केंद्रीय भूमि जल बोर्ड
जल शक्ति मंत्रालय
जलसंसाधन, नदीविकास और गंगा संरक्षण विभाग
भारत सरकार

Central Ground Water Board
Ministry of Jal Shakti

Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

AQUIFER MAPPING REPORT
ANGUL DISTRICT, ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर
South Eastern Region
Bhubaneswar

Government of India
MINISTRY OF JALSHAKTI

NATIONAL AQUIFER MAPPING & MANAGEMENT

HYDROGEOLOGICAL FRAMEWORK, GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN IN ANGUL DISTRICT, ODISHA (REVISED)

Shri D.N. Mandal
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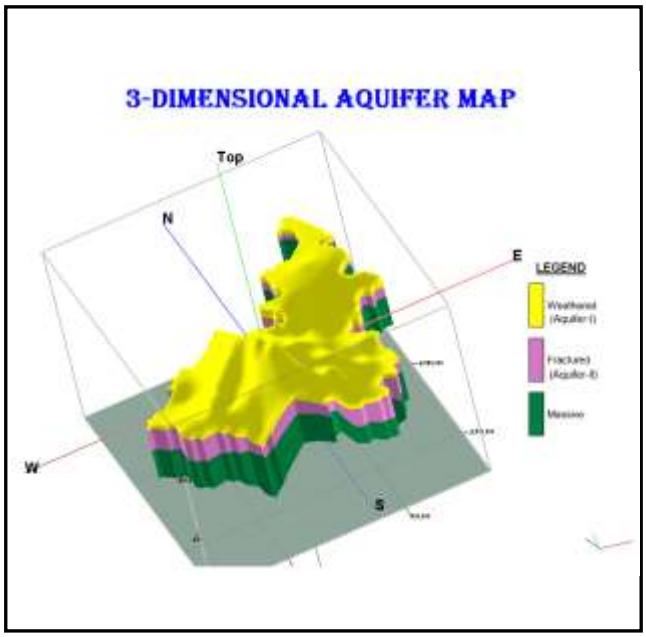

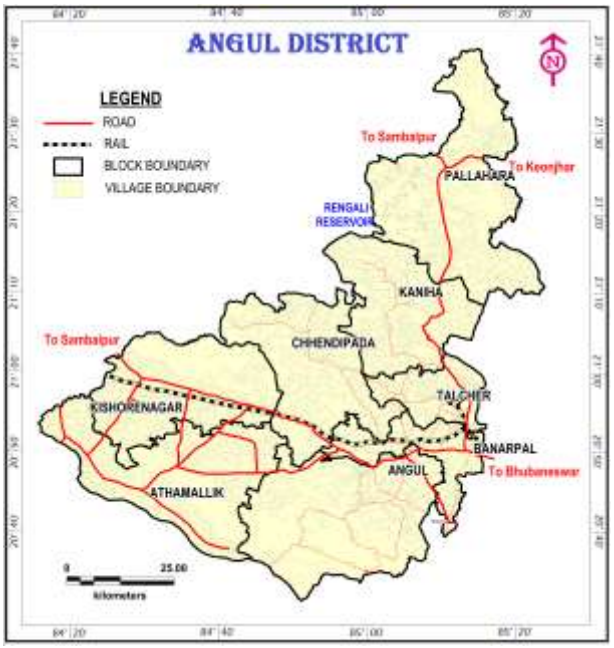

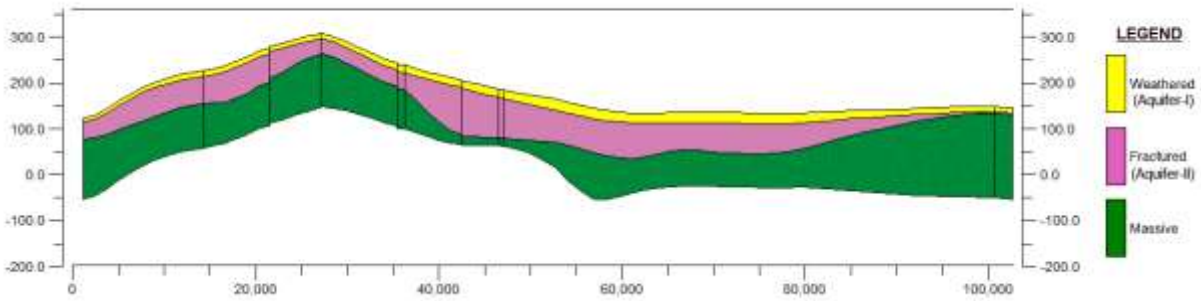

CENTRAL GROUND WATER BOARD
South Eastern Region, Bhubaneswar
March, 2020

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ANGUL DISTRICT AT A GLANCE

I. GENERAL PARTICULARS

(a) Location	:	20°31′ to 21°40′ North Latitudes 84° 15′ to 85° 23′ East Longitudes
(b) Area	:	**6375 Km²**
(c) District Head quarters	:	**Angul**
(d) Subdivision	:	**4** – *1. Angul* *2. Athmalik* *3. Talcher* *4. Pallahara*
(e)Tehsils	:	**8**
(f) Blocks	:	**8** *Angul* *Kaniha* *Athmalik* *Kishorenagar* *Banarpal* *Pallahara* *Chhendipada* *Talcher*
(g) Towns *(including 15 Census Towns)*	:	18– Angul (M), Talcher (M), Athmalik (NAC), Pallahara, Rengali Dam Project, Tipo, Danara, Dera Colliery, Ghantapada, Talcher Thermal Power Station (TTPS), Bada Jorada, Fertilizer Corp. of India (FCI), NALCO, Kandasar, Kulad, Budhapanka, Gotmara and Nuahata.
(h) Municipalities	:	2 – Angul, Talcher
(i) N.A.C.s	:	1 – Athmalik
(j) Police Stations	:	23
(k) Gram Panchayats	:	209
(l) Villages	:	Total : 1871 *Inhabited : 1654* *Uninhabited : 217*
(m) Parliamentary Constituency	:	Comes under Dhenkanal
(n) Assembly Constituency	:	4 - Angul, Talcher, Chhendipada, Pallahara
(g) Population *(as per Census 2011)*	:	Total : 12,73,821 *Male : 6,55,718* *Female : 6,18,103* *Sex Ratio : 943* *Density : 200 / Km²* *Growth : 14.05 % (Decadal Growth Rate)*

II CLIMATOLOGY

(a) Normal Annual Rainfall	:	1401.9 mm
(b) Average Annual Rainfall	:	1302.5 mm *(1995 – 2014)*
(b) Temperature (Mean Daily)	:	Maximum – 44°C Minimum – 12°C
(c) Relative humidity	:	30 % (Summer) 82 % (Rainy)

III LAND USE

(a) Forest Land	:	2,86,934 Ha
(b) Total Wasteland	:	37,321 Ha
(c) Barren & Non-Cultivable Land	:	14,401 Ha
(d) Permanent Pastures & Grazing Land	:	16,754 Ha

	(e) Misc. Tree, Crop & Groves Land	:	5,575 Ha
	(f) Cultivable Waste	:	17,882 Ha
	(g) Other Fallows	:	31,130 Ha
	(h) Current Fallows	:	36,635 Ha
	(i) Net Sown Area	:	2,59,460 Ha

			Kharif (Ha)	**Rabi (Ha)**
IV	**IRRIGATION POTENTIAL CREATED** *(source -wise)*			
	(a) Major& Medium irrigation Projects (Canal)	:	11,305	4000
	(b) MIP (Canal)	:	17,207	212
	(c) MIP (Lift, Diversion)	:	8,302	6,434
	(d) Water Bodies, RWH	:	532	115
	(e) Perennial Water Sources	:	46274	31215

V EXPLORATORY WELLS

Bore wells drilled by CGWB under Normal Exploration Programme	:	***Exploratory Wells***	***:***	**110**
		Observation Wells	***:***	**15**
		Piezometers	***:***	**5**

VI DYNAMIC GROUND WATER RESOURCES(As on 31.03.2017)

a) Annual ground water resource assessed	:	54,699 ham
b) Annual ground water draft (for all uses)	:	24,825 ham
c) Net ground water resource for future irrigation& industrial use	:	53,107 ham

VII Stage of ground water development : 45.38 %

VIII Ground Water Issues

Ground Water Troughs (Due to coal Mine dewatering): 1 – Talcher – Patch from Talcher to Dera

Water Quality Issues

Fluoride

In isolated villages

Shallowaquifer- Badabahal (2.32), Bantala(2.23), Gopalprasad (2.21), Kuio (1.2), Sendhogram (1.3 & 3.8), Samal (1.7), Rengali (1.4) and Bhogabereni (1.07)

Deeper aquifer-Korada (1.7), Santrapur(1.85), Thakurgarh (1.24), Ambsarmunda (2.01), Talamaliha (3.1), Anandpur (2.04) and Kundajhari (1.38)

Electrical Conductivity

Bhogaberini (4900), Salagadia(4007) Karnapur(2680) Derjang (2365), Tentulei (2210), Chhelia (2150), Ekagharia (2058), Bantala (2050) and Badabahal (2000)

FOREWORD

Angul district is centrally located in the state of the Odisha. The district is endowed with vast natural resources and is one of the agriculturally developed district of Odisha. The district is underlain by hard crystalline formations in north and south separated by central part with semi-consolidated Gondwana formations. Due to abundance of coal seams, the area is industrially developing very rapidly leading to stress on the quantity and quality of water resource in the district. The river Brahmani and its tributaries are the main surface water sources which provide water to the industries. The agrarian development of the district can be boosted by tapping this enormous ground water resources through dug wells, medium deep bore wells.

The present stage of ground water development is only 45.38 %, leaving a vast scope for future ground water development in the district. Ground water irrigation practices can insure increased agricultural production by enhancing the area irrigated and scope of irrigation. Apart from irrigation, drinking water scarcity can also be mitigated through judicious utilization of ground water.

With the large scale coal mining, rapid ground water decline has been observed in pockets of Talcher, Banarpal and Chhendipada Blocks. The Gondwana sandstone aquifer is hard &compact and is of very poor yield of ground water. On the other hand, granitic hardrock aquifers have water yielding fracture zones and have average success rate with 2-5 lps of discharge.

Due to wide variation in hydrogeological set up in the district, the occurrence and distribution of aquifers are non-uniform and so also their yielding properties. Proper site selection holds the key to the success of sustainable ground water development, which requires a thorough knowledge of hydrogeology and pattern of water usage in the terrain.

Based on the available data and the earlier hydrogeological studies taken up in 6 blocks of the district viz. Angul, Banarpal, Chhendipada, Kaniha, Pallahara and Talcher covering 3885.4 Sq. Km., an attempt has been made in this report to compile all relevant information, such as hydrogeological, agriculture, irrigation, land use, rain fall, chemical quality of water and other collateral data. **Shri D.N. Mandal, Scientist-'D'**, have compiled and prepared the present report on**"Hydrogeological Framework, Ground Water Development Prospects & Aquifer Management Plan in Parts ofAngul, Odisha"**. His sincere efforts in preparation of the report will no doubt be very useful and benefit the state. It is hoped that, it will be of immense help to different ground water user agencies, administrators and planners in preparation of ground water development plans and will be a handy tool in effective management of ground water resources in the district.

Place : Bhubaneswar
Date : 5th March 2020

(P.K Mohapatra)
Regional Director

EXECUTIVE SUMMARY

National Aquifer Mapping & Management(NAQUIM) in the District of Angul was undertaken during the XIIth Plan Period of 2012 – 2017. The district has a geographical area of 6375 Sq Kms and is divided into 8 Community Development Blocks namely Angul, Athmalik, Banarpal, Chhendipada, Kaniha, Kishorenagar, Pallahara and Talcher. The district is further subdivided into 209 Gram Panchayats comprising of 1871 villages in the rural front and on the urban side, it comprises of 2 Municipalities, 1 Notified Area Council and 15 Census Towns. Out of the total geographic area excluding the hilly and recharge non-worthy area, about 4283 km^2 area was takenup for study under NAQUIM. As per the Census Data of 2011, the total population of the District is 12,73,821. Of this, the Male population is 6,55,718 and the female population is 6,18,103. This gives an overall sex ratio of 943 females per 1000 males. The decadal growth rate is pegged at 14.05 % with a population density of 200 persons per square kilometres.

The district enjoys humid sub-tropical climate, where the peak temperature of the warmest month is over 44°C and at least 4 months the temperature remains near 40° C. Southwest monsoon is the principal source of precipitation in the district. The normal annual rainfall of the district is 1401.9 mm, out of which about 85% is received during monsoon season (mid June to mid October). The month of July and August gets the heaviest rainfall of the year, though rainfall is not very regular throughout the season, but fairly uniform throughout the district. There are on the average 60 – 85 rainy days in a year. Besides, the relative humidity varies between 30 to 82 %.

The land elevation varies from as low as 50 m above mean sea level in the southern part to as high as about 800 m above mean sea level in the northern and southern part. In between a major part covering more than 50% of the geographical area is having relatively plain to undulating land with elevation within the range of 50 – 200 metres above mean sea level.

The drainage in the area is controlled by two major rivers Brahmani and Mahanadi and their tributaries like Tikra-Jhor, Nandira-Jhor, Gambhari, Singhara-Jhor, Sindol-Jhor, Karandi-Jhor etc are the source of water supply and they act as the drainage system for all the

EXECUTIVE SUMMARY

industrial effluents / sewage discharge from the major industries located in Angul-Banarpal-Talcher area. Most of these rivers are having easterly to south-easterly flow direction.

Three main types of soil groups (USDA Soil Classification System) can be observed in the Angul District. These are Alfisols, Ultisols and Vertisols. The agriculture in the district is primarily rain fed because of inadequate irrigation facility. Area irrigated through all sources is only 22% during kharif season and 14% during rabi season as per the available data. The district has 259460 Ha of cultivable land. The total irrigation potential is 87423Ha. Most of the cultivated area of the district is covered with double crops like kulthi (kolath), bengalgram (harad), coriander, field pea; and vegetables are taken after harvest of ground nut and early kharif paddy. The kharif crops include paddy, maize, ragi, small millets, arhar, biri, mung, ground nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, rabi crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

There are a number of coal mines, large scale Industrial establishments and factories in and around the towns Angul, Banarpal, Chhendipada, Kaniha and Talcher. Apart from these, there are a number of small and medium scale agro based industries and drinking water packaging industries, in these area.

The major part of the district is underlain by hard crystalline rocks like granite, granite gneiss, khondalite, quartzite, phyllite, charnockite, mica schist, ultrabasics, which are devoid of any primary porosity and hence when weathered and fractured, secondary porosity is developed. The semiconsolidated Gondwana sandstone forms moderately good aquifer when weathered and fractured. The recent alluvium, which occurs in limited patches along the rivers and streams, sustains very good yield. Since major part of the district is underlain by hard rocks of diverse lithological compositions and structures, the water-bearing properties of the formations vary widely. Ground water occurs under water table conditions in shallow aquifers and under semi-confined to confined conditions in deeper aquifers. Hydrogeologically the major hydrogeological units in the state can be divided into three

EXECUTIVE SUMMARY

categories: i) consolidated formations, ii) semi-consolidated formations and iii) unconsolidated formations.

Water level measurements were carried out using the existing 54 National Hydrographs Network stations as well as by establishing a dedicated network of Key Wells. This involved measurement of water levels of both the phreatic aquifer through dug wells and measurement of Piezometric surface through the existing piezometers.

During the Pre-Monsoon season, the depth to water level in major part of the district remained within 5 – 7 metres below ground level. During the Post-Monsoon season, the depth to water level in major part of the district remained within 2 – 5 metres below ground level. The fluctuation in the Pre & Post Monsoon Water Level in the Phreatic Aquifer shows that there is a distinct rise in water level of 0 - 6 metres in most part of the district. Perusal of the data and hydrographs reveal that in major part of the district, the phreatic aquifer does not show any significant decline.

The long-term trend of water levels for pre-monsoon and post-monsoon periods for the last ten years (2006-15) have been computed. The long term water level data of 42 National Hydrograph Network Stations (NHNS) CGWB has been utilised. In the study area, rise in pre-monsoon water levels trend has been recorded at 24 stations while falling trend was observed in 15 stations. The falling water level trend has been observed in the areas surrounding Talchir coalfields and central and southern part of Banarpal block. The rest of the area is showing rise in water level trend. In the study area, post monsoon rise in water levels trend has been recorded at 16 stations while falling trend was observed in 25 stations. In post-monsoon, the falling water level trend has been observed in central part from Kaniha to Angul block however rising trend has been observed in southern part of Chhendipada block and eastern parts of Angul and Banarpal block and western part of Athamalik and Kishorenagar blocks.

A perusal of the water quality analysis data reveals that majority of the wells in both phreatic and deeper aquifers have potable water. However, high EC value ranging from 2000-4000 μS/cm has been observed in isolated villages mostly in Angul, Banarpal and Talcher

EXECUTIVE SUMMARY

blocks. Similarly there are isolated villages where higher F value was recorded in either or both the shallow and deep aquifers.

The 3D Disposition of the Aquifer System Map of Angul District clearly depicts a 3 layered aquifer system in the area. A combined aquifer map have been prepared. The 3 layered aquifer system have a top layer (Aquifer-I) of weathered rock layer constituting the phreatic aquifer. The 2nd layer from the top (Aquifer-II) is jointed and fractured aquifer layer characterising a semi-confined to confined aquifer. The bottom most 3rd layer is massive rock layer having minimum primary as well as secondary porosity.

Most of the blocks of the district have low to medium groundwater resource utilization. Talcher is the block with highest ground water utilization of 68.8% in the district. Pallahara is the block with lowest ground water utilization of 34.7% in the district. Net ground water availability is assessed to be 54,699ham and the gross annual draft for domestic, industrial, and irrigation uses is 24,825ham. The average stage of ground water development is 45.38%. All the 8 blocks have been classified as SAFE. The fresh in-storage resource in the Aquifer-I is 1,78,193ham and in Aquifer-II is 39,939 ham. Thus the total resource of Aquifer-I is 1,04,223ham and the total ground water resource including both Dynamic and In-storage resource is 272831ham.

A synopsis of data and maps reveals that major ground water related issues can be clubbed under the following heads – (1) Presence of Ground Water Troughs in both pre & post monsoon season in the coal mining area mainly near Talcher coalfield (2) Presence of High Fluoride in shallow as well as deeper aquifers in many villages.

It was ensured that the distinct ground water trough is Primarily due to heavy water pumpage for coal mine dewatering. The aquifer management strategy includes recommendation for recycling and reuse of dewatered mine water for drinking, water supply and Industrial or irrigation purpose and stop release of discharged to local drainage system and construction of water injection wells around the mining area to arrest the spreading of the cone of depression surround the mines.

EXECUTIVE SUMMARY

The occurrence of fluoride in the ground water is mostly geogenic and some may be from industrial contamination. The strategy for management in the fluoride affected villagesto ensure the marking of floride bearing ground water extraction structures to prohibit for human consumption and providing alternative safe source of ground water in the affected villages.

The ground water resource of the district is mostly untapped. The cumulative ground water development is mere 45.38%. There exists sufficient scope for development of this resource in the area for the overall socioeconomic development. The Chhendipada block has potential pheatic and fractured aquifer especially in the area occupied by the Kamthi formation, however construction of borewells is problematic in the area due to high instances of collapsible formation and lack of area specific suitable drilling equipments.

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PART-I

AQUIFER MANAGEMENT PLAN IN ANGUL DISTRICT, ODISHA

(4283 Sq Km)

1 INTRODUCTION

1.1 Objective

Central Ground water Board has taken up National Aquifer Mapping (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 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 study was carried out in Angul district in Odisha, which include Talcher Coal Fields and one of the important industrial clusters in Odisha.

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. The selected blocks of Angul district were included under NAQUIM, because it forms a part of Gondwana sedimentary terrain with cluster of coal based industries. The main issues and challenges are the effect on ground water by waste water from towns and effluents generated from the diverse industries which has already impacted the surface water quality. Apart from that, from the ground water point of view, other problems exist in the area such as limited aquifer thickness of unconfined aquifer, poor yield from deeper aquifers, failure of borewells due to collapsible formation, fluoride in ground water etc.

To resolve such issues, 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 dispositions 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

1.3.1 Approach and Working Methodology: Multi-disciplinary approach involving geological, geophysical, hydrological, hydrogeological and hydro-geochemical survey would be carried out in topo-sheet scale (1:50,000) to meet the aim and objectives listed above. GIS would be used to prepare the maps.

1.3.2 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. Also, Exploration data which have been carried out by CGWB and State agencies and by local administrations shall be collected and compiled to identify the data gaps in the study area. After the Data Compilation all the data were Integrated and Analysed.

1.3.3 Hydrogeological Investigations: Review of background information will lead the study teams to the 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 will be established and monitoring will be carried out. Village wise well inventory and data collection is to be carried out to strengthen the data base. Exploratory wells and Observation wells will be constructed, Litholog samples of aquifer materials and ground waters samples will be collected. Aquifer Performance tests will be carried out to determine the aquifer parameters. The analysis of the data will be carried out for construct maps.

1.3.4 Geo -hydro chemical Investigations: Water Samples will be collected, analyzed and interpreted to bring out ground water quality scenario of the study area.

1.3.5 Geophysical Investigations: Geophysical studies would be carried to assist the hydrogeological survey in aquifer mapping/geometry.

1.3.6 Generation of relevant thematic layers using GIS:

- Drainage
- Geomorphology
- Aquifer disposition
- Geology
- Land use and land cover
- Ground Water Quality
- Soil
- Hydrogeology

1.3.7 Development of aquifer wise management plan: Collaborative studies that combine geologic, hydrogeological, hydrological, geochemical and geophysical information are to be integrated. Determining aquifer potential for effective, development and management are cantered on for long-term sustainable development of aquifers.

1.4 Study area

During XII five year plan (2012-2017), the National Aquifer Mapping Programme (NAQUIM) was taken up for detailed hydrogeological investigation, data-gap analysis and Aquifer Mapping in six blocks of Angul district namely Angul, Banarpal, Chhendipada, Kaniha, Pallahara and Talcher covering an area of 2974 sq. km., during the period 2012-2017. The remaining two blocks i.e. Athamallik and Kishorenagar covering 1309 sq. km. were taken up during AAP 2018-19. The total geographic area of Angul district is 6375 sq. Km and the area covered under NAQUIM is 4283 sq. Km covering SOI toposheets 73C/12,15,16, 73D/5,6,9,10,13,14, 73G/2,3,4,6,7,8 and 73H/1&2. The block-wise areas of NAQUIM is described in **Table-1.1**. The index map of the study area is presented in **Fig.1.1a** while an administrative map is presented as **Fig. 1.1b.**

Table-1.1: Block-wise Areas Covered Under NAQUIM.

Sl No.	Block	Geographic Area (Sq. Km)	Hilly Area (Sq. Km)	Mappable Area (Sq.Km)
1	Angul	1146	654	492
2	Athamallik	996	284	712
3	Banarpal	357	21	336
4	Chhendipada	850	242	608
5	Kaniha	723	270	453
6	Kishorenagar	852	255	597
7	Pallahara	1163	366	797
8	Talcher	288	0	288
	Total	**6375**	**2092**	**4283**

1.5 Data Adequacy and Data Gap Analysis:

The available data of the Exploratory wells drilled by Central Ground Water Board, Southeastern Region, Bhubaneswar, Geophysical Survey carried out in the area, Ground water monitoring stations and ground water quality stations monitored by Central Ground Water Board were compiled and analysed for adequacy of the same for the aquifer mapping studies. The data adequacy and data gap analysis was carried out for each of the quadrant of falling in the study area mainly in respect of following primary and essential data requirements: **1. Exploratory Wells** **2. GeophysicalSurveys**

3. Ground Water Monitoring and Ground Water Quality

The details of data gap analysis are given in **Table-1.2**.

