluctuation in head and storage coefficient. Storage coefficient has been taken to be 0.005. In Balikuda and Naugaon there does not exist any fresh aquifer beyond 150m and their resource in 3rd aquifer is nil.

2nd aquifers in Biridi, Balikuda and Raghunathpur blocks serve as recharge zone for deeper aquifers in Kujanga and Ersama blocks. Pumping from recharge zone may impact landward movement of sea water in 2nd and 3rd aquifers in Kujanga and Ersama blocks. Monitoring of both head and quality is required in order to ascertain the effect of pumping on the aquifer and to determine the threat of sea water ingress.

Table 11 : Ground water resources of Jagatsinghpur District

Sl No	Block	GW resources of 1st aquifer (upto 50m)	GW resources of 2nd aquifer (upto 150m)	GW resources of 3rd aquifer (upto 300m)
1	Balikuda	5052	161.124	0
2	Biridi	6814	92.1	92.1
3	Ersama	0	33.541	187.5
4	Jagatsinghpur	8222	138.825	138.825

4	Kujanga	6409	29.4575	43.7075
6	Naugaon	2786	30.175	0
7	Raghunathpur	7340	69.6	69.6
8	Tirtol	8406	29.5	57
	District Total	**45029**	**584.3225**	**588.7325**

* Resoureces are in Hectare Meter (HaM)

7. MANAGEMENT PLAN TO GROUND WATER PROBLEMS

Groundwater salinity and water logging are the major problems the district is facing now. In coastal area of Kujanga and Ersama fresh ground water occurs on an average beyond 300m below surface. Aquifers from surface to 300m depth are saline either due to sea water intrusion or due to inherent salinity. It is not possible for common man for access to fresh ground water of its own. For drinking and domestic use the people depend upon the Govt. water supply. Rural Water Supply & Sanitation (RWS&S), Govt. of Odisha has constructed deep hand pumps in all most all villages. Moreover, RWS&S has constructed tube wells and supply drinking water through pipe lines. Piped water scheme covers maximum villages. In extreme coastal villages, hand pumps in sand dune area have poor yield. Water need for entire population is somehow managed now but with time, increase in population water requirement will increase. Measures should be taken up right now so that problems related to water may not arise. Measures should be taken up to reduce stress on particular group of aquifers. Some of the measures described below if taken up will improve the quality and quantity of groundwater resources.

1. Supplement Groundwater with Surface water

In coastal area groundwater is being extracted from a specific aquifer group. If this trend continues it will induce sea water intrusion. Already shallow aquifers have become saline. Stress on this group of aquifer needs to be reduced by reducing the pumping rate by supplementing ground water with surface water. In Paradeep town corporate houses like Paradeep port trust, Indian Oil, etc they meet their water requirement through surface water. Public Health Engineering Department is responsible for supplying groundwater for general population. PHED has constructed deep tube wells for water supply. Like corporate houses PHED should find out ways to supplement groundwater with surface water. Similarly RWS&S should reduce groundwater pumping and should take measures to supplement surface water particularly in coastal villages and towns like Kujanga and Ersama.

2. Exploring deeper good-quality aquifers

In coastal area in Kujanga and Ersama blocks, fresh aquifers immediate below saline aquifers (300m depth) are being exploited. Disposition of deeper aquifers (upto atleast 800m deep) has not been explored. The fig.34 shows the locations of exploratory wells with drilled depth and well construction depth. CGWB has drilled well maximum upto 610m at Ersama. But the well was logged upto 490m and quality of formation water beyond 490m could not be established. Exploration upto maximum depth should be carried out and if there are fresh

aquifers at deeper levels, they should be exploited. There may be some watershed leakage to Sea through deeper aquifers. The aim should be to reduce stress on particular group of aquifers to avoid sea water intrusion.

