केन्द्रीय भूमि जल बोर्ड
जल संसाधन, नदी विकास और गंगा संरक्षण
विभाग, जल शक्ति मंत्रालय
भारत सरकार
Central Ground Water Board
Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

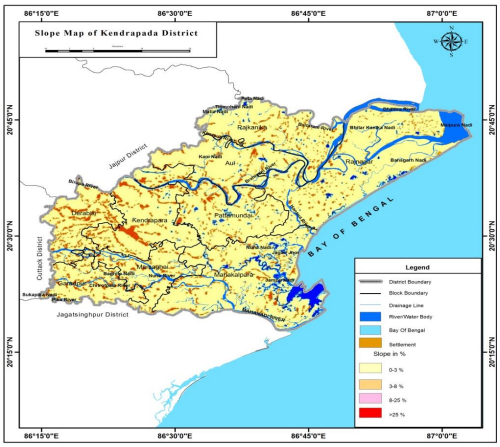
Kendrapara District
Odisha

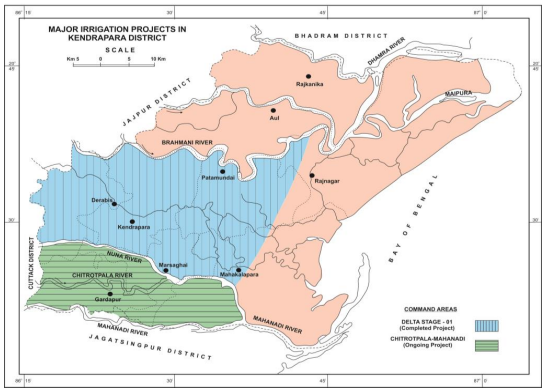
दक्षिण पूर्वी क्षेत्र, भुवनेश्वर
South Eastern Region, Bhubaneswar

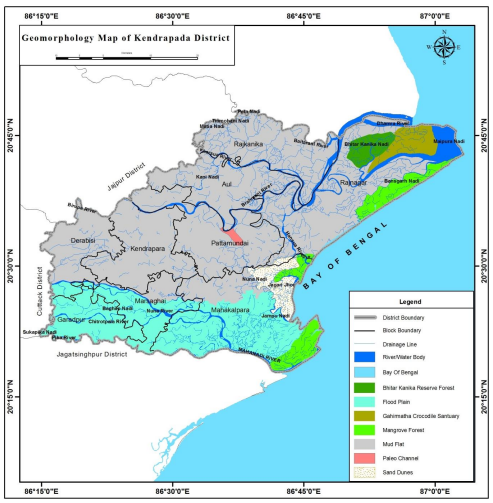
Government of India

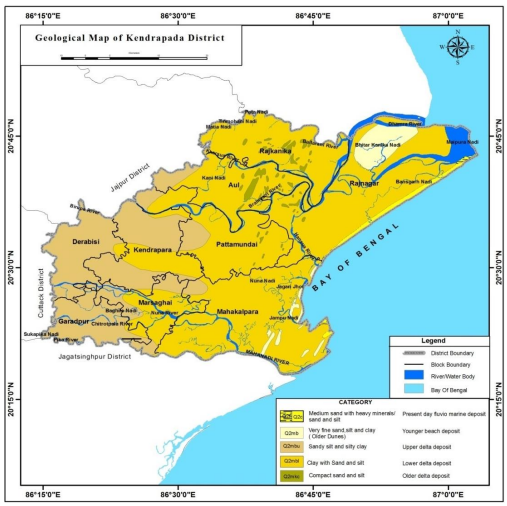
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

Report on
NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN
KENDRAPARA DISTRICT, ODISHA









CENTRAL GROUND WATER BOARD
SOUTH EASTERN REGION,
BHUBANESWAR-751030

Forward

Kendrapara district is one of the coastal districts in eastern part of Odisha. It was carved out of the erstwhile district of Cuttack. It is situated in Central Coastal Plain Zone of Odisha. The district covers an area of 2, 644 sq km and has 14.40 lakhs of population as per 2011 census. The rural and urban population is 1356827 and 83534 respectively. The level of urbanization stands at 5.80% of the total district population as against the 1.20% in the State. The district is characterised by a lush green patch of land crisscrossed by a network of rivers, creeks and rivulets with unique Bio-Diversity, splendid wildlife diverse flora and fauna.

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

The vast alluvial deposits form the main repository of ground water in the District. The phreatic aquifer is commonly been tapped by dug wells and shallow tube wells and are commonly been used both for domestic and irrigational use. The presence of saline formations makes the area hydro-geologically complex and hence necessary precautionary measures are to be taken care of for extensive ground water extraction.

Groundwater irrigation practices can insure increased agricultural production by enhancing the area irrigated and scope of irrigation. Apart from irrigation, drinking water scarcity can also be mitigated through judicious utilization of groundwater. The present stage of groundwater development is only 58.23%, leaving a vast scope for future groundwater development in the district. Groundwater irrigation practices can ensure increased agricultural production by enhancing the area irrigated and scope of irrigation.

Based on the available data and the earlier hydrogeological studies, an attempt has been made in this report to compile all relevant information, such as hydrogeological, agriculture, irrigation, land use, rain fall, chemical quality of water and other collateral data. Shri. G. Prasad, Scientist-'D' has compiled and prepared the present report on "**Aquifer Mapping and Management Plan in Kendrapara District, Odisha"**. Their sincere efforts in preparation of the report will no doubt be very useful and benefit the state. It is hoped that, it will be of immense help to different groundwater user agencies, administrators and planners in preparation of groundwater development plans and will be a handy tool in effective management of groundwater resources in the district.

Place: Bhubaneswar **(P. K. Mohapatra)**
Date: 21.09.2022 **Regional Director**

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A REPORT ON AQUIFER MAPPING AND MANAGEMENT PLAN OF KENDRAPARA DISTRICT, ODISHA

CONTENT

A REPORT ON AQUIFER MAPPING AND MANAGEMENT PLAN OF KENDRAPARA DISTRICT, ODISHA

CHAPTER-1

INTRODUCTION

1.0: Introduction: National Aquifer Mapping and Management Programme (NAQUIM) was launched in 2012 by the Ministry of Water Resources (now Ministry of Jal Shakti) with the aim to identify and map aquifers at the micro level to quantify the available groundwater resources.

As a part of implementation of this programme an integrated study of aquifer mapping and its management plan was taken up in the Kendrapara district of Odisha by CGWB, SER, Bhubaneswar in its AAP 2016-17.

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from "groundwater development" to "groundwater management". As large parts of India particularly has become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization and changing life style. Therefore, in order to have an accurate and comprehensive micro-level picture of groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through community participation.

1.1: Objective: The main objective of the study is to identify and map the available aquifer system down to 300 m depths, its geometry, vertical and lateral extension and characteristics in terms of quantitative and qualitative availability of ground water resource in time and space and accordingly to suggest and formulate ground water management plans for sustainable development and management of coastal alluvial aquifers of the Kendrapara district.

1.2: Scope of the study: The main scope of study is as below.

1. Compilation of existing data (exploration, geophysical, groundwater level and ground water quality with geo-referenced information and identification of principal aquifer units.
2. Periodic long term monitoring of ground water regime (for water levels and water quality) for creation of time series data base and ground water resource estimation.
3. Quantification of groundwater availability and assessment of its quality.
4. To delineate aquifer in 3-D along with their characterization on 1:50, 000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, through information dissemination, education, awareness and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management .

1.3: Approach and Methodology: Multi-disciplinary approach involving geological, geophysical, hydrological, hydrogeological and hydro-geochemical studies were taken out in toposheet scale (1:50000) to meet the aim and objectives listed above. GIS plate form was used to prepare the maps. Following steps were taken.

A. **Compilation of Existing data and identification of Data gaps:** Preliminary work was collection and review of existing data related to the area available with Governmental organization. In this regard ground water exploration data available with CGWB, State agencies and local administrations was collected and compiled to identify the data gaps in the study area. After the data compilation all the data were integrated and analysed.
B. **Hydrogeological studies**: Establishment and monitoring of key observation wells representing the different aquifers. Village wise well inventories were done and thus collected were analysed and processed. Aquifer Performance test was conducted to determine the aquifer parameters.
C. **Hydrochemical Studies:** Water Samples were collected, analyzed and interpreted to bring out ground water quality scenario of the study area.
D. **Geophysical studies:** VES were conducted for assessment of sub surface ground water conditions.
E. **Data Analysis**: Compilation, processing and analysis of these data were done to generate following thematic maps.
    1. Drainage
    2. Soil
    3. Land use and land cover
    4. Geomorphology
    5. Geology
    6. Hydrogeological map
    7. Aquifer disposition
    8. Ground Water Quality
F. Studies of ground water related issues and preparation of management plan: Based on the above data assessment of ground water issues were done and accordingly ground water development and management plan was prepared.

1.4: Area Details: Kendrapara district is one of the coastal districts in eastern part of Odisha. It was carved out of the erstwhile district of Cuttack. It is situated in Central Coastal Plain Zone of Odisha. The district is bounded by Bhadrak district at its North, Jajpur at its North West, Jagatsinghpur district at its South, Cuttack District at its West and Bay of Bengal at its East. Kendrapara district lies in 20° 20’ N to 20°7’ N Latitude and 86° 14’ E to 87° 01’ E Longitude and fall under Survey of India toposheet No 73 L and 73K. The Coastline of Kendrapara District covers 48 Km stretching from Dhamra Muhan to Batighar.

Headquarters of Kendrapara District is well known as the Tulasi Khetra. Kendrapara district was created form the mother district Cuttack on 1st April, 1993. Kendrapara is the administrative headquarters of Kendrapara District. The district covers an area of 2, 644 sq km. The district is characterised by a lush green patch of land crisscrossed by a network of rivers, creeks and rivulets with unique Bio-Diversity, splendid wildlife diverse flora and fauna.

The District constitutes coastal and delta areas in a transitional environment at the interface of terrestrial and unique marine and ecosystems. Because of its geographical location ecological diversity and environmental importance the district occupies one of the most promising and prosperous district of the country.

There are many prominent tourist places in Kendrapara District. One of the famous spot is 'Bhitara Kanika National Park'. Most popular Buddhist Shrines, Udaya Giri and Ratna Giri are just 10–15 km drive from Kendrapara. Sri Baldevjew Temple is the most popular temple of the District. Kendrapara is known as Tulashi Kshetra. Kendrapara District celebrates many festivals round the year like Ratha Yatra, Gaja Laxmi Puja , Durga Puja, Dola Yatra.

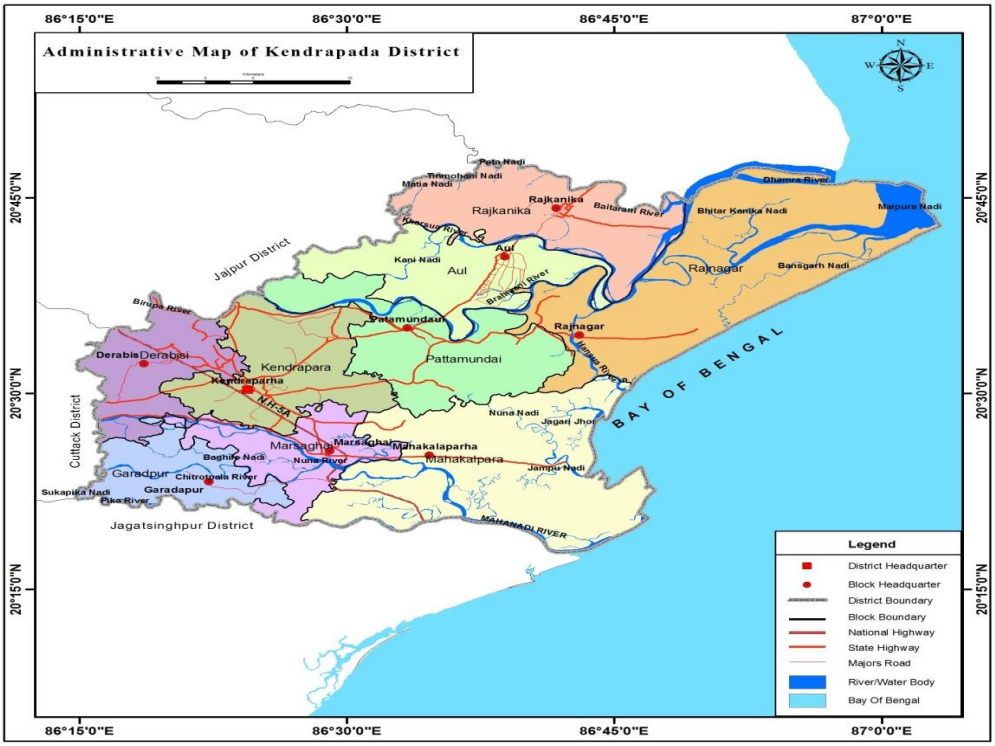


Fig-1.1: Administrative Map of Kendrapara District.

1.5: Brief Description and Socio-Economic Condition: The Kendrapara district is having 1 subdivision (Kendrapara) and 9 community development blocks. These are Aul, Derabis, Garadpur, Kendrapara, Mahakalpara, Marshaghai, Pattamundai, Rajkanika and Rajnagar etc. As shown in map-1.1. This district is having two towns/urban areas, viz.,Kendrapara and Pattamundai. Kendrapara comes under municipality while Patamundai is notified area council (NAG). There are total 1592 villages in the district comprising 1,440,361 population as per 2011 census. In the present scenario of administrative set up, there are 9 Blocks, 9 Tahsils, 1 Sub-division (Kendrapara) in the district. There is 249 gram Panchayats, 15 Police stations, 2 ULBs functioning in the district. Kendrapara Municipality was established in 1869, first Municipality of Odisha.

As per census 2011, the district accounts for 1.70 % of the states territory and shares 3.43 % of the state's population. The density of population of the district is 545 persons/ sq.km as against 270 persons/ sq.km of the state. The schedule caste population is 309780 (21.5%) and schedule tribe population 9484 (0.7%). Kendrapara is the 28th urbanised district in state having only 5.80% of its population live in urban areas as against 16.69 percent of state's population living in urban areas. The rural population of the district is 1,356,827 where as the urban population is 83,534 which are of 94.20% and 5.80% of the total population respectively. A sizeable section of Muslim population is also there in the district which is about 5.6% of the total population. Two urban bodies of this district are Kendrapara Municipality and Pattamundai NAC having a geographical area of 10.77 and 2.54 sq.km with

7208 and 6233 households respectively. Mohakalpara block is the most populous CD block in the district with a total population of 212463 followed by Rajnagar with a total population of 170, 110.

Its population growth rate over the decade 2001-2011 was 10.59%. Kendrapara district has a sex ratio of 1006 females for every 1000 males and a literacy rate of 85.93% against 72.9% of the state. The mother tongue of most of the people here is Odia. There is a sizable number of Bengali and Urdu speaking people. Hindi is also widely understood. The economy of the district is mainly dependent upon cultivation. Out of 100 workers in the district 68 are engaged in agricultural sector. Flood, cyclone and tornado are a regular phenomenon in the district due to its proximity to the coastal belt.

Table-1.1: Demography of Kendrapara District

Sl. No	Name of Block	No. of GP	No. of Villages	Population					
				Male	Female	Total	SC	ST	General
1	Kendrapara	27+1M	136	75827	75309	151136	37591	775	113545
2	Derabish	26	177	73866	70722	144588	36415	730	108173
3	Marshaghai	23	109	64606	62353	126959	23205	648	103754
4	Mahakalpara	27	223	107889	104574	212463	37409	3577	175054
5	Garadpur	18	137	55910	54706	110616	23906	121	86710
6	Pattamundai	30+1NAC	148	79064	83284	162348	45976	280	116372
74	Aul	32	132	65371	74257	139628	35754	459	103874
8	Rajkanika	29	168	66579	72400	138979	31859	51	107120
9	Rajnagar	18	310	85941	84169	17010	21576	2221	148534
	Total including urban	230+2	1540	675053	681774	1356827	293691	8862	1063135

1.6: Data Availability: Following data were available and utilized for preparation of this report.

1. **Data of ground water regime monitoring**: Ground water regime monitoring is done 4 times in a year i.e. in the month of January, April, August and November through 47 No of National Hydrograph Stations. So historical data of NHSs and generated hydrographs were used to study ground water level trends in seasonal and periodic manners.
2. **Ground Water Exploration Data**: Ground water exploratory well data of 30 wells (EWs, OWs and piezometers) were available and used in the preparation of this report. This includes litholog, electrical logs, water bearing granular zones, hydro-chemical profiles, design of wells and aquifer parameters etc.
3. **Maps**: various thematic maps related to area such as geological, geomorphological, Physiographic, soil, drainage maps are available and utilised in this report.
4. **Quality of ground water:** Hydrochemical data of Exploratory wells and NHSs were available but data of current monitoring of Key observation wells were used in this report.

1.7: Data Adequacy, Data Gap Analysis and Data Generation: The available data of the exploratory wells drilled by C G W B (SER), Bhubaneswar and ground water regime data through National Hydrograph Stations were compiled and analysed for adequacy of the

same for the aquifer mapping studies. The data adequacy and data gap analysis were carried out for the whole district. These are as below.

Table-1.2 : Data adequacy, Data Gap Analysis and Data Generation (Figures in number)

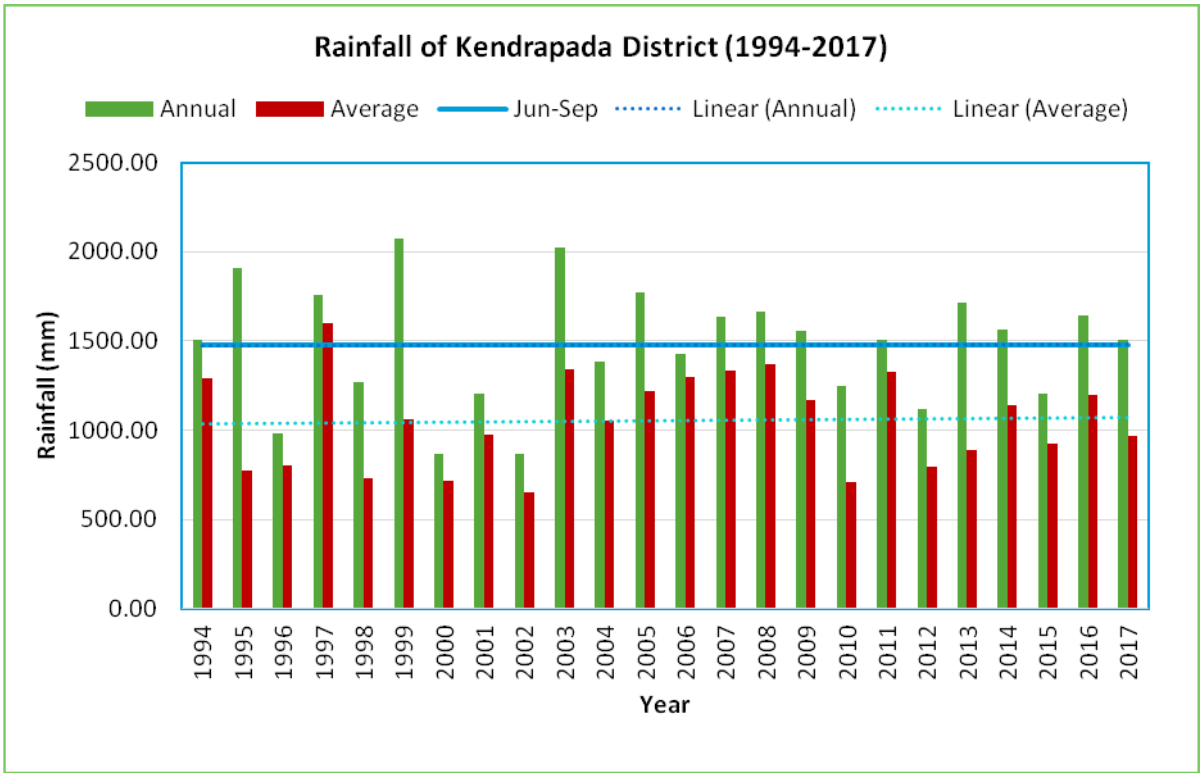
S. No	Types of data	Required data	Exis ting	Data filled up	Data Gap	Remarks
1	Exploratory wells	53	30	0	23	EWs are not uniformly distributed
2	Monitoring wells	27	29	-	0	Adequate data is available
3	Water quality	27	29		0	Adequate data is available
4	VES	53	0	36	17	VES are not uniformly distributed.

1.8: Rainfall: Average annual rainfall of Kendrapara is 1556 mm in 52.96 rainy days, out of which 80% rainfall occurs in monsoon season (June to September). The district experiences tropical hot and humid climate, with the summers being hot and the winter cold. The maximum temperature is 42.04°C (during summers) and the minimum at 12.8°C (during winters). Summers generally last from March to May and winters, from October to February. Rainfall is generally heavy during the monsoons, which occur during the months of June to September. South West monsoon is primarily responsible for the rainfall in this district.

Table1.3- Climatic condition of Kendrapara District

Blocks	Block Area (Sq.km.)	Normal Annual Rainfall (mm)	No. of Rainy Days (No.)	Average Weekly Temperature (^{0}C)					
				Summer (Mar. – May)		Winter (Oct.-February)		Rainy (June-Sept.)	
				Min.	Max.	Min.	Max.	Min.	Max.
Kendrapara	239.86	1637	55.33	30.6	42.04	12.08	33.8	22	34.5
Derabish	171.4	1773	53.00	30.6	42.04	12.08	33.8	22	34.5
Marshaghai	159.65	1544	53.67	30.6	42.04	12.08	33.8	22	34.5
Mahakalpara	490.57	1690	57.67	30.6	42.04	12.08	33.8	22	34.5
Garadpur	141.54	1069	47.67	30.6	42.04	12.08	33.8	22	34.5
Pattamundai	258.66	1627	44.67	30.6	42.04	12.08	33.8	22	34.5
Aul	224.45	1532	61.33	30.6	42.04	12.08	33.8	22	34.5
Rajkanika	263.49	1778	55.33	30.6	42.04	12.08	33.8	22	34.5
Rajnagar	346.25	1470	48.00	30.6	42.04	12.08	33.8	22	34.5
Total	**2644**	**1556**	**52.96**	**30.6**	**42.04**	**12.08**	**33.8**	**22**	**34.5**

Temporal Variation of Rainfall of Kendrapada District: The degree to which rainfall amounts vary in an area at different time period is an important characteristic of the climate of an area. The annual average rainfall (1994-2017) of Kendrapada district is 1474.5 mm. Around 72% of its annual rainfall is received during the four months of monsoon (Jun-Sep). Highest annual rainfall of 2072 mm received in the year 1999 and highest southwest monsoon rainfall of 1597 mm received in the year 1997.

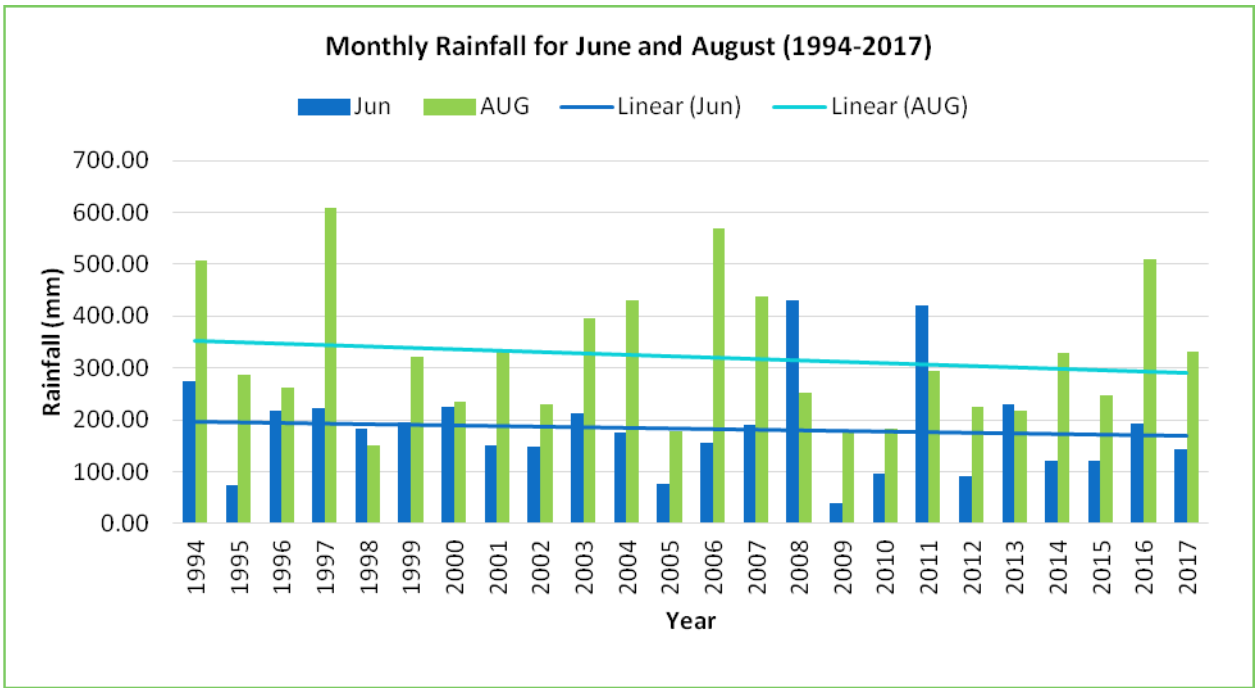


During the last 24 years, highest rainfall of June, July, August and September received in the year 2008, 2009, 1997, and 2008 respectively (431 mm, 589 mm, 608 mm, and 509 respectively). And the average rainfall in different months of monsoon is shown in the table below. It can be seen that district gets highest rainfall (22%) of annual rainfall in August month while the July month get 20% of the annual rainfall. September and June receive 17% and 12% of annual rainfall respectively. The variability of monsoon and annual rainfall is also very less (25% and 23% respectively).

Table-1.4: Variability of Monsoon Rainfall in Kendrapara District

Period: 1994-2017	**JUN**	**JUL**	**AUG**	**SEP**	**JUN-SEP**	**Annual**
Average (mm)	182.73	296.44	321.21	254.63	1055.00	1474.57
Percentage Distribution	12%	20%	22%	17%	72%	100%
Coefficient of Variation	52%	44%	40%	47%	25%	23%

Neither annual rainfall nor monsoon rainfall shows any significant trend. The rainfall in the month of June and August shows increasing trend while the rainfall in the month July and September shows decreasing trend as shown in the figure below.


Monthly Rainfall for June and August (1994-2017)
Jun
AUG
Linear (Jun)
Linear (AUG)
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Rainfall (mm)
1994
1995
1996
1997
1998
1999
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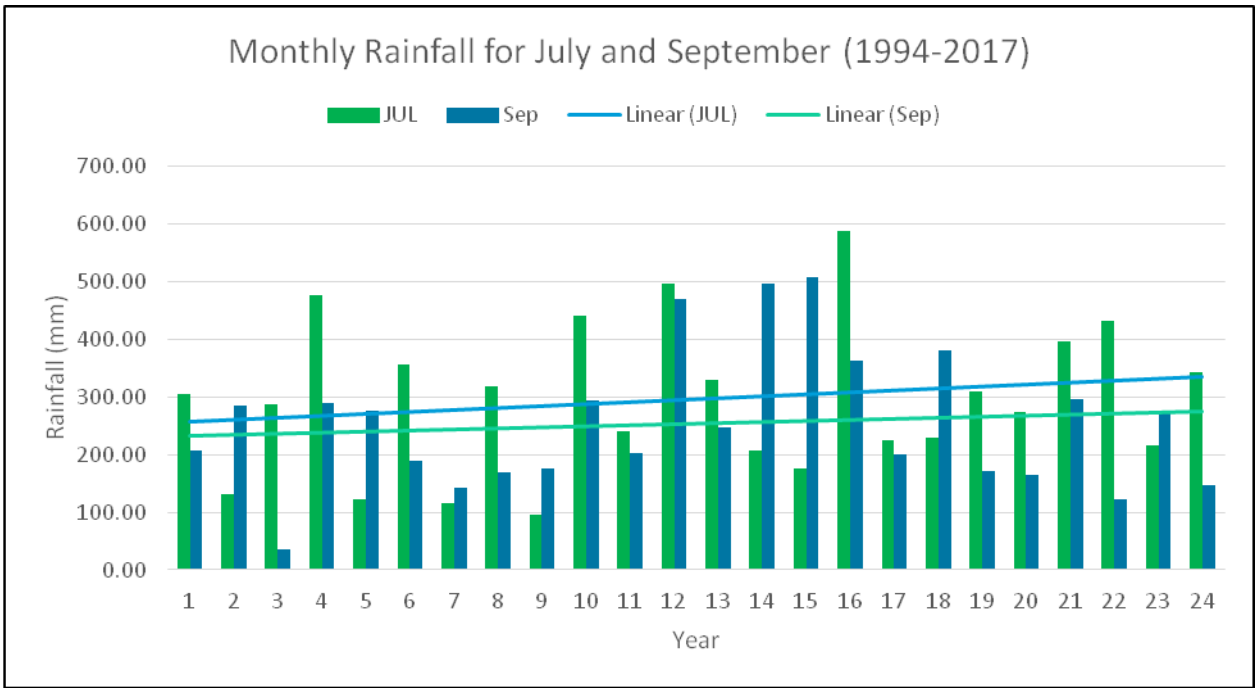
Monthly Rainfall for July and September (1994-2017)
JUL
Sep
Linear (JUL)
Linear (Sep)
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Rainfall (mm)
1
2
3
4
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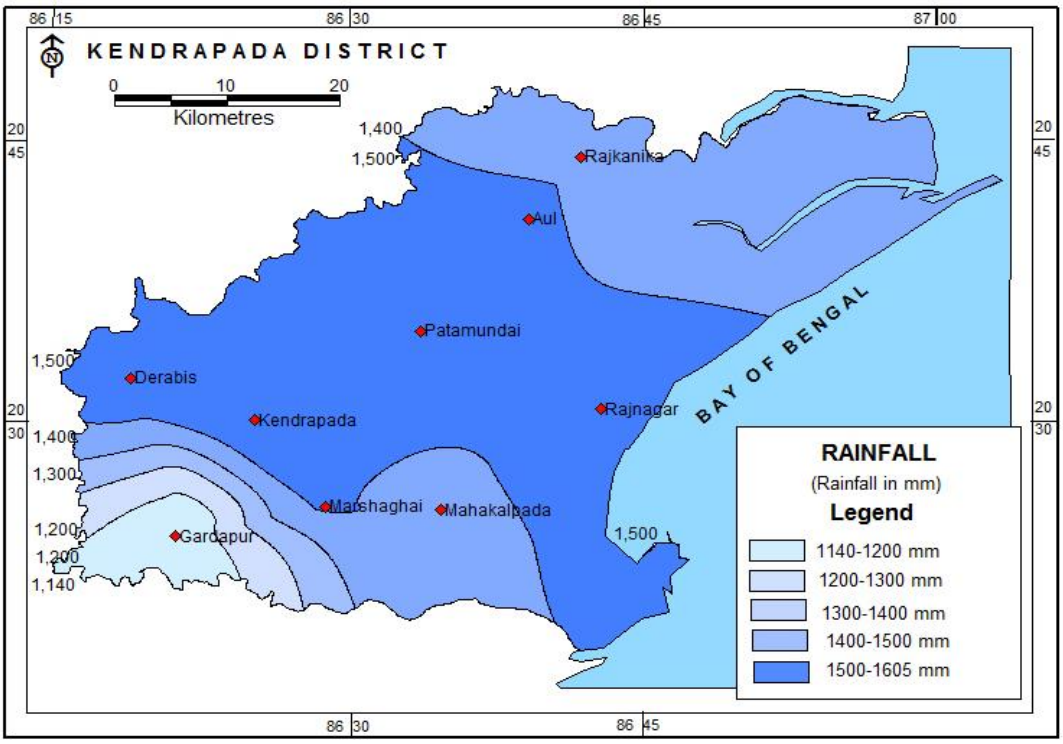
Year



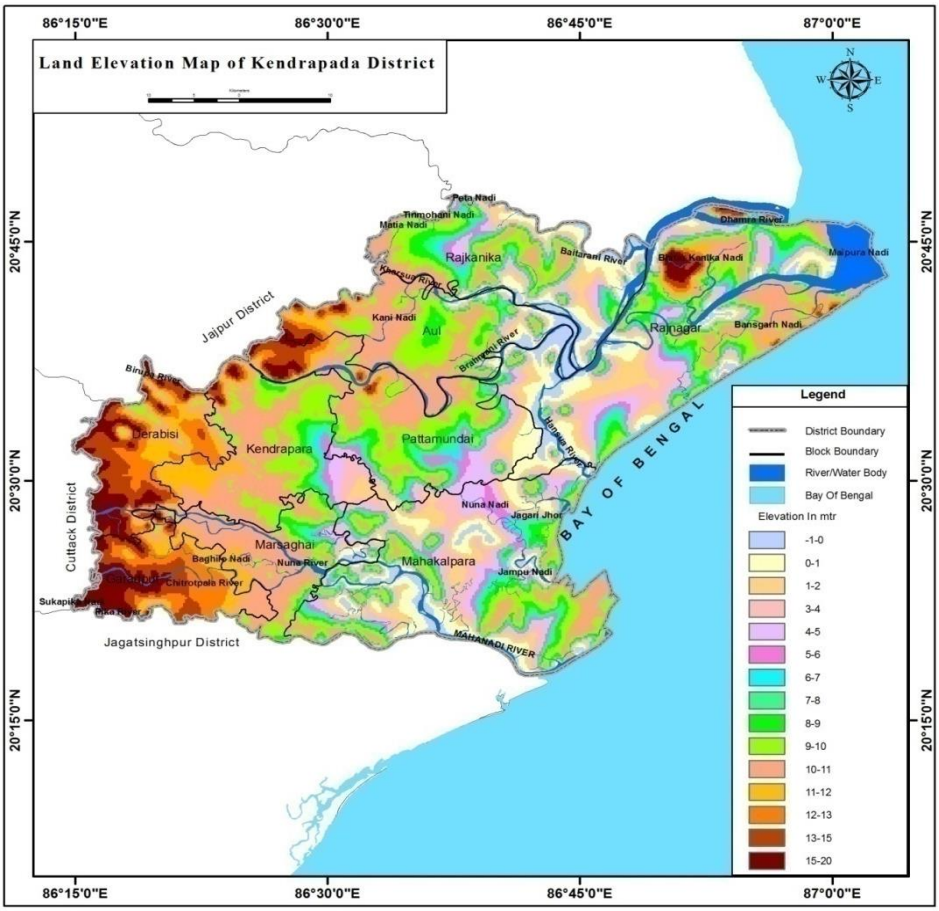
Map-1.2: Spatial distribution of Rainfall in Kendrapara district

1.9: Physiography: Physiographically the district can be broadly divided into two distinct units, Viz,

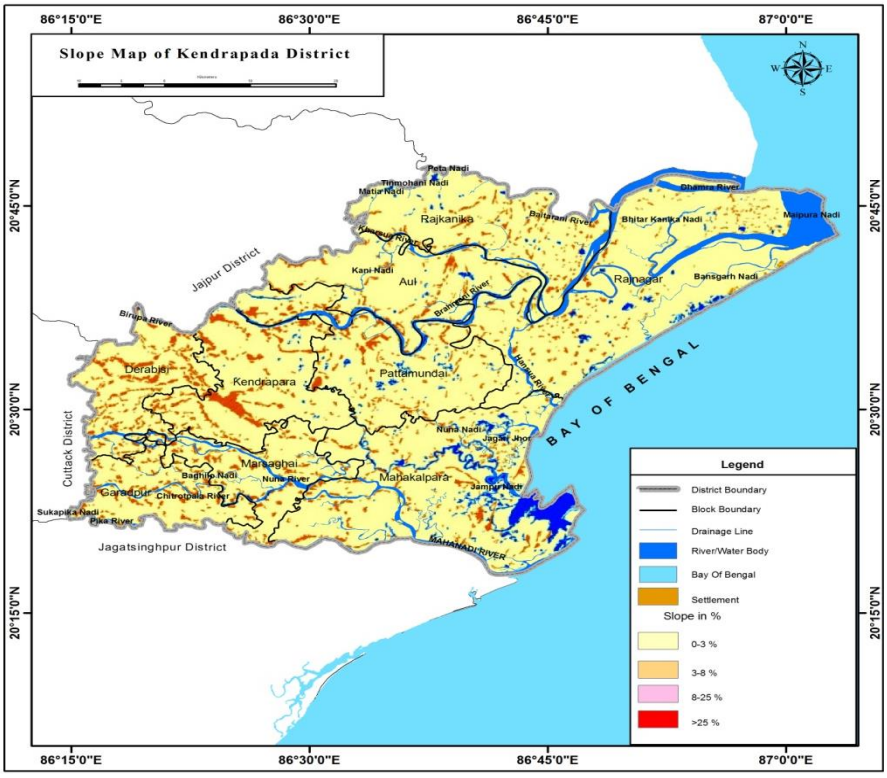
1. The Saline Marshy tract along the coast
2. The very gently sloping plain.