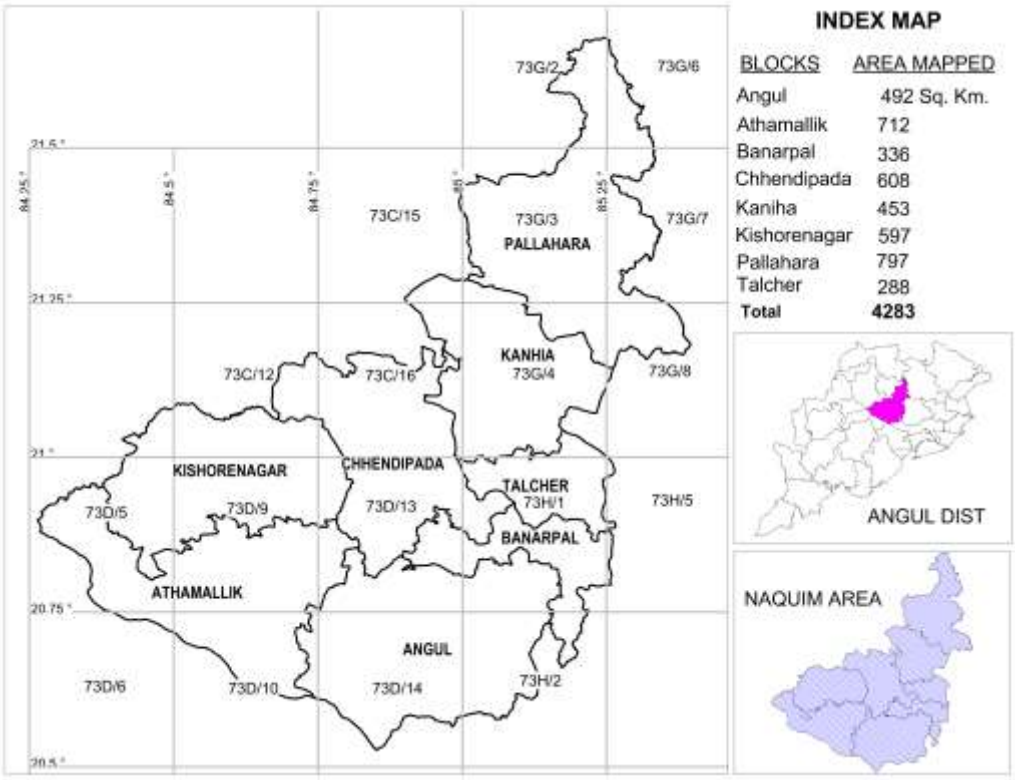


Fig. 1.1a: Index Map of Study Area Under NAQUIM in Angul District.

Fig. 1.1b: Administrative Map of Angul District.

Table-1.2: Data-Gap Analysis for Aquifer Mapping in Angul District.

Block with area in sq. km	No. of Additional EW required					No. of Additional VES/TEM required				Nos of Additional water level monitoring stations required					Nos of additional water quality stations required					Remarks
	Present Status	Total Reqd.	Aq-I	Aq-II	Aq-III	Total Reqd	Aq-I	Aq-II	Aq-III	Present Status	Total Reqd	Aq-I	Aq-II	Aq-III	Present Status	Total Reqd	Aq-I	Aq-II	Aq-III	
Chendipada (839 sq.km)	Total=8 Aq-I=4 Aq-II=0 Aq-III=0 Aq(cum)=4 T (value)=3 (all cum)	10	4	3	3	30	10	10	10	Total=9 Dw-9 Pz(Aq-I)=-0 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	75	19	28	28	Total=5 DW=5 Aq-I=0 Aq-II=0 Aq-III=0 Aq(cum)=0	117	37	40	40	
Angul (998 sq.km)	Total=9 Aq-I=4 Aq-II=2 Aq-III=0 Aq(cum)=3 T =2(A2-1, cum-1)	12	5	5	2	35	15	10	10	Total=13 Dw-8 Pz(Aq-I)=-5 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	86	20	33	33	Total=12 Dw-9 Pz(Aq-I)=-0 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=3	143	47	48	48	
Banarpal (351 sq.km)	Total=11 Aq-I=6 Aq-II=3 Aq-III=0 Aq(cum)=2 T =1(A1-1)	nil	0	0	0	12	4	4	4	Total=9 Dw-9 Pz(Aq-I)=-0 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	27	3	12	12	Total=9 Dw-7 Pz(Aq-I)=-0 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=2	36	6	16	14	
Talcher (237 sq.km)	Total=7 Aq-I=4 Aq-II=1 Aq-III=0 Aq(cum)=3 T =4 (A1-3,cum-1)	1	0	0	1	8	3	3	2	Total=7 Dw-6 Pz(Aq-I)=-1 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	17	1	8	8	Total=4 Dw-4 Pz(Aq-I)=-0 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	29	8	10	11	

Kaniha (664 sq.km)	Total=1 Aq-I=0 Aq-II=0 Aq-III=0 Aq(cum)=0 T =1(cum)	8	3	3	2	24	8	8	8	Total=5 Dw-2 Pz(Aq-I)=-3 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	61	17	22	22	Total=2 Dw-2 Pz(Aq-I)=-0 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	94	30	32	32	
Pallahara (797 sq.km)	Total=4 Aq-I=4 Aq-II=0 Aq-III=0 Aq(cum)=0 T =0(cum)	14	8	3	3	30	10	10	10	Total=4 Dw-4 Pz(Aq-I)=- Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	77	23	27	27	Total=4 Dw- 4 Pz(Aq-I)=-0 Pz(Aq-II)=0 Pz(Aq-III)=0 Pz(cum)=0	117	7	40	40	
Total Additional no. Required		**45**	**20**	**14**	**11**	**139**	**50**	**45**	**44**		**343**	**83**	**130**	**130**		**536**	**135**	**186**	**185**	

N.B.: **Aq-I**: 75 m depth **Aq-II**:- 150 m depth **Aq-III**: up to 300 m depth, T(value)= No of wells having T value. Data Gap Analysis had not been done for Athamallik and Kishorenagar blocks.

After taking into consideration, the available data of Ground Water Exploration, Geophysical survey, GroundWater Monitoring and Ground Water Quality, the data adequacy and datagap analysis was carried out.

As the study area is part of hardrock area where ground water occurs in phreatic condition in weathered portion generally upto30 meters depth and in semi-confinedcondition between 30 to 200 depths. Only two Aquifer system in hardrock areas i.e. Aquifer-I which extends up to weathered Zone followed by Aquifer-II which normally extends in the fractured portion of hardrock generally between 30 to 200 meter depth. Generally, water-bearing fractures also not uniform, the depth of water bearing fractures varies from one exploratory well to another.

1.5.1 Exploratory Wells

The information in respect of un-confined/Phreatic aquifer has been generated from the dug wells present in the area. Data from CGWB Exploratory wells (EW), Observation Wells (OW) and Piezometers are necessary for establishing aquifer geometry and determining aquifer parameters.

The existingexploratory wells drilled in the area under Ground Water Exploration programme of CGWB is presented in **Fig. 1.2** and the details of exploration are given in ***Annexure-I***.The data gap analysis indicates that,45 additional exploratory wells are required in the area.

1.5.2 Ground Water Geophysical Surveys

Ground water geophysical survey data (VES) is required for filling gaps while establishing aquifer geometry. So far no geophysical survey has been carried out in the aquifer mapping area of Angul district. The data gap analysis indicates that, 139 VES have to be carried out in the area.

1.5.3 Ground Water Monitoring

For ground water regime monitoring, open/dugwells were considered for phreatic aquifer and piezometers for monitoring deeper aquifers. The frequency of monitoring is four times annually (May, Aug., Nov. & Jan.) for three years in continuation to generate the long term data of the area. The locations of existing ground water monitoring stations are given in **Fig. 1.3**. The data gap analysis indicates that the 343 additional ground water monitoring stations are required in the area.

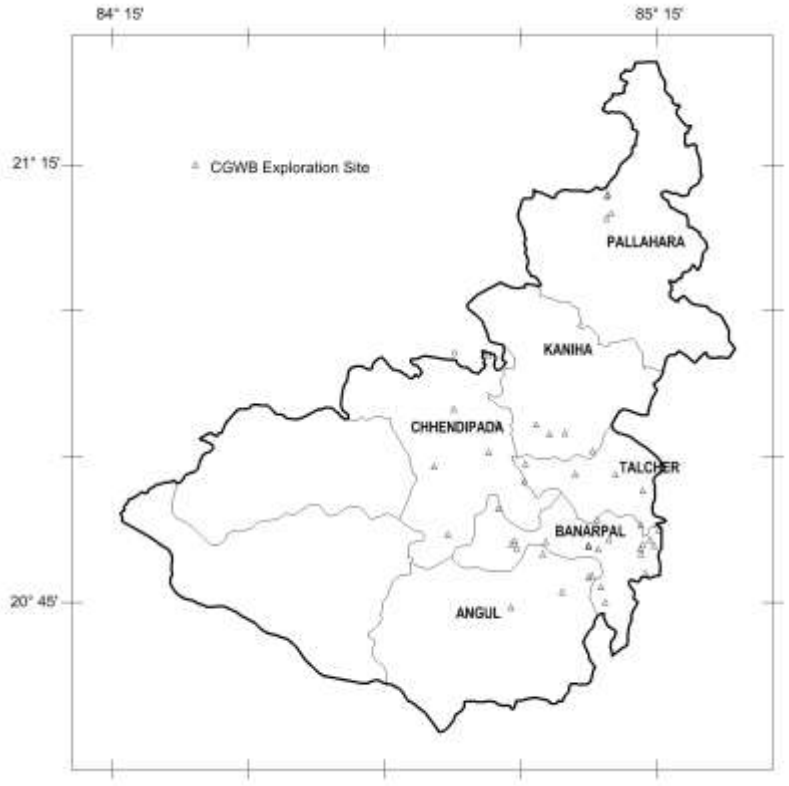


Fig. 1.2: Locations of Exploratory Wells in the Data-Gap AnalysisArea, Angul District.

1.5.4 Ground Water Quality

For the assessment of ground water quality, watersample from open/dugwells has to be collected for phreatic aquifer and for fracture zone aquifer water sample may be collected from EW/OW constructed for exploration. The locations of existing groundwaterquality stations are given in **Fig. 1.4**. The data gap analysis indicates that the 536 additional ground water sampling stations are required in the area.

1.6 Data Gap Identification and Data Generation

The summarised details of required, existing and datagap of Exploratory Wells, Ground Water Monioring Stations and Ground Water Quality Stations is given **Table-1.3** and discussed in detail.

Table 1.3: Summary of Data-Gap Analysis Under NAQUIM, Angul District.

EXPLORATORY DATA			GEOPHYSICAL DATA			GWMONITORING DATA			GWQUALITYDATA		
Req.	Exist.	Gap	Req	Exist.	Gap	Req.	Exist.	Gap	Req.	Exist.	Gap
85	40	45	139	0	139	390	47	343	572	36	536

After the data gap completed, further field works were carried out for generation of additional data and minimize the data gaps.

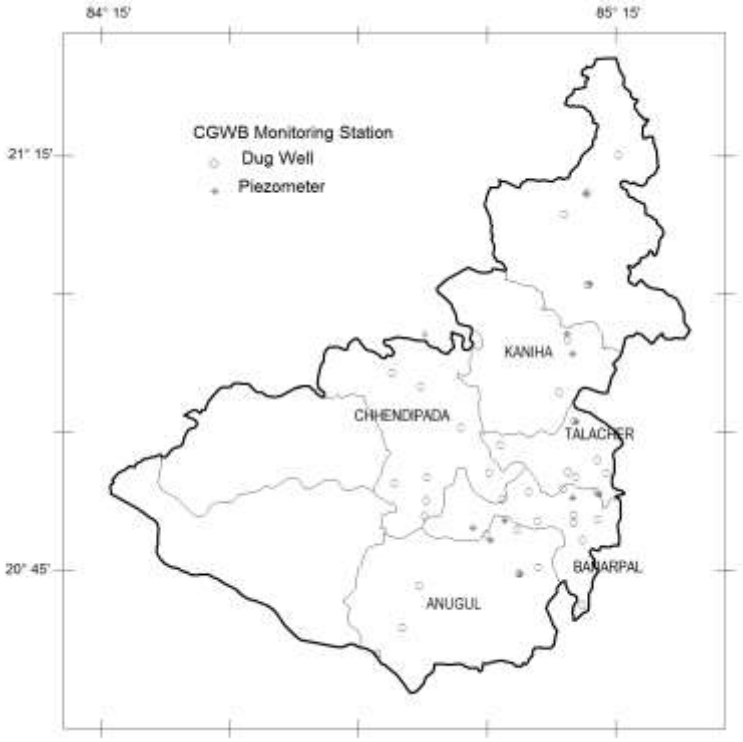


Fig. 1.3: Locations of GW Monitoring Stations in the Data-gap AnalysisArea, Angul District.

Fig. 1.4: Locations of Water Quality Stations in the Data-Gap Analysis Area, Angul District.

2 RAINFALL AND CLIMATE

The area experiences the sub-tropical to tropical temperate monsoon climate and characterised by a hot summer and general dryness throughout the year except during the south-west monsoon season, i.e., June to September. December is the coldest month with mean daily maximum temperature at 26.9^{0}Cand the mean daily minimum temperature at 13.4^{0}C. Both day and night temperature increases rapidly from March and by May the mean daily maximum temperature reaches to 42^{0}C, while the mean minimum temperature is 26.8^{0}C. As per the IMD observation in the district, the air is generally dry except during the monsoon period. In the summer months, the relative humidity is low in the range of 30%. During monsoon, the humidity goes up to 82% or more. Wind velocity in general is low to moderate with some increase in summer and monsoon season. Winds are mostly blown from southwest and northeast direction during monsoon period. In the cold season winds are mainly from west or north. In the summer months, the wind flows from variable directions. The mean annual wind speed is 6.8 km. /hr. The mean monthly potential evapotranspiration value range from 40 mm in December to 326 mm in May.

The South-west monsoon is the principal source of rainfall in the area. The normal rainfall of the district is 1401.9 mm. The rainfall pattern is erratic and drought is a common feature of the district. The long term analysis of rainfall data recorded at block headquarters for the period 1988-2017 has been carried out and the salient features of rainfall analysis are presented in **Table 2.1.**

Table 2.1: Long-Term Analysis of Rainfall in Angul District.

Sl No	Station	Years	No of Years	Avg. Annual Rainfall (mm)	Coefficient of Variation (%)	Droughts (No of yrs / % of Tot. Yrs)	Rainfall Received (No of yrs/ % of Tot. Yrs)		Rainfall Trend mm/yr
							Normal	Excess	
1	Angul	1988-2017	30	1324.7	24	3/10	26/87	1/3	-13.97
2	Banarpal	1988-2017	30	1079.4	25	5/16	20/67	5/17	11.013
3	Chhendipada	1988-2017	30	1126.7	23	4/13	21/70	5/17	-1.27
4	Kaniha	1988-2017	30	1203.3	29	5/17	23/76	2/7	-11.13
5	Talcher	1988-2017	30	1143.8	26	6/20	18/60	6/20	2.40
6	Pallahara	1988-2017	30	1820.3	28	5/17	20/66	5/17	-1.12

Sl No	Station	Years	No of Years	Avg. Annual Rainfall (mm)	Coefficient of Variation (%)	Droughts (No of yrs / % of Tot. Yrs)	Rainfall Received (No of yrs/ % of Tot. Yrs)		Rainfall Trend mm/yr
7	Athamallik	1988-2017	30	1387.2	27	6/20	18/60	6/20	-4.534
8	Kishorenagar	1988-2017	30	1398.6	27	7/23	20/67	3/10	-5.46

Perusal of **Table 2.1** shows that

1. The average annual rainfall for last 0 years period is minimum 1079.4 mm in Banarpal block and maximum 1820.3 mm in Pallahara block.
2. The coefficient of variation in rainfall ranges from 23 % to 29 %.
3. Normal rainfall has been received in 60 % to 87 % of the years.
4. The rainfall trend indicates that the blocks viz. Banarpal and Talcher have increasing rainfall trend over the years in comparison to the rest of the blocks where the trend of rainfall is negative. Angul and Kaniha blocks show a significant decreasing trend.

3 PHYSIOGRAPHIC SETUP

3.1 Physiography

Physiographically the district can be divided into three regions :

(i) Northern Mountainous Region

(ii) Central Undulating Plain

(iii) Southern & South-western Mountainous Region.

The variation in land elevations above MSL is shown in **Fig. 3.1**.

3.1.1 Northern Mountainous Region

The regions contains WNW – ESE trending hills immediately north of the Talcher coal field and NW-SE trending hills towards the boundary of Keonjhar district which locally change to E-W direction and form the Malayagiri hill, in the south of Pallahara. Malayagiri hill contains one of the loftiest peaks (1,187m.a.msl) in Orissa. The hills and ridges are separated by broad valleys and low hilly areas. The heights above sea level of this region vary from about 76 meters on the bank of Brahmani river to 1,187 meters on Malayagiri peak. The high hills of this region are composed of Quartzites while the lesser hills are made of Quartz-Mica schists, Granites and other rocks. The broad valleys are mostly underlain by gneissic rocks.

3.1.2 Central Undulating Plain

The Central part of the district is characterized by undulating plain. This region is covered by Talcher subdivision and northern parts of Angul and Athmalik subdivisions. The Brahmani valley portion of this region exposes mainly Granites and its variants and Gneisses with occasional hillocks of Khondalites, while the remaining part from west of Murhi and north of Angul up to the western end of the district is characterized by considerably flat country underlain by sedimentary rocks of Gondwana Group having large deposit of coal (Talcher Coalfields). The general slope of the country is from WNW-ESE.

3.1.3 Southern and South- Western Mountainous Region

The Southern and South Western parts comprise of hill ranges trending WNW-ESE and is covered by the sub-divisions of Athmalik and Angul. The elevations vary from 60 to 971 meters above sea level. Banamadali peak in Angul Sub-division is 790 meter in height. In Athamallik Sub-

division the main peaks are Panchadhara and Hingamandal hills. The southern & south western hilly regions form the watershed between Brahmani and Mahanadi river.

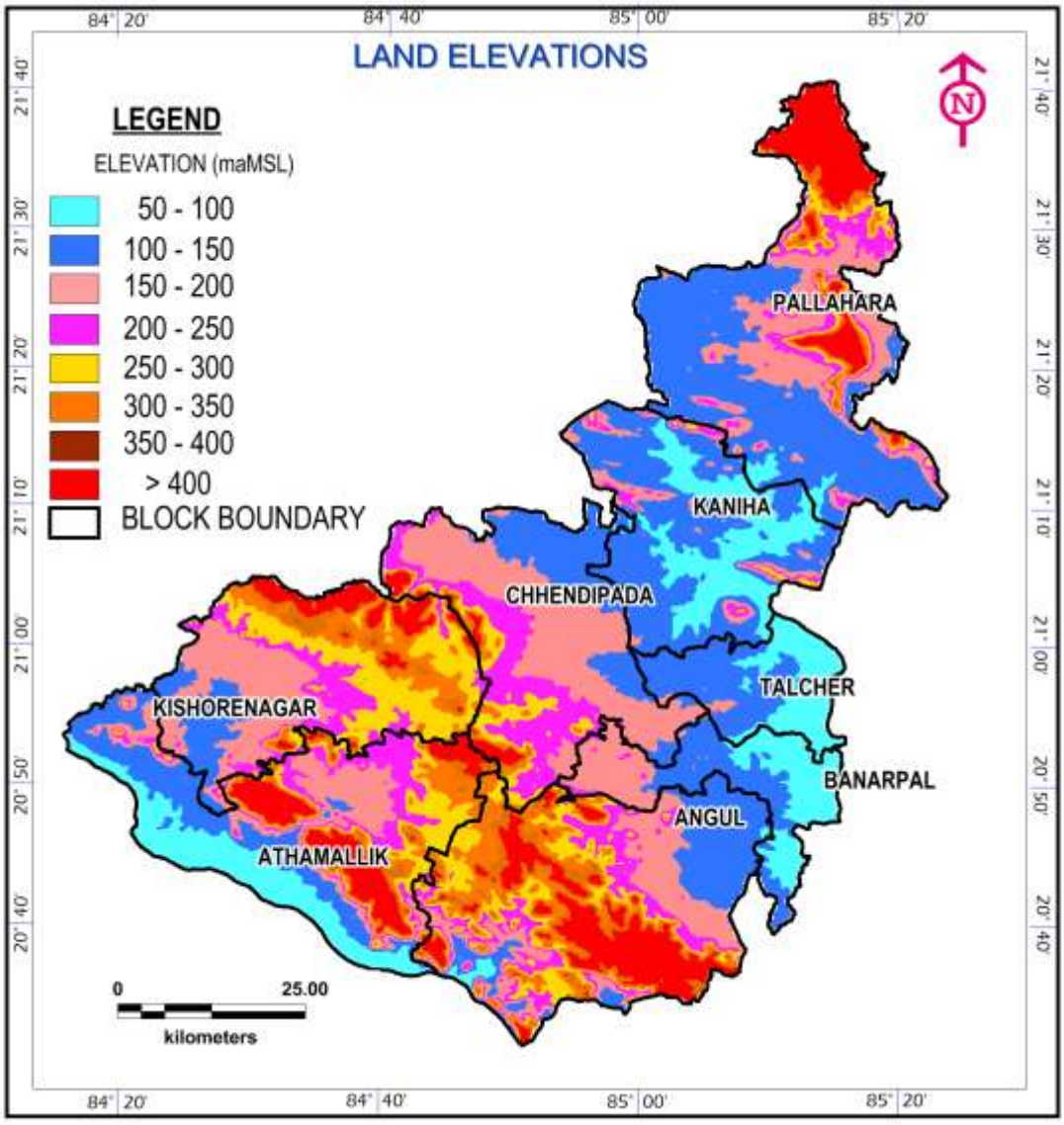


Fig. 3.1: Land Elevations in Angul District

3.2 Geomorphology

The analysis of geomorphological data and thematic map collected from MRSAC, Nagpur. reveals that the hilly terrains in northern and south-south western portions were separated by central undulating plains which comprises of predominantly pediments and shallow buried pediments. The geomorphology of the area is shown in **Fig. 3.2.**

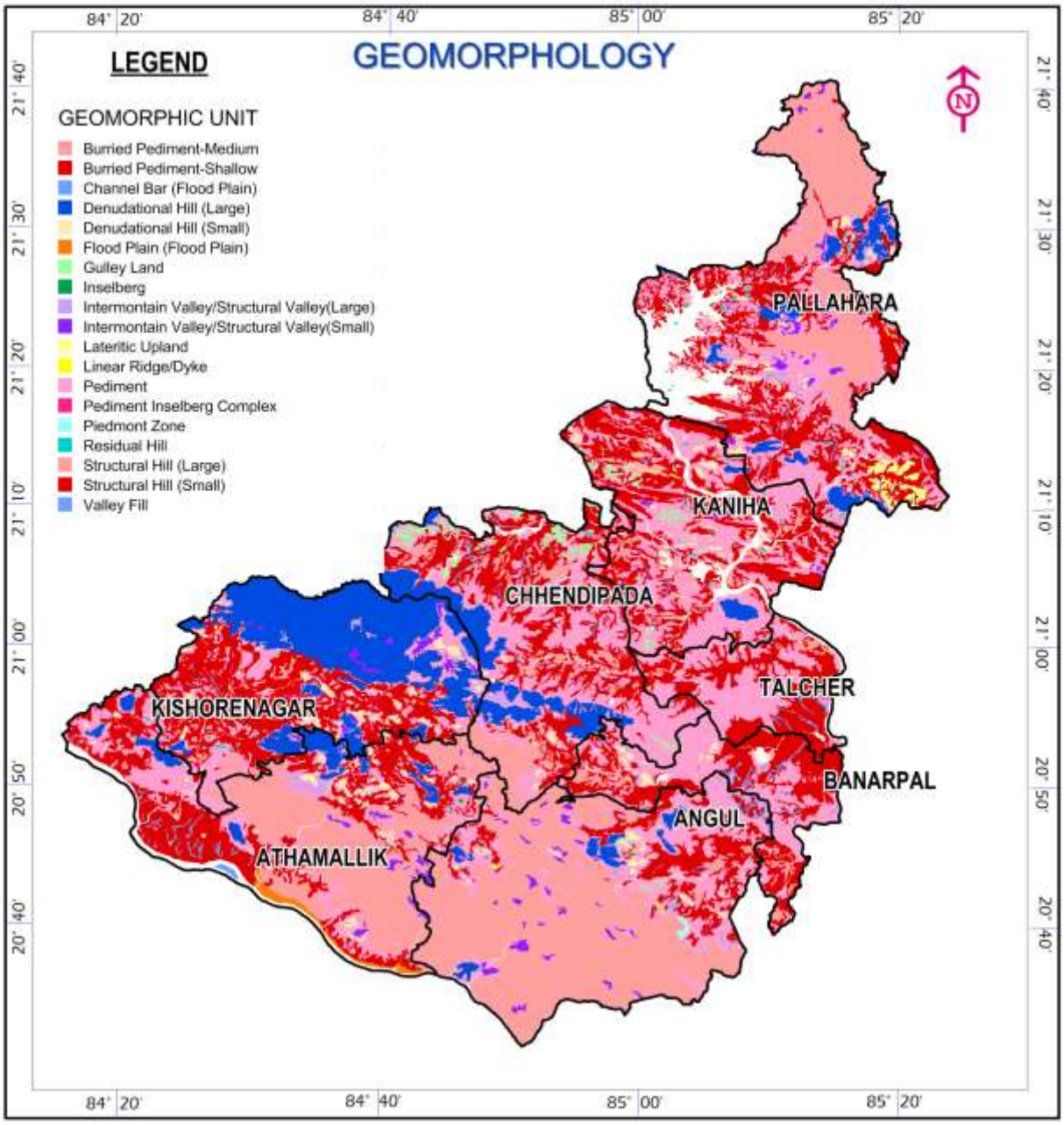


Fig. 3.2: Geomorphology of Angul District

3.3 Land Use and Cropping pattern

Agriculture occupies a vital place in the economy of Angul district. The total cultivable area of this district is about 33 percent of the total geographical area of the district. However, the total forest area (legal boundary) is higher than the state average. Within district, the forest area is maximum in the Pallahara block followed by Kaniha and Athamallik blocks. The landuse pattern of

the blocks under the study area is shown in **Table 3.1** and the thematic map on land use is shown in **Fig. 3.3**.