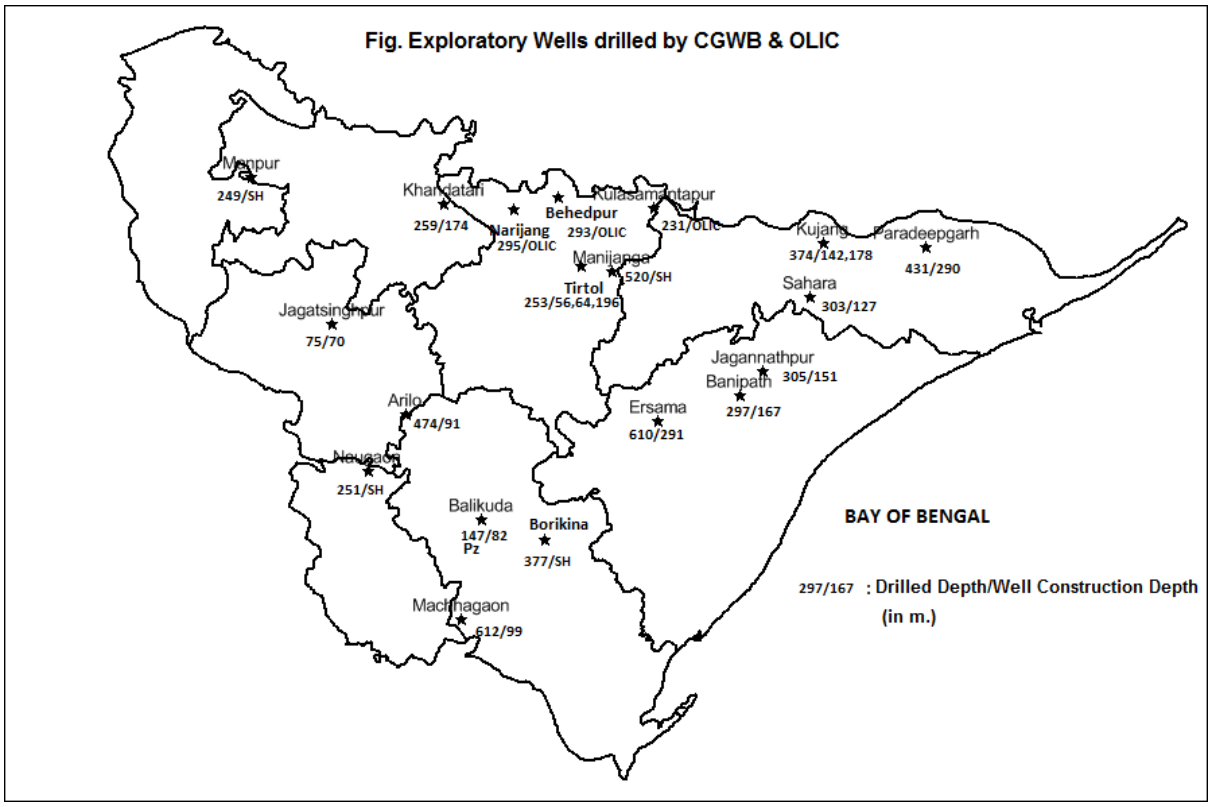


Fig.34: Location of Exploratory wells

3. Regulation for prawn cultivation

Due to favorable geographical location, coastal area in Ersama and Kujanga block, prawn cultivation has become life line and economic back bone of farmers. It has become an alternate farming to the traditional crop farming. Farmers are now shifting to prawn cultivation due to failure or low yielding paddy cultivation, agriculture land unfit for cultivation due to increase salinity and prolong water logging. But in the absence of any regulation, prawn cultivation has become a boon for the area. Prawns are grown in saline water. Farmers make ponds by excavating land and fill ponds with saline water from nearby creek. By the way of excavation for ponds, farmers cut across sand dunes and sometimes local fresh phreatic aquifers. Prawn cultivation acerage is spreading day by day from the coastal area to inland area. Standing saline water in ponds seeps through the permeable sand and make the phreatic dune aquifers saline. Certain regulating mechanism should be established to monitor the indiscriminate convert of land to saline ponds.

Fig.34: Prawn culture in Ersama block

4. **Judicious use of canal water for irrigation**

Use of canal water leads to water logging at the tail end which in turn lead to salinity. Canal water should be used so as to minimize water logging at the tail end.

5. **Raising & strengthening of the existing river embankments, construction of new embankments, Construction of new sluices, construction of seawalls, dredging of river mouths & drainage channels, slope protection measures.**

Inundation of land during high tides is very common occurrence in the district. Elevation of land close to sea is less than the elevation of sea. During high tides sea water moved landward through creeks and creeks overflow their banks and sea water submerge adjoining area and low lying area i.e. depressions. After tides recedes, the area still remain submerged due to poor drainage. Sea surge degrades the land as well as deteriorates the quality of ground water.

Govt.of Odisha has taken steps to arrest the sea surge. Govt. has constructed suice gates at suitable locations across creeks to stop land ward move of sea water. Creek embankments have been raised at places to stop overflow of embankment.

Upstream of the suice gates fresh rainwater accumulates which recharge the ground water system.
Such steps should be taken up in a massive scale to stop inundation of land by sea.

Fig.35: Sluice Gate across creek

6. Protection of Sand dunes

Sand dunes are good repository of groundwater system. Ground water occurs under perched water table conditions. Most villages in coastal area particularly Ersama block, the most problematic area grew up on sand dunes due to availability of water. Sand dune area is good sites for natural recharging. Ground water recharging can be artificially enhanced through construction of rainwater harvesting structures i.e. check dams, contour trenching, storage ponds in and around the dunes. Sand dunes should be protected and no man made activities should be allowed on dunes.

