केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

BOUDH DISTRICT, ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

South Eastern Region, Bhubaneswar

Government of India

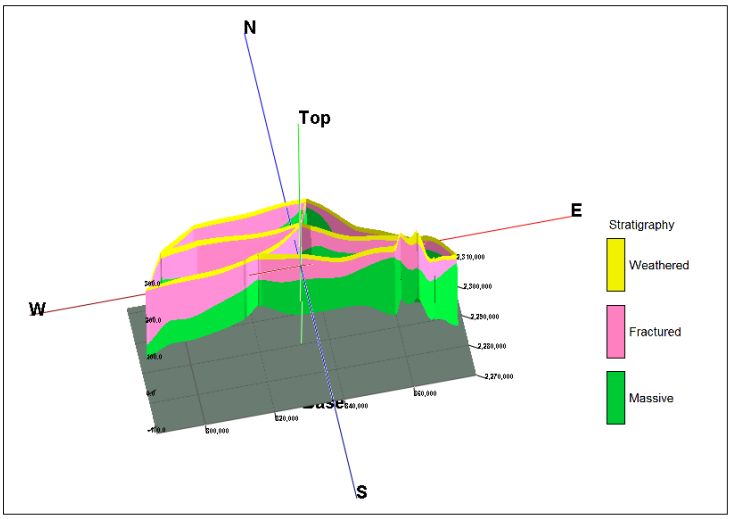
MINISTRY OF JAL SHAKTI, DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

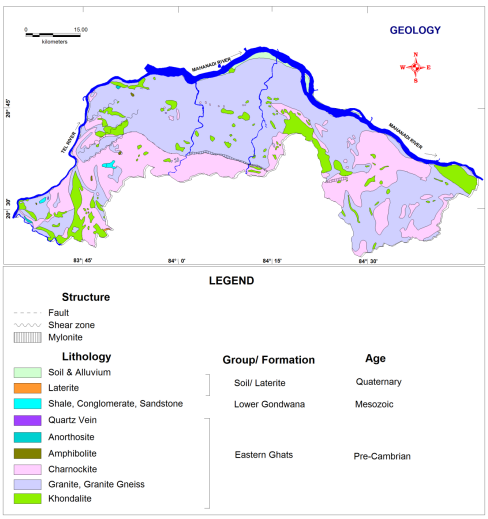
REPORT ON

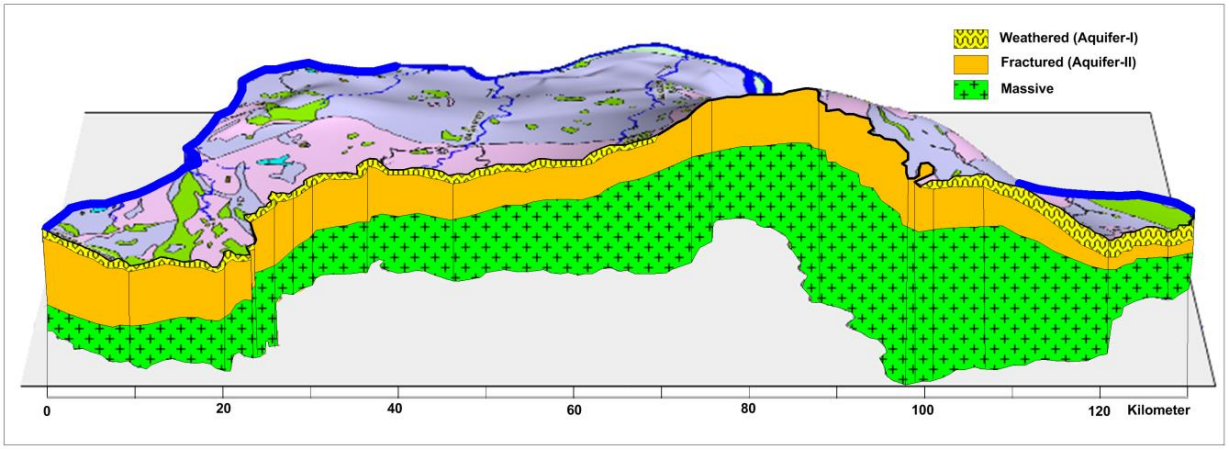
AQUIFER MAPPING AND MANAGEMENT PLAN IN BOUDH DISTRICT, ODISHA

by

D.N Mandal
(Scientist-D)







CENTRAL GROUND WATER BOARD
South Eastern Region, Bhubaneswar
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AQUIFER MAPPING AND MANAGEMENT PLAN BOUDH DISTRICT (1800 Sq. Km)

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1 INTRODUCTION

1.1 Objective

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

The activities under NAQUIM are aimed at identifying the aquifer geometry, aquifer characteristics their yield potential along with the quality of water occurring at various depths, aquifer-wise assessment of ground water resources and development. Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. With these aims, Aquifer Mapping was carried out in the hard rock terrain of Boudh district in Odisha covering all three blocks of the district namely, Boudh, Harbhanga and Kantamal.

1.2 Scope of the Study

Aquifer mapping is a multidisciplinary exercise wherein a combination of geological, geophysical, hydrological, hydrogeological, meteorological and hydro-chemical information is integrated to characterize the spatial and temporal variation of quantity and quality of the aquifer system and identification of local ground water related problems and issues.

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

1.3 Approach and Methodology

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

The area has been covered by Systematic Geological mapping by G. S. I. S/Sh. M. V. Rao, Asst. Geologist and B. B. Basak, Scientist 'B of CGWB carried out Systematic Hydrogeological Surveys on 1:50,000 scale during the field seasons 1975-76 to 1979-80 and covered the entire undivided Phulbani district. This was followed by Reappraisal Hydrogeological Surveys on 1:50,000 scale by S/Sh. G. C. Pati and A. Subburaj, Scientist 'B's in parts of the districts covering an area of 6160 sq. km. during field seasons 1986-87 and 87-88.

1.3.1 Compilation of Existing Data and Identification of Data Gaps

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

1.3.2 Hydrogeological Investigations

Review of background information will lead the study teams to carry out further studies in the field, where they will employ various techniques to determine the three-dimensional extent and aquifer characteristics of the significant water-bearing formations. Key Observation wells representing the different aquifers have to be established and monitoring to be carried out. Well inventory and collection of relevant data is to be carried out to strengthen the data base. The analysis of the data has to be carried out for preparation of thematic maps.

1.3.3 Geo -hydrochemical Investigations

Water Samples to be collected, analyzed and interpreted to bring out ground water quality scenario of the study area.

1.3.4 Generation of Thematic Layers Using GIS

- Drainage
- Soil
- Land use and land cover
- Geomorphology
- Geology
- Hydrogeological map
- Aquifer disposition
- Ground water quality

1.3.5 Development of Aquifer-Wise Management Plan

The dimension and disposition of the aquifer is figured out on the basis of integrated study of the geologic, hydrogeological, hydrological, geochemical and geophysical information.

Determining aquifer potential and characteristics are essential for their effective management and sustainable development. Local ground water related issues should be identified and studied in detail to make plans to solve them.

1.4 Study area

During XII five year plan, the National Aquifer Mapping and Management (NAQUIM) programme were taken up under Annual Action Plan (AAP) 2018-19 for detailed hydrogeological investigation and Aquifer Mapping in Boudh district. The district is bounded by 83°34'16" E and 84°48'20" E longitudes and 20°23'02" N and 20°52'45" N latitudes covering 3098 sq. Km. under the SOI Toposheet Numbers 64 P/10, 11, 13, 14, 15; 73 D/1, 2, 5, 6, 7, 10 and 11. The mappable area under NAQUIM is 1800 sq. Km, which was taken up for the study after excluding the hilly areas. The index map of the study area is presented in **Fig.1.1** while an administrative map is presented as **Fig. 1.2**. The study area is part of Mahanadi basin. The Mahanadi and Tel rivers together form the western, northern and eastern boundaries of the district separating from Bolangir, Subarnapur and Anugul districts respectively. The southern part of the district is covered with dense forest and hilly areas. The southern boundary separates the district from Phulbani (Kandhamal) and Nayagarh districts. The district headquarter Boudh (Boudhgarh) is connected by all weather metalled road from capital city Bhubaneswar (240 km) via Nayagarh, Madhapur and from Anugul via Rairakhol, from Bolangir via Sonepur, Manmunda and from Phulbani via Charichhak. The NH-57 connects Madhapur-Charichhak-Boudh-Manmunda (101 km.) and SH-41 connects Manamunda-Kantamal-Ghantapada-Sindhugora (57 km). Boudh district does not have any railway connection. Rairakhol is the nearest railway station in Sambalpur district which is about 27 km from Boudh.

The district comprises one subdivision i.e. Boudh and 3 CD Blocks/Tahasils namely Boudh, Harbhanga and Kantamal with the district headquarter at Boudh. There are 63 Gram Panchayats with 1186 villages. The block-wise demographic details are shown in **Table-1.1**.

Table-1.1: Block-Wise Demographic Details in Boudh District.

Sl No	Block	Area (Sq.km)	GPs	Villages	NACs	Population (2011)			Sex Ratio	Decadal growth rate		
						Rural	Urban	Total		Rural	Urban	Total
1	Boudh	960	22	415	1 (Boudh NAC)	144124	0	144124	992	17.16		17.16
2	Harbhanga	1154	18	362		126834	0	126834	987	15.64		15.64
3	Kantamal	984	23	409		148385	0	148385	999	20.97		20.97
4	Baudh NAC					20424		20424	947	13.31		13.31
Total		**3098**	**63**	**1186**	**1**	**439767**	**0**	**439767**	**993**	**17.78**		**117.78**

1.5 Rainfall and Climate

The district enjoys a humid sub-tropical climatic condition which is hot and dry in summer, cold and dry in Winter and cool and humid during the Rainy season. The maximum temperature rises to 45°C in summer and falls to a minimum of 10°C during winter. The humidity of the area is generally high especially in the monsoon and pre-monsoon months. Relative humidity is around 60 to 70 % throughout the year. In general, April is the driest month, whereas the months of July and August, are the wettest.

The South-west monsoon is the principal source of rainfall in the area. The rainfall is erratic with uneven distribution resulting in draught and flood conditions. The normal rainfall of the district is 1304.3 mm. About 87% of the annual rainfall occurs during monsoon period between June to October. Generally the monsoon breaks in the middle of June and continues till the end of October, which forms the rainy season. Maximum rainfall generally occurs during August followed by July and September. The result of long term analysis of rainfall is presented in **Table 1.2.**

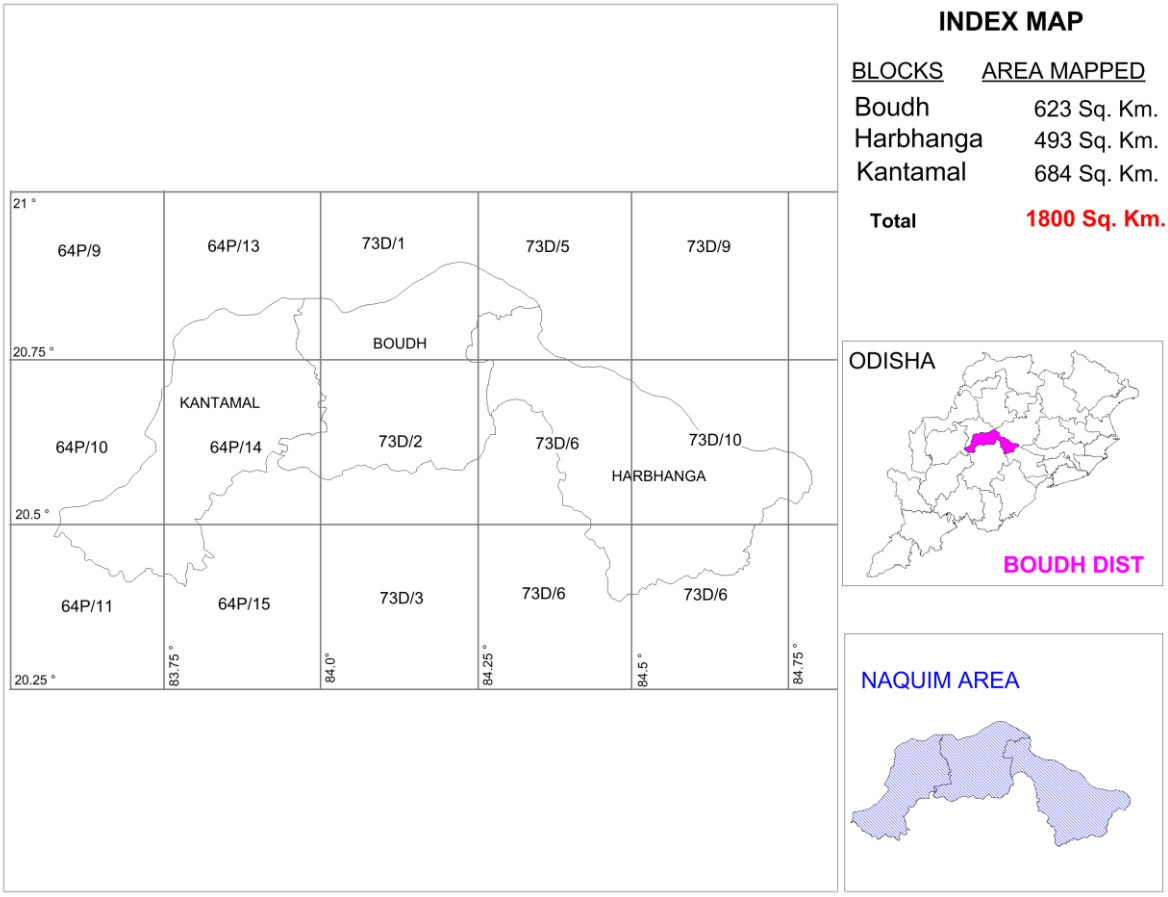


Fig. 1.1: Index Map of Study Area under NAQUIM in Boudh District.

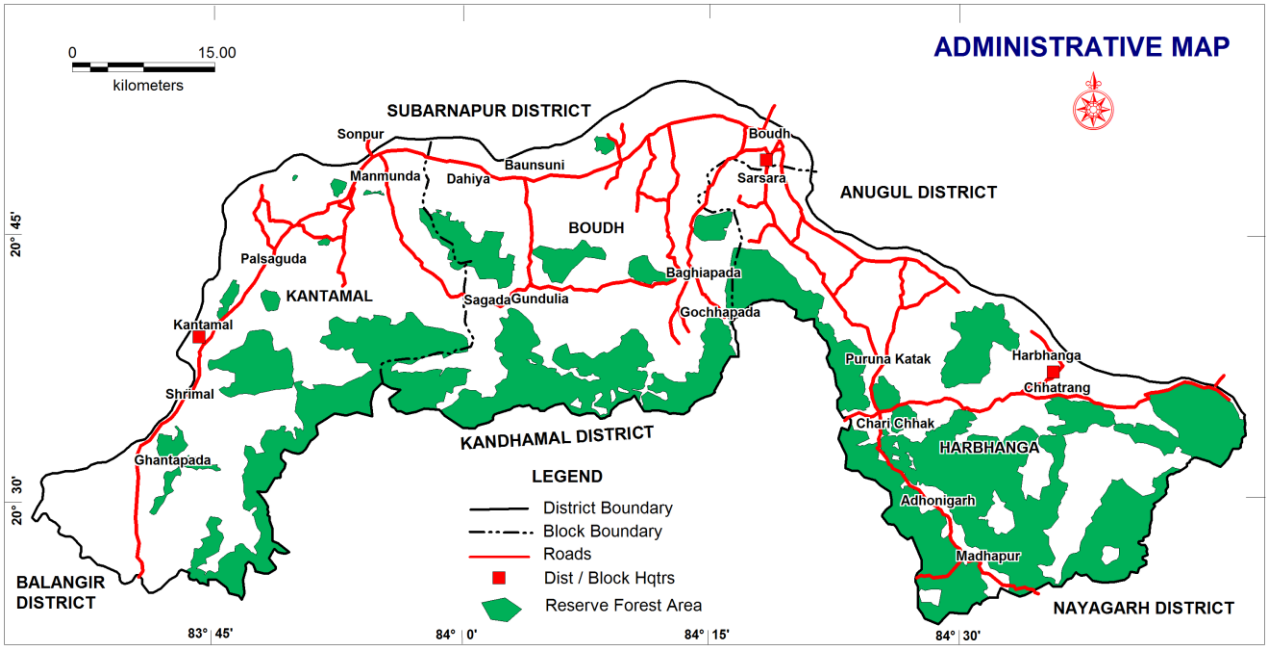


Fig. 1.2: Administrative Map of Boudh District.

Table 1.2: Long-term Rainfall Analysis of Boudh District.

Sl No	Station	No of Years	Average Annual Rainfall (mm)	Coefficient of Variation (%)	Droughts (No of yrs/% of Tot. Yrs)			Rainfall Received (No of yrs/% of Tot. Yrs)		Rainfall Trend (mm/year)
					Moderate -25 to -50% Departure	Severe -50 to -75% Departure	Acute above -75% Departure	Normal -25 to +20% Departure	Excess > +25% Departure	
Long Period (1988-2017)										
1	Boudh	30	1168.1	31	6/20	1/3	0/0	17/57	6/20	+10.973
2	Harbhanga	30	1237.1	25	4/13	1/3	0/0	20/67	5/17	- 4.667
3	Kantamal	30	1507.8	24	5/17	0/0	0/0	22/73	3/10	- 4.409
	District Avg		1304.3							
Decadal (2008-2017)										
1	Boudh	10	1184.5	13	0/0	0/0	0/0	9/90	1/10	-15.375
2	Harbhanga	10	1133.6	20	0/0	0/0	0/0	8/80	2/20	+2.905
3	Kantamal	10	1462.2	22	1/10	0/0	0/0	8/80	1/10	-29.601
	District Avg		1260.1							

Perusal of **Table 1.2** shows that

1. The coefficient of variation in rainfall is higher over long period (25-31%) than the decadal rainfall variation (13-22%), but the annual rainfall during the recent years is not significantly changed.
2. Normal rainfall has been received in 57% to 73 % of the years over 30 years long period however in the last decade normal rainfall is received in 80 to 90% of the years.

3. The rainfall data indicates that the rainfall in Kantamal Block has a declining trend both in the long-term and decadal analysis. For the other two blocks the figures of long term analysis show an insignificant fall of about 4.5%.

1.6 Physiographic Setup

The southern part of study area is mostly hilly and covered with thick forest. The remaining portion of the district is covered by intermontane valleys and leveled pediplains and flood plains of Tel-Mahanadi rivers. The regional slope is towards north in northern part, west or southwest in western part and east in eastern and south-easten part respectively. The highest elevation is 932 m amsl near Sunakania in Padmatala R. F. in the eastern part. The plain and gently sloping areas lnorthward from the hilly area have elevation between 100 to 200 mamsl. The variation in land elevations above MSL is shown in **Fig. 1.3**.

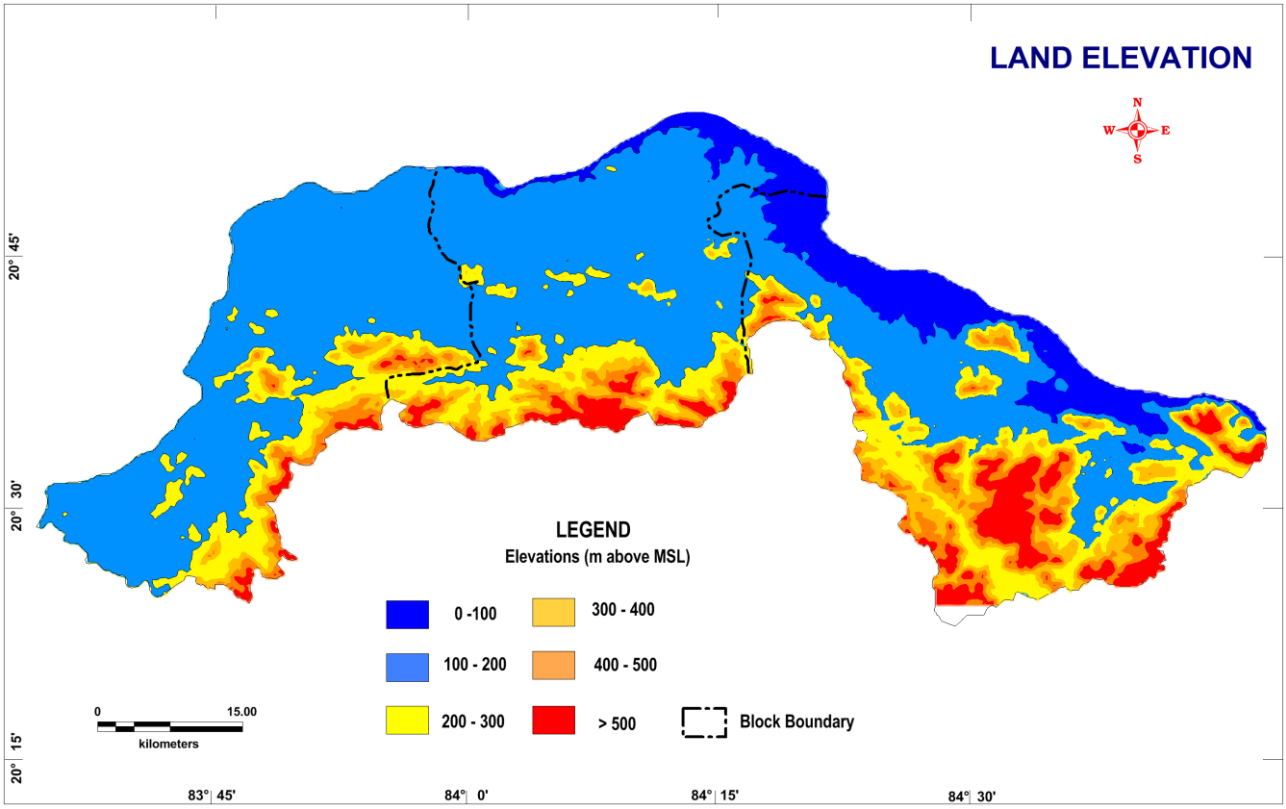


Fig. 1.3: Land Elevations in Boudh District.

