केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN

Parts of Bhadrakh District, Odisha

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

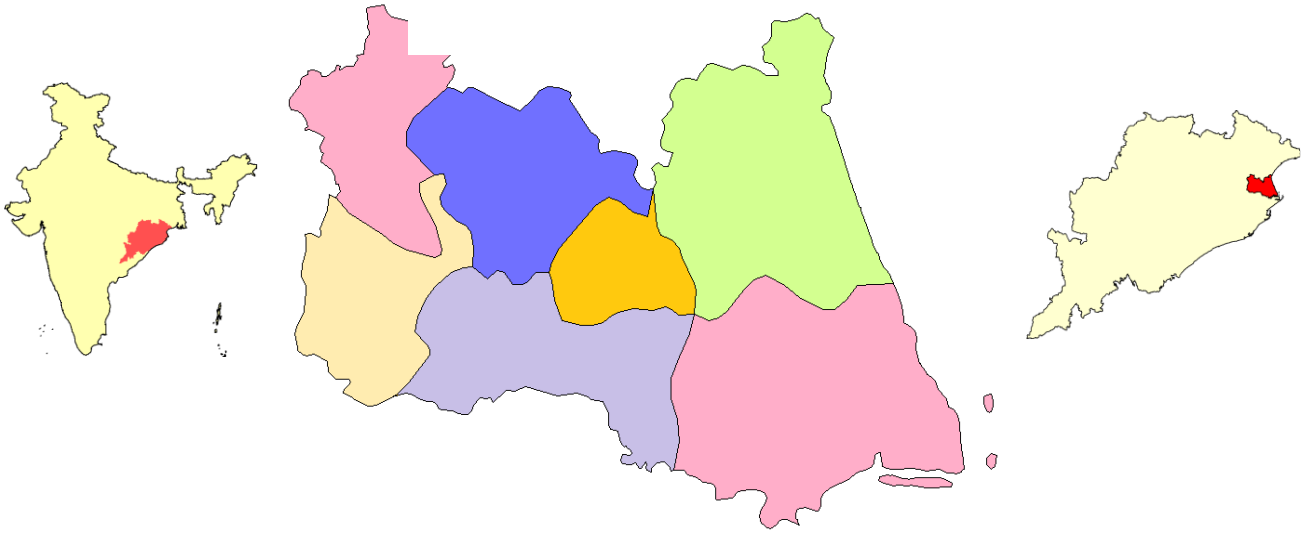
South Eastern Region, Bhubaneswar

Government of India

MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

NATIONAL AQUIFER MAPPING & MANAGEMENT

HYDROGEOLOGICAL FRAMEWORK, GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN OF BHADRAKH DISTRICT, ODISHA



CENTRAL GROUND WATER BOARD

South Eastern Region, Bhubaneswar

May – 2017

HYDROGEOLOGICAL FRAMEWORK, GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN OF BHADRAKH DISTRICT, ODISHA

CONTRIBUTORS PAGE

Data Acquisition	**:**	Shri A. K. Biswal, Scientist-'D' Shri P. Das, Scientist-'B' Shri S. K. Samantray, Scientist-'B' Shri D. Biswas, Scientist-'D'
Data Processing	**:**	Dr. N. C. Nayak, Scientist-'D' Shri P. Das, Scientist-'B' Shri A. K. Biswal, Scientist-'D'
Data Compilation & Editing	**:**	Dr. N. C. Nayak, Scientist-'D' Shri A. Choudhury, Asst. Hydrogeologist
Data Interpretation	**:**	Dr. N. C. Nayak, Scientist-'D'
Map Preparation	**:**	Dr. N. C. Nayak, Scientist-'D Shri A. Choudhury, Asst. Hydrogeologist
Report Preparation	**:**	Dr. N. C. Nayak, Scientist-'D'
Technical Guidance	**:**	Shri P. K. Mohapatra, Scientist-'D'
Overall Supervision	**:**	Shri D. P. Pati, Regional Director

C O N T E N T S

AQUIFER MAPPING REPORT OF BHADRAK DISTRICT, ODISHA UNDER NAQUIM, MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION, GOVT. OF INDIA

I. INTRODUCTION

1.1 Location:

Bhadrakh district is one of the coastal districts of Odisha State bounded by north latitudes $20^0$44'20" and $21^0$19'33" and east longitudes $86^0$16'30" and $86^0$59'20". It is covered under the Survey of India Sheet Numbers 74K & 73L (1:250,000). It spreads over an area of around 2505 Sq. Kilometers bounded by Jajpur district on its south, Keonjhar district on its west and by Bay of Bengal on the east. The district comprises of 7 Community Development Blocks with its headquarter Bhadrakh, which is a Municipality. Basudevpur, Chandbali and Dhamnagar are other major towns and business centers. The Akhandalamani Shiva Temple, which is situated at Aridi in the study area, is a famous pilgrim center. The Bhadrakali Temple from which the district owes its name, is situated 10 Kms east of Bhadrakh town. The recently commissioned Dhamara port is a big boom for the development of the area.

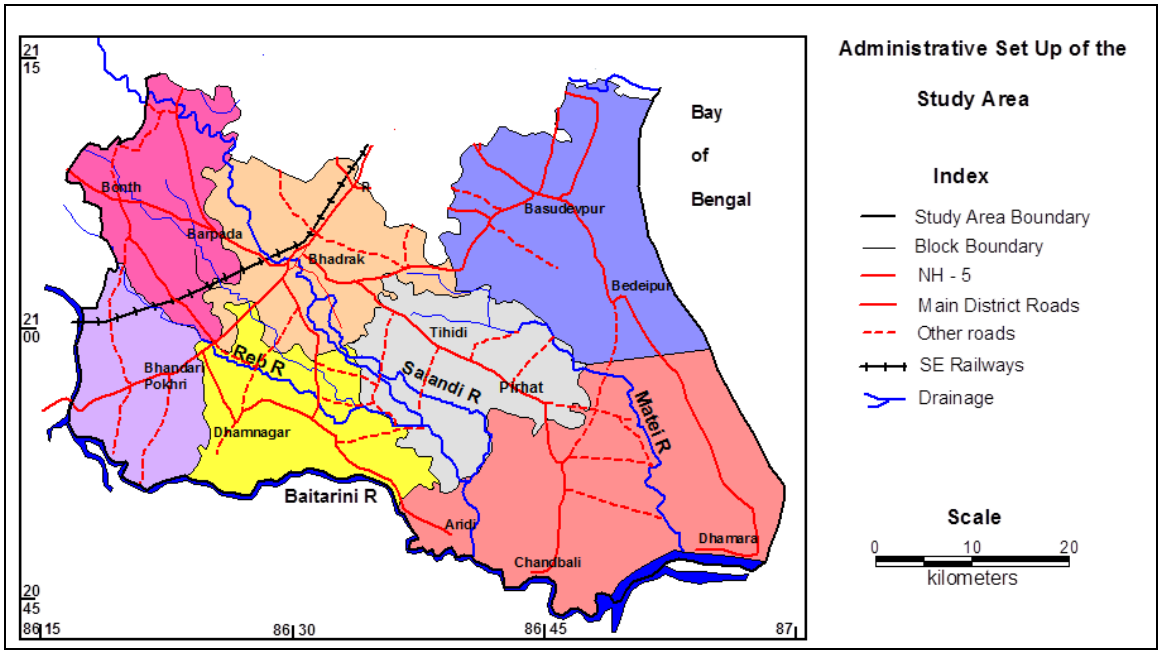


Fig -1.1: Administrative map of Bhadrak District

1.2 Socio-Economic Condition:

The study area is thickly populated having a total population of around 15,06,337 living in an area spreading over 2505 km^2. The district shows the highest decadal growth rate of around 12.9% among all the districts in the state. The population density is around 601 persons per square kilometer, which is very high as compared to State's average of 270. It stands 6^{th} in terms of literacy rate with 82.8%, 6^{th} in terms of density of population and 4^{th} from the bottom in terms of geographical area distribution in the state. Around 22.2 % and 2% of the population belongs to schedule caste and schedule tribe community.

88% of the State's population lives in villages with agriculture being their main occupation. The work force constitutes around 31% of the population. Agriculture and fishery is the backbone of the area's economy and the introduction of marine aquaculture and prawn farming has improved the socio-economic condition in the saline tracts, which were otherwise treated as unproductive areas.

Table – 1.1
(Demographical break up based on 2011 Population Census)

Sl No	Blocks Names	Total Population	Male	Female	SC Population	ST Population	Total Workers	Geographical Area in Sq.Km
Bhadrakh District								
1	Bhadrakh	217849	110916	106933	42876	11750	69490	315.41
2	Basudevpur	219108	109642	109466	52257	583	67427	389.21
3	Bhandaripokhari	127158	63751	63407	29632	4134	40133	237.13
4	Bonth	152063	76918	75145	37926	7932	48084	235.21
5	Chandbali	250037	126367	123670	56192	885	77707	528.45
6	Dhamnagar	181281	91334	89947	41917	1077	54440	230.29
7	Tihidi	194768	97557	97211	58023	619	61123	324.40
Total		1333749	675642	658107	286723	25141	385119	2505*
Urban Local Bodies (ULB)								
1	Bhadrakh(M)	1,21,338	62,335	59,003	10,021	4,560	38,524	45.36
2	Basudevpur(NAC)	33,690	16,927	16,763	5,626	103	9,785	47.78
3	Dhamnagar(NAC)	22,920	11,758	16,763	2,584	197	6,479	18.69
4	Erei(CT)	7,890	3,985	3,905	419	1,221	2,657	4.60

* The district total is not additive

Source: Census of India and Directorate of Economics & Statistics, Govt. of Odisha.

1.3 Land Use:

Due to the high density of population, there is enormous pressure on land. 63% of the total area of Bhadrak district is being put to different agricultural practices during 2010-11. This constitutes 93% of the Cultivable area that indicates the use of land resources to the optimum capacity, which is possible due to the availability of canal and ground water irrigation. Total cultivable area in Bhadrak District is around 157745 hectares with 25,359 cultivators and 76,057 agricultural workers.

The farmers are mainly marginal to small with less than 2 hectares of land holdings. Though they comprise of 81.8% of total workforce engaged in agriculture, they command only 49.1% of the total land resources. Medium and large farmers having more than 4 hectares of land constitute only 3.9% of population and enjoy about 19.2% of cultivable land.

Land Holdings Table – 1.2

Sl. No	Class in Hectares	Numbers of agricultural workers	% of Population engaged in agriculture	Area in Cultivation	% of the Cultivable area
1	Marginal Farmer (less than 1 hectare)	85779	58.5	38895	22.1
2	Small Farmer (1 to 2 hectares)	34178	23.3	47751	27.0
3	Semi-Medium Farmer (2 to 4 hectares)	20909	14.3	55615	31.6
4	Medium Farmer (4 to 10 hectares)	5486	3.7	30142	17.2
5	Large Farmer More than 10 hectares	265	0.2	3460	2.0

Source: DAO, Bhadrak

Land Utilisation Pattern in different blocks of Bhadrakh District (Area in Hectares) 2010-11													Table – 1.3
Sl. No	Block Name	Forest	Misc. Tree & Grooves	Permanent Pasture	Cultivable Waste	Barren & Uncultivable land	Land put to non agricultural uses	Current Fallows	Other Fallows	Cultivable Area	Water logged	Saline Area	Flood Prone Area
1	Basudevpur	25	613	1986	1356	0	5599	490	346	28585	5010	9100	4200
2	Bhadrakh	161	1475	688	2262	0	5950	104	572	20346	-	-	-
3	B.Pokhari	42	300	1304	1412	0	3342	319	342	16727	-	-	2250
4	Bonth	130	174	1106	398	0	3834	1215	1023	17298	-	-	-
5	Chandbali	39	375	1539	3329	0	7940	10882	281	30856	1150	7800	8338
6	Dhamnagar	21	503	1318	213	8	4216	2026	197	16355	215	800	12200
7	Tihidi	0	154	2076	1405	0	3146	716	1476	22967	750	2500	6140
	Urban	0	140	218	412	6	2124	137	179	4611			
Dist. Total		418	3734	10235	10787	14	36151	15889	4416	157745	7125	20200	33128
Source: Directorate of Economics & Statistics, Orissa, Bhubaneswar and DAO Bhadrak													

1.4 Agriculture

Agriculture is the main stay of the local population. The net sown area is around 173000 hectares with 65000 hectares are sown more than once, leading to a cropping intensity of around 138%. Paddy is the major crop raised during monsoon (Kharif season) in Bhadrak District with the paddy area constituting 155568 hectares out of the net sown area of 157745 hectares during 2010-11. Good monsoonal rainfall coupled with extensive irrigation facilities from canal has put most of the paddy area under the crop. During 2005 around 157266 hectares were being used for paddy cultivation out of which high yielding paddy was raised in 130428 (83%) hectares. The low productivity of local paddy in Chandbali, Basudevpur & Dhamnagar block is attributed to the salinity impact. However the salinity impact on high yielding paddy is less due to applied irrigation, still its impact on productivity in Chandbali Block is remarkable. Vegetable is the second important crop after rice and Spices in the form of Chilly takes third place in agriculture during Kharif season. Fiber mainly jute cultivated in 1219 hectares in Bhadrak district forms an important cash crop in the area.

Break up of Kharif Paddy — Table-1.4

Sl. No	Block Name	H.Y.V. Paddy		Local Paddy		Total Paddy		
		Area	Yield	Area	Yield	Area	Yield	Production
1	Basudevpur	23750	29.72	8973	16	32723	29.5	85080
2	Bhadrakh	23350	34	1230	23	24580	33.5	82343
3	B.Pokhari	16100	32.25	896	27	16996	31.5	54387
4	Bonth	16200	39.05	114	27	16314	33.5	63625
5	Chandbali	20200	23	10585	10.83	30785	21.5	65947
6	Dhamnagar	13745	29.79	2240	18	15985	30.5	46382
7	Tihidi	17083	30.04	2800	20.2	19883	28.5	58747
Bhadrak Dist. Total		130428	30.78	26838	15.14	157266	29.02	456511

Area, yield & Production are in Hectares, Quintals/Hectare & Metric Tons
Data of Bhadrak district for the year 2005

During Ravi season (winter), Pulses mainly Black gram (Biri) and Green gram (Mung) are raised in the district, as they need little irrigation and care. However Mung is raised in a little area in Chandbali and Basudevpur block while Biri takes backseat in Chandbali block. Vegetable is being cultivated second to pulses and is followed by paddy in areal extent. Only high yielding paddy is raised and the productivity is generally 10 to 20% more compared to Kharif paddy. Mustard is the main oilseed cultivated in Bhadrak district followed by Groundnut. Mustard is mainly raised in Bhadrak, Basudevpur and Bonth blocks while Groundnut is totally confined to Bhandari Pokhari and Dhamnagar blocks. Chilly is the main spices being raised followed by Coriander and Garlic.

Block wise crop distribution during Ravi Season										Table-1.5
Sl. No	Block Name	Paddy (HYV) Area	Yield	Wheat	Sugar Cane	Pulses	Oil seeds	Vege Tables	Spices	Grand Total
1	Basudevpur	1728	34	90	12	2049	720	2815	378	7792
2	Bhadrakh	2652	36	20	40	3860	918	3050	360	10920
3	B.Pokhari	325	37	10	230	4055	616	1172	174	6592
4	Bonth	105	35	14	15	2892	364	1565	328	5290
5	Chandbali	1452	25	80	-	892	197	2715	345	5686
6	Dhamnagar	1340	37	25	350	5487	593	1272	427	9509
7	Tihidi	2030	35	40	25	3945	130	1625	232	8032
Bhadrak Total		9632	33.93	279	672	23180	3538	14214	2244	53821
Area & yield are in Hectares & Quintals/Hectare for the year 2005-06										

1.5 Irrigation

The district is blessed with good canal systems and productive aquifer systems. Thus out of 173000 hectare of net sown area, net irrigated area constitutes 111800 hectares which is 64.6% of the net sown area of Bhadrak district (2008-09). During Kharif season, canal is the major contributor of irrigation. 65% of the area under irrigation gets water from Salandi Irrigation Project and High Land Canal (originating from Akhuapada). Almost all area cultivated in Bhadrakh and Bonth blocks are irrigated and the majority crop in Bhandari-pokhari and Dhamnagar block are under irrigation. In sharp contrast Chandbali block is least irrigated without any canal network. A good area is being irrigated in the coastal blocks i.e. Chandbali and Basudevpur from the creek irrigation by deepening and modifying tidal creeks into canal network. Impounded fresh water of the river systems is captured through sluice gate during new moon and full moon days and is being used for irrigation. 92% of irrigated tract of the district is put under paddy cultivation followed by vegetable.

.72% of the total area under Ravi crop is being irrigated. 45% of the irrigated tract gets irrigation from ground water and 23% get from Salandi Irrigation Project. Canal is the major water provider only in Bhadrak block while all other blocks get irrigation from ground water. Again a good chunk of land is being cultivated using water from creek irrigation in Basudevpur and Chandbali block. Vegetable is the main crop under irrigation in Ravi season followed by High Yielding Paddy and green gram. Around 38300 hectares of land got irrigated in Ravi season during the 2009 thus leading to a gross irrigated area of around150100 hectares.

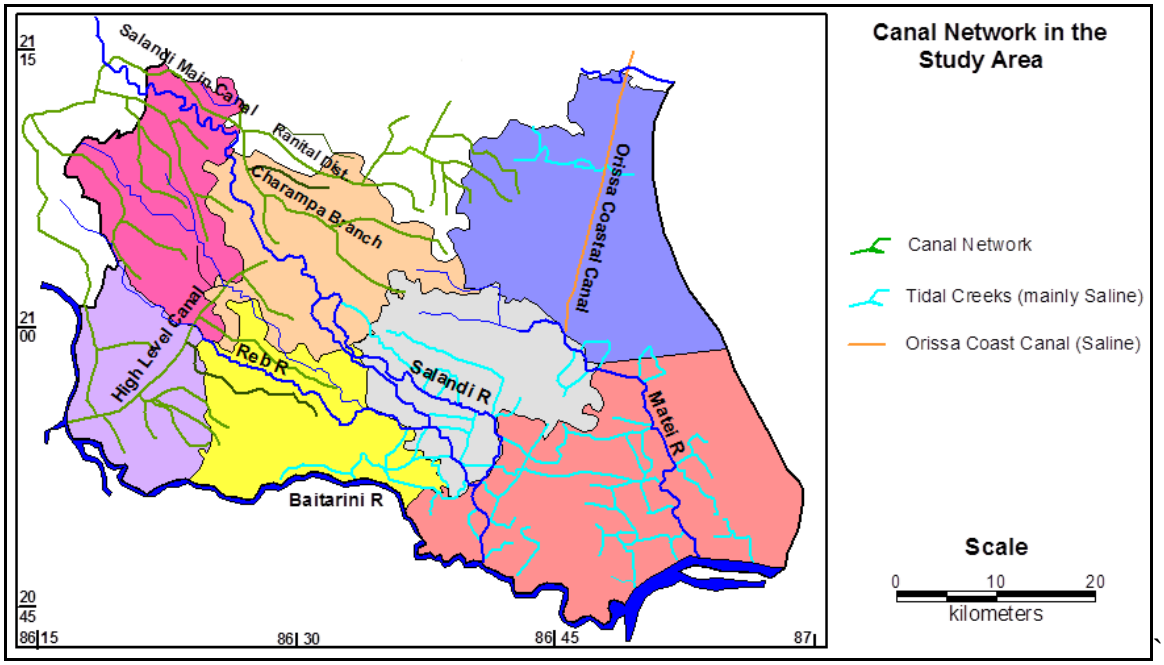


Fig -1.2: Irrigation Network of Bhadrak District.