Fig. 36:Sand dunes in coastal Area

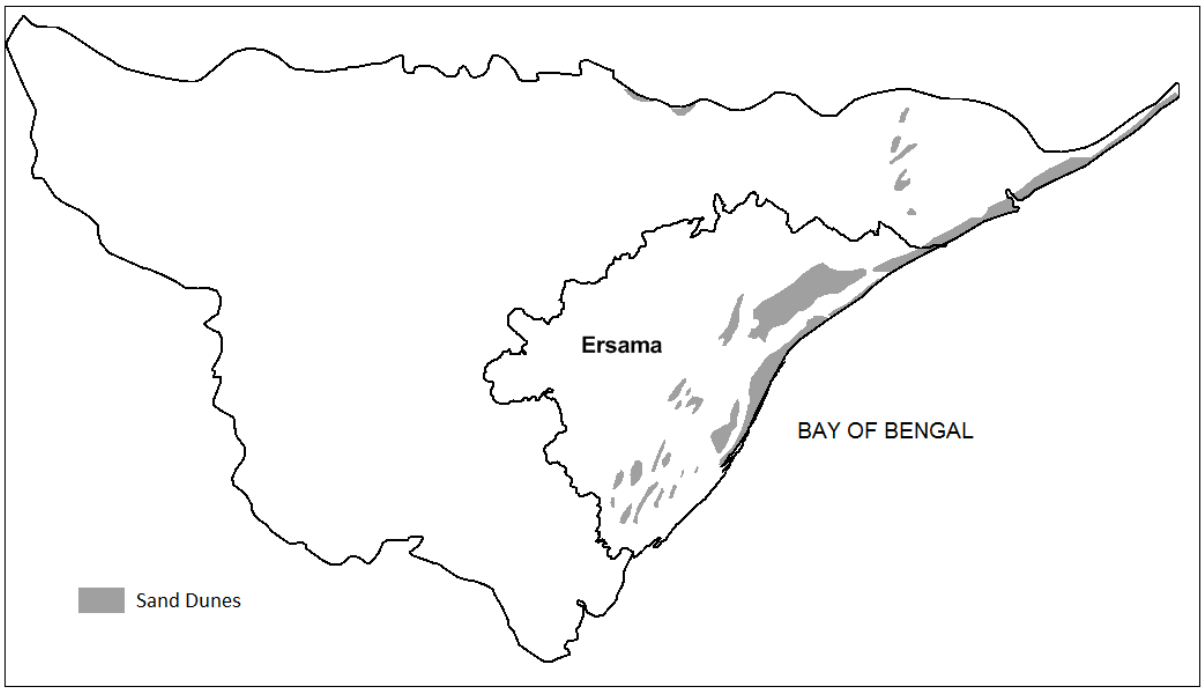


Fig.37: Sand Dunes in Coastal Jagatsinghpur

7. Reduction in groundwater pumping for irrigation

Pumping of ground water for irrigation particularly for major crops (water intensive) should be stopped. Pumping of ground water in coastal area i.e. in Kujanga and Ersama blocks induces seawater intrusion. Even pumping of ground water for irrigation purposes in western blocks i.e. Biridi, Raghunathpur & Jagatsinghpur will impact the landward movement of saline water in coastal blocks. The area of the blocks serves as a recharge zones for deeper aquifers in coastal area. Contribution of groundwater towards irrigation is high in Ersama, Balikuda and Kujanga blocks. The fig.38 shows the source of irrigation in the blocks.

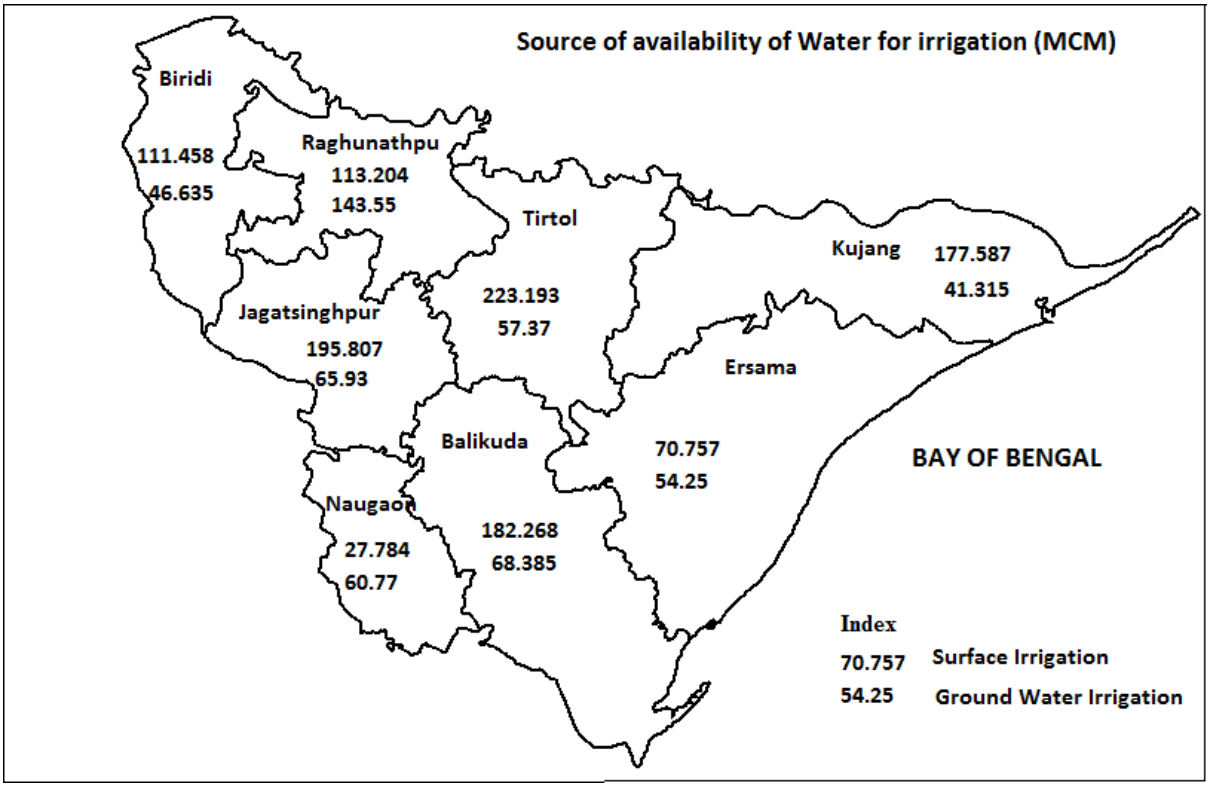


Fig.38: Source of availability of Water for Irrigation

8. **Revival of Old buried channels in recharging area, through periodic removal of silty layers deposited in the drainage beds.**

The coastal plain of the district is traversed by numerous streams active, partly active and dead. Some dead streams once upon were the distributaries of rivers Mahanadi and Devi. Some streams developed due to inland drainage.

Streams were feeding the phreatic as well as deeper aquifer systems and the hydraulic head of the aquifer system were remaining much above the sea level and saline water fronts were sloping sea ward. There was no danger of sea water intrusion. With due course of time the distributaries were cut off from rivers and became dead (buried channels) and their channel got deposited with silt and became impervious and no more recharging aquifers. Lower end of distributaries have become creeks carrying sea water. Creeks if cut across aquifers at places, recharge groundwater system with saline water.

These old buried channels should be revived. Channel bed should be de-silted making their bottom permeable. These channels will serve as recharging structures.

9. **Reclamation of waterlogged area**

Prolonged standing (water logging) of saline water deteriorates the quality of groundwater. In Ersama block low lying area are inundated with sea water. Suitable reclamations measures should be adopted to reduce the submerged area.