1.7 Geomorphology

The study area comprises of the following geomorphic units. The geomorphology of the area is shown in **Fig. 1.4.**

1.7.1 Flood Plains

They occur along a narrow stretch with limited thickness and areal extent along the course of Mahanadi and its tributary Tel. They comprise of loose unconsolidated materials like sand, silt, clay, pebbles, boulders etc. Fine to coarse sand form potential aquifer zones and yield a good quantity of water. Ground water in these areas may be developed through dug wells and shallow tube wells.

1.7.2 Deep Buried Pediment

This is the most extensive, common unit in the area covering parts of each block of the district. They are characterized by thick weathered zone with thickness varying from 10-15 m and forms potential phreatic aquifer. Ground water development can be through dug wells and dug-cum-bore wells.

1.7.3 Shallow Buried Pediment

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

1.7.4 Intermontane Valley

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

1.7.5 Valley Fills

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

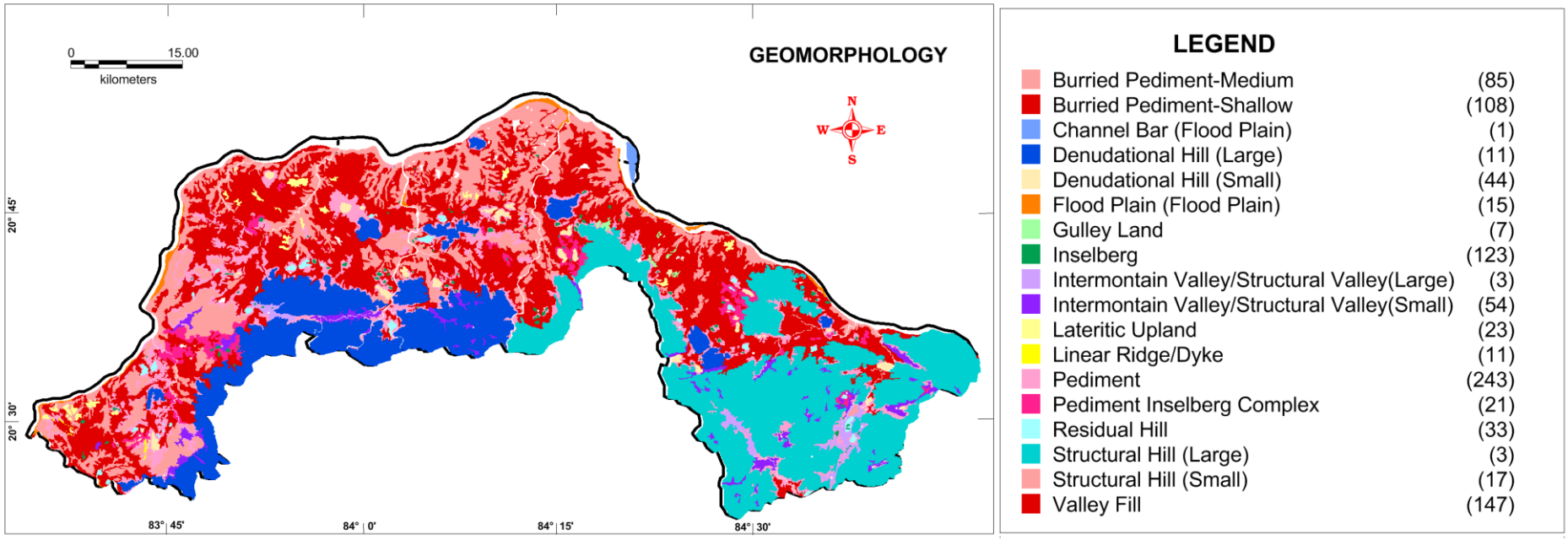


Fig. 1.4: Geomorphology of Boudh District.

1.7.6 Inselbergs

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

1.7.7 Structural Hills

The hills with escarpment characterize the feature steep slopes and narrow gorges. These are structurally controlled hills with complex folding, faulting and traversed by numerous joints/fractures facilitating infiltration and mostly act as run-off zone.

1.7.8 Residual Hills

This unit mainly consists of residual masses of granites. This unit behaves as a runoff zone.

1.7.9 Denudational Hills

Denudational hills are identified by their high relief representing resistant hill ranges. Rate of infiltration is very poor except along fractures/joints. These generally act as run-off zone.

1.8 Landuse and Cropping Pattern

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

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

Table 1.4: Land Use Pattern in Boudh District.

(Area in hectares)

Block	Total Geographic area	Forest area	Misc. tree crop &grooves	Permanent pasture & grazing land	Culturable waste	Land put to non-agriculture use	Barren and Uncultivable land	Current fallows	Other fallows
Boudh	101496	62966	2465	2136	400	2625	1624	819	1884
Harbhanga	102076	50816	4450	10692	3357	2385	13248	438	14921
Kantamal	106428	69213	2500	3427	3649	3428	1306	247	15626
Total	310000	182995	9415	16255	7406	8438	16178	1504	32431

Source: DDA, Boudh 2011

Table 1.5: Area Under Agriculture Boudh District. (in Ha)

Block	Area Under Agriculture			
	Gross Cropped Area	Net Sown Area	Area Sown More Than Once	Crop Intensity
Boudh	49696	32396	14300	153 %
Harbhanga	42662	25207	14455	169 %
Kantamal	40422	27577	10621	146 %
Total	**132780**	**85180**	**39376**	**155.8 %**

Source: District Irrigation Plan, Boudh, March 2016

1.8.1 Crop Water Requirement

The water requirement of different crops grown in the district as worked out by Dept. of Agricuture and Food Production, Govt. of Odisha are enumerated in **Table 1.6**.

Table 1.6: Crop Water Requirement in Boudh District.

Sl. No	Name of the Crop	Growing Season	Total Water Requirement
1	Cereal	Kharif & Rabi	125
2	Course Cereal	Kharif & Rabi	50
3	Pulses	Kharif & Rabi	35
4	Oilseeds	Kharif & Rabi	55
5	Fibres	Rabi	55
6	Vegetables	Kharif & Rabi	70
7	Spices	Kharif & Rabi	50

Source: DAO, Jajpur.

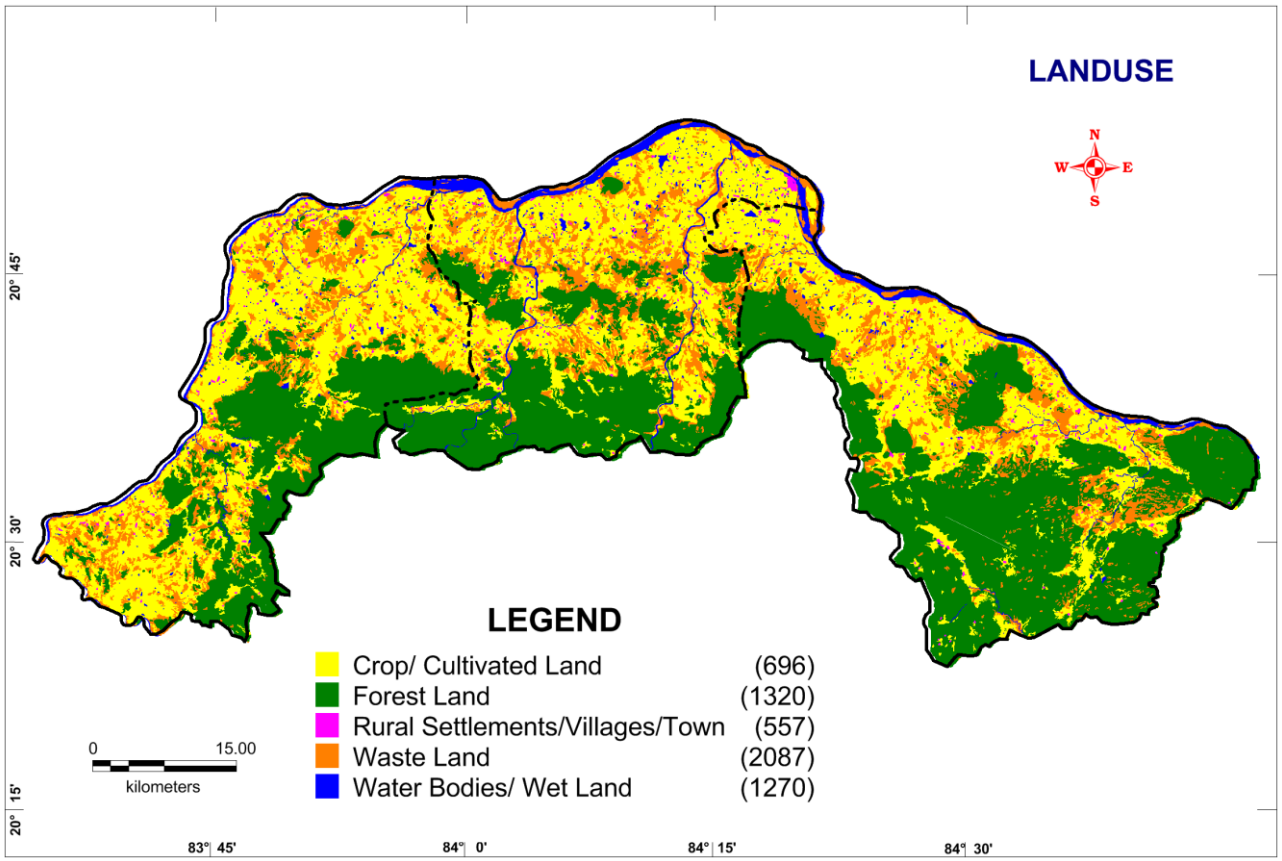


Fig. 1.5: Landuse in the NAQUIM Area in Boudh District.

1.9 Soil

The distribution of different soil types in the district depends much on its physiographic and lithologic variations. The major soil class of the district is mixed grey soil (Inceptisols) with an area of 275453.29 ha followed by black soil with more clay content (Vertisol). The other soil classes are Entisols which are unaltered soils with coarse parent materials and some unclassified soil (light mud flats).

The percentage of inceptisols (Mixed grey soil) is more in Harbhanga Block (88.99%) followed by Kantamal (88.87%) and Boudh (88.84%). The percentage of Vertisols is more in Kantamal (4.7%) followed by Boudh (4.15%) and lowest is in Harbhanga Block (2.93%) . But the area under Entisols is more in Harbhanga Block (2870.61 ha) followed by Kantamal (2163.58 ha) and Boudh (1309.18 ha). The black alluvial soils of the district are generally fertile due to deposit of silt and are with low status of nitrogen and available Phosphorus at certain places. The soil of the district

has high moisture retention capacity. The soils are mostly acidic in nature and some part of district has neutral soil. The availability of Phosphorous (P) and Potash (K) in soils are high whereas the Nitrogen status is medium in two blocks except Kantamal block. The status of Nitrogen is low in Kantamal block but with more phosphorous and potash content. The soil map of the Boudh districts is shown in **Fig. 1.6**.

1.10 Drainage and Hydrology

The river Mahanadi along with its tributary, the Tel forms the western, northern and eastern boundary of the Boudh district. The Salki, the Bagh, the Kharag, the Sagadia and the Bara Jor rivers rise in different parts of the plateau region and finally join the Mahanadi or the Tel river at various points. The master slope of the ground is towards north in Boudh and Kantamal block and towards east in the Harbhanga block. All the rivers exhibit dendritic drainage pattern and are structurally controlled. During summer season there is hardly any surface flow in the streams except the Tel and Mahanadi rivers which are perennial in nature. All the streams are of effluent in nature. The drainage map of the area is shown in **Fig. 1.7**.

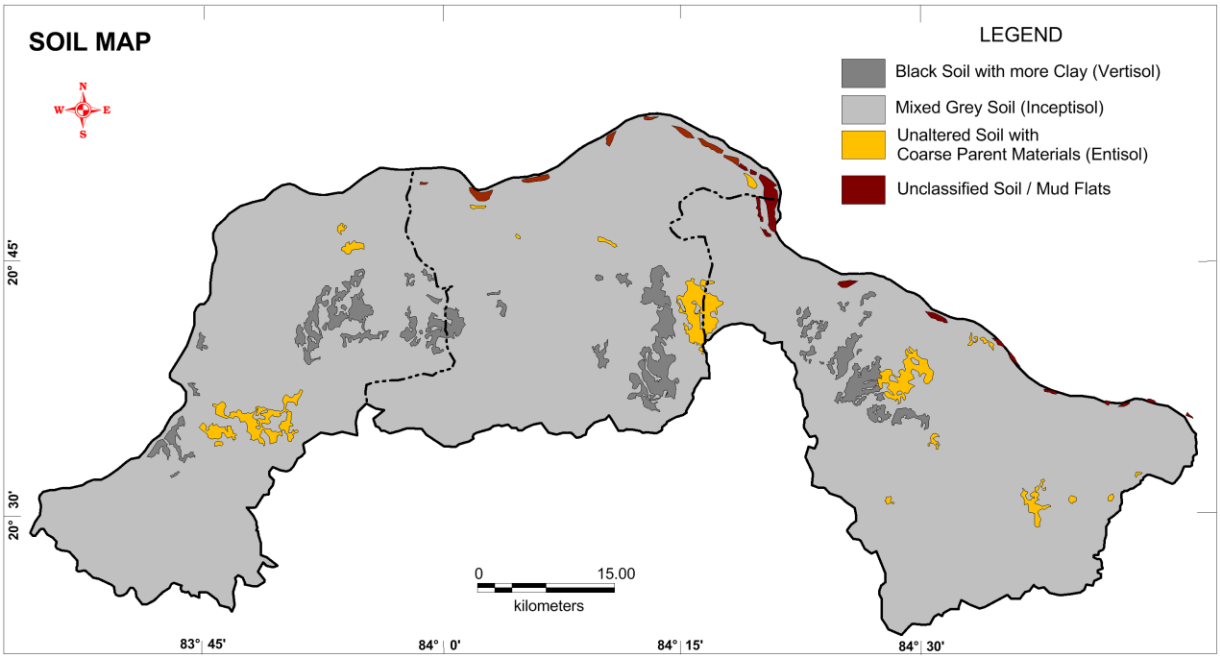


Fig. 1.6: The Soil Map of Boudh District.

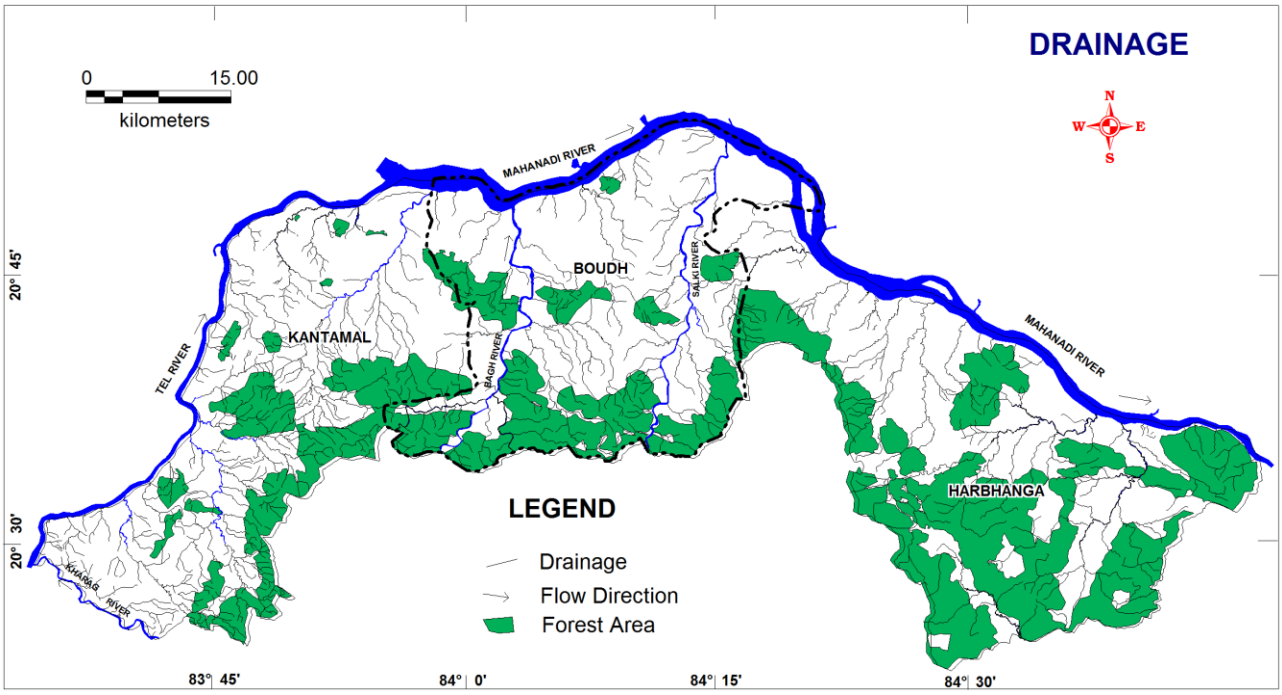


Fig. 1.7: Major Rivers in Boudh District.

Though agriculture in this district mainly depends on rain, irrigation facilities are provided through major/medium irrigation, minor irrigation and lift irrigation projects both for Kharif and Rabi crops. The district has about 35% land are irrigated. The total irrigation potential is 46570Ha the source wise details of which are given in **Table 1.7**.

Table 1.7: Source-wise Irrigation Potential in Boudh District. (in Ha)

Sl No	Block/ Department	Irrigated Area (Ha)	
		Gross Irrigated Area	Net Irrigated Area
1	**Major Irrigation (Salki Irrigation**		
a	Boudh	10678	8995
b	Harbhanga	6591	4655
c	Kantamal	-	-
2	**Minor Irrigation Project (BAGH)**		
a	Boudh	2039	
b	Harbhanga	-	-
c	Kantamal	5297	3297
3	**Lift Irrigation**		
a	Boudh	3470	2690

b	Harbhanga	3438	2063
c	Kantamal	4261	2084
4			
a	Boudh	3228	2228
b	Harbhanga	3812	2812
c	Kantamal	3759	2756
	TOTAL	**46570**	**31580**

Source: District Irrigation Plan of Boudh, DLIC Boudh, March 2016

The block-wise number and details of irrigation structures under different sources has been shown in **Table 1.8.**

Table 1.8: Source wise Irrigation Structures in Boudh District.

Sources of Irrigation	Surface Water				Ground Water	Other sources including traditional WHS / River Lift	Water Extraction Devices	Total	
	Canal Based		Tanks/Ponds/Reservoirs		Borewells		Electric Pumps	Irrigation Sources	Water Extracting Units
	No	Length (km)	Reservoirs/ Dams	Diversion Weirs	Govt.				
Major (Salki)	**99**	**270.23**	**59**	**1**				**159**	
Boudh	61	158.56	44	1				106	
Harbhanga	38	111.67	15	-				53	
Kantamal	-	-	-	-				-	
Medium (Bagh)	**77**	**143.87**	**1**					**78**	
Boudh	15	40.05	-					15	
Harbhanga	0	-	-					-	
Kantamal	62	103.82	1					63	
MIP	**59**	**286.15**	**57**	**17**				**123**	
Boudh	13	52.52	15	6				34	
Harbhanga	24	165.41	16	10				50	
Kantamal	22	68.22	26	1				49	
Lift Irrigation					**1782**	**525**	**2307**	**2307**	**2307**
Boudh					392	170	562	562	562
Harbhanga					326	148	474	474	474
Kantamal					1064	207	1271	1271	1271
TOTAL	**235**	**700.25**	**117**	**18**	**1782**	**525**	**2307**	**2667**	**2307**

Source: District Irrigation Plan of Boudh, DLIC Boudh, March 2016

1.10.1 Major and Medium Irrigation Projects

Presently there is one major irrigation project and one Medium Irrigation Project existing in the area. They are Salki Major Irrigation Project on Salki river and Bagh Barrage Medium Irrigation Project on Bagh river, both rivers are tributaries to the Mahanadi.