Source wise & cropping proramme of Bhadrak dist. For Kharif - 2006 (in Ha) Table-1.6								
Sl. No	Source Name	HYV Paddy	Local Paddy	Total Paddy	Jute	Vegetable	Spices	Ayacut Area
1	SIP	44275	2080	46355	570	3130	348	50483
2	HLC	17500	2169	19669	0	0	0	19669
3	MIP	716	100	816	145	280	126	1367
4	LIP	7406	220	7626	140	1250	120	9136
5	STW	9587	289	9876	185	2714	174	13144
6	CREEK	5869	2111	7980	40	1402	180	9602
7	Other Sources	2020	1513	3533	120	1057	220	5015
District Total		87373	8482	95855	1200	9833	1168	108416

Source wise & cropping proramme of Bhadrak dist. For Ravi – 2006-07 (in Ha) Table-1.7									
Sl. No	Source Name	HYV Paddy	Green Gram	Black Gram	Must ard	Sun flower	Other Veg etables	Chilly	Ayacut Area
1	SIP*	2960	3005	170	340	240	2027	185	9117
2	HLC*	-	435	30	45	-	240	20	800
3	MIP*	60	-	-	-	-	105	10	200
4	LIP*	1505	1560	448	560	335	2742	430	8360
5	STW*	1260	371	1014	735	160	3492	705	9290
6	CREEK	2160	180	86	200	125	3689	125	7155
7	Other Sources	1705	69	66	180	140	835	190	3767
District Total		9650	5620	1814	2060	1000	13130	1665	38689

Source: District Agriculture Officer, Bhadrak

- SIP – Salandi Irrigation Project (Source: Hadagarh Dam), HLC – High Level Canal (Source: Barriage at Akhuapada), MIP – Minor Irrigation Project, LIP – Lift Irrigation Project, STW – Shallow Tube Well.

Blockwise & Source wise irrigation for Kharif season 2006 (Area in Ha.)													Table-1.8
Sl. No	Block Name	Salandi Irrigation Project			H.L.C	M.I.P	Lift Irrigation Pr.		Shallow Tubewell		Creeks	Other Sources	Total
		Left	Right	Total			Number	Area	Number	Area			
1	Basudevpur	5501	-	5501		59	88	1760	1285	3120	4610	964	16044
2	Bhadrakh	13375	1755	15130	4771	622	72	1440	1531	4462	-	75	26500
3	B.Pokhari	-	5337	5337	6900	-	103	1545	707	1496	-	190	15468
4	Bonth	1067	16754	17821	-	-	42	756	70	173	-	50	18800
5	Chandbali	-	-	-	-	-	16	480	-	-	4045	1010	5535
6	Dhamnagar	-	-	-	7998	134	129	1935	846	2133	817	1350	14367
7	Tihidi	6694	-	6694	-	552	61	1220	680	1760	100	1376	11702
Bhadrak Total		26637	23846	50483	19669	1367	511	9136	5119	13144	9602	5015	108416

Blockwise & Source wise irrigation for Ravi season 2006-07 (Area in Ha.)													Table-1.9
Sl. No	Block Name	Salandi Irrigation Project			H.L.C	M.I.P	Lift Irrigation Pr.		Shallow Tubewell		Creeks	Other Sources	Total
		Left	Right	Total			Number	Area	Number	Area			
1	Basudevpur	300	-	300	-	-	88	1340	1100	1980	2360	360	6340
2	Bhadrakh	6900	-	6900	-	200	72	1080	1050	1890	-	75	10145
3	B.Pokhari	-	-	-	800	-	103	1545	660	1188	-	190	3723
4	Bonth	600	817	1417	-	-	42	840	990	1782	-	75	4114
5	Chandbali	-	-	-	-	-	16	400	-	-	4045	420	4865
6	Dhamnagar	-	-	-	-	-	129	1935	750	1350	-	1547	4832
7	Tihidi	500	-	500	-	-	61	1220	650	1100	750	1100	4670
Bhadrak Total		8300	817	9117	800	200	511	8360	5200	9290	7155	3767	38689

Source: District Agricultural Officer, Bhadrak

1.6 Climate

The study area enjoys a humid tropical climate, characterized by three distinct seasons viz: summer, rain and winter. Bhadrak district receives a normal annual rainfall of around 1427.9 mm out of which 82% of the annual rainfall occurs during monsoon period between June to October with July and August months contributing maximum rainfall. The Isohyetal map (Figure-3) shows large variation in rainfall with rain reducing drastically from east to west. Basudevpur receives maximum rainfall of around 2109mm while Bonth situated 45 kilometers west receives only 1140 mm (Table-1.11).

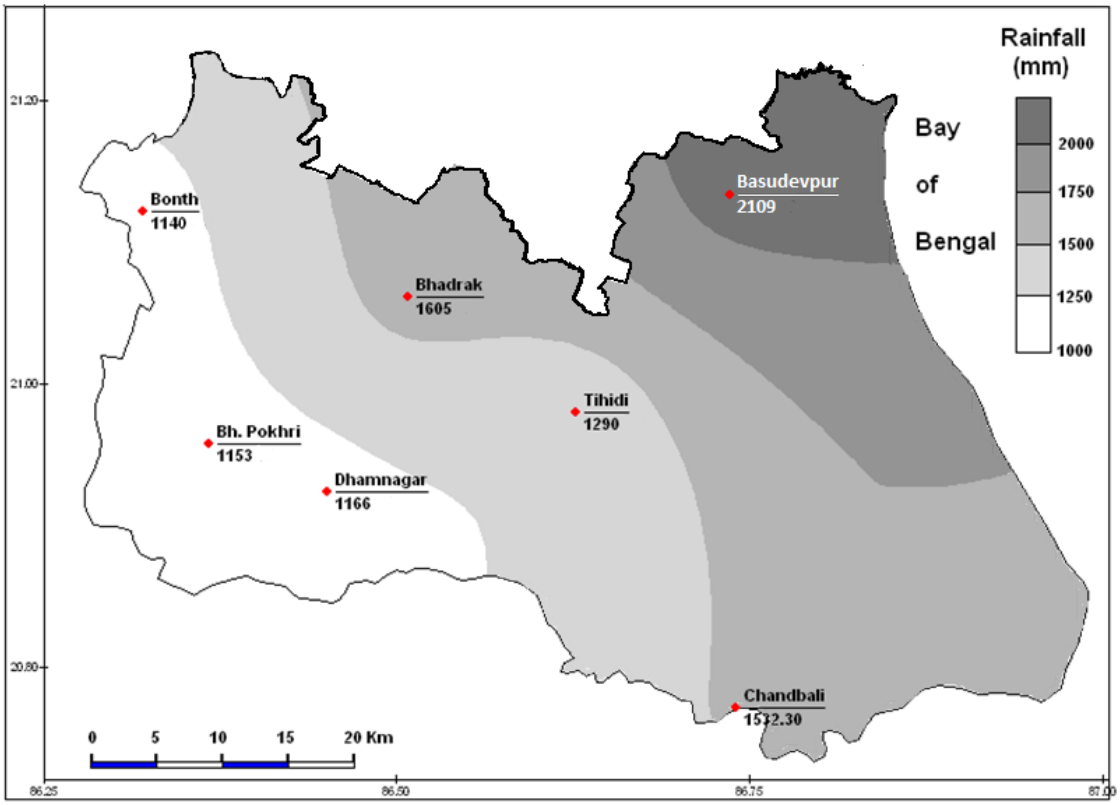


Fig -1.3: Areal distribution of rainfall in Bhadrak District

Analysis of rainfall of the last 20 years (1995 – 2014) shows moderate variation of rainfall in the district. The average annual rainfall is around 1438.4 mm which is very close to the normal annual rainfall. The standard deviation is around 283.2 mm. As per IMD classification, mild drought (0-25% deficient rainfall) occurs during the year 1996, 1998, 2008 & 2010 while moderate drought (25-50 % deficient rainfall) occur during 2000, 2002 and 2012. However excessive rainfall occurs during the year 2003, which exceeds average rainfall by 42.7%.

Block wise & Month wise Normal Rainfall of Bhadrak District (1901 to 1990) (data in mm)														Table-1.10
Sl. No	Block Name	January	February	March	April	May	June	July	August	September	October	November	December	Total
1	Basudevpur	12	25	51	79	120	244	431	466	375	240	61	5	2109
2	Bhadrakh	15	30	36	50	103	271	353	320	210	171	40	6	1605
3	B.Pokhari	14	35	35	30	73	195	218	242	183	87	38	3	1153
4	Bonth	12	29	30	42	83	137	281	260	134	100	26	6	1140
5	Chandbali	9.6	32.2	38.7	51.4	75.8	187.4	282.2	325.9	295.6	186.1	38.1	8.3	1532.3
6	Dhamnagar	9	32	37	52	92	167	220	295	157	83	19	3	1166
7	Tihidi	11	23	25	54	93	186	270	273	163	150	39	3	1290
Dist. Average		11.8	29.6	36.1	51.2	91.4	198.4	293.6	311.7	216.8	145.3	37.3	4.9	1427.9

Source: District Agricultural Officer, Bhadrak

Year and Block wise Annual Rainfall of Bhadrak District (1995 to 2014) (data in mm)								Table-1.11
Year	Basudevpur	Bhadrakh	B.Pokhari	Bonth	Chandbali	Dhamnagar	Tihidi	District Average
1995	2701.6	1922.3	1173.9	1547.1	1487.3	1549.0	1491.9	1696.2
1996	1996.0	1170.2	997.0	974.0	920.5	1020.0	899.0	1139.5
1997	2879.0	1853.0	1000.0	1490.0	1374.0	1647.0	1521.0	1680.6
1998	1797.0	1224.0	923.0	1323.5	1249.2		706.0	1203.8
1999	2981.0	2087.0	1373.5	1170.0	1767.2		815.0	1699.0
2000	1147.0	1149.0	733.0	1090.0	749.8		968.0	972.8
2001	2579.0	1523.0	1033.0	1211.0	1605.9	1610.0	1778.0	1620.0
2002	1529.0	1016.0	571.0	1078.0	1260.5	916.0	1009.0	1054.2
2003	2173.0	1676.0	2295.0	1850.0	2366.5	2133.5	1874.0	2052.6
2004	1752.0	1454.0	1432.0	1481.0	1318.5	1181.0	1441.2	1437.1
2005	2581.0	1669.0	1737.0	903.0	1973.9	1005.0	1937.0	1686.6
2006	1972.0	1731.0	982.0	1088.0	1452.8	827.0	1401.0	1350.5
2007	1857.0	1723.0	1158.0	824.0	1822.3	812.0	1848.0	1434.9
2008	1304.0	1421.0	1276.0	1294.0	1813.6	501.2	1300.0	1272.8
2009	1675.0	1713.0	1430.0	1992.0	1618.9	1366.0	1544.4	1619.9
2010	1459.0	1313.0	1178.0	1137.0	1256.7	1247.0	1353.2	1277.7
2011	1352.0	1632.0	1622.0	1602.5	1630.0	1664.0	1345.0	1549.6
2012	989.0	1077.0	1013.0	901.8	1158.0	994.0	629.0	966.0
2013	2043.0	1426.0	1355.0	1673.1	1577.6	1762.0	1198.0	1576.4
2014	1846.0	1234.3	1495.0	1465.0	1308.7	1442.2	1550.0	1477.3
Mean & SD	1930.6, 573.9	1500.7, 300.4	1238.9, 382.1	1304.7, 325.1	1485.6, 368.2	1275.1, 422.5	1330.4, 390.2	1438.4, 283.2

Source: Officer of Special Relief Commissioner, Govt. of Odisha

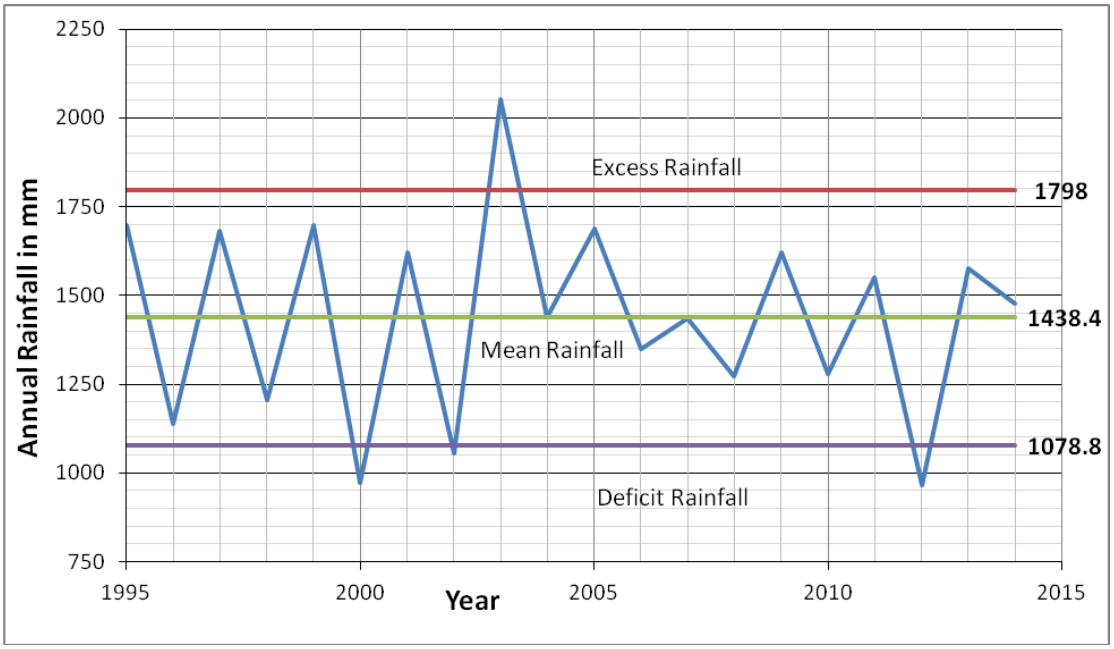


Fig -1.4: Rainfall Analysis for Bhadrak District

1.7 Physiography and Drainage

The district is characterized by a flat topography with the altitude varying from 37 meter above mean sea level (amsl) in the North-Western part to around 3m amsl in the extreme eastern part along the coast line. Physiographically, the district is composed of two distinct units, i.e. alluvial plain and the coastal belt. The gently sloping alluvial plain that occurs on the western part of the study area forms the most fertile land. The general slope is towards south east with 0.8 to 1 meter per Kilometer.

The coastal belt is situated on the eastern part of the district with an elevation between 0 to 10m amsl and is triangular in shape with a width of only 5 km on the northern side and over 50 Km due south. It is characterized by an anastomosing drainage pattern with criss crossing tidal creeks. Problems like tidal surge, drainage congestion during rainy season, flooding and inundation are common in this region.

The district forms the outfall area of the Baitarani river which is flowing along the Southern boundary of the district. The Baitarani river along with its tributaries like Salandi, Matei and Reb river form the major drainage system of the area. The rivers and streams are mostly effluent in nature. Kans Bans river entered the district north of Podhuan village to reach Bay of Bengal.

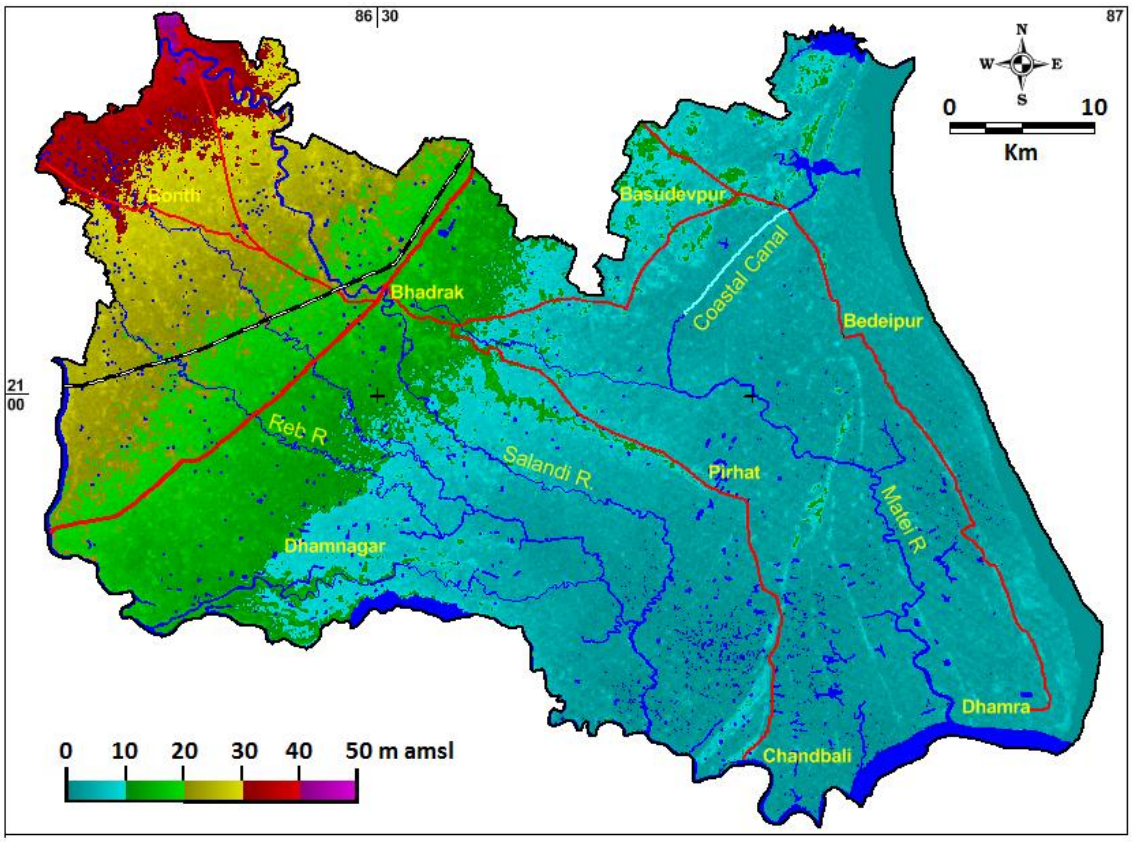


Fig -1.5: Digital Elevation Model of Bhadrak District

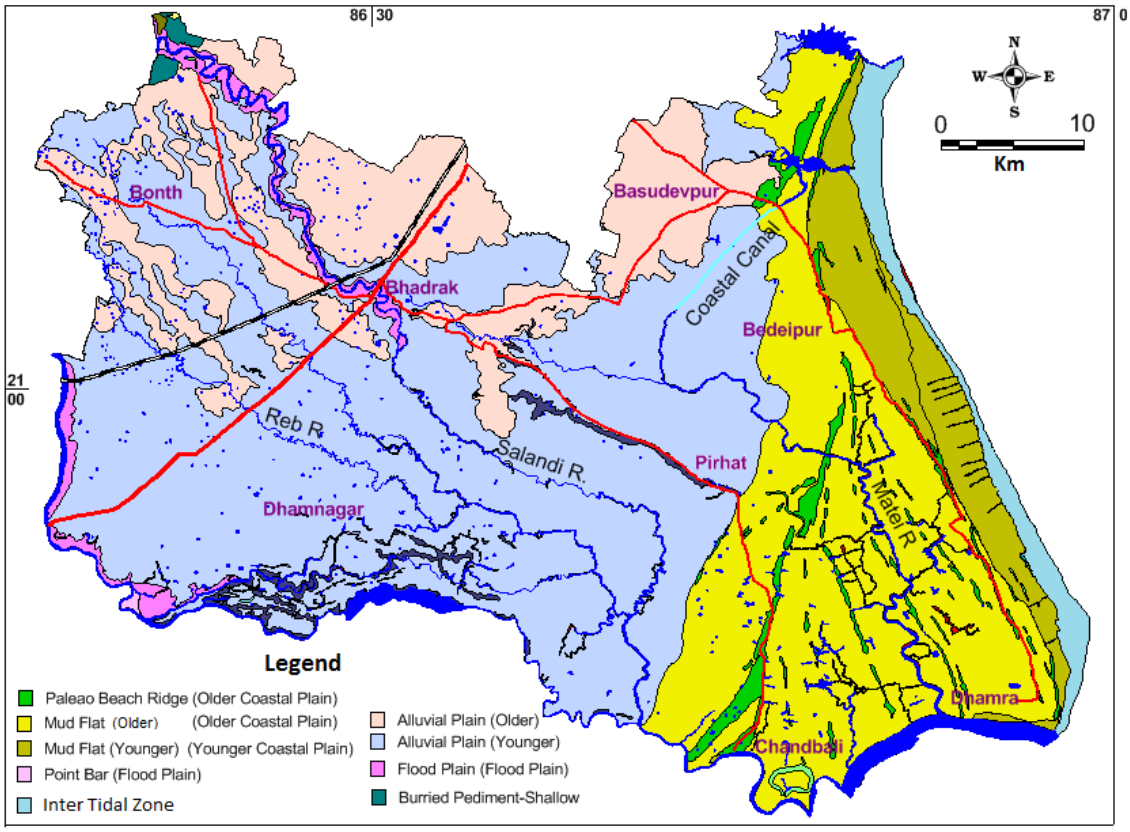


Fig -1.6: Geomorphic Map of Bhadrak District (modified after ORSAC)

1.8 Geomorphology

The district can be divided into 4 distinct geomorphic units; (1) Tidal flat (2) Coastal plain (3) Alluvial plain (4) Flood plain.