Fig.39:Water Logged area in Ersama block

10. Creating Hydraulic Head

Mahanadi and Devi are the tidal rivers in north and south of the district. Tidal impact prevails 32km upstream (shortest distance from sea) and 22 km upstream respectively in Devi and Mahanadi rivers (fig.40). Rivers if hydraulically connected to aquifers must be pumping saline water to aquifers. Area all along river Devi is having saline phreatic aquifers. Hydraulic head of saline river water can be over-balanced by raising fresh water hydraulic head. Gobari nala flows parallel to river Devi. If flow in Gobari nala can be made perennial, the head created will push saline front from river Devi. Similarly Taladanada canal flows parallel to River Mahanadi and same steps can be followed.

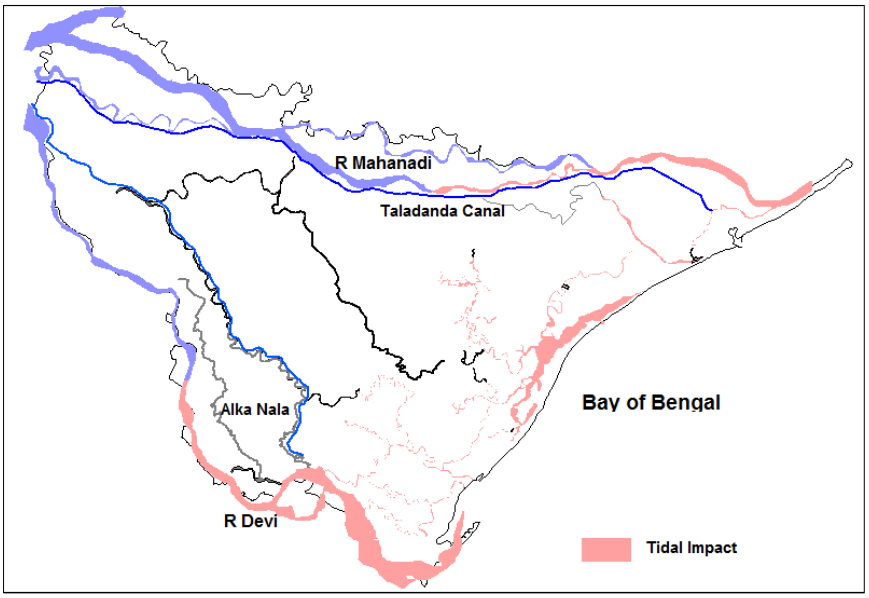


Fig. 40:Tidal Impact in Coastal Jagatsinghpur district

Receding Tides

Fig. 41: Tidal River Devi at Shikhar Ghat,River Devi

11. Public Awareness

Public awareness on the groundwater scenario of the district is required. Public who are the ultimate groundwater users should have knowledge of problems related to occurrence, distribution and quality of groundwater. They should be aware of the significance of ground water conservation.

8.CONCLUSION

Jagatsinghpur district is the most natural calamity prone eastern district of Odisha State. The entire district is covered with soft Quarternary sediments. Sand, silt and gravel form the principal aquifer systems. The district is bounded by tidal rivers on the north and on the south. The coastal belt of the district is traversed with numerous tidal creeks. Water for drinking and domestic use is based on groundwater. The economy of the people in the district is based on agriculture. Ground water contributes 28% of the total irrigation water. There is a gap in water requirement for irrigation in the tune of 868.6MCM. Salinity and water logging are the two big issues for the district. There is variation in salinity of aquifer both laterally and vertically. Two-third part of the district is facing salinity hazard problem. Around 238 sq.km area in coastal track is low lying and prone to water logging. Post-monsoon depth to water level in around 1380 sq.km area in coastal track especially in Ersama block lies in between 0 and 2m below ground level. Some measures have been suggested through this report to tackle the problems.

Annexure-1: Block-wise Rainfall (mm) in Jagatsinghpur District

	Year/Block	**Balikuda**	**Biridi**	**Erasama**	**Jagt'hpur**	**Kujanga**	**Naugaon**	**Raghunathpur**	**Tirtol**
1	**1995**	1582.2	1774.0	1868.0	1360.0	1605.6	1578.4	1836.9	1433.5
2	**1996**	684.0	737.0	1364.0	426.0	768.0	757.0	849.1	929.0
3	**1997**	1460.4	1577.0	3751.55	1172.0	1670.7	1244.4	1865.4	1460.0
4	**1998**	1730.0	1216.0	5102.0	973.0	1942.7	1196.0	1537.0	1372.0
5	**1999**	1506.0	1622.0	2146.0	1128.0	2060.0	1470.0	1866.0	1793.0
6	**2000**	706.0	631.0	644.0	661.0	769.0	972.0	908.0	813.0
7	**2001**	1257.0	1821.0	1316.5	1199.0	1283.0	1622.0	1578.0	1261.0
8	**2002**	829.0	1253.0	1081.9	637.5	1130.5	1112.0	1090.0	1139.0
9	**2003**	1502.0	1874.0	1823.0	1382.0	1799.0	1510.0	2080.0	1651.0
10	**2004**	894.0	1294.0	1229.0	894.0	1517.0	1057.0	1663.0	1079.0
11	**2005**	1280.0	1809.0	1709.0	1010.5	2148.0	2172.3	1360.0	1485.0
12	**2006**	1300.0	2105.0	1498.6	1114.0	1474.0	2174.0	1829.0	1380.0
13	**2007**	1100.0	1987.0	1270.3	1441.0	1361.0	1719.0	1865.0	879.0
14	**2008**	1192.0	1788.0	1503.0	1692.0	1722.0	2403.0	1485.0	1729.0
15	**2009**	1179.0	1654.0	1627.0	1061.0	1540.0	1852.0	1444.0	1515.0
16	**2010**	1032.0	1406.0	1369.5	801.0	1414.5	1213.0	1231.0	1204.0
17	**2011**	755.5	1687.0	1278.0	1364.0	1436.0	1006.0	1812.0	1227.0
18	**2012**	944.0	1501.0	1403.0	1147.0	1335.0	841.0	806.0	835.0
19	**2013**	828.5	1429.0	1359.0	1381.0	1042.0	994.0	1127.0	1072.0
20	**2014**	1255.0	1892.0	1491.0	1814.0	1493.0	1110.0	1343.0	1773.0
21	**2015**	1380.0	1395.0	931.0	1419.0	1125.0	694.0	1048.0	994.0
22	**2016**	1585	1521	1680.0	1640.0	1680	1440.0	1417.0	1668
Av.		**1144.56**	**1651**	**1410.6**	**1249.8**	**1468.75**	**1432.46**	**1448.64**	**1305.69**