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 covered by shrubby vegetation. Sand dunes of varied relief (6 to 3m amsl) extend for kilometers, occur parallel to the coast. The sand dunes are gently sloping on the bay side and slope steeply on land side because of their aeolian origin.

The gently sloping alluvial plain with the altitudes varying between 10.5m amsl in the north western part to 2.15 m amsl in the east occurs in the west of the saline marshy tract and form most fertile part of the district. The general slope of the district is towards east and south east and varies from 5 m/km in the west to 1.6 m/km. in the ea stern part. Physiographic map is shown as below.



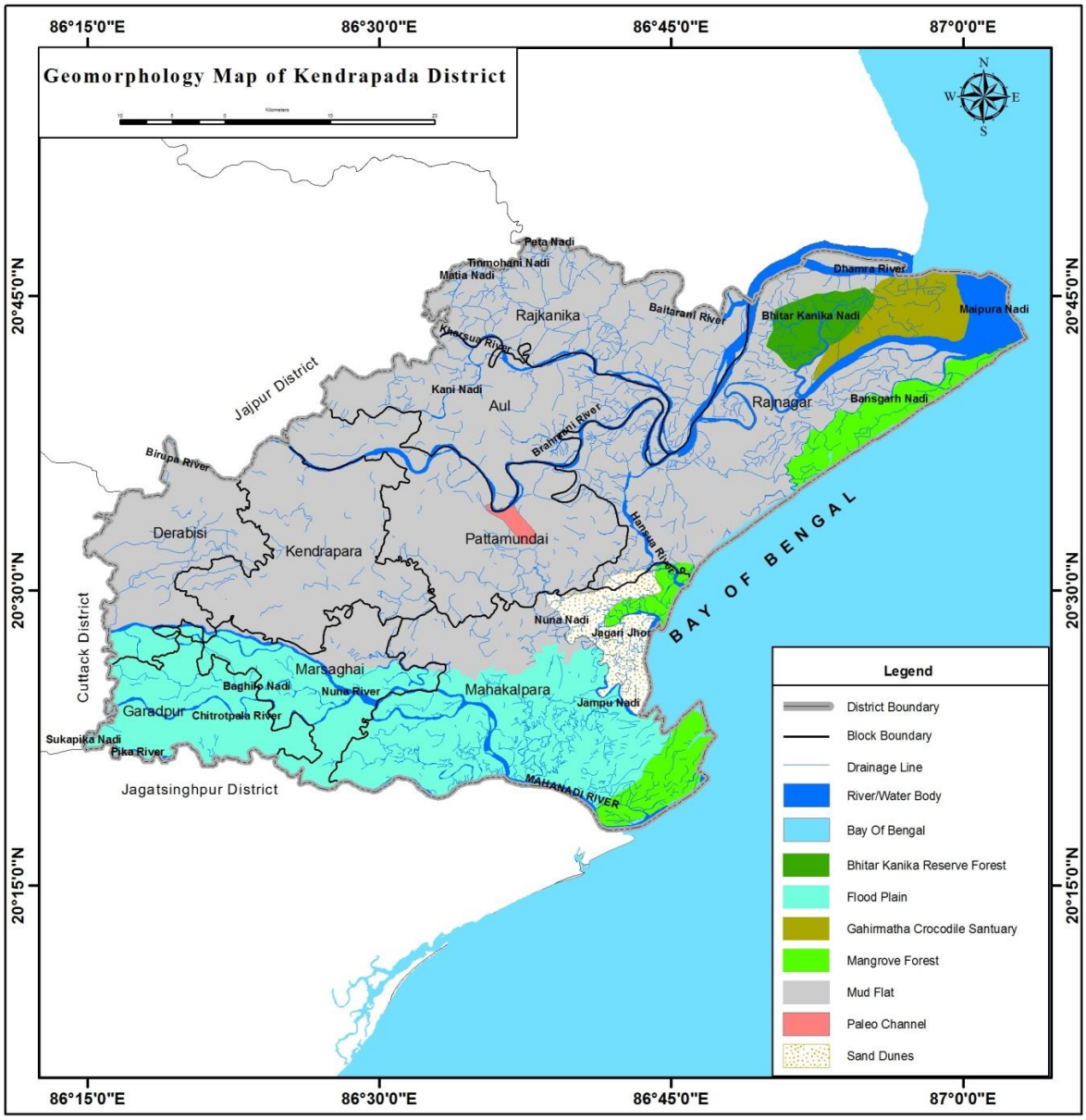
Map-1.3: Elevation Map of Kendrapara District



Map-1..4: Slope Map of Kendrapara District

1.10: Geomorphology: Geomorphologically the district can be broadly divided into four distinct units as shown in following map. These are as below.

1. **Mud flats:** It consists of upper zone of tidal flats formed due to depositional process dominated by the fallout of suspended sediments comprising sortable silts, flocks and aggregates. It is largest geomorphic features in the district. World famous Bhitar Kaniaka reserved forest comprising mangrove forests, Gahirmatha crocodile parks are found in these mud flats.
2. Flood planes
3. Sand dunes and
4. Paleo channel



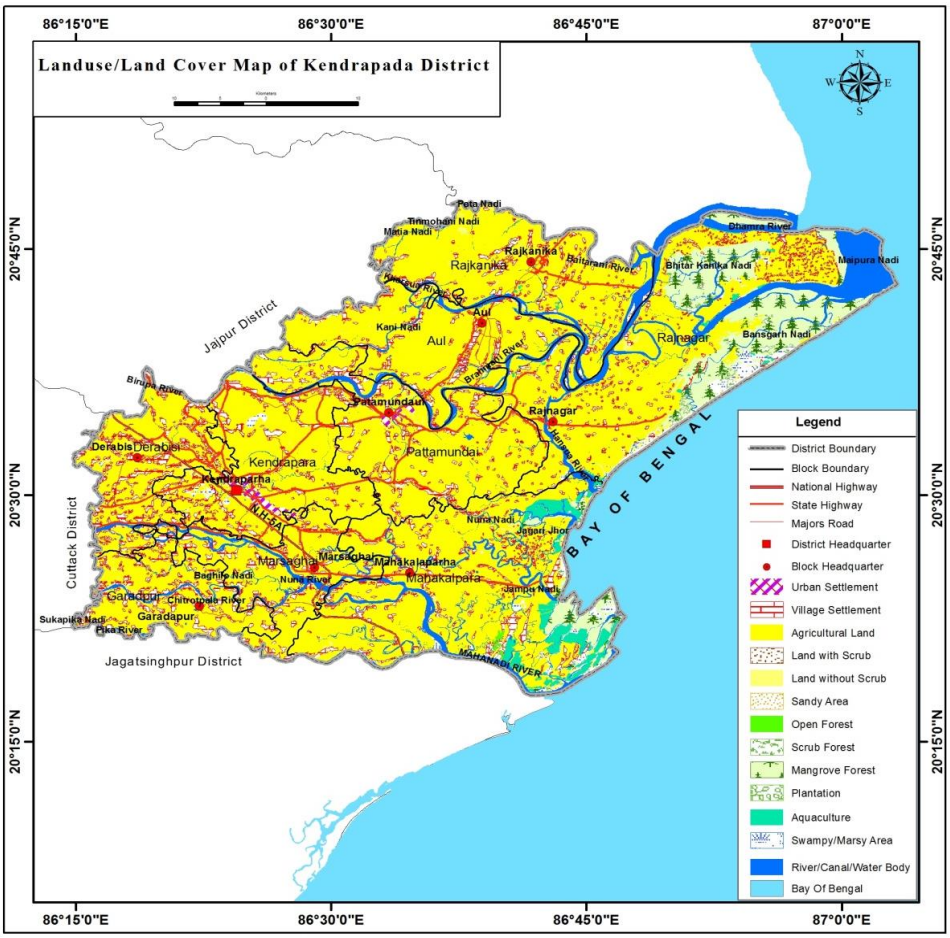
MAP-1.5: Geomorphological Map of Kendrapara District

1.11: Land Use pattern: Out of total geographical area of 2, 30,918 ha, cultivated area is 1, 45,096 ha with cropping intensity of 194 %. The total cropped area during kharif and rabi season area 1,73,089 ha and 114,277 ha respectively. Out of which, irrigated are during kharif, rabi and summer is 86,132 ha, 38,426 ha and 25,623 ha respectively. Maximum area is under irrigation due to large network of rivers and canal distributaries in the Kendrapara district. Out of total irrigated area, nearly 46,727 ha are covered under canal irrigation and have assured irrigation in Kharif season. Still 1, 24,558 ha area is under rain fed cropping

system in the district. Net sown area in the district is 1, 45,096 ha. Area under forest cover is 3552 ha. The block wise land use status is tabulated as below and land use map of the district is presented in following figure/ map.

Table- 1.5: Land Use Pattern of Kendrapara District (Area in Ha)

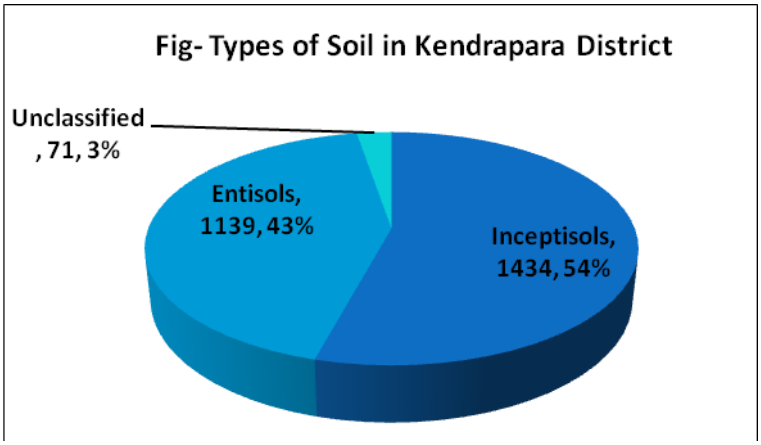
Block	Total Geographical Area,	Area under Agriculture, ha				Area under Forest	Area under Wasteland	Area under other uses,
		Gross Copped area	Net Sown area	Area sown more than once	Cropping Intensity (%)			
Kendrapara	25063	34445	18122	16323	190.07	0	906	1534
Derabish	171410	30525	14271	16254	213.90	0	183	231
Marshaghai	15965	21431	10379	11052	206.48	19	115	936
Mahakalpara	49057	50696	27455	23241	184.65	2811	2391	3405
Garadpur	14154	17352	9063	8289	191.46	0	840	650
Pattamundai	26120	29669	13810	15859	214.84	0	1865	902
Aul	22445	20070	10166	9904	197.72	0	639	1717
Rajkanika	26349	35709	17279	18430	206.66	0	90	1478
Rajnagar	34625	40695	24551	16144	165.76	722	422	1615
Total	**230918**	**280592**	**145096**	**135496**	**194.00**	**3552**	**7451**	**12468**

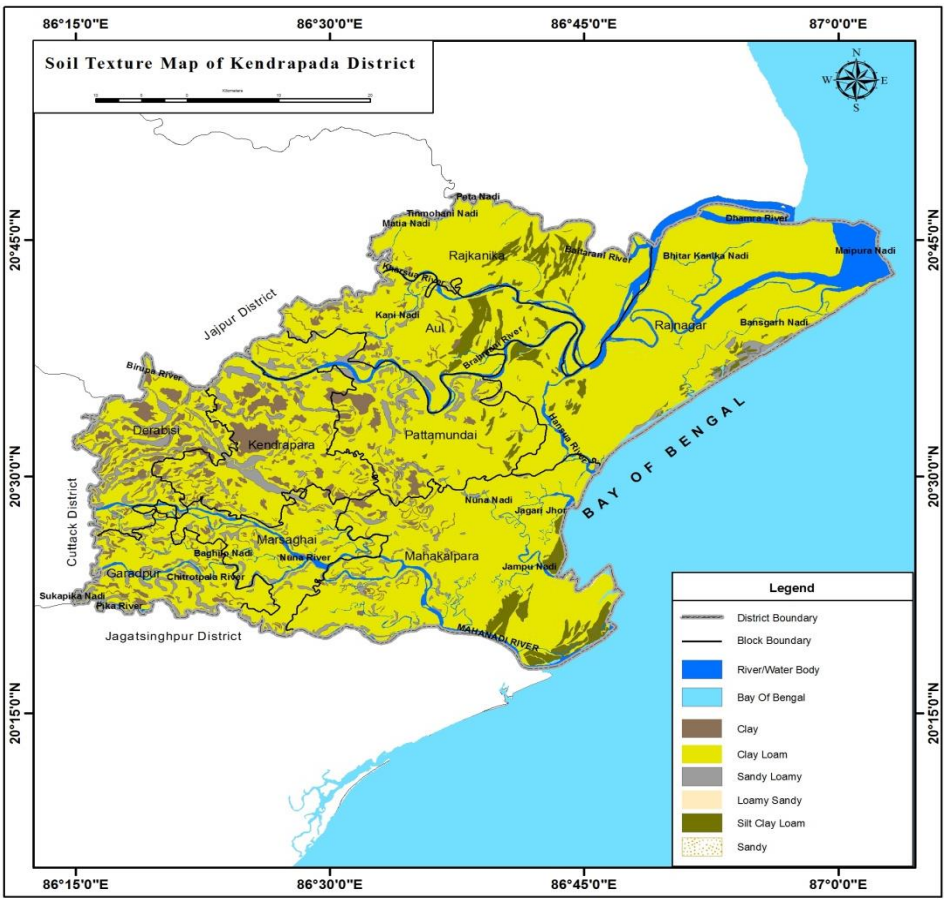


Map-1.6: Land Use Map of Kendrapara District

1.12: Soil: The district is predominately occupied by tertiary and recent alluvium brought down by distributaries of the rivers. The soil of the district is arable land and consists mainly of alluvium. There are mainly two types of soil predominantly occurs in the district. These

are 1. Inceptisols (Mixed Gray Soil) and Entisols. Their predominance in the district is shown in following pie diagram. Texturally mainly five types of soil occur in the district. In order of their textural predominance these are depicted in following map. These are as below.
1. Clay loamy soil 2. Silty clayey loamy soil 3. Silty loamy soil, 4. Clayey soil and
5. Sandy soil etc.





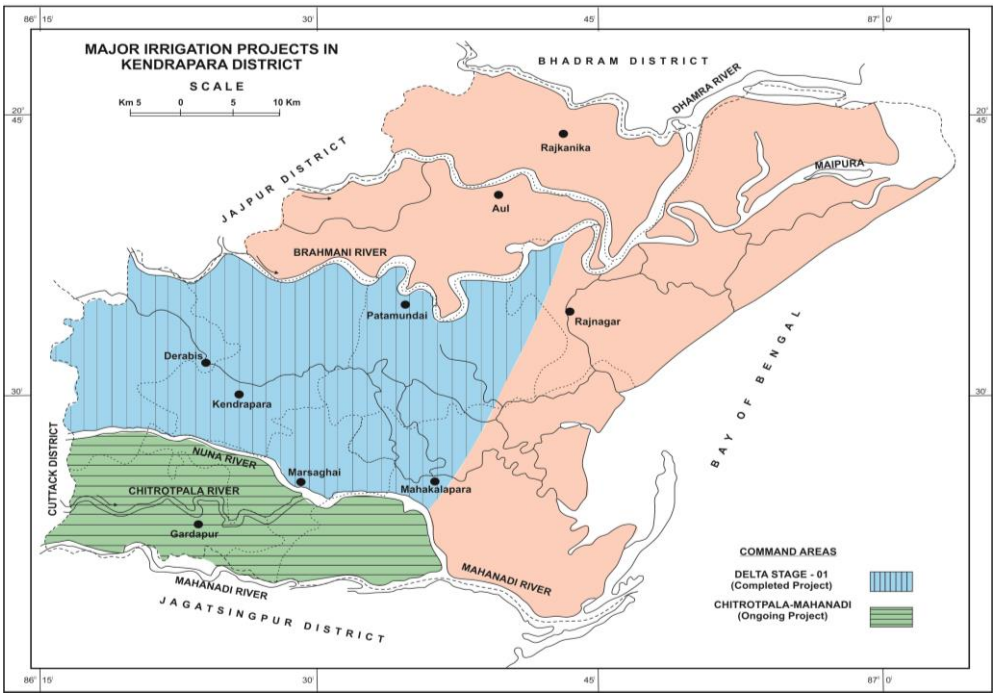
Map 1.7: Soil Texture in Kendrapara District

1.13: Hydrology:

1.13.1: Surface water Resource: The district is drained by the river Brahmani and Mahanadi along with their distributaries and the main rivers and their distributaries flow from west to east forming anastomasing drainage pattern, The surface water resources available from

these rivers and streams is approximately 62000 Ham annually.

1.13.2: Irrigation Projects: The major surface irrigation projects in the district are Delta stage I and Mahanadi-Chitrotpala irrigation system. The Delta Stage I is an old completed project and the Mahanadi-Chitrotpala is ongoing project. Besides these few minor flow irrigation projects also exist in the district. The major irrigation (Delta Stage-I) provides irrigation facility in both Kharif and Rabi season while the minor irrigation provides irrigation only during Kharif season. The area irrigated through existing major irrigation project is 62880 ha during Kharif and 40590 ha during Rabi and the total area irrigated by the minor irrigation projects is only 169 ha. After completion of Mahanadi-Chitrotpala project additional 25000 ha area will enjoy the irrigation facility. Command areas of major irrigation projects are shown following map.



Map-1.8: Hydrological Map Showing Major Irrigation Projects in the District

1.14: Drainage: The river Mahanadi, Brahmani and Baitarani along with their Distributaries form the drainage pattern which is mostly anastomosing in nature. The river Mahanadi flows along the southern boundary of the district, while the Baitarani forms the northern boundary of the district. The river Brahmani flows more or less through the central part of the district for a considerable distance and at Balisahipatna of Rajnagar block it takes a sharp turn and joins with the Baitarani river near Jainagar of Rajnagar block.

Cultivable alluvial plains are formed mainly from above river systems and contribute to the agricultural prosperity of the district. In addition to these three major river systems, there are presence of series of natural streams and river distributaries like Luna, Chitrotpala, Karandia, Gobari, Kharasuan, Dhamara, Kani and Birupa. The river Mahanadi enters Kendrapara district from Cuttack district in south at Raipur of Mahaklalpara block. Then it passes through Khurusia, Kulla and it embraces the river Luna at Chaumuhani. Then it makes its passage to Bahakud, Hetamundia and finally meets the Bay of Bengal near False Point. The Chitrotpala flows from Mahanadi at Bisharpur in Cuttack district and enters to this district at Mahanga (Talakusuma) in Garadpur block. Chitrotpala is a distributary of the river Mahanadi which flows parallel to Luna and again merges with Mahanadi. The river Luna

flows from the river Chitrotpala at Sunaria in Cuttack district and enters into Kendrapara district at Girigola of Derabisi block. Then it traverses through Danpur (Derabisi block) Baspur, Kalapada (Marshaghai block) and joins Chitrotpala at Kuanrpala. River Karandia flows from the river Luna in its right side at Balipada of Kendrapara district and proceeds to Sathilo Basupur, Ayatpur and rejoins Luna at village Karandia, creating an island known as "Luna karandia Island". The river Gobari flows from Mahanadi-Paika Island at Bahadulpur in Cuttack district, traverses through Jajpur district at
Panchupandav in north-west direction. River Paika flows from Mahanadi in Cuttack district and enters in to Kendrapara district in north-west at Benipur of Derabisi block. Then it proceeds to Indupur (Kendrapar block) and joins river Bramhani at Ghagara. The Bramhani originates as a combined stream of two small streams called Sankhua and Koel originates from Chhotnagpur plateau, which meet at Vedvyas near Panposh in Sundergarh district. River Kharasrota popularly known as Kharasuan enters in to the district Kendrapara from Jajpur district at Boijorudhia in Aul block in northwest, flows through Balijori, Giribandha, Ranipokhari, Balakati, Jamudanda and joins the river Bramhani at Dakshinabrdha in Rajnagar block. River Kani enters into Kendrapara from Jajpur district near Arilo, Kantipur in Aul block that the river penetrates in to the district, makes its passage through Natara, Thakurpatna, Manpur, Aul and finally joins the river Kharasrota at Baulajodi of Aul block. River Hansua a tributary of river Mianpora has originates from Patrapur of Rajnagar block where Bramhani is being splitted into Dhamara and Mianpora. The river Baitarani takes its rise in the up-lands of Keonjhar district located to the north-west of Kendrapara district. The southern branch of this river traverses through Cuttack district and touches Kendrapara district at Kanrapur in Rajkanika block. Other minor rivers of the district which are locally known as Nallas, Joras and Gullias are (1) Gahiramatha Nalla, (2) Baunsagada Nalla (3) Chitrotpala Nalla,(4) Kharanasi Nalla,(5) Hanumanta Nalla,(6) PapuliNalla,(7) Bhitarakanika Nalla (8) Sukhuamuhan Nalla,(9) Budhia Nalla,(10)Kani Nalla,(11) Chhedakani Nalla, (12) Singha Nalla,(13) Kandarapatia Nalla,(14) Jagarjora,(15) Manda Jora,(16) Kutha Jora (17)Batighara Gallia,(18) Ramachandi Gallia,(19) Babar Gallia etc. Most of these minor rivers of the district are charged with tidal ingression during monsoon season and give rise into flood

Map-1.9: Drainage Map of Kendrapada District

1.15 Agriculture & Cropping Pattern : Agriculture is the main stay of the local population. Paddy during kharif and pulses during rabi season are the major crops the district. Apart from that, millets are also grown in larger part of the district. Among pulses, arhar, green gram, black gram; oilseeds such as groundnut, till, sunflower, mustard and other vegetable crops are also grown in the district. Sugarcane is a cash crop grown in irrigated areas of Kendrapara, Derabish and Patamundai blocks. Average yield of the main crop rice, pulse crops is 3752 and 847 kg per ha under rainfed condition where as it is 4193 and 6281kg/ha under irrigated condition respectively. Source of irrigation wise area covered under various crops in Kendrapara district is given in following table.

Table-1.6: Cropping Pattern in Kendrapara district (Area is in Ha)

S. No	Crop Types	Kharif			Rabi		
		Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
1	Cereals	68458	53165	121623	7448	0	7448
2	Coarse cereals	0	65	65	259	0	259
3	Pulses	0	30	30	0	58394	58394
4	Oil Seeds	0	0	0	0	7040	7040
5	Fibres	1964	0	1964	0	0	0
6	Other crops	15710	11723	27433	30713	0	30713
7	Hotri & Plantation	-	-	-	-	-	-
8	Total	**86132**	**64983**	**151115**	**38420**	**65434**	**103854**

Table-1.6: Cropping Pattern in Kendrapara district (Area is in Ha) …. contd…..

S. No	Crop Types	Summer			Total		Harticulture & plantation
		Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
1	Cereals	0	0	0	75906	53165	-
2	Coarse cereals	0	0	0	259	65	-
3	Pulses	20150	0	20150	20150	58424	-
4	Oil Seeds	5473	0	5473	5473	7040	-
5	Fibres	0	0	0	1964	0	-
6	Other crops	0	0	0	46423	11723	-
7	Hotri & Plantation	--	-	-	-	-	32656
8	Total	**25623**	**0**	**25623**	**150175**	**130417**	**32656**

1.16: Irrigation: The district enjoys irrigation facilities through major, medium, minor and lifts irrigation projects. During Kharif total irrigated area from all source is only 136488 hectares. During Rabi season total area irrigated' is around 80494 hectare. Source wise irrigation potential for different blocks for Kharif and Rabi season are given in following table.

Table-1.7: Irrigation potential Created (Area-000 Ha)

Sl.	Sources	Kharif	Rabi
1	Major &Med (ending 03/2015)	78.46	40.59
2	Minor flow (ending 03/2015)	0.42	0
3	Minor Lift ending 03/2015(LIP)	41.896	24.737
	Minor Lift ending 03/2015(Deep bore wells	0	0
4	Other sources(ending 03/2015)	15.202	15.155
5	Other sources Jalanidhi-II during 2014-15	0.51	0.012
	Total	136.488	80.494

The area wise, crop wise irrigation status of all blocks of the district is given in following table. The crop wise details show a total cropping of 1, 51,115 ha in Kharif and 1, 03,854 ha in Rabi season. Out of which 86,132 ha in Kharif and 38,420 ha in Rabi are irrigated and rest area is under rain fed farming. While the area covered under lift irrigation project has some

sort of assured irrigation in Kharif as well as Rabi, the area irrigated under other sources has protective irrigation during lean period.

Table- 1.8: Block wise and source wise irrigated area (Area in Ha)

Sl. No.	Name of the Block	Irrigated (Area in ha)			Rainfed (Area in ha)	
		Net Irrigated Area (Kharif)	Net Irrigated Area (Rabi)	Net Irrigated Area (Summer)	Partially irrigated / Protective Irrigation	Un-Irrigated or Totally Rainfed
1	Kendrapara	18555	4223	8463	0	8024
2	Derabish	13134	3474	3175	0	13259
3	Marshaghai	8818	1978	2585	0	10981
4	Mahakalpara	6836	7195	105	0	39079
5	Garadpur	5492	2358	702	0	11491
6	Pattamundai	14709	4588	7175	0	5473
7	Aul	7506	3571	2215	0	9310
8	Rajkanika	6101	7350	235	0	24505
9	Rajnagar	4961	3683	968	0	33372
	Total	**86112**	**3842**	**25623**	**0**	**155494**

Table-1.9 : Crop wise irrigation potential (Area in Ha)

Sl. No.	Sources	Area (ha)			
		Kharif	Rabi	Summer	Total
1	Surface Irrigation				
(i)	Canal(Major & Medium Irrigation)	46727	0	0	46727
(ii)	Minor Irrigation tanks / minor Irrigation Command	9657	9657	0	19314
(iii)	Lift Irrigation / Diversion	25252	19672	0	44924
(iv)	Various Water Bodies including Rain Water Harvesting/ Community Tanks	34	34	0	68
(v)	Treated Effluent Received from STP	0	0	0	0
(vi)	Untreated Effluent	0	0	0	0
(vii)	Perennial Sources of water / Creek	4177	4177	0	8354
2	Ground water Irrigation				
(i)	Open Well	0	0	0	0
(ii)	Deep Tube Well	933	833	0	1866
(iii)	Medium Tube Well	0	0	0	0
(iv)	Shallow Tube Wells	3063	3063	0	6126
	Total	**89843**	**37536**	**0**	**127379**

1.17: Urban area, Industries, Mining activity: The urban areas are Kendrapara and Patamundai. The area of Kendrapara is only 10.77 sqkrn with population of 47006 (2011 census). The area of Patamundai is only 2.54 sqkm with population of 36528. (2011census). Kendrapara is under' municipality and the Patamundai falls under Notified area council (NAC). The district is having only 101 no of small scale industries with total number of employees of 500. These industries are mainly brick factory. Ice cream factory, grill & gate factory etc. There is no mining activity in the district.

Table-1.10: Small Scale, Cottage and Handloom Industries in Kendrapara District

Type of Industry	Numbers	Capital Investment (Rs Lakhs)
Small scale	101	319.29
Cottage	35	9.10
Handloom	375	-

1.18: Improvement in irrigation facilities: Govt of Odisha has proposed to renovated existing drainage channels (small streams and creeks) to create additional irrigation potential. Details are as below.