The tidal flat / mud flat is formed adjacent to the coastline due to the deposition of fine sediments carried back to land by tidal action which is originally the sediments deposited by the rivers. The width of this tidal flat varies from 2 to 5 Kms. Tidal flats and mud flats support growth of varieties of mangrove.

The coastal plain is a gently sloping plain occurring parallel to the coast and mainly formed by fluvio–marine action and is intersected by network of creeks, which are mainly saline due to tidal action. The area is marshy with shrubby vegetation. The width of this coastal plain varies from 5 to 25 Kms. The coastal plain encompasses a series of beach ridges characterized by sand dunes of varied relief (5 to 10 m amsl) and extends for kilometers, mostly parallel to the coast. However one such dune extending from Bedeipur on the north to Chandbali on the south with a length of around 25 kilometers indicates the position of palaeo-beach. It's orientation matches nicely with the coastline north of Basudevpur town, indicating the recent origin of the landmass east of Chandbali.

The gently sloping alluvial plain occurs to the west of the coastal plain and forms the most fertile part of the district. The alluvial plain can be further divided into two i.e (i) Older alluvial plain (ii) Younger alluvial plain

The north and north-western part of the district constitute the older alluvial plain. This is attributed mainly due to earlier cycle of deposition of sediments carried by rivers / streams and mainly of gravel, sand, and clay. Calcium carbonate Kankars is the conspicuous and at places lateritisation to a depth of few meters has also been observed.

The younger alluvial plain spreads over a large area and it represents major part of the district. This has developed due to depositional activities of the major river systems in a fluviatile environment. The human and agricultural activities are intense in this area. It also encompasses geomorphic units like palaeo channel, meander scars, ox-bow lakes of smaller dimension.

1.9 Soil

Three types of soils, viz. Alfisols, Aridisols and Entisols occur in the district. As per agro-climatic classification, the district falls under North Eastern Coastal plain. The soil distribution in the Bhadrak district is depicted in figure-7.

Alfisols:

These include deltaic and older alluvial soils. The deltaic soils are found along the course of Baitarani River while the older alluvial soils occur in the extreme north-western part. The deltaic alluvial soils are generally deficient in phosphate (P_2O_5) and nitrogen (N). Both the total and available potassium (K_2O) are fairly adequate and pH varies between 6.5 and 7.3.

Aridisols:

These are saline and saline alkali soils occurring all along the coast. They are rich in calcium, magnesium and consist of half decomposed organic matter.

Entisols:

These soils include coastal alluvial soils, which are deficient in nitrogen, phosphoric acid and humus, but not in potash and lime. The soil texture varies from loam to clayey loam. It is alkaline in nature and the most fertile soil in the area.

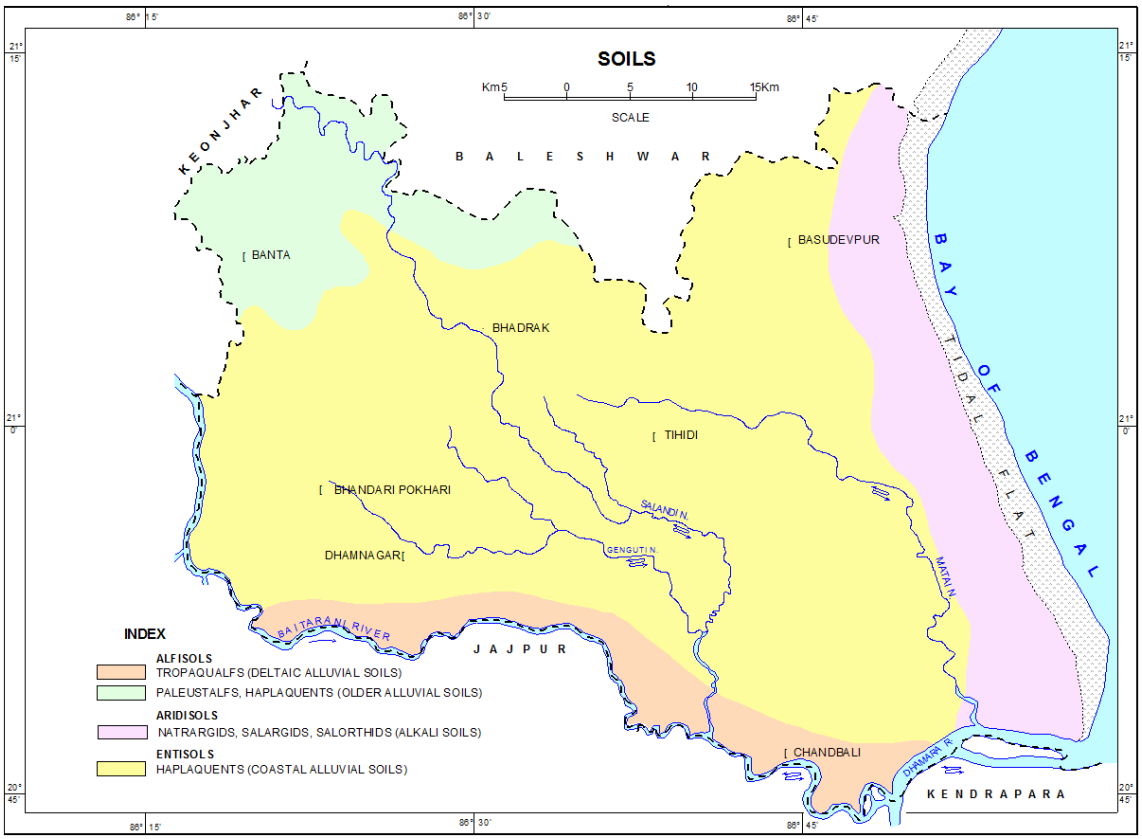


Fig -1.7: Soil Map of Bhadrak District

II. DATA COLLECTION AND GENERATION

2.1 Geology

Alluvium of recent to old deposits forms the main rock type of the study area. The older alluvium is exposed in the western part of the study area covering nearly entire Bhandari Pokhri & Khaira block, major part of Bonth block, north western and central part of Bhadrak & Simulia block and western part of Dhamnagar & Soro block. They are generally gray to brown in colour, unfossiliferous and contain plenty of calcareous concretions. They are mainly composed of sand, gravel and clay.

The laterites and lateritic gravels occur as capping over the older alluvium. They cover the entire Khaira and major part of Bonth block and north western part of Bhadrakh, Bhandari Pokhri & Simulia block. These laterites and lateritic gravels and pebbles are reddish brown to brown in colour. The thickness of laterite increases towards west. Very hard metallic coloured laterites are exposed due north of Salandi on Agarpada – Kupari road.

The recent alluvium occupies the central and eastern part of the study area covering Basudevpur, Chandbali, Tihidi and parts of Bhadrak, Dhamnagar, Soro and Simulia blocks. These deposits consist of clay, sand, silt and gravel. Aeolian sand deposits in the form of sand dunes are also seen near to coast and far inwards, the later indicating old beach positions.

The exploratory drilling of CGWB has revealed the existence of Precambrian crystallines and Tertiary sediments at depths. The generalised geological succession of the area is given below;

Era	Period	Epoch	Formation
Cenozoic	Quaternary	Pleistocene to Recent	Recent & Older alluvium, sand dunes, laterites
	Tertiary	Mio-Pliocene	Brown, Yellow and gray sand, gravels and clays, gritty sandstone, Shale
		Miocene	Gray clays, sands with molluscan shells, shelly limestone, shale
~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~			
Precambrian			Granite Gneiss

The Precambrian granite gneiss was encountered in the boreholes, at depths ranging 173 to 402 meters below ground level. The Tertiary sediments encountered in the boreholes comprise of marine fossiliferous sequence of Miocene overlain by an estuarine sequence of Mio-Pliocene formation. The fossiliferous marine formation is encountered at

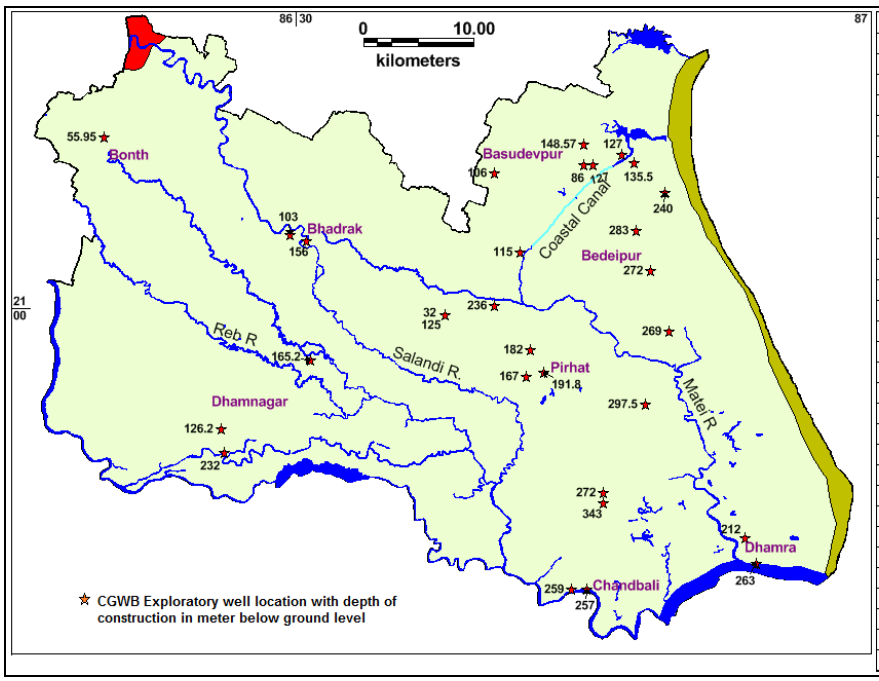
different depths ranging from 72 to 330 mbgl. The younger unfossiliferous estuarine sediments are encountered from 29 to 601 mbgl in different boreholes.

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. However in the eastern part of the district which is underlain by saline formations, deeper tube wells and hand pumps constructed by Rural Water Supply and Sanitation (RWS & S) Department, Govt. of Odisha 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 is shown in Figure – 2.1. The detail data generated from this exploration is given in Table – 2.1. The ground water quality of these wells has been given in Table-2.2.

CGWB is also engaged in ground water regime monitoring through 20 National Hydrograph Stations (NHS) spreading over the district. The ground water level data of four seasons and the water quality analysis result is given in Table – 3 & 4.



Sl No	Place	Construction
1	Churamamiary	135.50
2	Krushnapur	283.00
3	Nayakaidiha	269
4	Gopalpur (Churamari)	148.57
5	Mandari (Panchayat Office)	127
6	Biras	272
7	Bedeipur	240
8	Brahmanigaon	106
9	Balinagar	131
10	Padmapur	115
11	Rajgharpokhri	236
12	Basudevpur (Pz-1)	127
13	Basudevpur (Pz-2)	86
14	Bhadrak (Kuansa)	156
15	Bhadrak (PHED)	103
16	Bonth	55.95
17	Biriadia (Ghatenswar) ,	297.5
18	Chandbali (Dakha School	257
19	Chandbali (Kilo Padia)	259
20	Chasakhanda	343
21	Dhamra	263
22	Motto	272
23	Narsinghpur	212
24	Dakhinabad	126.2
25	Dobal	232
26	Sarapur	165.20
27	Pirhat (Barbatia)	191.8
28	Kolha	182
29	Pirhart	167.00
30	Tihidi (PZ shallow)	32
31	Tihidi (PZ deeper)	125

Figure – 2.1: Location of exploratory wells with construction depth in Bhadrak district

Table-2.1: Basic data of CGWB Exploratory wells drilled in Bhadrak District

Sl	Location	Latitude	Longitude	Depth Drilled	Construction Depth	Zone Tapped	Cumulative thickness	Discharge	Draw down	Transmissivity (T)	Storativity (S)	EC	Hydrochemical profile & Remarks
				(m)	(m)	(m)	(m)	(lps)	(m)	m^2/day		µs/cm	
	Basudevpur Block												
1	Churamamiary	21.1183	86.7942	402.4	135.50	65.5-133	34	47.22	14.51	554		1180	0-60 B,60-133 F, 133-253 B 253-272 S, 272-402 S Basement encountered
2	Krushnapur	21.0633	86.7961	600.6	283.00	174-280	35.5	52.7	17.43	522		1962	0-145 S, 145-326 F, 326-523 B to S
3	Nayakaidiha	20.9811	86.8247	600.6	269	216-268	30	29.9	21.88	499	2.456×10^{-4}	1230	0-10 F, 10-195 S, 195-290 F, 290-427 S, 427-504 S to B, 504-595 S
4	Gopalpur (Churamari)	21.1333	86.7500	281.9	148.57	77-147	57	43.7	15.63	435		1000	0-154 F, beyond clay
5	Mandari (Panchayat Office)	21.125	86.7833	278.5	127	25-125	54	67.3	8.25	690.5		920	0-159 F, beyond clay
6	Biras	21.0305	86.8083	504	272	200-268	33	13	6.8	685		927	0-180 S, 180-288 F, beyond brackish to saline
7	Bedeipur	21.0938	86.8203	300	240	190-234	24	32	14.62	637.5	3.5×10^{-5}	1116	0-190 S, 190-300 F
8	Brahmanigaon	21.11	86.6722	177.8	106	55-103	21	18	6	340		891	0-161 F, beyond Saline LSt from 134 m
9	Balinagar	21.1167	86.75	374.1	131	45.5-128	45	43.7	11.66	960		678	All Fresh
10	Deoli (Basudevpur)	21.0989	86.7829										
11	Padmapur	21.0458	86.6944	137	115	80-112	18	18	4.25	1294.5		687	0-28 F, 28-60 S, 60-133 F, Fish teeth & mollusca at 130m 62-66 cement seal
12	Rajgharpokhri	21.002	86.6725	250.5	236	199-233	18	14	6.05	540		1116	0-188 S, 188-246 F 184-188 cement sealing
13	Basudevpur (Pz-1)	21.1162	86.7581	250	127	117-123	6	8				1004	All Fresh
14	Basudevpur (Pz-2)	21.1162	86.7581	250	86	77-83	6	8				909	All Fresh
15	Basudevpur (AB High School)	21.1464	86.73	150	147	129.5-145	15.5	10				1032	All Fresh
	Bhadrak Block												
16	Bhadrak (Kuansa)	21.055	86.5094	164.7	156	47-153	50	41.29	8.458	680.43		653	All Fresh
17	Bhadrak (PHED)	21.06	86.4944	174.8	103	56-103	10	10				633	All Fresh L.St fron 129 m

Sl	Location	Latitude	Longitude	Depth Drilled	Construction Depth	Zone Tapped	Cumulative thickness	Discharge	Draw down	Transmissivity (T)	Storativity (S)	EC	Hydrochemical profile & Remarks
	Bhandari Pokhari Block												
18	Bhandari Pokhari	20.85833333	86.6855	198.6		not constructed							8 - 87, 96.7 - 121, 151 - 167 All Fresh Zones, Black ferruginous nodules from 145m
	Bonth Block												
19	Barpada	21.0938	86.4189	192.2	82	28-77	25	60	8.78	1786	3.9×10^{-4}		All Fresh
20	Agarpara	21.1965	86.3728	173	155	42-151	33	35.55	12.52				All Fresh
21	Agarpara	21.1965	86.3728	154.22	116.3		32	18.05	5.48	564			
22	Bonth	21.1389	86.3333	151.8	55.95	40-54	14	8.33				553	All Fresh Basement encountered
	Chandbali Block												
23	Kheranga	20.9083	86.7500	303.86	262	153-260	76	50.55	13.53	635			4-140B, 152-270 F Auto flowing
24	Charotarap	20.9283	86.7500	300	266.8	176-264	64	54.16	18.65	1093			6-65 B, 76-138 B ?, 150-283 F Auto flowing
25	Biriadia (Ghatenswar) ,	20.9219	86.8039	600	297.5	202.5-292.3	49	44.6	15.41	911.57		872,	0-162.5 B, 162.5-452 F, 452-574 B to S 156-162 Cement Sealing
	Biriadia, zone test	20.9219	86.8039			75-80 zone						2601	
26	Nalgunda	20.9319	86.7583	304.19	298.7		55	25.88	4.57	1181	8.3×10^{-4}		5-85 S, 85-124 B, 124-170 S, 170-304 F Auto flowing
27	Chandbali (Dakha School	20.7722	86.7528	257.65	257	240-255	15	10				838	0-192/208 S, beyond fresh 166-267 clay dominated
28	Chandbali (Kilo Padia)	20.7722	86.7394	265.2	259	215-255	27	15	3.5	698		1158	20-172 S, 172-265 F, Beyond Saline 168-180 sticy clay Horizon
29	Chasakhanda	20.8417	86.7667	406.9	343	225-341	82	49	20	1255		603	18-170 B, 170-320 F, Autoflowing, clay below 333m
30	Dhamra	20.7931	86.9003	267.65	263	205-261	24	28.07	20.62	1486		990	0-100 S, 100-206 B, 206-265 F
31	Motto	20.8500	86.7667	316.09	272	188-270	53	52.4	14.55	1793		941	0-170 B, 170-270 F Autoflowing, 172-227 clay
32	Narsinghpur	20.8139	86.8903	241	212	150-209	24	15	4.55	608		891	0-91 S, 91-117 B, 121-239 F 117-121 cement sealing

Sl	Location	Latitude	Longitude	Depth Drilled	Construction Depth	Zone Tapped	Cumulative thickness	Discharge	Draw down	Transmissivity (T)	Storativity (S)	EC	Hydrochemical profile & Remarks
	Dhamnagar Block												
33	Dakhinabad	20.9017	86.4350	251.2	126.2	41.7-123.2	42	68.7	7.77	1283		700	All fresh, Auto flowing, PZ head 1.6 magl
34	Dobal	20.8833	86.4375	346.2	232	112-229	68	58.7	10.55	592.1		573	Fresh all through
35	Asurali	20.9431	86.5222	259.7	167	50-163	49	30.55	10.18				Basement encountered
36	Dhamnagar	20.9315	86.4371	206.5	120	38-116	34	41.66	8.34	797			All fresh
37	Suryapur			205		94.5-180	50						0-94.5 S, 94.5-180 F, beyond Saline
38	Sarapur	20.9583	86.5122	215.2	165.20	50.9-163	68	65.2	8.695	1090		511	All fresh 169-215 sticy clay
	Tihidi Block												
39	Pirhat (Barbatia)	20.9478	86.7153	300.2	191.8	114.8-187	48	15.62	25.195	176.53		1026	9-74 B, 74-292 F, beyond B 74-80 Cement Seal Lime Stone from 292m
40	Kolha	20.9667	86.7033	309.6	182	96-180	42	50.75	13.3	555		912	0-65 B, 65-301 F, SO4 increases during pumping
41	Musang	20.7922	86.6667	306.8	183	100-183	49	53.05	11.46	784			0-80 B, 80-306 F, Autoflowing
42	Harsungpur	20.9333	86.7333	316.1	275.0	168-272	70	52.5	11.2	1282			
43	Pirhart	20.945	86.7	170.1	167.00	150-165	15					1000	0-69 S, beyond fresh 70-78 Cement Seal
44	Daulathpur	20.9727	86.7142	313.6	195	108-193	59	54.72	9.46	1299			28-100 B?, 100-224 F Autoflowing
45	Tihidi (PZ shallow)	20.9944	86.63	34	32	25-31	6	8.5	3.65	35.4		714	0-37 F, beyond Brackish 32-34 Cement seal
46	Tihidi (PZ deeper)	20.9944	86.63	265.5	125	110-120	10	13				714	0-37 F, 37-84 S to B, 84-247 F, 32-35 & 71-84 clay horizon, 75-80 Cement seal
47	Khamaria (PZ)	20.9685	86.6829	250	152	142-148							0-12 F, 12-77.5 S, 77.5-90 B, 90-238 F