Annexure-2: Hydrogeological Details of Exploratory borewell drilled in Jagatsinghpur District

Sr.No	Location	Well Type	Year	Depth drilled (mbgl)	Depth constructed (mbgl)	PACKER TEST				Aquifer zones tapped (mbgl)		Cement Plug	EC	TDS	Cl	Geophysical Recommendations		SWL (mbgl) / Date	Discharge (lpm)	Drawdown (m)	T (m²/day)	S
						Zones Tested	EC	TDS	Cl													
1	Ersama	**EW**	1975	609.62	291	**72-82**	**5733**	**3727**	**1673**									0.67	3333	13.02	1121	
	20.1997					**127-137**																
	86.4283											150-160										
						183-193	**1224**	**796**	**252**	184-189	**36**				461-590							
										203-208												
										226-232												
						257-267	**1994**	**1296**	**468**	257-267												
										279-289												
						320-330	**4221**	**2744**	**1223**													
						352-362																
						378-386																
						455-472	**15826**	**10287**	**5318**													
2	Machhagaon	**EW**	1975	612.41	99					30.83-50.58	**36**		1140	728	245			2.158	3338	3.932	936	
	20.0717					**80-86**	**612**	**398**	**24**	79.58-96.76												
	86.2888					**110-120**	**22938**	**14909**	**0**													
						156-163	**25481**	**16563**	**0**													
						240-247	**20765**	**13497**	**0**													

						340-350	7818	5082	0													
						460-470	24345	15824	0													
						485-492	4836	3143	24													
3	Kujang	EW		374.1	1,42,178	172-178	6357		1808	98-140	42	60-66	1564		312			2.07	1267	5.81	1858	$1.918x10^{-4}$
	86.526																					
	20.319,																					
4	Arilo	EW	1974	473.6	90.86					59-89	30		401	325	57			3.15	3825	3.795	5673	
	20.204																					
	86.227																					
5	Jagannathpur	EW	1975	305	151					83-92	40		1406	914	312			0.92	4498	12.48	1880	
	20.233									95-109												
	86.483									119-130												
										143-149												
6	Sahara	EW	1974	303	127					18-25	34							0.6	4159	4.08	2110	
	20.283									76-93												
	86.517									115-125					433							
7	Banipath	EW	1974	296.8	167					95-105	45	75-80	1082	762	204			0.3	4164	9.85	2110	
	20.217									115-130												
	86.467									145-165												
8	Manijanga	SH	###	520																		
	20.3																					
	86.375																					
9	Manpur	SH	1989	249.3																		
	20.383																					
	86.133																					

10	Borikina	SH	1985	376.7												40-80	Fresh					
	20.12															80-198	Saline					
	86.327															198-209	Brakish/Saline					
																209-254	Saline					
																254-325	Brakish/fresh					
11	Naugaon	SH	1986	251						75-81			1192		120							
	20.167																					
	86.2																					
12	Chatua	Pz								80-190												
13	Khandatari	Pz-I	1991	259.9	259.9					160-170			469	285	32							
	20.346	Pz-II		65	65					42-52			341	221	25							
	86.254																					
14	Jagatsinghpur	Pz	1986	74.6	70					50-68			247		14							
	20.265																					
	86.174																					
15	Paradeepgarh	Pz	1987	430.8	290	282-288	1972	1163	425	273-288			2519	1244	645	18-235	Highly Saline					
	20.317					294-300	2630	1552	610							236-244	cl:1900					
	86.6															265-288	1000					
																292-317	1000-					

																	1500					
																>317	highly Saline					
16	Tirtol	Pz-1	1990	253	56,64,196					186-196		160-164	545	120	60							
	20.304	Pz-II								80-90		62-64	11810	2650	3829							
	86.353	Pz-III								42-52			3600	485	957							
17	Balikuda	Pz	1986	147.2	82					62-80			458		32							
	20.133																					
	86.282																					

Annexure-3: Water Level data for Phreatic Aquifer

Location(Village)	Latitude	Longitude	Water Level(2017)		
			Pre-monsoon (mbgl)	Post-monsoon (mbgl)	WL_Fluctuation (m)
Bhutmundi1	86.576	20.32389	1.8	1	0.8
Nuagaon	86.537	20.22139	1.1	0.45	0.65
Siuli	86.128	20.34222	4.5	1	3.5
Nuapolbazar	86.14	20.29389	1.9	1.1	0.8
Kanakpur	86.3	20.28333		2.05	
Raghunathpur	86.14	20.34694	3.7	1.7	2
Paradeepgarh1	86.608	20.31611	2.08		2.08
Kujang	86.533	20.31528	2.33	0.83	1.5
Balarampur	86.536	20.32417		1.4	
Balikuda2	86.268	20.13806	2.2	1.5	0.7
Machgaon	86.238	20.06694		2.18	
Ersama2	86.407	20.20444	3.25	1.8	1.45
Balia Store	86.086	20.32778	1.75	1.05	0.7
Mukundpur	86.189	20.25028		1	
Sinharpur	86.136	20.29694		1.3	
Kumartola chak	86.173	20.30528	2.92		2.92
Machhagaon	86.278	20.06778	2.7	1.95	0.75
Kishorenagar	86.091	20.42472	3.2	2.3	0.9
Ranipada	86.061	20.35417	2.35	1.2	1.15
Chatua	86.506	20.27278	2.6	1.5	1.1