Table-1.11: Renovation of existing drainage channels

S.No	Block	No	**Irrigation potential (ha)**	Tentative cost Rs laks
1	Kendrapara	5	1025	91
2	Derabish	4	1050	40
3	Marshaghai	2	750	27
4	Mahakalapara	2	480	25
5	Pattamundai	4	850	65
6	Rajagar	2	500	40
7	Aul	1	350	20
	Total	**20**	**5005**	**308**

Table-1.12: Construction of check dam

SL. No.	Name of the Block	Total Number / capacity (cum)	Irrigation potential (ha)	Estimated cost (in lakh Rs.)
1	Kendrapara	15	450	450
2	Derabish	12	360	360
3	Marshaghai	8	240	240
4	Mahakalapara	8	240	240
5	Pattamundai	15	450	450
6	Rajagar	5	150	150
7	Aul	4	120	120
	Total	**67**	**2010**	**2010**

Table-1.13: Renovation of water conservation tanks

Block	GP	Village	No	IP (Ha)	Cost (Rs)
Kendrapara	Kansar	Chandiapali	1	20	7.00
	Kansar	Bandhapada	1	10	6.00
	Nilakanthapur	Chandanapur	1	5	4.00
	Jamodhara	Badagaon	1	10	8.00
	Jamodhara	Sanagaon	1	5	4.00
Marshaghai	Karilopatana	Karilopatana	1	12	3.00
	Karilopatana	Narayanur	1	10	3.00
	Ramanagar	Brajabahakuda	1	37.5	4.00
	Barakanda	Palli	1	18	6.00
	Khurusia	Khurusiapata	1	10	5.00
	Ameipala	Mahanangala	1	20	10.00
Garadpur	Kalabuda	Kalabuda	1	12	4.00
	Madhusasan	Naganpur	1	24	6.00
	Pakhad	Chhulia	1	8	4.00
	Pakhad	Bamara	1	12	5.00
Aul	Sanamanga	Sanamanga	1	24	5.00
	Atala	Atala	1	50	5.00
Rajkanika	Katana	Garapur	1	50	5.00
	Rantapada	Badagaon	1	20	5.0

Table-1.14: Details of creeks in the district proposed for renovation

Block	GP	Village	Name of creeks	Unit	Irrigation Potential created (ha)	Approximate cost (Rs) Lakhs
Kendrapara	Kansar	Baipur	Baipur Creek	1	7	5.00
	Kansar	Kansar	Patanali	2	20	20.0
Marshaghai	Pikarali	Pikarali	Pikarali Creek	1unit	40	8.00
Mahakalpara	Ameipala	Mahanangala	Mahanangala Creek	3km	18	9.00
	Ramanagar	Brajabahakuda	Brajabahakuda Creek	4km	20	8.00
Gardapur	Pakhad	Chaulia to Bamara	Bamara Creek	2km	40	4
	Badabetara	Badabetara Baghuasaphei	Badabetara Creek	2 km	40	4.00
Aul	Sanamanga	Panchanapada	Panchanapada Creek	2km	60	5.00
	Nial	Nial to Saliancha	Bhrahman Jora Ceek	4km	80	8.00
	Nial	Gumrazora nial	Gumra Jora (Nial)	2km	40	5.00
	Balakati	Balakati Mahu	Bada Ankua Creek	4km	120	10.00
	Balakati	Sanaankua	Sana Ankua Creek	2km	40	5.00
	Bada ambila	Beta	Old Mahu Beta Creek	2km	40	5.00
	Arehikana	Gavadia	Kundakhia- Gabhadia Creek	2km	40	5.00
	Tunga	Tunga	Kalia Ghai Creek	2km	40	5.00
Rajkanika	Bharigada	Mukundapur	Khajiri Creek	3km	60	6.00
	Bharigada	Maneidiha	Banki Nalla Creek	3km	80	7.00
	Bharigada	Dasabhagharia	Paikira Nalla Creek	2km	40	4.00
	Bharigada	Mukundapur	Bebarta Nalla Creek	2km	40	4.00
	Bharigada	Achyutapur	Ganeshpur Creek	3km	80	7.00
	Katana	PandurukIoli to Biswanathpur	Pandurukoli to Biswanath Creek	4km	120	8.00
	Katana	Singidi	Singidijora Creek	4km	120	8.00
	Deulatara	Deulatara	Sanapeta Nalla Creek	2km	20	4.00
	Deulatara	Deulatara	Kahuniabanka Nalla Creek	2km	40	4.00
	Jagulaipada	Ekatula	Ekatula creek	2km	40	4.00
	Jagulaipada	Langalabhanja	Kholanalla creek	3km	80	6.00
TOTAL			25 No	**60**	**1345**	**148**

Chapter-2

DATA COLLECTION AND GENERATION

2.1: Geology: The geological formations which are exposed in the district belong to the quaternary period and these are recent alluvium and sand dunes. The exploratory drilling of CGWB for ground water exploration, down to a maximum depth of 612m revealed the existence of older alluvium and Mio-Pliocene deposits. The generalized geological succession as revealed by the exploratory bore holes of CGWB is as below.

Table-2.1: Generalized Geological Succession in Kendrapara District

Era	Period Quaternary	Epoch Recent to Pleistocene	Formation Recent and Older alluvium, sand dunes etc.
Cenozoic	Upper Tertiary	Mio-Pliocene	Brown, yellow, gray clays, silt, sand, gravels, mudstone moluscan shell, fossiliferous lime stones etc.

The deep drilling of Oil India Limited in the Mahanadi and North East Coast (NEC) basin of Orissa indicates that the number of normal faults with dip toward SE or E had occurred in this area with the general NE-SW trend. Most of the faults were confined to the bottom sequence and did not extend above Eocene. The major graben which occurs in the off shore of Balasore may also extend inshore in Mahanadi delta area.

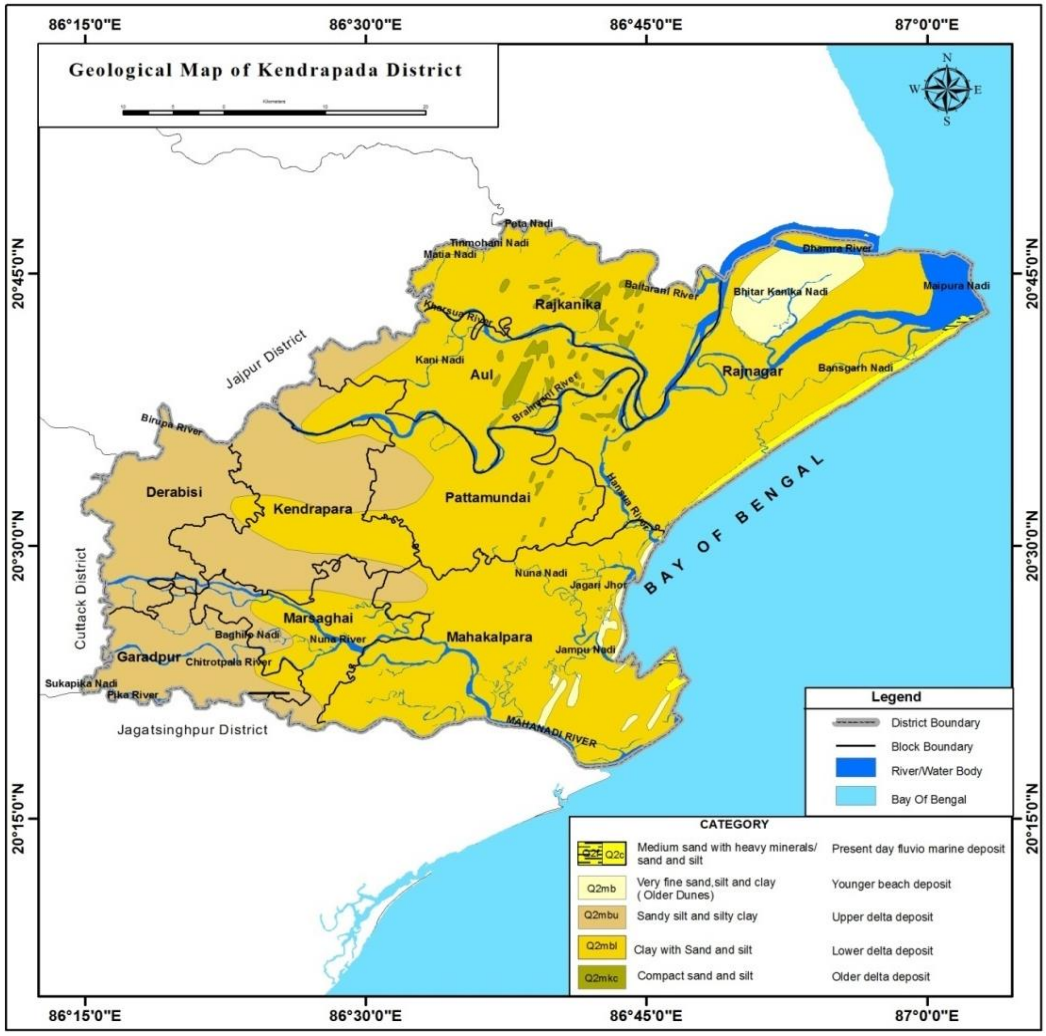
Sub-Surface Geology: Sub-surface geology has been described below based on the lithological logs of exploratory bore holes drilled by CGWB and are studied for different section/tract of the district. The tract/sections are shown in plate

Barsalar-Garjanga-Masakani Section: This section occurs in the south western part of the district and bore holes were drilled at Barsalar (5OOm) in the west, Masakani (301 m) in the east and at Ganjanga (S12m) in between. All the bore holes were ended in the sedimentary deposits and encountered alternate sequence of clay beds and granular horizons. The clay beds are yellow, brown, gray and dark gray in colour and mostly plastic in nature, though sometimes silty clays were also encountered. Normally the yellow and brown clays are restricted within 80 or 90m depth and below which grey .and dark grey clay occurred. The granular zones consisted of fine to coarse sand and fine gravels in general. The granular zones composed of either sand or gravel and also mixture of sand and gravel. The thickness of both clay beds and granular zones varied widely and generally thick zones (clay or granular) occurred within 200 or 250m depth, while at deeper depth the thickness of both zones became less (1 to 3m). The proportion of granular zones and clay beds also varied widely. At Barsalar the cumulative thickness of both the zones were found more or less same, i.e. 50:50, while at masakani granular zones predominates over 'clay horizon. But at Garjanga clay materials predominates over, granular materials. The occurrence of gravel were noted down to 600m at Basalar, up to 505 m at Ganjanja, but restricted down to 210m depth at Masakani.

Barsalar - Kendrapara - Patamundai-Gopalpur Section: This section occurs more or less along the central part of the district from west (Barsalar) to east (Gopalpur) and depth of the bore holes varied from 600 to 307m. All the bore holes ended in the sedimentary formation and bore holes generally encountered alternate sequence of clay and granular horizon.

The yellow and brown clays were restricted within 100m depth and normally grey and dark grey clays occurred be low this depth. The granular zones consisted of sand, gravel or mixture of sand and gravel. The granular zones predominated over clay materials in the eastern part (Patamundai-Gopalpur) while in the central part (Kendrapara) clay materials predominated over granular fraction and thick clay bed (more than 100m) encountered at Kendrapara at 342m depth, which extended down to 465m depth. The moluscan shells were found at 145m at Kendrapara and at 197m at Patamundai. The fossiliferous limestones were encountered at 290 m depth at Patamundai and at 263m depth at Gopalpur. The gravel zones were encountered down to 300m depth at Kendrapara while at Patamundai no grovels were encountered down to 300m depth and in the further east (at Gopalpur) the occurrence of gravels was less frequent.

Aul-Gopalpur-Sansarphal-Masakani: This section runs from north (Aul) to south (Masakani) and occurs in the eastern part of the district. The depth of the bore holes are around 300m. In this section in the northern part (Aul area) clay materials predominated over the granular zones while in the 'central and southern part granular zones predominated over the clay materials. The occurrence of gravels was common in the northern part while the same in the central and southern part is either absent or occurs as very less quantity and forms thin zone.



Map- 2.1: Geological Map of Kendrapara District

2.2: Hydrogeology: The vast alluvial deposits form the main repository of ground water in the District. The phreatic aquifer is commonly been tapped by dug wells and shallow tube wells and are commonly been used both for domestic and irrigational use. Almost entire part of district except an elongated patch in N-S direction in Derabis block in extremely western part of the district is affected by salinity problem. In this salinity affected areas only deep tube wells fitted with pumps is used only for water supply purpose. The presence of saline formations makes the area hydro-geologically complex and hence necessary precautionary measures like logging of the aquifers and cement sealing to prevent the inflow of saline water into the well are to be taken care of for extensive ground water extraction.

In order to decipher the aquifer system of the area, CGWB has constructed numerous exploratory wells, slim holes and piezometers of different depths which are shown in map-2.2. The detail data generated from this exploration is given in Table- 2.2. The ground water quality of these wells has been given in Table-2.3.

CGWB is also engaged in ground water regime monitoring through 27 National Hydrograph Stations (NHS) spreading over the district. Locations of NHSs are shown in map No-2.3. The ground water level data of two years for pre-monsoon and post-monsoon period of 2015 and 2016 and the water quality analysis result is given in Table- 2.3 and 2.4 respectively.

Map No2.2: Location of explorator y wells in Kendrapara District

Table-2.2: Basic data of CGWB Exploratory Wells Constructed in Kendrapara District

Sl No.	Location	Latitude	Longitude	Depth drilled (m) bgl	Depth Of T/W	Hydro chemical Profile (depth range) (m bgl)	Zone Tapped (depth range) (m bgl)	S.W.L. (m bgl.	Yield lps	Draw down (m)	T (m^2/day)	S
Block- Aul												
1	Aul	20.6811	86.6523	452.74	-	50-56 S , 120-126 B 278-288 F						
2	Aul (HP)	20.6811	86.6523	300	-	19-202S ,202-300F	272-278	1.72				
Block- Derabis												
3	Barimul -PZ-1	20.5387	86.3897	244	-	0-123S 123-240F	234-240	0.69	-	-	-	-
4	Barimul –PZ-2)	20.5387	86.3897	212	-	0-123S 123-240F	202-208	1.3				
5	Barimul –PZ-3	20.5387	86.3897	158	-	0-123S 123-240F	148-154	1.38				
6	Barosalar (Salar)	20.5055	86.2955	600	155	0-40F ,40-94 B to F 101-254.5F ,254.5-359.5S ,359.5-421 F ,421-459S ,460 - 528 F, 529 - 600 S	112-118 ,123-130 133-144,144-153 (C T- 33m)	1.76	38.29	24.52	110	-
7	Chatra	20.5542	86.3346	310	234	0-35F ,35-42B 42-87S ,87-106B , 106-298F	140-145 ,154-160, 164-176 ,192-198 206-232 ,224-230 (CT- 41m)	1.55	42	9.65	7445	$8.4x10^{-5}$
Block-Gardpur												
8	Patkura	20.373	86.39	248.7		154-160 S	Saline					

Block- Kendrapara Sadar												
9	Badamulabasant –PZ-2	20.5828	86.5242	300	264	-do-	251-257	0.66				
10	Badomulabasant -PZ-1	20.5828	86.5242	177	177	2-114S 114-296F	167-173	0.52				
11	Indupur	20.6182	86.4144	366.65	200	0-20 F ,20-120 S , 120-246 F ,246-265 B 265 - 366 S	128 -140 ,160-175 180-192, (CT- 39m)	2.71	22.14	15.71	285	-
12	Jajang	20.5314	86.4375	305.77	227.55	0-117B 117-243 F	125-136 ,147-159 166-197, 214-225 (CT-65 m)	0.91 (agl)	70.65	13.12		
13	Kendrapara	20.5077	86.3969	252.0	240.00	0-136 S ,136-151 B 158 onwards F	181-187 ,193-202 218-123	3.5 3	24			
14	Kendrapara	20.5134	86.4101	301.09	210.45	0-10 F ,18-81 S 84-151 S to B 151-290 F	169-175,177-18 192-198.5 ,202- 207.5 , (CT- 24m)	0.175	70	19.893	900	-
15	Kendrapara	20.5074	86.4246	463	313	10-155 S ,155-360F 360-460 S	162-168 ,172-183 218-232,238-243 269-274 ,280-308 (CT-69m)	1.04	48	12.14	1266	1.6×10^{-4}
Block- Mahakalpara												
16	Masakani	20.3851	86.5455	301.14	-	0-301.14S	Well abandoned due to salinity					
Block- Marshaghai												
17	Garjanga	20.4009	86.4686	612.60	365	0-66 B ,66-111F 111-304 S, 304-388 F 388-612.6 B	320-323 ,327-336 339-342 ,345-350 (CT-20 m)	0.815 (agl)	37.26	21.11	151	-
18	Marshaghai -PZ	20.4261	86.5998	248		0-185S ,185-246F	236-242					
19	Sillipur	20.4546	86.51	300	261	0-205S, 205-270F	227-233 ,238-252 254-256 ,(CT-22m)	0.14 m (agl)	13	13.96	319	8.8×10^{-5}

Block- Patamundai												
20	Pattamundai (Kakadipali)	20.5827	86.5713	304.76	233.20	0-90 B 90-300 F	99-104.80 , 114.3-121.55 140.58-147.85 155.85-163 211-231.2 (CT-47.62 m)	0.68	62	11.24	1672	-
21	Pattamundai	20.5922	86.5759	215.70			148-163	1.18				
22	Pattamundai (Beltala)	20.5922	86.5759	299.44	221.0	9-108 S ,108-136 B 136-276 F	182-200 ,204-216 CT-30m))	1.73	32.24	15.58	973	$3.1x10^{-4}$
23	Pattamundai - I(Kasananta)	20.5922	86.5759	200	126		112-124	2.40	20	5.00		
24	Pattamundai - II	20.5922	86.5759	220	217		148-154 ,165-168 176-179 ,200-203 208-214	2.50	45	8.80		
25	Pattamundai (Balipara)	20.5922	86.5759	229.89	225.0	0-125 S, Rest F 5-77B ,77-302 F	168-186 ,189-192 204-207 ,225-230	1.80 0.86m (agl)	50			
26	Sansarphal	20.5717	86.6867	306.7	230		126-132,168-177 194-209 211-218 222-228 (CT-43m)		75.4	11.41	2430	
27	Pattamundai	20.5922	86.5759	230	230	0-14 F ,14-82 S 82-106 B ,106-230 F	147-153 ,191-197 205-214 ,218-227	3.83	9	7.05	-	-
Block- Rajnagar												
28	Gopalpur	20.5997	86.7134	292	287	5-72B 72-292F	170-180 ,185-210 225-235 ,279-285 (CT-51m)	0.50m (agl)	68.8	9.704	2650	
29	Madanpur	20.6061	86.6867	307.5	202	5-92 B 92-302 F	130-150 ,160-180 190-200 , CT-50 m)	0.8m (agl)	67.48	10.31	1732	-

Note: F – Fresh, B – Brackish, S – Saline

Table-2.3: Ground water Quality data of CGWB Exploratory well drilled in Kendrapara District

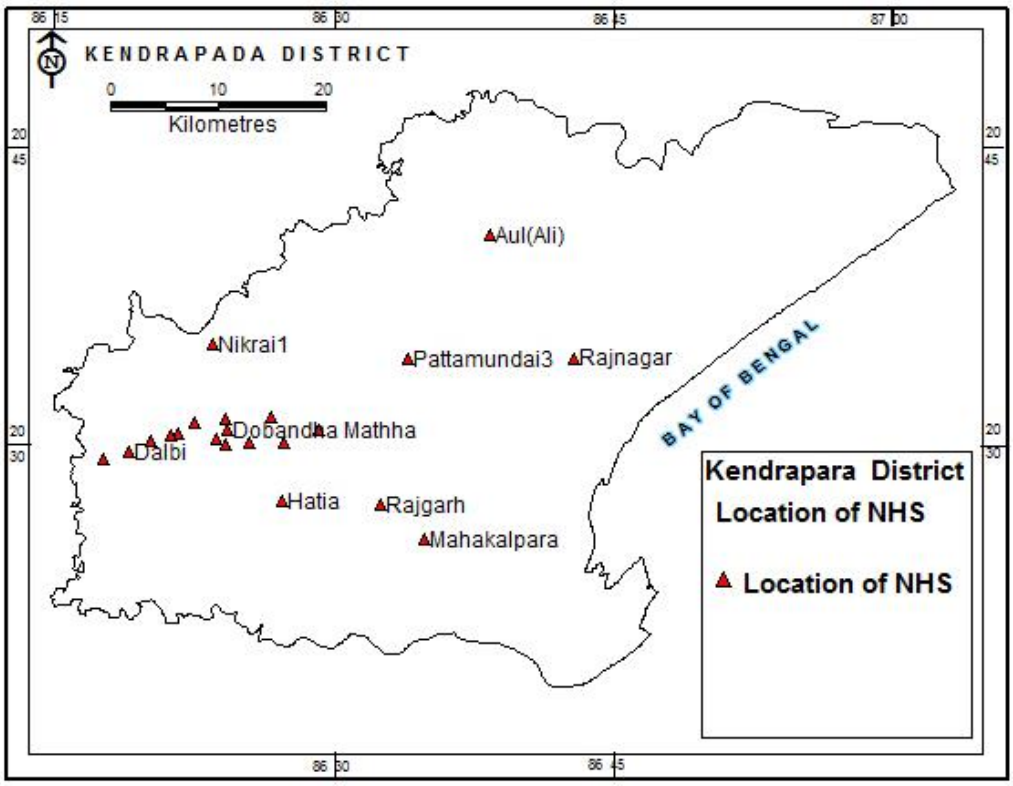
S. No	Location	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	TH	Ca	Mg	Na	K	TDS	SAR
1	Patamunda (Beltala)	-	942	0	281	142	43	2.3	0.36	275	70	24	93	5.7	-	2.44
2	Patamundai	-	67 2	35	130	60.4	-	-	-	185	42	19.5	-		437	-
3	Madanpur	-	774	15	165	67.5	-	-	-	175	12	35.3	-		553	-
4	Sansarpal	8.85	956	42	122	74	-	-	-	95	18	12	-		621	-
5	Indupur	7.46	837	-	232	138	-	-	-	-	78	9.7	76	5.7	-	2.15
6	Kendrapara	8.2	1023	-	244	149	50	-	0.35	180	44	17	14	7.8	-	0.45
7	Garjang	8	900	-	397	112	-	-	-	30	11	0.6	-		-	-
8	Gopalpur	8.45	879	24	259	74	-	-	-	185	24	30	-		571	-
9	Barasalar	7.8	800	-	281	99	-		-	210	48	22	-		-	-

Note: EC is in µs/cm at 25^0C, pH is unit less, and all others are in mg/liter

Table-2.4: Depth to water level data of CGWB National Hydrograph Stations.

Block	Location	Longitude	Latitude	April-15	Nov-15	April 16	Nov-16
Kendrapara	Dobandha Mathha	86°24'12" E	20°30'46" N	2.8	2	3.15	1.60
Kendrapara	Nikrai1	86°23'27" E	20°35'4" N	3.1	2	3.50	2.05
Patamundai	Pattamundai3	86°33'53" E	20°34'20" N	3	1.8	3.40	1.90
Rajnagar	Rajnagar	86°42'53" E	20°34'23" N	2.8	1.75	3.05	1.60
Kendrapara	Jamdhar	86°21'36" E	20°30'36" N	2.4	1.9	2.5	2.05
Kendrapara	Chandibazar	86°20'5" E	20°30'11" N	2.05	1.7	2.60	-
Derabis	Dalbi	86°18'52" E	20°29'39" N	2.6	2.15	3	1.40
Kendrapara	Duhuria	86°29'8" E	20°30'49" N	3	1.6	2.9	2.2
Kendrapara	Kasoti	86°22'26" E	20°31'8" N	2.9	1.8	3.10	1.60
Kendrapara	Kajala	86°24'11" E	20°30'44" N	4.8	3	4.5	3.0
Patamundai	Rajgarh	86°32'25" E	20°27'0" N	3	1.6	3.0	-
Mahakalpara	Mahakalpara	86°34'50" E	20°25'15" N	1.6	1.2	-	1.30
Garadpur	Patkura	86°24'20" E	20°23'15" N	3.2	-	-	-
Marshaghai	Hatia	86°27'7" E	20°27'11" N	3.9	2.15	4.3	2.05
Derabis	Chandola	86°17'30" E	20°29'20" N	2.1	1.5	2.50	2.50
Patamundai	Jajang-1	86°27'15" E	20°30'10" N	4.9	2.7	-	-
Patamundai	Aul(Ali)	86°38'20" E	20°40'34" N	3.4	2.0	3.80	1.60
Patamundai	Jajang-II	86°27'15" E	20°30'10" N	6.3	3.2	-	-
Kendrapara	Jajanga	86°26'31" E	20°31'24" N	3.2	1.7	3.3	1.85
Kendrapara	Ramnagar	86°24'4" E	20°31'21" N	2.45	1.8	3.20	1.90
Kendrapara	Shyamsundarpur	86°23'39" E	20°30'20" N	3.5	1.7	4	1.65
Kendrapara	Jantilo	86°21'8" E	20°30'29" N	3.2	2.1	-	-
Kendrapara	Kendrapara1	86°25'20" E	20°30'6" N	4.25	3	4.70	3.90
Kendrapara	Indupur	86°24'6" E	20°36'0" N	4.8	2.2	-	-

Note: Depth to water level in meter below ground level



Map-2.3: Location of NHSs in Kendrapara District

Table-2.5: Ground Water Quality data of CGWB National Hydrograph Stations

Location	PH	EC	Co_3	HCO_3	CL	SO_4	F	Ca	Mg	Na	K	TDS	TH	TA
Chandibazar	7.74	870	0	250	113	64	0.25	38	30.44	92	6.5	466	220	204.92
Jamdhar	8.25	1180	0	305	156	70	0.43	50	25.59	160	6.5	618	230	250
Mahakalpara	8.46	1100	0	250	177	42	0.1	50	18.3	151	15.5	597	200	239.92
Hatia	8.19	890	0	189	160	59	0.14	50	31.67	61	32.6	487	255	154.92
Chandola	8.04	680	0	134	121	54	0.19	18	26.77	74	5.8	365	155	109.84
Indupur2	7.95	430	0	110	78	11	0.09	30	14.62	32	3.2	223	135	90.16
Jajanga	8.23	2220	0	342	507	106	0.24	26	29.21	412	2.5	1250	185	280.33
Kasoti	7.77	6490	0	1379	918	596	0.09	250	164.42	860	47.5	3511	1300	1130.33
Kajala	8.13	500	0	92	64	76	0.1	44	23.15	18	3.6	274	205	75.41
Shyamsundarpur	8.06	640	0	122	103	62	0.08	28	42.58	31	2.3	329	245	100
Jantilo	8.1	420	0	61	67	56	0.17	44	13.43	18	3.1	231	165	50
Duhuria	7.91	1830	0	183	436	136	0.13	64	29.25	286	1.5	1042	280	150
Ramnagar	8.1	1250	0	226	241	97	0.12	36	32.87	173	15	706	225	185.25
Nikrai	8.06	490	0	128	60	47	0.18	50	14.65	19	4	258	185	104.92
Pattamundai1	8.37	1020	0	244	135	109	0.16	48	35.31	71	58.3	585	265	215
Gogua	8.12	470	0	214	40	3	0.27	42	13.42	20	12.2	235	160	175.41

Besides NHS monitoring 100 No of shallow tube wells fitted with hand pumps have also been monitored both for water level and water quality purposes. Details of these shallow tube wells established as key observation wells are as below.

Table-2.6: Hydrogeological data of key observation wells in Kendrapara District

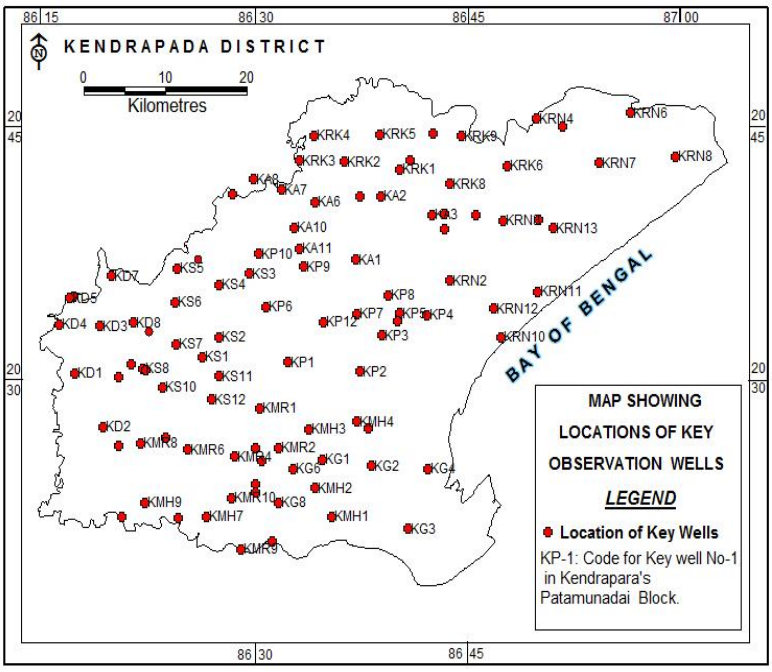
Sl No	Code No	Location	Latitude	Longitude	Depth m	Water level (mbgl)		
						Pre-monsoon	Post-Monsoon	Fluctuation (m)
1	KS1	Kapelleshwar	20.52246	86.438283	244	7.02	7.4	-0.38
2	KS2	Barua	20.54241	86.458178	229	5.07	6.9	-1.83
3	KS3	Chandakulota	20.60497	86.493792	213	9.65	9.3	0.35
4	KS4	Bhadamanadhiya	20.59368	86.457906	238	8.3	7.85	0.45
5	KS5	Dhumat	20.61015	86.408439	229	7.06	6.6	0.46
6	KS6	Matasahi	20.5764	86.406778	229	6.45	5.92	0.53
7	KS7	Goolnagar	20.535	86.407058	244	7.4	6.88	0.52
8	KS8	Bhadabhalapur	20.51095	86.367592	152	8.4	10.95	-2.55
9	KS9	Bhagavadhpur	20.50289	86.340303	152	6.79	6.54	0.25
10	KS10	Shamshadharipur	20.49265	86.390956	213	5.32	7.09	-1.77
11	KS11	Ostapur	20.50379	86.457783	229	6.47	6.35	0.12
12	KS12	Jhagaliapatna	20.48071	86.449322	229	8.07	6.63	1.44
13	KS13	Kanthia	20.50996	86.371489	229	5.7	8.06	-2.36
14	KS14	Dooria	20.51579	86.354336	213	7.87	5.96	1.91
15	KMR1	Kanipara	20.47224	86.505861	213	4.73	4.52	0.21
16	KMR2	Dasipur	20.43276	86.527872	213	4.09	4.1	-0.01
17	KMR3	Dumuka	20.43278	86.500719	213	4.59	4.6	-0.01
18	KMR4	Marshagahi	20.42413	86.475892	213	5.62	5.57	0.05
19	KMR5	Jirang	20.42053	86.507647	229	3.45	3.59	-0.14
20	KMR6	Pentha	20.43132	86.420936	213	6.35	6.62	-0.27
21	KMR7	Jamapara	20.44339	86.394589	268	7.55	7.65	-0.1
22	KMR8	Karilopatna	20.43762	86.365575	290	6.25	5.6	0.65
23	KMR9	Tihiri	20.33296	86.483917	229	5.03	4.89	0.14
24	KMR10	Bhagavanpur	20.38363	86.472119	229	5.01	4.9	0.11
25	KMH1	Mahakalpara	20.36497	86.589672	305	2.25	2.29	-0.04
26	KMH2	Pareshwarpur	20.39351	86.57	274	2.45	2.66	-0.21
27	KMH3	Jambonagar	20.45113	86.562694	274	1.78	1.9	-0.12
28	KMH4	Asharamabalukuda	20.4589	86.619433	229	4.55	4.35	0.2
29	KMH5	Karjang	20.45269	86.6331	229	4.9	4.25	0.65
30	KMH6	Badagaon	20.43457	86.339367	229	5.54	5.42	0.12
31	KMH7	Jadupur	20.36496	86.4427	213	1.76	2.75	-0.99
32	KMH8	Dekani	20.36336	86.409853	244	2.8	3.17	-0.37
33	KMH9	Subalah	20.37919	86.370692	274	1.06	1.97	-0.91
34	KMH10	Teragaon	20.36513	86.343106	213	1.9	2.13	-0.23
35	KG1	Basudevpur	20.42133	86.579256	290	4.23	4.42	-0.19
36	KG2	Padmapur	20.41547	86.636678	229	4.65	4.63	0.02
37	KG3	Srichandanpur	20.35316	86.679275	305	3.07	3.19	-0.12
38	KG4	Garadapur	20.41233	86.702508	305	4.67	4.85	-0.18

39	KG5	Bamara	20.39663	86.500919	213	4.7	5.17	-0.47
40	KG6	Kalapuda	20.41232	86.545292	305	4.76	5.17	-0.41
41	KG7	Biranjanga	20.3885	86.500614	37	4.4	4.76	-0.36
42	KG8	Dollakhusma	20.37895	86.527331	229	5.18	5.73	-0.55
43	KG9	Badhilo	20.34131	86.520767	305	5.55	5.68	-0.13
44	KD1	Palei	20.50639	86.288889	229	3.9	4.67	-0.77
45	KD2	Indalo	20.45361	86.321389	274	7.25	6.97	0.28
46	KD3	Laxminarayanpur	20.55306	86.3175	244	3.75	2.88	0.87
47	KD4	Endara	20.55472	86.270278	229	4.1	3.41	0.69
48	KD5	Kusunpur	20.58083	86.282778	229	0	3.98	-3.98
49	KD6	Panchu pandaba	20.58222	86.287778	244	6.64	6.37	0.27
50	KD7	Ghantapada	20.60222	86.330833	244	5.05	5.78	-0.73
51	KD8	Mantripada	20.55667	86.356667	244	6.21	5.75	0.46
52	KD9	Kusiapal	20.54778	86.375278	244	7.69	7.08	0.61
53	KA1	Aliha	20.61861	86.618056	305	7.39	7.08	0.31
54	KA2	Aul	20.68139	86.648056	259	8.63	8.02	0.61
55	KA3	Mohu	20.6625	86.708611	250	6.65	5.14	1.51
56	KA4	Bijaynagar	20.66389	86.722222	229	7.98	6.77	1.21
57	KA5	Tunga	20.68111	86.623611	329	7.63	6.96	0.67
58	KA6	Manpur	20.67556	86.571111	256	9.18	8.34	0.84
59	KA7	Madhuban	20.68722	86.531944	213	9.09	8.11	0.98
60	KA8	Gobindapur	20.69778	86.497778	207	9.57	8.71	0.86
61	KA9	Desahi	20.68306	86.473611	159	7.76	6.96	0.8
62	KA10	Sansidha	20.65028	86.546389	198	8.95	8.8	0.15
63	KA11	Mahadeipatana	20.62944	86.551944	256	8.27	7.62	0.65
64	KP1	Loknathpur	20.5175	86.538333	220	5.47	4.71	0.76
65	KP2	Sujanpur	20.50806	86.623611	238	2.71	2.34	0.37
66	KP3	Deuli	20.54389	86.648889	299	4.2	3.65	0.55
67	KP4	Balijhari	20.56417	86.7025	274	3.33	2.73	0.6
68	KP5	Sansaraphala	20.56583	86.670278	244	4.06	3.77	0.29
69	KP6	Badamulabasanta	20.57222	86.512778	235	7.51	6.86	0.65
70	KP7	Shasan	20.565	86.619167	280	6.4	5.99	0.41
71	KP8	Chhatradharipatana	20.58361	86.656944	293	4.75	4.76	-0.01
72	KP9	Balipatana	20.61139	86.557222	244	9.81	9.2	0.61
73	KP10	Andara	20.62417	86.503889	183	10.96	6.75	4.21
74	KP11	Alapua	20.61889	86.433056	183	9.75	9.11	0.64
75	KP12	Akharuni	20.55694	86.58	262	6.89	6.26	0.63
76	KRN1	Chandanpur	20.64889	86.723333	213	3.57	2.57	1
77	KRN2	Rajagarh	20.59778	86.729167	183	1.73	1.51	0.22
78	KRN3	Daru ora	20.65694	86.791111	226	1.78	1.6	0.18
79	KRN4	Nalitapatia	20.7575	86.830278	244	2.55	2.16	0.39
80	KRN5	Dangamala	20.74972	86.861667	207	3.18	3.9	-0.72
81	KRN6	Talachua	20.76306	86.941667	232	2.23	2.23	0

82	KRN7	Pataparia	20.71361	86.904722	229	1.39	1.46	-0.07
83	KRN8	Prabhati	20.72	86.994444	206	0	1.34	-1.34
84	KRN9	Mangarajpur	20.5575	86.666944	152	1.76	1.4	0.36
85	KRN10	Pentha	20.54222	86.788889	226	1.47	1.59	-0.12
86	KRN11	Kathuaganda	20.58722	86.831667	152	1.26	1.27	-0.01
87	KRN12	Hatina	20.57028	86.780556	168	1.53	1.46	0.07
88	KRN13	Gupti	20.64944	86.850556	195	1.45	1.5	-0.05
89	KRN14	Gopalpur	20.6575	86.833056	183	1.5	1.47	0.03
90	KRK1	Barunidiha	20.70778	86.669444	229	8.65	8.21	0.44
91	KRK2	Deultara	20.71528	86.604444	274	10.55	10.31	0.24
92	KRK3	Thakuranipal	20.71639	86.552222	229	9.1	8.77	0.33
93	KRK4	Hatasahi	20.74111	86.569722	244	8.32	7.06	1.26
94	KRK5	Pegarpada	20.74222	86.646111	244	7.38	6.8	0.58
95	KRK6	Shilapokhri	20.71111	86.796111	183	2.96	2.59	0.37
96	KRK7	Katana	20.66278	86.759444	183	1.75	1.71	0.04
97	KRK8	Ayatan	20.69306	86.728333	256	7.19	6.76	0.43
98	KRK9	Shikurdi	20.74056	86.741944	329	6.89	6.63	0.26
99	KRK10	Arasha	20.7425	86.709167	311	6.4	6.03	0.37
100	KRK11	Achyutpur	20.71639	86.681944	305	10.5	6.97	3.53

Note : Codes are given as short form of block name as below . Location of thse wells are shown as codes in maps and all tables.