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

Table-2.2: Ground water Quality data of CGWB Exploratory well drilled in Bhadrak District

Sl	Location	EC	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F
	Basudevpur Block										
1	Churamamiary	1180	40	32	191		421		89		
2	Krushnapur	1962	60	49			305		440		
3	Nayakaidiha	1230	36	33	168	7.8	336		230		
4	Gopalpur (Churamari)	1000	40	25.5			439.2		49.6		
5	Mandari (Panchayat Office)	920	34	30.4			372.1		46		
6	Biras	927	43	32	99	21	333		74		0.38
7	Bedeipur	1116	48	36	122	7	203		138		
8	Brahmanigaon	891	33	29	124	11	445		64		0.52
9	Balinagar	678	6	21.9			140	25	39.1		
10	Padmapur	687	48	19	65	3.7	284		43		0.5
11	Rajgharpokhri	1116	56	34	80	5.8	323		124		0.55
12	Basudevpur (Pz-1)	1004	18	9.7	191	4.9	403		99	42	0.83
13	Basudevpur (Pz-2)	909	50	27	108	4.9	415		35	80	0.24
14	Basudevpur (AB High School)	1032	18	8.5	195	5.5	421		117		
	Bhadrak Block										
15	Bhadrak (Kuansa)	653	52	17	58	2.9	360		18	20	
16	Bhadrak (PHED)	633	56	22	49	2.5	342		28	7.5	
	Bonth Block										
17	Bonth	553	48	16	32	2	299		25		
	Chandbali Block										
18	Biriadia (Ghatenswar) ,	872,	24	8.5	148	5	348	0	96	7.5	0.65
19	Biriadia, zone test	2601	80	68	327	23	226		636	80	
20	Chandbali (Dakha School	838	14	28	120	5.5	207		142	39	0.18
21	Chandbali (Kilo Padia)	1158	54	28	147	7.2	341.6		175		0.4
22	Chasakhanda	603	42	15.3	41.9		6.3	0.655	138.7	71.16	
23	Dhamra	990	22	11			439		92		
24	Motto	941	3.6	10.9	122.2		8.4	0.25	145.5	61.8	
25	Narsinghpur	891	33	29	124	11	445	0	64		0.52
	Dhamnagar Block										
26	Dakhinabad	700	38	21.8			280.6		14.1		
27	Dobal	573	52	18			329		11		
28	Sarapur	511	2	32.8			155		17.8		
	Tihidi Block										
29	Pirhat (Barbatia)	1026	64	28	99	5.7	348	0	89	70	0.46
30	Kolha	735	2.43	32.77	104.7		66.4	0.57	131.9	82.4	
31	Pirhart	1000	32	24	156		251		170		
32	Tihidi (PZ shallow)	714	10	4.9	138	7.8	311		58	19	0.61
33	Tihidi (PZ deeper)	714	54	12	78	4.1	390		21	15	

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

Table-2.3: Depth to water level data of CGWB National Hydrograph Stations

Sl No	Longitude	Lattitude	Location	Jan-13	Apr-13	Aug-13	Nov-13
1	86.587	20.865	Betaligaon	5.39	7.09	3.71	1.89
2	86.519	20.921	Kothar	5.29	7.49	5.2	3.18
3	86.289	20.926	Akhuapada	8.12	8.73	5.81	3.15
4	86.307	20.936	Puriparabenipur	6.08	8.03	5.51	2.68
5	86.367	20.959	Bhandaripokhri	7.19	8.51	5.2	3.2
6	86.546	21.000	Gujidarha	3.34	6.07	4.21	3.18
7	86.544	21.018	Bentola	4.21	6.21	2.4	1.31
8	86.522	21.019	Durgapur	3.72	5.67	3.31	2.3
9	86.531	21.019	Balipatna	4.07	5.13	3.13	1.31
10	86.646	21.052	Basudevpur-I	3.29	6.89	4.21	3.18
11	86.617	21.050	Sabrang	5.23	7.13	4.64	2.38
12	86.501	21.051	Bhadrak1	5.3	5.1	3.51	2.72
13	86.507	21.067	Uttarabahini	2.98	5.31	3.4	1.59
14	86.331	21.117	Banth	6.08	7.57	4.3	2.18
15	86.739	21.118	Bagdavinayakpur		4.31		1.48
16	86.518	21.133	Ada Sasan	5.18	5.41	2.7	1.31
17	86.531	21.133	Rambhila	5.63	5.21	3.1	1.4
18	86.394	21.209	Agarpara	4.2	7.4	5.08	2.14
19	86.7461	20.7797	Chandbali-2				
20	86.4017	21.1541	Kadabaranga				

Note: Depth to water level in meter below ground level

Table-2.4: Ground Water Quality data of CGWB National Hydrograph Stations

Sl.No	Village	pH	EC	TDS	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
1	Agarpara	8	350	176	154	42	12	7	0	0	146	28	15	0.5
2	Banth	8.1	500	262	134	34	12	52	0	0	232	32	18	0.6
3	Kadabaranga	8	360	177	131	36	10	18	0	0	165	28	4	0.6
4	Ada Sasan	8	400	198	163	34	19	15	0	0	146	43	15	0.8
5	Balipatna	8.2	850	450	117	22	15	133	0.1	0	390	50	38	0.9
6	Bentola	8.3	500	240	168	36	19	31	0	0	220	28	17	0.7
7	Bhadrak1	8.2	540	277	170	40	17	49	0	0	244	35	16	0.7
8	Durgapur	8	650	316	250	54	28	23	0	0	244	82	9	0.6
9	Gujidarha	8	490	230	201	36	27	14	0	0	214	43	5	0.5
10	Rambhila	7.9	380	191	127	36	9	27	0.1	0	159	35	6	0.4
11	Sabrang	8	450	203	196	34	27	8	0	0	183	39	5	0.8
12	Tihidi	7.9	600	286	272	38	43	16	0	0	195	85	8	0.7
13	Uttarabahini	8.3	500	228	166	32	21	27	0.1	0	232	28	6	0.7
14	Akhuapada	8	350	175	150	42	11	10	0	0	153	25	12	0.5
15	Bhandaripokhri	8.1	300	158	130	42	6	10	0	0	134	25	9	0.5
16	Puriparabenipur	7.9	600	288	239	56	24	16	0.1	0	189	92	7	0.7
17	Chandbali-2	8.3	450	237	174	50	12	31	0	0	220	25	11	0.6
18	Betaligaon	8.3	840	439	110	26	11	130	0.1	0	378	50	36	0.8
19	Dhamnagar	8.2	590	286	166	30	22	48	0	0	262	46	11	0.8
20	Kothar	8	300	147	131	36	10	8	0	0	146	21	0	0.6

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

Under NAQUIM, 39 dug wells were established during 2012-13 and water level is monitored both in pre and post monsoon and is given in Table – 2.5. Since ground water for domestic consumption is commonly been extracted through shallow tube wells and handpumps, 30 tubewells have been monitored both for water level and water quality and the detail result is given in Table – 2.6.

Table-2.5: Depth to water level data of Monitoring Dug wells established during 2012-13 under NAQUIM in 73 K/12 & 73 K/16 Toposheets

Sl No	Location	Logitude	Latitude	Pre DTWL	Post DTWL
	Basudevpur Block				
1	Matipaka	86.7511	21.0503	3.85	1.77
	Bhadrak Block				
2	Atto	86.5897	21.0708	3.41	2.08
3	Balipatna	86.5314	21.0325	3	1.39
4	Bania (Chapundiasahi)	86.5517	21.0750	4.27	2.63
5	Barabhagia	86.5981	21.0167	4.37	2.94
6	Belda	86.5297	21.0122	3.08	1.86
7	Bentala	86.5444	21.0264	3.16	1.52
8	Bhabanibindha	86.5467	21.0386	3.32	1.9
9	Bhadrakali	86.5378	21.0158	1.57	0.98
10	Chandigaon	86.5678	21.0994	3.95	2.37
11	Chhabhaga	86.5842	21.0453	4.17	2.81
12	Durgapur	86.5225	21.0297	1.8	1.07
13	Erei	86.5331	21.0750	2.77	1.14
14	Gandarparha	86.5681	21.0044	3.1	1.81
15	Gardanpur (Ranital)	86.5606	21.1300	4.22	2.51
16	Gopalbindha	86.5572	21.0108	1.82	0.93
17	Gujidarha	86.5458	21.0031	2.6	1.07
18	Kedarpur	86.5628	21.0297	2.26	1.04
19	Keshpur	86.5197	21.1419	4.5	2.94
20	Khirasahi	86.5911	21.0767	3.08	1.61
21	Kodabaruan	86.5331	21.0822	3.44	1.82
22	Kodagambhir	86.5689	21.0903	4.03	2.65
23	Mouda	86.5275	21.0231	3.03	1.65
24	Nuapokhari	86.5628	21.0297	3.46	1.94
25	Palli	86.5844	21.0778	3.43	2.04
26	Panchpara	86.5067	21.1278	4.15	2.58
27	Rahanja	86.5544	21.1214	4.17	2.45
28	Rambhila	86.5308	21.1347	4.30	2.86
29	Serpur	86.5839	21.0350	3.12	1.40
30	Srirampur	86.5097	21.1225	4.45	2.98
31	Tishalpur-Asura	86.5408	21.1078	3.06	1.40
32	Uttarbahini	86.5075	21.0725	2.00	1.32
	Tihidi Block				
33	Budhang (Alinagar)	86.5981	21.0167	3.37	1.52
34	Dolasahi	86.5844	21.0217	3.16	1.24
35	Hatuari	86.6033	21.0397	2.57	1.55
36	Nuanand	86.5922	21.0403	3.32	1.92
37	Paliabindha	86.6108	21.0275	4.32	2.44
38	Radhang	86.5872	21.0300	3.01	1.25
39	Teliapada	86.5861	21.0000	4.32	2.66

Note: DTWL: Depth to water level in meter below ground level

Table-2.6: Ground water Quality data of Monitoring Dug wells established during 2012-13 under NAQUIM

Sl No	Location	Longitude	Lattitude	Pre_WL	Post_WL	Type	pH	EC	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F
1	Agapur	86.6839	21.0339	2.95	1.24	TW	8.93	1791	8	34	628	1.2	15	311.1	401.2	42.6	1.04
2	Albaga	86.6681	21.0919	5.18	2.11	TW	8.04	500	30	33	19.4	0.1	0	122	106.5	10.9	0.74
3	Apartbindha,Bhadrak	86.5000	21.0503	4.14	3.21	TW	8.09	330	34	15	8.7	0.2	0	140.3	32.0	2.9	0.53
4	Ayodhya,Raghupur	86.7339	21.0514	2.76	2.40	TW	8.3	870	14	23	133.5	0.7	3	268.4	67.5	82.9	0.64
5	Bachhada	86.7844	21.2008	7.89	6.35	TW	8.1	1272	28	50	137	0.7	0	170.8	237.9	90.5	0.96
6	Bachhada	86.7844	21.2008	7.97	6.40	TW	8.08	1115	20	29	152	0.4	0	201.3	134.9	71.9	0.87
7	Badakiari	86.7000	21.0508	2.76	0.91	TW	8.08	1109	30	38	88	0.6	0	152.5	220.1	45.4	0.82
8	Bagdabinayakpur	86.7003	21.1003	6.62	2.12	TW	7.92	297	30	9	10	0.2	0	128.1	14.2	4.2	1.00
9	Balimedh	86.7506	21.0169	5.93	5.43	TW	8.18	1046	26	34	81.6	0.9	0	164.7	152.7	94.0	0.54
10	Barapur	86.7836	21.1839	7.87	6.76	TW	8.17	644	18	27	50.6	0.7	0	176.9	32.0	78.8	0.82
11	Binapada	86.7014	21.0681	4.15	2.53	TW	8.09	527	24	28	31.6	0.6	0	158.6	28.4	59.1	0.83
12	Binayakpur	86.7167	21.0847	5.91	2.85	TW	7.96	315	24	13	100.8	0.1	0	109.8	28.4	3.3	0.90
13	By-pass, Bhadrak	86.5008	21.0667	2.02	1.40	TW	8.02	410	36	12	14	0.1	0	115.9	42.6	9.6	0.85
14	Chandimal	86.8000	21.0511	6.05	5.87	TW	8.19	972	20	33	93.1	0.8	0	213.5	120.7	83.6	0.54
15	Chirol	86.7014	21.0839	5.04	2.34	TW	7.98	564	18	39	25.1	0.2	0	115.9	92.3	16.0	0.94
16	Chudamani	86.7675	21.1336	6.96	4.30	TW	7.9	1761	52	49	149.5	0.1	0	140.3	248.5	81.8	0.85
17	Dadhibamanpur	86.7003	21.0336	3.35	1.97	TW	8.47	2220	10	32	341.3	0.2	6	329.4	497.0	64.1	1.10
18	Dohrasahi	86.6981	21.0044	3.00	1.71	TW	8.26	694	14	18	105.9	0.4	0	268.4	46.2	47.2	0.65
19	Eram	86.7839	21.1508	9.81	7.24	TW	8	1056	28	58	51.5	0.1	0	122	241.4	31.4	0.76
20	EreiBhadrak	86.5333	21.0669	3.07	NA	TW	8.04	400	32	26	14.5	0.1	0	189.1	42.6	5.3	0.69
21	Garadpur,Bhadrak	86.5014	21.0339	4.02	3.08	TW	7.86	650	42	33	26.7	0.2	0	158.6	106.5	14.6	0.64
22	Korkora,Bhadrak	86.5000	21.0175	4.44	3.14	TW	7.94	350	30	19	14	0	0	183	21.3	3.4	0.95
23	Kumarpur	86.8006	21.1828	5.52	3.35	TW	7.87	1980	102	53	175	0.3	0	128.1	308.9	158.0	0.70
24	Lunga	86.6847	21.0669	4.74	2.50	TW	8.22	520	16	22	42.8	0.6	0	195.2	17.8	39.8	0.88
25	Mandari	86.7639	21.1169	7.46	4.22	TW	8.02	600	22	23	41.6	0.1	0	134.2	85.2	26.5	1.01
26	Matipaka	86.7511	21.0503	5.71	5.20	TW	8.21	1050	16	29	99.3	0.9	0	195.2	142.0	91.2	0.44
27	Patna Mishrapur	86.7200	21.0181	2.66	2.17	TW	8.22	1000	24	33	262.6	0.4	0	189.1	514.8	49.3	0.55
28	Ramachandrapur	86.7667	21.0681	3.24	1.67	TW	8.37	2788	32	34	375	0.8	3	250.1	639.0	127.9	0.97
29	Sadanandapur	86.6506	21.0336	3.24	1.09	TW	8.37	720	58	61	15.6	0.6	60	256.2	63.9	12.4	0.88
30	Santhia,Bhadrak	86.5003	21.0506	3.80	3.22	TW	7.95	700	30	28	48.5	0.1	0	152.5	110.1	7.4	0.54

III DATA INTERPRETATION, INTREGRATION AND AQUIFER MAPPING

3.1 <u>Shallow aquifers</u>: Ground water occurs under phreatic condition in shallow aquifers and is commonly been utilized by means of dug wells. Generally the depth of dug wells varies from 4.3 to 12.2 meter below ground level with average depth of around 7m. The shallow aquifer is commonly overlain by 3 to 6 meter of silt to clay layer, which necessitates the need for deep dug wells. The diameter of the dug wells varies from 0.5 to 3m. The wells are generally lined to the total depth except in the lateritic aquifer, which is present in the western part of the district.

The average depth to water level during pre-monsoon period ranges from 3 to 5 meter. However deep water level condition is found in three pockets:

(a) In the south western part, in parts of Bonth, Bhandari Pokhri and Dhamnagar blocks
(b) In the north western part surrounding Agarpada and Kupari where the main shallow aquifer is laterite
(c) In and around Basudevpur

The deepest water level of around 7.50 mbgl was found at Bandhatia village on Dhamnagar - Kothar road. Most part of Simulia block shows shallow water level due to canal recharge during summer.

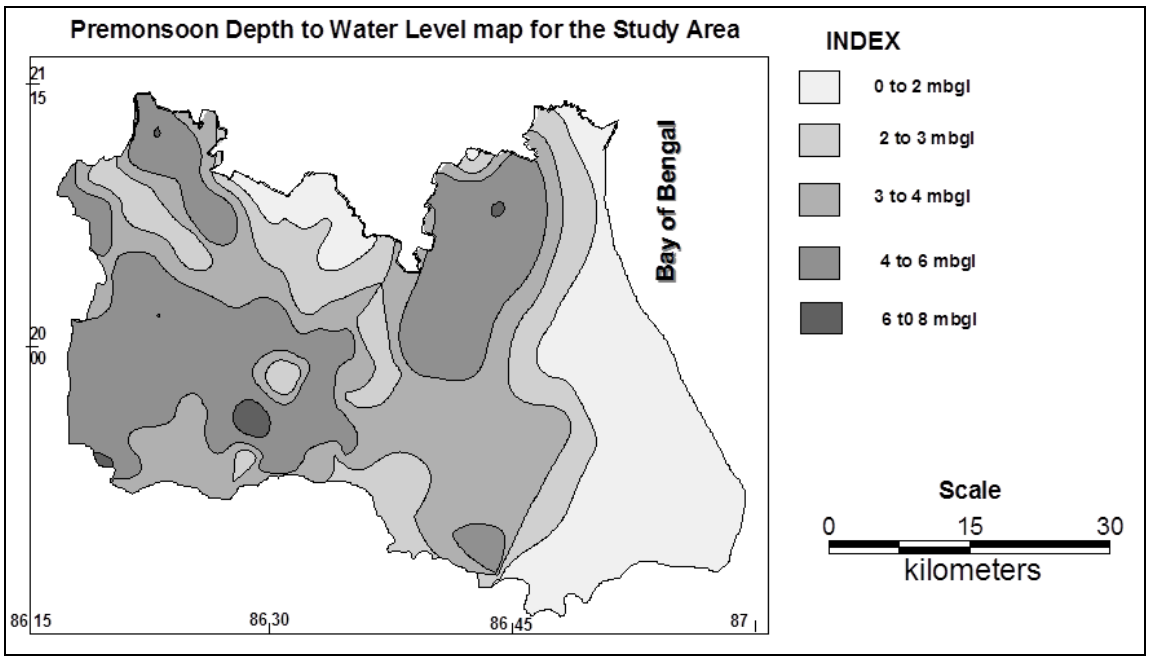


Fig -3.1: Pre-monsoon depth to water level map of Bhadrak District

The post monsoon water level remains shallow within 3 m below ground level in most part of the district. Again Bandhatia well is an exception with depth to water level at 4.36 mbgl. Generally the water level fluctuation between Pre & Post Monsoon seasons varies from 1 to 2m. However, very high fluctuation of around 4 to 5 meters is observed in and around Kupari, Agarpada and Bandhatia village. Long term water level trend shows no appreciable rise and fall in the area.

In addition to this, for detail study 32 & 7 dug wells have been monitored in Bhadrakh and Tihidi block respectively. To know both the water level and quality of shallow aquifer, 30 tube wells were monitored in both the blocks, which details are mentioned in Table – 2.6.