Salki Irrigation Project: This is a diversion weir scheme constructed across river Salki near village Paljhar about 20 Km from Boudh town. The project was completed in the year 1972. It is designed to provide irrigation to 21650 Ha in Khariff and 4050 Ha in Rabi in 252 villages in Boudh and Harbhanga Blocks of Boudh District. Salki Irrigation Project is a largest diversion weir Project in Orissa having a catchment area of 1638 Sq. Kms. River Salki is a longest tributary of river Mahanadi which originates from Eastern Ghat range (Baliguda range) and after traversing the hilly areas it confluence with river Mahanadi about 8 Km. from west of Boudh town.

There are two canal systems namely Right Main Canal and Left Main Canal in the Salki Project. The Right Main Canal is 28 Km. long and a network of 138.21 Km of distribution system and design discharge of 10.76 cumecs. The Left Main Canal is 24 Km. long with 107 Km. of distribution system with a design discharge of 10.33 cumecs. This is the most successful irrigation Project in drought affected areas of Boudh and Harbhanga Block in the district for last 37 years. 36 Nos. of Pani Panchayats with five Distributary committee and one Apex Committee has been formed as per Pani Panchayat Act for smooth management and distribution of water supply for 216 nos. of villages of Boudh District.

Bagh Barrage Project: The Bagh Barrage Medium Irrigation Project has been taken-up in November 1997 under NABARD assistance. The Project is being constructed across river Bagh at Sagada. The project on completion as a whole will provide irrigation to 12834 Ha in Kantamal and Boudh Block. Bagh Barrage Project envisages with construction of barrage of length 167 meters with vertically lifted gates across river Bagh near village Sagada of Boudh District and excavation of Left Main Canal of 24.27 Km.

The project was proposed to take up under NABARD Assistance in phased manner. The works under Phase-I of the project is completed. In Phase-II works, comprises excavation of Left Main Canal from 11.355 km to 24.270 km. (Tail), Excavation of Dahiya Distributary from RD 3120m

to 4770m and Masinapada Minor from RD 00m to 375m which were under Reserve Forest has been completed during March 2009 and created an additional irrigation potential of 4000 Ha. Hence the irrigation potential of Kantamal Block increased from 27.55% to 42.50% and in Boudh from 59.02% to 61.20%. The Right Main Canal proposal has been sanctioned by NABARD for an amount of Rs. 3014.87 lakhs during 2010 with target additional ayacut of 2039 Ha in Boudh block. The block-wise details of Minor Irrigation Projects in the study area are given in **Table 1.9.**

Table 1.9: Block-wise MIPs in Boudh District. (As on 31.12.2013)

Sl. No.	Block	No of Projects	Ayacut Area (Ha)		
			Kharif	Rabi	Total
1	Boudh	20	2802.71	47.61	2850.
2	Harbhanga	24	6018.94	304.52	6323.
3	Kantamal	28	3464.15	205.16	3669.
	Total	**72**	**12285.8**	**557.29**	**12843**

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

2 DATA COLLECTION AND GENERATION

2.1 Geology

The study area forms a part of the Peninsular crystalline complex. The formations fall under the Eastern Ghat Super Group comprising of Khondalite suite of rocks, Charnockite suite of rocks and Granite Gneisses. Besides isolated outcrops of Gondwana formations consisting of sandstone and carbonaceous shales occur in the western part of district having limited areal extent. The development of laterite is rare and where ever it's seen it occurs as thin film capping the crystalline rocks. Discontinuous patches of Alluvium are restricted to major river courses. It occurs as elongated patch along the southern bank of river Mahanadi near Boudh. In the hard rock terrain, alluvium occurs as narrow and discontinuous valley fill deposits. The generalized stratigraphic sequence is given in **Table 2.1** and the geological map of the study area is shown in **Fig. 2.1.**

Table 2.1: **Generalized Stratigraphic Sequence in Boudh District.**

Group/Formation	Lithology	Age
Alluvium/ Laterite	Sand, silt, clay	Quartenery Recent to Sub-recent
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	~ ~ ~~ ~ ~ ~ ~ Unconformity ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	~ ~ ~ ~ ~ ~ ~ ~ ~
Lower Gondwana	Gritty sandstone, Felspathic sandstone, carbonaceous shale, conglomerate	Mesozoic
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	~ ~ ~~ ~ ~ ~ ~ ~ Unconformity ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	~ ~ ~ ~ ~ ~ ~ ~ ~
Eastern Ghat	Intrusive pegmatites and quartz veins Charnockite suite Granite Gneiss	Precambrians

The crystalline complex representing Eastern Ghat Super Group constitute oldest rock formations and are exposed in entire Boudh district, where as Lower Gondwana sandstones and shales and alluvium representing younger formations have restricted occurrence and the same is seen in the area as detached and isolated units.

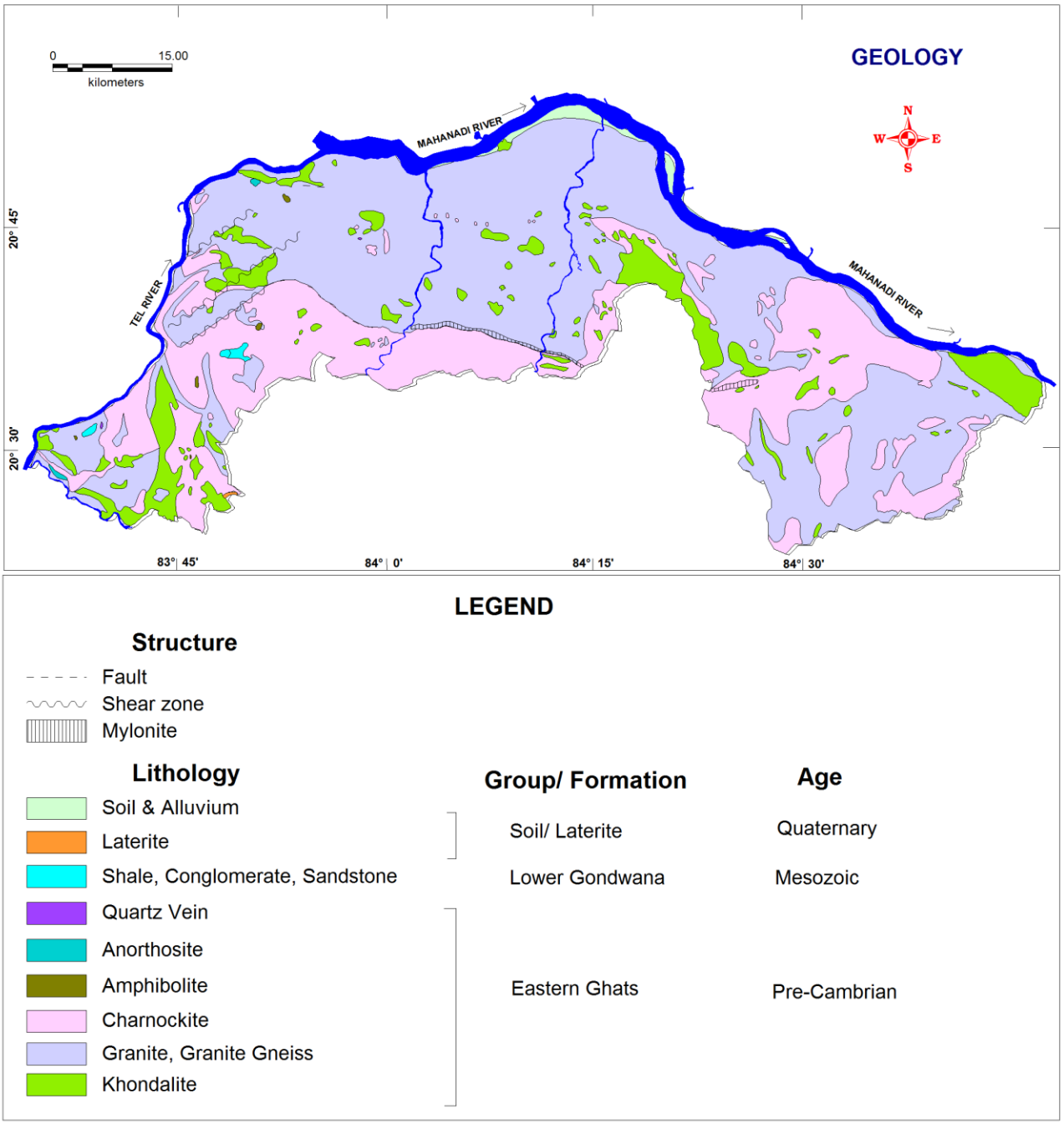


Fig. 2.1: Geological Map of Boudh District.

Khondalite Suite of Rocks: These comprise quartz-garnet-sillimanite schists and gneisses and calc-silicate rocks. The typical Khondalites are reddish brown in colour with specs of pink or red garnets and sillimanite needles aligned to schistosity of the rock units. The rocks strike ENE-WSW with subvertical dip. These have

been extensively weathered with the depth of weathering varying from 8.5 to 30m depending on the topography.

Charnockite Suite of Rocks: These occupy most of hilly areas of the district and more predominant than the Khondalites. These include acid, intermediate and basic Charnockites. They strike N35°E with vertical dips. These have undergone spheroidal weathering. The depth of weathering in the rocks ranges up to 15m depending on the topographic situation.

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

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

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

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

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

Alluvium: These comprise of various grades of sand, gravel with subordinate silt and clay and occur in the northern part of Boudh district, on the southern bank of river Mahanadi. The thickness of the alluvium varies from less than a metre along the fringe of rock exposures to more than 10m and is largely controlled by the topography of the basement crystallines. The alluvium as discontinuous patches are also encountered along the major streams.

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

2.2 Hydrogeology

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

In the major part of district groundwater occurs under phreatic and semiconfined conditions, the water being stored in the secondary conduits viz. weathered mantle, fractures and joint planes etc. Infiltration of atmospheric precipitation is the principal source of ground water recharge. Besides other contributory sources are the seepage from irrigation canals, return seepage from applied irrigation and seepage from the reservoirs. Most of the rainfall in the hilly terrain goes as surface run-off where as in the moderately undulating plains and valley areas,

rainfall contributes significantly to the ground water recharge to form potential aquifers under favourable conditions.

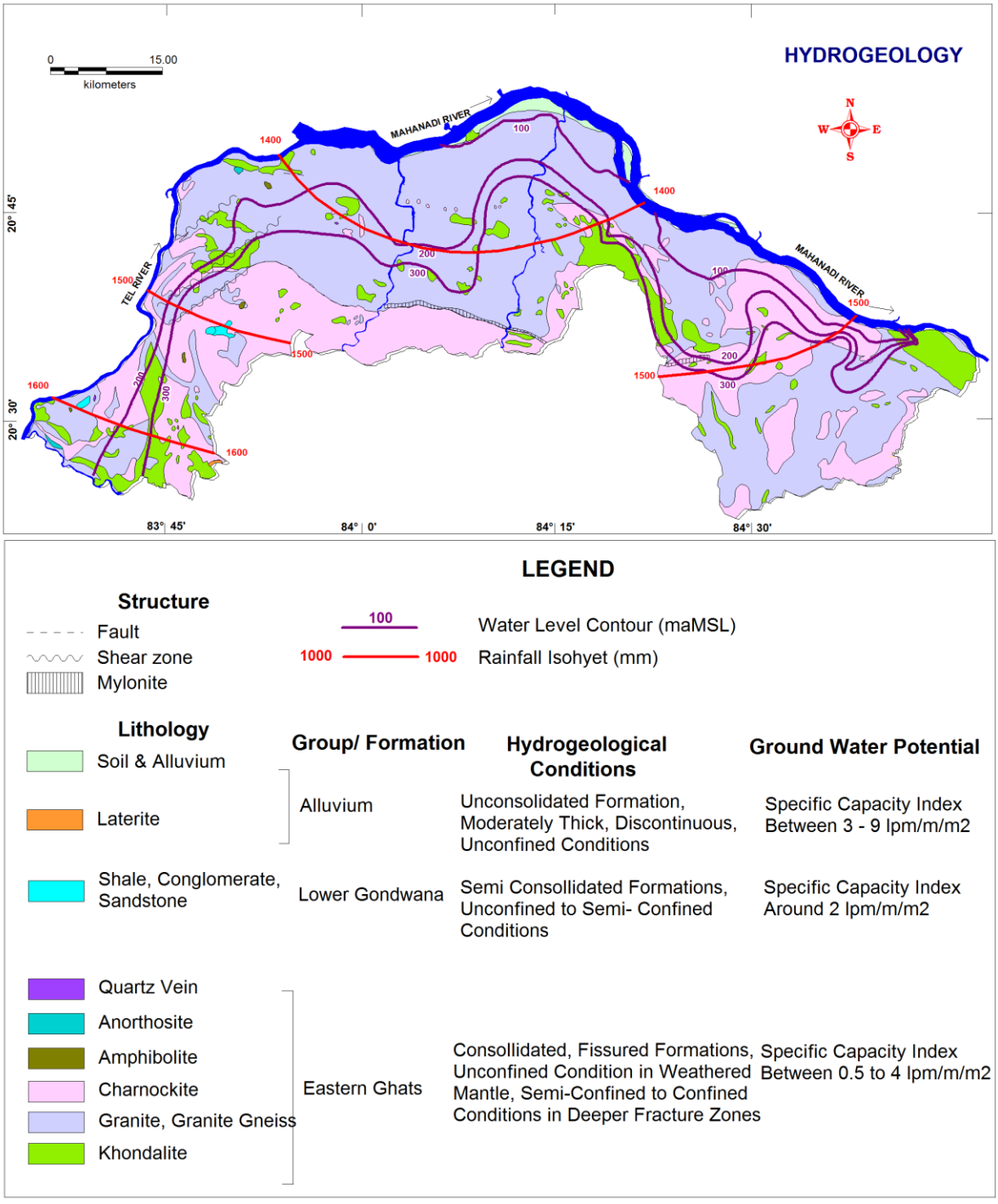


Fig. 2.2: Hydrogeological Map of Boudh District.

2.2.1 Water Bearing Formations

A. Consolidated and Fissured Formation

Major part of the study area is occupied by crystalline rocks comprising of granite gneiss, charnockites and khondalites. These rocks lack primary porosity. Weathering plays an important role in ground water occurrence and movement in these rocks. Under favourable conditions the weathered residuum forms potential phreatic aquifer. The fissures and joints, when interconnected depending on the extent, size, openness, continuity and interconnection form potential ground water repositories at favourable locales. Ground water occurs under water table conditions in the weathered zones while it occurs under semi-confined conditions in the deeper fracture zones. The topography, extent of weathering and development of joints and fractures contribute immensely towards occurrence, storage and movement of ground water in the consolidated formations. Community dug wells and the bore wells fitted with hand pumps exist in the district for rural water supply. The water level in the dugwells depletes in peak summer and quite often wells support little column of water which prelude heavy drawal of water.

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

Charnockites: This is one of the predominant rock types occurring extensively in the southern hilly parts of the district mostly in the Harbhanga block. Charnockite generally form hilly terrain but at places occur as undulating terrain dotted with hills. The weathering in these rocks is neither uniform not extensive, the thickness of weathered mantle ranges from 4m to 18m depending

upon the topographic setup. The ground water potential of this litho unit is poor. The specific capacity of dugwells varies from 10 lpm/m to 37 lpm/m. Borewells yield less than 1 lps.

Khondalites: These rocks generally form undulating hilly terrains. Moderately weathered rocks exhibit development of porosity with moderate water yielding capacity. Intensive weathering results in the formation of kaolin reducing permeability. The depth of weathering varies from 8m to 30m. The specific capacity of the only tested dugwell is 11 lpm/m. The yield of borewells is poor and less than 1 lps.

B. Semi Consolidated Formations

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

C. Unconsolidated Formation

They generally comprise alluvium and valley fill deposits.

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

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

2.3 Ground Water Exploration

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

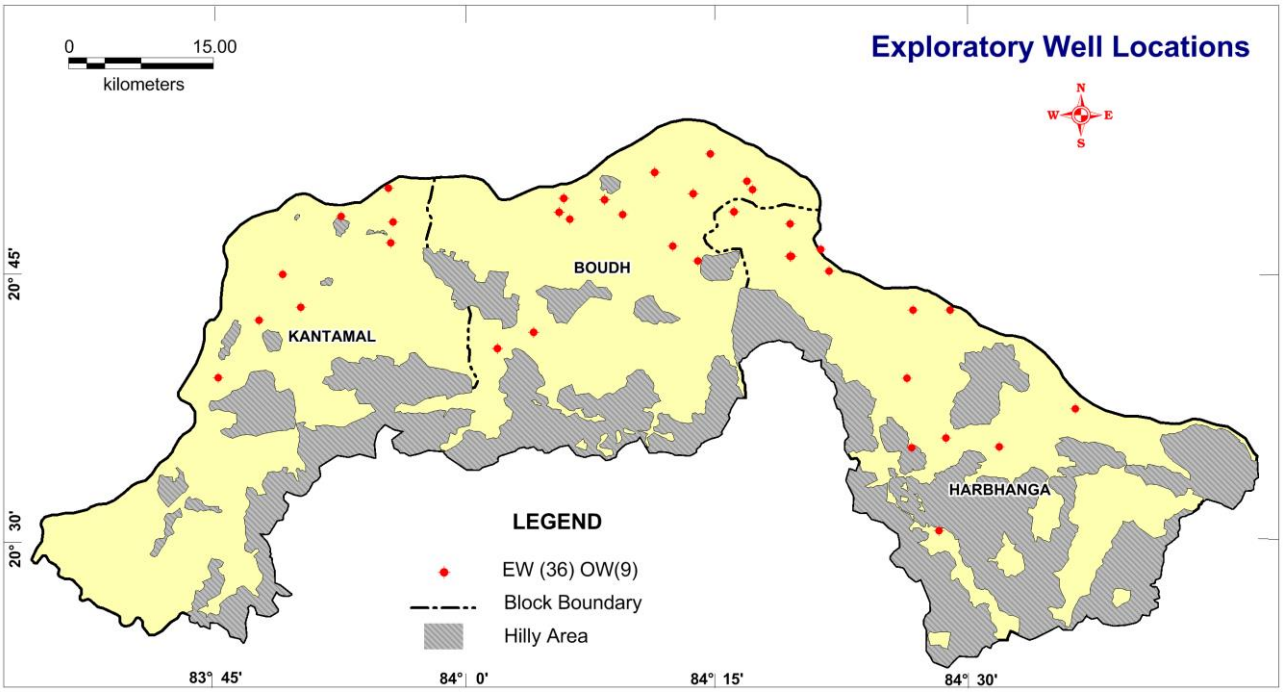


Fig. 2.3: Locations of Exploratory Wells Drilled by CGWB in Boudh District.

2.4 Monitoring of Ground Water Regime

Under NAQUIM, the ground water regime of the phreatic aquifer was monitored during pre- and post-monsoon periods in 2018-19 in 58 National Hydrograph Network Stations (NHNS) and 24 Key Observation wells (dug wells). The details of the monitoring wells are shown in **Table 2.3** and the locations of the monitoring stations are shown in **Fig. 2.4**. The chemical quality of ground water in the district is monitored annually on a routine basis by CGWB through its National Hydrograph Network Stations. During the NAQUIM programme, 69 water samples were collected from the monitoring wells and results of their chemical analysis is given in **Table 2.4.** Quality of ground water from deeper aquifers is assessed during the drilling and pumping tests. The chemical data of 28 water samples collected during the exploration is given in **Table 2.5.**

Table 2.2: Basic Data of Exploratory Wells Drilled by CGWB in Boudh District.