Goda	86.388	20.10167	2.53	1.78	0.75
Ibrisingh	86.363	20.23028	2.9	1.1	1.8
Alipingala	86.15	20.22028	4.55	2.4	2.15
Mukundapur	86.191	20.24944	2.2	1.05	1.15
Kujanga	86.523	20.32	4.2	2.75	1.45
Pankapal	86.429	20.3025	5.3	2.9	2.4
Alanahat	86.201	20.16167	3.2	2.45	0.75
Gajarajpur	86.181	20.16167	1.85	1	0.85
Garei	86.247	20.05139	4.32	3.97	0.35
Raghunathpur	86.16	20.35889	4.92	2.62	2.3
Adheikula	86.173	20.31944	3.4	1.25	2.15
Kolor	86.385	20.33861	4.4	2.95	1.45
Sagabaria	86.334	20.23056	1.85	0.65	1.2
Nuapada	86.284	20.32417	3.5	2.1	1.4
Tirtol	86.339	20.30639	1.9	1.4	0.5
Borikina	86.328	20.12139	3.8	1.85	1.95
Sailo	86.411	20.29472	3.1	1.95	1.15
Jaisol	86.118	20.31472	1.8	1.1	0.7
Sankhaswar	86.343	20.34222	2.9	1.9	1

Annexure-4: Water Level (Piezometric head) of deep aquifers

Location(Village)	Longitude	Latitude	Water Level (2017)		
			Premonsoon (mbgl)	Postmonsoon (mbgl)	WL_Fluctuation(m)
Alipingal	86.15333	20.22583	6.68	5.33	1.35
Purunagarh	86.17306	20.20778	8.18	6.83	1.35
Charbatia	86.17694	20.185	6.73	5.6	1.13
Manguliakanta	86.18417	20.15583	6.54	5.6	0.94
Ghodansha	86.19778	20.135	5.13	4.15	0.98
Naugaon	86.18806	20.10361	5.02	4.24	0.78
Shikhar	86.17528	20.07833	4.63	4.34	0.29
Mutunia	86.22556	20.03583	3.62		
Deriki	86.22333	20.07361	4.02	3.55	0.47
Dhiasahi	86.21833	20.21111	5.84	4.53	1.31
MadhuriBazar	86.24611	20.17028	3.82	3.35	0.47
Balikuda	86.27444	20.13444	5.05	1.9	3.15
Machhagaon	86.27444	20.07139	5.24	4.02	1.22
Balipatana	86.32889	20.04722	1.96	1.85	0.11
Marichpur	86.35306	20.00917	2.04	1.63	0.41
Brahmandi	86.35111	20.06722	3.63	2.91	0.72
Tentuli Belari	86.36306	20.05861	2.67		
Goda	86.3875	20.10306	2.25	1.8	0.45
Garia	86.42389	20.09194	2.33	1.56	0.77
Jagatsinghpur	86.19528	20.24444	6.5	4.6	1.9
Borikina	86.32556	20.12083	3.27	2.5	0.77
Naradia	86.37861	20.1425	3.25	2.3	0.95
Garh Bishnupur	86.42	20.14083	1.99	1.36	0.63
Ambiki	86.45833	20.15167	2.89	1.84	1.05

Kimilo	86.41861	20.18139	1.97	1.11	0.86
Ersama	86.40389	20.20167	2.08	1.51	0.57
Ebrisingh	86.36528	20.21639	2.66	1.6	1.06
Paida	86.35472	20.17889	4.04	2.01	2.03
Tiran	86.34639	20.23722	5.75	4.65	1.1
Katara	86.27333	20.23056	5	3.6	1.4
Baiganigaon	86.28222	20.18889	4.15		
Dandhashuradeuli	86.22611	20.27722	5.55	3.81	1.74
Taladanda	86.25306	20.30972	4.7	3.55	1.15
Shekhpatana	86.13833	20.29556	7.95	6.18	1.77
Mandasahi	86.10944	20.26917	7.07	6	1.07
Anakhia	86.09194	20.32611	6.49	4.75	1.74
Raghunathpur	86.05333	20.30806	8.11		
	86.05778	20.31528		6.52	
Biridi	86.05306	20.34611	5.68	4.38	1.3
Kaijanga	86.02	20.37861	7.29	6.74	0.55
Sompur	86.07278	20.375	6.05	4.77	1.28
Kishorenagar	86.08944	20.42444		4.64	
Paikarabati	86.09917	20.36222	5.14	3.7	1.44
Raghunathpur	86.15694	20.36	4.77	3.67	1.1
Sadeipur	86.16944	20.31917	6	4.61	1.39
Tarapur	86.22861	20.35389	4.84	4.91	-0.07
Narijanga	86.3025	20.34056	3.62		
Shakheswar	86.34472	20.33917	4.74		
Sampur	86.42167	20.32306	9.14		
Sampur1	86.42194	20.32389		6.27	
Tritol	86.34111	20.3075	4.66	4.08	0.58

Kanakpur	86.29028	20.28361	4		2.9	1.1
Jaipur	86.2675	20.33528	4.92		4.78	0.14
Rahama	86.39722	20.30333	6.1		4.89	1.21
Pandua	86.40528	20.2525	0.7		1.05	-0.35
Irrebina	86.44083	20.21528	3.54		0.78	2.76
Balitutha(Khurantut)	86.47472	20.18	2.17		1.1	1.07
Balitutha	86.52667	20.2375			2.61	
Botiga	86.44917	20.20306	3.23			
Baleipur	86.48556	20.2525	2.43			
Kartutha	86.5	20.285	2.03		1.24	0.79
Kujanga	86.52306	20.31944	4.3		3.62	0.68
Taladanda	86.48444	20.31194	3.42		3.2	0.22
Pankapal	86.4425	20.30278	4.06		3.47	0.59
Paradeep	86.66111	20.26333	4.36	NA	NA	
Sendhakuda	86.65111	20.25222	4.04	NA	NA	
Baliplot	86.65389	20.28972	4.13	NA	NA	
Nehru Banglow	86.7125	20.28833	1.9	NA	NA	
Atharabanki	86.645	20.28611	4.05	NA	NA	
Paradeepgarh	86.61139	20.31667	1.67	NA	NA	
Bhutumundi	86.57361	20.32611	2.46	NA	NA	
Siju	86.58194	20.28806	1.97	NA	NA	
Trilochanpur	86.58083	20.25444	2.58	NA	NA	