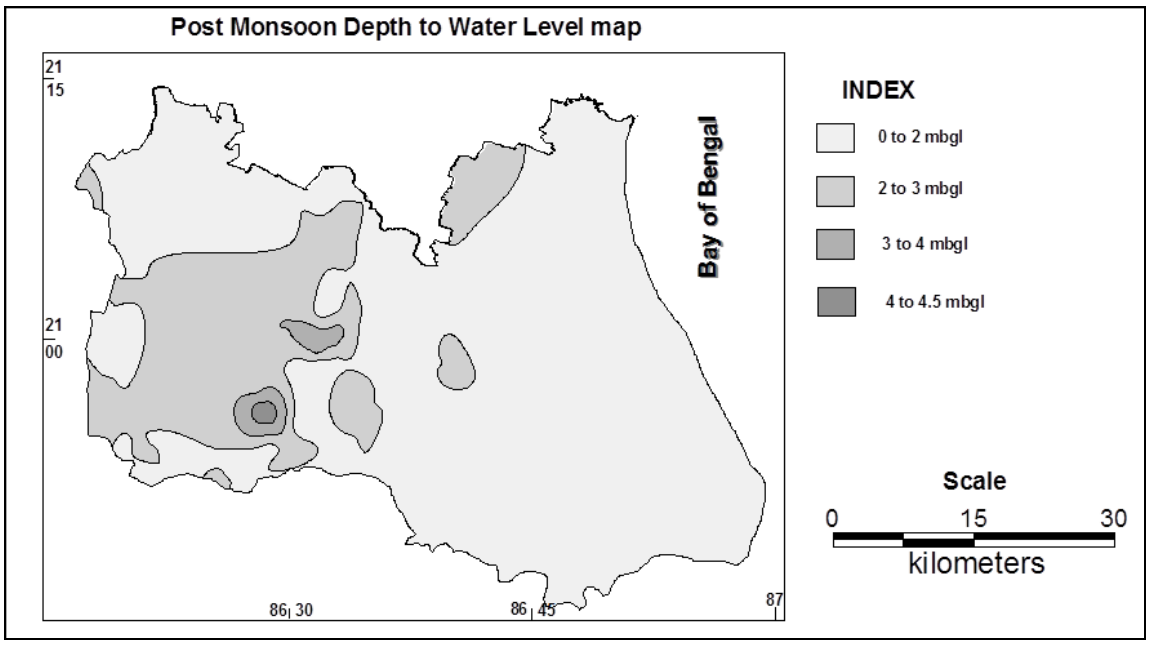


Fig -3.2: Post-monsoon depth to water level map of Bhadrak District

The quality ground water is very good with EC ranging from 350 to 850 µs/cm and all chemicals under permissible limit. Ca-Mg-HCO_3 type of water is encountered in the phreatic aquifer in most part of the district. However water samples of Tihidi, Durgapur and Puripara-Benipur show somewhat higher in chloride content with an appreciate amount of Ca-Mg-HCO_3, which indicates mixing of saline water with fresh ground water. Tihidi and Durgapur being situated on the line separating saline and fresh water area, different types of water qualities are observed in the same locality. Na-HCO3 type of water with some amount of sulphate content is observed at Balipatna and Betaligaon which indicates freshening up of the shallow aquifers by meteoric water. The ground water quality of phreatic aquifer is enumerated in Figure – 3.3 & 3.4.

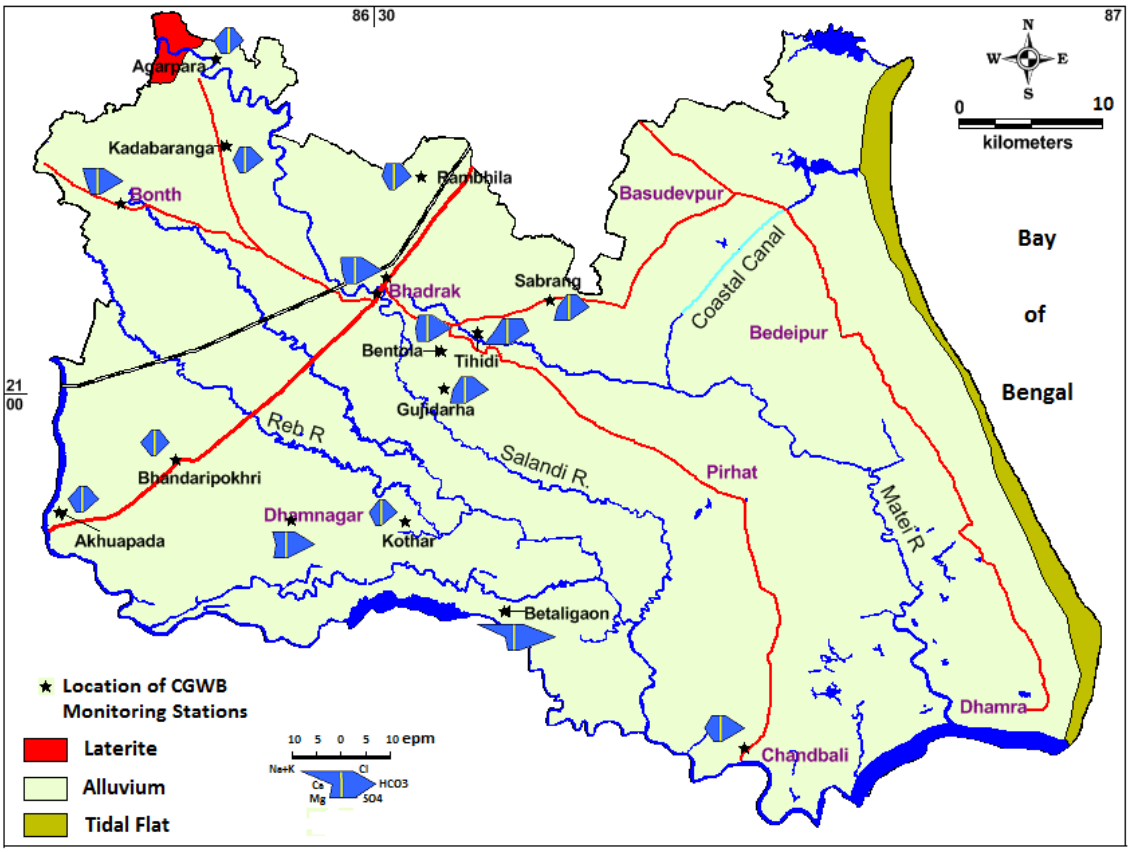


Fig -3.3: Quality of shallow aquifer of Bhadrak District (Stiff Diagram)

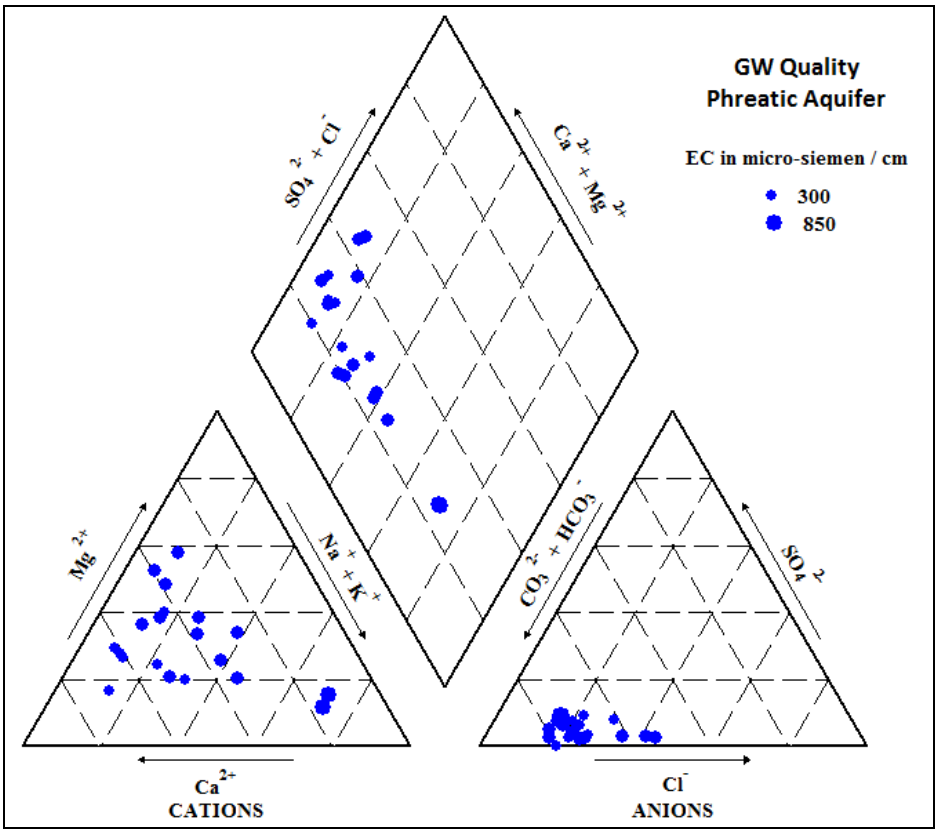


Fig -3.4: Quality of shallow aquifer of Bhadrak District (Piper Diagram)

3.2: <u>Deeper Aquifer</u>: Unlike phreatic aquifer, ground water occurs under confined condition in the deeper aquifers. The presence of coarse sand and gravel of terrestrial deposits form numerous prolific aquifer systems in the study area. To know the disposition of deeper aquifers, Central Ground Water Board has drilled 18 exploratory wells, 20 piezometers and 1 slim hole under exploratory drilling programme till date. Besides this, another 19 tube wells were drilled under deposit well drilling programme. Another 30 well drillings were carried out by outsourcing during 2001-02 under drought assistance scheme mostly confined to the western part of the study area.

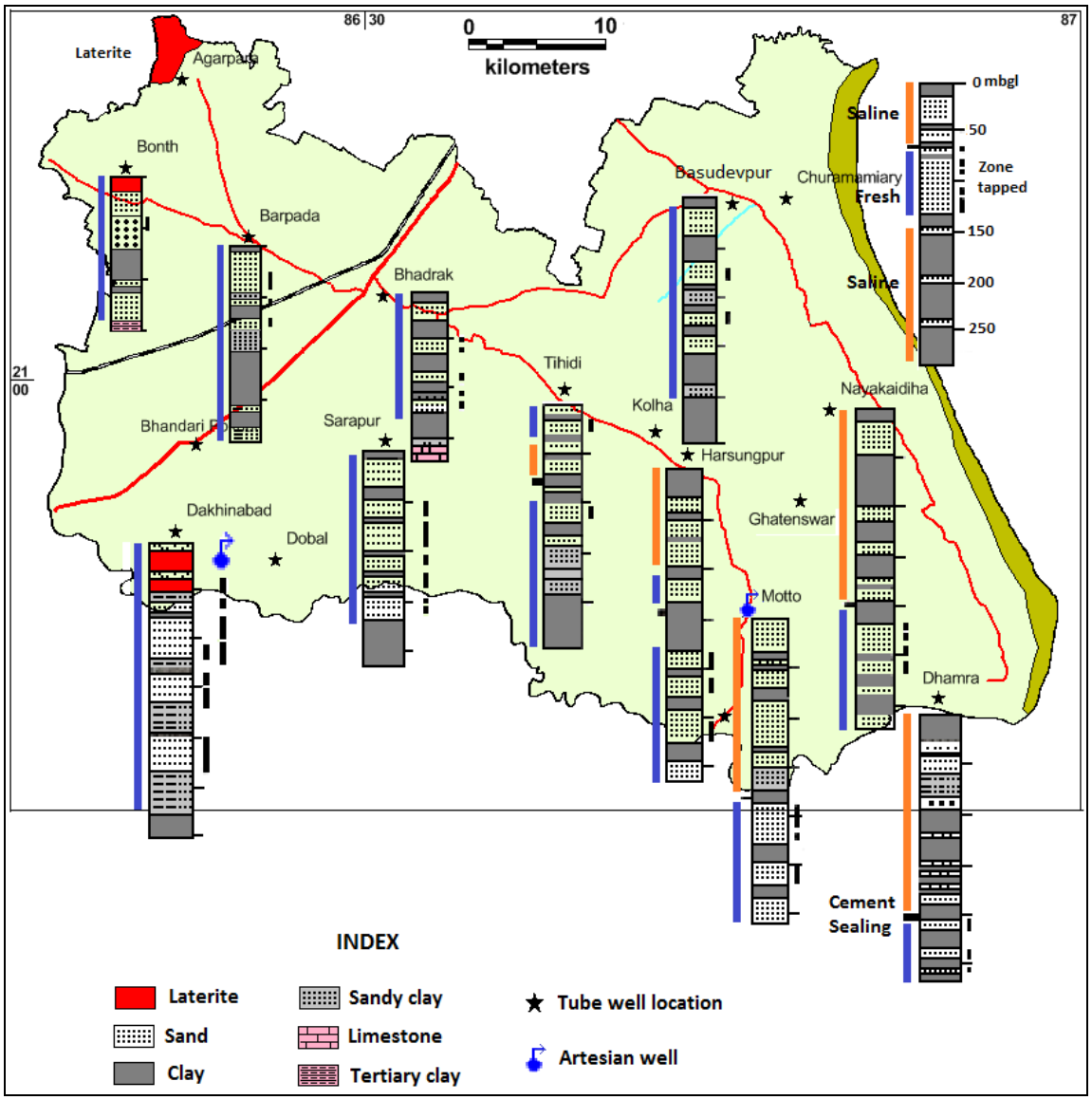
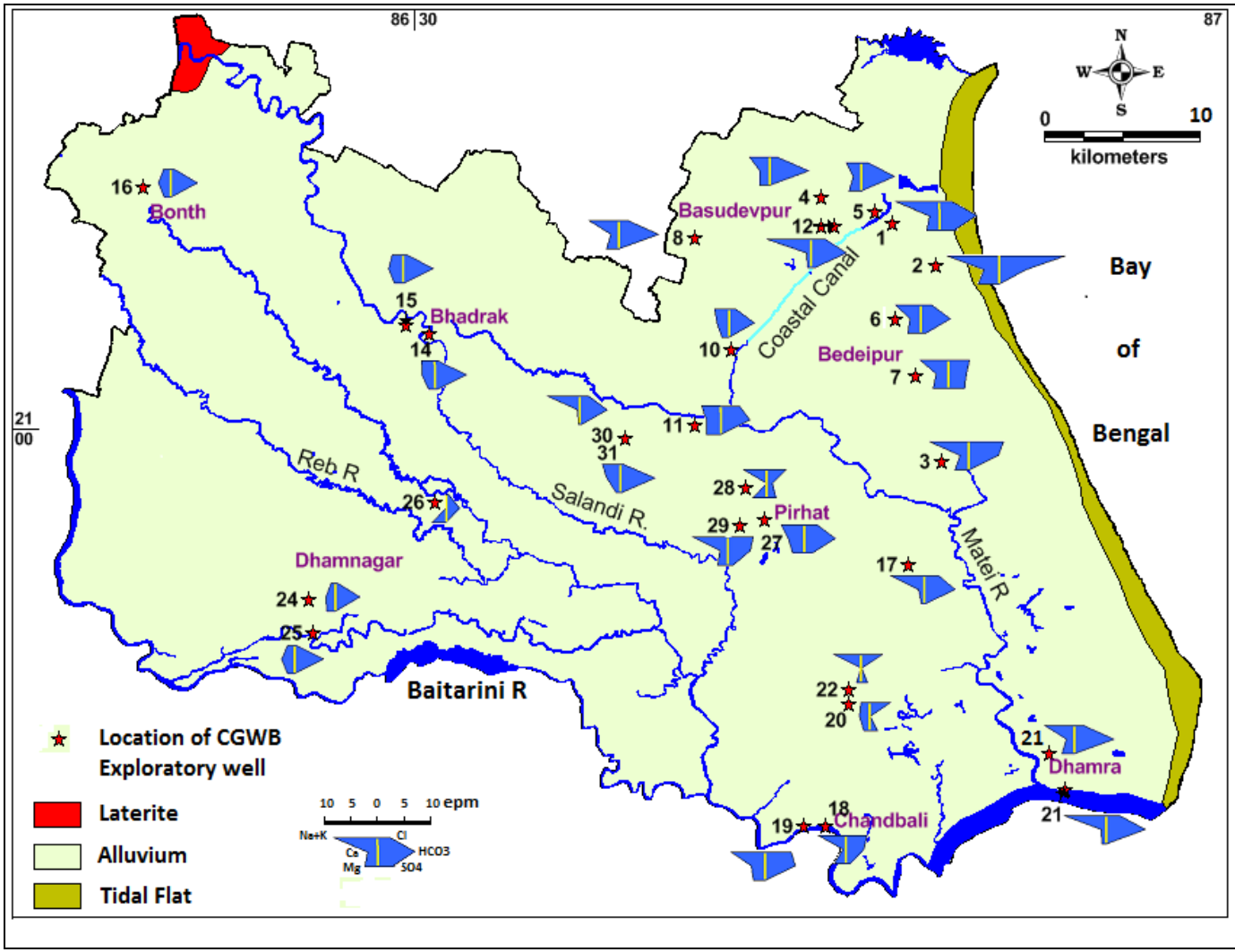


Fig -3.5: Litholog of representative exploratory wells of Bhadrak District

All these drilling data reveals that the thickness of alluvium increases from NW to SE direction in the study area. The basement is reached at a depth of 50 to 60 meter in the western part, while the same is not encountered till to a depth of 602 meter below



Sl No	Place	Construction
1	Churamamiary	135.50
2	Krushnapur	283.00
3	Nayakaidiha	269
4	Gopalpur (Churamari)	148.57
5	Mandari (Panchayat Office)	127
6	Biras	272
7	Bedeipur	240
8	Brahmanigaon	106
9	Balinagar	131
10	Padmapur	115
11	Rajgharpokhri	236
12	Basudevpur (Pz-1)	127
13	Basudevpur (Pz-2)	86
14	Bhadrak (Kuansa)	156
15	Bhadrak (PHED)	103
16	Bonth	55.95
17	Biriadia (Ghatenswar) ,	297.5
18	Chandbali (Dakha School	257
19	Chandbali (Kilo Padia)	259
20	Chasakhanda	343
21	Dhamra	263
22	Motto	272
23	Narsinghpur	212
24	Dakhinabad	126.2
25	Dobal	232
26	Sarapur	165.20
27	Pirhat (Barbatia)	191.8
28	Kolha	182
29	Pirhart	167.00
30	Tihidi (PZ shallow)	32
31	Tihidi (PZ deeper)	125

Fig -3.6: Location of exploratory wells constructed by CGWB in Bhadrak District with ground water quality represented by Stiff Plot

Nayakandihi and Biriadia situated near to the coast. The study of the lithological log of tube wells reveals the presence of alternate sand and clay layers deposited in gently sloping sedimentary basin. Ferruginous and calcareous concretions, rock fragments, Molluscan shell fragments and heavy minerals are also noticed in some of the wells. Tertiary in the form of clay and Limestone deposited in a marine environment is also encountered in the north central part of the study area.

Though generally argillaceous sediments predominate towards east, predominant clay horizon also occurs in the central and north eastern part. The thickness of the clay horizon varies from 50m (Barpada and Asurali) to 137 m (Mandari). This clay horizon occurs at 104 mbgl at Barpada, 194 mbgl at Asurali, 191 mbgl at Tihidi and 163 mbgl at Basudevpur (mandari). Commonly it is deep grey in colour. Again thick remarkable clay horizon associated with shale and limestone, which is characteristics of Tertiary, is observed in the lithologs of Bhadrakh (107.7 to 174.8mbgl). This limestone is in continuation of that found on the southern part of the adjacent Baleswar district, where limestone formations are encountered at different depths, i.e., Saud (88.5 to 247mbgl), Talanagar (88.5 to 202mbgl), Markona (93.8 to 194.4mbgl).

In general, the calcareous facies predominates in the NW part while clay dominates in the SE part of the sedimentary basin. Besides this major clay horizon, numerous clay layers varying in thickness from 1 to 10 m are encountered in all the tube wells at different depths. The colour of the clay layers varies from brown, reddish brown, gray and deep steel gray. The brown and reddish brown clays are generally terrestrial in origin and are restricted to shallow depths and are found in the western part of the district. The gray and deep gray generally occurs from very shallow depths in the central and eastern part. The dark sticky clay is generally of marine origin.

The sand grains vary in size from fine to very coarse and are yellow, yellowish brown, grayish white and gray in colour and are quartzo-felspathic in nature. They are angular to sub rounded in shape. The sand grains occur as i) only sand zone ii) mixed with either clay and gravel iii) mixed with both clay and gravel. Generally mixture of fine to coarse or medium grains is quite common, while sometimes highly sorted medium to coarse sand horizons are also encountered. The thickness of individual sand layers ranges from 1 to 28 m.