S.No	Location	Type	Latitude	Longitude	Depth Drilled (mbgl)	Lithology	Casing Depth (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Disch-arge (lps)	Draw-down (m)	T (m^2/day)	S
Block : BOUDH													
1	Erada	EW	20.7625	84.2333	180	Granite	18.2	22.0-23.0	0.9	0.8			
2	Girisingha	EW	20.7666	84.3250	38.6	Granite	14.5	Dry					
3	Girisingha II	OW	20.7666	84.3250	160.6	Granite	11	116.0-117.0	6.46	2.3	17.9		
4	Maneswar	EW	20.8194	84.1402	180	Granite	8	27.0-28.5,30.0-31.0	4.4	3	22.1		
5	Maneswar	OW	20.8194	84.1402	180	Granite	13	13.2-15.3	3.55	1.2	24.75		
6	Mundipadar	EW	20.8055	84.1583	172.8	Granite	12.5	146.50-150.50	4.2	0.5			
7	Padmanpur	EW	20.8250	84.2283	173.2	Granite gneiss	11.5	Dry	6.1				
8	Padmanpur II	OW	20.8250	84.2283	173.2	Granite	6	Dry	25.9				
9	Palasa	EW	20.8291	84.2875	166.7	Granite gneiss	12.9	20.0-23.0	2.3	0.6			
10	Sagada	EW	20.6805	84.0333	166.7	Granite	8.5	64.80-65.90	3.26		15.47	15.62	
11	Sagada	OW	20.6805	84.0333	166	Granite	9.5	19-20,94-96	2.92		4.04	18.54	
12	Gundulia	EW	20.6958	84.0694	136.2	Granite	16.5	20-23,63-65	3.26		15.67	11.12	
13	Gundulia	OW	20.6958	84.0694	130.1	Granite	21	23-29,35.5-37,35.7-38.7,63-66.10	5.08	4.4	14.36	6.44	
14	Telibandh	EW	20.8450	84.1902	100	Granite	12.05	21.00-22.50, 30.00.31.00	1.32	9	1.32	12.96	
15	Telibandh	OW	20.8450	84.1902	112	Granite	12.10	20.00-21.00,64.00-65.00, 73.00-	2.51	12	2.51	21.45	
16	Ainlapali	EW	20.8077	84.0950	136.2	Granite	9.00	72.00-73.50,112.00-114.00	19.85	4	19.85	33.26	
17	Ainlapali	EW	20.8077	84.0950	124	Granite	12.00	63.0-64.0,102.0-103.0	5.57	5.75	5.57	44.06	
18	Amruda	EW	20.8208	84.0994	156	Granite	17.70	60.0-63.0, 105.0-106.0, 154.0 -155.0	2.14	4	2.14	1.52	
19	Amruda	OW	20.8208	84.0994	154	Granite	12.00	25.0-28.0, 105.0-	1.9	5.5	1.9	3.24	
20	Mundapara	EW	20.7763	84.2083	180	Granite	4.00	44.0-45.0, 136.0-137.0	33.7	1.96	33.7	3.168	
21	Khuntabandh	EW	20.8625	84.2458	180	Granite	12.20	Dry		Dry		-	
22	Boudh	EW	20.8368	84.2821	204	Gr. Gneiss	6.5	7,8,20	2.68	0.42	7.3		

23	Baunsuni	EW	20.8015	84.1056	203.3	Porphyrihic Granite	14.7	15,20	5.66	0.3			
Block : HARBHANGA													
24	Kelakata	EW	20.7666	84.3263	69.1	Granite gneiss	13.5	12.8-14.2	6.9	1.56	19.01		
25	Bandhapathar	EW	20.8083	84.2694	149.7	Granite gneiss	11	27.0-28.5,33.0-35.0	1.68	2.2	22.12		
26	Bandhapathar	OW	20.8083	84.2694	180	Granite	9.5	41.0-42.5	2.82	3			
27	Badabankapada	EW	20.7972	84.3250	173	Granite	12	14.0-16.0,135.0-136.0	3.83	0.9			
28	Tukulunda	EW	20.5972	84.4805	166.7	Granite	11.5	16.0-18.0,53.0-56.0	8.2	0.9			
29	Kardi	EW	20.7733	84.3555	97	Granit gneiss	13	11.0-14.0		Dry			
30	Kharabhuin	EW	20.5888	84.5333	160	Granite gneiss	8	54.5-62.0	8.2	1.5	15.92		
31	Karadi	EW	20.7527	84.3638	93.5	Charnokite	11.5	53.80-56.90	7.62		30.85	4	
32	Ramgarh	EW	20.7166	84.4477	160.6	Granite gneiss	14.20	43.0-45.0	7.3	0.37	7.3	-	
33	Birnarsinghpur	EW	20.7166	84.4847	186	Granite gneiss	18.00	22.0-21.0	6.1	0.84	6.1	-	
34	Purnakatak	EW	20.6532	84.4416	204	Granite gneiss	17.34	18	4.2	0.5	25.5		
35	Charichack	EW	20.5881	84.4463	190.0	Charnokite &	7.00	14,97	2.59	2.00	19.44		
36	Harbhanga	EW	20.6244	84.6095	200.20	Gr. Gneiss	11.70	13,15	3.80	1.00	26.36		
37	Adenigarh	EW	20.5109	84.4734	185.00	Charnockite	39.60	48,114	11.97	1.50	39.40		
Block : KANTAMAL													
38	Manmunda	EW	20.8305	83.9250	180	Granite gneiss	8	Dry		-			
39	Rundimahal	EW	20.7069	83.7958	136	Granite gneiss	6.00	29.0-32.0	6.1	1	6.1	0.95	
40	Uchabahali	EW	20.7986	83.9294	180	Granite	15.50	75.0-77.0, 95.0 - 97.0	25.9	0.6	25.9	-	
41	Gopalmal	EW	20.7500	83.8194	160.6	Granite	19.50	20.30 - 21.00, 44.80 - 45.80	4.45	8	4.45	50.11	
42	Ratakhandi	EW	20.8041	83.8777	180	Granite gneiss	18.30	Dry		Dry			
43	Manamunda	EW	20.7795	83.9271	185.00	Gr. Gneiss	18.50	19,172	7.88	0.75	21.90		
44	Kantamal	EW	20.6536	83.7554	200.20	Charnockite	5.50	19,172	1.13	0.50	27.50		
45	Palsaguda	EW	20.7193	83.8375	200.20	Gr. Gneiss	15.40	105,194	1.23	1.50	22.34		

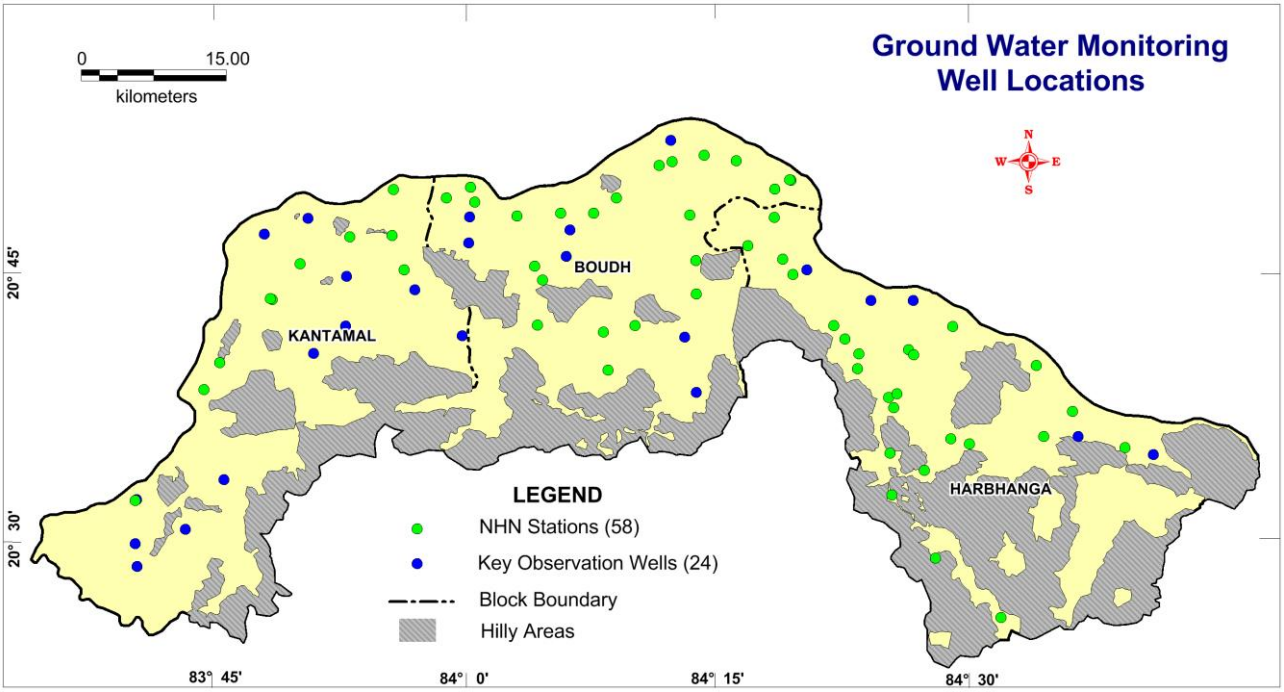


Fig. 2.4: Locations of Ground Water Monitoring Stations in Boudh district.

Table 2.3: Details of Monitoring wells in Boudh District.

Sl No	Location	Block	Type	Longitude	Latitude	Elevation (maMSL)	Pre-Monsoon DTWL (mbgl)	Post-Monsoon DTWL (mbgl)
1	Adenegarh	Harbhanga	NHS	84.4689	20.4856	367.8	5.36	1.46
2	Anlapali	Boudh	NHS	84.0958	20.8067	107	4.55	1.15
3	Auinla Chua Chhak	Kantamal	NHS	83.7567	20.6675	144	6.55	2.2
4	Baghiapada	Boudh	NHS	84.2308	20.7317	141	6.15	2.4
5	Bala Singha	Boudh	NHS	84.2706	20.8556	107.6	5.4	2.45
6	Baring	Harbhanga	NHS	84.5339	20.4303	223.3	5.45	1
7	Boudh	Harbhanga	NHS	84.3250	20.8375	96	4.99	4.24
8	Bruhaspatipur	Harbhanga	NHS	84.5692	20.6647	84	5.65	3.45
9	Butupalli	Boudh	NHS	84.3092	20.8292	100	6.4	2.55
10	Dahya	Boudh	NHS	84.0064	20.8308	103.3	6	2.95
11	Dhalpur	Harbhanga	NHS	84.4861	20.7014	84.8	5.55	0.45
12	Erada	Boudh	NHS	84.2306	20.7625	132	5.2	2.4
13	Gaundisahi	Boudh	NHS	84.1697	20.7022	170.6	5.5	2.75
14	Gohipita	Kantamal	NHS	83.8861	20.7847	135	6.32	2.12
15	Gudveli Padar	Kantamal	NHS	83.9283	20.7861	126.7	5.25	2.55
16	Gundulia	Boudh	NHS	84.0731	20.7025	139	6.5	3.95

17	Harbhanga	Harbhanga	NHS	84.6050	20.6222	79.3	7.31	3.81
18	Harekrishnapur	Harbhanga	NHS	84.3928	20.6758	121.3	7	2.1
19	Jahanapank	Boudh	NHS	84.2067	20.8547	116.3	6.35	1.35
20	Kamira	Boudh	NHS	84.2244	20.8050	113.3	5.3	3.3
21	Kantamal	Kantamal	NHS	83.7411	20.6422	137.1	6.3	2.15
22	Karoda Kutha	Harbhanga	NHS	84.4253	20.5442	222.7	7.5	2.45
23	Khajuripada	Boudh	NHS	84.1386	20.6958	156	5.7	3.75
24	Khatkhatia	Kantamal	NHS	83.8369	20.7597	143.4	7.7	4.2
25	Kusang	Harbhanga	NHS	84.6572	20.5883	79.7	8.16	4.66
26	Landibandh	Harbhanga	NHS	84.3167	20.7639	100.7	5.83	1.03
27	Laxmanpur	Harbhanga	NHS	84.5028	20.5919	132.8	4.78	1.28
28	Lumurjena	Boudh	NHS	84.0703	20.7572	120.1	4.8	1.7
29	Lunibahal	Harbhanga	NHS	84.3911	20.6617	135.7	6.02	2.07
30	Maheswar Pinda	Boudh	NHS	84.0103	20.8172	110.9	6.7	2.7
31	Manamunda	Boudh	NHS	83.9294	20.8286	112.3	7.45	3.6
32	Nuapada	Harbhanga	NHS	84.3675	20.7019	118.7	6.32	2.72
33	Nuapada 1(Tikira	Harbhanga	NHS	84.4578	20.5672	172.4	6.3	3.15
34	Nuapali	Boudh	NHS	83.9822	20.8211	115.9	4.95	0.95
35	Palasaguda	Kantamal	NHS	83.8089	20.7261	140.6	6.6	3.3
36	Palasaguda1	Kantamal	NHS	83.8072	20.7272	142.4	7	2.95
37	Polam 2	Boudh	NHS	84.2389	20.8608	106.3	5.2	2.25
38	Purunakatak	Harbhanga	NHS	84.4222	20.6353	139.9	5.4	3.4
39	Radha Nagar	Harbhanga	NHS	84.3272	20.7494	105.8	7.15	3.4
40	Rambhikata	Harbhanga	NHS	84.3786	20.6894	122.8	6.65	2.8
41	Sangrampur	Boudh	NHS	84.1514	20.8208	109.7	4.9	1.75
42	Sanrahajhar	Kantamal	NHS	83.9403	20.7539	125.3	5.57	2.47
43	Sarsara	Harbhanga	NHS	84.3086	20.8028	98.2	4.75	0.7
44	Sarta-Guda	Harbhanga	NHS	84.5764	20.5986	95.7	6.35	2.9
45	Singari chhak	Boudh	NHS	84.1289	20.8069	113.4	6.56	3.16
46	Tilesar 1	Harbhanga	NHS	84.4422	20.6797	103.2	8.35	6.6
47	Tileswar	Harbhanga	NHS	84.4472	20.6750	101.3	7.63	6.73
48	Tukulunda	Harbhanga	NHS	84.4842	20.5967	138	7.64	3.69
49	Udaipur	Harbhanga	NHS	84.4306	20.6383	136.7	8.3	4.05
50	Usbelika	Boudh	NHS	84.0778	20.7444	127.6	6.1	2.8
51	Usbelika I	Boudh	NHS	84.1433	20.6606	199	5.7	3.2
52	Badhigaon	Boudh	NHS	84.2822	20.7764	118.8	4.82	2.97
53	Kelakata	Harbhanga	KW	84.3411	20.7542	95.3	5.09	1.8
54	Sampochh	Harbhanga	KW	84.4044	20.7253	87.1	4.65	3.1
55	Ramgarh	Harbhanga	KW	84.4467	20.7253	80	3.87	1.3
56	Bhavpur	Harbhanga	KW	84.6856	20.5819	87.6	4.3	1.6
57	Kutijhar	Boudh	KW	84.6106	20.5986	81.2	2.95	1.3
58	Laxmiprasad	Boudh	KW	84.2056	20.8744	110.4	5.54	2.34
59	Jharmunda	Boudh	KW	84.1014	20.7667	131	7.1	1.95
60	Bauri-Jharkata	Boudh	KW	84.1050	20.7911	123	6.78	2.62
61	Talapadar	Boudh	KW	84.0044	20.7792	120.3	4.46	2.1

62	Khamarisahi	Boudh	KW	84.0053	20.8033	112.7	5.55	2.7
63	Gopalpur	Boudh	KW	83.9508	20.7353	142	7.63	3.48
64	Baragochha	Boudh	KW	83.9981	20.6925	156.7	4.17	2.2
65	Phuruda	Boudh	KW	84.2194	20.6911	152.7	6.15	2.85
66	Jamkhol	Boudh	KW	84.2311	20.6400	198.7	7.7	3.6
67	Ghantapada	Kantamal	KW	83.6739	20.5400	151.7	5.8	2.55
68	Ambagaon	Kantamal	KW	83.6728	20.4989	158.4	6.55	3.85
69	Landabahal	Kantamal	KW	83.6744	20.4778	166	5.65	2.65
70	Khemargarh	Kantamal	KW	83.7225	20.5122	179.3	6.1	2.8
71	Baragaon	Kantamal	KW	83.7608	20.5583	154	9.05	3.75
72	Jaimumal	Kantamal	KW	83.8011	20.7872	134.2	6.95	4.5
73	Dopla	Kantamal	KW	83.8822	20.7017	148.3	7.9	4.95
74	Lambasari	Kantamal	KW	83.8503	20.6761	151.3	6.8	4.05
75	Kumarkeli	Kantamal	KW	83.8828	20.7481	139.7	8.4	2.1
76	Ghikundi	Kantamal	KW	83.8444	20.8019	125.7	6.55	4.3

Table-2.4: Ground Water Quality Data of Monitoring Wells in Boudh District.

Sl No	Location	Block	Latitude	Longitude	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg	Na+	K+	CO3=	HCO3-	Cl-	SO4=	F-	SAR
						µS/cm	mg/L	as CaCO3 mg/L		mg/L									
1	Kelakata	Harbhanga	84.3411	20.7542	7.54	940	486.34	420	377	132	22	19.34	5.4	0	460	81	0	1.2	0.4
2	Sampochh	Harbhanga	84.4044	20.7253	7.82	1360	694.97	335	449	58	46	157.85	1.1	0	548	109	53	**1.5**	3.7
3	Ramgarh	Harbhanga	84.4467	20.7253	7.5	2760	1476.61	970	558	263	77	172.34	26.3	0	681	490	114	0.28	2.4
4	Bhavpur	Harbhanga	84.6856	20.5819	7.86	1280	624.51	590	423	88	90	22.5	0.49	0	516	81	89	0.68	0.4
5	Kutijhar	Boudh	84.6106	20.5986	7.92	650	335.89	155	311	38	15	76	0.88	0	379	12	5	3.3	2.7
6	Laxmiprasad	Boudh	84.2056	20.8744	7.63	820	415.34	315	332	72	33	34	13.1	0	405	43	21	0.79	0.8
7	Jharmunda	Boudh	84.1014	20.7667	7.72	830	415.97	345	250	80	35	30	1.7	0	305	100	19	0.82	0.7
8	Bauri-Jharkata	Boudh	84.1050	20.7911	7.75	650	327.83	265	250	78	17	27	0.7	0	305	40	15	0.68	0.7
9	Talapadar	Boudh	84.0044	20.7792	7.71	890	425.44	350	423	52	53	41	0.9	0	516	14	10	**1.7**	1.0
10	Khamarisahi	Boudh	84.0053	20.8033	7.69	750	372.94	265	306	60	28	46	6.3	0	373	29	20	0.87	1.2
11	Gopalpur	Boudh	83.9508	20.7353	7.77	940	444.39	435	377	62	68	15	0.3	0	460	52	21	0.69	0.3
12	Baragochha	Boudh	83.9981	20.6925	7.67	1700	813.9	640	449	70	113	95	0.6	0	548	169	97	0.78	1.6
13	Phuruda	Boudh	84.2194	20.6911	7.79	680	337.86	285	270	78	22	23	1.3	0	329	33	19	0.35	0.6
14	Jamkhol	Boudh	84.2311	20.6400	7.68	770	352.89	350	281	68	44	13	1.6	0	343	33	25	0.22	0.3
15	Ghantapada	Kantamal	83.6739	20.5400	7.37	1860	909.57	805	321	138	112	55	1.9	0	392	366	44	0.59	0.8
16	Landabahal	Kantamal	83.6744	20.4778	7.75	1700	788	695	495	98	109	67	6.90	0	604	157	52	**1.90**	1.1
17	Khemargarh	Kantamal	83.7225	20.5122	7.75	1570	755	550	485	72	90	105	1.50	0	592	126	69	**1.80**	1.9
18	Baragaon	Kantamal	83.7608	20.5583	7.70	1120	595	465	295	114	44	28	25.80	0	360	107	99	0.36	0.6
19	Jaimumal	Kantamal	83.8011	20.7872	7.89	940	447	375	321	86	39	36	10.50	0	392	76	7	0.53	0.8
20	Dopla	Kantamal	83.8822	20.7017	7.77	1610	818	665	279	154	68	60	7.20	0	341	273	88	0.50	1.0
21	Lambasari	Kantamal	83.8503	20.6761	8.07	830	399	370	352	68	49	20	0.90	0	429	17	33	1.20	0.5
22	Kumarkeli	Kantamal	83.8828	20.7481	7.78	960	451	410	398	58	64	30	0.70	0	486	43	16	1.20	0.6
23	Ghikundi	Kantamal	83.8444	20.8019	7.63	730	380	260	193	68	22	47	2.10	0	235	100	25	0.38	1.3
24	Adenegarh	Harbhanga	84.4689	20.4856	7.83	340	167	130	138	30	13	17	0.80	0	168	19	5	0.19	0.6
25	Anlapali	Boudh	84.0958	20.8067	7.49	1110	604	375	223	94	34	81	1.40	0	272	154	106	0.20	1.8
26	Auinla Chua Ghhak	Kantamal	83.7567	20.6675	7.79	310	163	115	102	34	7	16	0.80	0	124	26	18	0.29	0.6
27	Baghiapada	Boudh	84.2308	20.7317	7.60	670	316	290	295	42	45	20	0.60	0	360	19	12	0.68	0.5