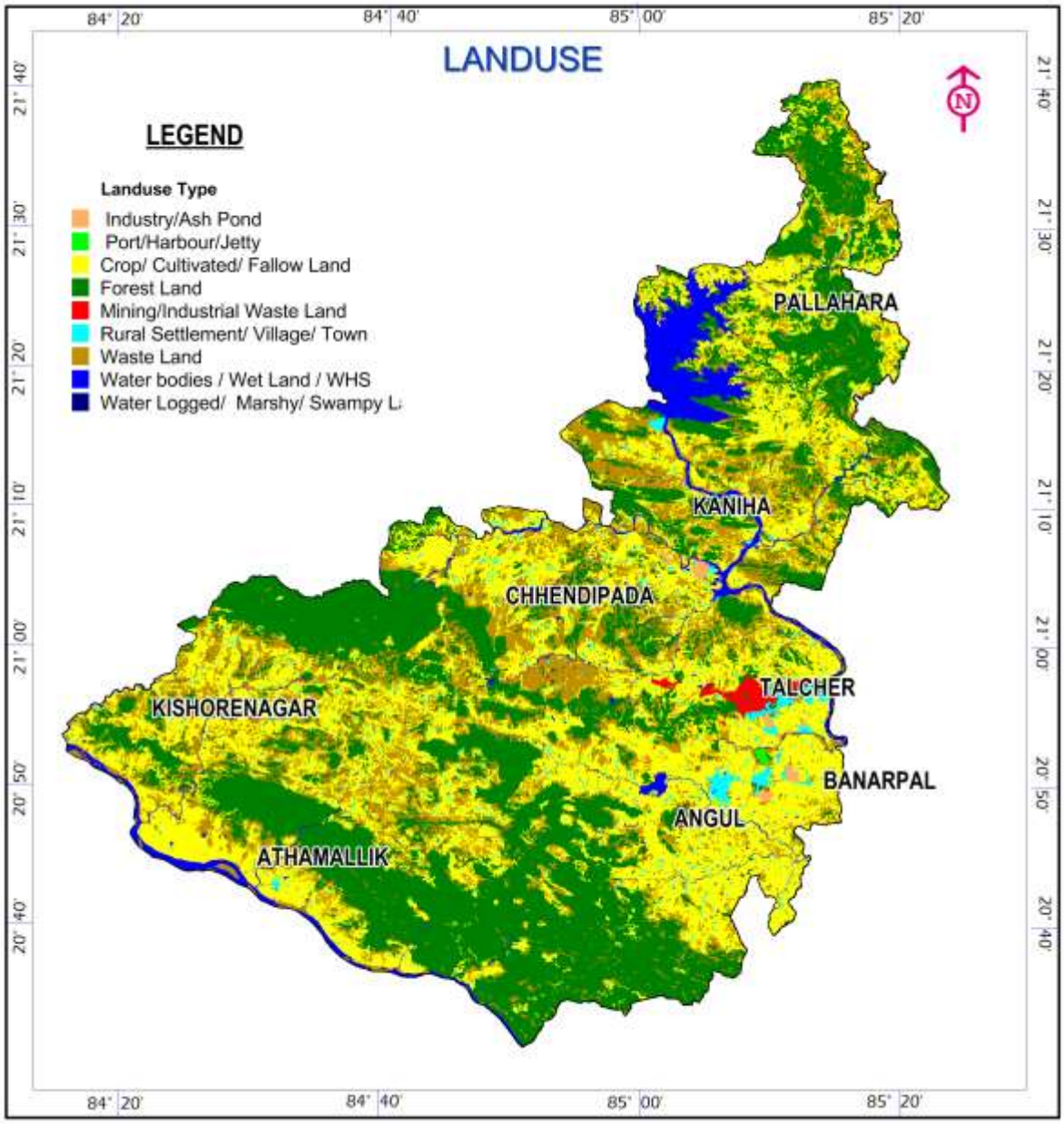


Fig. 3.3: Landuse Angul District.

Most of the cultivated area of the district is covered with double crops like kulthi (kolath), bengalgram (harad), coriander, field pea; and vegetables are taken after harvest of ground nut and early kharif paddy. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, ground nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri,

mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

Table 3.1: Land Use Pattern in Different Blocks of Angul District.

(Area in hectares)

Particulars	Blocks								Total
	Angul	Banarpal	Chhendipada	Kaniha	Pallahara	Talcher	Athamallik	Kishorenagar	
Total Geographic Area	112257	35119	86051	71144	117395	28487	102995	84049	**637497**
Forests	73176	1643	32012	27920	53825	4187	49976	44195	**286934**
Misc. tree crops & Groves not included in net area sown	537	364	2359	954	231	376	324	430	**5575**
Barren & Uncultivable land	727	90	205	2369	2576	577	5200	2657	**14401**
Land put to non-agricultural use	3432	5005	5307	7151	3795	3486	8653	2308	**39137**
Culturable waste	2755	940	3607	2003	1880	1083	1876	3678	**17822**
Permanent pastures and other grazing land	2547	2451	2470	1271	2622	551	2662	2180	**16754**
Current Fallows	6209	4076	8103	24735	2400	2615	5664	4529	**58331**
Other Fallows	5048	4719	6380	2969	2379	1724	4279	3632	**31130**
Total Wasteland	1491	1120	9460	8811	11891	1268	2280	1000	**37321**
AREA UNDER AGRICULTURE									
Gross Cropped Area	36373	29840	43011	27527	37321	15816	44372	36681	**270941**
Net Sown Area	34182	26896	39665	26410	37040	15062	43825	36380	**259460**
Area Sown More than once	2190	2944	3346	1117	281	754	547	301	**11480**
Cropping Intensity	106	111	108	104	101	105	101	101	**105**

Source: Angul District Plan, TSI-ERA/DISTRICT ADMINISTRATION/ANUGUL 2011-12& Dist Irrigation Plan, Angul 2016

The crop rotation practice followed by the farmers in the district are:

In Upland region: Kulthi and vegetables are taken after harvest of short duration paddy, gram, coriander and groundnut crop.

In Mid land region: Wheat, onion, garlic, mung, biri, vegetables and groundnut are taken after harvesting of kharif season paddy.

In Low land region: Paddy and pulses are taken after harvest of rabi season paddy crop. In assured irrigation farmlands, three crops like paddy-vegetable-pulses, paddy-potato-til and paddy-pulses-groundnut are taken.

Table 3.1 reveals that the average cropping intensity in the district is around 105 percent. The highest cropping intensity is found in Banarpal block followed by Chhendipada and Angul

block. Athamallik block has highest Gross cropped area and on the other hand Talcher block has lowest Gross cropped area, which is mainly due to the inadequate irrigation facilities in the block. The season-wise irrigation areas in different blocks of the district are given in **Table 3.2**.

Table 3.2: Season-wise Irrigation in Angul District. *(Area in hectares)*

Season	Kharif			Rabi			Total		
Block	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
Angul	8583	11360	19943	4505	879	5384	13088	12239	25327
Banarpal	9615	12869	22511	5404	1548	6952	15019	14444	29463
Chhendipada	8657	12171	20828	4251	977	5228	12908	13148	26056
Kaniha	6414	7144	13558	4540	1801	6341	10594	8946	19900
Pallahara	8241	11471	19712	3627	1248	4875	11868	12719	24587
Talcher	3044	3505	6549	1963	596	2559	5007	4101	9108
Athamallik	6976	9116	16092	3145	1420	4565	10121	10536	20657
Kishorenagar	6005	6678	12683	2813	1079	3892	8818	7757	16675
TOTAL	**57535**	**74314**	**131876**	**30248**	**9548**	**39796**	**87423**	**83890**	**171773**

Source: District Irrigation Plan, DLIC, 2016

3.4 Soil

It has been observed that the major part of the area is occupied by Alfisols which includes red sandy soil, red loamy soil and mixed red and black soils. It is porous and friable, tight textured, usually devoid of lime kankars and is also free of carbonates. It is usually suitable for cultivation of paddy and a large variety of other crops.The Ultisols include red and yellow soils found in western part and also lateritic soil found in the northern end of the district. It's poor in nitrogen, phosphorus, potassium and organic matter. The pH of this soil varies from 4.5 to 6.0. Medium black soil (Vertisol) found along the Mahanadi river in the south part of the district. It contains high amount of Fe, Ca and Mg. It's poor in organic matter, nitrogen and phosphorus but rich in potash and lime. The pH of the soil varies from normal to alkaline. The texture varies from loam to clayey loam. It's quite fertile and crops grown are generally cotton, wheat, tobacco and chilly. The thematic map on the soil distribution in the study area is shown in **Fig.3.4.**

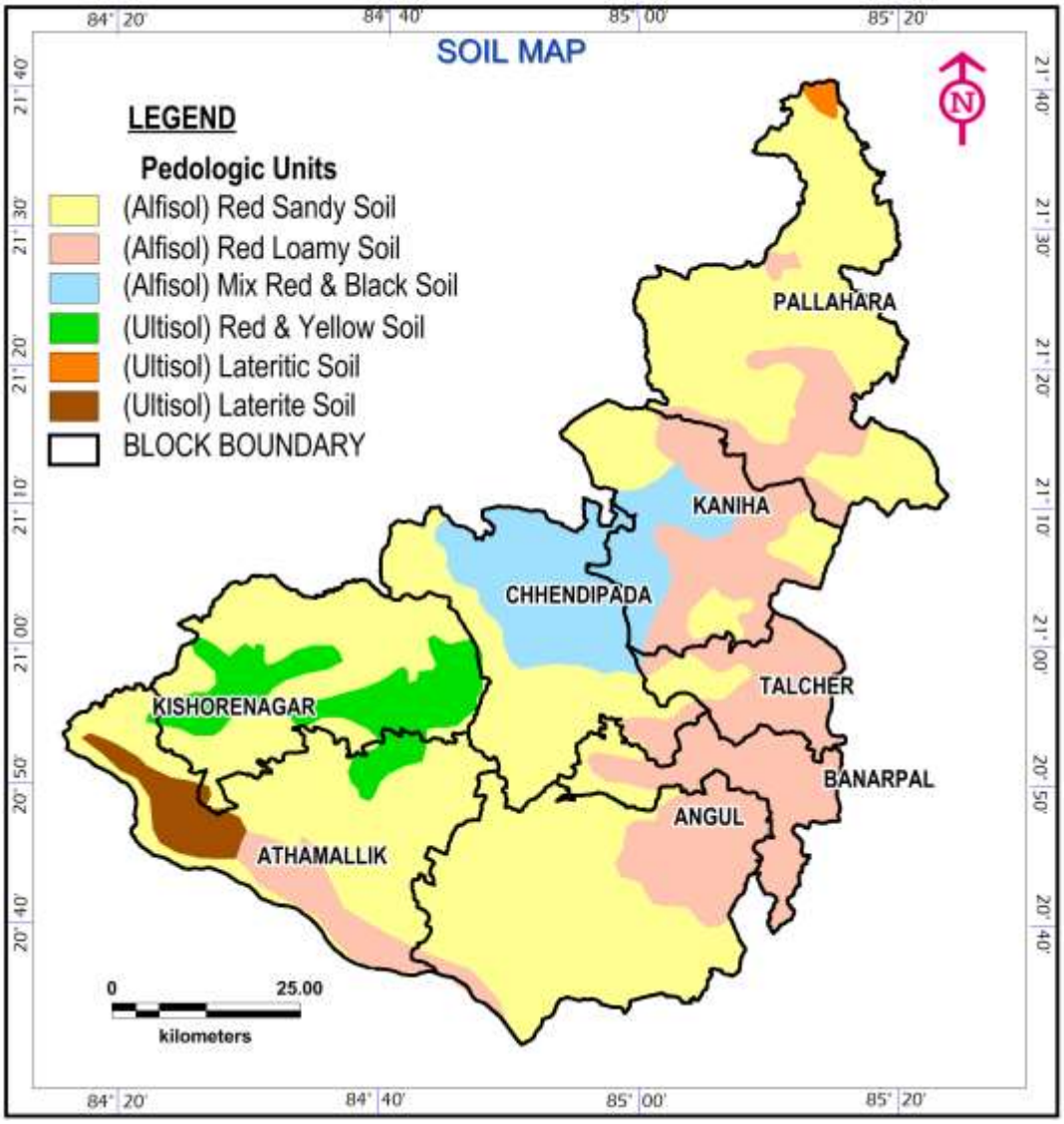


Fig. 3.4: Soil in Angul District.

3.5 Hydrology and Drainage:

3.5.1 Hydrology

The agriculture in the district is primarily rain fed because of inadequate irrigation facility. Area irrigated through all sources is only 22 % during kharif season and 14% during rabi season as per the available data. The district has 259460 Ha of cultivable land. The total irrigation potential is 87423Ha (Table 3.1). The source-wise irrigation areasof the district are given in **Table 3.3**.

Table 3.3: Source-Wise Irrigation in Angul District. *(Area in hectares)*

Sl. No.	Source	Kharif	Rabi	Total
1	**Surface Irrigation**			
i	Canal (Major & Medium Irrigation Project)	11305	4000	15305
ii	Minor Irrigation Tanks	17207	212	17419
iii	Lift Irrigation/ Diversion	8302	6434	14736
iv	Water Bodies, RWH	532	115	647
v	Perennial Sources of Water	46274	31215	77489
	Total	**83620**	**41976**	**125596**
2	**Ground Water**			
I	Dug Well	18818	6098	24916
Ii	Deep Tube Well	11454	9707	21161
	Total	**30272**	**15805**	**46077**
TOTAL		**113892**	**57781**	**171673**

Source: District Irrigation Plan, DLIC, 2016

There are 2 medium irrigation projects in the study area. The Derjung Medium Irrigation Project is constructed on Ningara and Matalia river in Angul block having total catchment area of 399 sq. km. with CCA of 7392 Ha. The Aunli Medium Irrigation Project is constructed on Aunli river in Chhendipada block**.** Its catchment area is 150 sq. km. and is having CCA of 1746 Ha during Kharif and 300 Ha in Rabi. The block-wise details of Minor Irrigation Projects in the study area are presented as **Table 3.4.**

Table 3.4: Block-wise MIPs in Angul District *(As on 31.12.2012)***.**

Sl. No.	Block	No of Projects	Ayacut Area (Ha)
1	Angul	25	2493
2	Banarpal	9	1243
3	Chhendipada	21	6709
4	Kaniha	19	2806
5	Pallahara	18	4540
6	Talcher	6	525
7	Athamallik	42	4538
8	Kishorenagar	24	4497
	Total	**164**	**27351**

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

There are 5 large dams in the study area under MIP, namely, Kansabansa MIP, Kukurpeta MIP, Raijharan MIP, Durgapur MIP and Jhinitipal MIP all of which comes in the Chhendipada block. There are 22 no of *Pani Panchayats* for MIPs and 205 for LIPs have been formed and most of these

are registered. It has been planned to hand over all the maintenance of all the MIPs and LIPs to Pani Panchayats.

3.5.2 Drainage

Brahmani and Mahanadi are the two major rivers of the district. Both these rivers have numerous perennial and non-perennial tributaries. Most part of the district lies within the Brahmani basin while the Mahanadi basin spreads over Athmalik subdivision and southern part of Angul sub-division. The drainage map of study area is shown in **Fig.3.5**.

The Brahmani river which is the second longest river in Orissa flows through Talcher subdivision. The major portion of the district is drained by Brahmani and its tributaries. The Brahmani flows in a general SE direction, broadly parallel to the general strike trends of the prevalent rock formations, but locally guided by major joints and faults. The major tributaries of Brahmani are Tikra Jhor, Singhara Jhor, Samakoi, Nandira Jhor, Gambhira, Nigra, Bade Jhor etc. These major streams show a general right angle pattern while joining with the river Brahmani.

The Mahanadi flows along the south-west boundary of the district, parallel to the strike of Khondalites and is guided by a major shear zone. The major tributaries of this river are Karandi Jhor, Ghosar Jhor, Sindol Jhor, Chanagorhi and Malia Jhor etc., all flow from the northern side of the river originating in Athmalik and Angul subdivisions. The river Mahanadi though flows in a general SE direction, but occasionally flows due south or east at places.

Fig. 3.5: Drainage in Angul District.

4 HYDROGEOLOGY

4.1 Geology Sequence

The study area exposes rocks of Iron-Ore Super Group, Easternghat Super Group and Gondwana Super group. Besides these laterites and alluvial deposits of Quaternary period also occurs at places. The generalized stratigraphic sequence is given in **Table 4.1** and the geological map of the study area is shown in **Fig**. **4.1.**

Table 4.1: **Generalized Stratigraphic Sequence of Angul District.**

Age		Lithology
Quaternary		Alluvial and Laterites
Upper Paleozoic to Lower Mesozoic		Sandstones, Shales, Conglomerates, Coal, Boulder Beds (Gondwana Super Group)
Pre-cambrian	Proterozoic	Quartz-feldspar-garnet-sillimanite-graphite schist/gneiss, charnokite, pyroxene granulite and gneiss (Eastern Ghat Super Group)
	Archean	Mica Schists, quartzites (Iron-Ore Super Group)

4.1.1 Pre-Cambrians

The rocks of Iron-Ore super group are exposed to the north of Brahmani River and consist mainly of Quartzites (known as Tikra Quartzites), BHQ,BHJ, BMQ and Mica schists. Basement gneiss and Eastern Ghat Supergroup of rocks mainly comprising quartz-feldspar-garnet-sillimanite-graphite schist/gneiss, charnokite, pyroxene granulite and gneiss (augen, garnetiferous, biotite gneiss, migmatised khondalite) occur in central and southern parts covering around 70 % of the study area.

Gondwana Supergroup consisting of Conglomerate, sandstone, shale and coal occur in north and northeastern parts of the study area. The area of Talcher coal-field is underlain by Pre-cambrian basement rocks on which the lower Gondwana sediments unconformably rest. Gondwana rocks are overlain by recent alluvium and or valley-fill materials at places.

4.1.2 Alluvial Deposits and Laterites

The recent to sub-recent alluvium occur as flood-plain and channel deposits along the tributaries of Brahmani River. It comprises coarse to fine sand, gravel, silt and clay. The average extent of these formations is limited and their maximum thickness is about 25m. Laterites occur as patches capping over the country rocks and attain a limited thickness.

4.1.3 Structural Features

The Iron-Ore Super group of metasediments have undergone three phase of deformations. The axis of the first generation fold trends in E-W direction, the second generation fold in WNW-ESE direction and the youngest one by the N-S trend.The Gondwana rocks occupy faulted troughs with beds dipping at low angles (60 to 100 towards north). A number of NW-SE trending faults are observed within Gondwana supergroup of rocks.

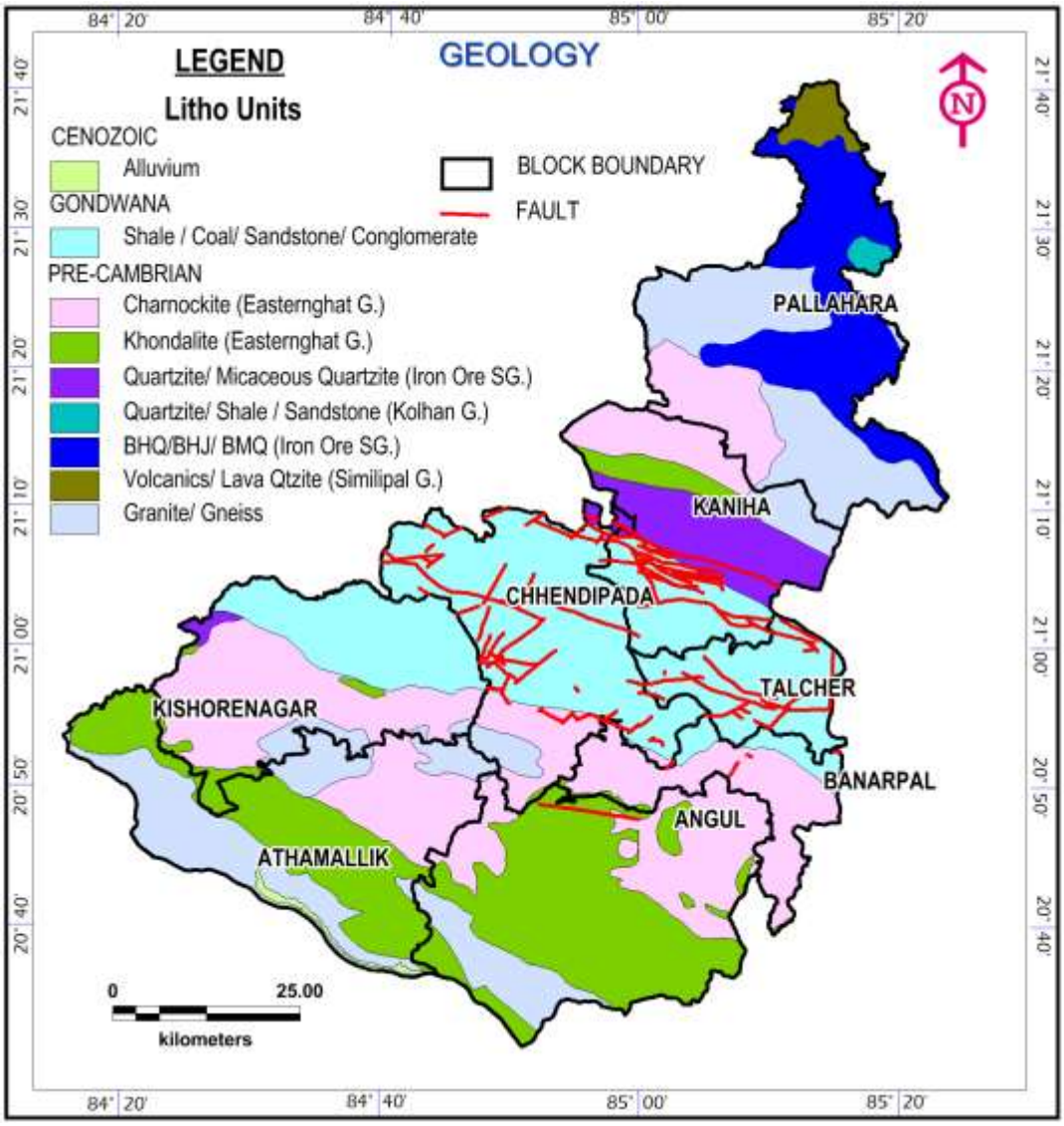


Fig. 4.1: Geological map of Angul District

4.2 Hydrogeology

The hydrogeological condition of the study area can be broadly grouped into three units viz. Consolidated Formation, Semi-Consolidated Formation and Unconsolidated Formation. The hydrogeological map of the area is presented in **Fig. 4.2**.