S.No	Name of Block	Code	S.No	Name of Block	Code	S.No	Name of Block	Code
1	Kendrapara Sadar	KS	4	Gardpur	KG	7	Patamundai	KP
2	Marshaghai	KMR	5	Derabis	KD	8	Rajnagar	KRN
3	Mahakalpara	KMH	6	Aul	KA	9	Rajkanika	KRK



Map-2.4: Map showing locations of Key observation Wells in Kendrapara District

Table 2.7: Ground water Quality of deeper aquifer of Kendrapada District
(Samples collected from 100 No of shallow tube wells established during 2016-17 as key observation wells)

Sl No	Code No	LOCATION	Lat	Long	pH	EC	CO_3	HCO_3	Cl	SO_4	F	TH	Ca	Mg	Na	K	TDS	TA
1	KS1	Kapelleshwar	20.52246	86.43828	7.88	680	0	258	83	12	0.78	157	30	19.9	79.7	8	359	212
2	KS2	Barua	20.54241	86.45818	7.93	810	0	203	130	27.9	0.41	215	42	26.7	80.2	8.1	415	167
3	KS3	Chandakulota	20.60497	86.49379	7.89	670	0	203	87	16.4	0.26	150	18	25.5	80.5	5.7	333	167
4	KS4	Bhadamanadhiya	20.59368	86.45791	8.02	680	0	246	71	10.5	0.32	140	16	24.3	87.8	5.8	336	202
5	KS5	Dhumat	20.61015	86.40844	8.01	830	0	215	144	15.9	0.32	210	40	26.7	87.9	6.7	427	177
6	KS6	Matasahi	20.5764	86.40678	8	850	0	215	134	27.4	0.34	225	34	34	85.9	7.8	429	177
7	KS7	Goolnagar	20.535	86.40706	8.19	730	0	227	97	13.3	0.58	160	24	24.3	90.5	5.3	366	187
8	KS8	Bhadabhalapur	20.51095	86.36759	7.95	880	0	215	149	15.3	0.18	210	22	37.7	99.2	8.8	438	177
9	KS9	Bhagavadhpur	20.50289	86.3403	8.08	690	0	233	113	11.2	0.18	140	24	19.4	89	8.7	379	192
10	KS10	Shamshadharipur	20.49265	86.39096	8.09	720	0	270	97	2.5	0.2	105	6	21.9	111.3	7.9	379	222
11	KS11	Ostapur	20.50379	86.45778	8.03	750	0	233	94	19.3	0.31	185	32	25.5	80.5	7.7	374	192
12	KS12	Jhagaliapatna	20.48071	86.44932	7.9	670	0	215	83	8.9	0.21	155	26	21.9	77.1	8.2	331	177
13	KS13	Kanthia	20.50996	86.37149	8.36	740	15	319	85	0.8	0.15	100	24	9.7	118.5	8.8	419	288
14	KS14	Dooria	20.51579	86.35434	8.07	680	0	264	106	4.6	0.15	115	24	13.4	98.5	8.8	384	217
15	KMR1	Kanipara	20.47224	86.50586	7.92	660	0	227	71	15.2	0.27	140	24	19.4	82.2	8	331	187
16	KMR2	Dasipur	20.43276	86.52787	7.81	720	0	215	97	17.7	0.27	180	28	26.7	76.9	8.2	360	177
17	KMR3	Dumuka	20.43278	86.50072	8.06	760	0	301	85	23.8	0.23	170	28	24.3	91.4	8.9	409	247
18	KMR4	Marshagahi	20.42413	86.47589	8.12	640	0	282	61	4	0.19	130	16	21.9	80.1	8.2	330	232
19	KMR5	Jirang	20.42053	86.50765	7.98	940	0	233	165	30.7	0.22	260	32	43.7	89.5	9.1	485	192
20	KMR6	Pentha	20.43132	86.42094	8.06	680	0	282	85	1.1	0.17	105	14	17	102.3	8.7	366	232
21	KMR7	Jamapara	20.44339	86.39459	8.22	650	0	270	90	1.4	0.12	125	16	20.7	85.3	8.8	355	222
22	KMR8	Karilopatna	20.43762	86.36558	8.22	470	0	209	24	11.8	0.19	115	16	18.2	32	39.1	243	172
23	KMR9	Tihiri	20.33296	86.48392	8.41	900	24	289	134	0	0.4	80	10	13.4	162.2	11.6	497	278
24	KMR10	Bhagavanpur	20.38363	86.47212	8.46	780	21	276	111	0.3	0.3	85	16	10.9	133.1	8.8	437	263
25	KMH1	Mahakalpara	20.36497	86.58967	7.31	2280	0	203	769	3.9	0.2	555	123	60.1	260.8	19.5	1331	167

26	KMH2	Pareshwarpur	20.39351	86.57	7.99	2130	0	258	585	0.7	0.22	230	34	35.2	374.8	14.9	1171	212
27	KMH3	Jambonagar	20.45113	86.56269	8.28	2530	0	252	837	0	0.76	220	42	27.9	464.4	24.1	1520	207
28	KMH4	Asharamabalukuda	20.4589	86.61943	8.2	970	0	209	238	4.8	0.22	155	30	19.4	144.5	11.6	551	172
29	KMH5	Karjang	20.45269	86.6331	7.87	1330	0	184	335	44.5	0.3	430	81	55.3	101.6	5.9	714	152
30	KMH6	Badagaon	20.43457	86.33937	8.02	830	0	215	139	45	0.33	240	22	45	76.8	5.1	439	177
31	KMH7	Jadupur	20.36496	86.4427	7.98	1270	0	227	288	77.7	0.25	345	42	58.3	128.4	8.2	714	187
32	KMH8	Dekani	20.36336	86.40985	8.25	700	0	203	123	31.4	0.3	135	26	17	83	24.8	405	167
33	KMH9	Subalah	20.37919	86.37069	7.88	1340	0	166	368	29.7	0.25	445	91	52.9	97.9	7	728	136
34	KMH10	Teragaon	20.36513	86.34311	8.08	680	0	239	90	15.2	0.36	165	30	21.9	74.4	6.5	356	197
35	KG1	Basudevpur	20.42133	86.57926	8.51	930	39	338	104	3.1	0.4	75	10	12.2	173.3	9	516	343
36	KG2	Padmapur	20.41547	86.63668	8.48	980	30	282	170	0.2	0.29	65	12	8.5	187.8	9.3	557	283
37	KG3	Srichandanpur	20.35316	86.67928	8.45	1030	24	295	132	0	0.28	70	14	8.5	197.5	9	530	283
38	KG4	Garadapur	20.41233	86.70251	8.31	1200	15	307	259	0	0.28	75	16	8.5	232.3	10.9	693	278
39	KG5	Bamara	20.39663	86.50092	8.4	610	12	295	26	33.5	1.23	40	6	6.1	116.3	8.9	355	263
40	KG6	Kalapuda	20.41232	86.54529	8.28	630	0	319	40	8.4	0.98	90	12	14.6	95	12.7	340	263
41	KG7	Biranjanga	20.3885	86.50061	8.1	640	0	227	80	17.1	0.8	100	12	17	88.9	20.6	347	187
42	KG8	Dollakhusma	20.37895	86.52733	7.96	250	0	80	35	7.7	0.19	70	16	7.3	23.8	3	132	66
43	KG9	Badhilo	20.34131	86.52077	8.09	1040	0	417	101	2.7	1.32	60	12	7.3	202.2	13.2	544	343
44	KD1	Palei	20.50639	86.28889	7.63	940	0	329	117	17	0.2	205	70	7.3	112	14	499	269.7
45	KD2	Indalo	20.45361	86.32139	7.81	700	0	250	92	16	0.1	185	32	25.5	72	8	368	204.9
46	KD3	Laxminarayanpur	20.55306	86.3175	7.93	860	0	366	74	12	0.1	325	86	26.7	33	35	446	300
47	KD4	Endara	20.55472	86.27028	7.83	1180	0	226	230	80	0.2	350	74	40.1	95	9	639	185.2
48	KD5	Kusunpur	20.58083	86.28278	7.92	950	0	201	216	10	0.3	260	58	27.9	87	16	513	164.8
49	KD6	Panchu pandaba	20.58222	86.28778	7.82	1230	0	214	298	15	0.2	325	90	24.3	129	14	675	175.4
50	KD7	Ghantapada	20.60222	86.33083	7.58	1160	0	244	238	29	0.1	345	62	46.2	102	10	607	200
51	KD8	Mantripada	20.55667	86.35667	8.01	1160	0	348	177	15	0.1	165	48	10.9	156	17	594	285.2
52	KD9	Kusiapal	20.54778	86.37528	8	790	0	207	142	24	0.3	195	30	29.2	86	8	421	169.7
53	KA1	Aliha	20.61861	86.61806	8.01	950	0	275	152	32	0.2	250	42	35.2	91	8	495	225.4
54	KA2	Aul	20.68139	86.64806	7.58	1250	0	256	191	139	0.3	430	78	57.1	84	7	682	209.8
55	KA3	Mohu	20.6625	86.70861	8	1020	0	311	135	60	0.3	280	46	40.1	102	9	544	254.9

56	KA4	Bijaynagar	20.66389	86.72222	8.11	1050	0	305	145	70	0.3	310	48	46.2	98	2	559	250
57	KA5	Tunga	20.68111	86.62361	7.57	1600	0	287	262	188	0.2	465	88	59.5	154	2	894	235.2
58	KA6	Manpur	20.67556	86.57111	7.85	940	0	281	117	71	0.3	265	52	32.8	90	5	505	230.3
59	KA7	Madhuban	20.68722	86.53194	7.64	1090	0	268	149	109	0.4	360	72	43.7	81	6	592	219.7
60	KA8	Gobindapur	20.69778	86.49778	7.66	1120	0	293	149	104	0.3	340	62	45	89	6	599	240.2
61	KA9	Desahi	20.68306	86.47361	7.7	1060	0	317	131	81	0.2	265	44	37.7	110	8	567	259.8
62	KA10	Sansidha	20.65028	86.54639	7.81	1170	0	360	177	40	0.2	375	96	32.8	92	7	621	295.1
63	KA11	Mahadeipatana	20.62944	86.55194	7.5	2420	0	256	588	153	0.2	585	130	63.2	280	13	1353	209.8
64	KP1	Loknathpur	20.5175	86.53833	7.8	970	0	305	138	36	0.3	290	48	41.3	85	7	505	250
65	KP2	Sujanpur	20.50806	86.62361	8.02	1120	0	305	163	57	0.3	290	44	43.7	121	7	585	250
66	KP3	Deuli	20.54389	86.64889	8.1	1090	0	287	163	90	0.3	320	50	47.4	92	7	590	235.2
67	KP4	Balijhari	20.56417	86.7025	7.97	1030	0	287	135	84	0.3	300	50	42.5	87	7	546	235.2
68	KP5	Sansaraphala	20.56583	86.67028	8.1	1080	0	281	138	84	0.3	290	60	34	90	6	550	230.3
69	KP6	Badamulabasanta	20.57222	86.51278	8	860	0	342	92	19	0.3	230	44	29.2	90	7	449	280.3
70	KP7	Shasan	20.565	86.61917	7.8	1100	0	244	177	98	0.3	370	52	58.3	85	5	595	200
71	KP8	Chhatradharipatana	20.58361	86.65694	7.96	1310	0	299	181	153	0.3	365	64	49.8	110	10	714	245.1
72	KP9	Balipatana	20.61139	86.55722	8.1	930	0	305	124	31	0.3	250	52	29.2	92	8	486	250
73	KP10	Andara	20.62417	86.50389	7.96	980	0	305	142	35	0.2	240	48	29.2	110	8	522	250
74	KP11	Alapua	20.61889	86.43306	7.84	835	0	317	128	25	0.3	355	44	59.5	48	5	465	259.8
75	KP12	Akharuni	20.55694	86.58	7.66	1545	0	238	337	106	0.4	535	118	58.3	111	6	853	195.1
76	KRN1	Chandanpur	20.64889	86.72333	7.8	1142	0	476	96	86	0.3	245	44	32.8	146	8	646	390.2
77	KRN2	Rajagarh	20.59778	86.72917	7.7	1050	0	384	53	93	0.3	240	36	36.5	111	6	524	314.8
78	KRN3	Daru ora	20.65694	86.79111	7.9	1155	0	445	124	95	0.3	240	50	27.9	190	11	716	364.8
79	KRN4	Nalitapatia	20.7575	86.83028	8	1305	0	506	121	126	0.4	180	34	23.1	220	10	782	414.8
80	KRN5	Dangamala	20.74972	86.86167	7.9	1265	0	519	74	104	0.3	245	34	38.9	187	10	702	425.4
81	KRN6	Talachua	20.76306	86.94167	8	1225	0	482	85	87	0.3	440	94	49.8	68	17	637	395.1
82	KRN7	Pataparia	20.71361	86.90472	8	1210	0	458	110	96	0.3	375	52	59.5	111	12	665	375.4
83	KRN8	Prabhati	20.72	86.99444	7.5	1335	0	360	241	30	0.2	305	50	43.7	151	26	718	295.1
84	KRN9	Mangarajpur	20.5575	86.66694	8	1185	0	464	96	64	0.2	380	90	37.7	93	6	614	380.3
85	KRN10	Pentha	20.54222	86.78889	8.2	1250	0	470	152	63	0.2	315	56	42.5	156	12	712	385.2

86	KRN11	Kathuaganda	20.58722	86.83167	8.2	1340	0	329	262	110	0.3	350	50	54.7	174	18	830	269.7
87	KRN12	Hatina	20.57028	86.78056	8.3	1340	0	427	167	86	0.3	350	84	34	143	10	733	350
88	KRN13	Gupti	20.64944	86.85056	8.2	1210	0	537	67	101	0.3	290	42	45	156	15	689	440.2
89	KRN14	Gopalpur	20.6575	86.83306	8.3	1350	0	397	195	90	0.2	320	38	54.7	144	17	733	325.4
90	KRK1	Barunidiha	20.70778	86.66944	8.2	1325	0	244	170	107	0.1	305	22	60.8	94	9	582	200
91	KRK2	Deultara	20.71528	86.60444	8.2	1315	0	262	195	98	0.2	275	48	37.7	133	7	647	214.8
92	KRK3	Thakuranipal	20.71639	86.55222	7.2	1165	0	293	128	74	0.2	250	48	31.6	93	17	535	240.2
93	KRK4	Hatasahi	20.74111	86.56972	8	1110	0	305	135	107	0.3	335	78	34	93	6	602	250
94	KRK5	Pegarpada	20.74222	86.64611	8.1	1240	0	262	163	184	0.2	415	130	21.9	95	6	728	214.8
95	KRK6	Shilapokhri	20.71111	86.79611	8.2	1070	0	390	96	45	0.2	155	14	29.2	160	6	541	319.7
96	KRK7	Katana	20.66278	86.75944	8.3	1165	0	421	131	72	0.3	250	38	37.7	164	9	658	345.1
97	KRK8	Ayatan	20.69306	86.72833	8.3	1190	0	366	145	90	0.2	310	48	46.2	127	7	643	300
98	KRK9	Shikurdi	20.74056	86.74194	8.3	1200	0	360	117	104	0.2	335	70	38.9	95	6	607	295.1
99	KRK10	Arasha	20.7425	86.70917	8.1	1235	0	354	160	131	0.2	415	70	58.3	94	6	693	290.2
100	KRK11	Achyutpur	20.71639	86.68194	8.1	1330	0	244	188	104	0.2	470	116	43.7	37	7	615	200

Note: EC is in µs/cm at 25^0C and pH is unit-less, all others are in mg/liter

2.3: Geophysical Studies:

2.3.1 Surface Geophysical Studies: Total 57 Nos. of VES (Vertical Electrical Sounding) was conducted in the investigated area using Schlumberger configuration. Locations of these VES points are shown in map No-2.5. Data is tabulated as below.

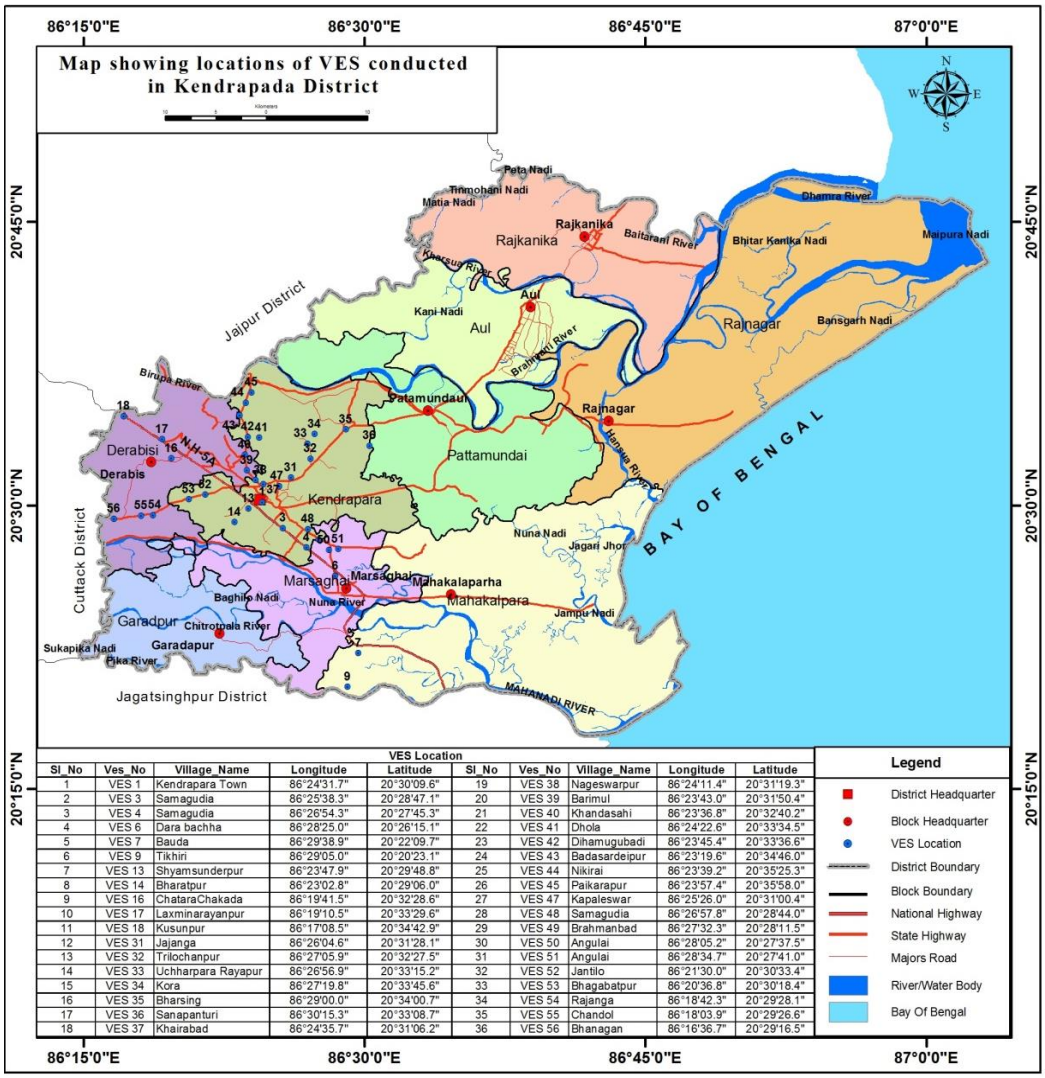
Table-2.8: Symbol for geophysical parameters used in VES

S. No	Symbol	Detail description	Unit
1	ρ_1	Resistivity of the second earth layer from top earth layer	Ωm
2	P_2	Resistivity of the second earth layer from top earth layer	Ωm
3	P_3	Resistivity of the third earth layer from top earth layer	Ωm
4	P_4	Resistivity of the fourth earth layer from top earth layer	Ωm
5	P_5	Resistivity of the fifth earth layer from top earth layer	Ωm
6	h_1	Thickness of the first earth layer from top earth layer	m
7	h_2	Thickness of the second earth layer from bottom of first earth layer	m
8	h_3	Thickness of the third earth layer from bottom of 2nd earth layer	m
9	h_3	Thickness of the third earth layer from bottom of 2nd earth layer	m
10	H	Cumulative thickness from top first layer towards bottom layers	m

Table-2.9: Locations of VES Points and Earth Layer Parameters

Sl. No	VES Number	ρ_1 Ωm	ρ_2 Ωm	ρ_3 Ωm	ρ_4 Ωm	h_1 m	h_2 m	h_3 m	H m	Location Coordinates
1	VES 1	21. 3	6. 52	0. 81	--	1. 5	3. 1	--	4. 6	N 20° 30′ 09. 6″ E 86° 24′ 31. 7″
2	VES 3	2. 77	1. 10	0. 53	--	1. 8	3. 2	--	5	N 20° 28′ 47. 1″ E 86° 25′ 38. 3″
3	VES 4	2. 2	1. 3	0. 48	--	1. 8	3. 2	--	5	N 20° 27′ 45. 3″ E 86° 26′ 54. 3″
4	VES 6	2. 58	2. 86	0. 02	--	1. 8	4. 2	--	6	N 20°′26 15. 1″ E 86° 28′ 25. 0″
5	VES 7	1. 76	2. 63	9. 41	--	2.32	9. 89	--	12. 2	N 20° 22′ 09. 7″ E 86° 29′ 38. 9″
6	VES 9	37. 5	5	0.17	--	1. 67	4. 31	--	5. 98	N 20° 20′ 23. 1″ E 86° 29′ 05. 0″
7	VES 13	8.52	2. 7	7. 65	--	2	14. 4	--	16. 4	N 20° 29′ 48. 8″ E 86° 23′ 47. 9″
8	VES 14	15. 7	3. 4	5. 63	--	2. 76	7. 12	--	9. 88	N 20° 29′ 06. 0″ E 86° 23′ 02. 8″
9	VES 16	26	0. 323	345	--	5. 22	4. 27	--	9. 5	N 20° 32′ 28. 6″ E 86° 19′ 41. 5″
10	VES 17	2. 97	0.671	24. 4	0. 007	2. 41	1. 61	4. 37	8. 39	N 20° 33′29.6″ E 86° 19′ 10. 5″
11	VES 18	21. 5	4. 53	0. 16	--	3.65	47. 7	--	51. 4	N 20° 34′ 42. 9″ E 86° 17′ 08. 5″
12	VES 31	6. 48	2. 37	3. 28	0.046	0. 75	9	38. 3	48. 1	N 20° 31′ 28. 1″ E 86° 26′ 04. 6″
13	VES 32	3. 91	18. 6	2. 41	0. 002	0. 75	5. 93	38. 6	45. 3	N 20° 32′ 27. 5″ E 86° 27′ 05. 9″
14	VES 33	13. 3	59. 7	1. 4	--	0. 75	16. 3	--	17. 1	N 20° 33′ 15. 2″ E 86° 26′ 56. 9″

15	VES 34	6. 5	2. 2	1. 35	ρ_4 =3. 22 ρ_5 = 0. 5	0. 9	3. 6	h_3 = 5. 54 h_4 = 12.4	22. 44	N 20° 33′ 45. 6″ E 86° 27′ 19. 8″
16	VES 35	13. 4	2. 62	1. 18	0. 711	0. 9	1. 17	8. 86	10. 9	N 20° 34′ 0. 7″ E 86° 29′ 0. 0″
17	VES 36	13. 5	29. 6	6. 47	1. 09	0. 9	4. 38	7. 3	12.58	N 20° 33′ 08. 7″ E 86° 30′ 15. 3″
18	VES 37	10. 5	15	0. 74	--	1. 08	10. 6	--	11. 7	N 20° 31′ 06.2″ E 86° 24′ 35.7″
19	VES 38	31	12. 4	0.004	--	2. 89	8.49	--	11. 38	N 20° 31′ 19.3″ E 86° 24′ 11.4″
20	VES 39	13. 1	3.09	1. 37	--	2. 72	7. 33	--	10. 05	N 20° 31′ 50.4″ E 86° 23′ 43.0″
21	VES 40	16. 4	1. 41	0. 76	--	3. 8	24. 2	--	28	N 20° 32′ 40.2″ E 86° 23′ 36.8″
22	VES 41	6. 07	2. 73	12. 7	0. 023	2. 06	14. 5	18. 5	35. 1	N 20° 33′ 34.5″ E 86° 24′ 22.6″
23	VES 42	13	3. 12	1. 5	2. 3	0. 88	3. 8	5. 8	10. 48	N 20° 33′ 36.6″ E 86° 23′ 45.4″
24	VES 43	66	9. 9	22	0. 024	1. 92	22. 7	18	42.6	N 20° 34′ 46. 0″ E 86° 23′ 19.6″
25	VES 44	12.8	23. 3	0. 61	--	2. 3	1. 2	--	3. 5	N 20° 35′ 25.3″ E 86° 23′ 39.2″
26	VES 45	18. 6	4. 47	0. 66	--	2. 4	4. 84	--	7. 24	N 20° 35′ 58.0″ E 86° 23′ 57.4″
27	VES 47	31. 5	9. 5	2. 36	0.05	1. 33	2. 41	33. 1	36. 84	N 20° 31′ 0.41″ E 86° 25′ 26.0″
28	VES 48	23. 8	147	5. 2	0. 034	1. 19	10. 9	32. 4	44. 5	N 20° 28′ 44. 0″ E86° 26′ 57.84″
29	VES 49	7. 1	2. 77	9. 3	0. 013	0. 75	2.31	19. 4	22. 46	N 20° 28′ 11.5″ E86° 27′ 32.34″
30	VES 50	2. 11	1. 66	0. 003	--	0. 75	2. 93	--	3. 68	N20°27′ 37.54″ E 86° 28′ 5.17″
31	VES 51	5. 6	1. 73	0. 48	--	0. 9	2. 6	--	3. 5	N 20° 27′ 41.0″ E86° 28′ 34.73″
32	VES 52	14. 4	8. 2	2. 94	--	2. 07	2. 68	--	4. 75	N 20° 30′ 33.4″ E 86° 21′ 30.0″
33	VES 53	2. 05	2. 95	29	1. 78	1. 47	7. 76	6. 6	15. 84	N 20° 30′ 18.4″ E 86° 20′ 36.8″
34	VES 54	16. 23	5. 83	9	--	0. 75	5. 18	--	5. 93	N 20° 29′ 28.1″ E 86° 18′ 42.3″
35	VES 55	7. 3	9. 7	7. 5	17. 8	0. 9	3. 85	20. 4	25.15	N20°29′ 26.63″ E 86° 18′ 3.94″
36	VES 56	34. 3	301	12. 6	--	0. 75	0. 24	--	0. 99	N 20° 29′ 16.5″ E 86° 16′ 36.7″