The gravels are generally medium to fine in size, grayish white to brownish in colour,

subrounded in nature and quartzitic in composition. Though the gravels have been encountered in most of the tube wells, the prominent occurrences are observed along the southern sector of the district. Deep drilling at Ghanteswar and Naikandihi indicates the presence of gravels down to a depth of 600 mbgl. In the northern part, gravels are generally restricted to shallow depth.

The sand and gravel horizon forms the prolific aquifers in the district. The thickness of individual aquifer varies from 1 to 70m with the average thickness ranging from 4 to 10 m. The aquifer zones containing fresh water all through occupies the western part of the study area while the aquifer zones contain saline and fresh water at different depths in the eastern part. Top saline condition is observed in the entire Chandbali block, eastern part of the Tihidi and Dhamnagar Block (55% & 45% respectively) and narrow eastern part of Basudevpur Block (30%). The saline tract is triangular in shape with a wide base of 50 km in the southern part. The Dhusuri – Tihidi – Lunga – Mandari – Chudamani Aria line demarcates the saline tract on the east from the rest. The spatial distribution of the fresh water and saline water bearing areas are shown in Figure – 3.7.

CGWB has constructed numerous deep tube wells both exploratory and production to decipher the aquifer characteristics and their yield potentials. The depths of these tube wells vary from 92 to 343 mbgl. The cumulative thickness of the aquifer zones tapped varies from 16 to 76 m with the average thickness around 35 to 50m. The yield varies from 15 to 68 lps (average value ranging from 30 to 50 lps) for drawdowns ranging from 5.48 to 25.19m (average being 13 to 17m). The static water level varies from 1.2 m above ground level to 6.36m below ground level. The artesian conditions with the water level heights varying between 0.3 to 1.2 m above ground level exists in the South eastern part covering Chandbali – Dhamara – Matto – Musang - Daulatpur - Kohla area. These are all deeper aquifers, which are auto-flowing in the saline tract. The Transmissivity values ranges from 177 to 1790 m^2/day with the majority of the values falling between 500 to 1000 m^2/day. The Storage Coefficient values varies from 2.11×10^{-4} to 8.3×10^{-4}.

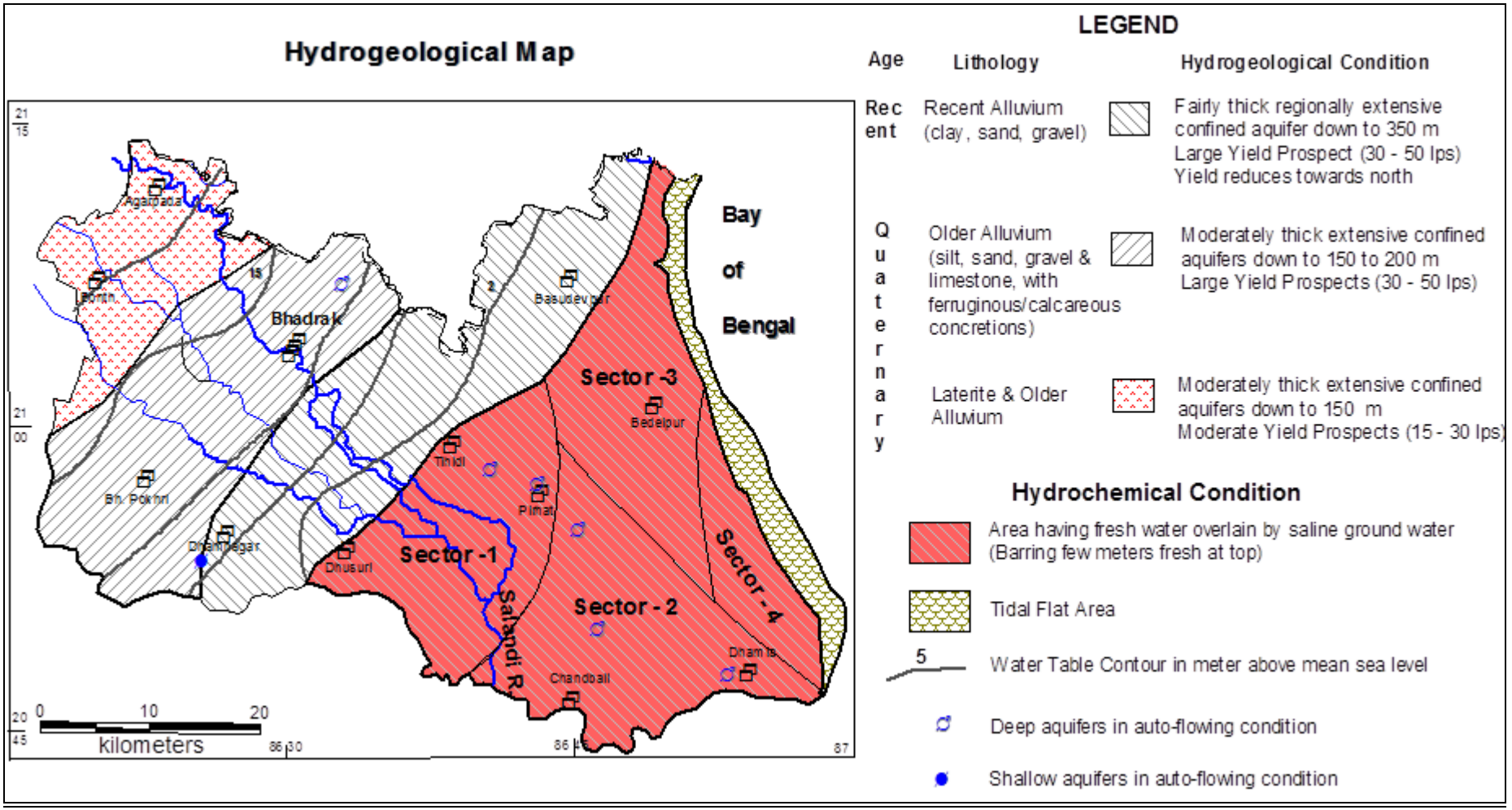


Fig -3.7: Hydrogeological map of Bhadrak district with yield prospect

Yield Characteristics of Non – Saline areas:

The non-saline area forms 62% of the study area covering most of the west central and northern part. The depth of the aquifer zones tapped varies from 8 to 163 mbgl with the exception at Dhobal, where aquifer zones upto 229 m is being tapped. The cumulative thickness of aquifer zones varies from 25 to 85 m with discharge varying from 31 to 68 lps. High discharge coupled with less drawdown makes the aquifer very much potential from the yield perspective. Shallow aquifers tapped between 42 to 126 mbgl are auto-flowing in and around Dhobal. Generally the thickness of potential aquifers reduces northwestwards which is being reflected in the yields of the tube wells. The hydrogeological details of individual tubewells are given in Table –3.1.

Table 3.1: Hydrogeological details of the wells constructed in non-Saline area

Location	Depth drilled (mbgl)	Depth range of aquifer zones (mbgl) tapped	Cummulative Thickness of aquifer tapped (m)	Yield (lps)	S.W.L. (mbgl)	Drawdown (m)
Agarpada	173	42-151	33	35	5.3	12.52
Bonth	151	14-142	85	30	2.7	
Bh. Pokhri	199	8-160	85	-	-	-
Dhakhinbad	251	42-126	63	68	1.6(agl)	7.77
Dhobal	346	112-229	68	58	2.59	10.5
Dhobal	150	42-118	24	30	0.9(agl)	1.85 ?
Barpada	193	28-77	25	60	0.46	8.78
Dhamnagar	210	38-116	34	41	0.70	8.34
Sarapur	215	50-163	75	65	1.95	8.69
Asurali	260	50-163	51	31	4.22	10.18
Bhadrak (Kuans)	165	47-153	49	41	5.89	8.45
Basudevpur (Balinagar)	374	46-128	45	44	4.27	11.66
Mandari	300	62-125	43	44	4.57	14.14
Gopalpur (Churamani)	282	77-146	57	43	2.38	15.63

* mbgl- meters below ground level agl – above ground level lps – liters per second

Yield Characteristics of Saline areas:

Saline tract covers an area of around 1300 km^2 showing complex hydrogeological setting. The fresh water bearing formations are overlain by saline formations and are encountered at different depths varying from 37 m & 60 m (at Tihidi & Chudamani Aria) to 200 m (at Dhamara). Based on the depth at which this aquifer is encountered at different locations of the district, a contour map is generated as shown in Fig –3.8.

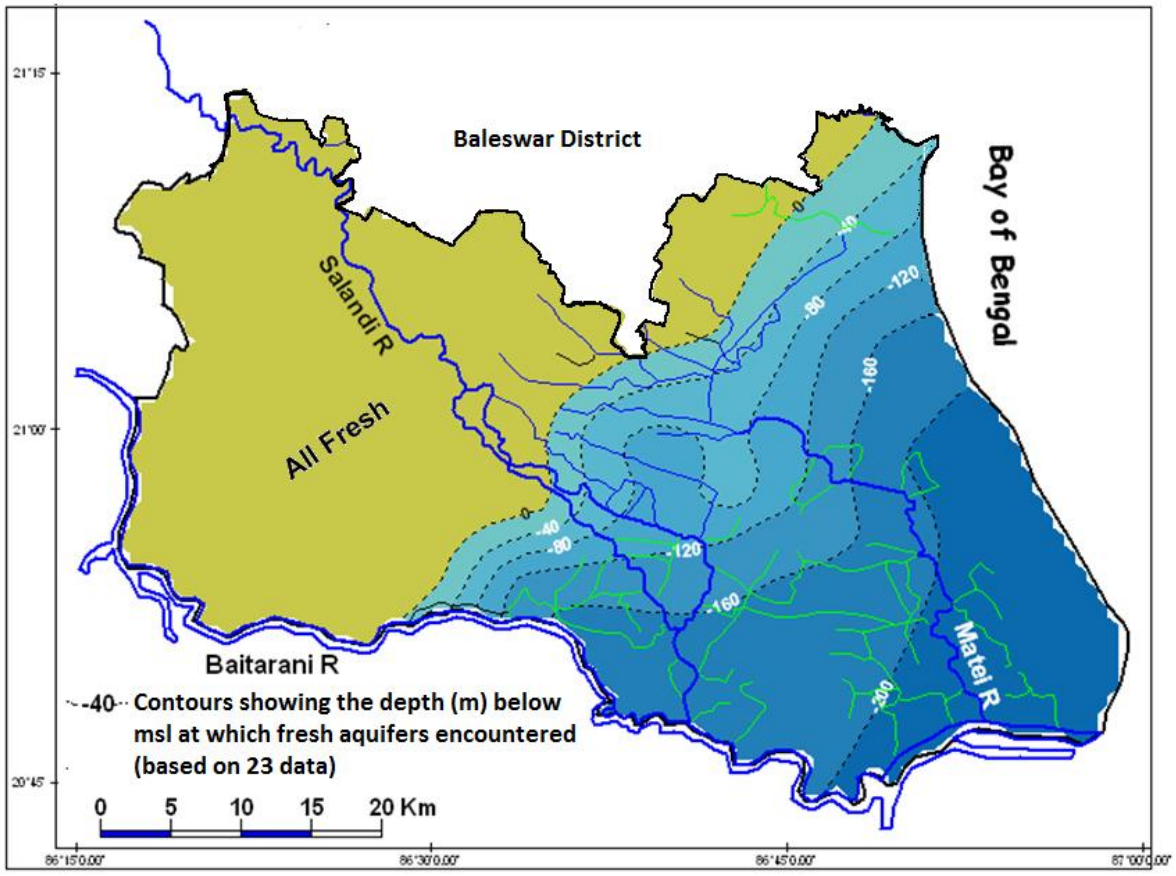


Fig -3.8: contour map showing the disposition of fresh aquifers

The map reveals the following facts:

1. The older alluvium is being deposited in a gentle sloping (0.3^0) wedge shaped basin during the delta progadation phase. The sedimentary load progressively got deposited in a SE direction as evidenced from the closing of depth contours on the northern (Basudevpur-Bedeipur section) and south-western side (Dhusuri-Aridi section) of the saline tract. They are mainly terrestrial in origin and are arenaceous in the southern part (Fig-3.5 & 3.8).
2. The rise of sea level in the recent period has lead to the alternate deposition of both terrestrial (sand) and marine (gray to steel gray sticky clay) formations. At the end of a terrestrial sand deposition marine transgression occurs, which turns the underlying fresh water aquifer saline. The process is still evidenced now in the tidal flat environment on the eastern part of the study area. The matching of the saline tract with the 6 meter land contour (Fig – 3.9) again supports the above said hypothesis.

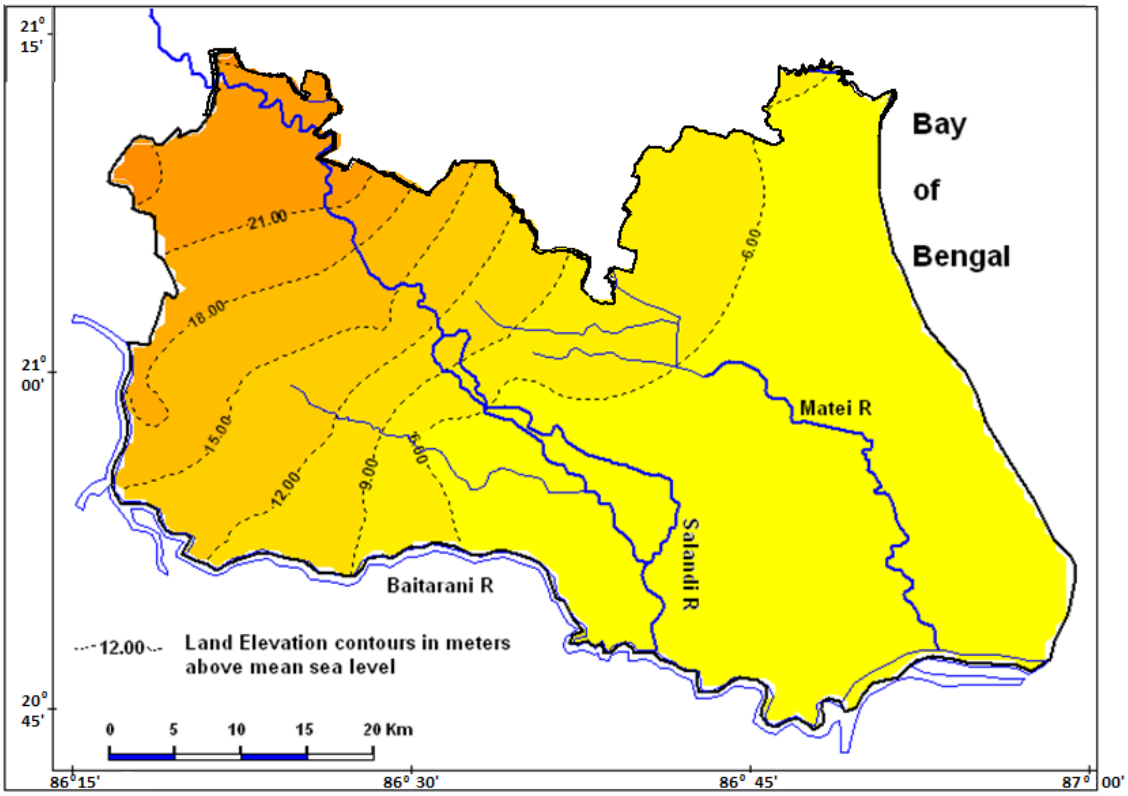


Fig -3.9: Land elevation contour map of Bhadrak district

Though this gives a general hydrogeological scenario of the study area, a sector wise analysis of the drilling data shows 4 different hydroeological setting in the saline area.

Sector-I

The Dhusuri-Tihidi-Pirhat-Aridi area falls in this sector. The saline ground water generally overlies the fresh ground water except in and around Suryapur (Dhusuri) area. In Suryapur fresh ground water is sandwiched between saline zones. The fresh water bearing zones occur between 95 to 180 mbgl. In general the top saline zone (barring a few meters at the top) extends down to 65m (Kolha) to 100m (Daulatpur), below which fresh water bearing zones occur down to a depth of 310m (maximum explored depth). The tapable fresh water bearing aquifers occur between 84 & 238m depth and the cumulative thickness of the aquifer zones varies from 42m (Kolha) to 77m (Daulatpur). The yield varies from 15 to 54 lps with the average around 40 to 45 lps against drawdown ranges between 9.46 and 25.19m (average 11 to 13m). The thickness of the top fresh water zone (dug well zone), though in general restricted to a few meters, at Tihidi-Khamaria sector it extends beyond dug well zone. At Tihidi the top fresh zone extended upto 37 meters depth while at Khamaria it is upto 12 m deep.

Sector-II

The Harsinghpur-Nalgunda- Matto-Chandbali-Dhamra area falls in this sector. The depth of the boreholes varies from 267 m (Dhamra) to 407 m (Chasakhanda) with the average depth around 300 meters. The extension of top saline zone varies from 125 m (Harsinghpur) to 206 m (Dhamra) bgl and on an average it extends down to 170 mbgl in Nalgunda-Chandbali section. Below this depth the formation continues to be fresh water bearing down to 407 m depth, which is the maximum drilled depth. The fresh water aquifer zones occur between 153 and 342 mbgl and the cumulative thickness of aquifers ranges from 12m (Dhamra) to 76m (Kherang). The yield varies from 28 lps at Dhamra to 54 lps at Charotaraf. The average drawdown ranges from 13 to 18 m. The static water levels rest within 1 mbgl and in majority of cases (Charotaraf to Chandbali section) it is under flowing condition (0.1 to 1magl).

Sector-III

The Chudamani Aria-Krushnapur-Ghanteswar section falls in this sector. In this sector fresh ground water bearing zones are sandwiched between saline ground water zones. The extension of top saline zone though varies from 60 m (Chudamani Aria) to 195 mbgl (Nayakandihi), generally top saline zone extends down from 145 to 170 m in most of the cases. The bottom of the saline zone occurs at 133 m depth at Chudamani Aria and at 452 m depth at Ghanteswar and it extends beyond 600 m depth. The depth range of fresh water bearing zones, occurring in between top and bottom saline zones varies from 60 to 133 m at Chudamani Aria, 145 to 326 m at Krushnapur, 195 to 290 m at Nayakandihi and 162 to 452 m at Ghanteswar. The depth range of fresh water bearing tapable aquifer zone varies from 65 to 292 mbgl and the cumulative thickness of the aquifer zones tapped from 24m (Bedeipur) to 60m (Ghanteswar). The yield varies from 30 to 53 lps against the drawdown of 14.5 to 22m. The static water level varies from 0.04m (Ghanteswar) to 4 mbgl (Chudamani Aria) with the majority of the values lying within 1 mbgl.

Sector-IV

The Dosingha-Gourprasad-Bansada-Baincha section falls in this sector and occurs as an elongated zone along the coast, covering the extreme eastern part of Chandbali block. In this sector though CGWB has not drilled any well. RWS&S under DANIDA Project drilled numbers of hand pump fitted tubewells. Detailed hydrogeological

information of these wells is not available except the disposition of fresh and saline zones. Moreover the entire thickness of the freshwater zones was also not explored. In majority of cases, drilling stopped after encountering the fresh water zone occurring below the saline water zones. The drilling data of DANIDA indicates that, though this sector is very close to the sea, the extension of the top saline zone varies from 75 m (Gauraprasad) to 130m (Bansada) bgl and in majority of cases it is restricted within 100 mbgl and below this depth fresh water bearing zones occur. At Baincha two fresh water zones occur, first one from 116 to 146m and second from 200 to 240mbgl. The disposition at Baincha is saline/Fresh/Saline/Fresh. This type of situation is not reported from any other place of the study area.

Basement Condition

Based on the basement data of 7 drilling locations and considering the deep drilling data of Nayakandihi, Biriadiha, Dhobal and Sahur, approximate basement contour map is prepared by Minimum Curvature Method. This is verified against all other drilling data and accordingly corrected to give a final and most possible basement map (Fig – 3.10).