28	Bala Singha	Boudh	84.2706	20.8556	7.87	1300	717	410	376	114	30	62	79.60	0	459	116	90	0.25	1.3
29	Badhigaon	Boudh	84.2822	20.7764	8.05	540	265	190	228	36	24	35	0.80	0	278	19	13	0.95	1.1
30	Boudh	Boudh	84.3250	20.8375	7.62	1450	728	435	362	56	72	131	3.80	0	442	143	105	0.54	2.7
31	Bruhaspatipur	Harbhanga	84.5692	20.6647	7.94	890	425	340	377	54	50	45	2.10	0	460	33	15	0.91	1.1
32	Butupalli	Boudh	84.3092	20.8292	7.90	420	219	135	168	40	9	34	0.70	0	205	21	13	0.98	1.3
33	Dahya	Boudh	84.0064	20.8308	7.72	490	253	185	179	50	15	20	9.80	0	218	33	18	0.28	0.6
34	Dholpur	Harbhanga	84.4861	20.7014	7.75	1400	701	420	332	50	72	126	3.70	0	405	190	60	0.49	2.7
35	Erada	Boudh	84.2306	20.7625	7.74	990	482	290	291	42	45	92	0.40	0	355	83	44	1.40	2.3
36	Gaundhisahi	Boudh	84.1697	20.7022	8.03	760	354	340	342	46	55	16	1.10	0	417	14	16	1.30	0.4
37	Gohipita	Kantamal	83.8861	20.7847	7.84	1250	669	390	326	112	27	60	80.00	0	398	140	55	0.29	1.3
38	Gudveli Padar	Kantamal	83.9283	20.7861	8.05	490	240	195	209	50	17	22	1.40	0	255	10	14	1.10	0.7
39	Gundulia	Boudh	84.0731	20.7025	7.70	860	429	350	280	62	47	33	5.30	0	342	74	40	0.48	0.8
40	Harbhanga	Harbhanga	84.6050	20.6222	7.64	1350	698	410	342	56	66	119	3.50	0	417	188	61	0.52	2.6
41	Harekrishnapur	Harbhanga	84.3928	20.6758	8.20	770	336	345	311	50	53	16	1.50	0	379	17	12	1.20	0.4
42	Jahnapanka	Boudh	84.2067	20.8547	7.86	520	275	200	158	66	9	20	9.90	0	193	55	20	0.29	0.6
43	Kamira	Boudh	84.2244	20.8050	7.91	1080	542	335	393	44	55	92	0.80	0	480	59	55	1.40	2.2
44	Kantamal	Kantamal	83.7411	20.6422	7.88	380	189	150	147	38	13	16	0.80	0	179	17	16	0.34	0.6
45	Karoda Kotha	Harbhanga	84.4253	20.5442	7.79	300	143	110	121	20	15	17	0.80	0	148	17	0	0.20	0.7
46	Khajuripada	Boudh	84.1386	20.6958	7.82	1430	665	680	323	24	151	15	1.70	0	394	221	58	0.83	0.3
47	Khatkhatia	Kantamal	83.8369	20.7597	7.88	1190	648	525	332	150	36	25	11.70	0	405	147	80	0.34	0.5
48	Landibandh	Harbhanga	84.3167	20.7639	8.02	1160	573	540	282	48	102	16	1.30	0	344	173	64	0.14	0.3
49	Laxmanpur	Harbhanga	84.5028	20.5919	7.84	690	352	335	321	92	26	4	1.00	0	392	29	8	0.19	0.1
50	Lumurijena	Boudh	84.0703	20.7572	7.69	390	193	185	126	56	11	2	1.50	0	154	38	9	0.43	0.1
51	Lunibahal	Harbhanga	84.3911	20.6617	8.07	670	306	320	290	52	46	4	2.00	0	354	17	10	1.26	0.1
52	Maheswarpinda	Boudh	84.0103	20.8172	8.21	1070	600	395	286	88	43	11	89.40	0	349	143	54	0.28	0.2
53	Manamunda	Boudh	83.9294	20.8286	8.03	290	153	130	94	44	5	4	1.30	0	115	24	18	0.32	0.2
54	Nuapada 1	Harbhanga	84.4578	20.5672	8.22	590	259	280	237	30	50	4	1.80	0	289	19	11	1.20	0.1
55	Nuapali	Boudh	83.9822	20.8211	8.17	440	226	195	145	50	17	5	10.50	0	177	36	20	0.29	0.2
56	Palasaguda 1	Kantamal	83.8072	20.7272	7.60	1560	831	710	158	178	64	25	11.30	0	193	382	76	0.27	0.4
57	Poulam 2	Boudh	84.2389	20.8608	8.14	460	235	200	158	48	19	5	11.80	0	193	33	23	0.29	0.2

58	Purunakatak	Harbhanga	84.4222	20.6353	7.91	1100	542	510	248	60	87	16	1.00	0	303	166	63	0.13	0.3
59	Radha Nagar	Harbhanga	84.3272	20.7494	7.80	700	355	325	168	46	51	9	1.60	0	205	114	33	0.40	0.2
60	Rambhikata	Harbhanga	84.3786	20.6894	8.16	920	456	430	245	84	53	11	2.70	0	299	128	30	0.37	0.2
61	Sahajpal	Boudh	84.1601	20.8209	7.61	1310	707	585	143	124	67	25	11.20	0	174	320	74	0.27	0.4
62	Sangrampur	Boudh	84.1514	20.8208	8.03	1530	823	690	260	206	43	27	12.00	0	317	310	69	0.30	0.4
63	Sarsara	Harbhanga	84.3086	20.8028	8.09	1060	511	490	321	44	92	16	1.00	0	392	113	53	0.14	0.3
64	Sarta-Guda	Harbhanga	84.5764	20.5986	8.28	660	321	305	275	76	28	9	2.10	0	336	26	14	0.86	0.2
65	Singarichhak	Boudh	84.1289	20.8069	8.30	430	216	205	199	46	22	4	1.00	0	243	12	11	1.14	0.1
66	Tilesar 1	Harbhanga	84.4422	20.6797	8.08	1250	619	585	352	94	85	16	1.00	0	429	150	63	0.16	0.3
67	Udaypyr	Harbhanga	84.4306	20.6383	8.27	700	340	325	311	66	39	9	2.40	0	379	26	11	0.88	0.2
68	Usbelika	Boudh	84.0778	20.7444	7.94	460	223	220	164	54	21	2	1.40	0	200	36	10	0.47	0.1
69	Usbelika1	Boudh	84.1433	20.6606	7.88	710	329	330	173	50	50	6	5.50	0	211	78	36	0.44	0.1

Table-2.5: Ground Water Quality Data of Exploratory Wells in Boudh District.

Sl No	Location	Block	Longitude	Latitude	pH	EC	TDS	Hardness	Ca++	Mg	Na+	K+	CO3=	HCO3-	Cl-	SO4=	NO_3^-	F^-	Fe	SAR
						µS/cm	mg/L	as CaCO3 mg/L	mg/L											
1	Birnarasinghpur	Harbhanga	84.4847	20.7167	7.83	760		225	22	41	66	16		421	20	0	6.12	1.42	0	1.9
2	Telebandh	Boudh	84.1903	20.845	7.76	400		130	36	10	25	12		177	35	0	<1	0.09	0	1.0
3	Ainlapali	Boudh	84.095	20.8078	7.79	590		160	40	15	48	20		195	77	0	5.29	1.34	0	1.6
4	Amruda	Boudh	84.0139	20.8208	7.59	420		160	40	15	22	<1		220	21	0	<1	1.28	0	0.8
5	Mundapada	Boudh	84.2083	20.7764	7.8	1190		160	40	15	193	13		323	220	0	<1	0.68	0	6.6
6	Uchbahali	Kantamal	83.9294	20.7986	7.85	540		140	38	11	52	9		165	85	0	5.24	0.83	0	1.9
7	Rundimahal	Boudh	83.7958	20.7069	7.86	590		155	36	16	51	21		220	66	0	2.41	1.14	0	1.8
8	Gopalmal	Kantamal	83.8194	20.75	7.79	290		125	36	8.51	12	<1		153	11	0	<1	0.98	0	0.5
9	Kelakata	Harbhanga	84.3264	20.7667	7.81	450		180	58	8.51	16	3		238	13	0	2.98	0.84	0	0.5
10	Bandhapathar	Harbhanga	84.2528	20.8083	7.86	620		155	42	11	58	18		287	38	0	7.45	1.21	0	2.0
11	Erada	Boudh	84.2333	20.7625	7.9	510	264	185	20	48.6	28.8	1.7		305	10.6	2.9	0.8	0.92	0	0.9
12	Maneswar	Boudh	84.1403	20.8194	7.8	750	402	190	34	57.1	88	0.8		390	21.3	7.4	1.5	0.94	0.9	2.8

13	Giradsinga	Boudh	84.325	20.7667	7.7	770	452	240	10	52.2	72	1.5		146	163	80.5	0.3	0.77	0	2.0
14	Badabankapada	Harbhanga	84.325	20.7972	7.5	530	255	210	18	40.1	23	2.7		268	35.3	3.5		0.7	0.22	0.7
15	Mundipadar	Boudh	84.1583	20.8056	7.6	580	281	185	24	30.4	51.6	2.6		311	14.2	4.8		0.8	0.7	1.6
16	Palas	Boudh	84.2875	20.8292	7.8	750	425.5	250	76	14.6	76.2	1.2		378	56.7	15.5		1.12	0	2.1
17	Tukulunda	Harbhanga	84.4806	20.5972	7.8	420		160	12	31.6	19.4	0.4		232	10.6	2.73	3.2	0.4	0	0.7
18	Kharbhuin	Harbhanga	84.5333	20.5889	7.6	730	194	240	46	30.4	48.4	0.7		378	46.1	3.04	0.61	0.7	0	1.4
19	Karadi	Harbhanga	84.3643	20.7516	7.6	820	361.2	170	34	20.7	96	1.7		384	60.3	30.3	4.54	0	0	3.2
20	Sagada	Boudh	84.035	20.692	7.41	680	323	300	70	30	12	0.9	0	287	53.175	15		0.62	0	0.3
21	Charichhak	Harbhanga	84.42444	20.58389	8.3	833	476	260	26	47	68	0.68	0	268	67	54	42		0.83	1.8
22	Baunsuni	Boudh	84.1056	20.8015	7.66	773	411	325	54	46	19	2		311	46	34	7.8	0.64	0.17	0.5
23	Boudh	Boudh	84.20833	20.85444	7.67	988		345	112	16	33	49	0	256	121	32	65	0.46	0.01	0.8
24	Gundulia	Boudh	84.06944	20.69583	7.51	1020		410	38	77	52	1.4	0	378	106			1.1		1.1
25	Harbhanga	Harbhanga	84.325	20.62083	7.65	500	304	220	72	9.7	15	0.6		275	14	6	1.6	0.86	0.52	0.4
26	Kantamal	Kantamal	83.74861	20.64583	6.9	425			40	4.9	16	2		88	82	3.5	2.4	**1.58**	0.39	0.6
27	Manmunda	Boudh	83.91667	20.82833	8.21	416	243		28	16	33	2	0	165	32	14	3.1	0.69	0.1	1.2
28	Purunakatak	Harbhanga	84.42722	20.62583	8.05	583	336	120	20	17	78	1.6		323	14	10	0.9	1.1	1.04	3.1

3 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Shallow Aquifer

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

3.1.1 Pre-monsoon Depth to Water Level

Depth to water level in pre-monsoon period (May 2018) varies from 2.95 mbgl (Kutijhar, Boudh) to 9.05 mbgl (Bargaon,Kantamal), the average being 6.13 m bgl. In general, the study area has the depth to water level in between 5 to 7 mbgl during the pre-monsoon. Water logging condition (<3 mbgl) is found nowhere during the pre-monsoon. Shallower water level of 3-5 mbgl is observed in Boudh block and in northern parts of Harbhanga block. They are mainly due to adequate irrigation facility through the Boudh Main Branch canal and its distributaries. Deeper water levels (> 7 mbgl) are found mostly in Kantamal block and in patches of Harbhanga block. The locations where the depth to water level more than 8 m bgl are Baragaon (9.05), Kumarkani (8.4) in kantamal block and Kusang (8.16), Tileswar (8.35) and Udaipur (8.3) in Harbhanga block. Purunakatak, Charichhak & Baringi in Harbhanga block are also the areas of deeper water level. The pre-monsoon depth to water level map is shown in **Fig. 3.1**.

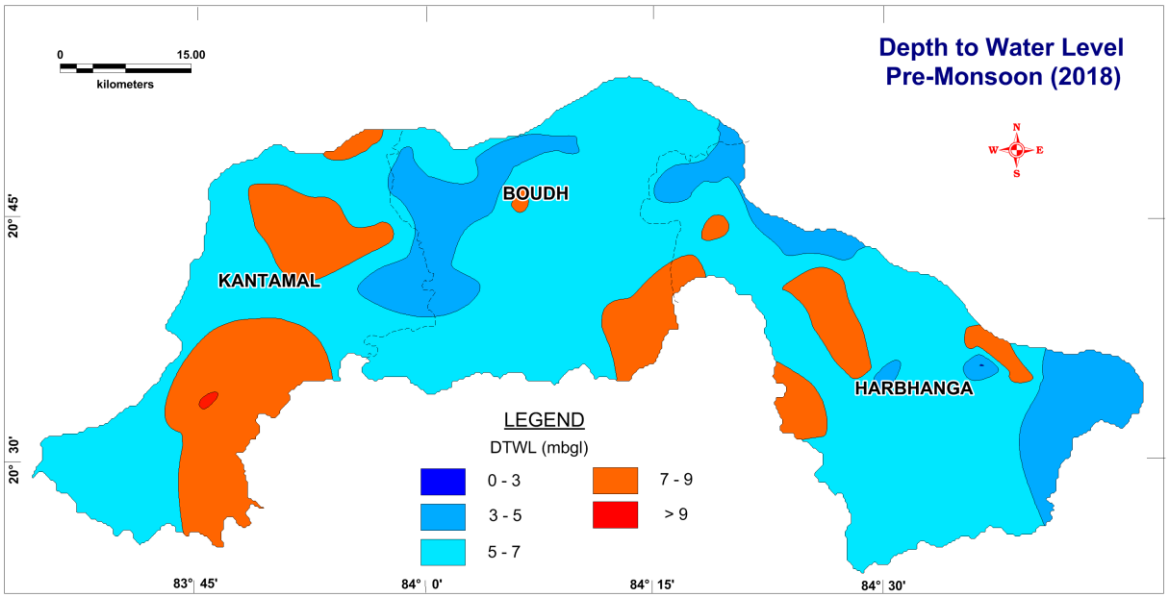


Fig. 3.1: Depth to Water Level in Phreatic Aquifer During Pre-monsoon.

3.1.2 Post-monsoon Depth to Water Level

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

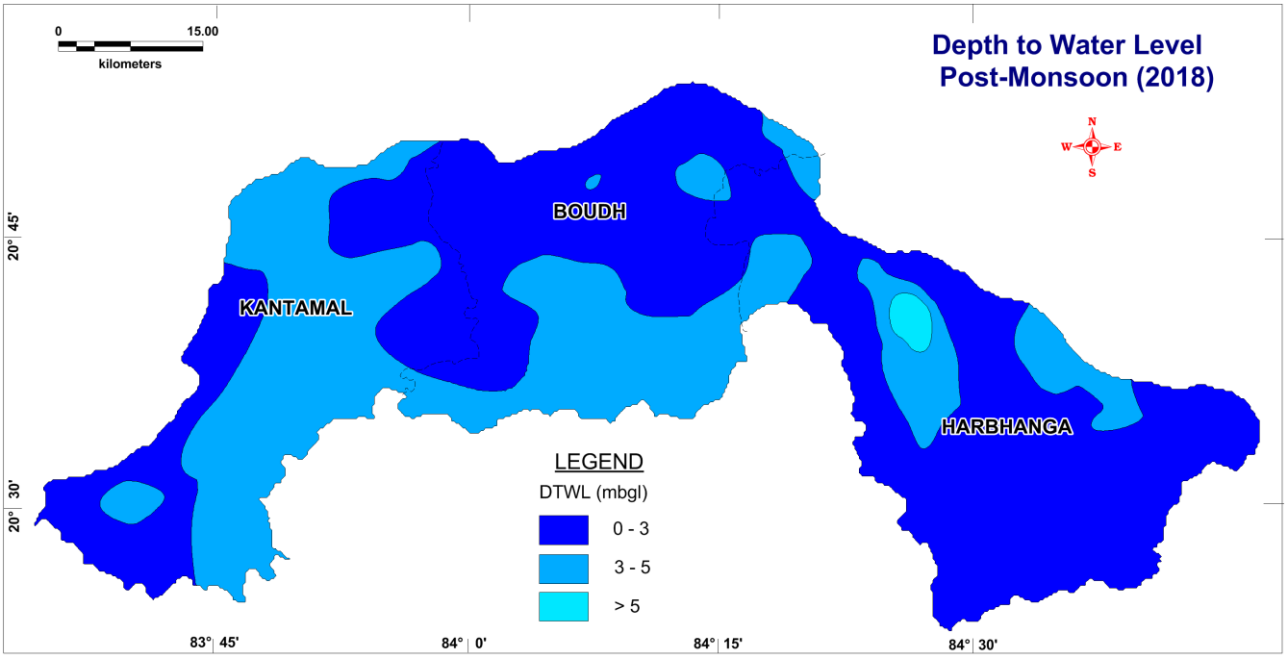


Fig. 3.2: Depth to Water Level in Phreatic Aquifer During Post-monsoon.

3.1.3 Seasonal Fluctuation of Water Level

Fluctuation of ground water table between pre and post monsoon period in the study area varies from 0.75 to 6.3 m, the average being 3.33 m. The general range of fluctuation in water level in the study area is between 2-4m. These are generally the plateau areas in the northern part of the

district covering parts of each block. The locations where the fluctuation of water level is more than 5 m bgl are Jharmunda (5.3) in Boudh block, Karoda Kutha (5.05), Dholpur (5.1m) in Harbhanga block and Baragaon (5.3) and Kumarkeli (6.3) in Kantamal block. The shallow post-monsoon water level along with fluctuation pattern indicates that the annual replenishment of phreatic aquifer due to monsoon rainfall is adequate in the district but deeper summer level is due to rapid dewatering of the phreatic aquifer due to steep gradient towards the Mahanadi and Tel rivers which surround three quarter of the district. The seasonal fluctuation of water level of Aquifer-I is shown in **Fig. 3.3**.

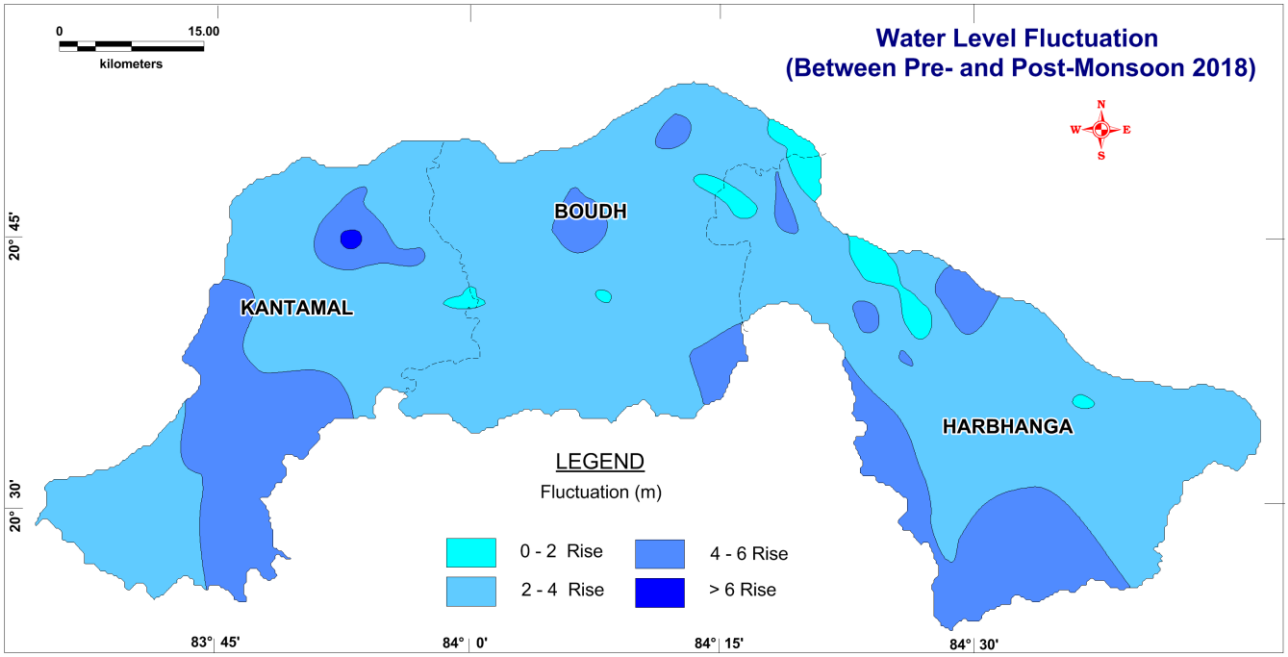


Fig. 3.3: Seasonal Fluctuation in Water Level in Phreatic Aquifer.