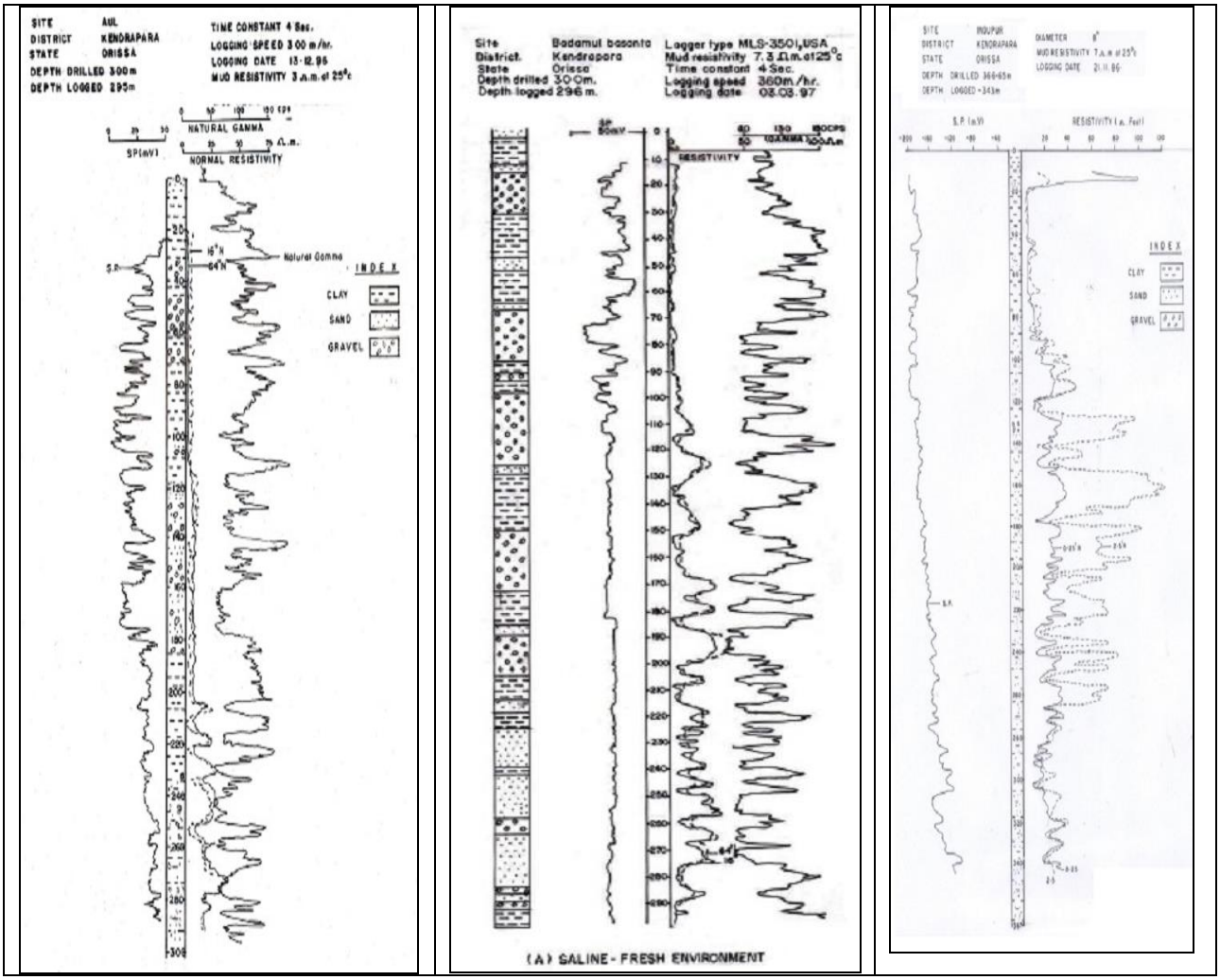
VES Location

Sl_No	Ves_No	Village_Name	Longitude	Latitude	Sl_No	Ves_No	Village_Name	Longitude	Latitude
1	VES 1	Kendrapara Town	86°24'31.7"	20°30'09.6"	19	VES 38	Nageswarpur	86°24'11.4"	20°31'19.3"
2	VES 3	Samagudia	86°25'38.3"	20°28'47.1"	20	VES 39	Barimul	86°23'43.0"	20°31'50.4"
3	VES 4	Samagudia	86°26'54.3"	20°27'45.3"	21	VES 40	Khandasahi	86°23'36.8"	20°32'40.2"
4	VES 6	Dara bachha	86°28'25.0"	20°26'15.1"	22	VES 41	Dhola	86°24'22.6"	20°33'34.5"
5	VES 7	Bauda	86°29'38.9"	20°22'09.7"	23	VES 42	Dihamugubadi	86°23'45.4"	20°33'36.6"
6	VES 9	Tikhiri	86°29'05.0"	20°20'23.1"	24	VES 43	Badasardeipur	86°23'19.6"	20°34'46.0"
7	VES 13	Shyamsunderpur	86°23'47.9"	20°29'48.8"	25	VES 44	Nikirai	86°23'39.2"	20°35'25.3"
8	VES 14	Bharatpur	86°23'02.8"	20°29'06.0"	26	VES 45	Paikarapur	86°23'57.4"	20°35'58.0"
9	VES 16	ChataraChakada	86°19'41.5"	20°32'28.6"	27	VES 47	Kapaleswar	86°25'26.0"	20°31'00.4"
10	VES 17	Laxminarayanpur	86°19'10.5"	20°33'29.6"	28	VES 48	Samagudia	86°26'57.8"	20°28'44.0"
11	VES 18	Kusunpur	86°17'08.5"	20°34'42.9"	29	VES 49	Brahmanbad	86°27'32.3"	20°28'11.5"
12	VES 31	Jajanga	86°26'04.6"	20°31'28.1"	30	VES 50	Angulai	86°28'05.2"	20°27'37.5"
13	VES 32	Trilochanpur	86°27'05.9"	20°32'27.5"	31	VES 51	Angulai	86°28'34.7"	20°27'41.0"
14	VES 33	Uchharpara Rayapur	86°26'56.9"	20°33'15.2"	32	VES 52	Jantilo	86°21'30.0"	20°30'33.4"
15	VES 34	Kora	86°27'19.8"	20°33'45.6"	33	VES 53	Bhagabatpur	86°20'36.8"	20°30'18.4"
16	VES 35	Bharsing	86°29'00.0"	20°34'00.7"	34	VES 54	Rajanga	86°18'42.3"	20°29'28.1"
17	VES 36	Sanapanturi	86°30'15.3"	20°33'08.7"	35	VES 55	Chandol	86°18'03.9"	20°29'26.6"
18	VES 37	Khairabad	86°24'35.7"	20°31'06.2"	36	VES 56	Bhanagan	86°16'36.7"	20°29'16.5"

Map No 2.5: Map showing Locations of VES conducted in Kendrapara District

2.3.2: Sub Surface Geophysical Studies: Due to salinity hazard problem all the bore holes of the district were electrically logged to demarcate the saline and freshwater bearing zones. In earlier days logging were done based on the self potential (S.P) and Point Resistance (P.R.) and by these technique no quantitative determination of salinity could be done precisely and for this reason zone tests were conducted to demarcate precisely saline and fresh water zones. In the later time the electrical logging are being conducted by measurement of short normal and long normal in addition to S.P. and by which the precise demarcation of saline zone and fresh zone are possible. The natural gamma ray logs are being used to identify the occurrence of granular and non granular zones to a great extent. The short normal is generally used for determining formation boundaries, even presence of one meter thick clay or sand zone may also be picked up by using short normal resistivity. In Kendrapara district for long normal if the resistivity value is less than 5 ohm, it indicates presence of saline water bearing zone and if the value of resistivity ranges between 5 to 10 ohm. then it indicates presence of clay zone. Normally long normal resistivity greater than 20 ohm indicates presence of fresh granular zones. In this district maximum value of long normal resistivity was noted to the tune of 48 ohm. m, which is indicative of very coarse sand or gravel zones. Similarly in Kendrapara district, the value of natural gamma is generally measured in counts per second (CPS) and ranges from 45 to 210 CPS. When the

value ranges between 45 to 100 CPS, it indicates presence of pervious zones and the occurrence of semi-pervious zones is indicated by the value ranging between 100 to 130 cps. The clay zones register a value of 130 to 210 cps. These are the counts of natural gamma ray logs in the Kendrapara district. In Kendrapara district electrical loggings have been done in almost all the EWs, and Piezometers based on which composite litholog were prepared and designing of well constructions were performed. Three electrical logs of Kendrapara district are shown as below.



(A) Aul (B) Badamulabasant (C) Indupur

Figure-2.1: Showing three electrical logs (A) EW at Aul, (B) EW at Badamulabasant and (C) EW at Indupur in Kendrapara District.

Chapter-3

Data Interpretation, Integration and Aquifer Mapping

3.1 Hydrogeology:

Aquifer System: The aquifer system in the district may be broadly divided into

1. Shallow aquifers and
2. Deeper aquifers.

3.1.1: Shallow Aquifers: The thickness of shallow aquifers (near surface aquifer) varies widely due to salinity problem in the district barring a narrow tract occurring along the extreme western part of the district where there is no salinity problem. In the saline hazard areas the thickness of the shallow fresh water bearing zones varies from negligible to a maximum of 95m. The extensions of shallow fresh water bearing aquifers are directly controlled by the depositional environment of geological formations. The occurrence of clay horizon at the top surface (from ground level) reduces the thickness of fresh water bearing zones to almost zero level. Normally the thickness of fresh shallow aquifers varies from 15 to 20 m or more within the saline hazard tract lying west of Indupur-Kendrapara-Karilopatna section and east of this section the thickness of shallow aquifers generally attains almost negligible thickness except In isolated pockets (in abandoned river/stream channels and sand dunes) where shallow/top fresh water bearing zones extend down to a maximum depth of 10 to 15m with the average thickness of 5 to 6m. The top fresh water bearing zones extends down to 90 or 95 m depth in the south western part of the district.

Water Levels in Phreatic Aquifers: The water levels of the shallow aquifers or phreatic zone are being monitored 4 times (January, April, August, and November) in a year by permanent hydrograph net work stations. Seasonal water level variations recorded from these 23 No of stations are tabulated as below and shown in maps No-3.1.1, 3.1.2 and 3.1.3 for pre-monsoon, post monsoon periods and fluctuations etc respectively.

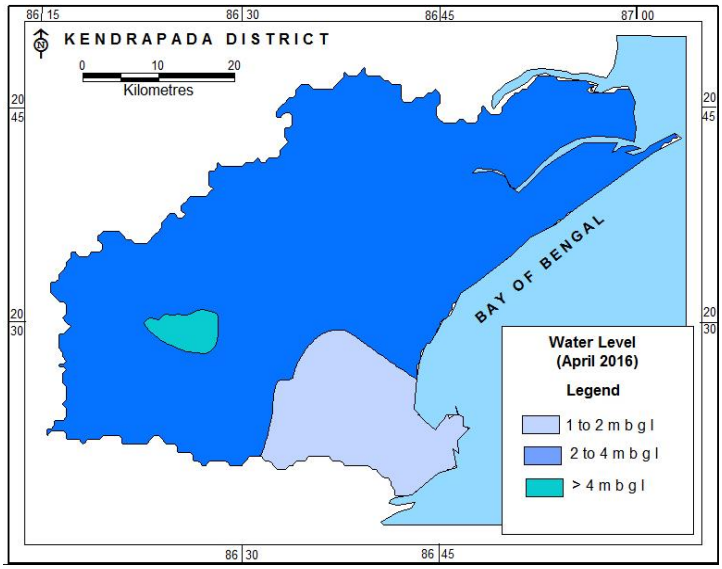
Table-3.1: Seasonal variation in Water level in shallow aquifer

2016 NHS data (23 Stations)

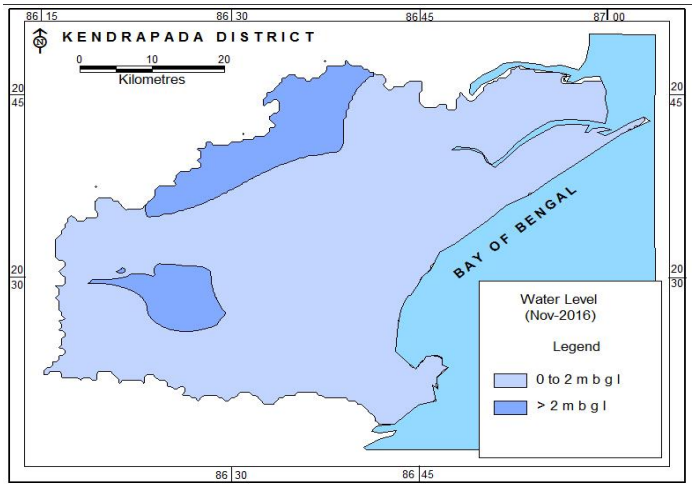
Parameters	Water Level		
	April-2016 Pre-monsoon (mbgl)	Nov-2016 Post-Monsoon (mbgl)	Fluctuation (m)
Minimum	1.6	1.2	0.35
Maximum	6.3	3.2	3.1
Average	3.31	2.02	1.28

Table-3.2: Variation in Water Level in a year (April, 2016 to Jan, 2017)

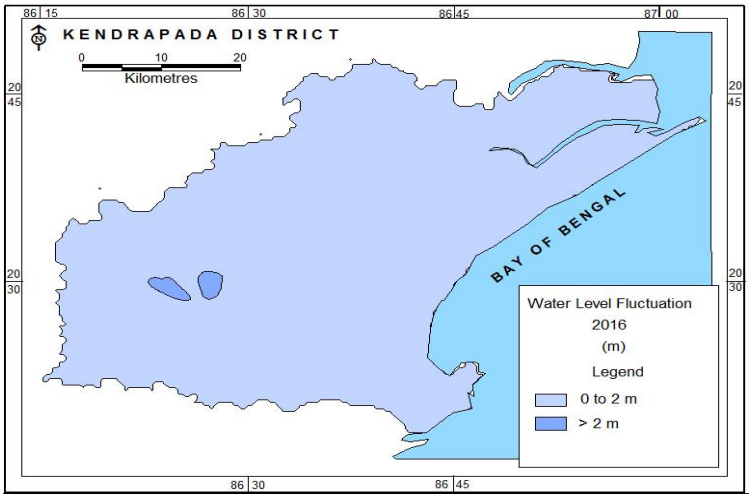
Period	No of wells analyzed	Depth to water level (mbgl)		No. and percentage of wells showing depth to water level (mbgl) in the range of					
				< 2m		2 to 5 m		5 to 10 m	
		Min	Max	No.	%	No.	%	No.	%
April-2016	22	2.5	4.7	0		22	100	0	
Aug-2016	25	0.65	2.35	24	96	1	4	0	-
Nov-2016	22	1.2	3.9	13	59	9	40.9	0	
Jan-2017	23	2.69	8.8	0		70	84.3	13	15.7



Map-3.1.1: Depth to Water level during Pre-monsoon Period (April, 2016)



Map-3.1.2: Depth to Water level during Post-monsoon period (Nov, 2016)

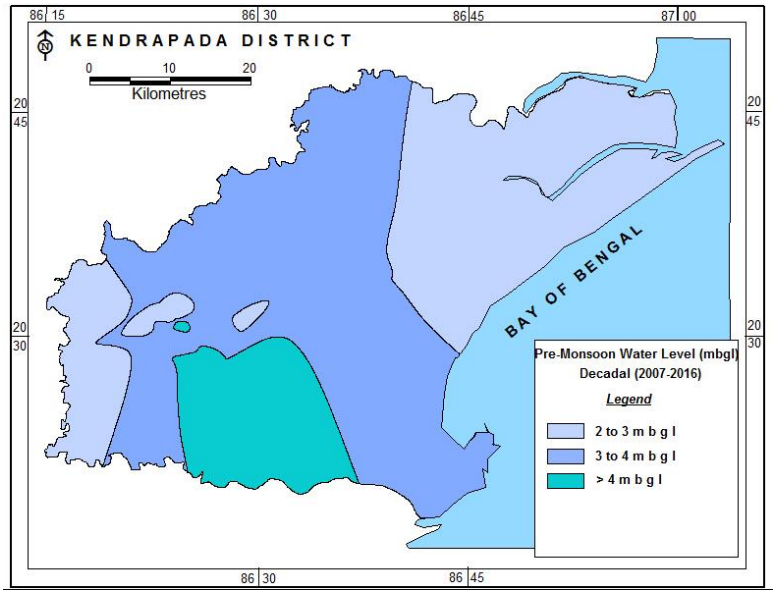


Map-3.1.3: Water level Fluctuation

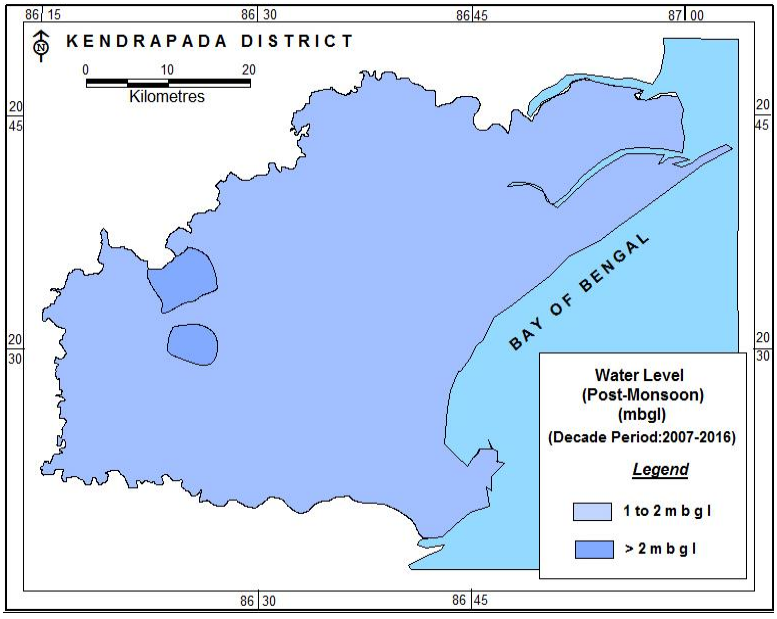
Decadal Changes in Water Level: Depth to water levels during a decade of 2007 -2017 were studied and recorded following seasonal variations as tabulated and shown in maps as below.

Table- 3.3: Decadal changes in water level during different seasons.

Parameters	Water Level		
	April-2007 to 2016 Pre-monsoon (mbgl)	Nov-2007 to 2016 Post-Monsoon (mbgl)	Fluctuation (m)
Minimum	2.40	1.09	0.88
Maximum	4.43	2.63	2.64
Average	3.22	1.60	1.62



Map-3.1.4: Depth to water level map of a decade during pre-monsoon (April, 2007 to 2016)



Map-3.1.5: Depth to water level map of a decade during post-monsoon (Nov, 2007 to 2016)

Change in Ground Water Scenario over a Decade of 2007 to 2017: It is as below

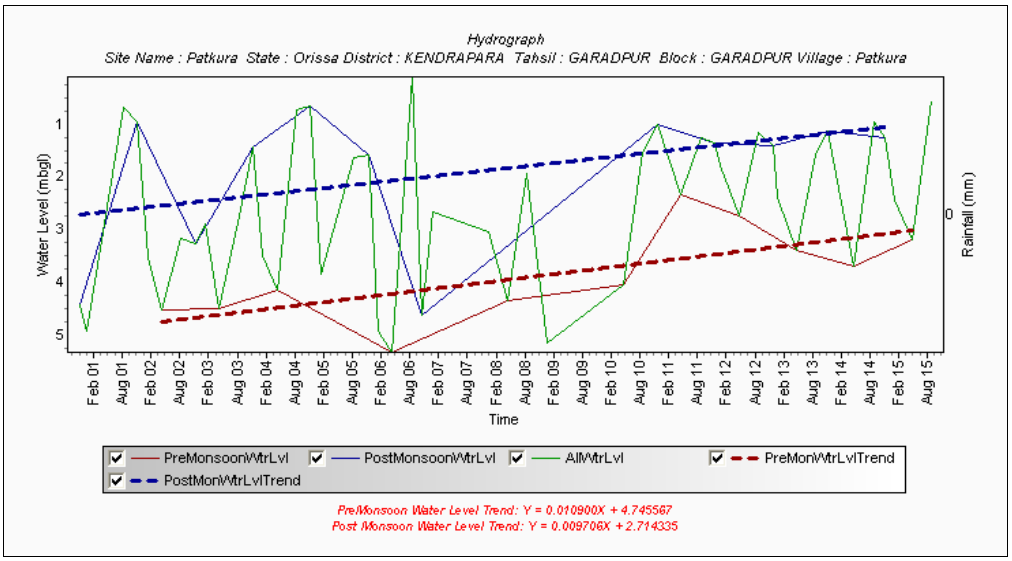
Table-3.4: Change in Ground Water Scenario over a Decade of 2007 to 2017

Period	No of	No of well	Range	No and % age of wells showing

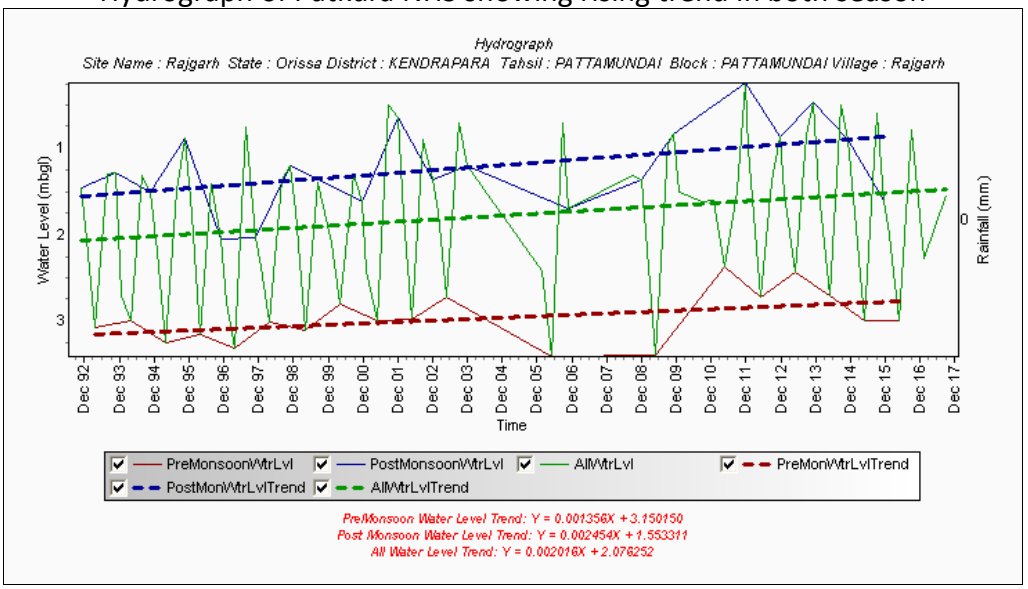
of Decade	wells analyzed	showing		Rise		Fall		Rise						Fall					
								0 to 2 m		2 to 4 m		>4 m		0 to 2 m		2 to 4 m		>4 m	
		Rise	Fall	Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
1*	17	14	3	0.2	2.2	0.1	5.6	13.0	76.5	1.0	5.9	0		2.0	11.8	0.0		1.0	5.9
2*	18	2	16	0.1	1.0	0.1	2.0	2.0	11.1	0.0		0		15.0	83.3	1.0	5.6	0.0	
3*	18	12	6	0.4	1.3	0.1	1.1	12.0	66.7	0.0		0		6.0	33.3	0.0		0.0	
4*	17	16	1	0.2	2.1	0.0	0.0	15.0	88.2	1.0	5.9	0		1.0	5.9	0.0		0.0	

Note: * Period of decade defining 1 as April-2007 – April-2017, 2 as August 2007-August-2017
3 as Nov-2007 – Nov-2017 and 4 as Jan-2008- Jan-2018

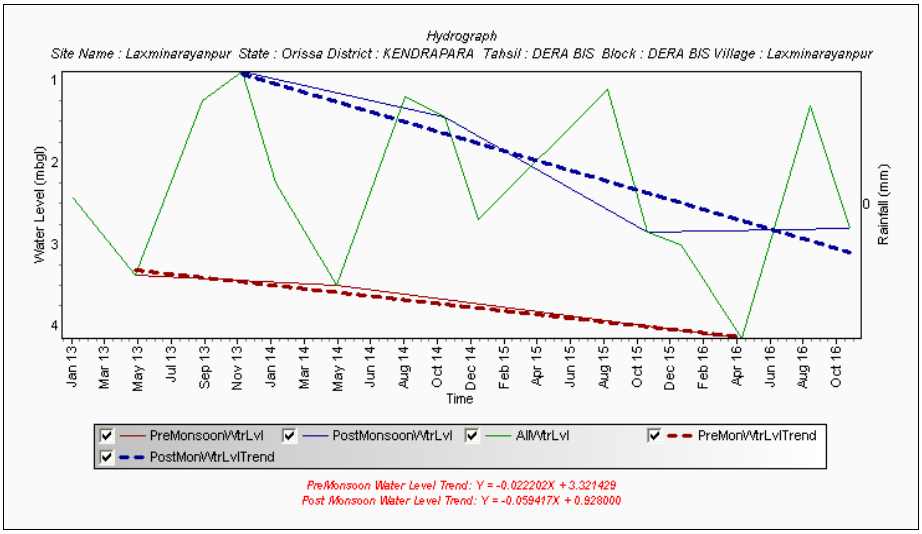
Change in Ground Water Scenario over the years: The long term trend of water levels of hydrograph stations (dug wells) indicate that 50 percent of the wells show rising trend with the rise of water levels varying between a to 0.5m while the rest 50 percent wells show falling trend with the fall of water levels ranging between 0.01 to 0.6 m. Rising and falling trends of water levels are depicted in some of the following hydrographs.



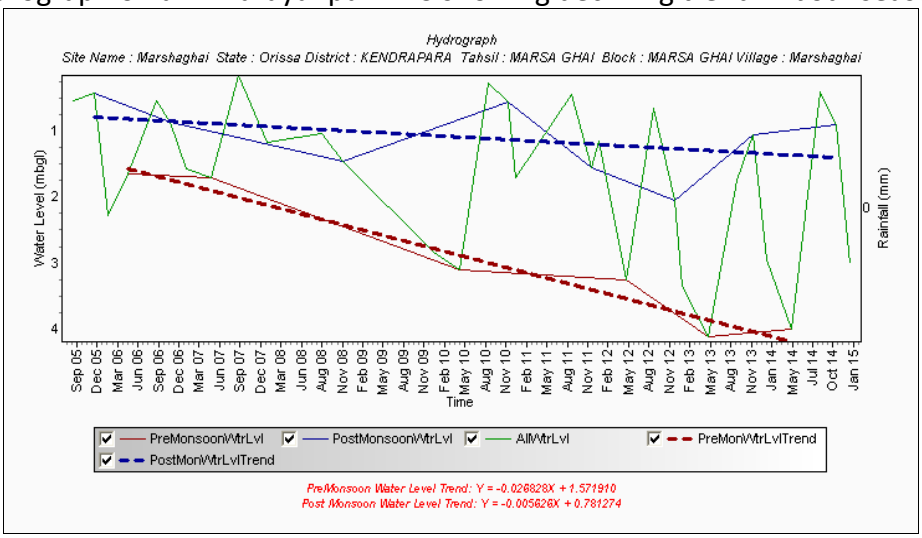
Hydrograph of Patkura NHS showing rising trend in both season



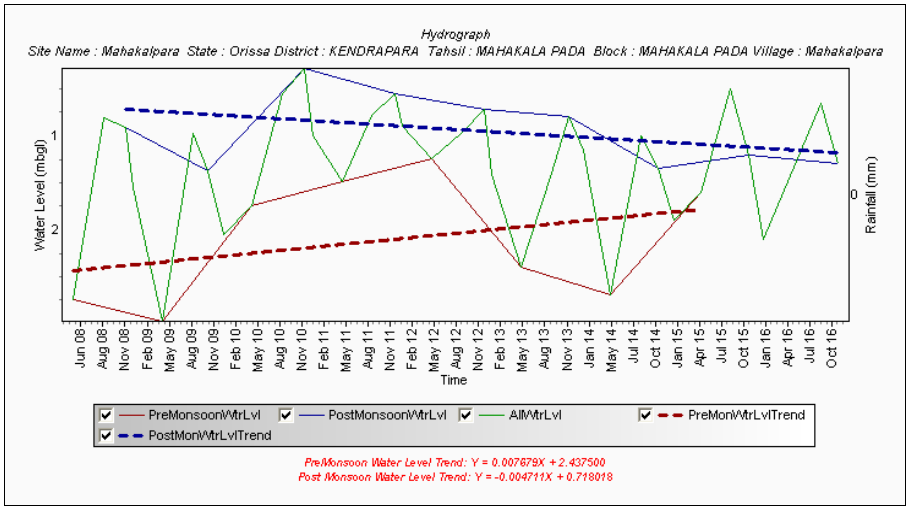
Hydrograph of Rajgarh NHS showing rising trend in both season



Hydrograph of laxminarayanpur NHS showing declining trend in both seasons

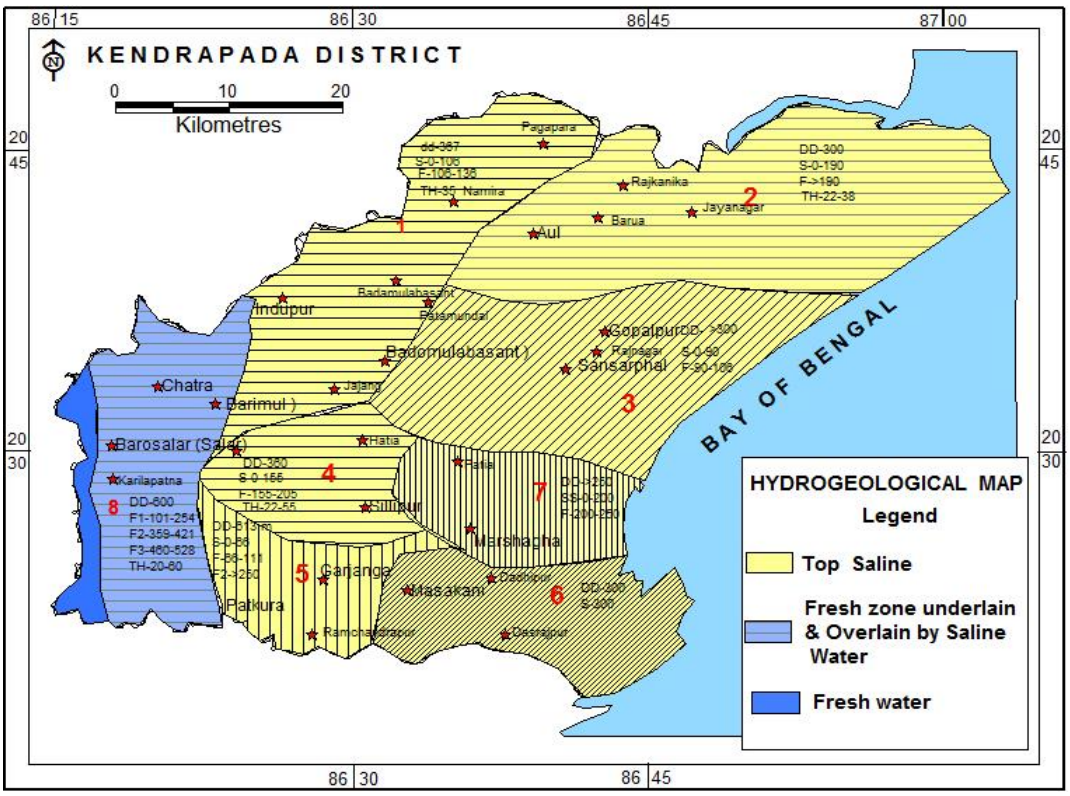


Hydrograph of Marshaghai NHS showing declining trend in both seasons



Hydrograph of Mahakalpara NHS showing rising trend in Pre-monsoon while declining in Post Monsoon period.

3.1.2: Deeper Aquifers: The occurrences of fresh water bearing deeper aquifers are identified from available bore holes data down to a maximum depth of 612m. In the major part of the district, the depths of the bore holes are restricted to 300m. Only for a small part in the south west the information are available down to 600 m depth (Barsalar- GarJanga area). The available information indicates that in general the deeper fresh water bearing zones are sand witched between saline water bearing zones. The fresh water bearing zones are composed of sand, silt, clay, gravel and among these materials sand and gravel horizon and mixture of sand and gravel zones form the prolific fresh water bearing aquifers. The sand grains vary in size from fine to very coarse while gravels are normally fine to medium in size. The distribution of fresh water bearing zones is described below for different sectors of the district. The different sectors are shown in following map.



Map-3.: Map of Kendrapara District divided into eight sectors depending on variation in lithology and hydro chemical profile. Sectors are shown in numbers from 1 to 8.

Description of each sector is as below.

Sector-I: Indupur-Chatra-Barimul-Jajang-Pattamundia-Namtara-Pegapara:

This sector occupies the north western and also major area of northern part of the district and fresh water bearing zone occurs from 106m (Chatra) to 136m (Pattamundai, eastern part) depth with the average depth around 120m below ground level and extends down to 300m depth, except at Indupur (265m). The cumulative thickness of the aquifer zones vary between 32 and 63m and the cumulative thickness reduces in the Namtara & Pegapara area. The occurrences of aquifer zones are generally restricted within 230m depth. In the extreme western part of this sector (west at Chatra) ground water is fresh all through.

Sector-II: Aul-Baruna-Jaynagar :

This sector occupies the north eastern part of the district and the fresh water bearing zones occurs on an average, below 190 m depth and extends down to 300 m depth or more. The

cumulative thickness of aquifer zone varies from 22 to 38 m and thickness reduces towards east. The occurrence of aquifer zones extend down to 300m depth.

Sector-III: Patamundai Gopalpur (Rajnagar)-Basantapur :

This sector occupies the middle portion of the eastern and east central part of the district and fresh water bearing zones occurs below 90 to 100m depth except at Basantapur near coast where fresh zone occurs below 114m depth and fresh zone, on an average, extends beyond 300m depth. The cumulative thickness of fresh water bearing aquifer zone varies from 47 to 166m and the aquifers are mostly composed of sand horizons. The thick aquifer zone (75 to 166m) composed mostly of sand horizons occur in Madanpur-Gopalpur-Sansarphal area. The occurrence of prominent aquifer zones in the eastern part (Gopalpur) extends down 280m depth while in the west (Patamundai) it is restricted to 230m depth.

Sector-IV: Kendrapara-Karilopatna-Marshagahai-Silipur:

This sector occupies the central portion of the western part of the district and the fresh water bearing zone occur below 155m (Kendrapara) to 205m (Silipur) depth and on an average it occurs beyond 180m below ground level and extends down to a maximum depth of 360m depth (Kendrapara) with the average depth around 300m below ground level. The cumulative thickness of fresh water bearing aquifers varies from 22m (Silipur) to 52m at Kendrapara. The thickness reduced from west to east and normally the occurrences of prominent aquifers zones are restricted within 250 m depth.

Sector-V: Ramchandrapur-Garjanga-Adampur:

This sector occupies the west central portion of the southern part of the district and fresh water bearing zones occur below 60m depth at Ramchandrapur in the south and below 80 m depth at Adampur in the north and in between at Garjanga ,fresh zone occurs below 66 m depth. At Adampur only one fresh water zone occurs which extends beyond 282 m depths while at Garjanga and Ramchandrapur 2 fresh water bearing zones occur. At Garjanga the first fresh zone occurs between 66-111 m depth range and second zone occurs between 304 and 388m depth range while at Ramchandrapur the first zone occurs between 60 and 170m· depth and second zone below 250m depth. The cumulative thickness of aquifer zone varies from 26 to 42m and thickness gradually reduces towards Adampur.