4.2.1 Consolidated Formation

This includes Granite, Granite gneiss, Charnockites, Khondalites, Quartzite, Phyllites, Mica schist etc. These rocks are devoid of primary porosity. The secondary porosity developed in the rocks due to intense weathering and fracturing, which forms repository and passage for movement of ground water. Groundwater occurs under water table condition in the weathered residuum and in semi-confined to confined condition in fractured rocks at deeper depths. The thickness of weathered residuum varies from 5 to 20m, which form repository of ground water at shallow depth. Groundwater from this zone is developed through dugwells.

In the hard crystalline rocks, the recharge of ground water from precipitation or seepage from surface water bodies percolate into the weathered and semi-weathered (Saprolite) zone. The presence of fractures in the basement rock, which open up to the overlain saprolite zone facilitate downward percolation and movement of the waterwhich can be tapped through dug wells in the weathered and semi-weathered zoneand through bore wells in the deeper horizons. At places, confined condition gives rise to auto-flowing wells (Athmallik). The groundwater potential of various zones i.e. saprolite (tapped through dug wells), weathered basement rock and shallow fracturedrocks (tapped mostly through hand pumps) and deeper fractured rock (tapped through deep bore wells) vary considerably depending upon their lithological and structural characteristics. By conducting pumping tests both in dug wells and in bore wells indifferent litho-units and by analysing the data adopting various methods, it has been concluded that granite gneiss forms the most potential aquifer followed by khondalite.Yield is poor in Gondwana sediments, charnockite, phyllite etc in deeper horizons,whereas moderate yield can be obtained in the weathered zone. But the unconsolidated alluvium forms the most prolific aquifer.

4.2.2 Semi-consolidated Formation

It includes semi-consolidated Gondwana formation comprising mainly of sandstone and shale. The sandstone when weathered and fractured form good aquifer. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the fracture zone.

4.2.3 Unconsolidated Formation

Laterite occurs as capping over the older formation and groundwater occurs under water table condition. The aquifer supports moderate yield. The alluvium occurs along the course of major rivers and streams and is having limited occurrence in pocket. The alluvium supports good yield.

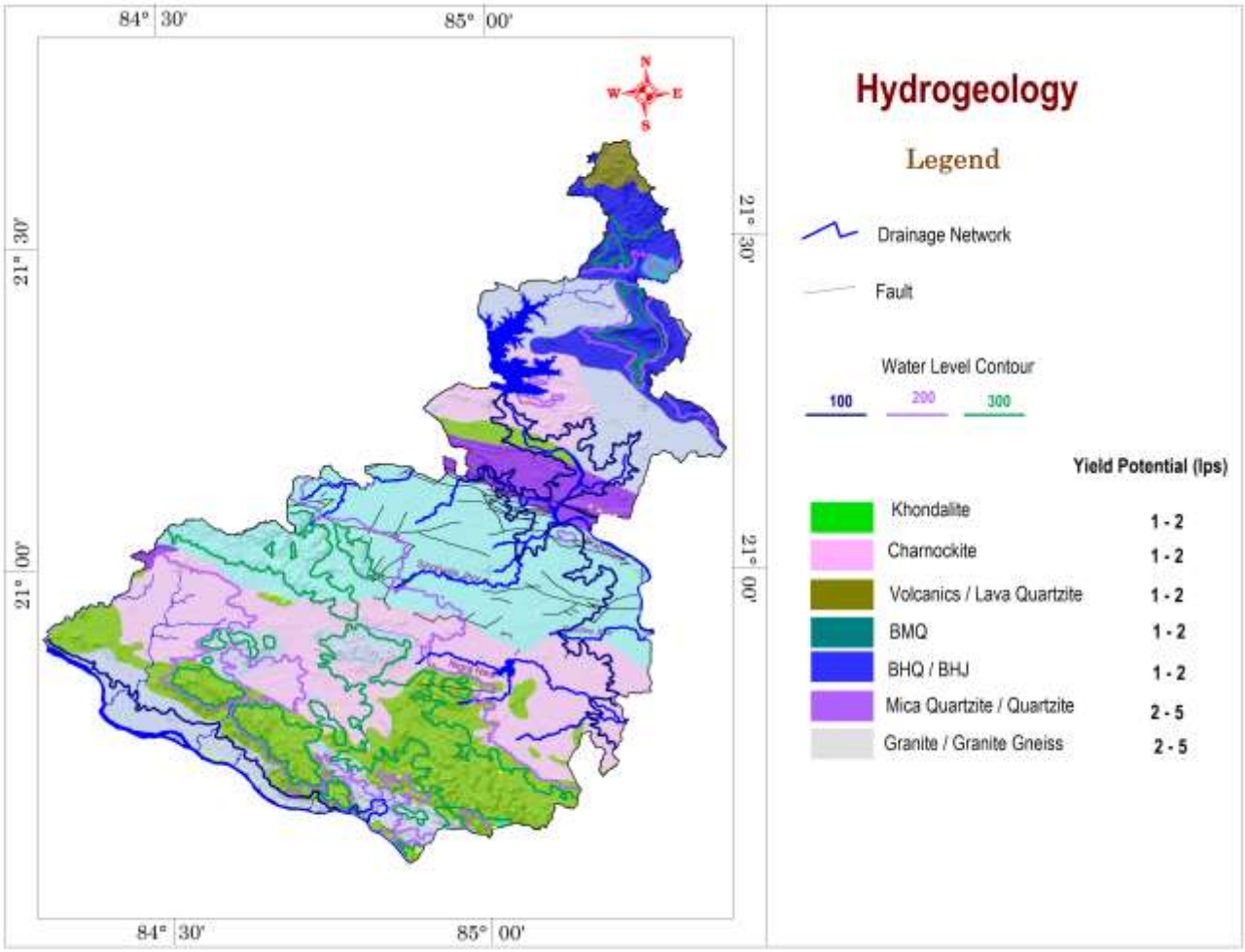


Fig. 4.2: Hydrogeology of Angul District

4.2.1 Ground Water Exploration and Ground Water Monitoring for Aquifer Mapping

Ground water exploration data, down to the depth of 200 m bgl in the NAQUIM area, has been taken up for the preparation of Aquifer Map. The total no of Exploration points including EW, OW and piezometers are 130.

The major objectives of ground water exploration in the study area were

I. To understand aquifer geometry and estimation of aquifer parameters of the area.

II. Assessment of ground water quality in various aquifers.

Similarly 237 no. of key observation wells were established in the NAQUIM area for monitoring of ground water regime as well as assessment of ground water quality of the phreatic aquifer (classified as **Aquifer-I** in chapter-6). CGWB has 54 National Hydrograph Network Stations in the district. The data from 46 monitoring stations from State Govt. (GWSI) were included for analysis for aquifer mapping. The exploration and monitoring locations are shown on map in **Fig. 4.3.**The details of key observation wells are given in ***Annexure-II***.

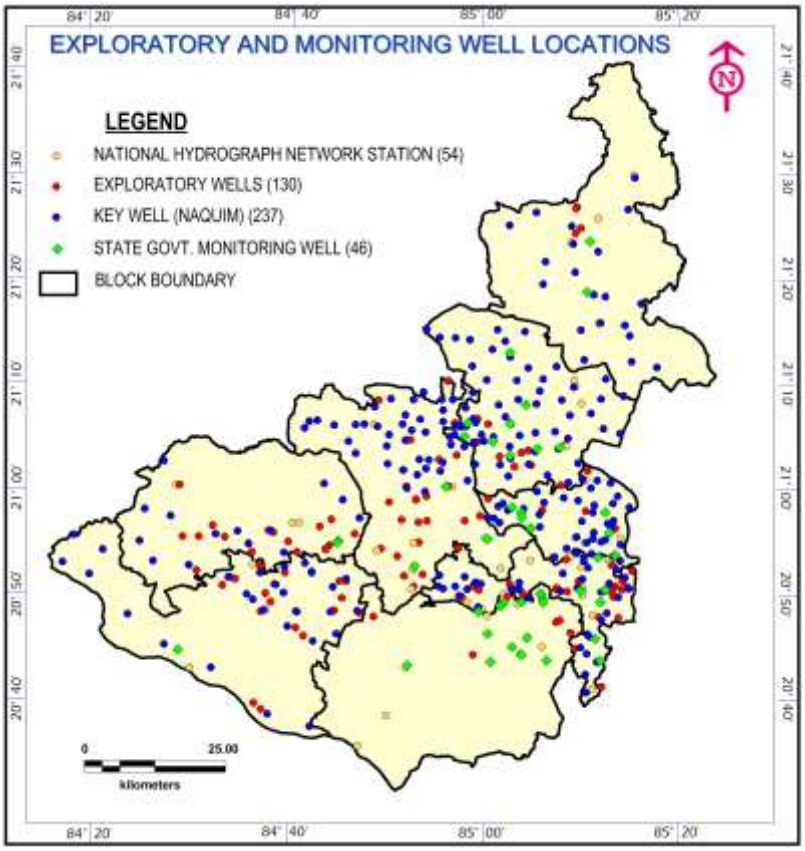


Fig. 4.3: Locations of Ground Water Exploration and Monitoring Stations in Angul District.

4.3 Ground Water Dynamics

4.3.1 Depth to water level (Aquifer-I)

The depth to water level of the key observation wells were monitored during the pre-monsoon (May-June) and post-monsoon (November-December) seasons during the year 2015 in all the blocks except Athamalik and Kishorenagar whereas the keywells of Athamallik and Kishorenagar blocks were monitored during the year 2018.

4.3.1.1 Depth to Water Level (pre-monsoon)

The depth to water levels during pre-monsoon ranges between 1.56 mbgl (Kalamchuin in Talcher block) and 11.85 mbgl (Gopinathpur in Chhendipada block). Depth to water levels during pre-monsoon shows water levels mostly within 5-7 mbgl and shallow water level of 2-5 mbgl in parts of Banarpal and western part of Talcher block. Deepest water level of more than 8 mbgl is observed in patches mostly in Chhendipada block, eastern parts of Athamalik and Kishorenagar and coal mining areas in Talcher block. The pre-monsoon depth to water level map is given in **Fig.4.4**.

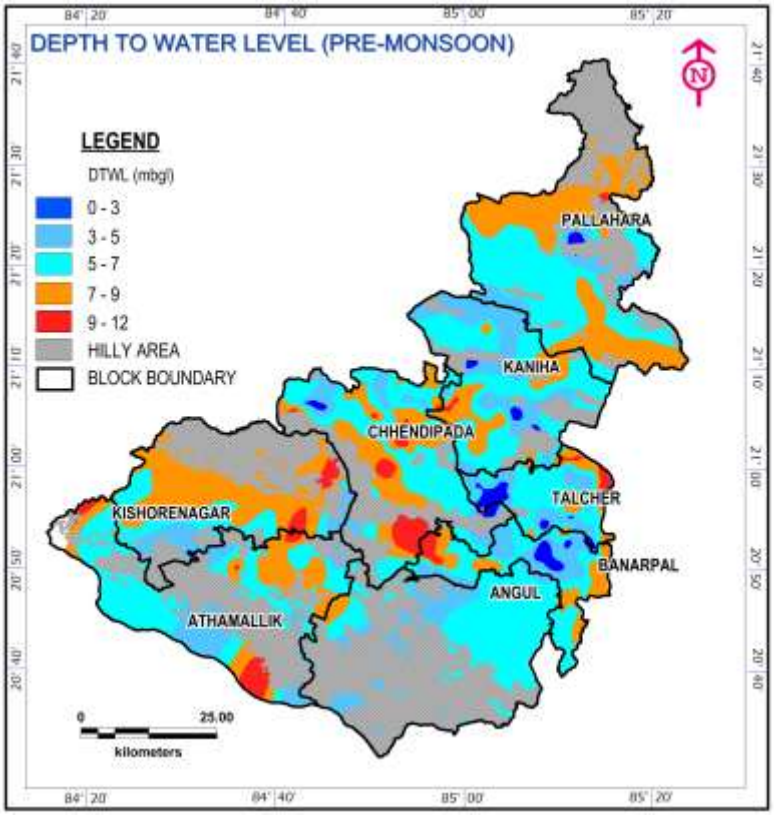


Fig. 4.4: Depth to Water Level during Pre-Monsoon (Aquifer-I).

4.3.1.2 Depth to Water Level (Post-monsoon)

The depth to water levels during post-monsoon ranges between 0.51 mbgl (Bankhol in Pallahara block) and 9.28 mbgl (Talcher). Except small isolated patches, depth to water level is mostly within 2-5 mbgl. Deeper water level of more than 7 to 9.28 mbgl was observed at the boundary of Banarpal and Chhendipada blocks near villages Partara-Jaruda-Derjung. The post-monsoon depth to water level map is given in **Fig.4.5**.

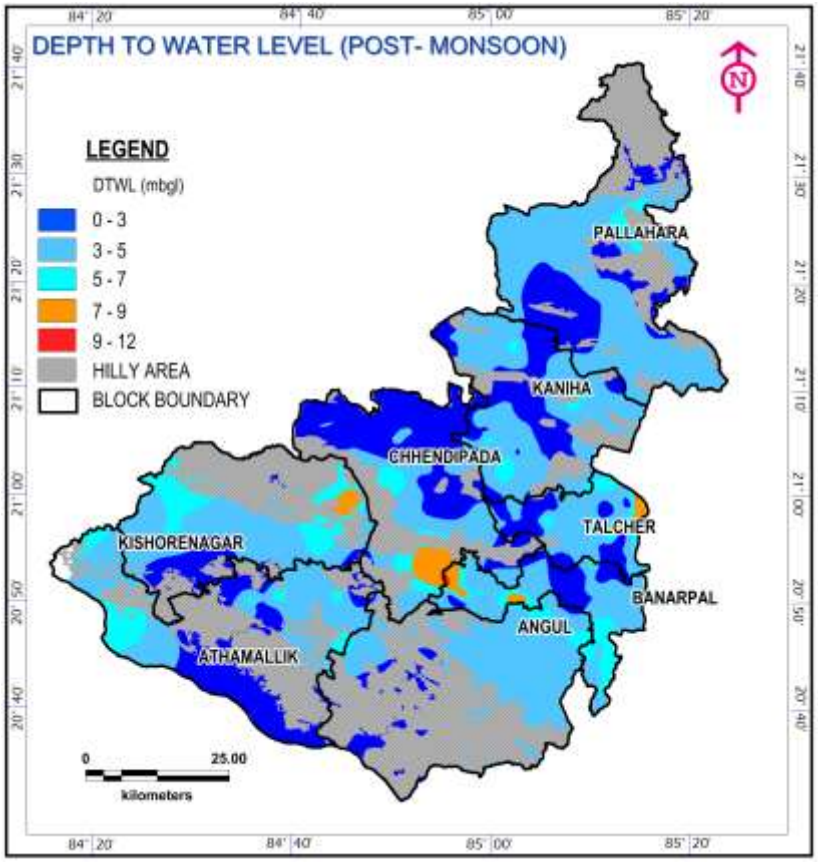


Fig. 4.5: Depth to Water Levelduring Post-Monsoon (Aquifer-I)

4.3.2 Water Level Fluctuation (Aquifer-I)

The water level measured during pre and post-monsoon period was used to calculate the fluctuation. The seasonal fluctuation in water level was obtained from difference in water level during pre and post monsoon water level. In the area, number of wells and their percentage falling in each fluctuation range is presented in **Table 4.2**.

Table 4.2: Seasonal Fluctuation (Difference Pre- & Post-Monsoon) in Water Level.

No. of key wells	Seasonal fluctuation in water level m with % of wells				
	0 to 2	2 to 4	4 to 6	6 to 8	8 to 10
237	87 (36.7%)	98 (41.35 %)	42 (17.72 %)	9 (3.79 %)	1 (0.42 %)

It is observed that minimum water level fluctuation was measured at Gahama Village in Kaniha block (0.05m) while maximum water level fluctuation was measured at Kakudia in Chhendipada (8.35m). The water level fluctuations are grouped under three categories and are discussed under.

0-2 m and 2-4 m - Less water level fluctuation

4-6 m - Moderate water level fluctuation

>6 m - High water level fluctuation

Area with less water level fluctuation, about 78% wells were showing the water level fluctuation less than 4m. The area with less water level fluctuation is observed in patches mostly in Kaniha-Talcher-Banarpal-Angul blocks.

Area with moderate water level fluctuation, about 17.7 % wells were showing the moderate water level fluctuation between 4 and 6 m mostly inChhendipada block. Maximum water level fluctuation (> 6m) was observed in about 4% (10 wells). These are Bada Changudia in western part of Kaniha block and Podapada, Gopinathpur, San Changudia, Gambharipal, Dahibar, Kanloi and Kakudia in northern part of Chhendipada block and Pataka in Athamallik block. The higher water level fluctuation is indicative of being recharge area. The seasonal fluctuation of water level of Aquifer-I is shown in **Fig.4.6**.

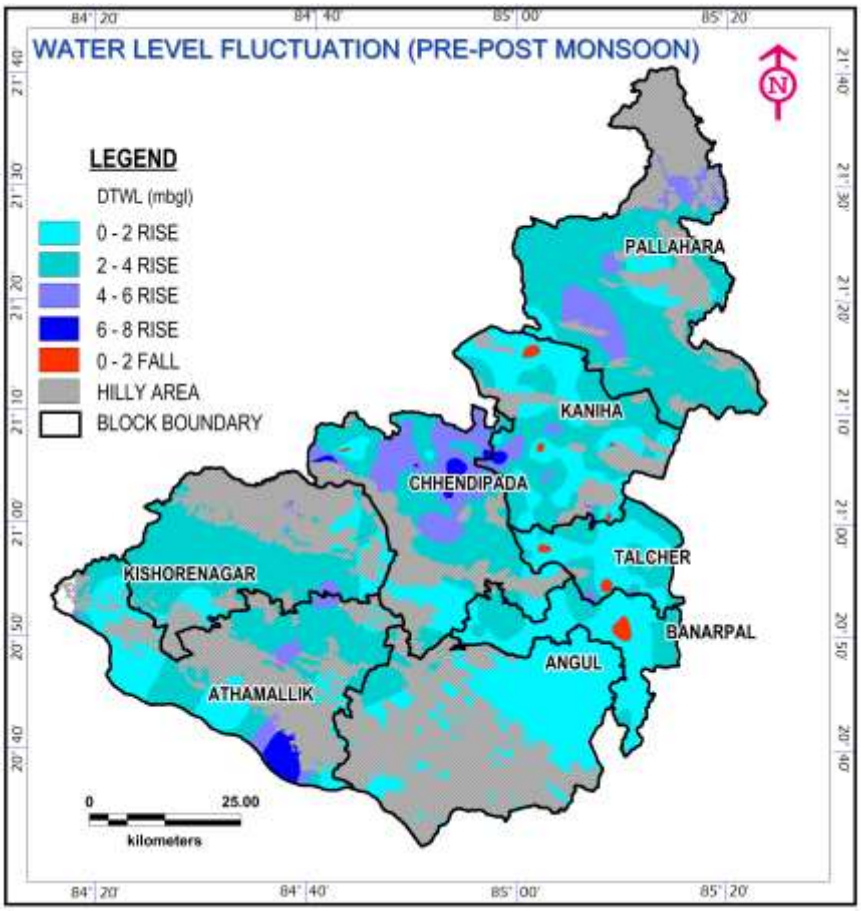


Fig. 4.6: Seasonal Fluctuation in Water Level (Aquifer-I) (Pre vs. Post-monsoon)

4.3.3 Depth to Water Level Trend (2006-15 Aquifer-I)

The long-term trend of water levels for pre-monsoon and post-monsoon periods for the last ten years (2006-15) have been computed. The long term water level data of 42 National Hydrograph Network Stations (NHNS) CGWB has been utilised. The maps depicting the special variation in long-term water level trend is presented as (**Fig. 4.7 and 4.8**). In the study area, rise in pre-monsoon water levels trend has been recorded at 24 stations and it ranges between 0.034 m/year (Kulnara1) to 0.57 m/year (Kukurang) while falling trend was observed in 15 stations varying from -0.011 m/year (Nisa) to -0.370 (Pallahara1).

In pre-monsoon,falling water level trend has been observed in Pallahara block and in the areas surrounding Talchir coalfields and central and southern part of Banarpal block. The rest of the area is showing rise in water level trend.

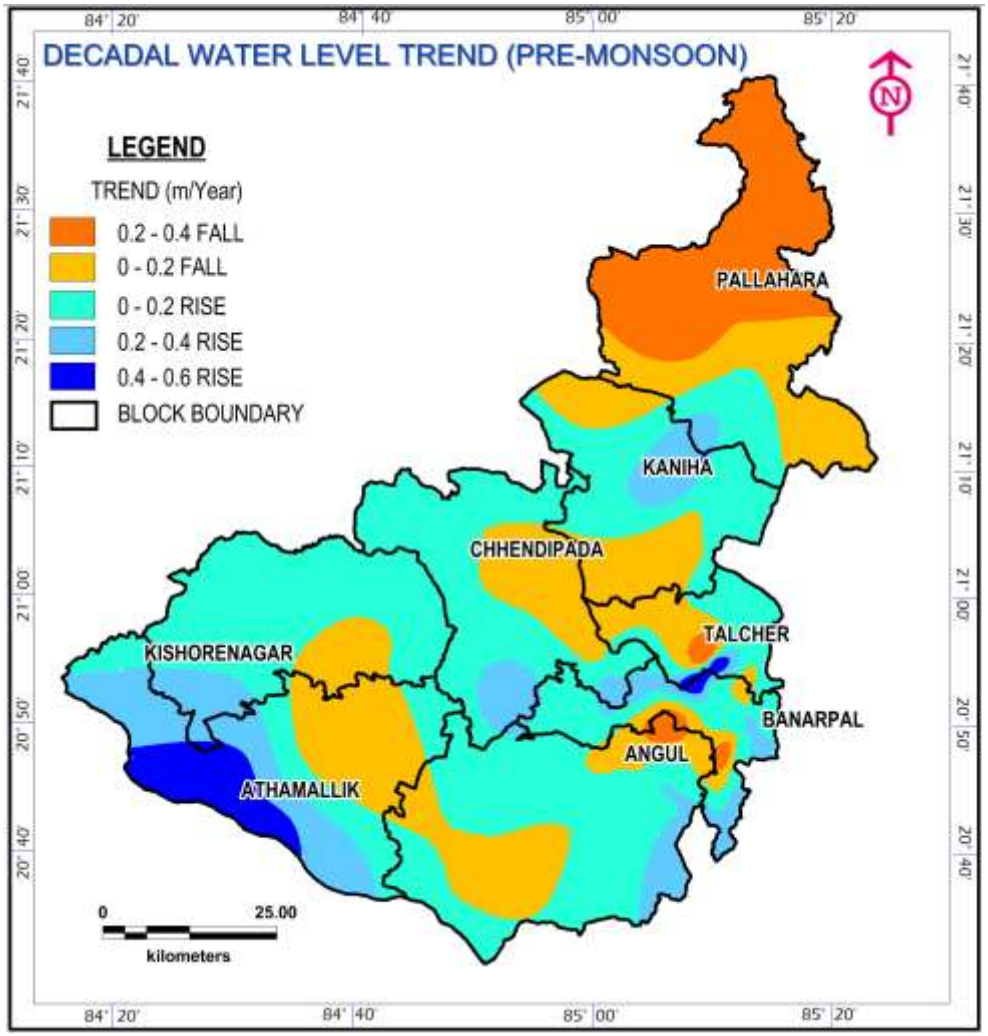


Fig. 4.7: Pre-Monsoon Decadal Water Level Trend (2006-15)

In the study area, post monsoon rise in water levels trend has been recorded at 16 stations and it ranges between 0.004 m/year (Kuio) to 0.354 m/year (Bhogaberini) while falling trend was observed in 25 stations varying from -0.008 m/year (Kosala1) to -0.502 (Talcher1).In post-monsoon the falling water level trend has been observed in central part from Kaniha to Angul block and parts of Kishorenagar and Pallahara block. however rising trend has been observed in southern part of Chhendipada block and eastern parts of Angul and Banarpal block and western parts of Athamallik and Kishorenagar blocls.