Annexure 5: Ground Water Quality

Shallow Aquifer

SL NO.	Village	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3=	HCO3-	Cl-	SO4=	F -
			Micro mhos/ cm	----------mg/l----------											
1	Balia store	8.72	1000	501	285	312	32	50	82.8	25	20.79	338	73	51	0.67
2	Balikuda	8.59	400	215	25	159	6	2	73.8	2.9	6	181	27	8	0.41
3	Bhutmundi	8.29	1370	714	340	238	50	52	145.6	25	0	290	220	79	0.09
4	Erasama-2	8.37	1300	691	325	153	48	50	130.4	28.9	2.97	181	281	61	0.33
5	Kujang	8.41	560	282	190	178	42	21	36.6	8.4	5.94	205	54	14	0.36
6	Nuagaon	8.42	400	190	135	144	34	12	27.7	2.2	5.94	163	24	3	0.13
7	Nuapolabazar	8.4	480	243	170	144	44	15	29.5	5.8	5.94	163	37	26	0.18
8	Paradeepgarh-1	8.33	730	380	200	183	48	19	73.4	6.5	2.97	217	78	45	0.11
9	Raghunathpur	8.14	710	354	250	233	48	32	48.7	0.5	0	284	71	15	0.26
10	Siuli	8.19	760	358	270	238	40	41	50.2	0.4	0	290	71	13	0.33
12	Paradeep	8.2	990	446	235	250	62	19.4	75	14	0	305	124	2	0.1
13	Paradeep	7.7	1220	728	265	415	68	23.1	183	6	0	506	199	1	0.8

Deep Aquifer

Sl No	LOCATION	Lon	Lat	pH	EC	TDS	Hardness	Alkalinity	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F
					Micromhos /cm	----------mg/l----------											
1	Alipingal	**86.15333**	20.2258	6.7	380	171	115	145	26	12.2	17	11	0	177	14	4	0.3
2	Purunagarh	**86.17306**	20.2078	7.1	280	147	115	115	26	12.2	14	2	0	140	18	6	0.2
3	Charbatia	**86.17694**	20.185	7.7	310	228	130	175	26	15.8	42	1	0	214	25	13	0.6
4	Manguliakanta	**86.18417**	20.1558	8.1	370	236	110	145	26	10.9	51	3	0	177	43	15	0.5
5	Ghodansha	**86.19778**	20.135	7.8	380	227	95	155	20	10.9	58	2	0	189	32	11	0.5
6	Naugaon	**86.18806**	20.1036	8.1	400	273	150	205	30	18.2	52	4	0	250	39	7	0.5
7	Shikhar	**86.17528**	20.0783	7.8	960	541	395	130	84	45	51	9	0	159	259	15	0.3
8	Mutunia	**86.22556**	20.0358	7.8	2050	1439	215	390	26	36.5	434	32	0	476	266	411	0.5
9	Deriki	**86.22333**	20.0736	8	1190	306	85	140	14	12.2	91	6	0	171	89	10	0.6
10	Dhiasahi	**86.21833**	20.2111	7.9	650	307	110	195	20	14.6	80	2	0	238	46	28	0.6
11	MadhuriBazar	**86.24611**	20.1703	7.9	480	281	110	215	14	18.2	74	3	0	262	32	11	0.5
12	Balikuda	**86.27444**	20.1344	8.1	440	302	100	215	18	13.4	84	3	0	262	39	16	0.6
13	Machhagaon	**86.27444**	20.0714	8.2	580	411	230	225	56	21.9	70	6	0	275	89	33	1.1
14	Balipatana	**86.32889**	20.0472	7.7	940	726	290	90	46	42.5	155	16	0	110	333	80	0.5
15	Marichpur	**86.35306**	20.0092	7.9	430	162	135	125	20	20.7	12	2	0	153	21	11	0.1
16	Brahmandi	**86.35111**	20.0672	7.6	940	546	315	175	70	34	75	17	0	214	174	71	0.1
17	Tentuli Belari	**86.36306**	20.0586	7.7	1110	620	240	140	34	37.7	85	60	0	171	128	192	0.1
18	Goda	**86.3875**	20.1031	7.5	1050	627	280	45	34	47.4	82	30	0	55	149	258	0.1
19	Garia	**86.42389**	20.0919	7.5	1330	800	320	60	74	32.8	143	21	0	73	308	185	0.1
20	Jagatsinghpur	**86.19528**	20.2444	7.8	770	262	190	210	30	27.9	33	3	0	256	21	22	0.3
21	Borikina	**86.32556**	20.1208	8	1526	1358	255	290	48	32.8	433	7	0	354	500	164	0.4
22	Naradia	**86.37861**	20.1425	7.8	940	565	345	245	72	40.1	83	6	0	299	145	72	0.2
23	Garh Bishnupur	**86.42**	20.1408	7.8	1790	969	840	480	22	190.8	88	3	0	586	358	20	2.1
24	Ambiki	**86.505**	20.1589	8.3	2390	1644	1005	205	290	68	202	16	0	250	826	119	0.2
25	Kimilo	**86.37139**	20.1325	8	2190	1066	630	185	138	69.3	161	7	0	226	482	98	0.2