3.1.4 Decadal Water Level Trend

There are 32 National Hydrograph Station (NHS) in the district, the data from which are considered for analysis of long-term decadal trend for the period 2009-2018. The decadal trend of water level for both pre-monsoon and post-monsoon periods were analyzed. The results of trend analysis have been shown in **Table-3.1**. The long term trend analysis indicates that out of 32 stations, 20 (62.5%) show falling trend and the rest 12 stations (37.5%) show rising trend in both the seasons. The area around Dahya in Boudh block has significant falling trend of about 20-30 cm/year. In all

other stations with falling trend, the extent of fall is not significant.

Table-3.1: Decadal Water Level Trend Analysis of CGWB NHS (period 2009-2018) in Boudh District.

Block	Location	Pre-monsoon		Post-monsoon	
		Trend (m/Yr)	Remark	Trend (m/Yr)	Remark
Boudh	Ainlapali	-0.0285	**Fall**	0.0969	Rise
	Badhigan	-0.0406	**Fall**	-0.1663	**Fall**
	Baunsuni	-0.0288	**Fall**	-0.0179	**Fall**
	Boudh	0.1179	Rise	0.0064	Rise
	Dahya	-0.3331	**Fall**	-0.2157	**Fall**
	Maheswarpinda	-0.6643	**Fall**	-0.1943	**Fall**
	Nuapali	-0.2430	**Fall**	0.0774	Rise
	Sangrampur	-0.0210	**Fall**	-0.0646	**Fall**
	Singari chhak	-0.1346	**Fall**	-0.1707	**Fall**
	Telebandha	-0.1018	**Fall**	-0.0968	**Fall**
Harbhanga	Adhenigarh	-0.2591	**Fall**	0.0437	Rise
	Arakhpadar	0.5328	Rise	0.2116	Rise
	Birnarsingpur	0.0452	Rise	-0.6518	**Fall**
	Charichhak	0.2757	Rise	0.2561	Rise
	Chatarang	0.4078	Rise	-0.0553	**Fall**
	Dholpur	-0.1087	**Fall**	0.0466	Rise
	Harbhanga	-0.0673	**Fall**	-0.109	**Fall**
	Harekrishnapur	-0.1639	**Fall**	-0.0904	**Fall**
	Kusang	0.0017	Rise	-0.036	**Fall**
	Nuapada	0.0179	Rise	-0.0307	**Fall**
	Landibandh	-0.1241	**Fall**	-0.0479	**Fall**
	Lunibahal	-0.0183	**Fall**	-0.0346	**Fall**
	Purunakatak1	0.180	Rise	-0.0142	**Fall**
	Radhanagar	-0.3041	**Fall**	-0.0997	**Fall**
	Tileswar	-0.0628	**Fall**	-0.2335	**Fall**
	Tukulunda	-0.0551	**Fall**	-0.0677	**Fall**
Kantamal	Damamunda	-0.0128	**Fall**	0.0753	Rise
	Gohipita	-0.3948	**Fall**	0.2070	Rise
	Palsaguda	-0.0909	**Fall**	-0.0732	**Fall**
	Sanrahajhar	0.2059	Rise	0.2766	Rise
	Kantamal	0.0236	Rise	0.1143	Rise
	Manmunda	0.0646	Rise	0.0928	Rise
Total	**32**		**Rise-12 Fall-20**		**Rise-12 Fall-20**

3.1.5 Aquifer Characteristics of Phreatic Aquifer

The pumping tests were conducted on selected dugwells representing different hydrogeological

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

Table-3.2: Aquifer Characteristics of Major Hydrogeological Units in Boudh District,

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

3.2 Deeper Aquifer

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

CGWB has constructed 36 EW and 9 OW in Boudh district through its Ground Water Exploration Programme, whose depths range from 38.6 m bgl (Giradsinga) to 203.3 m bgl (Boudh & Purunakatak). The static water level varies from 0.9 m bgl (Erada) to 33.7 m bgl (Mundapada). The discharge of successful borewells varies from 0.30 lps (Baunsuni) to a maximum of 12 lps (Telebandh)). The drawdown varies from 1.32 m (Telebandh) to 39.40 m (Adenigarh). The transmissivity (T) of the aquifers ranges from 0.95 m^2/day (Rundimahal) to 50.11 m^2/day (Gopalmal). The details of the exploratory wells are given in **Table-2.2.** Generally 1 to 4 potential fracture zones are encountered within the depth range of 200 m. The first promising zone occurs in the depth range of 15 to 35 m., which is just below the zone of weathering. The depth range of prime importance is from 40 to 100 m. Normally, the fracture zones in this depth range have high water yielding capabilities and majority of successful bore wells in the study area tapped zones within this depth range. The other potential fracture zones are found at the depth ranges of 40-65,

70-75, 95-115, 135-155 and 170-195 mbgl. Granite suites rocks have more promising aquifers in comparison to other rocks like Charnockites and Khondalites. However the success of bore wells is site specific and depends on topographic and hydrogeological conditions.

3.3 Ground Water Quality

The chemical quality of ground water in the district is monitored annually on a routine basis by CGWB through its national Hydrograph Network Stations. Quality of ground water from deeper aquifers was assessed during the exploration activities like drilling and pumping tests. The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water.

Taking the results of chemical analysis during NAQUIM work and the available historical chemical data, the aquifer wise ranges of different chemical constituents present in ground water, are determined and shown in **Table 3.3.**

Table 3.3: Aquifer-Wise Ranges of Chemical Constituents in Boudh District.

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

Based on the chemical analysis of water samples from different sources, it was observed that, almost all chemical parameters lie within permissible limit for drinking and irrigation purpose except few samples of some isolated pockets. For example, fluoride in excess of permissible limit has been found certain villages, which is discussed in detail in Chapter-5. The iso-conductivity map

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

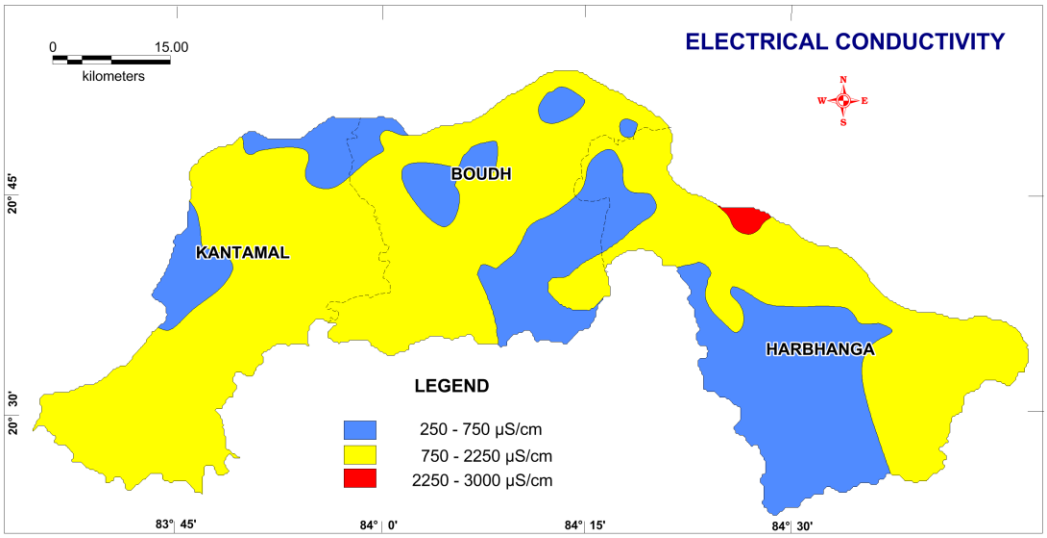


Fig. 3.4: Iso-conductivity Map of Phreatic Aquifer.

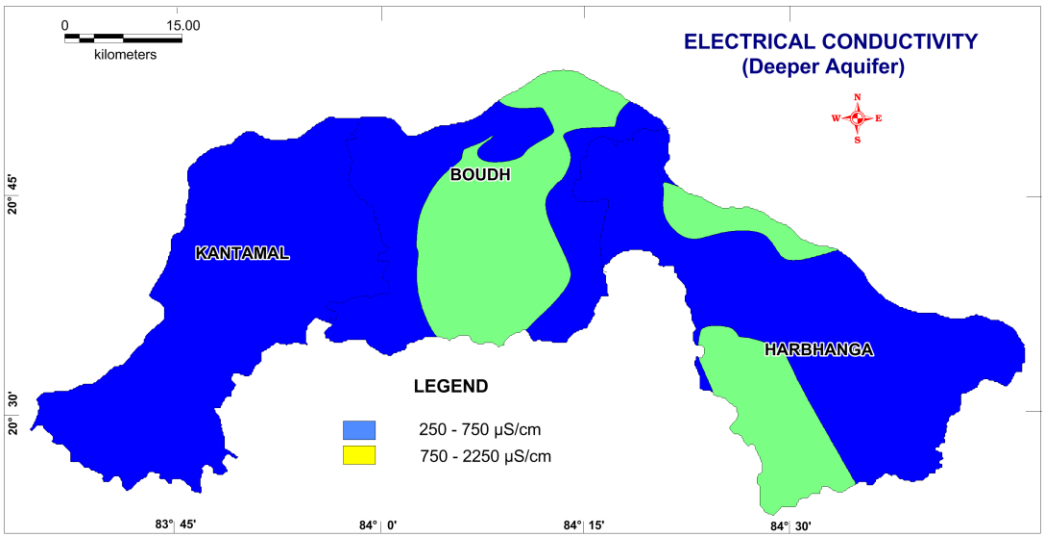


Fig. 3.5: Iso-conductivity Map of Fractured (Deeper) Aquifer.

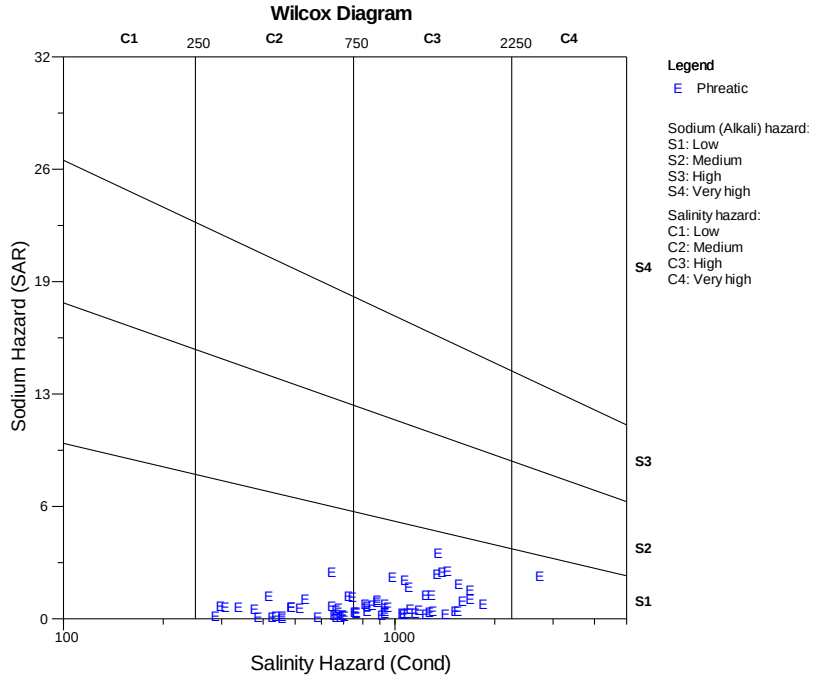


Fig. 3.6: US-Salinity Diagram, Phreatic Aquifer in Boudh District.

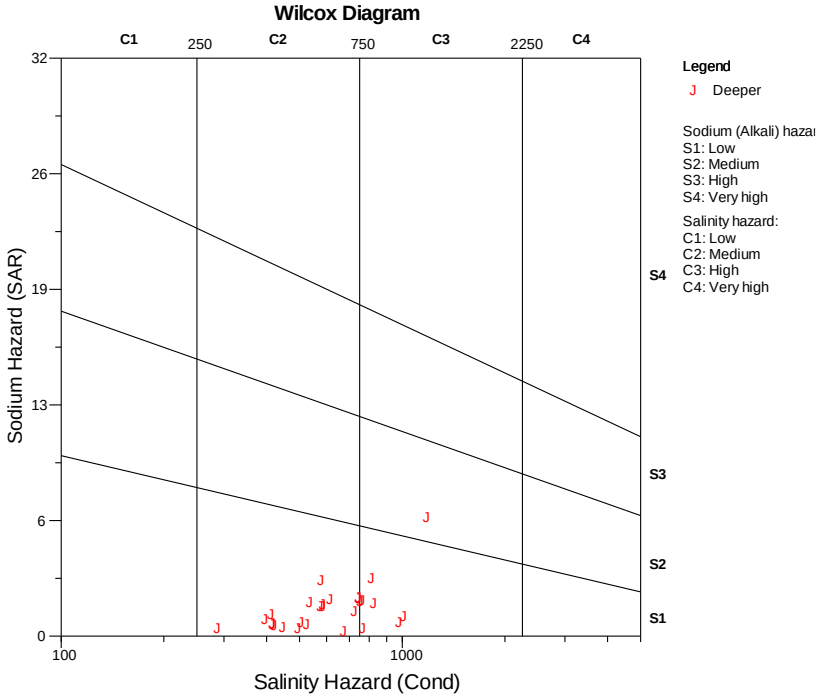


Fig. 3.7: US-Salinity Diagram, Deeper Aquifer in Boudh District.

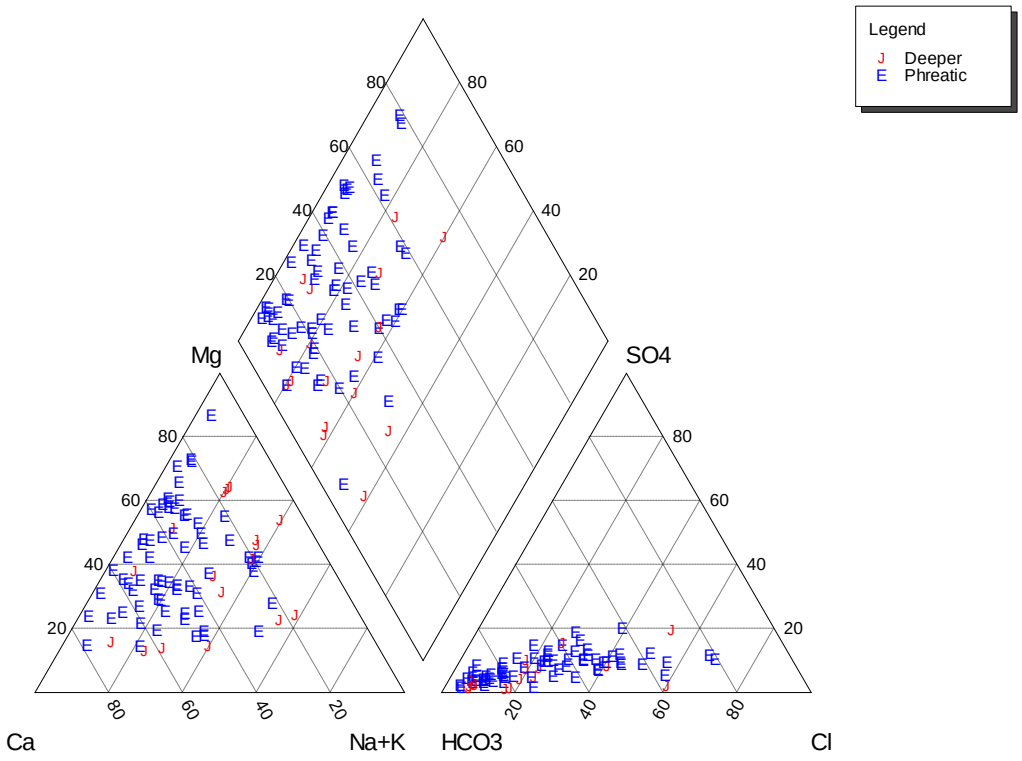


Fig. 3.8: Piper Diagram of Water Samples, Boudh District

3.4 Aquifer Groups and Their Demarcation

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

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

Aquifer-II (Semi-Confined to Confined Aquifer): Semi-confined to confined aquifer occurs as fracture zone aquifers in the entire area irrespective of rock types. However the aquifer properties, the yield of bore wells constructed in them depends on the rock type. As per the ground water exploration, carried out by CGWB. Aquifer-II in Granitic rocks has better yield in comparison to Gondwanas, Charnockites and Khondalites. In general, most of the fracture zones

are encountered within 0 to 150 mbgl and seldom beyond that. Thus the maximum depth for the Aquifer-II has been taken as 200 mbgl.

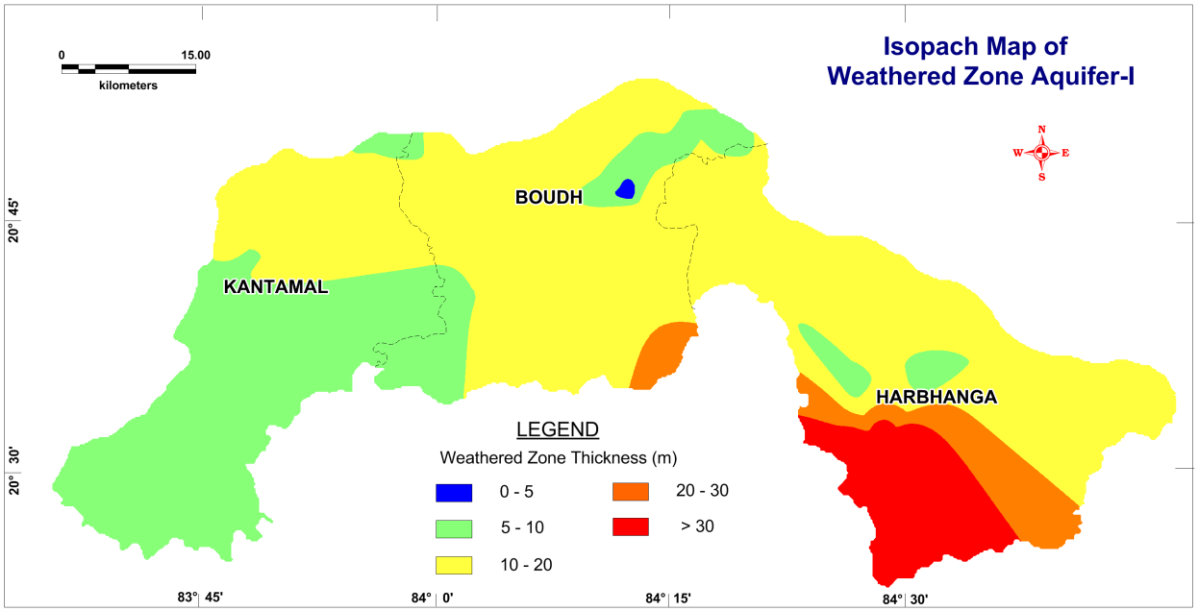


Fig. 3.9: Isopach of Weathered Zone (Aquifer-I) in Boudh District.

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

Table 3.4: Characteristics of Aquifer Groups in Boudh District.

Type of Aquifer Group	Formation	Depth range (mbgl)	Yield	Aquifer parameter	Suitability for drinking/ irrigation
Aquifer-I (Phreatic)	**Unconsolidated and Weathered** **Recent**: Soil, Alluvium & Laterite **Lower Gondwana**: Sandstone, Shale and conglomerate **Pre-cambrian**: Granite Gneiss, Charnockite, Khondalite,	0-30	10-50 m^3/day	Specific Capacity Index: 0.5-40 lpm/m/m^2	Yes for both
Aquifer-II (Semi-confined to Confined)	**Fractured** Granite Gneiss, Charnockite, Khondalite, Gondwanas	30-200	Negl.-12 lps	Transmissivity: 0.95-50.11	Yes for both

3.5 Aquifer Disposition

The ground water exploration data has been used to generate the 3D disposition of the aquifer system. It comprises of all existing litho-units and the zones tapped during the ground water exploration, forming an aquifer. Based on the ground water exploration and micro-level hydrogeological survey data and aquifer delineation method, a schematic 3-D aquifer disposition is prepared and shown in **Fig. 3.10.** Five 2D schematic sections were drawn along lines A-B, C-D, E-F, G-H and I-J, which are shown in plan view in **Fig.3. 11** and the corresponding 2D schematic sections are shown in **Fig. 3.12**, **3.13, 3.14, 3.15** and **3.16**. A 3D Fence diagram is shown in **Fig. 3.17**.