4.3.4 Hydrograph Analysis

The hydrographs of 16 ground water monitoring stations were analysed for the period from 2006 to 2015. The variation in short term and long-term water level trends may be due to

variation in natural recharge due to rainfall and withdrawal of groundwater for various agricultural activity, domestic requirement and mining & industrial needs.

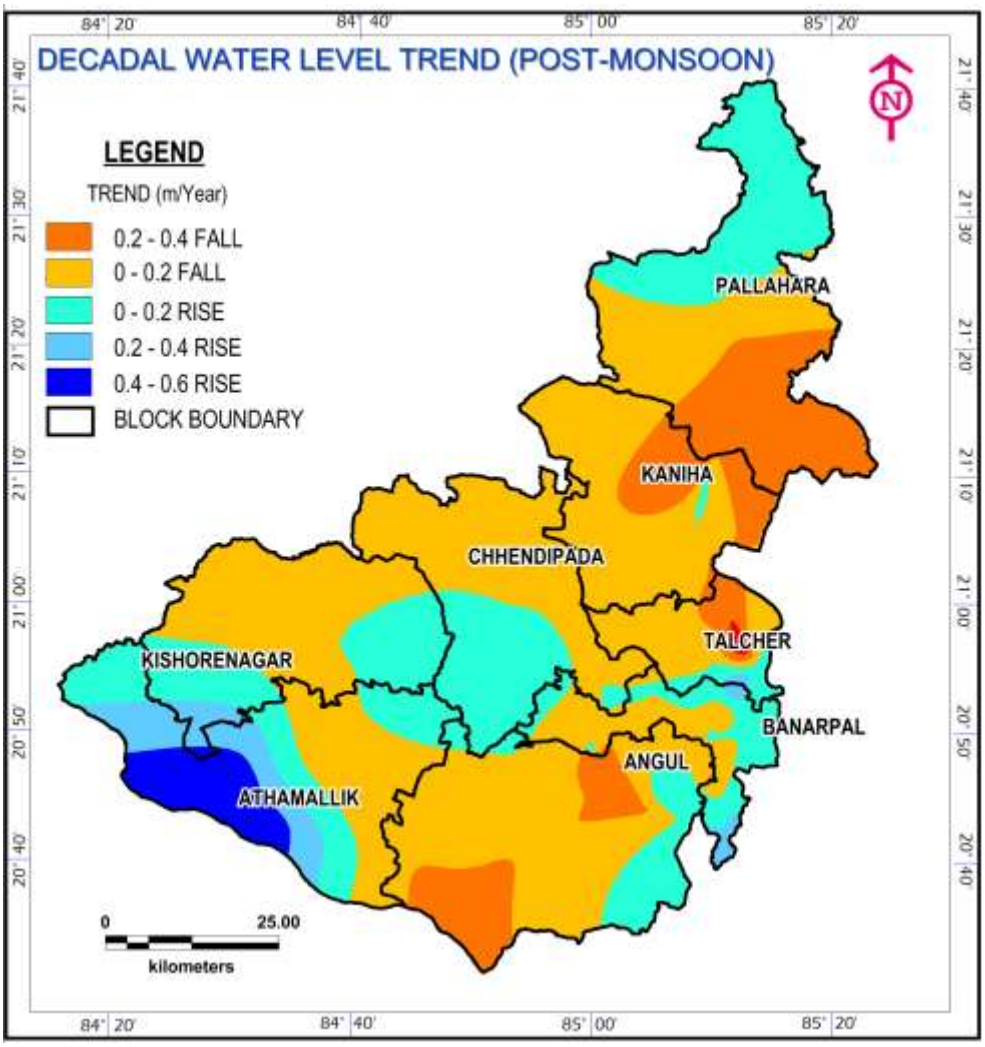


Fig. 4.8:Post-Monsoon Decadal Water Level Trend (2006-15)

The water level hydrographs of selected National Hydrograph Network Stations (NHNS) are shown in **Fig. 4.9a** through **4.9q**. An annual rising limb in hydrographs indicate the natural recharge of groundwater regime due to monsoon rainfall, as the monsoon rainfall is the only source of water. However, the groundwater draft continuously increases as indicated by the recessionary limb. The groundwater resources where not replenished / recharged fully, the groundwater levels come under continuous stress and deplete. It has also been observed that there were few years when the recharge exceeded draft for a particular period or year but in the next successive year, the draft again exceeded recharge.

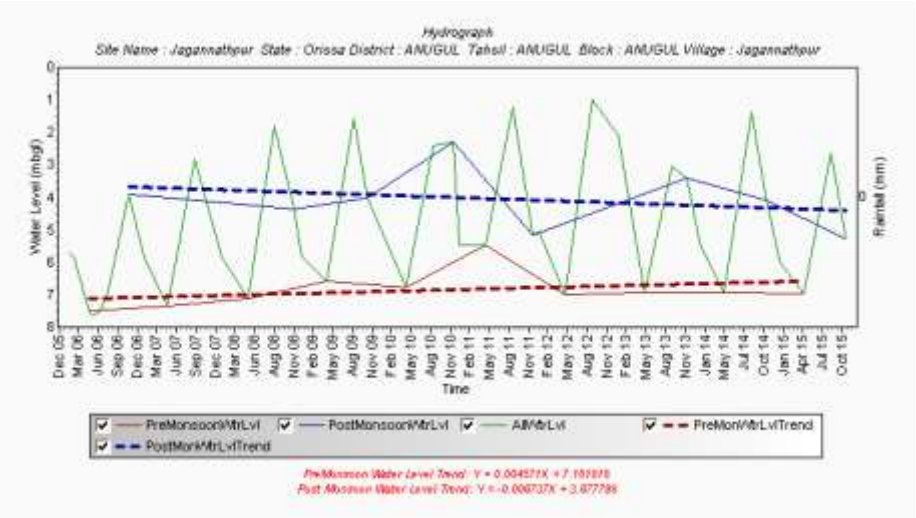


Fig. 4.9a: Hydrograph (2006-15), Jagannathpur, Angul Block.

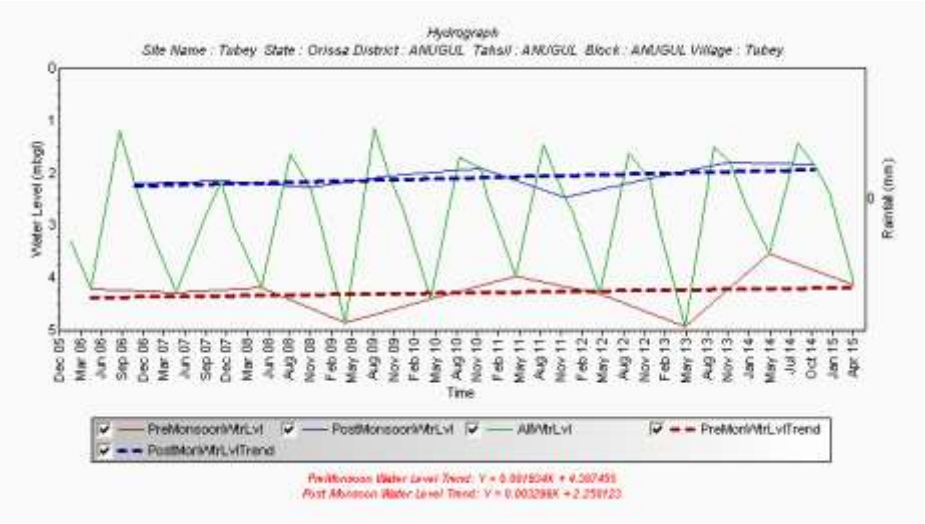


Fig. 4.9b: Hydrograph (2006-15), Tubey, Angul Block.

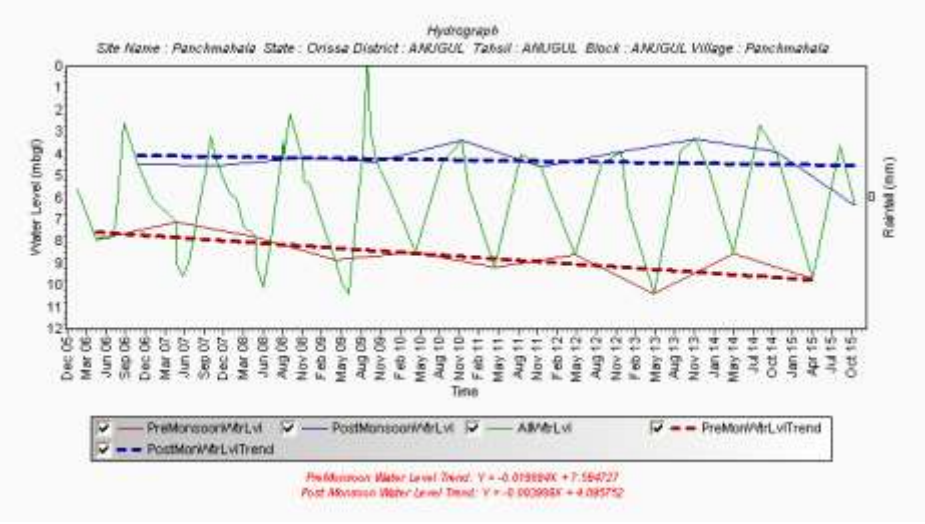


Fig. 4.9c: Hydrograph (2006-15), Panchmahala, Angul Block.

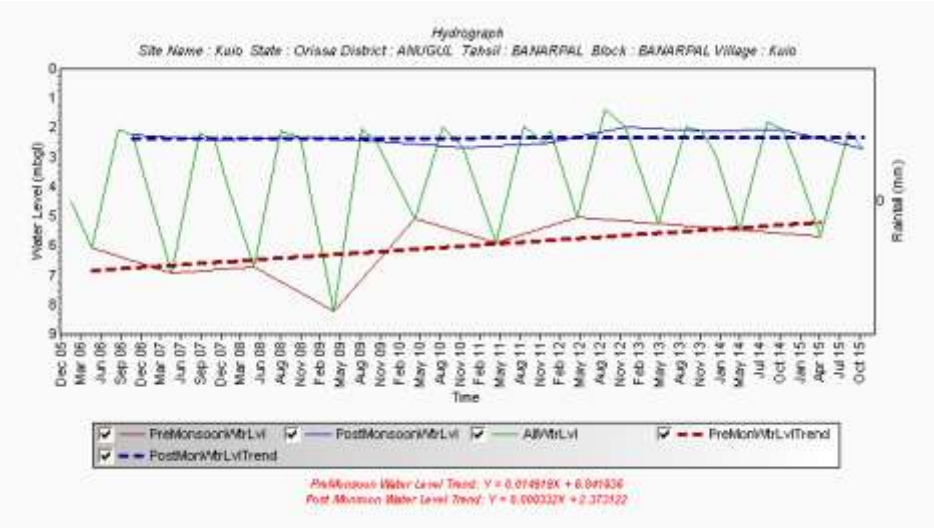


Fig. 4.9d: Hydrograph (2006-15), Kuio, Banarpal Block.

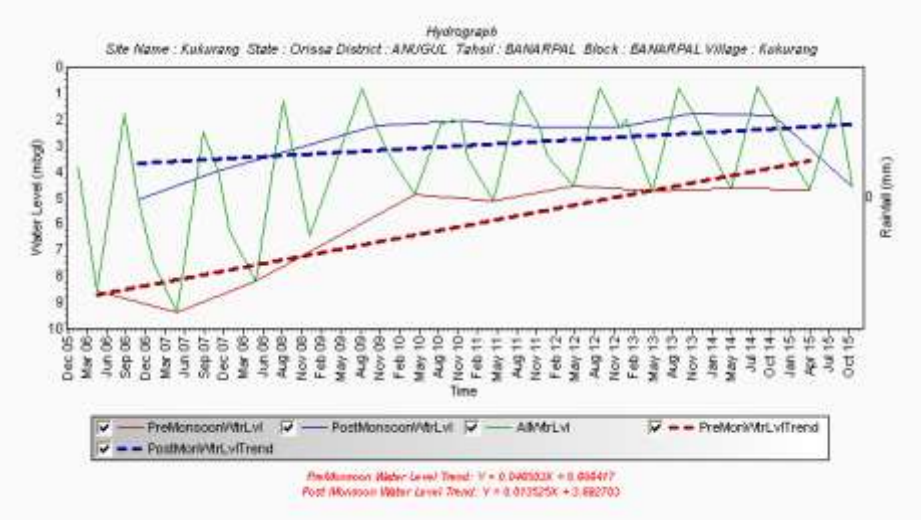


Fig. 4.9e: Hydrograph (2006-15), Kukurang, Banarpal Block.

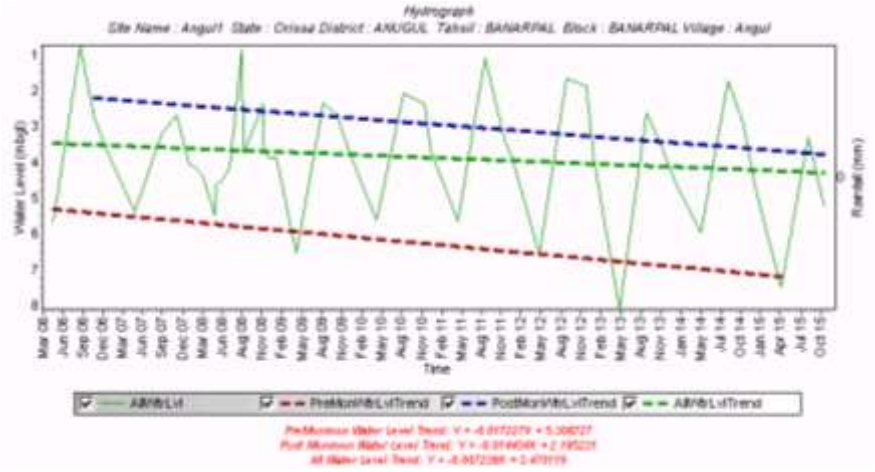


Fig. 4.9f: Hydrograph (2006-15), Angul1, Banarpal Block.

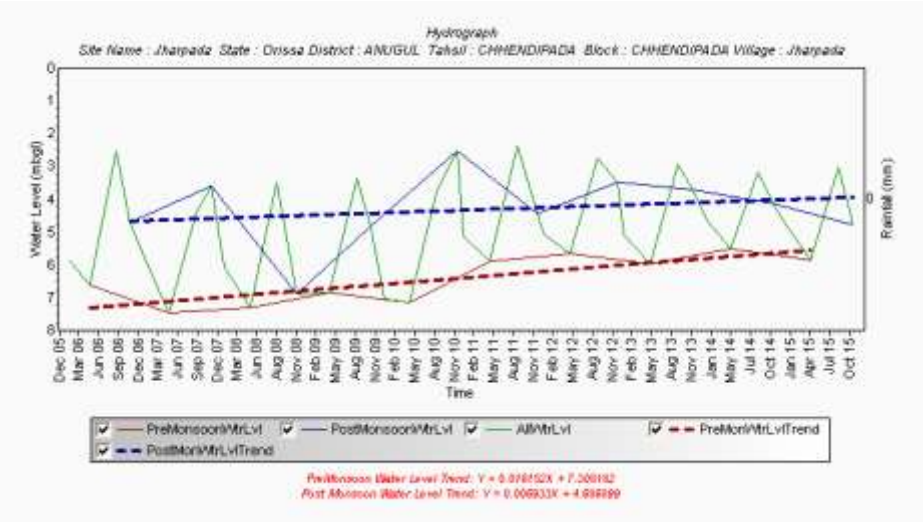


Fig. 4.9g: Hydrograph (2006-15), Jharpada, Chhendipada Block.

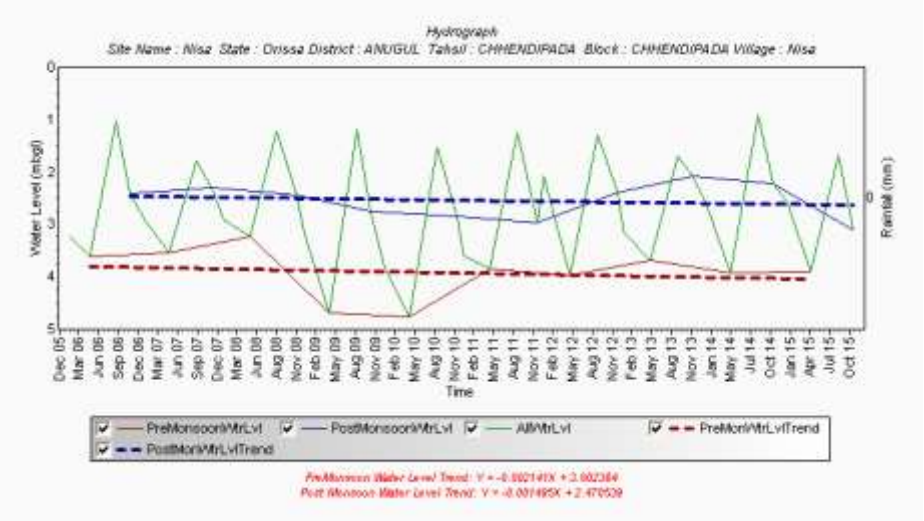


Fig. 4.9h: Hydrograph (2006-15), Nisa, Chhendipada Block.

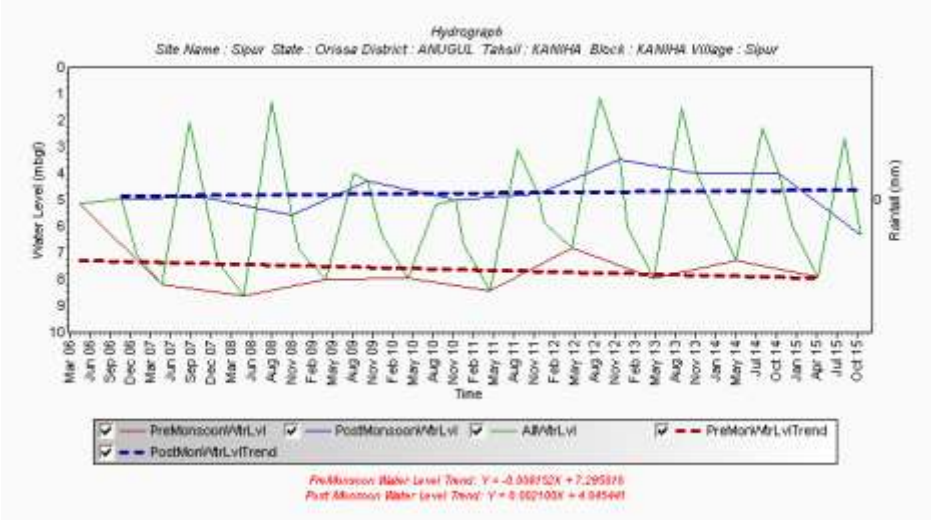


Fig. 4.9i: Hydrograph (2006-15), Sipur, Kaniha Block.

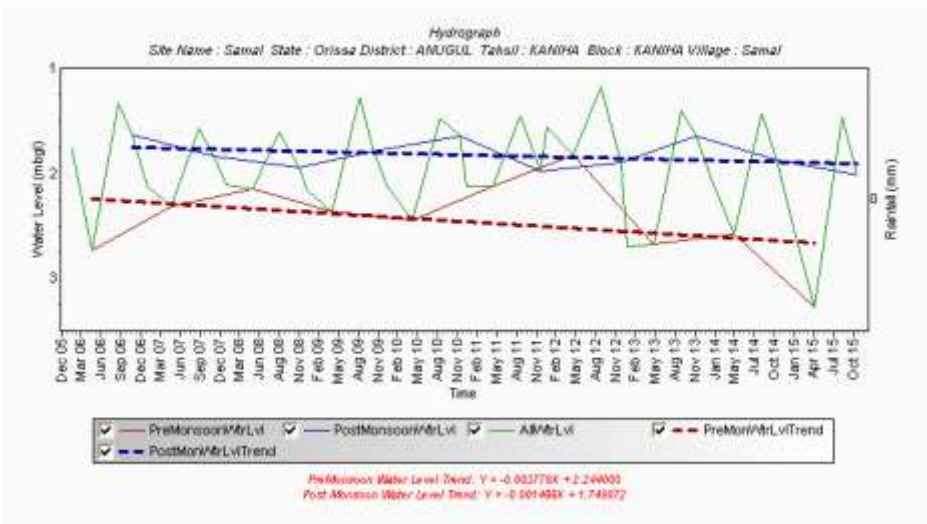


Fig.4.9j: Hydrograph (2006-15), Samal, Kaniha Block.

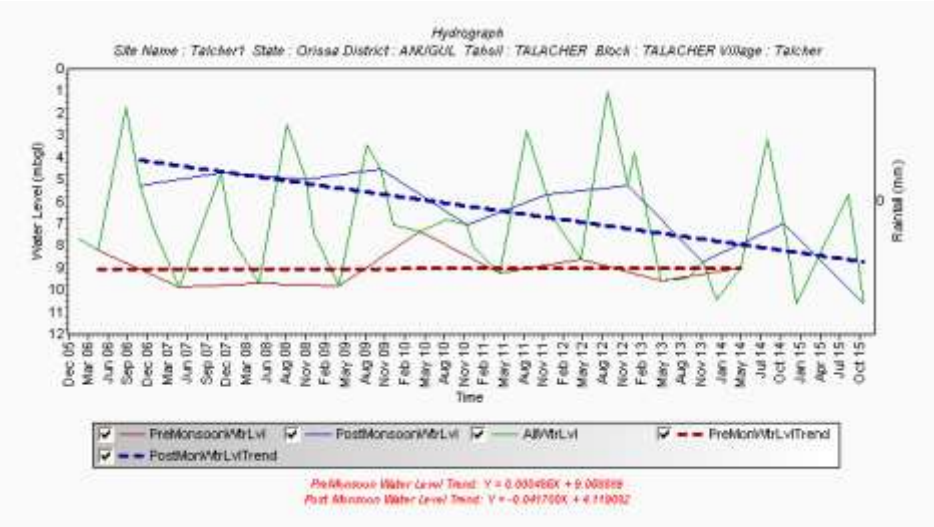


Fig. 4.9k: Hydrograph (2006-15), Talcher1, Talcher Block.

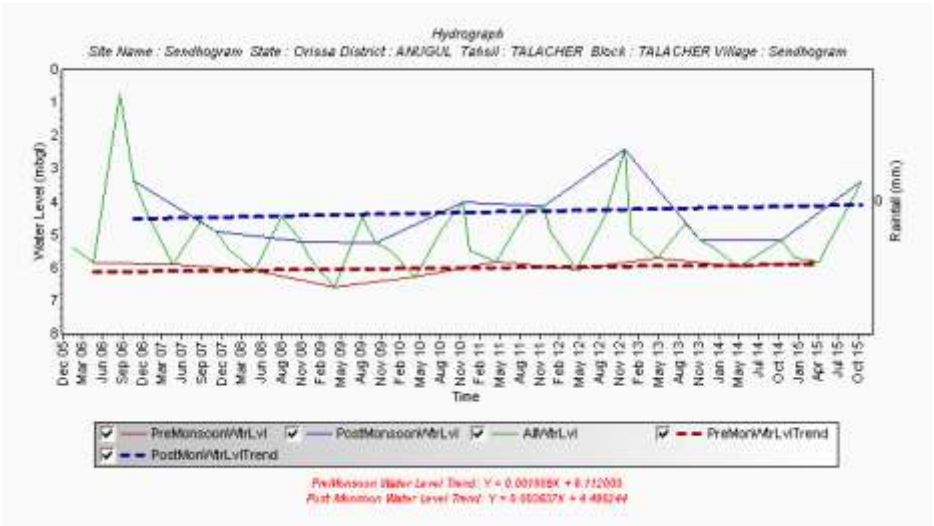


Fig. 4.9l: Hydrograph (2006-15), Sendhogram, Talcher Block.