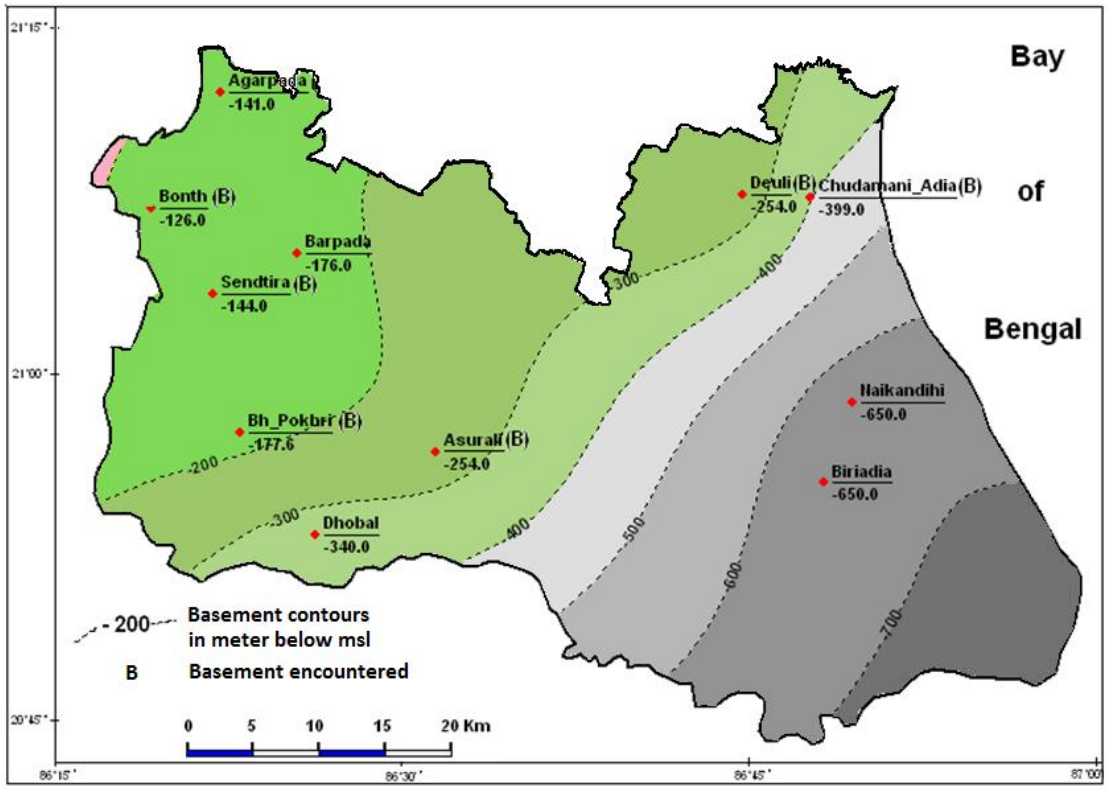


Fig -3.10: Basement contour map of Bhadrak district (approximate)

It is interesting to note that the fresh water and saline water boundary (Fig – 3.7 & 3.8) closely follows the basement contour. This indicates the deposition of sediments (now in contrasting hydrogeological conditions i.e. fresh and saline) occurs in similar basin condition and slope. The all-fresh aquifers extending to 350 meter in the western part forms the recharge zone for the deep aquifers encountered in the eastern saline tract. This is again reflected in the chemical quality of the ground water on its way from west to east from west to east as described in quality chapter..

With this backdrop, a 2D section from Bonth in the west to Dhamra in the east is drawn and is given in figure – 3.11. The section clearly shows the stratigraphic sequence and the depositoal history of both terrestrial and marine formations. It also depicted the occurrence of fresh and saline water aquifers and the recharge zone of the deeper fresh aquifer systems present in the eastern part of the district.. A 3D model is also created incorporating all the drilling data to decipher the disposition of the aquifer systems in the district and is given in figure- 3.12.

Ground Water Quality

The ground water of Bonth, Bhadrakh & Dhamnagar block which fall on the western part of the district have EC between 500 to 700 μs/cm with chloride content less than 50 ppm and is Ca,Mg,HCO_3 type. The ground water quality of the deeper aquifers is good and is devoid of hazards like iron and fluoride and thus is portable. The quality is also very good from irrigation point of view with quality falling in C_2S_1 type of USSL Classification.

Top saline condition is observed in the eastern part of the district and deeper aquifers with EC between 900 to 1250 μs/cm are the only source of ground water. The ground water quality is generally mixed type with Ca,Mg,HCO_3 and Na,Cl type. However at some places i.e., Dhamra, Chudamaniyar & Ghaneswar, Na,HCO_3 type of ground water is observed. Ground water of Nayakandihi, Bedeipur, Chandbali & Matto shows a typical type, i.e., Na,HCO_3 and Na,Cl type (Fig-3.6 & 3.13). The ground water is free from iron and fluoride and is portable. It is also suitable for irrigation as it falls in the C_2S_1 and C_3S_1 class of USSL Classification. However the difficulties in the construction of tube wells due to the top saline condition, restricts its use for irrigation. Moreover proximity to sea and limited recharge zone of this aquifer, needs a careful planning before going for its extensive utilization especially for agriculture.

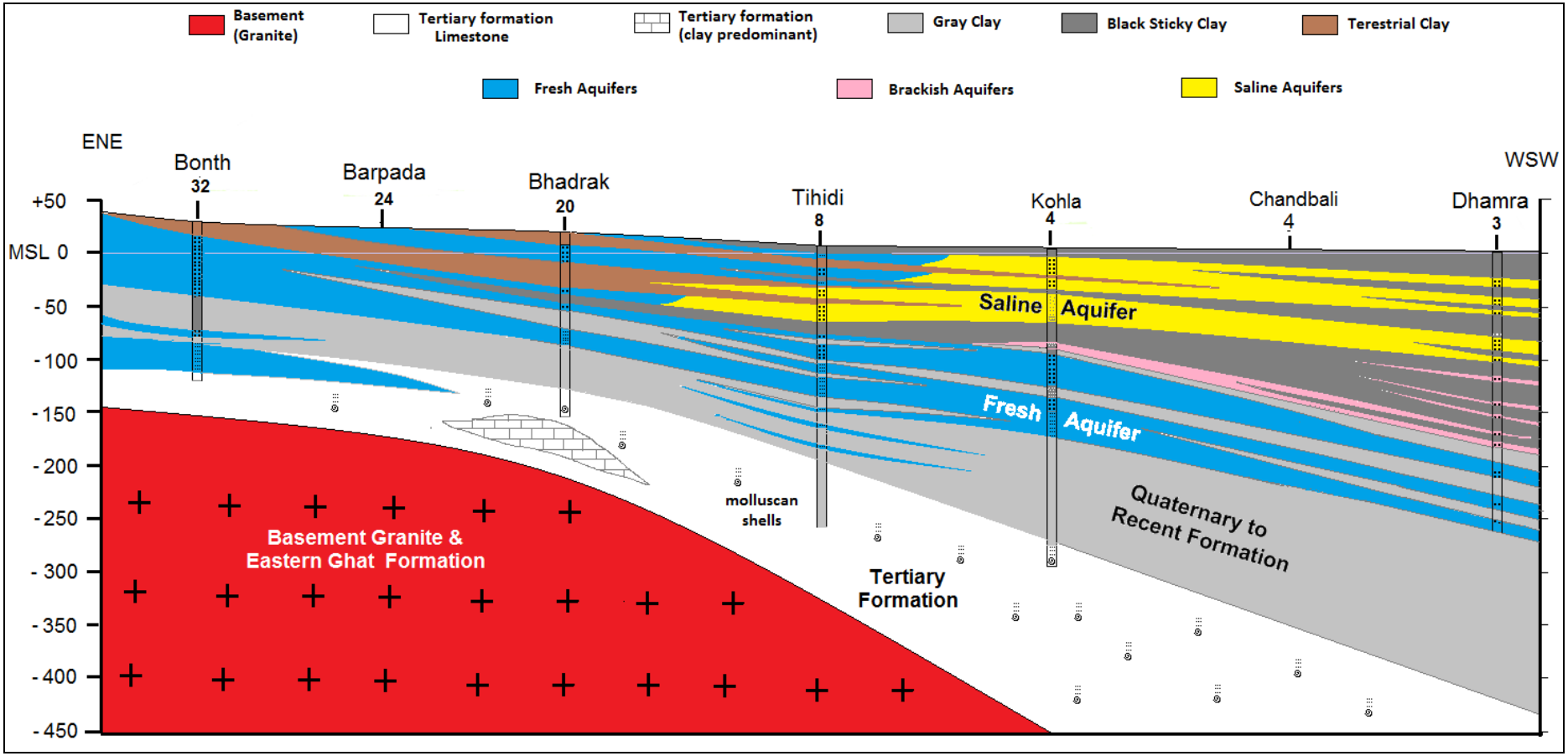


Fig -3.11: 2D section showing different geological formations and the main aquifer systems of the district

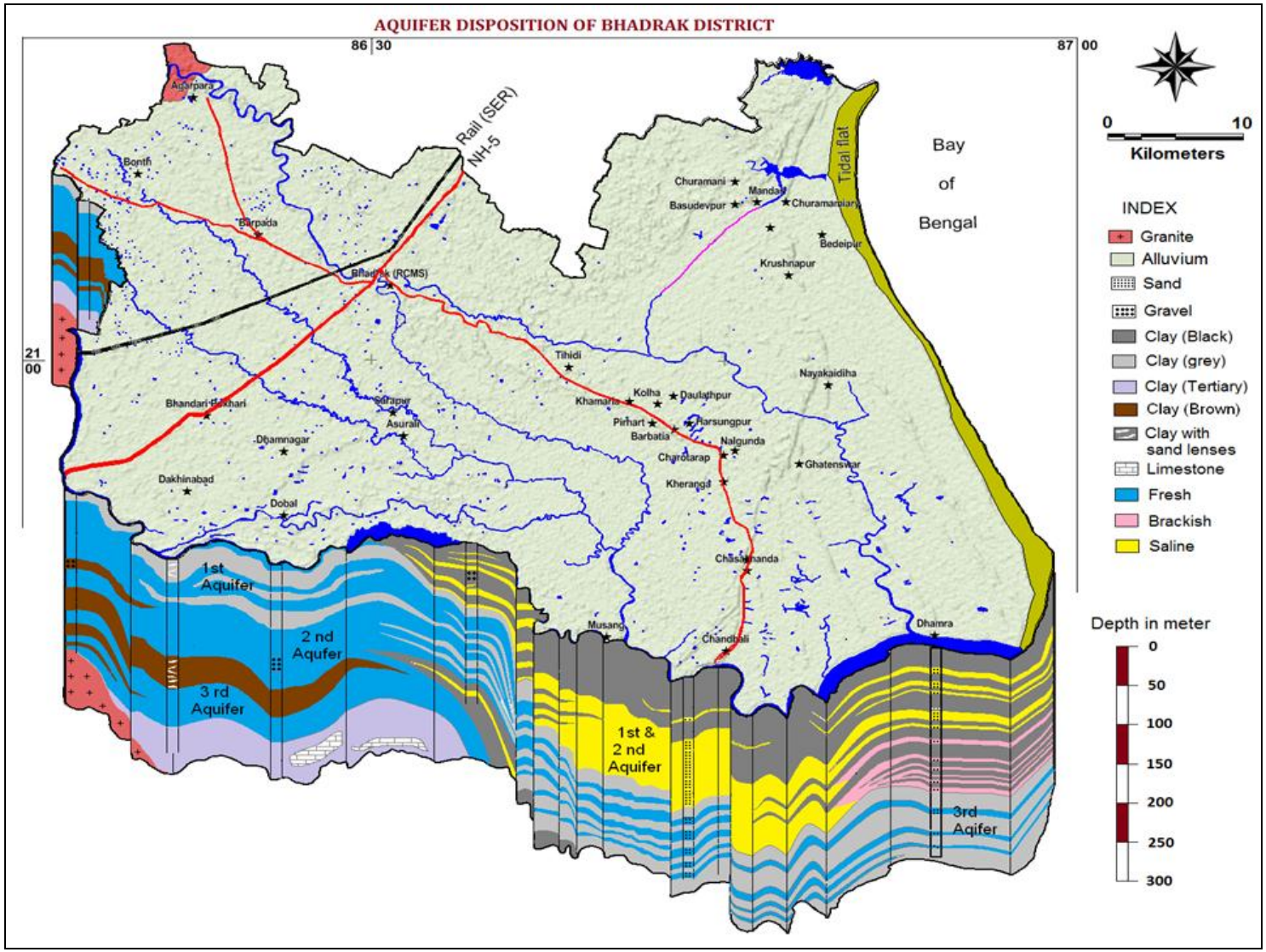


Fig -3.12: 3D section showing disposition of different aquifer systems vis a vis their quality

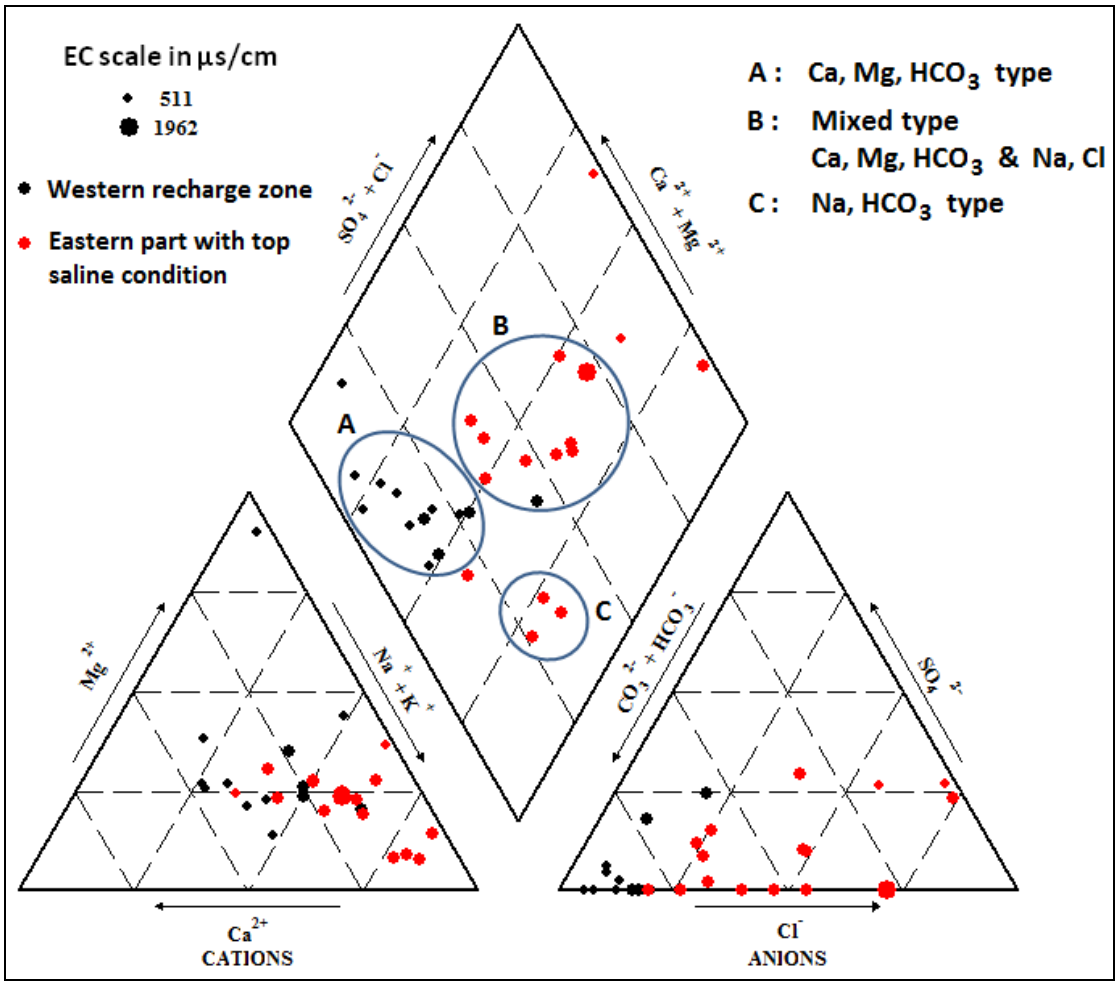


Fig -3.13: Quality of deeper aquifer of Bhadrak District (Piper Diagram)

IV GROUND WATER RESOURCES

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

Table – 4.1: Ground water resources of the 1st aquifer (phreatic & shallow aquifers upto 50 m of depth), Bhadrakh District

Sl No	Block	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
		(ham)	(ham)	(ham)	(ham)	(ham)	(%)	
1	Basudevpur	8365	7791.00	3876.18	365.00	3549.82	49.75	Safe
2	Bhadrak	11504	10815.00	7291.12	745.00	2778.88	67.42	Safe
3	Bhandari pokhari	10110	9604.00	6288.80	701.00	2614.20	65.48	Safe
4	Bonth	8130	7724.00	4307.52	927.87	2488.61	55.77	Safe
4	Chandbali	0	0.00	0.00	0.00	0.00	0.00	Saline
6	Dhamnagar	3966	3715.00	2215.17	396.00	1103.83	59.63	Safe
7	Tihidi	6141	5760.00	2679.33	283.00	2797.67	46.52	Safe
	District Total	48216	45409.00	26658.12	3417.87	15333.01	58.71	Safe

* Resources are in Hectare Meter (HaM)

A vast replenishable ground water resource is available, mainly confined to the 4 western blocks of the district. However the ground water utilization in this part is also high to the tune of 62.3% of the ground water resources. Thus there is a scope for further development of ground water resources to the tune of 90%, by keeping an eye on the ground water trend behavior of the aquifer system. Though in Tihidi and Basudevpur blocks good amount of ground water resources are available, its quality is a main deterrent for its exploitation for irrigational 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 methodology is 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. The 30 km long and 15 km wide area between Bonth and Anandapur (Keonjhar district) serves as recharge zone for the deeper confined aquifers. Taking specific yield of the shallow aquifers of the recharge zone as 0.08 and by permitting the water level to decline to 3 m from its present level during post-monsoon period, the total ground water resources of deeper confined aquifers of Bhadrakh district is calculated as 10800 HaM. This resource is holistically divided among the blocks against the two (2^{nd} & 3^{rd} aquifer) as shown in the table - 4.2. In Dhamnagar block, the 3^{rd} aquifer seems to be getting recharge from other recharge zone and hence based on its thickness a tentative resource is allocated. However it is worth to mention that the quality is not so good as compared to that of the shallow aquifers especially in Chandbali, Tihidi and Basudevpur block. Since the electrical conductivity remains between 1000 to 1500 µs/cm, quality testing is necessary before using for drinking and irrigation purpose. Moreover nearness to sea needs a careful monitoring of both head and quality in order to ascertain the effect of pumping on the aquifer and to determine the threat of sea water ingress.

Table – 4.2: Ground water resources of Bhadrakh District

Sl No	Block	GW resources of 1^{st} aquifer (upto 50m)	GW resources of 2^{nd} aquifer (upto 150m)	GW resources of 3^{rd} aquifer (upto 300m)
1	Basudevpur	7791	Limited (Saline)	2091
2	Bhadrak	10815	1367	Limited (clay & basement)
3	Bhandari pokhari	9604	1043	Limited (Basement)
4	Bonth	7724	1142	Limited (Basement)
4	Chandbali	0	Nil (Saline)	2655
6	Dhamnagar	3715	1082	361 (tentative)
7	Tihidi	5760	Limited (Saline)	1418
	District Total	45409	4634	6525

* Resoureces are in Hectare Meter (HaM)

V ISSUES AND MANAGEMENT STRATEGY

Issue – 1

Paddy Cultivation during Rabi Season has led to heavy ground water withdrawal from the shallow aquifers present in the western part of the Basudevpur block. This has led to the rapid decline of ground water level during post monsoon season and water levels remains 1 to 2 meter below mean sea level. However during the monsoon, the aquifer gets full recharge with the water level rising to 3 to 4 meter below ground level. Though it is a temporary phenomenon, in a long run it may affect ground water quality due to sea water ingress as the aquifer is shallow in nature. This is observed in an area of around 140 km^2.

Remedy - 1

The Salandi Canal (Figure - 1.2) especially Charampa and Ranital Distributory can be extended to the area and conjunctive use of surface water and ground water is to be promoted, instead of pure ground water based irrigation.