Sector-6: Masakani-Dodhipur-Dasorajpur :

This sector occupies the part of east central and eastern portion of the southern part of the district and it is reported that in this sector saline water bearing zone extends down to 300m depth. No information is available beyond 300m depth. It is also reported that in this sector in some isolated pockets number of thin aquifer layers containing brackish water having chloride content 450 to 600 mg/l occur in between 70 and 225m depth range.

Sector-7 Sijaynagar-Rajghar-Gobindpur- Patia - Babur:

This sector occupies the northern portion of the south eastern part of the district and no detail data are available as no exploratory bore holes are drilled by any central or state agencies. Only scanty data of **PHED** tube wells indicate that fresh water bearing zones with chloride concentration less than 100mg/l occurs in between 200 and 250m depth range. It is also reported that 15 to 22m of aquifer zones (cumulative thickness) are available in this sector down to 250m depth and the thickness reduces towards east.

Sector-8: Barsalar-Karilopatna-Balada :

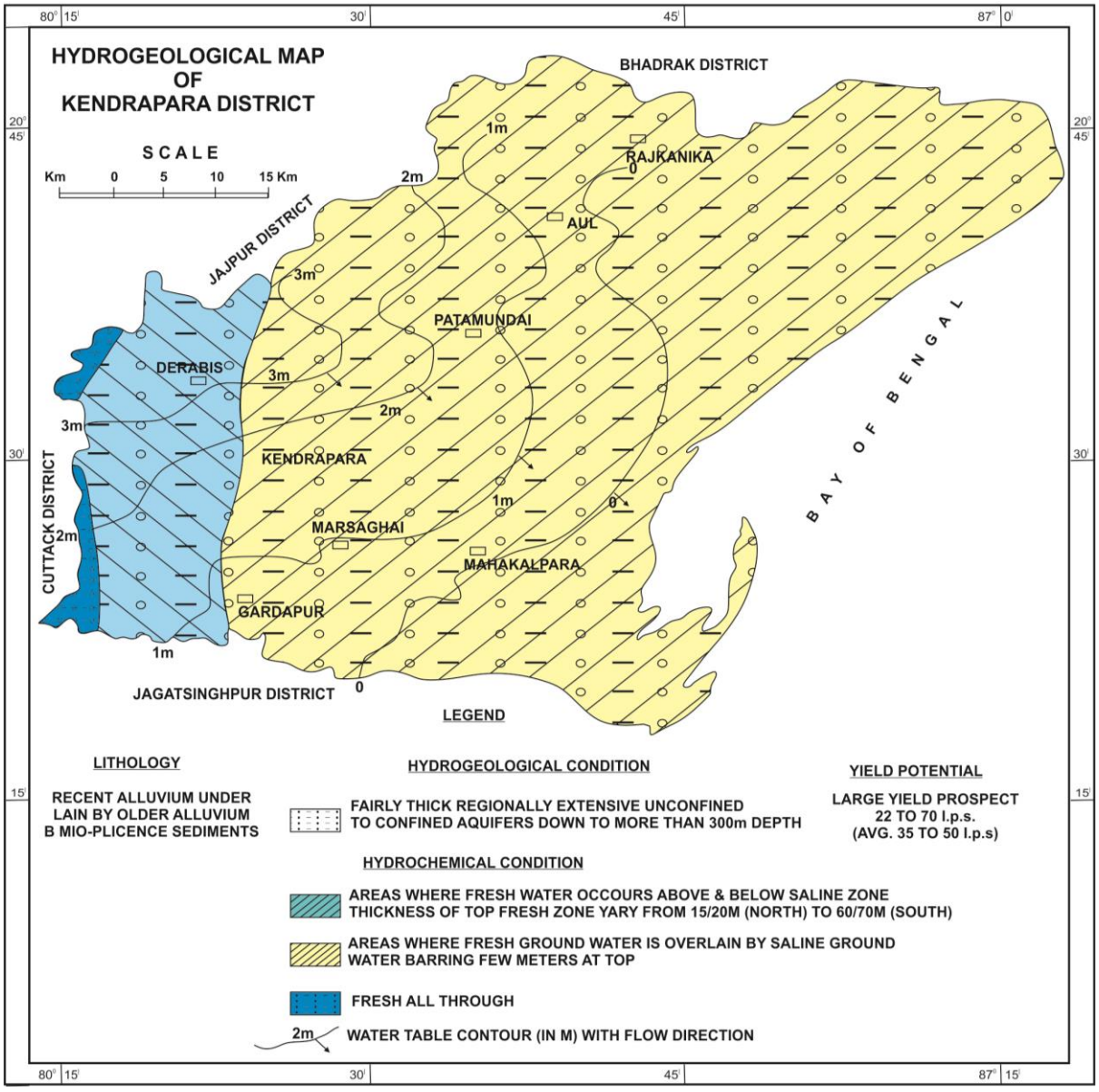
This sector occupies the south western corner of the district and in this sector the small pocket occurring in extreme south west corner (North of Khandatari) of the district do not suffer from any salinity problem and the ground water is fresh all through. In Barsalar-Karilopatna at deeper depth saline and fresh water bearing zones occur alternately and this

behavior matches with the behavior of Garjanga-Ramchandrapur area occurring south east of this sector. At Barsalar three fresh zones occur alternating with saline zone down to 600m depth and first deeper fresh zone occurs between 101 and 254m depth, second zone between 359 & 421 m depth and third zone between 460 and 528m depth. Besides these, the thickness of fresh to brackish zone which occurs below top fresh zone at 60 m (Barsalar) and 20m (Karilopatna) and which extends down to 90m depth becomes thinner towards south and ultimately near the southern boundary of the sector this fresh to brackish zone vanishes and the top fresh zone extends down to 90 or 95m depth and below which the first saline zone occurs.

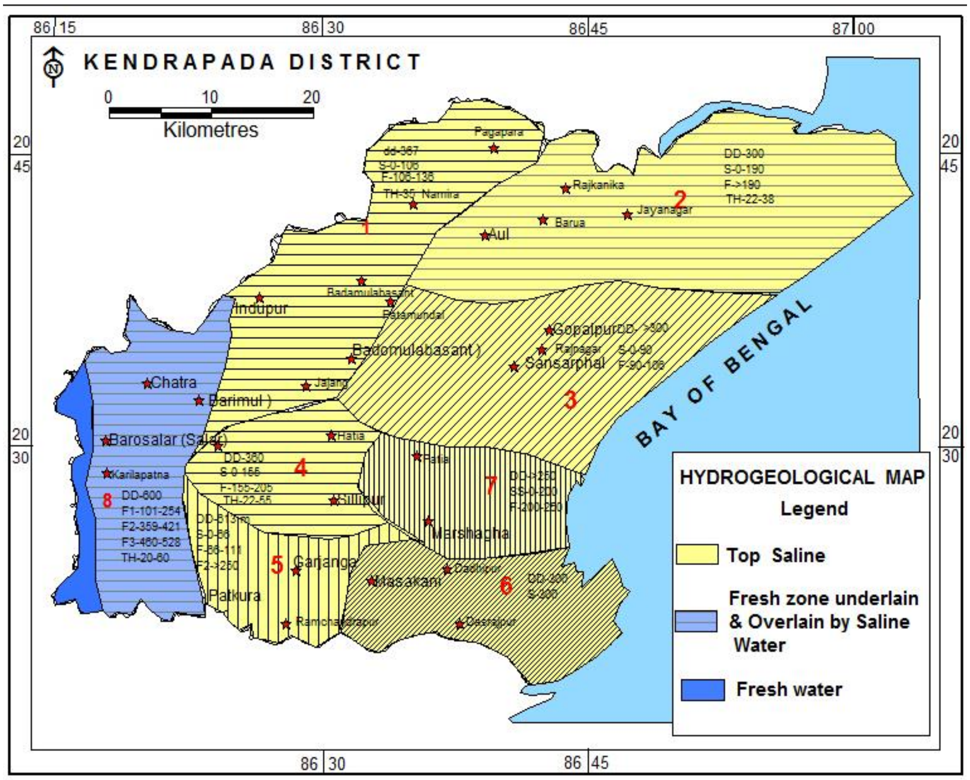
3.2 Aquifer Parameters:

The deeper fresh water bearing aquifers are being exploited extensively through deep tube well and the aquifer parameters have been studied from the available pumping that data of deep exploratory and deposit wells of CGWB.

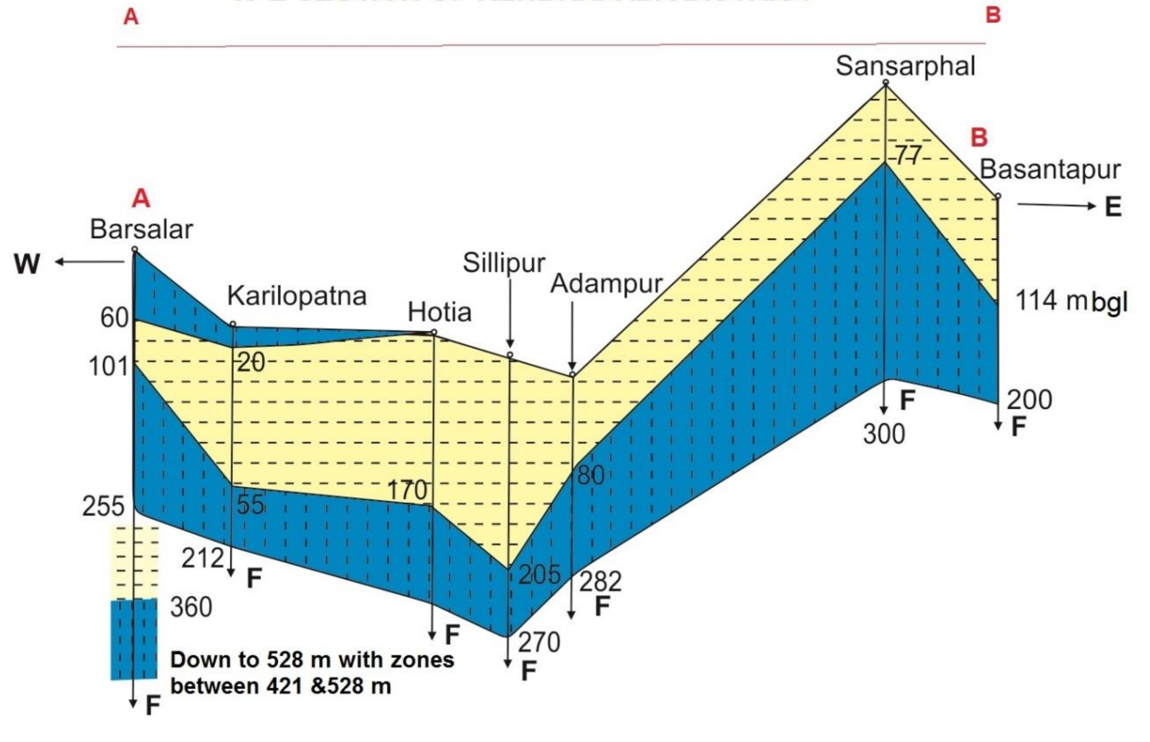
The cumulative thickness of the aquifers which have been tapped by these wells varies from 20 to 69 m with the average value ranging between 30 and 40 m. The yield of these tube wells varies from 22 to 71 liters per second. The yield is normally high (75Ips) in the Patamundai-Madanpur-Gopalpur-Sansarphal area (sector 3) while in other areas, on an average, the yield ranges between 30 to 401ps. The piezometric heads (static water levels) in the tube wells vary from 2.19m b.g.1 to 0.91m a.g.l. The draw downs of pumping water levels vary from 9.70 to 24.52m with the average values ranging from 10 to 15m. The Transmissivity values range from 110 to 7445 m2/day with the average value occurring between 1000 to 1500 m2/day. The storage co-efficient varies from 1.6x1 $0.^{4}$ to 8.8x1 $0.^{5}$ which indicate that the deeper aquifers are under confined conditions.



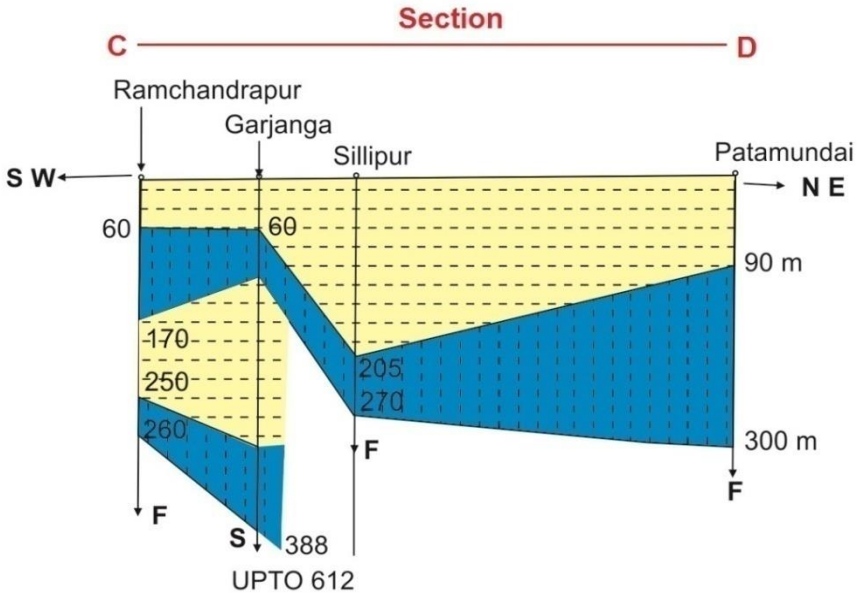
Map-3.: Hydrogeological map of Kendrapara District

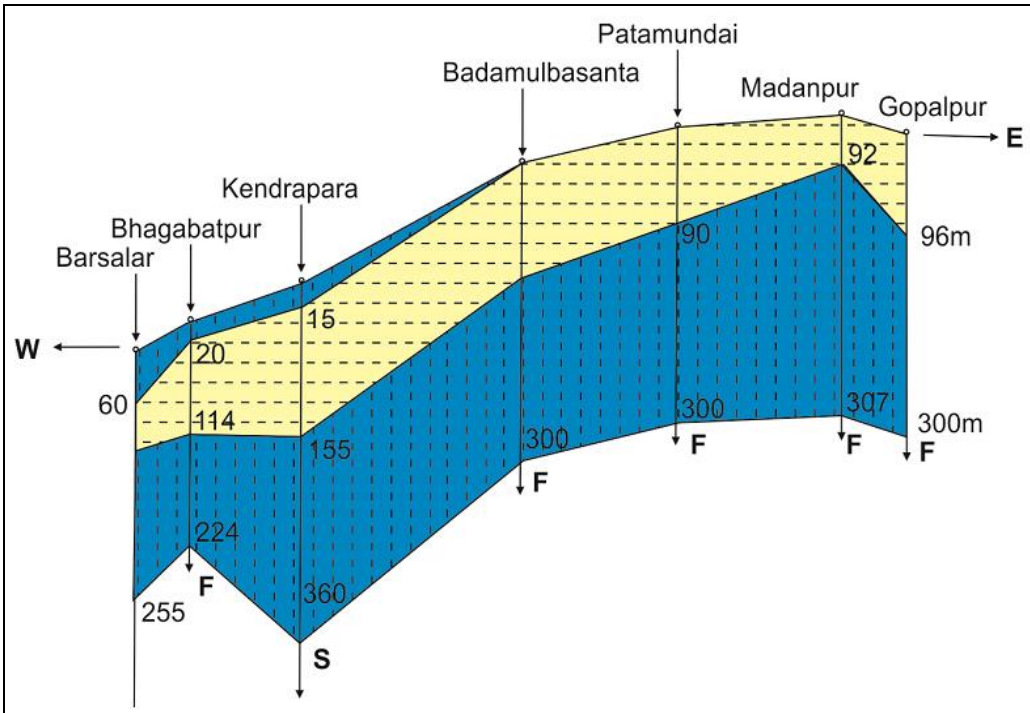


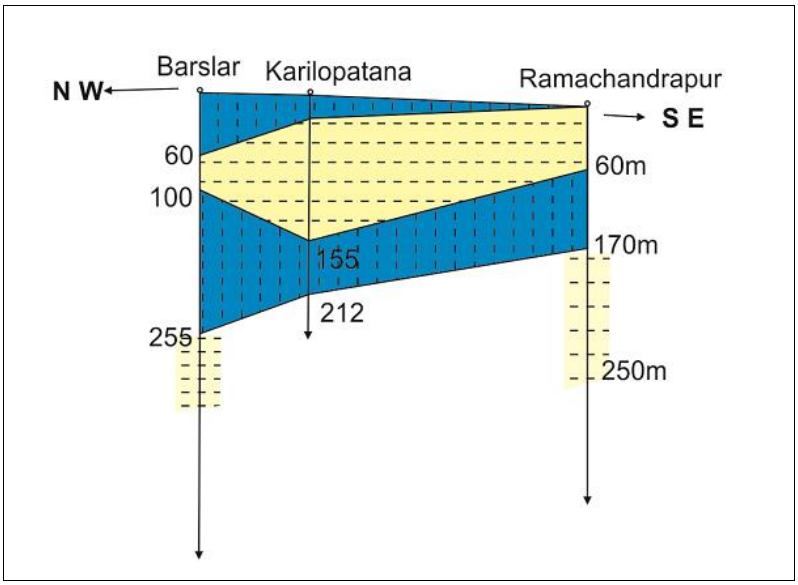
DISPOSITION OF FRESH AND SALINE WATER BEARING ZONES IN W-E SECTION OF KENDRAPADA DISTRICT

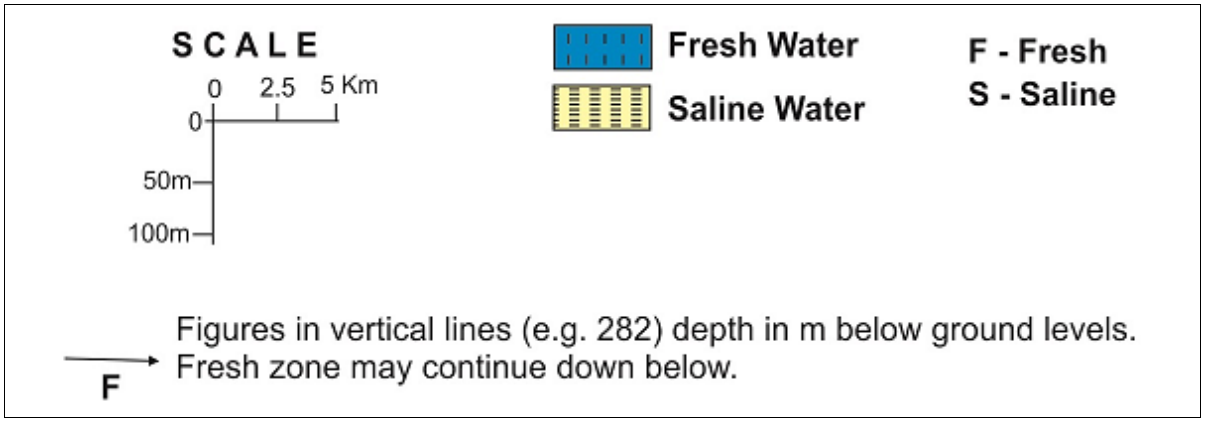


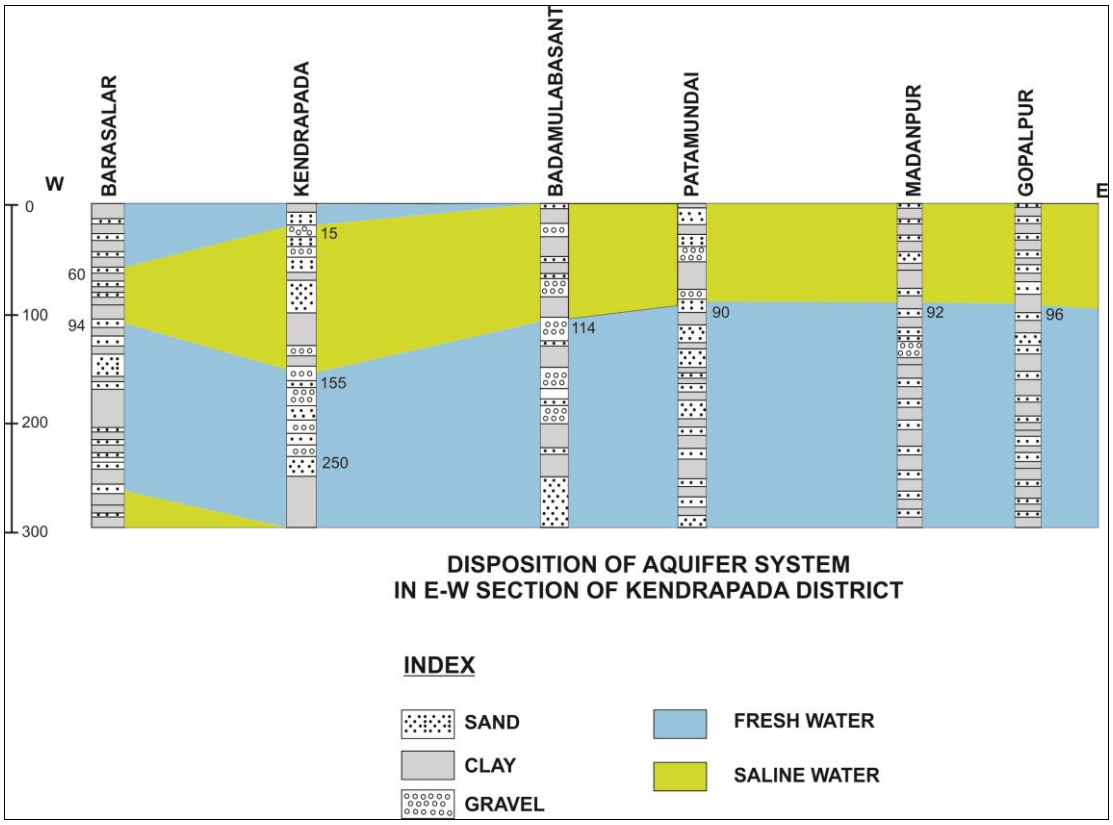
DISPOSITION OF FRESH AND SALINE WATER BEARING ZONES IN SW-NE SECTION OF KENDRAPADA DISTRICT

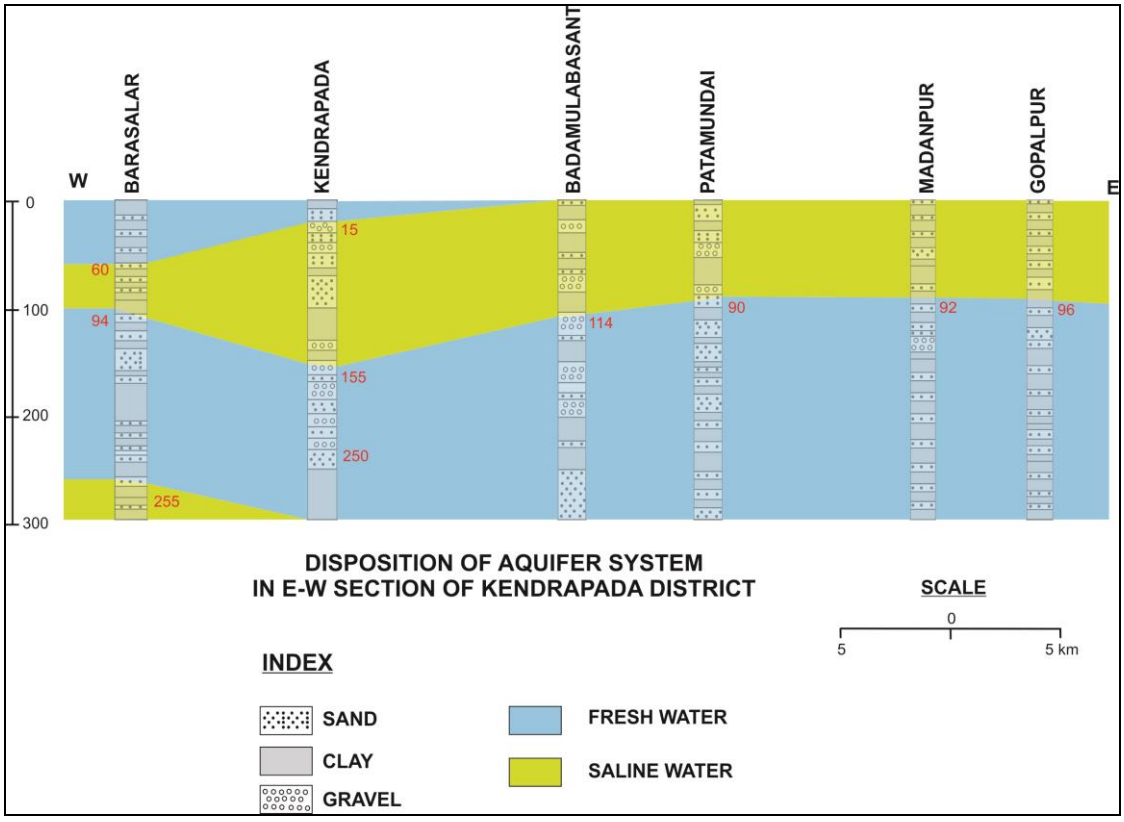


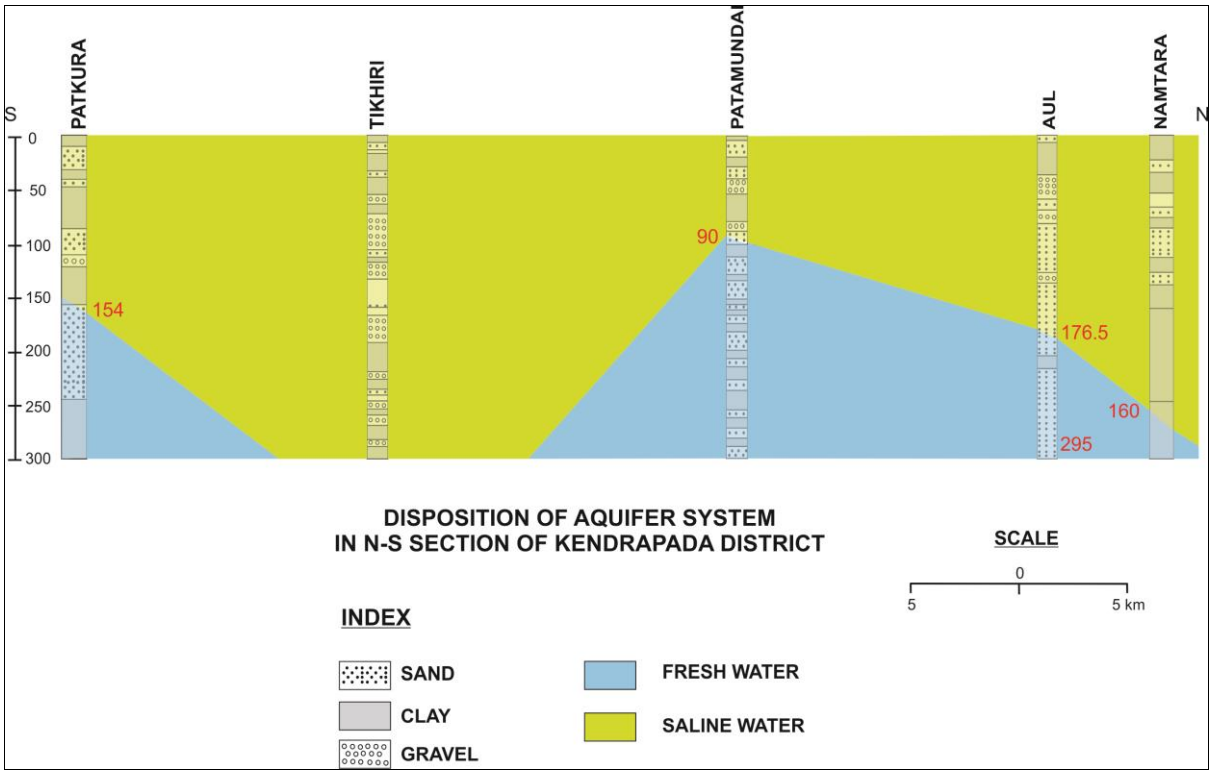



Barslar
Karilopatana
Ramachandrapur
N W
S E
60
100
155
212
255
60m
170m
250m

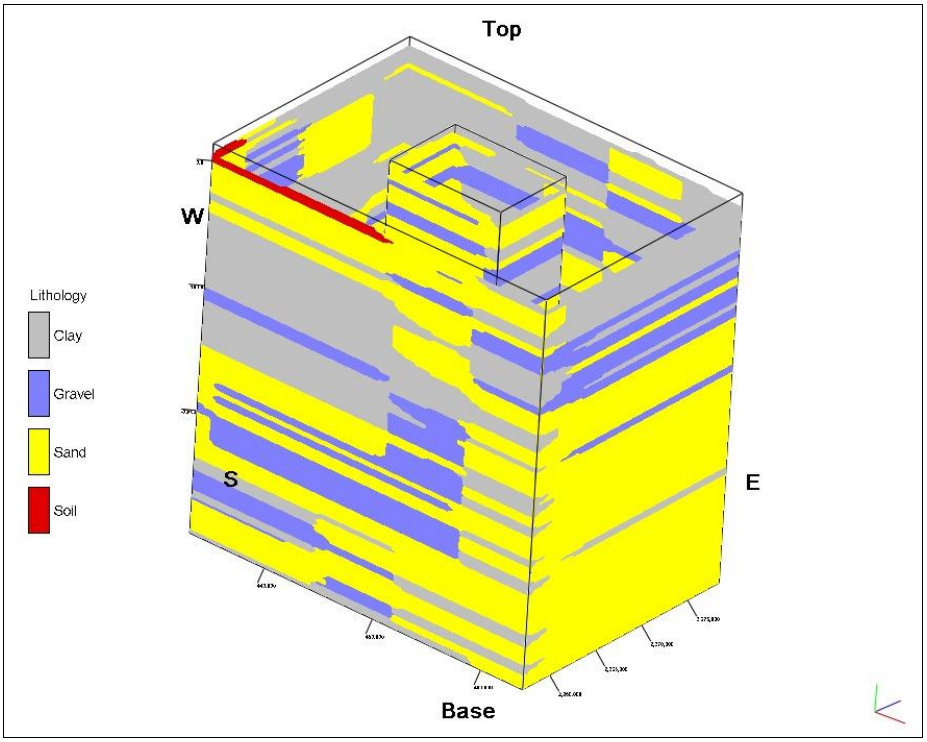

S C A L E
0 2.5 5 Km
0
50m
100m
Fresh Water
Saline Water
F - Fresh
S - Saline
Figures in vertical lines (e.g. 282) depth in m below ground levels.
Fresh zone may continue down below.
F

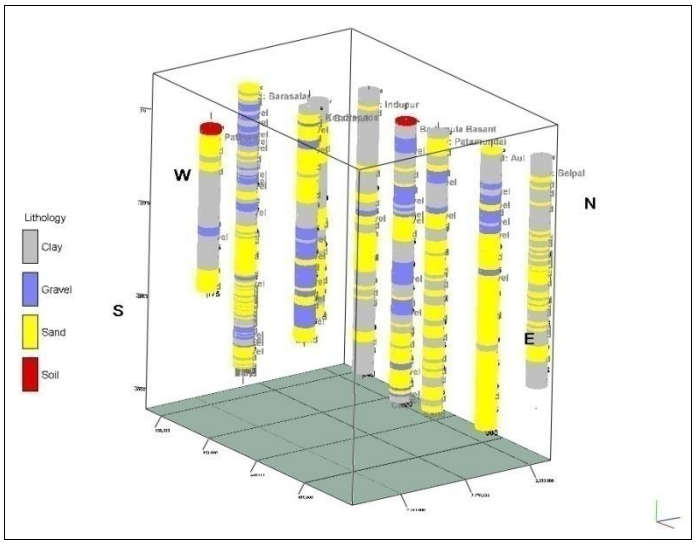

W
E
BARASALAR
KENDRAPADA
BADAMULABASANT
PATAMUNDAI
MADANPUR
GOPALPUR
0
100
200
300
60
94
15
155
250
114
90
92
96
DISPOSITION OF AQUIFER SYSTEM
IN E-W SECTION OF KENDRAPADA DISTRICT
INDEX
SAND
CLAY
GRAVEL
FRESH WATER
SALINE WATER