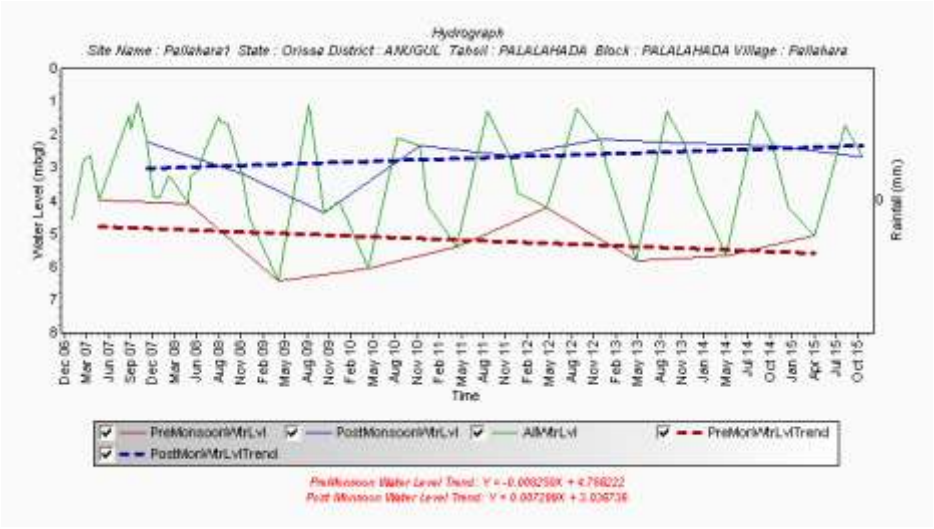


Fig. 4.9m: Hydrograph (2006-15), Pallahara1, PallaharaBlock.

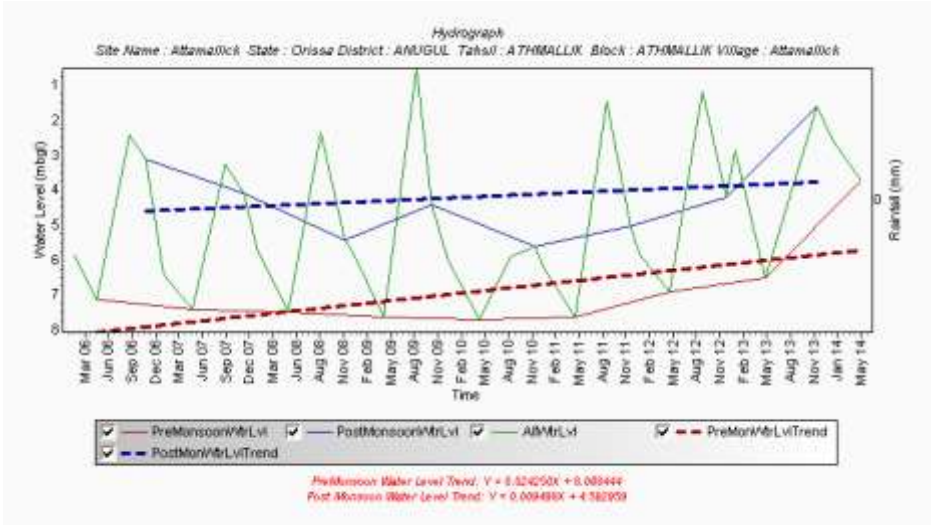


Fig. 4.9n: Hydrograph (2006-15), Athamallik, Athamallik Block.

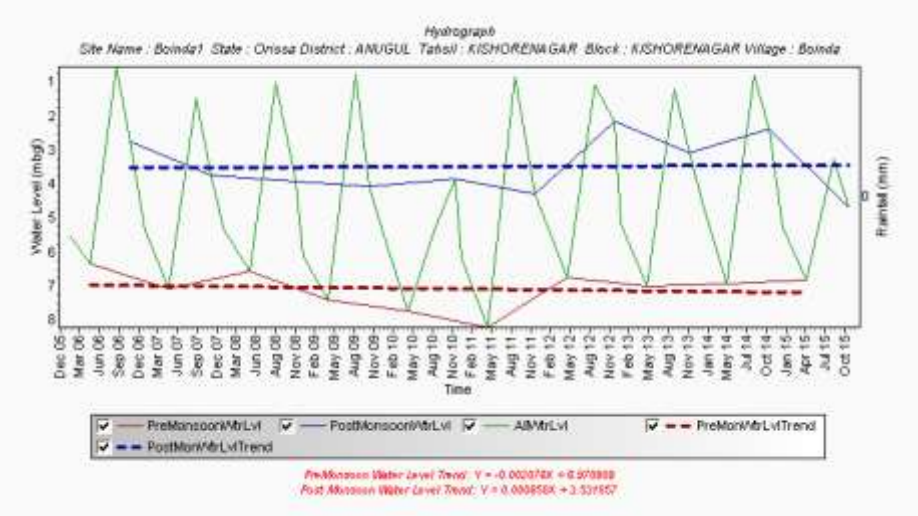


Fig. 4.9o: Hydrograph (2006-15), Boinda1, Kishorenagar Block.

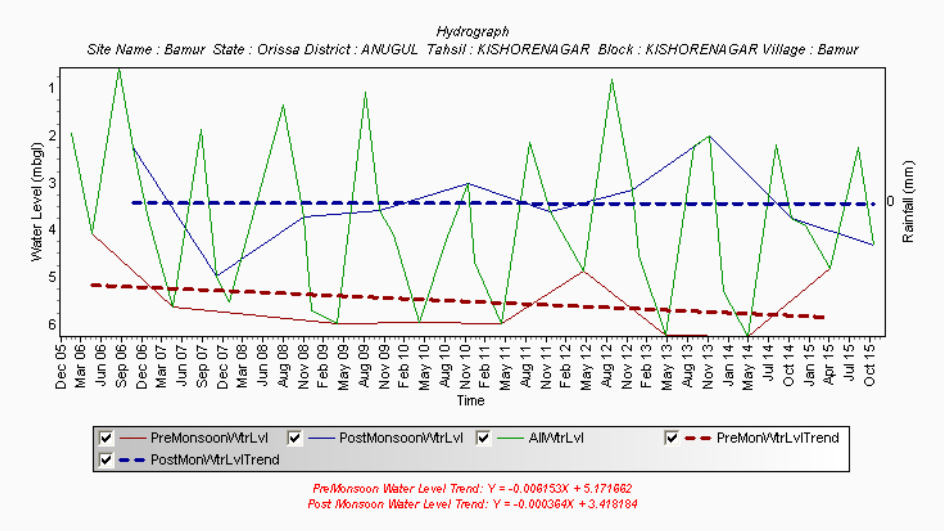


Fig. 4.9p: Hydrograph (2006-15), Bamur, Kishorenagar Block.

4.3.5 Ground Water Flow

In a groundwater regime, equipotential lines, the line joining points of equal head on the potentiometric surface, were drawn based on the area of variation of the head of an aquifer. Based on the Water table elevation, ground water flow directions are drawn (F**ig. 4.10**). It has been observed that the ground water flow directions follow the major drainage channels and topography of the area. This indicates the topographic control for the ground water movement.

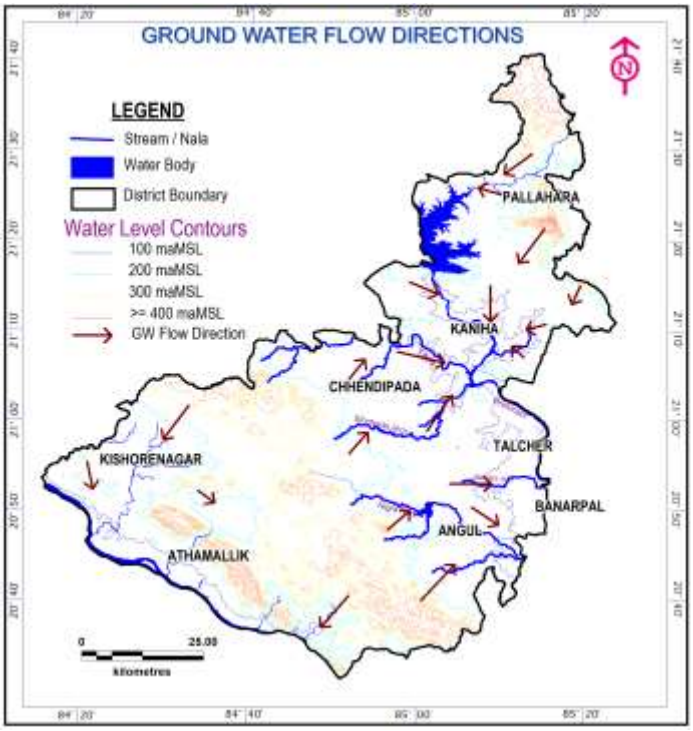


Fig. 4.10: Ground Water Flow Directions in Angul District.

5 Ground Water Quality

The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of various plants, animals,human beingsand industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. 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. Apart from these, a number of special studies have been carried out by CGWB in the area on ground water quality and its pollution aspect. During the NAQUIM programme, about 213 water samples collected during pre-monsoon period and were analysed for chemical quality. The ground water samples were analysed for major chemical constituents and the results are shown in ***Annexure-III***. Taking the results of chemical analysis during NAQUIM field work and the available historical chemical data, he aquifer wise ranges of different chemical constituents present in ground water, are determined andgiven in **Table 5.1.**

Table 5.1: Aquifer-Wise Ranges of Chemical Constituents in Angul District.

Parameter	Unit	Shallow (Aquifer-I)			Deep (Aquifer-II)		
		Min	Max	Avg	Min	Max	Avg
pH	-	7.31	8.69	8.07	6.10	8.44	7.67
EC	mS/cm	60	**4007**	864	213	2010	685
TDS	mg/L	49	1951	424	109	972	351
TH	mg/L	40	1355	304	85	615	220
TA	mg/L	40	660	193	21	480	185
Ca	mg/L	6	340	59	8	286	40
Mg	mg/L	5	**197**	38	1	114	33
Na	mg/L	1	370	44	0.8	169	46
K	mg/L	0.09	121	6	0.1	376	34
CO_3	mg/L	0	66	1	0	72	2
HCO_3	mg/L	49	781	234	85	549	285
NO3	mg/L	0.6	**105**		<1	9	
Cl	mg/L	7	**1127**	120	7	508	54
SO_4	mg/L	0	272	40	<1	69	24
F	mg/L	0.03	**3.80**	0.57	0.1	**3.1**	
Cu	ppm	0	0.03	0.01			
Fe	mg/L	0	0.75	0.15			
Mn	ppm	0	0.25	0.05			
Pb	ppm	0	0.03	0.02			
Zn	ppm	0	0.28	0.04			
As	ppb	0	1.46	0.19			
SAR	-	0	12.7	1.3	0	6.2	1.4

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. Higher EC (µS/cm) has been found at Bhogaberini (4900), Salagadia(4007) Karnapur(2680) Derjang (2365), Tentulei (2210), Chhelia (2150), Ekagharia (2058), Bantala (2050) and Badabahal (2000). The iso-conductivity map of Aquifer I and II has been prepared and presented as **Fig. 5.1**. From the diagram it's found that higher EC value is in the area between Angul, Talcher and Banarpal.

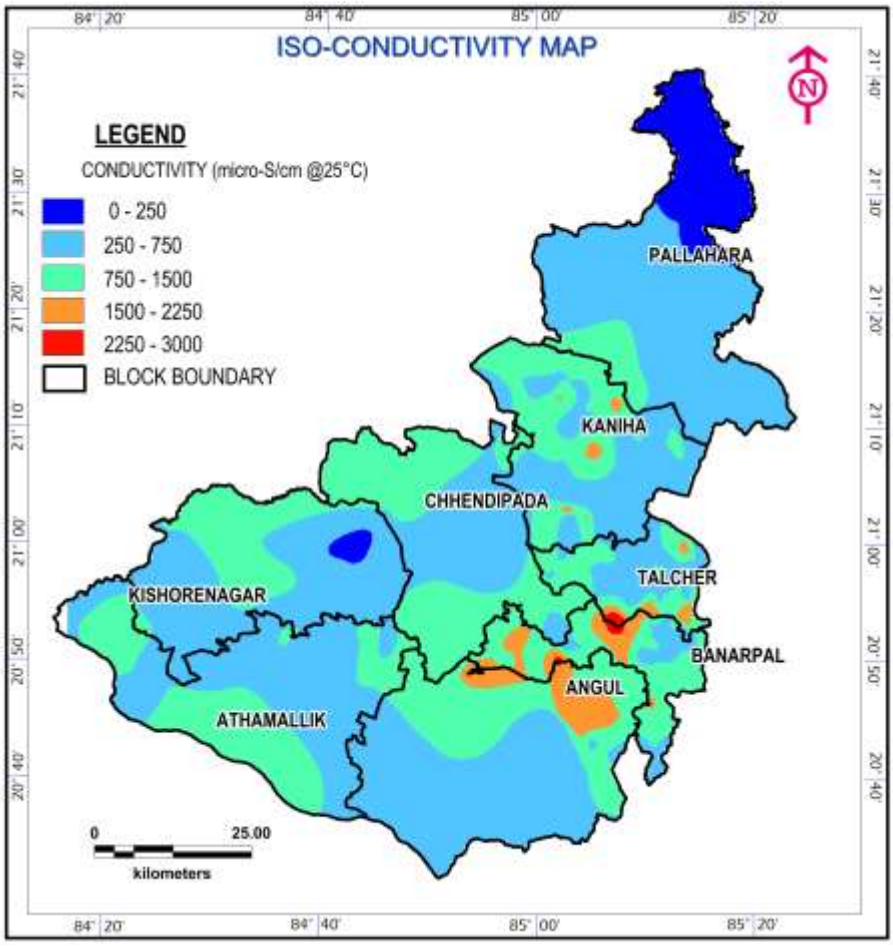


Fig. 5.1: Iso-Conductivity Map of Angul District.

The SAR value of irrigation water indicates the level to which water undergoes cation exchange with the soil. The SAR of the samples of Aquifer-I ranges from 0 to 12.7. The suitability of the ground water for the purpose of irrigation analysed in the US-Salinity diagram as shown in **Fig. 5.2** and **5.3** the predominant USSL classes of the water samples for both phreatic and deeper aquifers fall within C2-S1 and C3-S1 classes, which indicates low sodium hazard and medium to

high salinity hazard. Groundwaters that fall within the C1-S1 and C2-S1 can be used for irrigation on all types of soil with little danger of the development of harmful levels of exchangeable sodium. However, C3-S1 types of water could only be used to irrigate certain semi-tolerant crops.

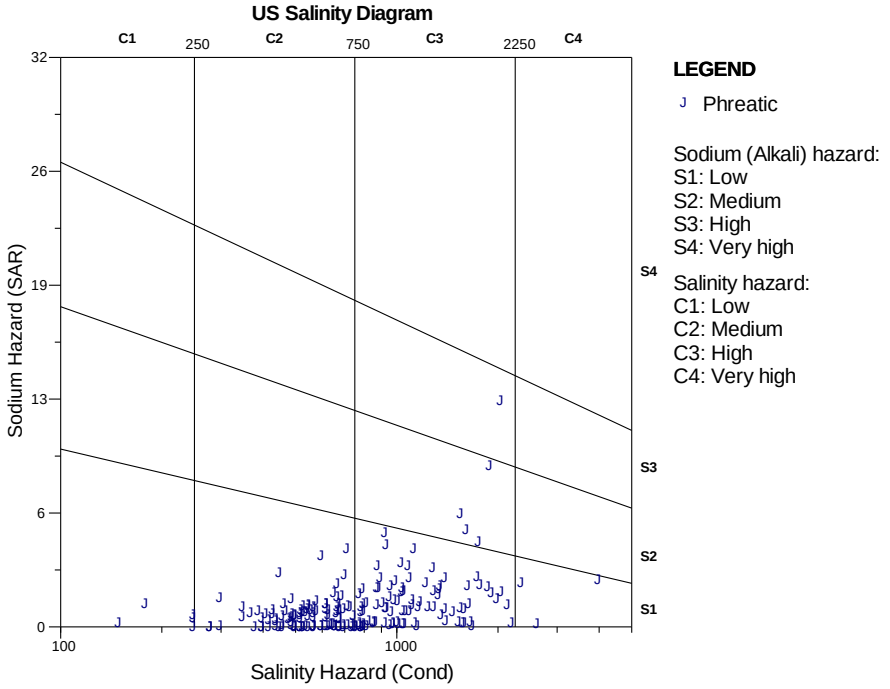


Fig. 5.2: US-Salinity Diagram, Aquifer-I (Phreatic) in Angul District.

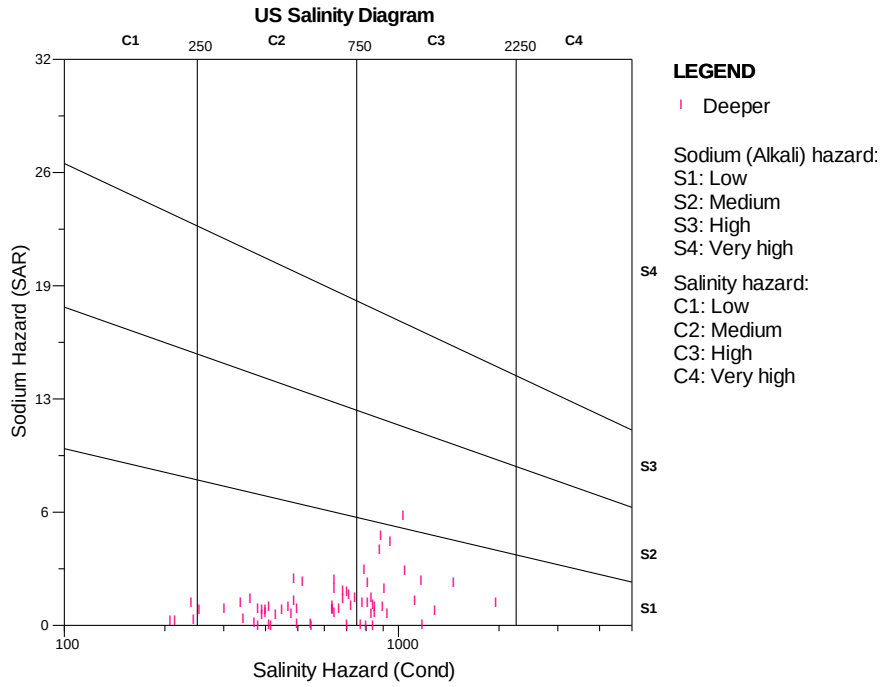
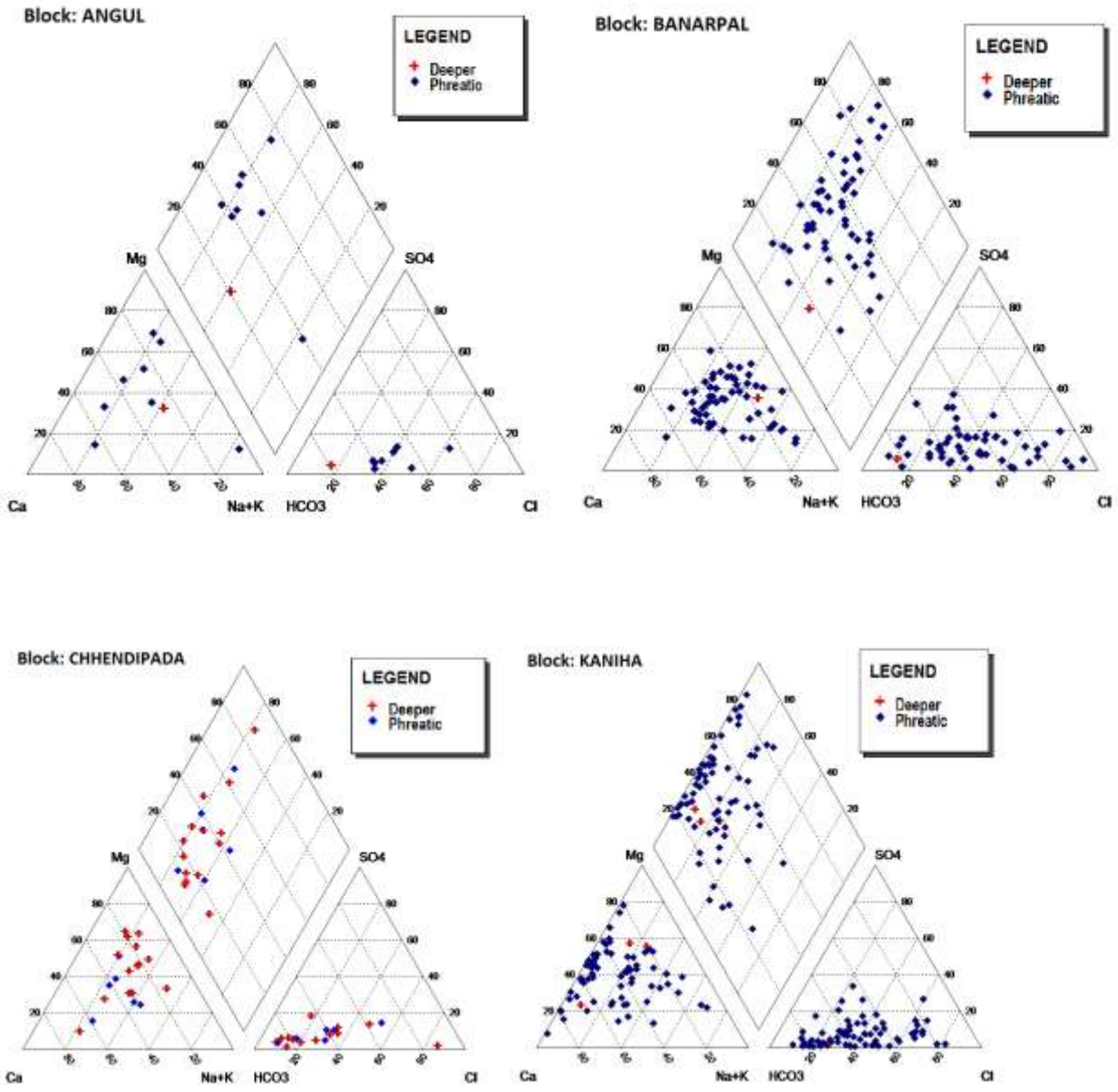


Fig. 5.3: US-Salinity Diagram, Aquifer-II (Deeper) in Angul District.

The water samples represent mixed facies of water, the predominant type being the Na-Ca-Mg-HCO_3-Cl-SO_4 type as shown in the Piper diagrams in **Fig.5.4**. This indicates a transitional or mixing environment between the younger water and resident water.