Remedy – 1I

Odisha Coastal Canal can be renovated with sluice control systems, so that during flood time it will serve the purpose of drainage and in normal time, for the purpose of fresh water harvesting.

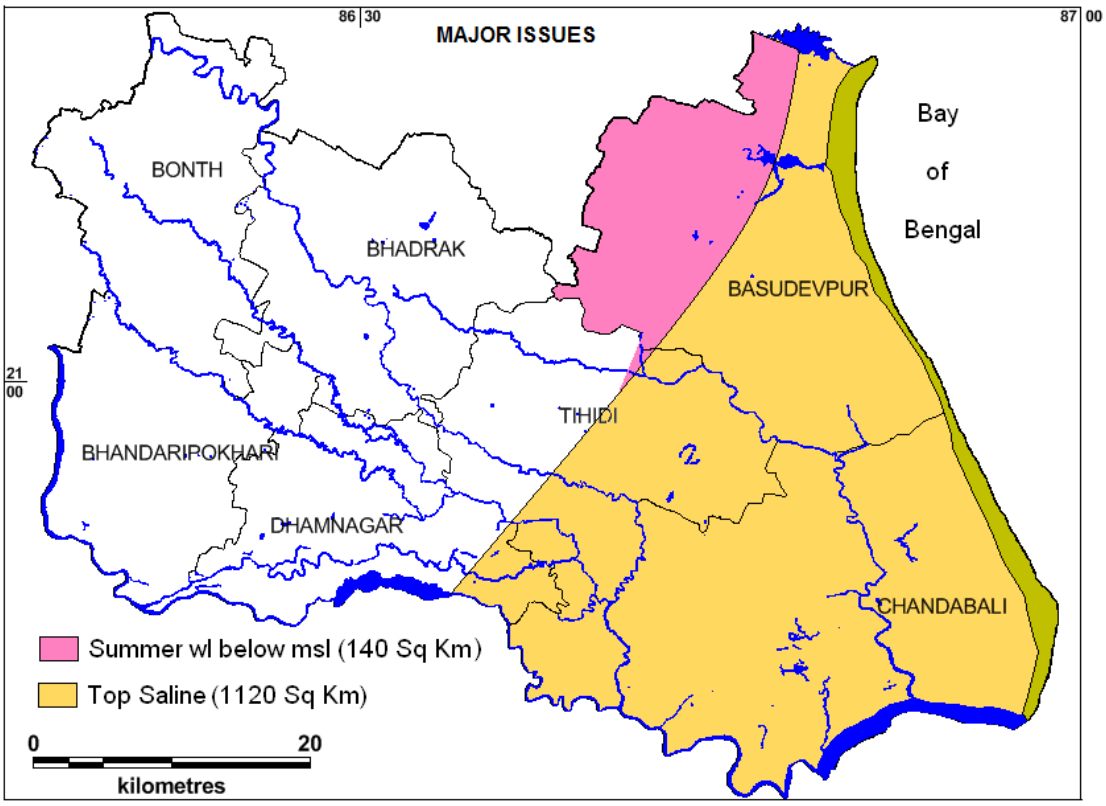


Fig -4.1: Major ground water related issues of Bhadrak District

Issue – I1

Barring few pockets underlain by old dunes, top saline condition is observed in whole of the Chandbali Block and Parts of Basudevpur, Dhamnagar and Tihidi block. Fresh water bearing aquifers exist between 150 to 280 m bgl, both overlain and underlain by saline formations. The geographical spread is around 1120 Sq. Kms. State Government department, Rural Water Supply & Sanitation (RWS & S) has constructed tube wells tapping deep aquifers from which have been used for hand pumps and for piped water supply purpose. However there is a shortage of water for irrigation due to absence of canal and shallow source of ground water. Moreover inundation of paddy field due to tidal surge into the creeks during Ravi season is leading to destruction of soil as well as crops in the area.

Remedy - 1

The area is characterised by a flat topography and its elevation is 1 to 6 meter above msl. Numerous creek systems have naturally developed to give passage to the water heaped over the area during the rainy season to nearby river and ultimately to sea. However after the cessation of monsoon, river water remains fresh for quite a period of time depending on the volume of base-flow. River course near to the coast first gets salinity and the saline front advances to tens of kilometres inland with the progress of summer. During tide, the river water can't be released to sea leading to the impounding of fresh water. This has led to a rise in the water level of the river which forces the fresh water in the river to enter and fill the creeks connected to it. During ebb, the water level in the river recedes, leading to drying up of the creeks. Since daily two tides are observed in this area, daily twice creeks have been filled and dried up. This phenomenon can be utilised for storing sufficient fresh water in the creeks by suitably modifying the creeks in the following manner;

1. Excavation of creeks to sufficient width and depth for storing water
2. To stop the release of the impounded water during ebb, one sluice at the creek and river junction is to be constructed. The sluice gates are to be opened during full moon and new moon days when the tidal forces are at the peak, so that maximum amount of fresh water of the river can be harvested. Once the creeks are full, the gates are to be closed and the harvested water can be utilised for next 15 days till the next filling.

3. Generally creeks connected to the lower reaches of the river, first gets affected with salinity while those associated with the upper reaches turns saline during middle of March. The sluice gates are permanently closed accordingly so as to deny the entry of saline water into the creek system.
4. By means of this 6 to 10 fillings are possible and the water can be used for cultivation of Ravi crops. Moreover additional possibilities like pisciculture can also be promoted.

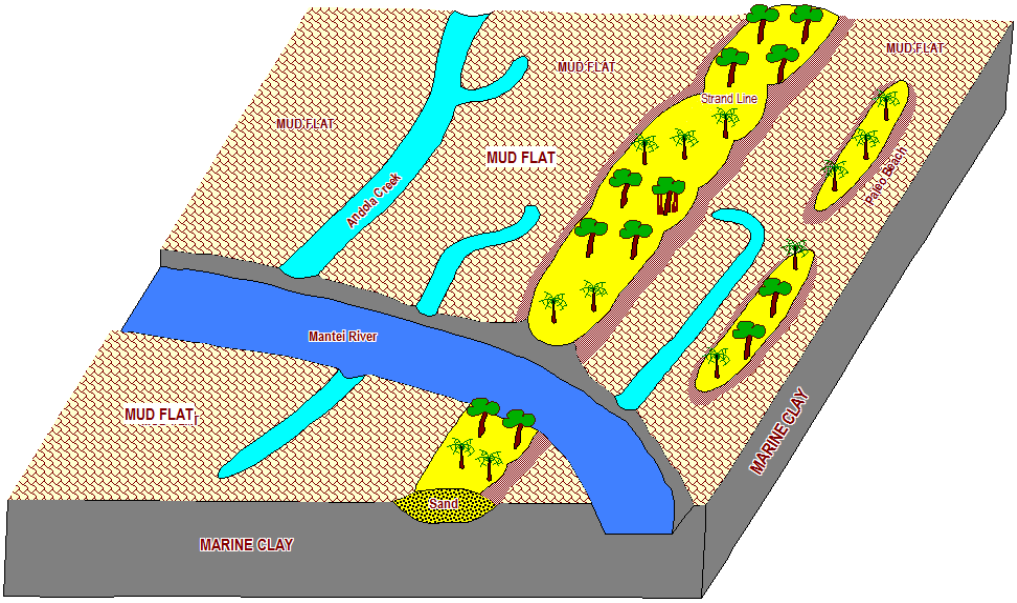


Fig -4.2: Creek and related river system of Bhadrak District

Fig -4.3: Renovation (deepening & widening) of Creeks underway

Fig-4.4: Sluice gate under construction at the creek entrance

Fig - 4.5: Creek filled with fresh water, ready for use in irrigation

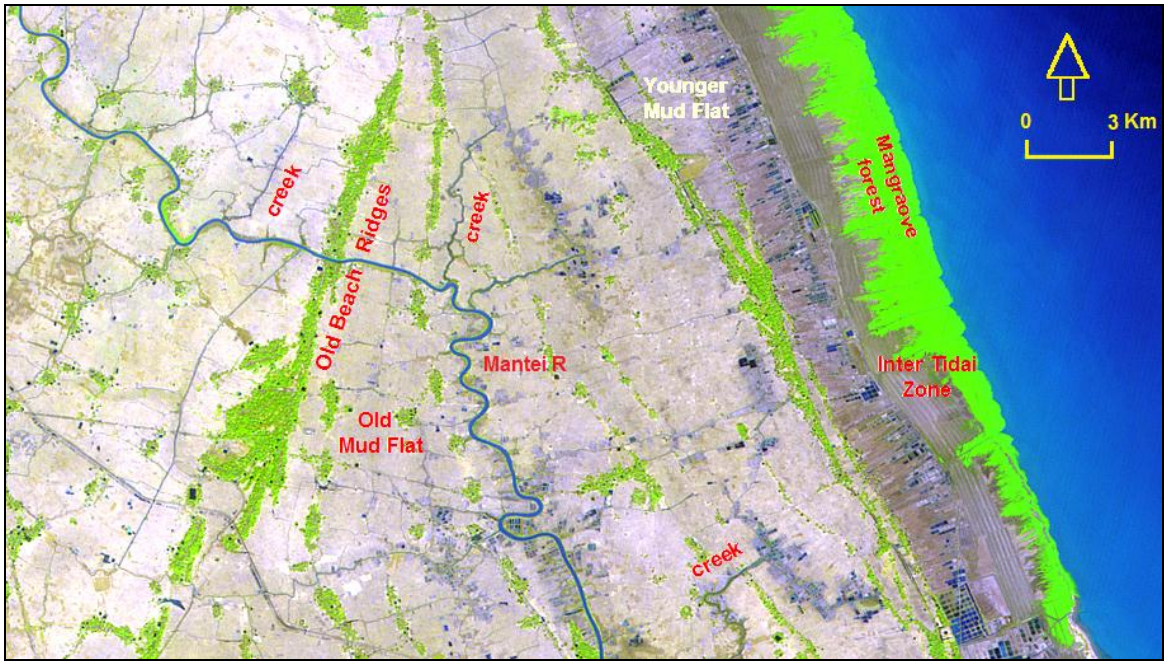


Fig - 4.6: LISS – III imagery (Band combination 432) showing different hydro-geomophic features of the coastal areas of Basudevpur & Chandbali block

A false colour composite is prepared assigning Red, Green, Blue colour to Band 4, 3, 2 of LISS – III, 2013 imagery. Two sets of sand dunes have been well demarcated in the barren mud flat which occupies the main part of the region. The older dunes are much inland with NNE – SSW orientation indicating the location of old beach line. However younger dunes have NNW – SSE orientation and are parallel to the recent coast line. The Mantei river and the associated creeks are well observed.

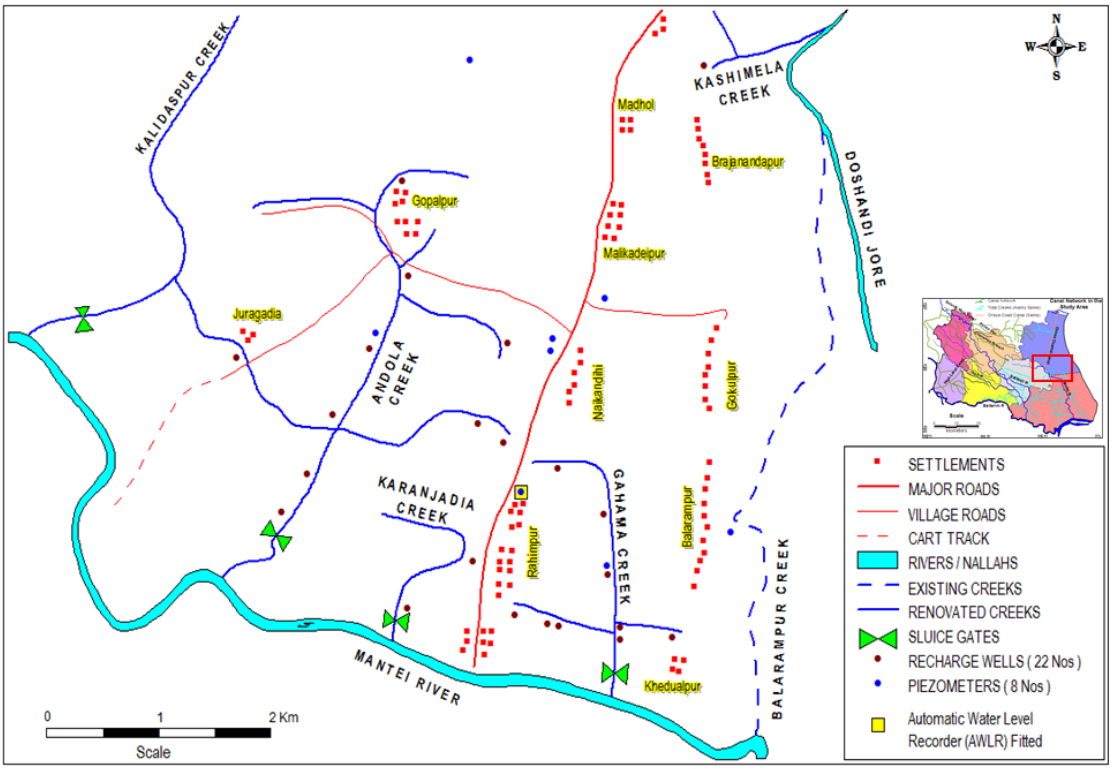


Fig - 4.7: Creek system of Mantei river was renovated and modified into creek irrigation project

To this effect CGWB, SER, Bhubaneswar had taken up a Pilot Project during 2004-05 and modified some of the creeks of Basudevpur and Chandbali blocks of Bhadrakh district. As per the figure – 4.2 & 4.7, creeks had been demarcated for renovation followed by widening and deepening. Then slice systems were erected at suitable locations (Figure – 4.7). The Montei river remains fresh upto the middle of March in the project area and thus upto that period, around 8 fillings were undertaken and the water was used for cultivation of cash crop like vegetable.

However an optimistic project of recharging the shallow confined aquifer (20 to 45 mbgl) which is brackish to saline was tried. The fresh water impounded in the creek was injected into specially designed gravelled packed recharge well through suitable filter media. The experiment showed that the aquifer could take water at the rate of 1 to 3 liter per second. A fresh water lense is created by this recharge and with a low rate of pumping it had thrived for 5 minutes. However though it showed some possibilities of recharge, its complicated nature and the problem of choking of the filter by the muddy water of the creek are the main deterrent.

Cost implications:

- A total of 27 Creeks & Sub-Creeks were renovated spanning a length of 93.65 Kms in Basudevpur & Chandbali Blocks with a total cost of Rs 647 Lakhs, implemented during 2004-05
- Approximate present cost of Renovation = Rs. 259 Lakhs (Pro Rata)

(@ 10% of the Present Costing which is 4 times the original implemented Cost)

- Additional Creeks proposed to be modified **= 50 Nos**
- Approximate renovation cost = Rs. 4793 Lakhs
- Total Cost of renovation of 27 Old + 50 Proposed New Creeks **= Rs. 5232 Lakhs**
- Cost per Year on Principal(@ 10Years Life) = Rs. 523.2 Lakhs
- Interest Component (Soft Loan @7.5% per annum) = Rs. 392 Lakhs
- Total Yearly Cost = Rs. 915.6 Lakhs
- Additional area to be benefitted **(From New Creeks)** = 5000 Ha
- Monetary Return from Cultivation of Rabi Paddy, Wheat & vegetables (@ Rs. 25,000/- per Ha Flat Rate Combined) = Rs. 1000 Lakhs
- Monetary Return from Pisciculture (@ Rs. 5 lakhs per Creek) = Rs. 250 Lakhs

Total Yearly Benefit = Rs. 1250 Lakhs

The cost benefit analysis shows that with an initial cost of **52 Crores**, a huge amount of water can be made available for irrigation in the area.

Remedy – 1I

Tidal creeks are not present in all part of the saline belt and hence deeper aquifers are to be exploited for extending irrigation in these area. Around 50 numbers of deep Tube Wells tapping the 3rd Aquifer (150 – 300 mbgl) can to be constructed and energized. Since these aquifers are both underlain and overlain by saline formations, controlled pumping is to be adopted. By pumping the well for 10 hours at a rate of 25 to 30 liter/second, 20 Hectares of area under Potato, oilseeds and low water requiring vegtables can be irrigated taking 75 - 90 days of growing season. Hence 50 such energized tube wells can be constructed as an experimental basis to see its efficacy.

Cost implications:

- Total Area proposed to be irrigated on experimental basis = 1000 Ha
- Approximate cost of Tube Well, Transformer & Pumps etc = Rs.**1000** Lakh
- (including conveyance)
- Life of Wells + Peripherals = 20 years
- Cost per Year(including maintenance) = Rs. 50 Lakhs
- Interest Component(soft loan @ 7.5% / annum) = Rs. 75 lakhs
- Total Cost per year = Rs. 125 Lakhs
- Revenue collected from Irrigation = Rs 10 Lakhs
  (Water Cess @ Rs. 1000/- per Ha)
- Benefit to farmer from Patato / Oil Seed / Vegetable = Rs. 250 lakhs
  (@ Rs 25,000 per Hectare)
- Benefit Per Year = Rs. 260 Lakhs

All these above calculations are tentative and will vary as per the design and location.

Since top saline condition exists in the region, rigorous GW regime monitoring (both level & quality) will be mandatory to know if there is any adverse impact of pumping in form of sea water ingress.

SUMMARY AND CONCLUSION

The study area being part of the coastal tract of Orissa, is rich in natural resources like land, man power and water resources. As its economy solely depends upon agriculture and its allied activities like fishery, water resource and its management plays important role for its development. As such there is no dearth of water resources in the district due to wide spread canal network and good amount of ground water resources. However water quality is a major hindrance in the use of ground water in the saline tract present in the eastern part of the district. As the potential fresh water aquifers exist beyond 195 mbgl in most part of the Chandbali block, it is not possible for a common man to have even his own drinking water source. Thus government's initiative is very much essential especially for the development of the saline tract. Moreover this tract faces problems like water logging and drainage congestion, which are to be addressed. Under this backdrop, the author has recommended some of the strategies to tackle these major issues related to ground water which will improve the situation in the district.

ACKNOWLEDGEMENTS

The author expresses his sincere thanks to the Chairman and Member (SAM) for their inspiration and guidance during preparation of the report. Sincere thanks also goes to the scrutiny and reviewing committee, CHQ, Faridabad who have given constructive suggestions and inputs regarding the study. He is also thankful to the Regional Director, CGWB, SER, Bhubaneswar for extending all possible support during field and report preparation work. Thanks are also due to the numerous previous workers who were attended drilling and well testing in the area. Last but not the least, the different Central and State Government Organizations who have contributed a lot in providing valuable data have been acknowledged.

REFERENCES

1. Bhatnagar, N. C. et. al. (1970) – Geology and ground water resources of parts of Balasore and Cuttack districts, Orissa, Bulletin, G.S.I, Series B. No. 29.
2. Basic Data Reports of Tube wells and Slim holes drilled in Bhadrakh and Balasore district, C.G.W.B.
3. Chakldar. S. (1981) – Report on the exploration by deep drilling in parts of coastal Orissa. C.G.W.B. Tech. Report. Series A. No. 12.
4. Das, P. K. (1998) - Ground Water Resource and Development Potential of Bhadrak district, Orissa, CGWB Technical report. Series 'D'.
5. District Statistical Hand Book of Bhadrak and Balasore 2005, Directorate of Economics and Statistics, Orissa, Bhubaneswar Publication
6. Hydrogeological Atlas of Orissa, Published by CGWB, SER, Bhubaneswar.
7. Naik, K. C., Behera, S. C., Nayak, N.C. (2005) – A report on "Arresting salinity ingress & artificial recharge to ground water in parts o Basudevpur & Chandbali blocks of Bhadrak District, Orissa", CGWB Technical report.
8. Nayak, N.C. (2008) - Ground water management studies in Bhadrakh and adjoining areas of Balasore district, Odisha, CGWB Technical report
9. Raju, D. V. N. (1991) – Ground Water Resource and Development Potential of Balasore district, Orissa, CGWB Technical report.