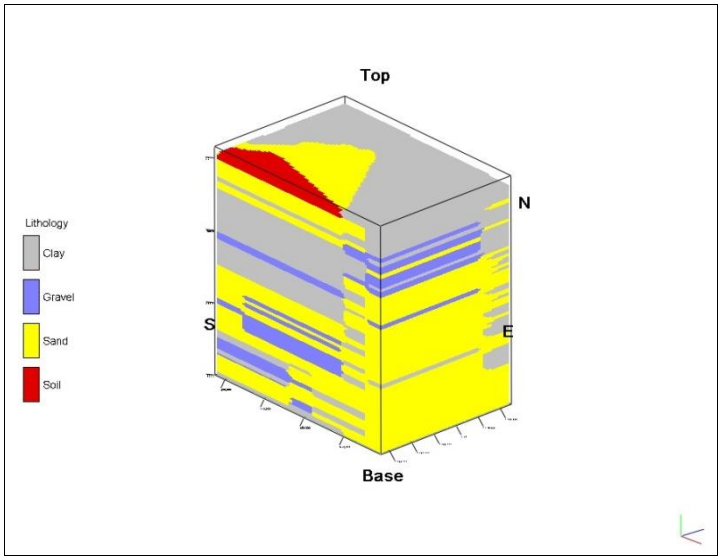

W
E
BARASALAR
KENDRAPADA
BADAMULABASANT
PATAMUNDAI
MADANPUR
GOPALPUR
0
100
200
300
60
94
255
15
155
250
114
90
92
96
DISPOSITION OF AQUIFER SYSTEM
IN E-W SECTION OF KENDRAPADA DISTRICT
SCALE
0
5
5 km
INDEX
SAND
CLAY
GRAVEL
FRESH WATER
SALINE WATER

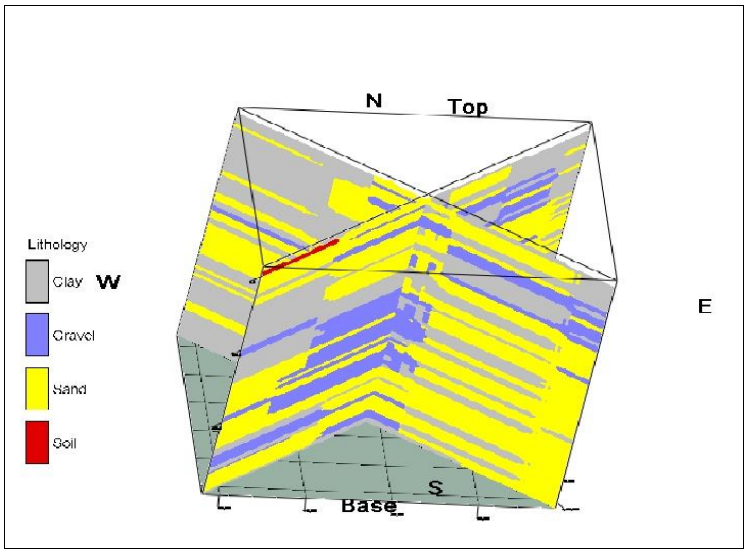


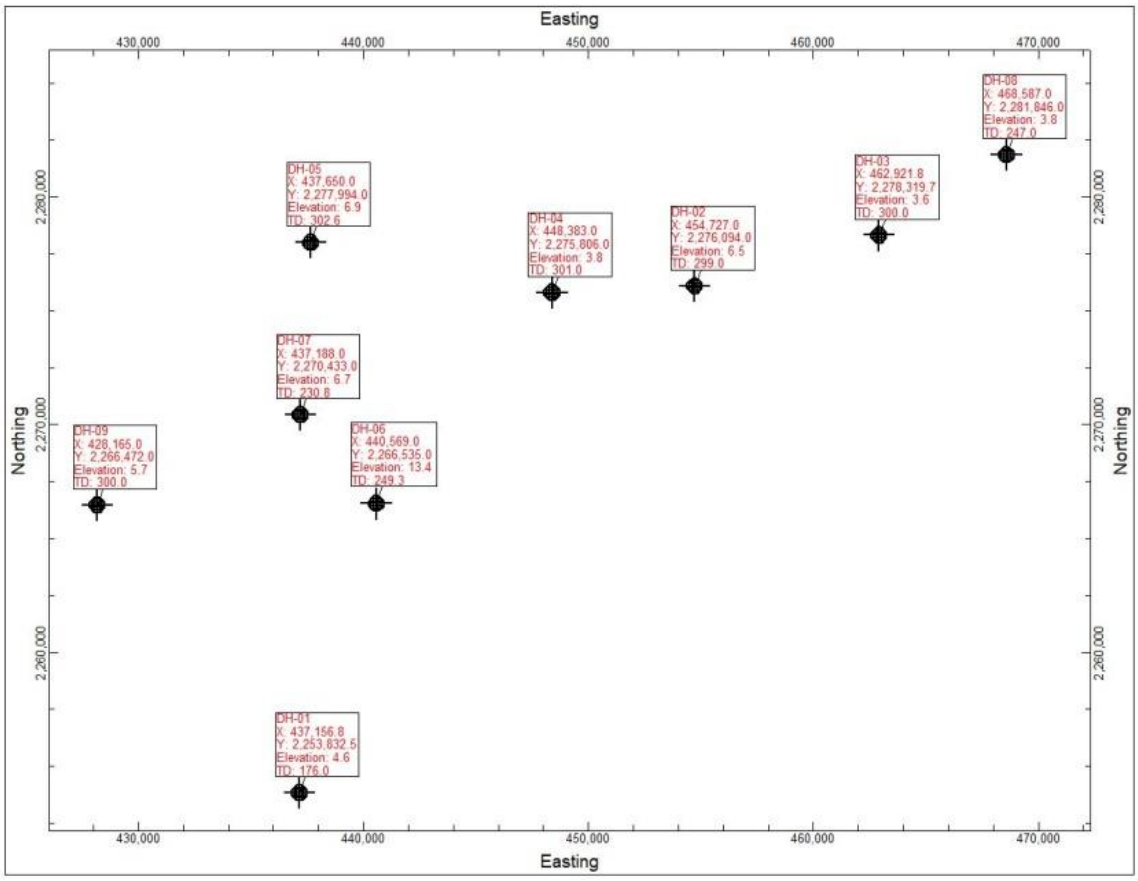
3 D View of litholog of 9 tube wells




Lithology
Clay
Gravel
Sand
Soil
W
S
N
E
Barasalai
Indupur
Selpal


Top
Lithology
Clay
Gravel
Sand
Soil
N
S
E
Base


N
Top
Lithology
Clay
W
Gravel
Sand
Soil
E
S
Base



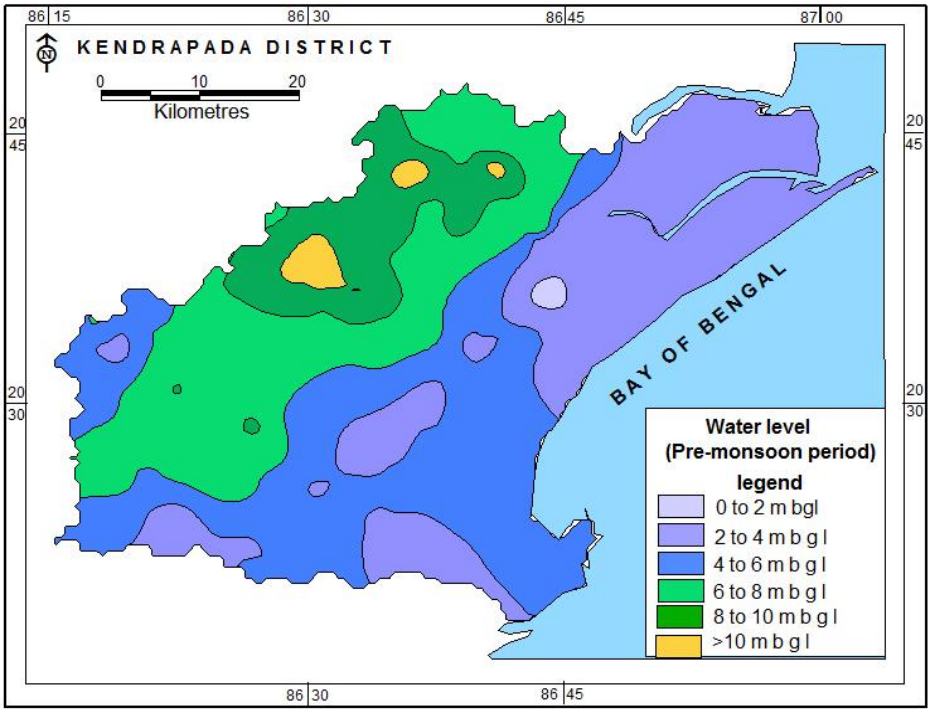
Locations of 9 Tube wells for which 3 D view of lithology is made.

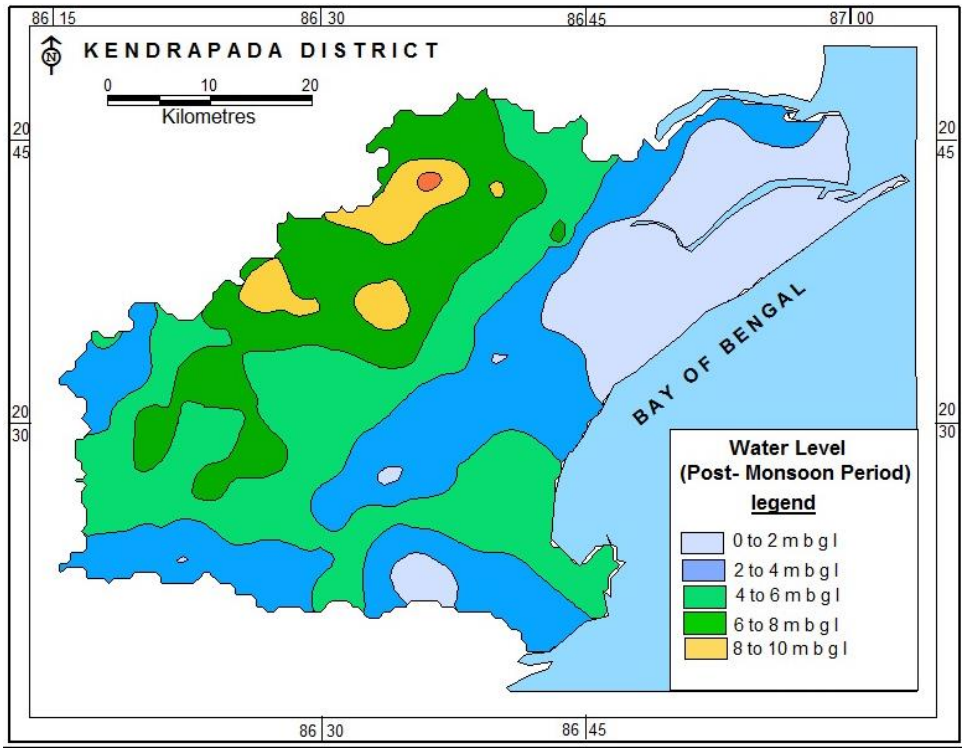
Symbol	Location	Longitude	Latitude	Symbol	Location	Longitudes	Latitudes
DH-1	Patkura	86 23 52	20 22 54	DH-6	Kendrapada	86 25 48.2	20 29 47.6
DH-2	Patamundai	86 33 55	20 35 00	DH-7-	Barimul	86 23 51	20 31 54
DH-3	Aul	86 38 39	20 36 13	DH-8	Belpal	86 41 54.5	20 38 08.1
DH-4	Badamula Basant	86 30 17	20 34 50	DH-9	Barasalar	86° 18′ 40″	20° 29′ 44″
DH-5	Indupur	86 24 06	20 36 00				

Water level in Deeper Aquifer: The depth of the tube wells (100 nos.) vary from 150 to 300 and the average depth to water levels (piezometic surface) during pre-monsoon vary from 1.73 to 10.95 and during post monsoon 1.27 to 10.30 and on an average the average fluctuation. is 1.28 m. Details are as below.

1. No of wells monitored:100
2. Depth : 150 to 300 m
3. Pre-monsoon DTW: 1.73-10.95 mbgl
4. Post Monsoon DTW: 1.27-10.30 mbgl
5. Average fluctuation : 1.28 m

Map depicting water level during pre-monsoon, post monsoon and fluctuation are shown in following maps.





3.3: Ground Water Quality:

3.3.1:Quality of shallow ground water: The quality of shallow ground water is being monitored by analyzing the water quality of permanent net work stations (dug wells) once in a year (April). The range of chemical constituents and characteristic of ground water from phreatic aquifer for the year 2016 (April) are shown the following table.

Table-3.5: Ground Water Quality in Shallow Aquifer

Parameters	Minimum	Maximum	Average
PH	7.74	8.46	8.09
EC	420	6490	1280.00
Co_3	0	0	0.00
HCO_3	61	1379	264.31
CL	40	918	211.00
SO_4	3	596	99.25
F	0.08	0.43	0.17
Ca	18	250	54.25
Mg	13.42	164.42	34.11
Na	18	860	154.88
K	1.5	58.3	13.76
TDS	223	3511	698.56
TH	135	1300	275.63
TA	50	1130.33	219.78

Note: All components are in mg/l except EC which is in micro mho/cm at 25°C

The ground water is alkaline in nature and is suitable for drinking purpose except in local pockets. The higher concentration of chemical constituent (E.C=6490 and 2220) are noted at Kasoti and Jajang respectively and where the ground water is brackish is nature (CI= 918 and 507). The slight higher concentrations of different chemical constituents including chloride (436 mgl) are also noted from Dahuria. The concentration of fluoride is within normal limit. The details of chemical analysis results are given in annexure-4.

Suitability for Irrigation: The Sodium Adsorption Ratio (SAR) Values along with specific conductance of ground water of select hydrograph stations (dug wells) are presented below in following table.

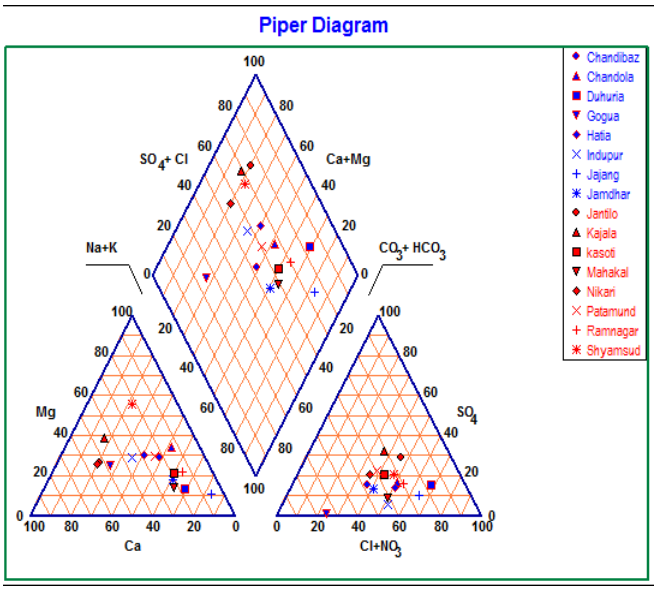
Table-3.6: EC, SAR, RSC and % Na values of shallow aquifers

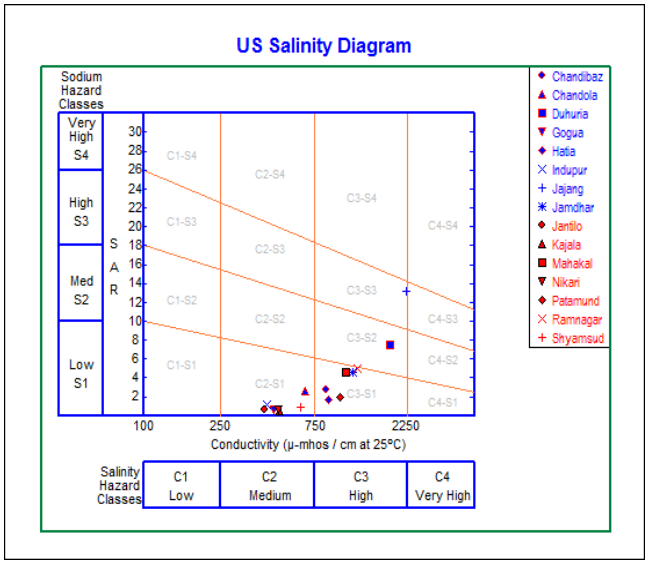
Location	pH	EC	SAR	RSC	%Na	Class
Chandibazar	7.74	870	2.70	-0.31	46.66	C_2S_1
Jamdhar	8.25	1180	4.58	0.39	59.31	C_3S_1
Mahakalpara	8.46	1100	4.64	0.09	59.85	C_3S_2
Hatia	8.19	890	1.66	-2.01	30.86	C_2S_1
Chandola	8.04	680	2.58	-0.91	49.73	C_2S_1
Indupur2	7.95	430	1.20	-0.90	33.31	C_2S_1
Jajanga	8.23	2220	13.16	1.90	82.62	C_3S_3
Kasoti	7.77	6490	10.36	-3.43	57.84	-
Kajala	8.13	500	0.55	-2.60	15.71	C_2S_1
Shyamsundarpur	8.06	640	0.86	-2.90	21.36	C_2S_1
Jantilo	8.1	420	0.61	-2.31	18.78	C_3S_1
Duhuria	7.91	1830	7.43	-2.61	68.77	C_3S_2
Ramnagar	8.1	1250	5.01	-0.80	60.60	C_3S_1
Nikrai	8.06	490	0.61	-1.61	17.83	C_2S_1
Pattamundai1	8.37	1020	1.90	-1.31	31.22	C_3S_1
Gogua	8.12	470	0.69	0.30	19.82	C_2S_1

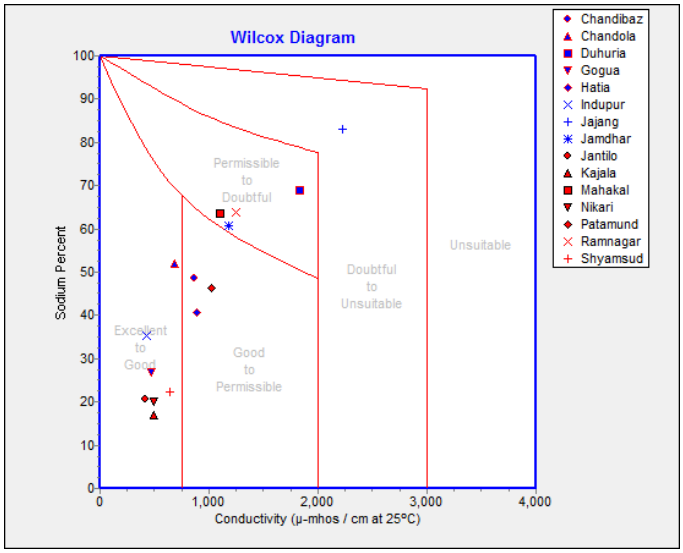
Table-3.7 : Statistical parameters of water quality of shallow aquifers

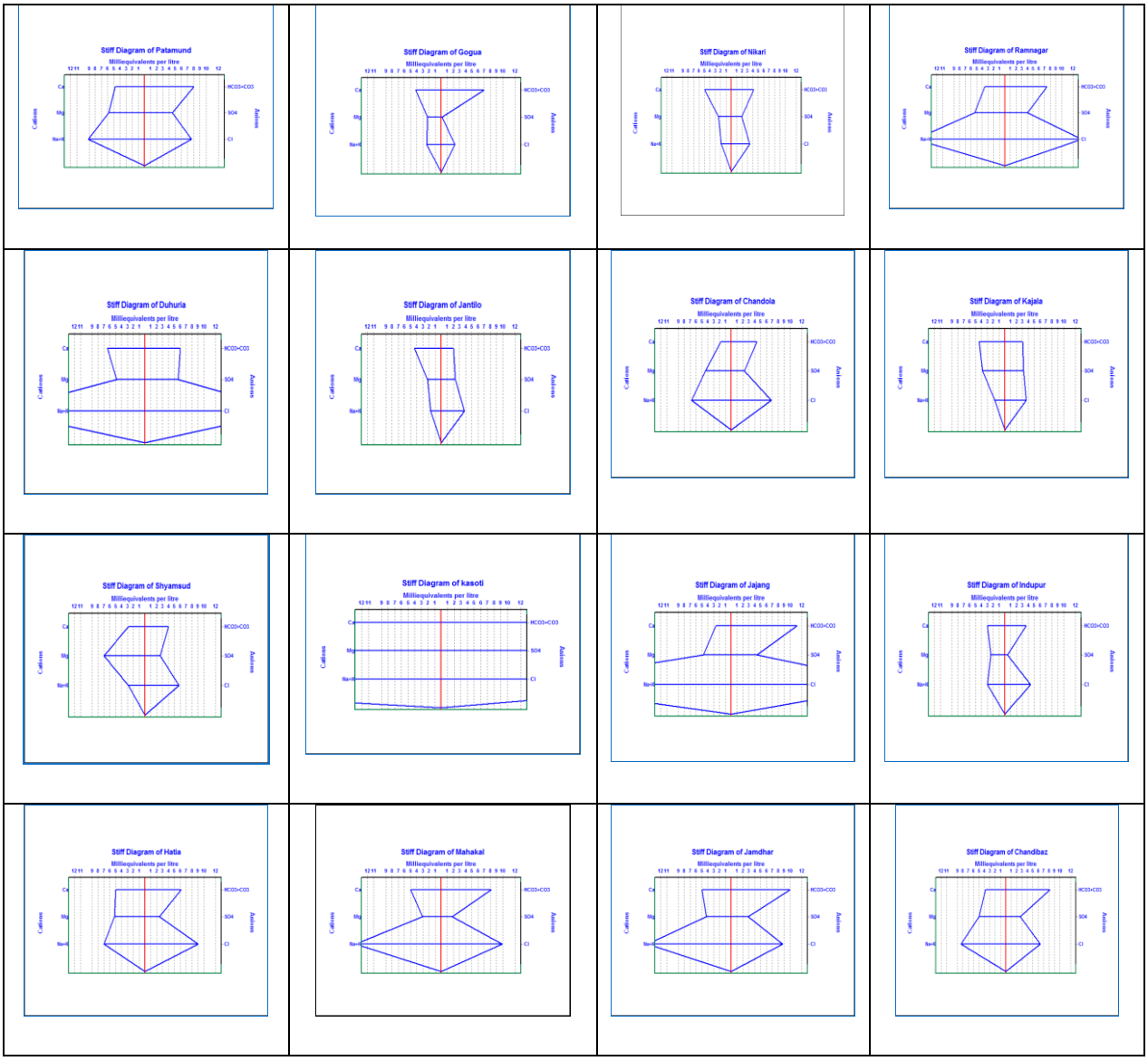
Parameters	PH	EC	SAR	RSC	%Na
Minimum	7.74	420	0.55	-3.43	15.71
Maximum	8.46	6490	13.16	1.90	82.62
Average	8.1	1280.0	3.66	-1.19	42.14

The sodium Adsorption values ranges from 0.55 to 13.16 with average of 3.66 indicating its suitability for irrigation purposes except at Kasoti where it is extremely high (SAR-13.16) . Similarly EC values of all samples making its suitability for irrigation except at Kasoti. The ground water of the phreatic zone may be classified under low alkaline and medium to high salinity classes i.e . C_2S_1 and C_3S_1 class of U.S. Salinity laboratory classification. The C_2S_1 type of Water is suited for most types of crops, while C_3S_1 type may be used for salt tolerant crops. Qualities of ground water of shallow aquifers are represented by following diagrams making its suitability for drinking as well as for irrigation purposes except at Kasoti.









Stiff diagram showing water quality of shallow aquifers of Kendrapara District.

3.2.2: Quality of Water from Deeper Aquifers: The ground water from deeper aquifers is

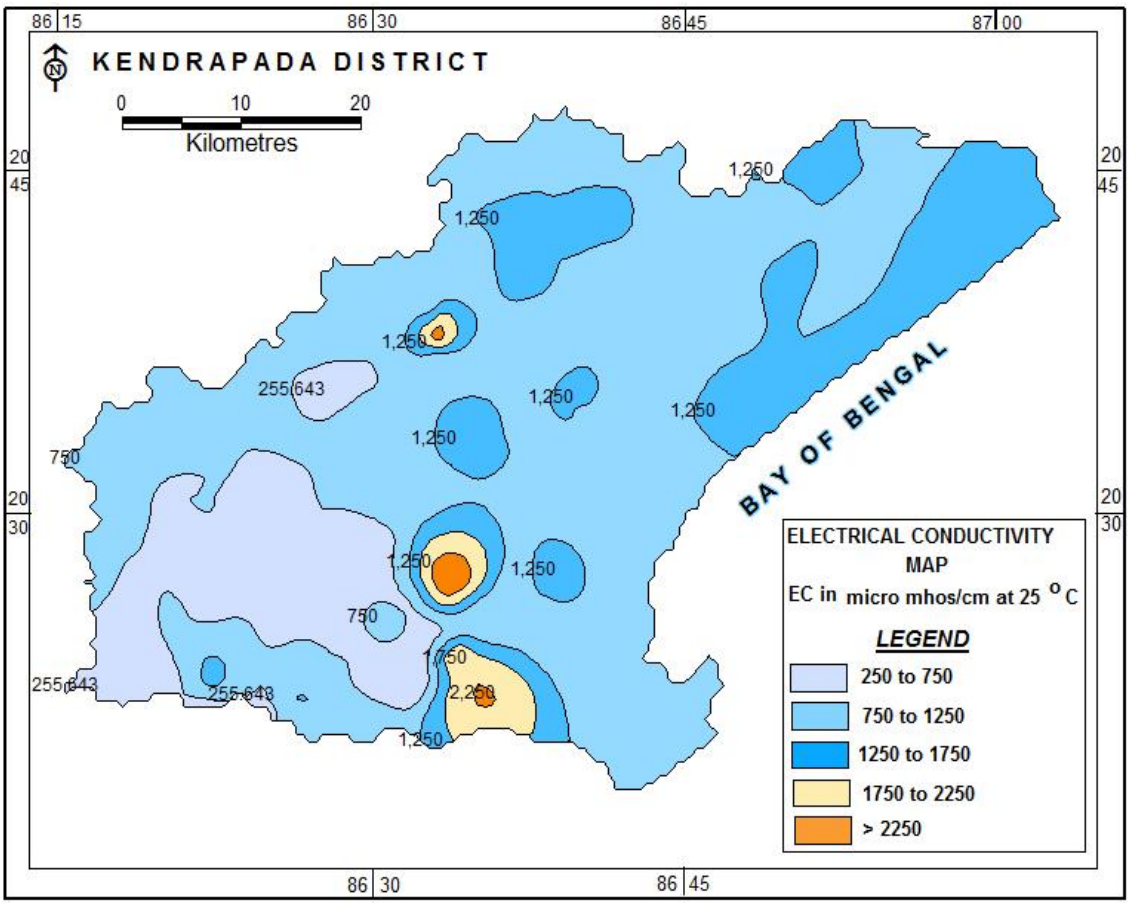
also alkaline in nature and suitable and for domestic and irrigation purposes. The ranges of important chemical constituents in groundwater are given in following table.

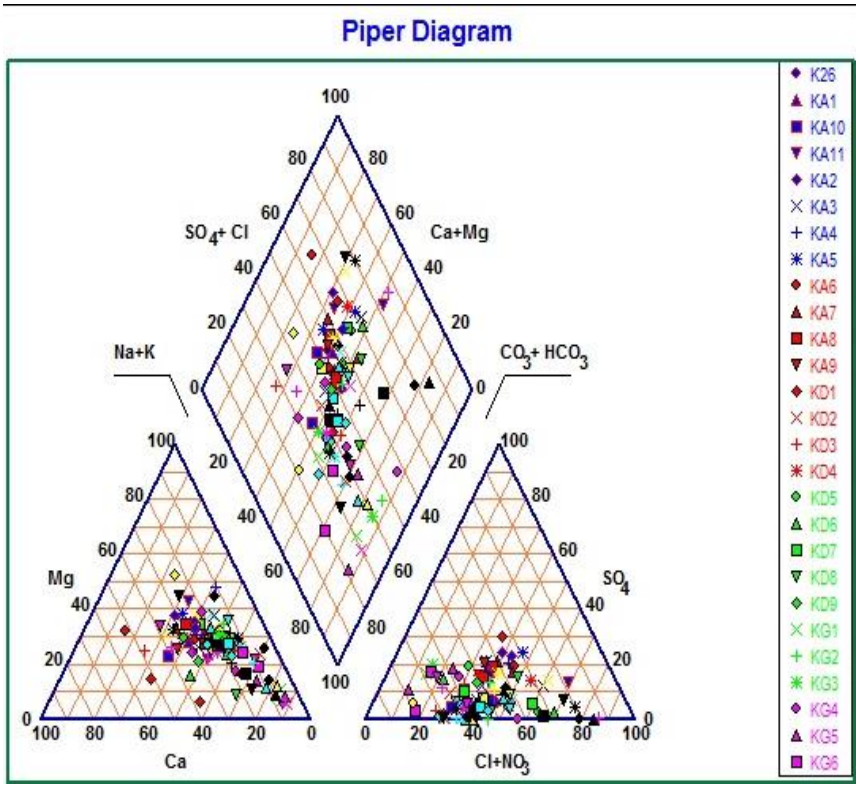
Table3.8: Statistical parameters of water quality of deeper aquifers

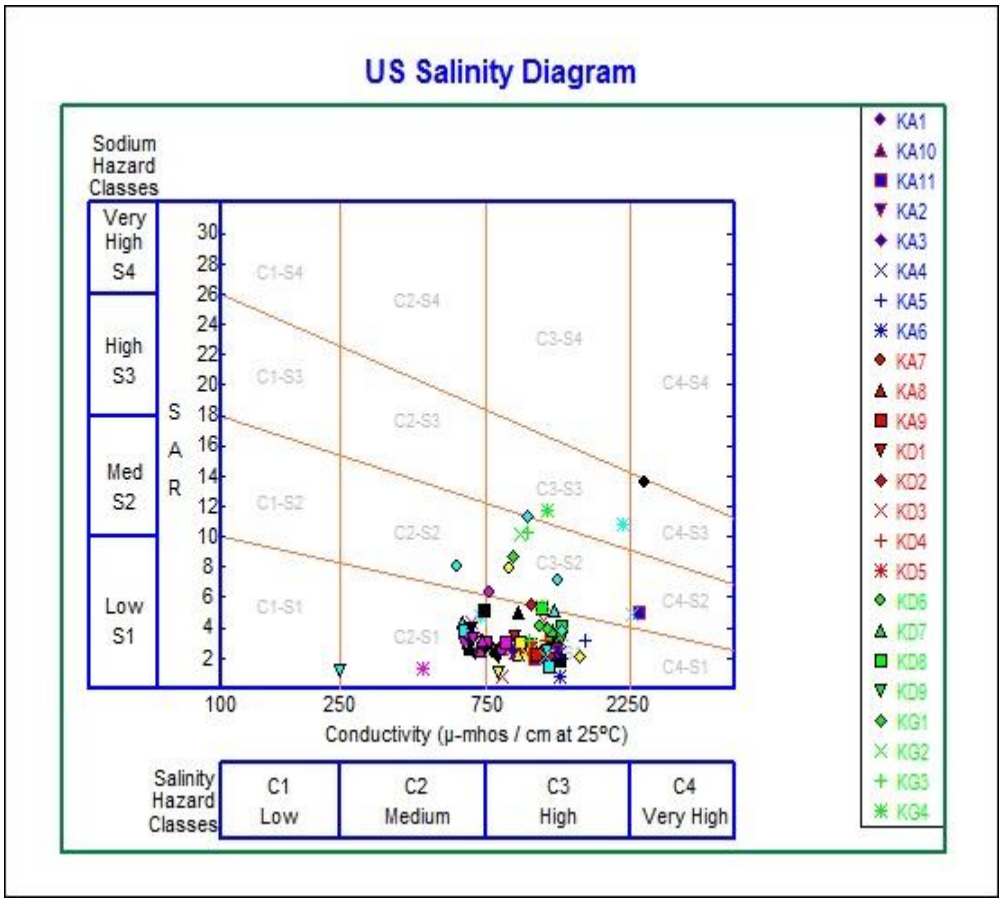
Parameters	Minimum	Maximum	Average
pH	7.2	8.51	8.0037
EC	250	2530	1051.47
CO3=	0	39	1.8
HCO3-	80	537	294.8
Cl-	24	837	162.84
SO4=	0	188	50.476
F-	0.1	1.32	0.3001
Hardness	40	585	251.27
Ca++	6	130	46.11
Mg	6.1	63.2	33.047
Na+	23.8	464.4	118.243
K+	2	39.1	10.009
TDS	132	1520	567.1
Alkalinity	66	440.2	245.014
SAR	0.74	13.62	3.66
RSC	-7.77	5.64	-0.13
% NA	14.38	85.10	49.39

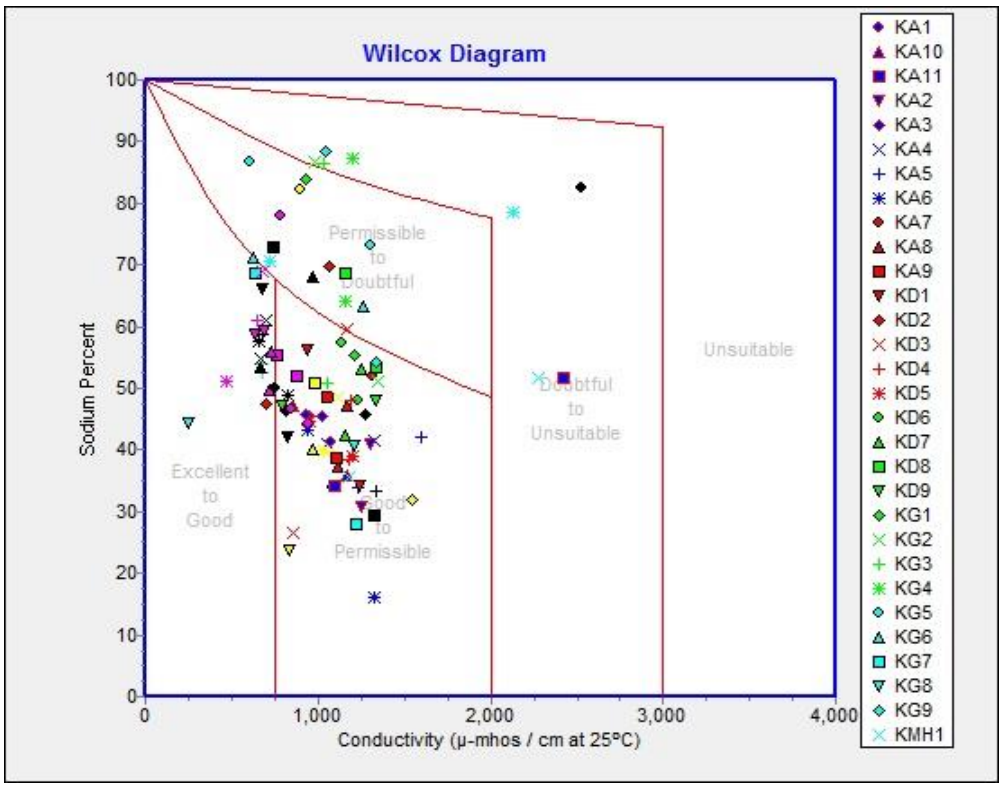
Suitability for irrigation purpose: The sodium Adsorption values ranges from 0.7 to 13.62 with average of 3.66 indicating its suitability for irrigation purposes except at a very few localized pockets where it is extremely high up to 13.62 and suitable for salt tolerant crops. The ground water of the deeper aquifers in general is suitable for drinking as well as for irrigation purposes. Qualities of ground water of deeper aquifers are represented by following diagrams.