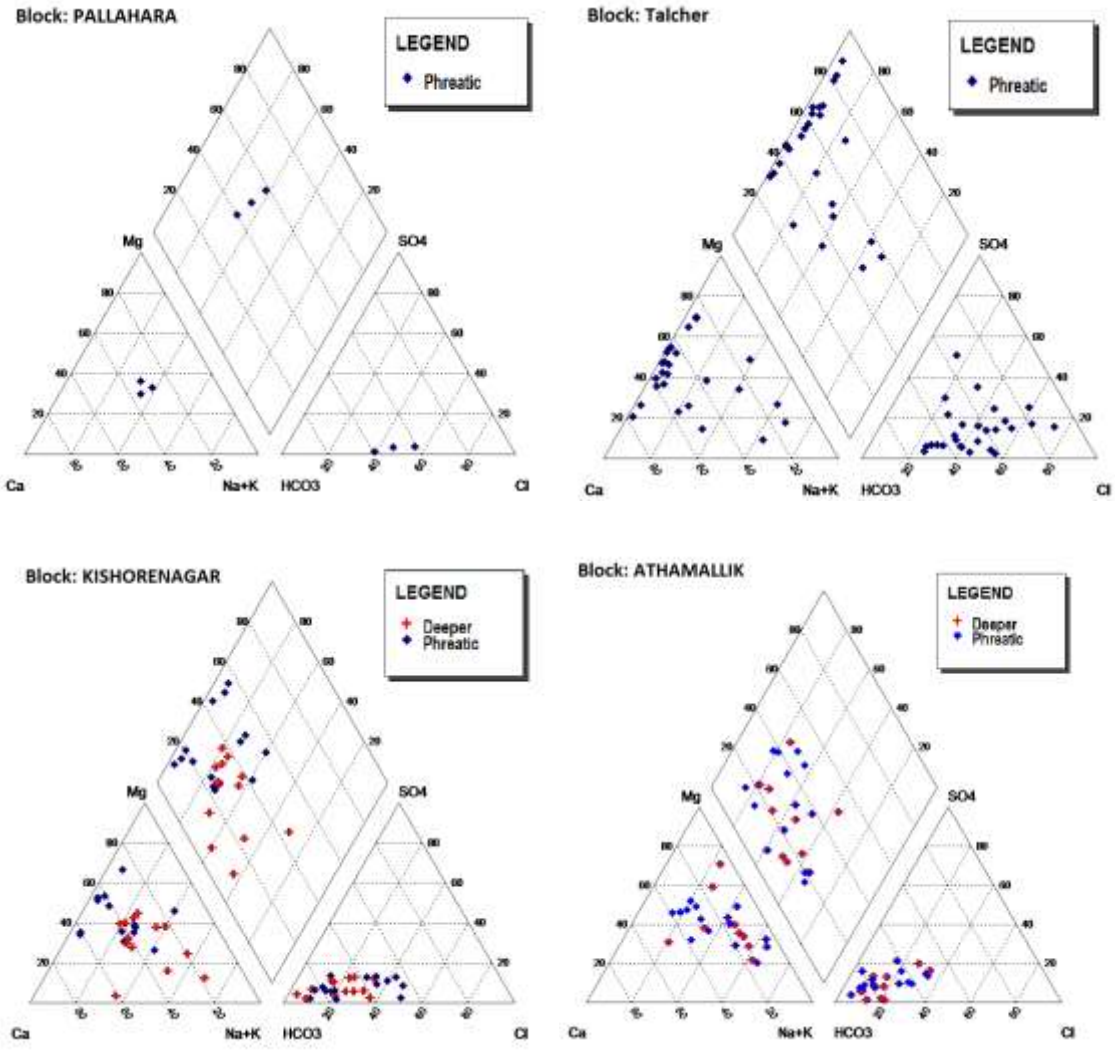


Fig. 5.4: Block-Wise Piper Diagrams of Shallow and Deeper Aquifers in Angul District.

A perusal of the piper diagrams indicate that, ground water of Angul, Chhendipada, Kaniha, Athamallik and Kishorenagar are similar and they represent Mg-Bicarbonate to Mixed type. Similarly Banarpal, Pallahara and Talcher have Ca-Cl type to mixed type of ground water.

Higher fluoride (F>1.0 ppm) has been recorded at numerous locations. The occurrence of higher fluoride point sources are shown in **Fig.5.4**.In shallow aquifer at Badabahal (2.32), Bantala(2.23), Gopalprasad (2.21), Kuio (1.2), Sendhogram (1.3 & 3.8), Samal (1.7), Rengali (1.4) and Bhogabereni (1.07), Chhendipada (1.7), Paranga (1.7), Bentapur (1.43), Turanga (1.28), Talamaliha (1.71), Thakurgarh and Tulasipal and in deeper aquifer at Korada (1.7), Santrapur (1.85), Thakurgarh (1.24), Ambsarmunda (2.01), Talamaliha (3.1), Anandpur (2.01) and Kundajhari

(1.38). The occurrence of high F does not show any pattern and can not be linked with the Industries. The waste water from NALCO effluent channels contains high F, whereas the same is low in ground water in that area. Any adverse effect of effluent discharged from ash pond areas like NTPC Kaniha, on the ground water quality has not been noticed.

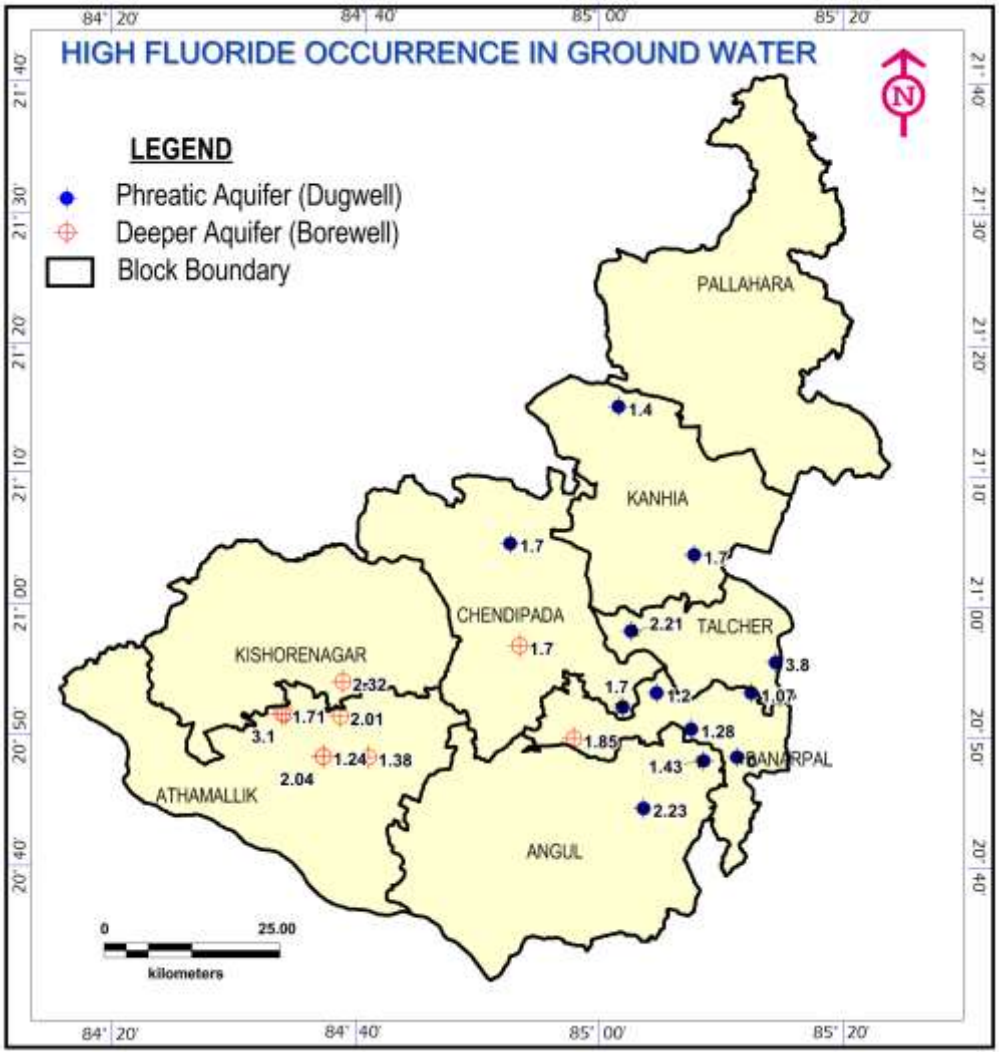


Fig. 5.5: Higher Fluoride Content in Ground Water of Angul District.

6 AQUIFER MAP AND AQUIFER CHARACTERISTICS

6.1 Aquifer Characteristic

The main rock type of the area are Pre-cambrian consolidated formations like Granite, Granite-Gneiss, Charnockites, Khondalites, Quartzites, Phyllites and Mica Schists and Gondwana semi-consolidated formations like Sandstone and Shale. The Pre-cambrian crystalline formations are hard, compact and does not have primary porosity and hence impermeable. Weathering, jointing and fracturing induces secondary porosity. Ground water occurs under phreatic/ unconfined condition in weathered residuum from which water moves downward through joints, fractures etc. Ground water occurs in semi-confined to confined conditionsinsuch deep fracture zones. The semi-consolidated Gondwana formations in the area have very little or no primary granular porosity. They are of hard and indurated in nature. Fracture and faults play an important role in occurrence and movement of ground water in them. Ground water occurs in top weathered zones as phreatic aquifer and at depth, water occurs in the fractured zones only in these formations lacking primary porosity. The yield of bore wells is generally poor in comparison to the Pre-Cambrian formations.

6.2 Aquifer Group Thickness & 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, 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. 6.1.**

Aquifer II – Semi-confined to confined aquifer. Generally occurs in 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 have 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 that maximum depth for the Aquifer-II can be safely taken as 200 mbgl. Based on the exploration data, delineation of Aquifer-I and Aquifer-II has been done based on the lithologs from the borewell exploration data.

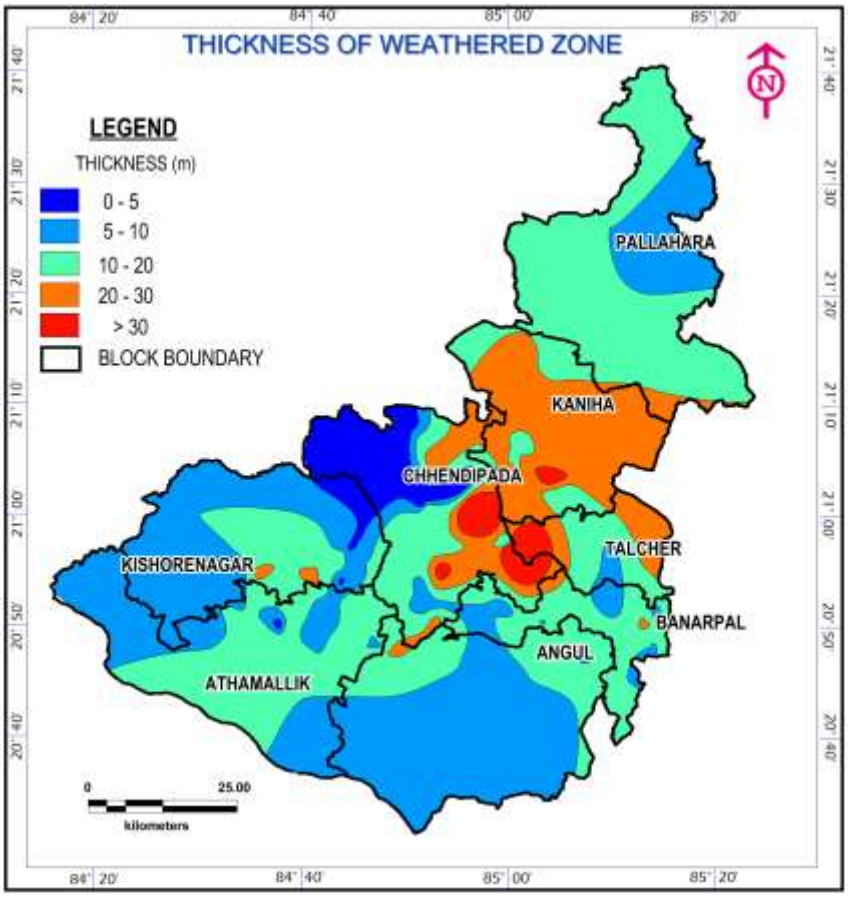


Fig. 6.1: Isopach of Weathered Zone (Aquifer-I) in Angul District.

Based on field survey and ground water exploration, the deeper aquifer i.e. Aquifer-II in Easternghat formations viz. Charnockite and Khondalite and Gondwana formations viz. Sandstone and Shale have comparatively poorer yield prospect than the Granitic aquifers. the aquifer characteristic of NAQUIM area has been computed and is given in **Table 6.1.**

Table 6.1 : Aquifer Characteristics of NAQUIM Area, Angul District.

Type of Aquifer	Formation	Depth range of the aquifers (mbgl)	Yield (m3/day)	Aquifer parameter (T : m^2/day)	Suitability for drinking/ irrigation
Aquifer-I (phreatic)	Weathered- Granite Gneiss, Charnockite, Khondalite, mica quartzite, Sandstone, shale	0-30	10-50	-	Yes for both (except Fluoride affected villages for drinking)
Aquifer-II (semi-confined to confined)	Fractured- Granite Gneiss Fractured Charnockite, Khondalite, mica quartzite	30-200 30-200	Negl. to 1730 Negl. to 380	0.6-60 -	Yes for both Yes for both
Aquifer-II (semi-confined to confined)	Fractured- Sandstone, Shale	30-200	Negl. to 730	0.84-46	Yes for both

6.3 Aquifer Disposition

The ground water exploration data has been used to generate the 3D disposition of deeper basaltic aquifers. 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 adopted. A schematic 3-D diagram of aquifer disposition has been prepared and shown in **Fig. 6.2** and a lithological Fence diagram has been generated and shown in **Fig. 6.3**. To visualize the Aquifer-I and Aquifer-II, based on ground water exploration data, different sub-surface aquifer sections have been prepared to know their continuity and extent. The aquifer sections are drawn along A-A', B-B' and C-C' as shown in **Fig. 6.4a** and these sections are shown in **Fig.6.4b to 6.4d.**

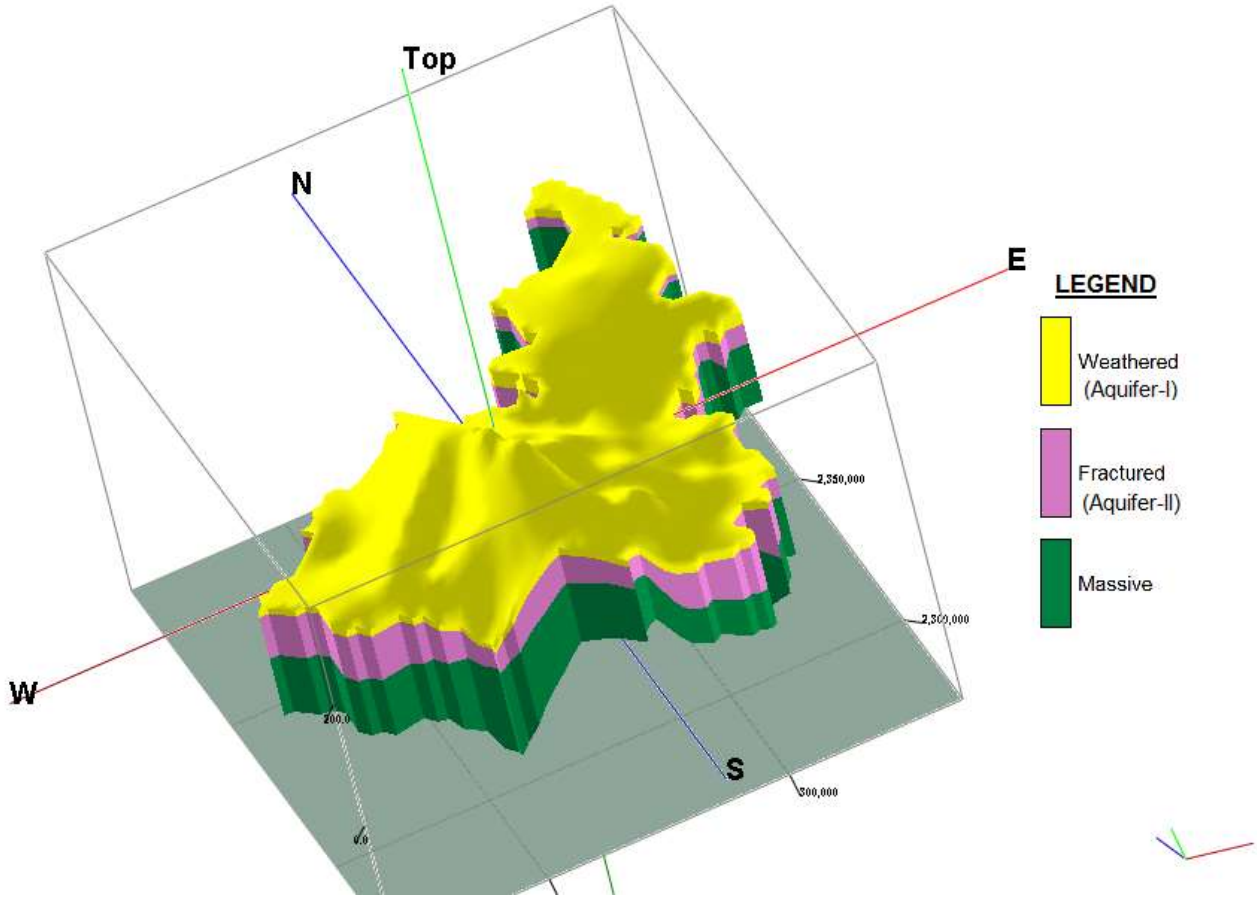


Fig. 6.2: Schematic 3-D Aquifer Disposition in NAQUIM Area, Angul District.

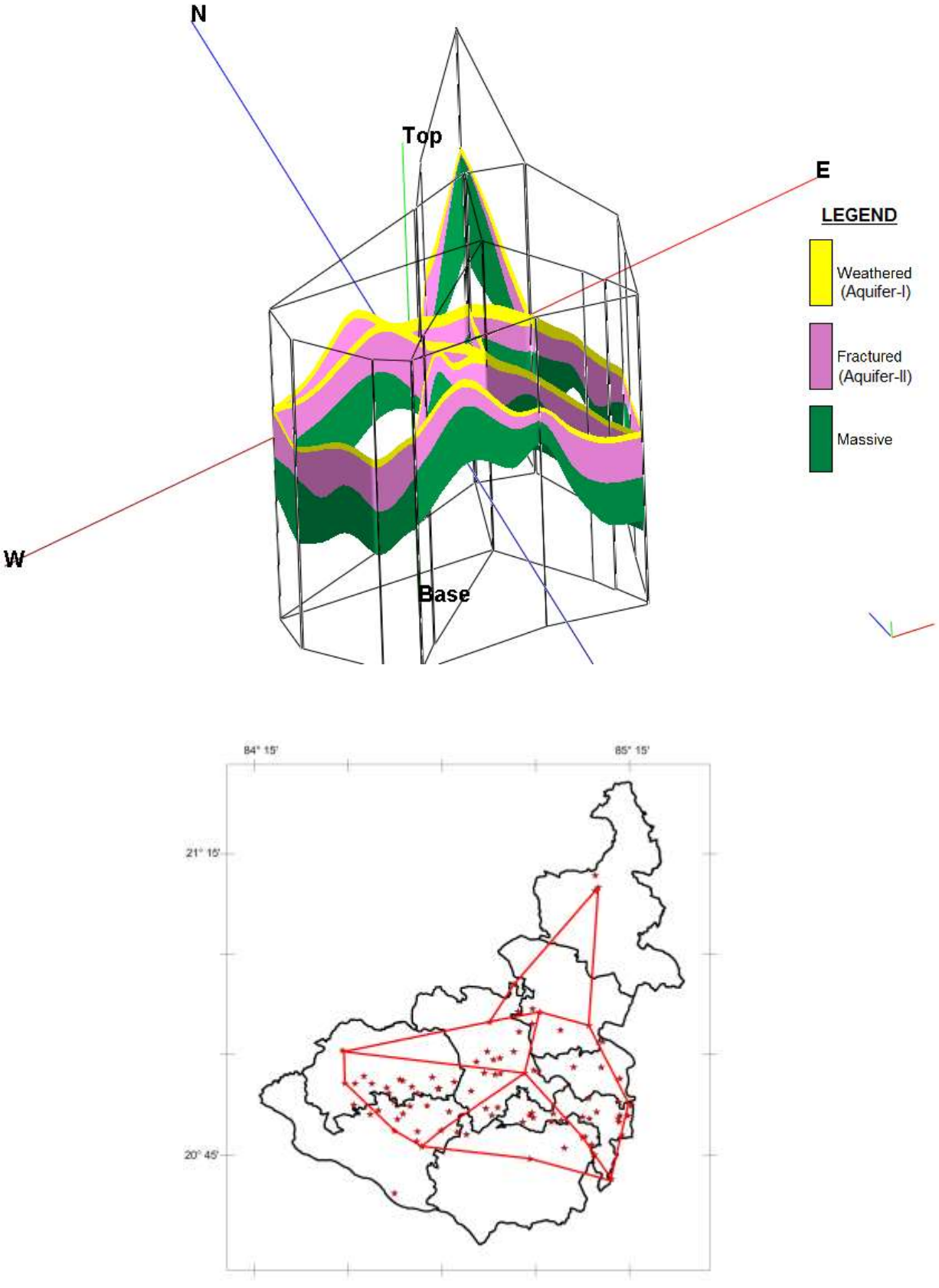


Fig. 6.3: 3-D Fence Diagram of Aquifers in Angul District.

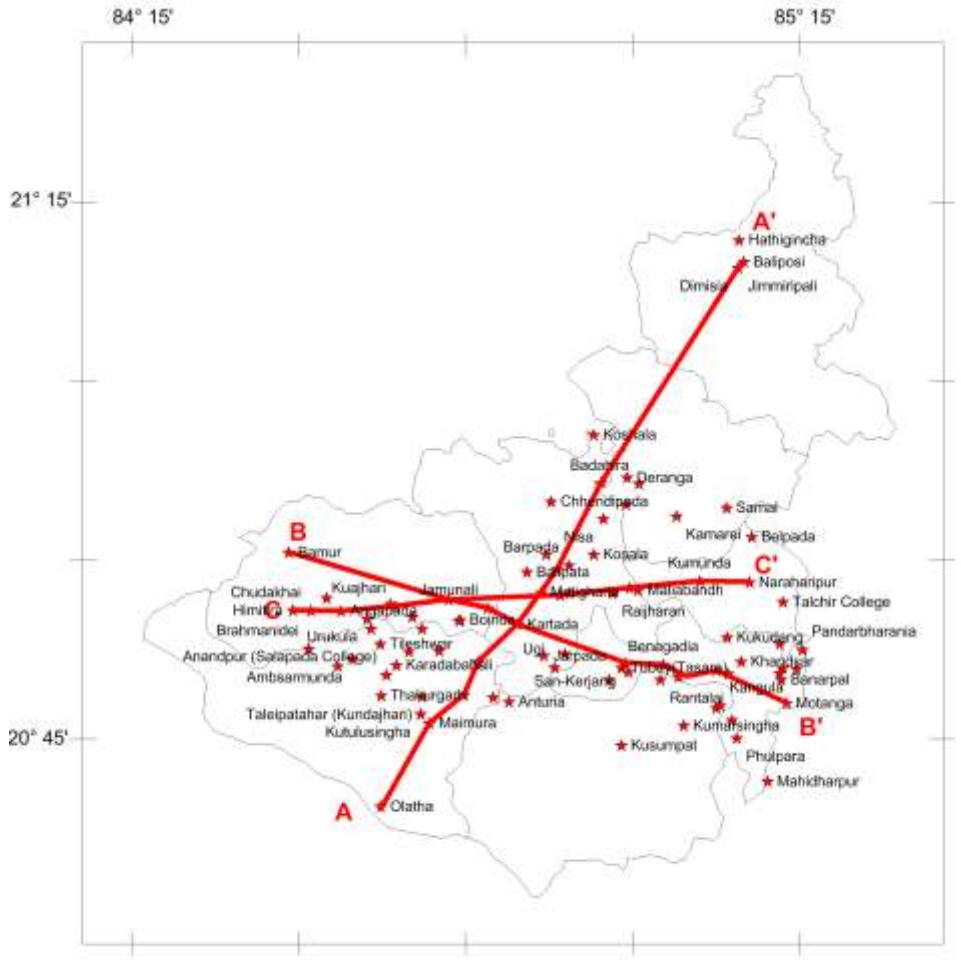


Fig. 6.4a: Aquifer Cross-Sections Along the Lines A-A', B-B' and C-C'.