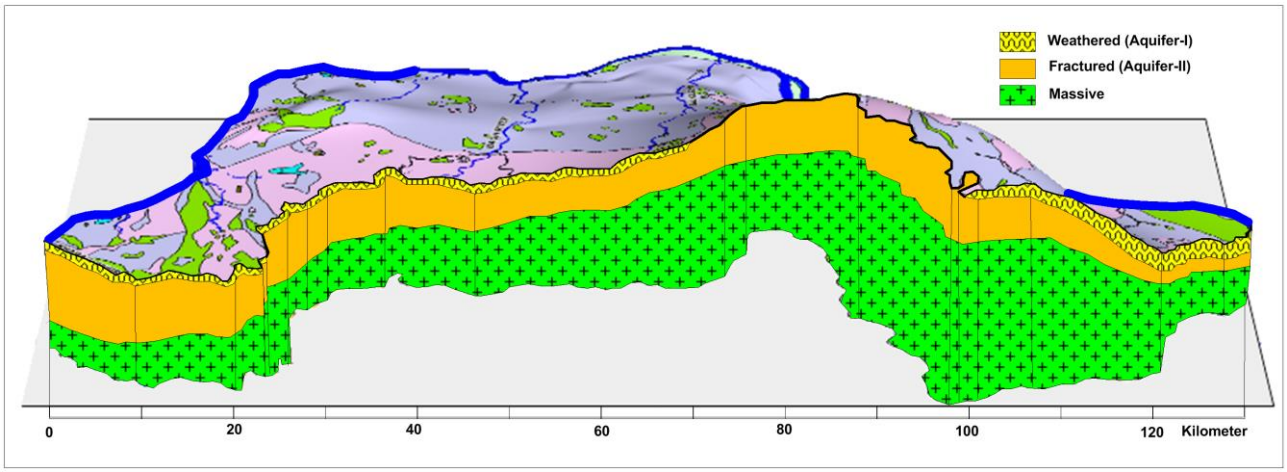


Fig. 3.10: Schematic 3D Aquifer Disposition in Boudh District.

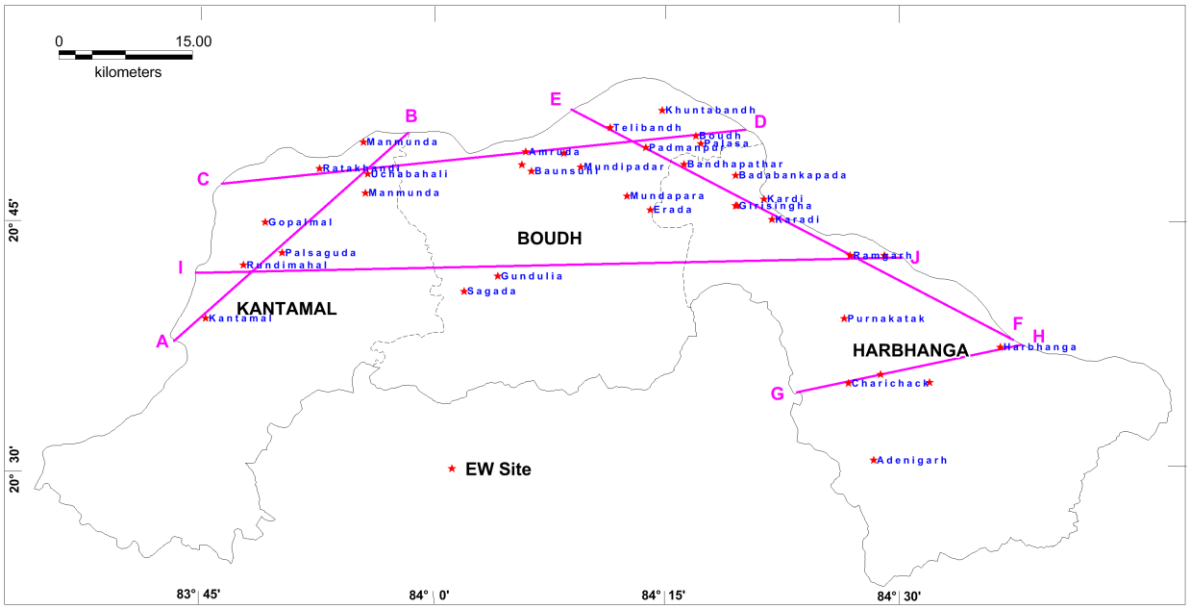


Fig. 3.11: Aquifer 2D Section Lines along A-B, C-D, E-F, G-H and I-J.

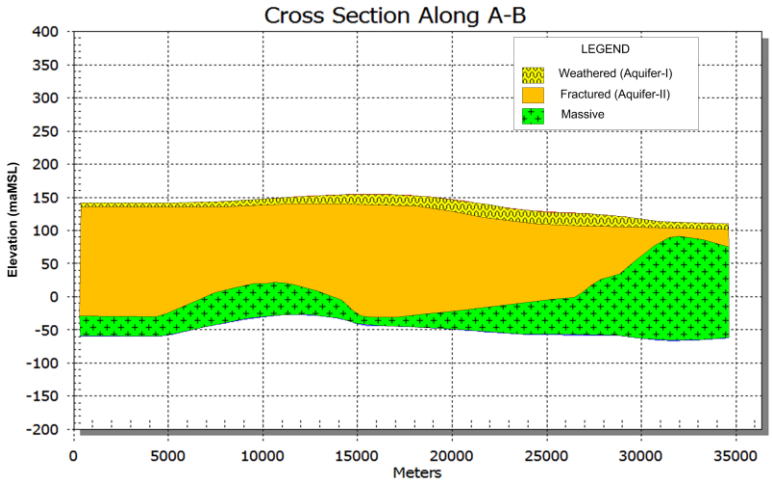


Fig. 3.12: Schematic Aquifer Cross-Section Along A-B in Boudh District.

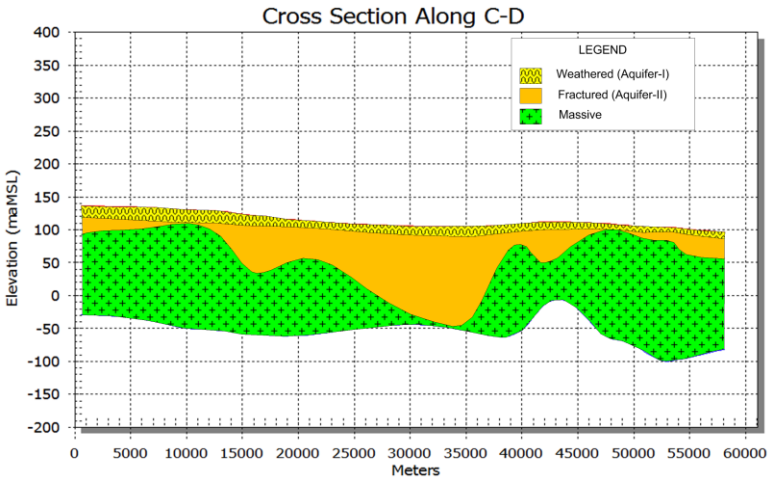


Fig. 3.13: Schematic Aquifer Cross-Section Along C-D in Boudh District.

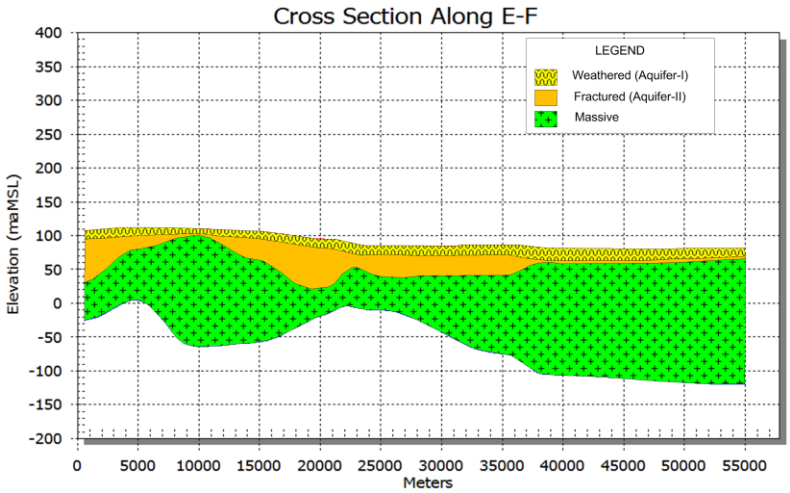


Fig. 3.14: Schematic Aquifer Cross-Section Along E-F in Boudh District.

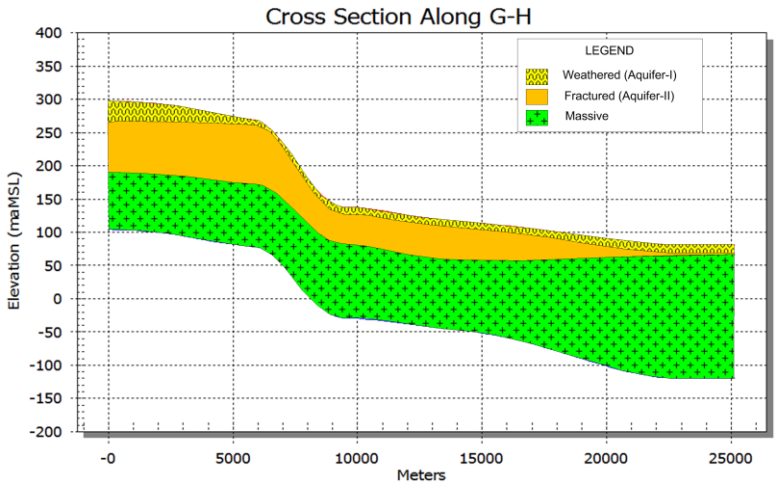


Fig. 3.15: Schematic Aquifer Cross-Section Along G-H in Boudh District.

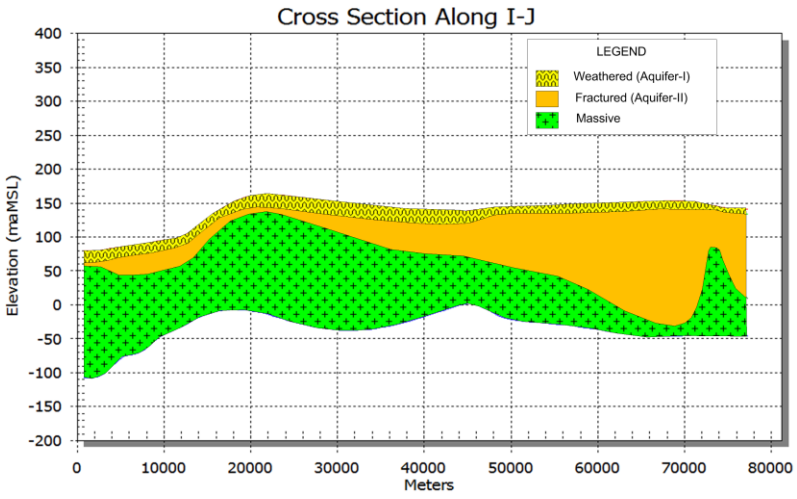
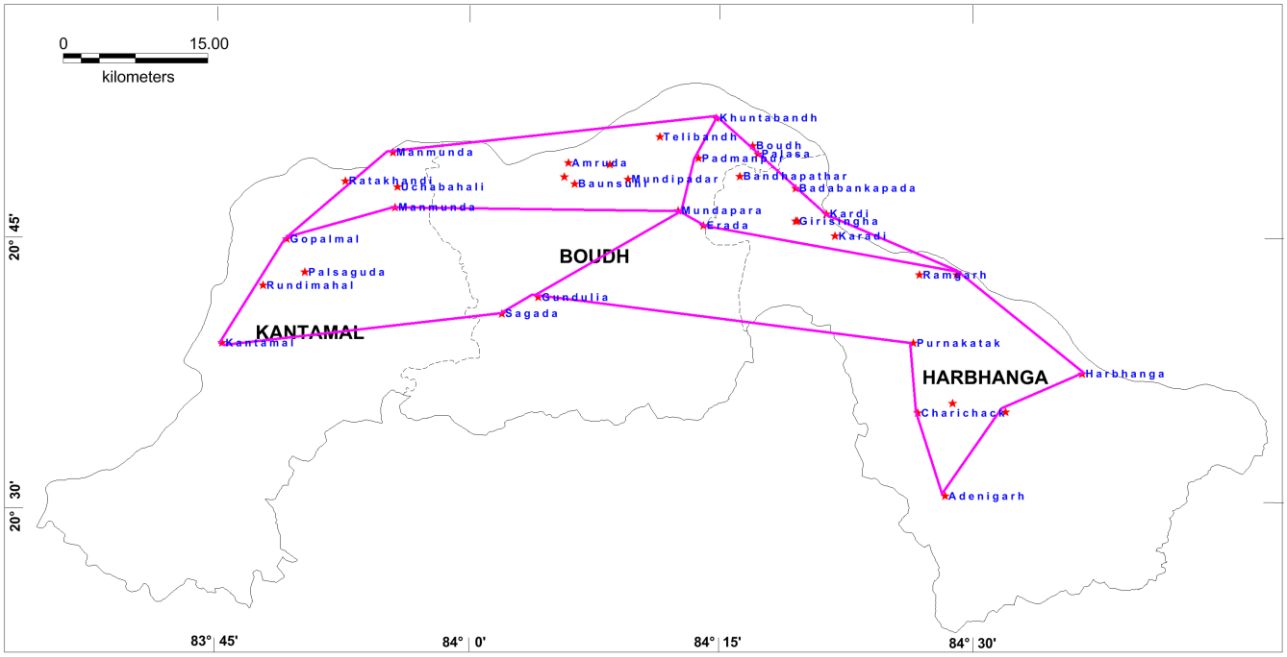


Fig. 3.16: Schematic Aquifer Cross-Section Along I-J in Boudh District.



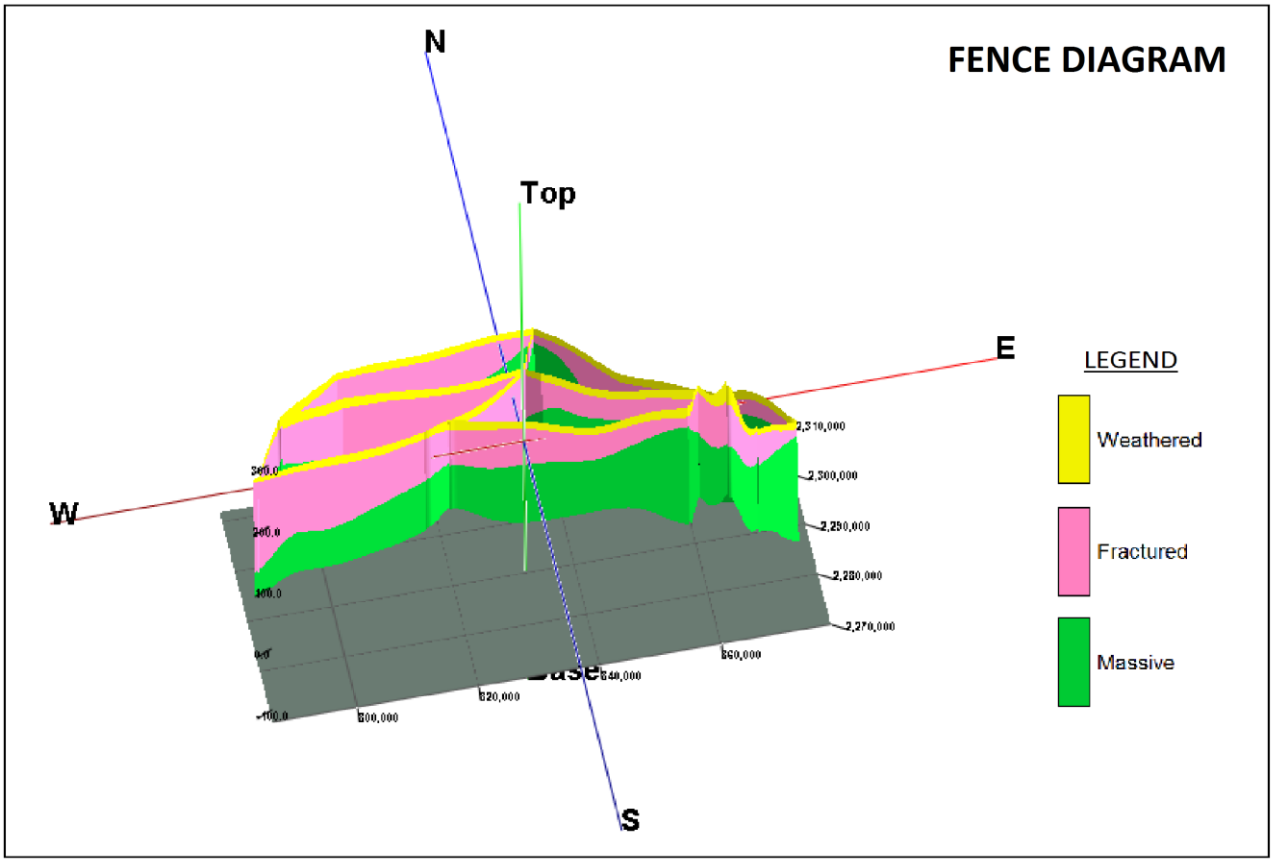


Fig. 3.17: Schematic 3D-Fence Diagram in Boudh District.

4 GROUND WATER RESOURCES

The dynamic ground water resource of the district was jointly carried out in 2017 by Central Ground Water Board (CGWB) and Ground Water Survey and Investigation (GWS&I) adopting the methodology recommended by GEC 2015. The ground water resource can be aquifer wise divided into Dynamic and Static resource. The dynamic resource is the part of resource within the water level fluctuation zone which is also the annual replenishable resource. The resource below the water level fluctuation zone is termed as the In-storage (Static) resource. Mainly the water level fluctuation method was adopted for calculation of recharge. The block-wise resource of the aquifer mapping blocks as on 2017 is given below in **Table 4.1.**

Table 4.1: Dynamic Ground Water Resources of Aquifer-I in Boudh District. (2017)

Sl No	Block	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for Irrigation	Existing Gross Ground Water Draft for domestic & Industrial Supply	Existing Gross Ground Water Draft for all uses	Annual ground water allocation for domestic water supply as on 2025	Net Ground Water Availability for future irrigation development	Stage of Ground Water Development
		(Ham)	(Ham)	(Ham)	(Ham)	(Ham)	(Ham)	(%)
1	Boudh	8004.97	2318.4	542.55	2860.9	586.43	7418.54	35.74
2	Harbhanga	5619.98	1522.4	351.8	1874.2	372.03	5247.95	33.35
3	Kantamal	8468.45	4715.3	429.12	5144.4	490.45	7978	60.75
	Total	**22093.4**	**8556.26**	**1323.47**	**9879.73**	**1448.91**	**20644.49**	**44.72**

The combined net ground water available is 22093.4 Ham and gross annual draft is 9879.73 Ham. The stage of ground water development is minimum for Harbhanga block which is 33.35 %. The highest ground water development is in Kantamal block that is 60.75 % and all the blocks are in Safe category.

The In-storage resources are calculated for Aquifer-I and II separately. However the semi-confined to confined deeper aquifers have linkage to the unconfined aquifer through the fractures and receive continuous recharge. The In-storage ground water resources of

Aquifer-I are given in **Table 4.2** and the total resources of Aquifer-I in **Table 4.3** below.

Table 4.2: In-Storage Ground Water Resources of Aquifer-I in Boudh District.