The ground water from deeper aquifer does not contain any pollutants like nitrate and fluoride in excess amount, rather the concentration of nitrate and fluoride is much less than the prescribed limit.


KENDRAPADA DISTRICT
0 10 20
Kilometres
86 15
86 30
86 45
87 00
20 45
20 30
1,250
750
255 643
BAY OF BENGAL
ELECTRICAL CONDUCTIVITY MAP
EC in micro mhos/cm at 25 °C
LEGEND
250 to 750
750 to 1250
1250 to 1750
1750 to 2250
> 2250


Piper Diagram
SO4+ Cl
Ca+Mg
Na+K
CO3+ HCO3
Mg
SO4
Ca
Cl+NO3
K26
KA1
KA10
KA11
KA2
KA3
KA4
KA5
KA6
KA7
KA8
KA9
KD1
KD2
KD3
KD4
KD5
KD6
KD7
KD8
KD9
KG1
KG2
KG3
KG4
KG5
KG6


US Salinity Diagram
Sodium Hazard Classes
Very High S4
High S3
Med S2
Low S1
SAR
C1-S4
C2-S4
C3-S4
C4-S4
C1-S3
C2-S3
C3-S3
C4-S3
C1-S2
C2-S2
C3-S2
C4-S2
C1-S1
C2-S1
C4-S1
Conductivity (µ-mhos / cm at 25°C)
Salinity Hazard Classes
C1 Low
C2 Medium
C3 High
C4 Very High
KA1
KA10
KA11
KA2
KA3
KA4
KA5
KA6
KA7
KA8
KA9
KD1
KD2
KD3
KD4
KD5
KD6
KD7
KD8
KD9
KG1
KG2
KG3
KG4


Wilcox Diagram
Sodium Percent
Permissible to Doubtful
Unsuitable
Doubtful to Unsuitable
Excellent to Good
Good to Permissible
Conductivity (µ-mhos / cm at 25°C)
KA1
KA10
KA11
KA2
KA3
KA4
KA5
KA6
KA7
KA8
KA9
KD1
KD2
KD3
KD4
KD5
KD6
KD7
KD8
KD9
KG1
KG2
KG3
KG4
KG5
KG6
KG7
KG8
KG9
KMH1

Chapter-4
Ground Water Resources

4.1: Introduction: The dynamic ground water resource of the district was jointly estimated by CGWB (SER) Bhubaneswar and Directorate of Ground Water Development (erstwhile GWS & I), Govt. of Odisha 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- 4.1: Ground water resources of the 1st aquifer (phreatic & shallow aquifers up to 50 m of depth), Kendrapara District.

SNo	Assessment Unit	Annual Replenishable Ground Water Resources	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
	Block	(ham)	(ham)	(ham)	(ham)	(ham)	(%)	Safe
1	Aul	804	764	407.97	50	346.47	53040	Safe
2	Derabis	4312	4096	2178.95	174	1876.97	53.20	Safe
3	Garadpur	3895	3700	2546	306	1071.17	68.84	Safe
4	Kendrapara	2565	2422	1314.83	107.22	1079.99	54.29	Safe
5	Pattamundai	6129	5799	3323.04	193	2429.06	57.30	Safe
6	Mahakalpara	0	0	0	0	0	0	0
7	Marshaghai	0	0	0	0	0	0	0
8	Rajnagar	0	0	0	0	0	0	0
9	Rajkanika	0	0	0	0	0	0	0
	District Total	**17705**	**16781.0**	**9771.72**	**830.22**	**6803.66**	**58.23**	

A vast replenishable ground water resource is available, mainly confined to the 5 blocks of the district namely Aul, Derabis, Gardapur, Kendrapara Sadar and Pattamundai etc. In rest of the four blocks namely Mahakalpara, Marshaghai, Rajnagar and Rajkanika blocks no resources is available in phreatic aquifer as the entire phreatic aquifer (down to 50 m) is affected by salinity problem. However the ground water utilization in this part is also moderately high to the tune of 58.23% of the ground water resources. Thus there is enough scope for further development of ground water resources to the tune of 90%, by keeping an eye on the ground water trend behavior of the aquifer system. Another feature of resources in these five blocks is that there is almost more or less equal scope for the development of ground water resources for all purposes.

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 methodologies are applicable to the 1st aquifer system. However the resources of the confined aquifer existing below to a depth of 300m is calculated by taking the ground water resources of the recharge zone in the manner similar to that of potential recharge.

Table-4.2: Aquifer wise Ground Water Resources: (Figure in ham)

Block	Dynamic GW Resources (1st AQ) (0 to 50 m)	Stages of GW Development	In Storage GW Resources (1st AQ) (0 to 50m)	In Storage GW Resources (2nd AQ)(50-150)	In Storage GW Resources (3rd AQ) (150-300m)
Aul	764	53.40	0.0	0.0	100.3
Derabish	4096	53.20	111.5	115.0	95.8
Garadpur	3700	68.84	0.0	0.0	80.2
Kendrapara	2422	54.29	139.6	136.3	147.2
Pattamundai	5799	57.30	0.0	391.3	429.0
Mahakalapara	0	0	0.0	0.0	0.0
Marshaghai	0	0	0.0	0.0	208.9
Rajnagar	0	0	0.0	149.6	164.0
Rajkanika	0	0	0.0	0.0	95.0
Total	16781	58.23	251.10	792.2	1321
Grand Total = 16781+ 251.10+ 792.2+1321= 19145					

Table-4.3: Ground Water Surplus and Number of Structures Feasible

Block	Net Ground Water availability (Ham)	Stage of Ground Water development (%)	Present Ground Water Draft (Ham)	Ground Water draft at 70% Stage of development (Ham)	Surplus Ground Water at Present Stage of Development (Ham)	Number of STW Recommended in Each block (assuming unit draft as 2.21/ ham/ structure/ year)
Aul	764	53.4	408.0	534.8	126.8	57
Derabish	4096	53.2	2179.0	2867.2	688.3	311
Garadpur	3700	68.8	2546.9	2590	43.1	19
Kendrapara	2422	54.3	1314.8	1695.4	380.6	172
Pattamundai	5799	57.3	3323.0	4059.3	736.3	333
Mahakalapara	0	0.0	0.0	0	0.0	0
Marshaghai	0	0.0	0.0	0	0.0	0
Rajnagar	0	0.0	0.0	0	0.0	0
Rajkanika	0	0.0	0.0	0	0.0	0
Total	**16781**		**9771.9**	**11746.7**	**1974.8**	**894**

Table-4.4: Additional Irrigation Potential to be created from GW in Kendrapara District

Block	Present Stage of Ground Water Development (%)	Surplus Ground Water Available for 70% stage of Development (Ham)	Irrigation Potential likely to be created for Paddy (Ha)	Irrigation Potential likely to be created for Ground Nut, Oil seed (Ha)	Irrigation Potential likely to be created for vegetables (Ha)	Total area Irrigated (ha)
Aul	53.4	126.8	70	122	122	314
Derabish	53.2	688.3	382	662	662	1706
Garadpur	68.8	43.1	24	41	41	107
Kendrapara	54.3	380.6	211	366	366	943
Pattamundai	57.3	736.3	409	708	708	1825
Mahakalapara	0	0	0	0	0	0
Marshaghai	0	0	0	0	0	0
Rajkanika	0	0	0	0	0	0
Rajnagar	0	0	0	0	0	0
Total		1974.8	1096	1899	1899	4894

Chapter-5

Ground Water Related Issues

5.1: Identification of problem: Following issues regarding ground water have been identified in Kendrapara district.

Vulnerable areas: Vulnerable areas generally include area vulnerable to salinity ingress, water logged areas, polluted areas and water table depleted areas. These are discussed as below.

5.1: Area vulnerable to salinity Ingress: Entire Kendrapara district except a very small patch of fresh water aquifer occurring in north south elongated patch in extreme western part of Derabis block covering an area of only 50.4 km2) suffers from salinity hazards. The vertical distributions of fresh and saline water bearing aquifers are mainly of three types.

1. **Fresh water bearing aquifer** (area=50.37 km). This type of aquifers occurs in north – south elongated patch in extremely western part of the district and Derabis block. It covers an area of 50.4 sq km.
2. **Fresh water zone occurring above and below saline water zone (Area =368.17 km).** While moving from west to east towards coast aquifers containing alternate saline and fresh water zones encounter. This also occurs in north south elongated patch covering an area of 368.17 sq km. In this area wells have been constructed mainly at Barsalar, Karilopatna, Garjang, and Ramchandrapur etc. In this area at Barsalar there are occurrences of three deeper fresh zones, but within 300 m depth only one zone occurs between 101 and 254 m. At Garjanga the deeper fresh water zone occurs in between 66 and 111 m and deepest fresh water zone between 304 and 388 m depth. The yield of wells varies from 30 to 40 lps against the drawdown varying from 21 to 24 m and static water levels vary from 1.77 m bgl at Barsalar to 0.81 m bgl at Garjanga. The yield reduces towards Garjanga and in general yields of deeper aquifer in this sector is less.
3. **Fresh water zones overlain by saline water zones:** (Area=2275.83 km): This phenomenon occurs in major part of the district and toward coast. The distribution of saline and fresh water zones at depths are describes as below.

   In the Indupur- Chatra- Barimul- Jajang- Pattamundai- Namtara and Pegapara areas fresh water bearing zones occur at 106 m depth at Chatra in the west and at Pattamundai in the east and on an average fresh water zones occur from 120 m depth and extends beyond 300 m depths except at Indupur where it is restricted down to 265 m depths. The cumulative thickness of aquifers varies from 32 to 66 m and the same dwindles towards Namtara- Pepagara area. The occurrence of aquifers in this sector is generally restricted within 230 m depths. The yield varies from 22 to 60 lps. In general, the yield is less in the northern part (22 to 40 lps) while in central part it is around 50 to 60 lps (Jajang- Pattamundai area). The drawdown varies from 10 to 15 m and the static water level from 0.6 to 2 m bgl.

In the Pattamundai- rajnagar- basantapur (near coast) area,fresh ground water bearing zones occure below 90 to 100 m depth and extends beyond 300 m depth. The cumulative thickness of aquifers varies from 47 to 166 m and the average yield is generally around 65 lps. The drawdown ranges from 9.7 to 11.41 m and aquifers very often exibit autoflow condition with the head varying from 0.5 to 0.91 magl.

In Kendrapara Karliopatna, marshaghai- Silipur area the fresh water bearing zones occur below 155 m (Kendrapara) to 205 (Silipur) depth. Fresh water zone occurs at deeper depth (>190m) in Marshaghai- Silipur Area. The fresh water zone in the entire sector

extends beyond 300 m depth and cumulative thickness of aquifer varies from 22 m at Silipur to 55 m at Kendrapara and occurrences of aquifers are generally restricted within 250 m depth. The yield varies from 13 lps at Silipur to 48 lps in Kendrapara area. The static water level very often coincides with the ground levels. The drawdown is generally more than 15 m.

In Masakani- Dadhipur- Dasrajpur area the aquifers are saline from near surface to beyond 300 m depth. In this section at isolated pockets thin layers of aquifers occur which yield little brackish water with chloride content 450 to 600 mg/l

5.2: Water Logged area or low water level areas: The geographical distribution of water levels during different seasons is as below.

Table 5.1: Geographical distribution of water levels

Period	Range of water level	Area (Sq km)	Location	Water level trend	Remarks
Pre-monsoon (2016)	<2 m	370.4	Mahakalpara & SE part of Marshaghai block	Insignificantly rise & fall	Water logged
	2 to 4 m	2228.8	Rest of block except above	-do-	-
	> 4 m	44.4	Central part of Kendrapara block	-do-	-
Post- Monsoon (2016)	0-2 m	2276	Entire district except following	-do-	Water logged
	>2m	369	NW part of Rajkanika & central part of Kendrapara block	-do-	Low water level area
Decadal Pre-monsoon (2007-2016)	2 -3	1050	Part of Kendrapara & Derabis block, Enrire Rajnagar & part of Rajkanika	-do-	Low water level area
	3-4 m	1269	Parts of Aul, Pattamundai & Kendrapara blocks	-do-	-
	>4 m	325	Marshaghai and part of Mahakalpara blocks	-do-	-
Decadal Post-monsoon (2007-2016)	0 - 2	2564	Entire district except a small following patch	-do-	-
	>2	80	Central part of Kendrapara block	-do-	-

Depth to water level map of the district for the pre- monsoon period of 2016 reveals that the water levels rest more than 2m below ground level in the area of only 370 km2 in parts of Mahakalpara & SE part of Marshaghai blocks. Depth to water levels during post monsoon period (Nov'2016) also rests below 2 m in the major part of the district covering an area of 2276 sq km, except in central part of Kendrapara and north western part of Rajkanika blocks. Water levels in these areas rest within even within 1 m below ground level covering approximately 350 sq km resulting water logging conditions. But long term trend of water levels show insignificant rise and fall. Though on the basis of water level conditions parts of the district can be said water logged but due to insignificant in rise and fall of water level indicates that these areas are only low water level area. The Water logging condition in this sector is a temporary phenomenon and occurs only during rainy season which extends up to post monsoon period. The water levels in the same sector during pre-monsoon period rest below 2m from ground surface hence water logging is not a problem for the area.

5.3: Polluted Area: Though in present study in ground water quality nitrate analysis could not be done but historical data of phreatic and deeper aquifer including nitrate analysis is available which indicates presence of pollutants like nitrate, Chloride, fluoride, etc occurs beyond prescribed limit in isolated local pockets. The ground water from deeper zones do not contain any such chemical constituent in excess concentration which is harmful to local population. More over the district does not have any major industrial establishment or Industrial estate and these is no mining activity in the district. Hence the chance of pollution is very limited. Till now no report has been received either from Govt. or from any other source regarding large scale pollution in the district. However Central Ground Water Board is continuously monitoring the chemical quality of the district to keep a vigil over the quality of ground water of the district.

5.4: Water Table Depletion: It has already been mentioned that the stage of ground water development is in a low tune in the district. Hence, the chances of depletion of water table are rare in the district. Till now no report has been received from any source regarding depletion of water table in any part of the district. Moreover the results of long term water level trend analysis of hydrograph stations located in phreatic zone do not indicate any alarming situations. The results indicate that 50% wells show rise of water level, maximum up to 0.5m and rest 50% wells show a fall of water levels restricted to 0.5m which are insignificant.

5.5: Improvement in low water level condition: There are numerous drainage channels including small streams and creeks in the area. There are about 25 creeks in the eastern part of district. By renovating their condition and making sluice gates inflow of saline water from sea can be checked and irrigation facilities can be developed. By cleaning these drainage channels and creeks and constructing deep tube wells and utilization of water in a conjunctive manners, improvement in low water level condition can be done.

Implementation these creeks projects will lead to increase the agricultural productivity during Kharif and Rabi seasons. The schemes will ensure sweet/ fresh water and mitigate drought and go a long way to stabilize the socio economic condition of the people in the area. Fresh water impounded in the main creeks and sub creeks will facilitate recharge to ground water regime. The impounding of fresh water in the creeks and sub creeks and through agricultural activities by creek irrigation is likely to improve water quality of phreatic aquifer.

Chapter-6:

Management Strategies:

Keeping in view of prevailing hydrogeological conditions and availability of ground water resources in different aquifer systems following management strategies for ground water utilization can be adopted in Kendrapara district.

6.1: Management Strategy No -1: Construction of ground water abstraction structures in salinity hazards areas: Out of 9 Blocks 4 blocks (Marshaghai, Mahakalpada, Rajnagar and Rajkanika block) are affected by Ground Water salinity in which from ground surface to 300 m depth fresh ground water does not occur except at a few places dominated by sand dunes. In other five blocks viz, Kendrapara, Pattamundai, Derabis, Gardapur and Aul fresh water occurs either floating or sandwitched with saline water. Present status of ground water development in the district indicates that there is ample scope for ground water development. Ground Water resource may provide sustained source of irrigation and drinking even during critical periods of delayed monsoon or droughts. Based on hydrogeological conditions of the district feasibility of ground Water structures and their yield prospects have been indicated in the following table

Table-6.1: Feasibility of Ground Water Structures.

Type of Structure	Specification of Structures	Yield Prospects
Dug wells fitted with pumps	8 to 10m deep, diameter-4 m	45 to 50 m^3/day
Filter point tube wells	15 to 25m deep, 10cm x 5 cm diameter	Up to 5 lps.
Shallow tube wells	Up to 50m deep, 15cm diameter	Up to 15 Ips
Medium deep tube wells	Up to 150m deep in non saline areas, Maximum up to 80 m deep in saline areas, 25cmx20cm diameter.	30 to 50 Ips. (avg. 40 Ips)
Deep tube wells	Up to 300m deep, Diameter 25 x 20 cm.	20 to 50 Ips. (30 to 40 Ips avg)

It is proposed to construct following ground water abstraction structures.

1. Construction of medium and deep tube wells down to 300 m depths at least in cluster of 3 nearby villages. Thus in 5 blocks total 243 no of deep tube wells down to average depth of 250 m depths can be constructed. Details are as below.

Table-6.2 : Proposed No of deep tube wells

S. No	Blocks	No of GP	No of villages	No of tube wells
1	Kendrapara	28	136	45
2	Derabish	26	177	59
3	Garadpur	18	137	46
4	Pattamundai	31	148	49
5	Aul	32	132	44
	Total	135	730	243

No of wells=243

Tentative cost of 1 No of well = 7.5 Lakh

Total cost 243*7.5=1823 lakh.

2: Construction of shallow tube wells: Shallow tube wells down to average depth of 50 m can be constructed in these five blocks. No of shallow tube wells feasible are 894 or say 900. Per well cost is Rs 2.0 lakhs. Thus total cost of wells= 1788 lakh

3: Construction of filter point tube wells: Filter point tube wells down to average depth of 15 to 25 m can be constructed at least in 50% of wells. Thus no of filter point tube wells would be 365. Per well cost is Rs 1.5 lakh. Thus total cost of wells= 548 lakh.

4: Construction of dug wells: Dug wells down to average depth of 15 to 25 m can be constructed at least in 50% of wells. Thus no of dug wells would be 365. Per well cost is Rs 0.5 lakh. Thus total cost of wells= 183 lakh.

5: Total cost of wells construction =4342 lakh.

6: Water supply in Mahakalpra, Marsshaghai, Rajnagar and Rajkanika blocks: Deep tube wells down to a depth of 300 m can be constructed with the condition of their dilution from surface water. Already State Government has made plan to supply water to these blocks from surface sources.

7: In Mahakalpada block construction of 10 number deep tube wells down to 450-500 m with RO facilities as deeper zone water contains EC >2500.

8: Construction of Sanctuary Tube well in each block headquarters to meet the drinking water requirement during natural calamities period such as cyclone and floods etc.

The area feasible for different type of ground water structures are stated below.

Dug Wells: The dug wells are feasible in the western part of the district covering Derabish, Patkura and parts of Kendrapara blocks. The depth of the dug wells should be 8 to 10 m and the diameter should be around 4 m. The expected yield of the dug wells is 45 to 50 m^3/day and centrifugal pumps of 1 to 1.5 H. P. may be installed in the dug wells. The distance between any two energized dug wells should be kept at least 150m to avoid interference.

Filter point tube wells: These structures are feasible in the western part covering Derabish, Patkura and parts of Kendrapara blocks. These wells are very successful on the recent flood plain deposits occurring along the banks of river and stream and also on the bank of moribund channels of rivers or streams and within the dried up stream courses. The depth of these structures may be 15 to 25 m and diameter 10 cmx5cm or all through 5cm. 2 H.P. ejector (jet) or centrifugal pumps may be fitted depending on the design of wells. Generally in low lying areas where water levels are very shallow and drawdown is less, in these places centrifugal pumps may be used and diameter of the wells may be fixed to 5 cm all the through. But where pumping water levels go beyond 7 or 8m below ground level, the installation of ejector pumps are advisable and the design of well should also be made accordingly (10cmx5cm) to accommodate the pump accessories within wells. The yield of these wells is generally within 5 Ips, but field experiences indicate that these welts can yield up to 10 Ips when thick aquifer zones (>4m) are tapped. These wells can be run for 6 to 7 hours daily. The distance between any two structures should be kept at least 150 m to avoid any interference resulting higher drawdown of pumping water levels.

Shallow tube wells:

The shallow tube wells are feasible in the western part of Patkura and Derabish blocks. The depth of the shallow tube wells may be restricted within 50 m and diameter is 15 cm. The expected yield is generally within 15 Ips and submersible pumps of 3 H.P. may be installed. The field experience indicates that these wells can be run for 8 to 10 hour in a day. The distance between any two structures should preferably be at least 300m.

Medium deep tube wells: The medium deep tube wells are feasible in the western part of Garadpur and Derabish blocks. The depth of the wells may vary from 70 to 150m and within

this depth range the thickness of aquifer zones vary from 20 to 35 m. Normally the deeper depth (>100m) are feasible in the extreme south western part of Derabish and Garadpur blocks, while in other parts of the said blocks the depths may be restricted to 70 to 80 m due to salinity problem. The yield of these tube wells may vary from 30 to 50 Ips and the wells may be pumped for 10 hours in a day. The distance between any two medium deep tube wells should not be less than 500m.

Deep tube wells: The deep tube wells having the depth range between 200 to 300 m are feasible in entire district except in few isolated patches. These tube wells are to tap the deeper fresh water bearing zones. The depth of occurrence of fresh water zone varies from area to area and details of which has been described in the item 5.2. The yield of these tube wells on an average varies from 30 to 40 Ips, and these tube wells can be run for 10 hours in a day. The distance between any two deep tube wells should be kept at least 500m.

Benefit from tube well construction:

1. There would be tangential benefits from tube well construction. Irrigation potential up to 500 ha will be created which will help farmers to increase their income.
2. Safe and secure drinking water will be available even in the area which is devoid of fresh water aquifer e.g. Mahakalpada block
3. In other saline affected area also safe and secure drinking water will be available
4. Land up to 250 ha (50% of water logged areas) will be reclaimed and thus agricultural production will improve.
5. Construction of sanctuary wells will facilitate drinking water during natural calamity periods.
6. Construction of deep drilled tube wells (480 to 600 m depth) will further explore the possibilities of deeper aquifers.
7. Change in cropping pattern by growing high salt tolerant crops in high salinity areas will improve agricultural production.

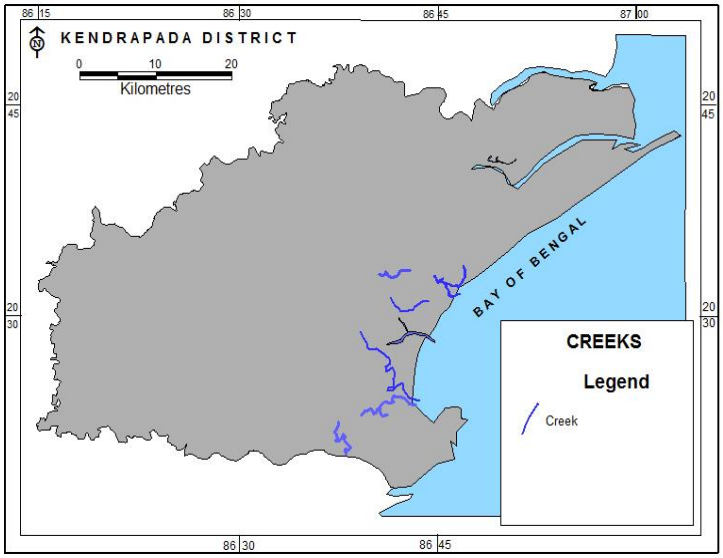
6.2: **Management Strategy No 2: Conjunctive use of water:** Conjunctive use studies are generally taken up in the canal command areas mainly to minimize the effect of water logging and also to provide better irrigation facilities in the tail end areas through surface water source. In general more ground water is withdrawn from water logged area to deplete the shallow ground water table for minimizing the effect of water logging.

Water logging phenomena occurs in the some part of the district seasonally, covering approximately 370 sq km area, though the major part of the district enjoys surface irrigation facility through delta stage-1 project for a long time. It is also reported that particularly during Rabi season water scarcity is generally felt in the tail end areas of canal systems. There are numerous surface water structures in this district. Renovation and modification in these structures will be highly fruitful to control low water level conditions (or areas prone to water loggings) and in creation of additional irrigation potential. Govt. of Odisha has already proposed following structures for renovation. These are as below.

Table-6.3: Surface water structures proposed for renovation

S. No	Types of structures	No	Creation of Irrigation potential (Ha)	Approximate cost (Rs in Lakh)
1	Creeks (length-60km)	25	1345	148
2	Check dams	67	2010	2010
3	Drainage channels	20	5005	305
4	Water tanks	20	363	102
	Total		**8723**	**2565**

Map of creeks in Kendrapara district is as below.



6.3: Management Strategy 3: Change in cropping pattern: As per available irrigation facilities following suggestions have been proposed to change in cropping pattern.

Table-6.4; Proposed cropping pattern in the district

Type of Structure	Suggested Cropping Pattern/ Area(ha)		
	Kharif	Rabi-I	Rabi-Ii
Dug well with pump set	Paddy-2	Wheat-0.2, ground Nut-1.0	Ground Nut.0.8
Filter point tube well	Paddy-4	Potato-1.4 ,Wheat-1.0	Pulses-1.6
Shallow Tube well	Paddy-12	Potato-2.0 ,Ground Nut-2.0 Vegetable-2.0, Wheat-2.0	Paddy-2.0 Ground Nut-2.0
Medium deep tube well	Paddy-20	Potato-3.0, Ground Nut-3.0 Vegetable-3.0 ,Wheat-3.0	Paddy-2.0, Pulses-4.0 Ground Nut-2.0
Deep Tube wells	Paddy-20	-do-	-do-

Management Strategy 4: Scope for Artificial Recharge: As the stage of ground water development is <60% and there is no report of large scale depletion of water levels, at present, the artificial recharge is not required for the district.

III: Issues and Management Strategies for Utilization of Ground Water Resources

1. Out of 9 Blocks 4 blocks (Marshaghai, Mahakalpada, Rajnagar and Rajkanika block) are affected by Ground Water salinity.
2. Under utilization of Ground Water Resources in some blocks.
3. Water logging condition in all blocks.
4. Salinity ingress from creeks along sea coast

Chapter-7:
Conclusion:

The Kendrapara district has a total geographical area of 2644 sq.km. The district is having one subdivision which is divided into 9 community development blocks.

The types covered by the forest is only 4926 hectares and the net sown area is 151604 hectares. The crops seasons can be divided into autumn, winter and summer. Paddy is the main crop during all the three seasons.

The area covered by the forest is only 4926 hectares and the net sown area is 15160 hectares. The crops seasons can be divided into autumn, winter rand summer. Paddy is the main crop during all the three seasons.

The area irrigated from all s0urces during Kharif (autumn + winter) is 89408 hectares and during the summer is only 66949 hectares. The delta stage-I is the major surface irrigation project. The Mahanadi-Chtrotpala is ongoing irrigation project. The district can be divided into 2 distinct geomorphic units. (i) The saline marshy tract along the coast and (ii) remaining area having very gently sloping.

The geological formations which are exposed in the district are alluvium and sand dunes of recent age. The exploratory drilling down to a maximum depth of 612m revealed the existence of older alluvium and Mio-Pliocene sediments at depths. The lithological logs of bore holes indicate occurrence of alternate sequence of clay beds and granular horizons. The clay beds are yellow brown, grey and dark grey in color and plastic in nature. Normally yellow and brown clays are restricted within 100m depth and below which grey and dark grey clay occurs. The granular zones include sand and gravel horizon and also mixture of sand and gravel in varying proportion. The thickness of both granular zones and clay beds vary widely and normally below 250m depth both the zones occur as thin layers (1 to 3m thick). The granular zones down to 100 or 175m depth contain saline water and below which it contain fresh water. The deeper granular zones form prolific fresh water bearing aquifers.

The fresh waste bearing aquifers system in the district may be broadly divided into (i) Shallow and (ii) Deep. The thickness of the shallow aquifers varies widely due to salinity problem which occurs almost entire district barring a narrow tract occurring along the extreme western part of the district. In the saline hazard area the thickness of top aquifer (Shallow) varies from negligible to a maximum of 80m. Normally the thickness of fresh shallow aquifers varies from 15 to 20m. within saline hazard tract lying just west of Indipur-Kendrapara-Karilopatna section and thickness gradually increases towards further west, and east of this section the shallow aquifers generally attains almost negligible thickness except in isolated pockets underlain by abandoned river or stream channels and in sand dune areas and in these areas shallow fresh water bearing zones may extend down to a maximum of 10 or 15m depth with the average thickness of 5 to 6m.

The deeper fresh water bearing zones occur at varying depth in the different sectors. In the major part of the district fresh ground water bearing zones occur below 100 to 155m depth. In the extreme north eastern part (Aul-Jaynagar area) the fresh water bearing zones occurs below 190m depth and in Marshaghai-Sillipur area in the south central part, fresh ground water occurs below 180 to 200m depth. In the major part of the area the deeper fresh water zones extends down to 300m or more depth except in the Garjang-Ramchandrapur area in the south and Barsalar in the west. In the Garjanga-Ramchadrapur n area alternate saline and fresh zone occurs and within 600m depth 2 fresh water bearing zone occurs between 60 to 388m depth ranges. In Barsalar 3 fresh water zone occurs

between 101 and 528m depth. In the Masakani-Dadhipur-Dasarajpur area ground water is saline down to 300m depth.

The CGWB has drilled 7 exploratory,. 7 deposit wells and also 12 piezometer and 2 slim boles till March 98. The cumulative thickness of aquifers tapped by these exploratory and deposit wells vary from 22 to 69m. The yield of these tube wells vary from 22 to 71 liter per second with the average yield varying between 30 and 40 litres per second. The drawdown of pumping water levels varies from 9.7 to 24.5 m with the average value of 10 to 15 m. The average value of Transmissivity ranges between 1000 to 1500m^2/day. The value of storage co-efficient varies from 1.6 x 10-4 to 8.8 x 10-5 which indicates that the deeper aquifers are under confined condition.

The ground water is fit for domestic purpose except in few isolated pockets. As the ground water falls under C2 S1 and C3S1 class of U.S. Salinity classification, salt tolerant crops may be grown by using the ground water of the district.

The estimated annual replenishable ground water resources of the district is 5507 ham and out of which 826 ham. It is reserved for domestic and industrial purpose. The available ground water resource for irrigation in net term is 4681 ham. The nest annual draft is only 1168 ham and the balance ground water resource is 3514 ham. The state of ground water development is only 57% percent.

The balance ground water resources may be developed by installation of 894 shallow tube wells and filter point tube wells. The additional expected irrigation potential from these structures is 8723 ha.

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