26	Ersama	**86.40389**	20.2017	7.6	1700	768	415	210	98	41.3	133	6	0	256	316	48	0.3
27	Ebrisingh	**86.36528**	20.2164	7.9	1560	819	490	260	116	48.6	130	8	0	317	326	35	0.2
28	Paida	**86.35472**	20.1789	8	1090	515	350	305	54	52.2	69	5	0	372	124	29	0.3
29	Tiran	**86.34639**	20.2372	8.1	1260	798	285	285	62	31.6	188	25	0	348	230	91	0.5
30	Katara	**86.29639**	20.2675	8.2	790	356	210	240	34	30.4	62	3	0	293	60	23	0.5
31	Baiganigaon	**86.31333**	20.2336	8.2	1430	999	200	240	34	27.9	302	10	0	293	337	145	0.6
32	Dandhashuradeuli	**86.27667**	20.2617	8.1	1040	467	290	245	62	32.8	70	2	0	299	99	55	0.6
33	Taladanda	**86.27083**	20.2997	8.2	550	261	180	170	40	19.4	32	3	0	207	57	8	0.5
34	Shekhpatana	**85.895**	20.4339	8	400	223	165	180	40	15.8	25	2	0	220	25	7	0.4
35	Mandasahi	**86.18361**	20.2583	8.1	420	252	155	185	54	4.9	38	3	0	226	25	16	0.4
36	Anakhia	**86.19528**	20.2444	7.5	420	162	115	105	26	12.2	16	4	0	128	39	2	0.9
37	Raghunathpur	**86.0775**	20.3497	7.6	210	101	70	70	24	2.4	11	3	0	85	11	8	0.1
38	Biridi	**86.03389**	20.2678	7.7	220	131	100	100	28	7.3	11	3	0	122	21	1	0.2
39	Kaijanga	**86.02**	20.3786	7.7	260	149	115	130	30	9.7	14	2	0	159	11	4	0.2
40	Sompur	**86.07278**	20.375	7.8	200	114	90	90	22	8.5	12	2	0	110	14	2	0.1
41	Paikarabati	**86.09917**	20.3622	7.9	250	137	105	100	30	7.3	13	2	0	122	25	0	0.2
42	Raghunathpur	**86.15694**	20.36	8	350	185	155	160	38	14.6	14	3	0	195	21	0	0.1
43	Sadeipur	**86.16944**	20.3192	7.7	480	245	205	190	48	20.7	17	3	0	232	39	4	0.2
44	Tarapur	**86.22861**	20.3372	7.6	450	217	175	145	44	15.8	17	3	0	177	50	0	0.2
45	Narijanga	**86.3025**	20.3406	7.9	450	207	110	130	26	10.9	17	31	0	159	39	5	0
46	Shakheswar	**86.34472**	20.3392	7.8	280	166	110	115	28	9.7	13	13	0	140	28	6	0.1
47	Sampur	**86.42167**	20.3231	7.8	2830	2077	270	320	38	42.5	734	7	0	390	964	100	0.2
48	Tritol	**86.34111**	20.3075	8.2	1545	1124	90	295	6	18.2	263	202	0	360	376	82	0.6
49	Kanakpur	**86.29028**	20.2836	8.1	670	430	35	230	6	4.9	147	22	0	281	71	41	0.2
50	Jaipur	**86.2675**	20.3353	8	600	361	160	175	34	18.2	81	4	0	214	99	20	0.3
51	Rahama	**86.39722**	20.3033	7.7	750	385	185	205	42	19.4	79	6	0	250	96	20	0.2
52	Pandua	**86.40528**	20.2525	8.1	1030	650	70	235	10	10.9	214	29	0	287	230	15	0.3
53	Irrebina	**86.44083**	20.2153	7.8	790	414	175	245	46	14.6	89	6	0	299	78	34	0.1
54	Balitutha	**86.47472**	20.18	7.4	1820	1313	565	170	140	52.2	258	21	0	207	674	66	0.1
55	Botiga	**86.44917**	20.2031	7.7	1110	567	280	245	50	37.7	98	16	0	299	163	56	0.1
56	Baleipur	**86.48556**	20.2525	7.6	1580	1087	465	175	90	58.3	231	20	0	214	546	37	0.1

57	Kartutha	**86.5**	20.285	8	500	241	190	205	46	18.2	17	9	0	250	28	0	0.1
58	Kujanga	**86.52306**	20.3194	7.6	1300	680	385	190	68	52.2	98	21	0	232	280	47	0.1
59	Taladanda	**86.48444**	20.3119	8.2	2570	1470	85	505	10	14.6	540	25	0	616	482	97	0.9
60	Pankapal	**86.4425**	20.3028	7.7	5190	241	105	65	30	7.3	50	4	0	79	74	37	0.1
61	Paradeep	**86.66056**	20.2672	8.2	2040	1154	60	440	12	7.3	440	11	0	537	418	3	0.7
62	Sendhakuda	**86.65111**	20.2522	8.3	2120	1200	50	460	14	3.6	469	9	0	561	429	1	0.9
63	Baliplot	**86.65389**	20.2897	8.2	1490	876	60	335	14	6.1	324	9	0	409	266	56	0.3
64	Atharabanki	**86.645**	20.2861	7.9	1445	792	335	345	54	48.6	175	10	0	421	255	43	0.3
65	Paradeepgarh	**86.61139**	20.3167	7.4	1515	989	345	250	80	35.2	170	102	0	305	308	144	0
66	Bhutumundi	**86.57361**	20.3261	8.2	2065	1115	450	505	48	80.2	232	41	0	616	305	107	0.2
67	Siju	**86.58194**	20.2881	8.2	1960	1349	245	275	44	32.8	437	10	0	336	659	2	0.1
68	Trilochanpur	**86.58083**	20.2544	7.7	6150	2328	1330	135	184	211.4	232	186	0	165	1333	101	0

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