Sl No	Block	Assessment Area	Bottom Depth of Aquifer	Average Pre-monsoon Water Level	Total Effective Saturated Thickness 5% of (2-3)	Average Specific Yield	In Storage Ground Water Resources [(1)*(4)*(5)]
		(Ha) (1)	(mbgl) (2)	(mbgl) (3)	(m) (4)	(5)	(Ham) (6)
1	Boudh	74377	11.97	6.27	5.7	0.025	10598.72
2	Harbhanga	60354	12.68	5.75	6.93	0.02	8365.06
3	Kantamal	79367	13.46	6.36	7.1	0.025	14087.64
	Total	**214098**					**33051.42**

Table 4.3: Total Ground Water Resources of Aquifer-I in Boudh District. (2017)

Sl No	Block	Dynamic Resource	In Storage Resource	Total Ground Water
1	Boudh	8004.97	10598.72	18603.69
2	Harbhanga	5619.98	8365.06	13985.04
3	Kantamal	8468.45	14087.64	22556.09
	Total	**22093.4**	**33051.42**	**55144.82**

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

Table 4.4: In-Storage Ground Water Resources of Aquifer-II in Boudh District. (2017)

Sl No	Block	Assessment Area (Ha)	Top Depth of Aquifer (mbgl)	Bottom Depth of Aquifer (mbgl)	Total Satu-rated Thickness (m)	Productive Zone (5% of Total Thickness) (m)	Avg. Sp. Yield	In Storage Ground Water Resources (Ham)
		(1)	(2)	(3)	(4)=(3-2)	(5)	(6)	(7)=(1*5*6)
1	Boudh	74377	11.97	200	188.03	9.4	0.015	10487
2	Harbhanga	60354	12.68	200	187.32	9.36	0.015	8474
3	Kantamal	79367	13.46	200	186.54	9.32	0.015	11095
	Total	**214098**						**30056**

5 AQUIFER MANAGEMENT PLAN

The highly diversified occurrence and considerable variations in the availability and utilization of groundwater makes its management a challenging task. Scientific development and management strategy for groundwater has become imperative to avert the looming water crisis. In this context, various issues such as, prioritization of areas for development of groundwater resources vis-a-vis its availability, augmentation of groundwater through rainwater harvesting and artificial recharge, pricing and sectoral allocation of resources and participation of the stakeholders must be considered.

5.1 Ground Water Related Issues

5.1.1 Fluoride in Ground Water

Incidence of high concentration of fluoride in ground water of Boudh district has been detected by CGWB during the past Reappraisal Hydrogeologic Surveyss. Chemical analysis of detailed sampling in Harbhanga block has revealed occurrence of fluoride in and around the Chatrang area. The details of Fluoride contamination is shown in **Table 5.1** and depicted in **Fig. 5.1**.

Table 5.1: Fluoride Point Sourced Villages in Boudh District.

Sl No	Village	Source	Block	Longitude	Latitude	Fluoride
1	Ramgarh	DW	Harbhanga	84.44667	20.72528	1.5
2	Khamarisahi	DW	Boudh	84.00528	20.80333	1.7
3	Khemargarh	DW	Kantamal	83.72250	20.51222	1.9
4	Baragaon	DW	Kantamal	83.76083	20.55833	1.8
5	Kantamal	EW	Kantamal	83.74861	20.64583	1.58
6	Charichhak	DW & BW	Harbhanga	84.42361	20.58333	4.2
7	Baisipada	DW	Harbhanga	84.52134	20.59158	2.3
8	Kharbhuin	DW & BW	Harbhanga	84.53333	20.58889	2.5
9	Chatrang	DW & BW	Harbhanga	84.57917	20.59861	2.9
10	Trilochanpur	DW & BW	Harbhanga	84.58640	20.61060	5.7
11	Bhaliagora	DW & BW	Harbhanga	84.56961	20.61287	1.7
12	Karanjakata	DW	Harbhanga	84.47258	20.59187	2.6
13	Nedisahi	DW & BW	Harbhanga	84.58982	20.59472	1.7
14	Jharkhaman	DW & BW	Harbhanga	84.58977	20.60245	2.6
15	Barajhuli	DW	Harbhanga	84.39639	20.72104	1.5
Note: DW- Dug Well, EW- CGWB Exploratory Well, BW- Bore Well						

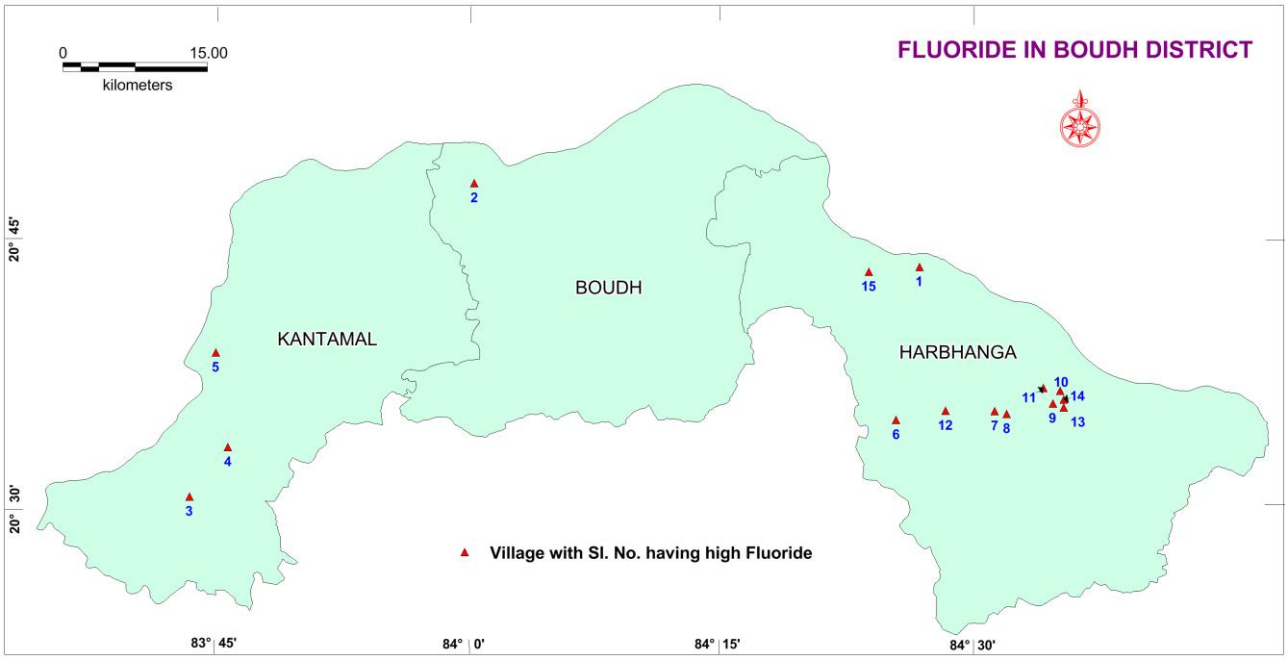


Fig. 5.1: Locations Having High Fluoride Content in Ground Water of Boudh District.

It has been revealed during the previous studies that, high fluoride concentrations are present both in dugwells and borewells in Baispada-Chatrang-Jharkhaman and Chatrang-Bhaliagora-Harbhanga tracts. There are hydrochemically three types of ground water in the area viz. $Ca(HCO_3)_2$ type, $NaHCO_3$ type and Mixed type. $Ca(HCO_3)_2$ type waters are mainly associated with DWs in granite gneiss and rarely in Charnockite. Fluoride in this type of ground water is generally low and less than 1 mg/L. Ground water in dugwells tapping weathered residuum with charnockite is generally of $NaHCO_3$ type which plays an important role in presence of high F^- in this type of water. The Mixed type water resemble both $Ca(HCO_3)_2$ type, $NaHCO_3$ type waters and F^- concentrations from 0.41 to 2.6 mg/L have been observed in these wells. The studies also reveal that the high bicarbonate concentrations are indicative of surface water recharge to the aquifers which while percolating down through the subsurface materials, extract F^- from the fluoride bearing minerals, exchange Ca^{++} with Na^+ ions and finally appear as $NaHCO_3$ type water with high fluoride content.

5.1.2 Under Utilisation of Ground Water Resources

As per the ground water resource estimated jointly by CGWB and State Govt. in 2017, the Net Ground Water Availability of Boudh, Harbhanga and Kantamal blocks are 8004.97, 5619.98 and

8468.45 ham respectively. The stages of ground water development are 35.74, 33.35 and 60.75 % respectively. Thus there is ample scope exists for further ground water development.

5.1.3 Ground Water Problem in Hilly Areas

Boudh district receives adequate rainfall and the normal annual rainfall is 1304 mm. The southern parts of the district are mainly of of hilly terrain and thus high run off zone. They act as recharge zones as well as good reservoir of ground water. Once they get saturated, during monsoon the excess water flows as run off and base flow. During the post-monsoon period, the thin weathered zones soon loose the entire storage water due to base flow. So there is scarcity of water in these areas in lean and summer season.

5.1.4 Less Productive Deeper Aquifer

The exploratory drilling in the district reveals that the deep fractured aquifer is less productive. Many of the borewells drilled in the district have very poor discharge. The failure rate of borewells is very high in the Easternghat Group of rocks like the Charnockites and Khondalites. Granite gneiss are comparatively better for laying bore wells.

5.1.5 Depleted Water Level in Phreatic Aquifer

Ground water level in the phreatic aquifer is found to be deep in many parts of Boudh district. Depth to water level during pre- and post-monsoon periods is deeper (>5m bgl) in northern part of Kantamal block in between Manmunda, Kantamal and Mardol and southern part between Khuntigora-Baragaon-Ghantapada. The western parts of Boudh block covering Sundipadar-Sariapali-Gundulia-Usbilika-Mangalmunda have deeper water level (>5mbgl) during pre-monsoon. Area between Purunakatak-Charichhak-Chatrang in Harbhanga block has deeper water level (>7.5mbgl). The seasonal fluctuation in some of the villages in this area indicates inadequate monsoon recharge which face problems of water scarcity round the year.

5.2 Aquifer Management Plan

5.2.1 Management Plan for Higher Concentration of Fluoride

Though there are fluoride in many of the villages as discussed earlier, they are mostly found in shallow aquifers (dugwells) and medium deep borewells mostly drilled by the state govt. agencies.

The occurrence of fluoride are point specific and there are alternate sources available. For example, the deep borewells drilled by CGWB at Purunakatak, Charichhak and Harbhanga show that the concentration of fluoride are 1.1, 0.99 and 0.86 mg/L respectively. Hence deeper aquifers form a better alternative source for the domestic use in this area.

5.2.2 Management Plan for Under-Utilisation of Ground Water

Demand and Supply Scenario: The water demand and supply scenario of the district is depicted in **Table 5.2** where the demand figures were projected for year 2020 and the supply represents the existing water supply status.

Table 5.2: Water Demand and Supply Scenario in Boudh District.

Block	Existing Water Availability (MCM)			Water Demand (MCM)		Water Gap (MCM)	
	Surface Water	Ground Water	Total	Present	Projected (2020)	Present	Projected (2020)
Boudh	370	76.9	446.9	3090	3511	2643	3064
Harbhanga	460	135.3	595.3	2650	3011	2054	2415
Kantamal	380	66.1	446.1	2750	3120	2303	2673
Total	**1210**	**278.3**	**1488.3**	**8490**	**9642**	**7000**	**8152**

Source: District Irrigation Plan of Boudh, DLIC Boudh, March 2016

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

For the supply side intervention, further development of ground water resource is possible as there is sufficient scope for this is available in the district as the present ground water development ranges from 33.35 % to 60.75 % in the district. The quantum of water available for extraction from the phreatic aquifer is thus calculated, keeping the percentage of ground water development within 60%. The same is shown in the **Table 5.3**.

Table 5.3: Ground Water Development Potential of Boudh District.

Block	Net Ground Water Availability (Ham)	Stage of Ground Water Development (% in 2017)	Present Ground Water Draft (Ham)	Ground Water draft at 60% Stage of development (Ham) (1)*0.6	Surplus Ground Water at Present Stage of development (Ham) (4)-(3)	Number of BW/ STW Recommended in Each block (assuming unit draft as 2.21 ham per structure per year) 50%	Number of DW Recommended in Each block(assuming unit draft as 0.26 ham per structure per year) 50%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Boudh	8004.97	35.74	2860.97	4802.98	1942.01	439	3735
Harbhanga	5619.98	33.35	1874.28	3371.99	1497.71	339	2880
Kantamal	8468.45	60.75	5144.48	-	-	-	-

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

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

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

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

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

5.2.3 Management Plan for Scarcity of Water in Hilly Areas

Due to uneven and hilly terrain and lower ground water recharge and storage capacity, there are many areas where the phreatic aquifer quickly desaturates causing water scarcity during non-monsoon periods. To enhance the ground water availability, suitable measures for augmentation of monsoon recharge, should be taken up. In the foot hill regions, contour trenching alongwith gabion structures should be constructed to arrest the surface runoff and improve rainfall recharge. The details of the structures proposed is discussed in detail under heading **5.2.5**.

5.2.4 Management Plan for Less Productive Deeper Aquifer

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

5.2.5 Management Plan for Depleted Water Level in Phreatic Aquifer

The problem of water level depletion in the phreatic aquifers can be addressed through artificial recharge and through various water conservation structures. As the deeper aquifer is usually less productive, injection wells are less feasible. Rather surface spreading techniques will be useful in these areas. The Main Canals of Bagh Barrage Project runs through the valley in between the southern hills and Mahanadi at the northern boundary of the district. During the canal running days the phreatic aquifer gets adequate recharge from the canal water. Thus the foot hill areas to the south of the Main Canals are suitable areas for construction of recharge structures such as percolation tanks. Similarly 2nd and 3rd order drainages are suitable for the construction of check dams. For the mitigation of deeper water level areas in the district, the following measures can be taken up:

1. Contour trenching, staggered trenching and gully plugging in foot-hill areas.
2. Construction of farm ponds and renovation of existing water bodies.
3. Construction of 20 percolation tanks, 52 checkdams can be done.

The proposed sites for these structures are shown in **Fig. 5.2**.

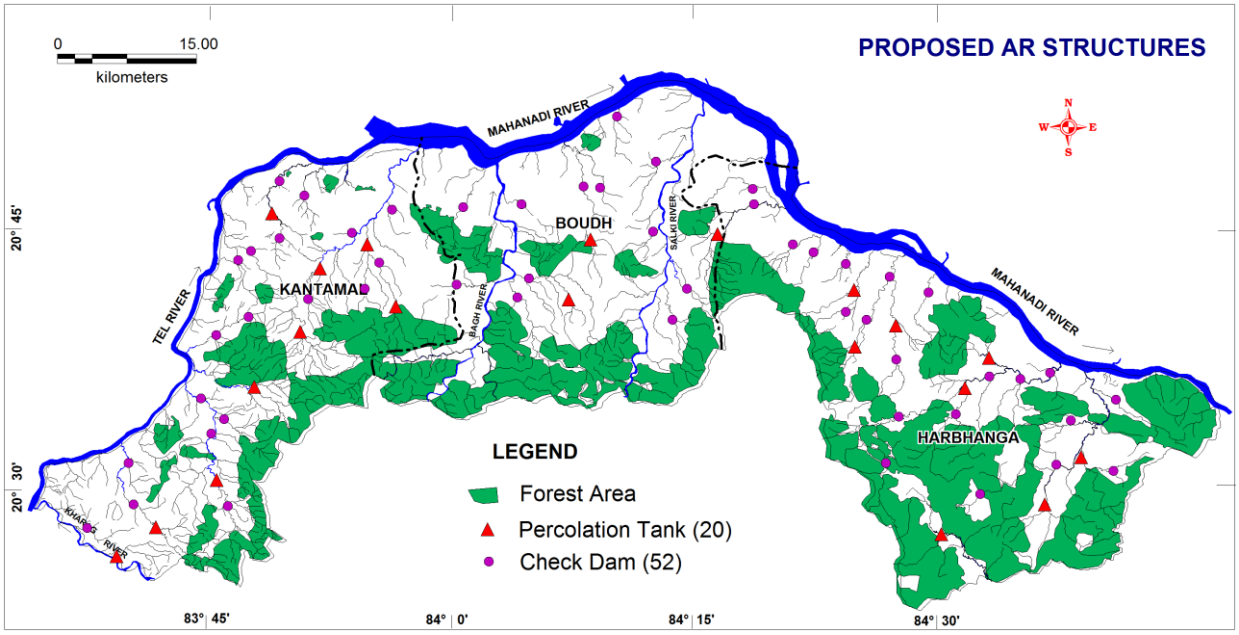


Fig. 5.2: Proposed sites for Artificial Recharge Structures.

6 SUMMARY AND RECOMMENDATIONS

6.1 Summary

National Aquifer Mapping Programme (NAQUIM) was taken up for detailed hydrogeological investigation, data-gap analysis and Aquifer Mapping and Management in the tribal district of Boudh, covering the blocks of Boudh, Harbhanga and Kantamal covering an area of 1800 sq. km., during the period 2018-2019. The following are the summarised details.

1 The Boudh district lies between 83°34'16" E and 84°48'20" E longitudes and 20°23'02" N and 20°52'45" N latitudes covering 3098 sq. Km. under the SOI Toposheet Numbers 64 P/10, 11, 13, 14, 15; 73 D/1, 2, 5, 6, 7, 10 and 11. The mappable area under NAQUIM is 1800 sq. Km. This study area was taken up after excluding the hilly areas.

2 The average rainfall of the district is 1304.3 mm. Normal rainfall has been received in 57% to 73 % of the years during the period 1988-2017.

3 The area covered by forest in the district is 59% of total geographical area of 3098 km^2. The net area sown is 27.5% with cropping intensity of 155.8 %.

4 Three types of soil are found in the district viz. Inceptisols, Vertisols and Entisols.

5 The total cropped area is 132780 Ha out of which 35% (46570 Ha) is irrigated and rest 65% area are rainfed.

6 Salki Irrigation Project is the only Major Irrigation Project with designed irrigation potential of 21650 Ha in Khariff and 4050 Ha in Rabi in 252 villages in Boudh and Harbhanga Blocks. Bagh Barrage is the only Medium Irrigation Project with irrigation potential of 12834 Ha in Kantamal and Boudh Block. There are total 72 MIPs with irrigation potential of 12843 Ha.

7 The district is underlain by Easternghat suite of rocks, Lower Gondwana formations and Alluvial formations.

8 The crystalline formations like Charnockite, Khondalite and Granite Gneiss are classified under Consolidated water bearing formations. Here ground water exists in unconfined

conditions in the weathered mantle and in semi-confined to confined conditions in deeper fractured aquifers. The felspathic sandstones, conglomerate and shale constitute the Semi-consolidated water bearing formations. The alluvium on major river courses and valley fill deposits are classified under Unconsolidated formations.

9 CGWB has constructed 36 EWs and 9 OWs during the ground water exploration programme. For the monitoring of ground water level and quality CGWB has established 58 National Hydrograph Network Stations in the district.

10 Depth to water level in pre-monsoon period (May 2018) varies from 2.95 to 9.05 mbgl , the average being 6.13 m bgl. Depth to water level in post-monsoon period (Nov 2018) varies from 0.45 to 6.73 mbgl, the average being 2.80 m bgl. The seasonal fluctuation of ground water table between pre and post monsoon period in the study area varies from 0.75 to 6.3 m, the average being 3.33 m. The decadal water level trend analysis indicates that out of 32 stations, 20 (62.5%) show falling trend and the rest (12 stations & 37.5%) show rising trend in both the seasons.

11 The chemical quality of ground water both from shallow and deeper aquifers are good and can be suitably utilised for all purposes. Fluoride contamination has been detected in the district and the area between Harbhanga-Chatrang-Charichhak in harbhanga block studied in detail which revealed that higher fluoride concentration is restricted to shallow aquifers tapped by dugwells and shallow bore/tubewells. Deeper aquifer can provide alternative fluoride free sources of water.

12 The estimated dynamic ground water resource is 22093.4 Ham and the stages of development of ground water range from 33.35 to 60.75 %.The ground water development is most in the Kantamal block.

6.2 RECOMMENDATIONS

For a sustainable ground water development in the area, a systematic, economically sound and politically feasible framework for groundwater management is required. Considering the local physiographical and hydrogeological set up the following ground water management strategy is suggested.

1 Proper guidance has to to be provided to the farmers siting proper ground water structure in favourable hydrogeological setting.

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

3 For the irrigation requirement in relatively water deficient areas, efficient irrigation techniques such as drip and sprinkler should be practiced.

4 The occurrence of fluoride are point specific and there are alternate sources available. Deeper aquifers form a better alternative source for the domestic use in this area.

5 In the foot hill regions, contour trenching, staggered trenching along with gabion structures should be constructed to arrest the surface runoff and improve rainfall recharge

6 Artificial recharge projects may be taken up in the district especially in hard rock areas for augmentation of ground water resources through construction of percolation tanks, check dams, farm ponds.

7 Rain water harvesting should be adopted in all govt. and public buildings.

8 The farmers should be educated through agricultural extension services for adopting suitable cropping patterns for optimal utilization of available ground water and surface water resources.

9 Industrial waste waters and effluents should be treated and disposed off properly under an effective monitoring mechanism.

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर
South Eastern Region, Bhubaneswar

Phone 0674-2350342
Fax 0674-2350332
E-Mail:rdser-cgwb@nic.in
Website www.cgwb.gov.in