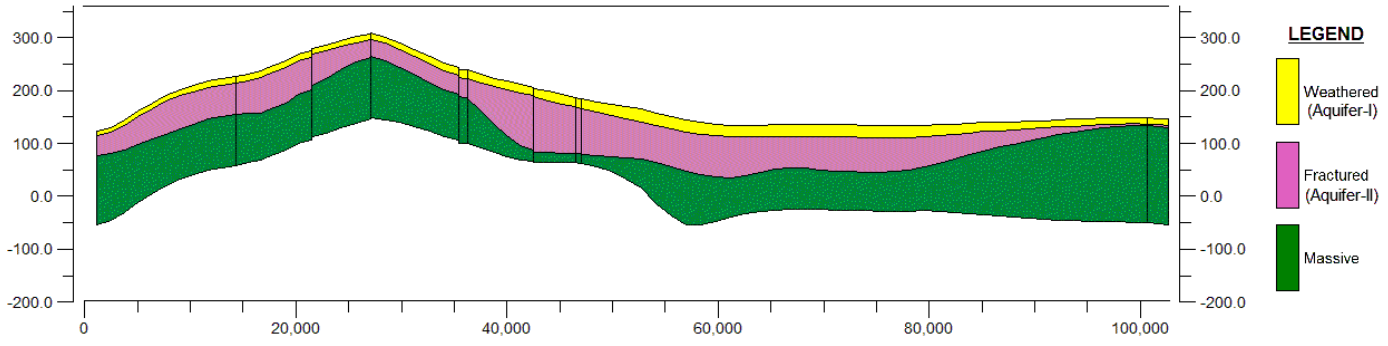


Fig. 6.4b: Cross- Section along A-A'

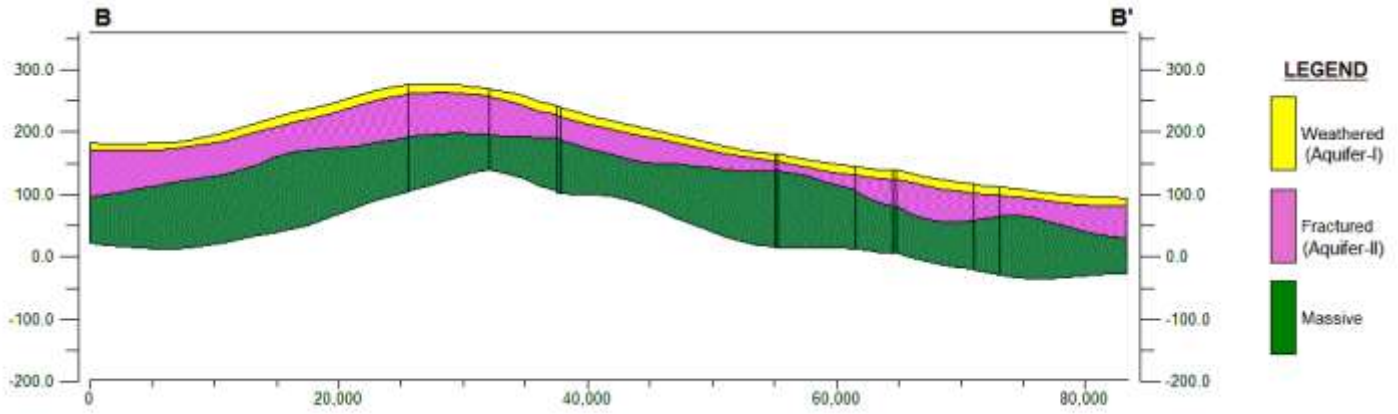


Fig. 6.4c: Cross-Section along B-B'

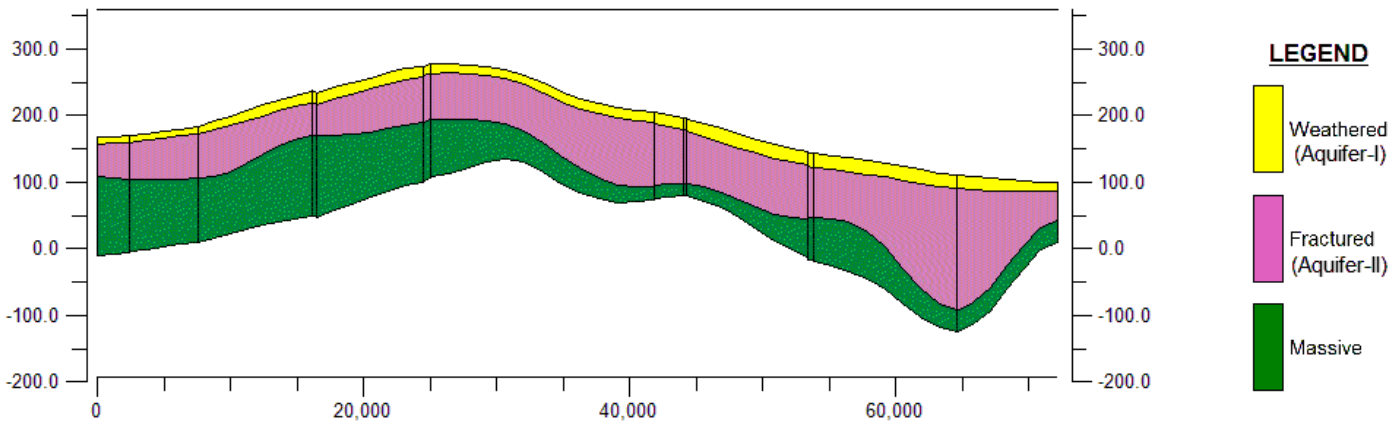


Fig. 6.4c: Cross-Section along C-C'

6.4 Fracture Analysis (Aquifer-II)

Based on the exploration data, the bottom depth of the Aquifer-II is taken down to 200 mbgl depth because this is the maximum likely depth within which fracture zones are encountered. Most of the fractures are encountered within 0-30 mbgl and then 30-100 mbgl and beyond that, the chances of encountering fracture zones gradually reduces. The occurrence of fracture with respect to depth down to 300 mbgl as explored by CGWB, in different lithology of the NAQUIM area are analysed and the result is summarized in **Table 6.2** and the number and percentage of fractures at different depths is shown in **Table 6.3**.

Table: 6.2: Depth-Wise Occurrence of Fracture Zones in NAQUIM Area in Angul District.

Fracture	Depth Range of Fracture Zone (mbgl) (No of wells)		
	Granite/Gr.Gneiss	Gondwana	Charnockite/Khondalite
1st	6.0-149.0 (68)	3.0-143.5 (32)	13.31-15.5 (2)
2nd	28.4-150.4 (46)	11.5-153.7 (12)	-
3rd	60.0-141.7 (12)	36.7-137.0 (5)	-
4th	80.0-99.6 (2)	105.7-156.0 (3)	-
5th	-	133.1-195.0 (2)	-
6th	-	207.0-214.0 (1)	-
7th	-	231.0-238.0 (1)	-
8th	-	247.0-254.0 (1)	-
9th	-	262.0-268.0 (1)	-
10th	-	282.0-286 (1)	-

Table: 6.3: No and Percentage of Fractures in NAQUIM Area in Angul District.

Formation	No of fractures encountered in the Depth Range (mbgl)						
	0-30	30-50	50-100	100-150	150-200	200-300	Total
Granite/ Gr. Gneiss	40	14	38	16	1	-	109
Gondwana	15	14	13	16	2	6	66
Charnockite/Khondalite	3	-	-	-	-	-	3
Total No of Fractures	**58**	**28**	**51**	**32**	**3**	**6**	**178**
%ge	**32.58**	**15.73**	**25**	**18.65**	**1.68**	**3.37**	**100**

6.5 Aquifer Parameters and Yield Potentials

The principle of pumping test is that if we pump water from an Exploratory well and measure the discharge and drawdown in both EW and OW, which is at known distance, we can substitute these measurements to calculate different aquifer parameters such as Transmissivity (T) Storativity (S) and yield potentials.

Transmissivity (T): It is defined as rate of flow under a unit hydraulic gradient through a cross-section of unit width over the saturated thickness of aquifer. It is expressed as m^2/day. The T value in the NAQUIM area range between 0.59 m^2/day (Anturia) to 60.05 m^2/day (Ugi) in pre-Cambrian granitic rocks, between 0.84 m^2/day (Jarada) to 46.13 m^2/day (Koshala) in Gondwana sandstone.

Storativity (S): It is the volume of water released from storage per unit surface area of the aquifer per unit decline in the hydraulic head normal to that surface. It is dimensionless property. The S value in the area available for 2 places. They are 0.0000423 (Ugi, granite gneiss) and .00045 (Maliabandh, Sandstone).

Yield potential (Q): The yields of wells are functions of the permeability and transmissivity of aquifer encountered and varies with location, diameter and depth etc. There are three type of ground water structures i.e. dugwells, shallow tubewells and borewells in the area. Their yield characteristics are described below.

Aquifer-I: Dugwells tapping weathered residuum in Granite, Granite gneisses, mica quartzites, phyllites, khondalites, charnockites, sandstone and shale range in their depth 4.3 to 15.75 mbgl. The yield of dugwells range from 10 to 50 m^3/day. Shallow tube wells are feasible in very limited areas, especially in the flood plains of the Brahmani and Mahanadi rivers. The depth of these wells may be <30 m, tapping (through slotted pipe) 5-10 m thickness of the aquifer. The effective diameter of these wells can be even 155 mm and the yield may be up to 15.0 lps. Areas in Chhendipada block with Kamthi formation have very good yielding shallow as well as deeper aquifer.

Aquifer-II: The data of exploratory wells in NAQUIM area reveals that, high yielding area is restrict to western part of area mostly in Chhendipada block where most of the successful wells have been

drilled, where out of 31 exploratory wells 14 have discharge 3.0 lps or more with maximum at 20.3 lps. Success rate is least in Talcher and Kaniha block followed by Banarpal block. This indicates that Gondwana sandstone are least productive in Talcher and Kaniha block and not in Chhendipada block where it shows good yield because of Kamthi formation which is most prolific among the Gondwana formations. Among the consolidated crystalline formations granitic aquifers have promising yield mainly in Chhendipada block and western part of Banarpal block where as the eastern and southern parts have poor yield.

6.6 Recharge Parameters

During monsoon season, the rainfall recharge is the main recharge parameter, which is estimated as the sum total of the change in storage and gross draft. The change in storage is computed by multiplying groundwater level fluctuation between pre and post monsoon periods with the area of assessment and specific yield. The specific yield value as estimated from dry season balance method or field studies was taken, wherever available. In absence of field values of specific yield values through above methods recommended values as per GEC-1997 norms has been taken. The sp. yield value of 0.03 has been used for ground water estimation in the Angul district.

The monsoon ground water recharge has two components- rainfall recharge and recharge from other sources. The other sources of groundwater recharge during monsoon season include seepage from canals, surface water irrigation, tanks and ponds, ground water irrigation, and water conservation structures. During the non-monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) method. Recharge from other sources is then added to get total non-monsoon recharge. In Angul district, the infiltration factor is taken as 0.08. The details of recharge and discharge parameters are given in **Table 6.4.** The discharge parameters include natural discharge in the form of springs and base flow and discharge for ground water irrigation, domestic and industrial draft.

Table 6.4: Recharge and Discharge Parameters Estimated Based on Ground Water Resources Estimation (2017). (*In Ham*)

Taluka	Command / Non command	Recharge from Rainfall during Monsoon	Recharge from other sources during monsoon	Recharge from Rainfall during Non-Monsoon	Recharge from other sources during non-monsoon	Total Annual GW Recharge	Natural Discharge	Discharge for Irrigation	Discharge for Domestic and Industrial
Angul	Command	84.9	304.9	21.7	186.6	598.0	59.8	657.9	1502.3
	Non-	4981.1	266.9	1015.6	398.0	6661.6	333.1	6994.7	14387.3
	Total	**5066.0**	**571.8**	**1037.3**	**584.6**	**7259.6**	**392.9**	**7652.5**	**15889.6**
Banarpal	Command	300.1	999.1	48.6	262.9	1610.7	161.1	1771.8	3806.5
	Non-	1735.0	312.1	241.0	240.9	2529.1	126.5	2655.5	5552.0
	Total	**2035.0**	**1311.3**	**289.6**	**503.9**	**4139.8**	**287.5**	**4427.3**	**9358.5**
Chhendipada	Command	91.1	477.7	14.4	314.2	897.4	89.7	987.2	2288.5
	Non-	5680.1	247.1	617.6	392.0	6936.7	346.8	7283.5	14959.0
	Total	**5771.2**	**724.8**	**632.0**	**706.2**	**7834.1**	**436.6**	**8270.7**	**17247.6**
Kaniha	Command	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Non-	5358.5	1268.1	477.9	851.7	7956.2	397.8	8354.1	17559.8
	Total	**5358.5**	**1268.1**	**477.9**	**851.7**	**7956.2**	**397.8**	**8354.1**	**17559.8**
Pallahara	Command	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Non-	8786.5	2883.0	343.2	1085.0	13097.7	654.9	13752.6	28590.2
	Total	**8786.5**	**2883.0**	**343.2**	**1085.0**	**13097.7**	**654.9**	**13752.6**	**28590.2**
Talcher	Command	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Non-	2513.4	244.2	248.2	245.4	3251.3	325.1	3576.4	7398.2
	Total	2513.4	**244.2**	**248.2**	**245.4**	**3251.3**	**325.1**	**3576.4**	**7398.2**
Athamallik	Command	264.6	441.7	41.8	255.3	1003.3	100.3	1103.7	2462.7
	Non-	4318.8	285.8	485.9	379.6	5470.1	273.5	5743.6	11866.9
	Total	**4583.4**	**727.5**	**527.6**	**634.9**	**6473.5**	**373.8**	**6847.3**	**14329.5**
Kishorenagar	Command	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Non-	6804.1	285.5	406.5	456.9	7953.0	397.6	8350.6	17158.1
	Total	**6804.1**	**285.5**	**406.5**	**456.9**	**7953.0**	**397.6**	**8350.6**	**17158.1**
District	**TOTAL**	**40918.1**	**8016.2**	**3962.3**	**5068.6**	**57965.2**	**3266.3**	**61231.5**	**127531.6**

7 Ground Water Resources

Central Ground Water Board and Ground Water Survey and Investigation (GWSI) have jointly estimated the ground water resources based on GEC-97 methodology as on 2011. 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. As per the resource estimated during 2011, the stage of ground water development is maximum in Talcher block (52.05%) and minimum in Pallahara block (24.07%) which indicates that sufficient scope exists for further ground water development. The district average development is 34.47 % while the same in these 6 NAQUIM blocks is 37.66 %. The ground water resources for Aquifer-I as estimated in year 2011, are given in **Table 7.1** and **7.2 and 7.3.**

Table 7.1: Dynamic Ground Water Resources of Aquifer-I, Angul District (2017)

Sl No	Block	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for Irrigation	Existing Gross Ground Water Draft for domestic Supply	Existing Gross Ground Water Draft for 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 & Industrial development	Stage of Ground Water Development	Category
		(Ham)	(Ham)	(Ham)	(Ham)	(Ham)	(Ham)		(%)	
1	Anugul	6867	2327	1077	75	3479	1415	6453	50.7	Safe
2	Banarpal	3852	1450	404	70	1924	417	3769	49.9	Safe
3	Chhendipada	7398	2554	458	482	3493	609	6764	47.2	Safe
4	Kaniha	7558	4132	381	56	4569	394	7489	60.4	Safe
5	Pallahada	12443	3956	363	2	4321	395	12409	34.7	Safe
6	Talcher	2926	1277	703	32	2012	735	2862	68.8	Safe
7	Athmallik	6100	1970	366	0	2336	406	6059	38.3	Safe
8	Kishorenagar	7555	2176	293	222	2691	325	7302	35.6	Safe
	Total	**54699**	**19842**	**404540**	**939**	**24825**	**4696**	**53107**	**45.38**	**Safe**

Table 7.2: In-Storage Ground Water Resources of Aquifer-I, Angul District.

Sl No	Block	Assessment Area	Bottom Depth of Aquifer	Average Pre-monsoon Water Level	Total Saturated Thickness (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	Angul	71240	30	7.33	22.67	0.015	24225
2	Banarpal	34876	30	6.42	23.58	0.015	12336
3	Chhendipada	76552	30	6.94	23.06	0.015	26479
4	Kaniha	68587	30	6.55	23.45	0.015	24125
5	Pallahara	89188	30	7.27	22.73	0.015	30409
6	Talcher	28866	30	6.48	23.52	0.015	10184
7	Athamallik	67714	30	4.98	25.02	0.015	25413
8	Kishorenagar	71562	30	6.69	23.31	0.015	25022
	Total	**508585**					**178193**

Table 7.3: Total Ground Water Resources of Aquifer-I, Angul District.

Sl No	Block	Dynamic Resource	In Storage Resource	Total Ground Water
		(Ham) (1)	(Ham) (2)	(Ham) (3)
1	Angul	6867	24225	31092
2	Banarpal	3852	12336	16188
3	Chhendipada	7398	26479	33877
4	Kaniha	7558	24125	31683
5	Pallahara	12443	30409	42852
6	Talcher	2926	10184	13110
7	Athamallik	6100	25413	31513
8	Kishorenagar	7555	25022	32577
	Total	**54699**	**178193**	**104223**

The ground water resource in Aquifer- II (Fractured Aquifer) is entirely in-storage. The

estimation of Aquifer-II resource is shown in **Table 7.4**.

Table 7.4: In-Storage Ground Water Resources of Aquifer-II, Angul District.

Sl No	Block	Assessment Area	Top Depth of Aquifer	Bottom Depth of Aquifer	Total Saturated Thickness (3-2)	Productive Zone (5% of Total Thickness)	Avg. Sp. Yield	In Storage Ground Water Resources (1)*(5)*(6)
		(Ha) (1)	(mbgl) (2)	(mbgl) (3)	(m) (4)	(m) (5)	(6)	(Ham) (7)
1	Angul	71240	30	200	170	8.5	0.015	9083
2	Banarpal	34876	30	200	170	8.5	0.015	4447
3	Chhendipada	76552	30	200	170	8.5	0.015	9760
4	Kaniha	68587	30	200	170	8.5	0.015	8745
5	Pallahara	89188	30	200	170	8.5	0.015	11371
6	Talcher	28866	30	200	170	8.5	0.015	3680
7	Athamallik	67714	30	200	170	8.5	0.015	8634
8	Kishorenagar	71562	30	200	170	8.5	0.015	9124
	Total	**508585**						**64844**

8 AQUIFER MANAGEMENT PLAN

A through study was carried out based on data gap analysis, data generated in-house, data acquired from State Govt. departments and maps procured from GSI and other sources, an integrated approach was adopted while preparing aquifer management plan of the NAQUIM area of Angul district. Based on this, geomorphology, soil, land use, field data, lithological information and ground water related issues, aquifer management plan is carried out and the detailed taluka wise aquifer management plan is prepared.

8.1 Ground Water Related Issues

8.1.1 Impact of Mine Dewatering

The study area occupies a significant position in the mineral map of India because of its huge deposit of coal. Talcher Coal Field is one important coal field of the country occurs in the study area. The coal mining activities are centeredaround Talcher and spread over an area of about 1814 km^2. The anticipated coal resource is about 44,30,943 million tones comprising of all grades of coal. There are 4 underground mines namely Nandira, Handidhua, Deulbera and Talcher and opencast mines at Balanda, Jagannath, Ananta, Kalinga, Bharatpur, Lingaraj, Hingula, Bhubaneswari, Chhendipada and Kaniha. A map showing the operational mines is given in **Fig. 8.1**.

Though coal mining is important for Industry, Power and national economy, it has the main demerit as coal mining needs large scale dewatering of ground water and thus greatly affects the ground water regime and the ecology. The impact of mine dewatering is assessed in the Talcher Coal Field area which comes in the NAQUIM area in Angul district. The seasonal quantum of water dewatered from various coal mines are given in **Table 8.1**. The total ground water discharged is about 277.8 Ham during summer and 405.2 Ham during the monsoon season. Thus the annual mine dewatered is around 683 ham. The effect of dewatering is reflected in the lowering of water table and piezometric head and formation of a ground water trough in the coal mining blocks. The effect is more pronounced in the piezometric head because of the fact that the deeper aquifer formed by the Barakars has poor ground water potential. The piezometric head has fallen down to maximum depth of about 34 mbgl at Kandhal near Talcher. However outside the mine boundaries the piezometric head is in the range of 3-7 mbgl. The map showing the depth to water level of Aquifer-I and piezometric heads of Aquifer-II, in the mining blocks are given in **Fig 8.2**and **8.3**.

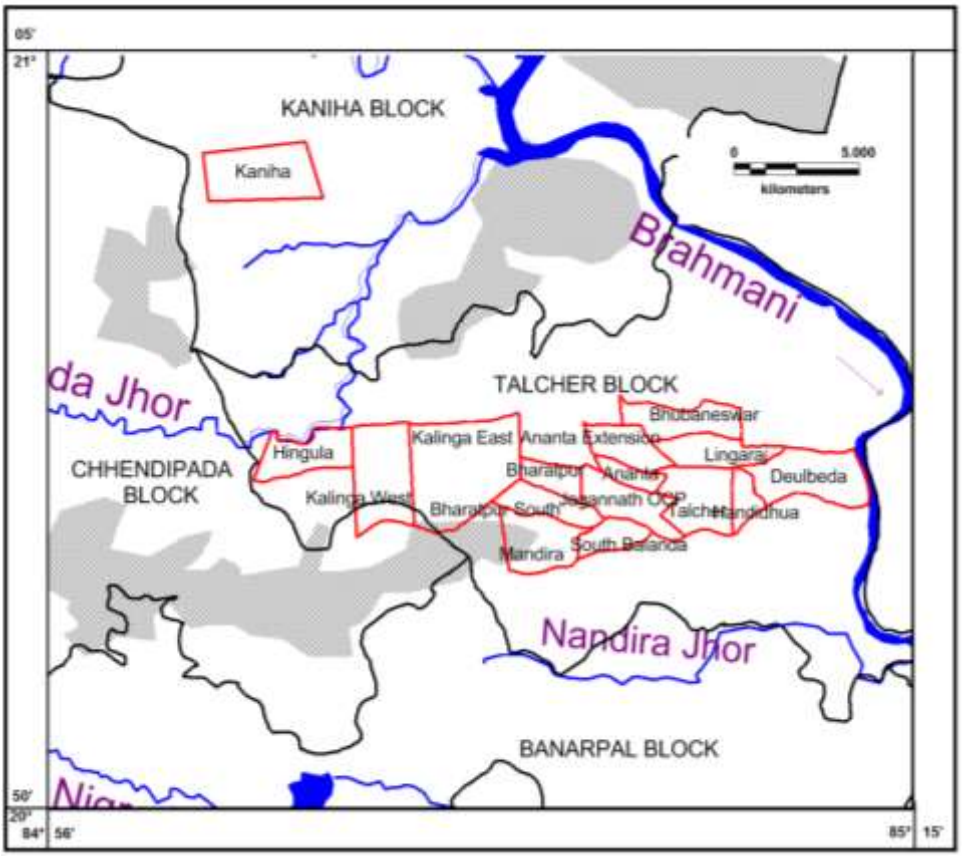


Fig. 8.1: Coal Mines in Talcher Coal Field, Angul District.

Table 8.1: Quantum of Coal Mine Dewatering in Talcher Coal Fields, Angul District.

Sl No	Name of Mines	Total Area (Sq. Km)	Type of Mining	Coal Reserve (MTons)	Mine Water Discharge (Ham)		Total Summer Discharge	Total Monsoon Discharge	Annual Discharge
					Summer	Monsoon	Ham	Ham	Ham
1	Talcher	6.53	UG	58.1	0.0571	0.4006	15.7025	36.054	51.76
2	Dulbera	7.15	UG	28.16	0.059	0.059	16.225	5.31	21.54
3	Handidhua	2.13	UG	5.2	0.1308	0.9806	35.97	88.254	124.22
4	Nandira	5.19	UG	36.7	0.147	0.147	40.425	13.23	53.66
5	Jagannath	4.89	OC	134	0.0572	0.5148	15.73	46.332	62.06
6	South Balanda	2.27	OC	34.6	0.32	1.0869	88	97.821	185.82
7	Ananta	4	OC	258.9	0.0204	0.4412	5.61	39.708	45.32
8	Bharatpur	6.76	OC	133.2	0.109	0.109	29.975	9.81	39.79
9	Kalinga	8.21	OC	347.6	0.1098	0.764	30.195	68.76	98.96
	Total	**47.13**		**1036.**			**277.8325**	**405.279**	**683.11**

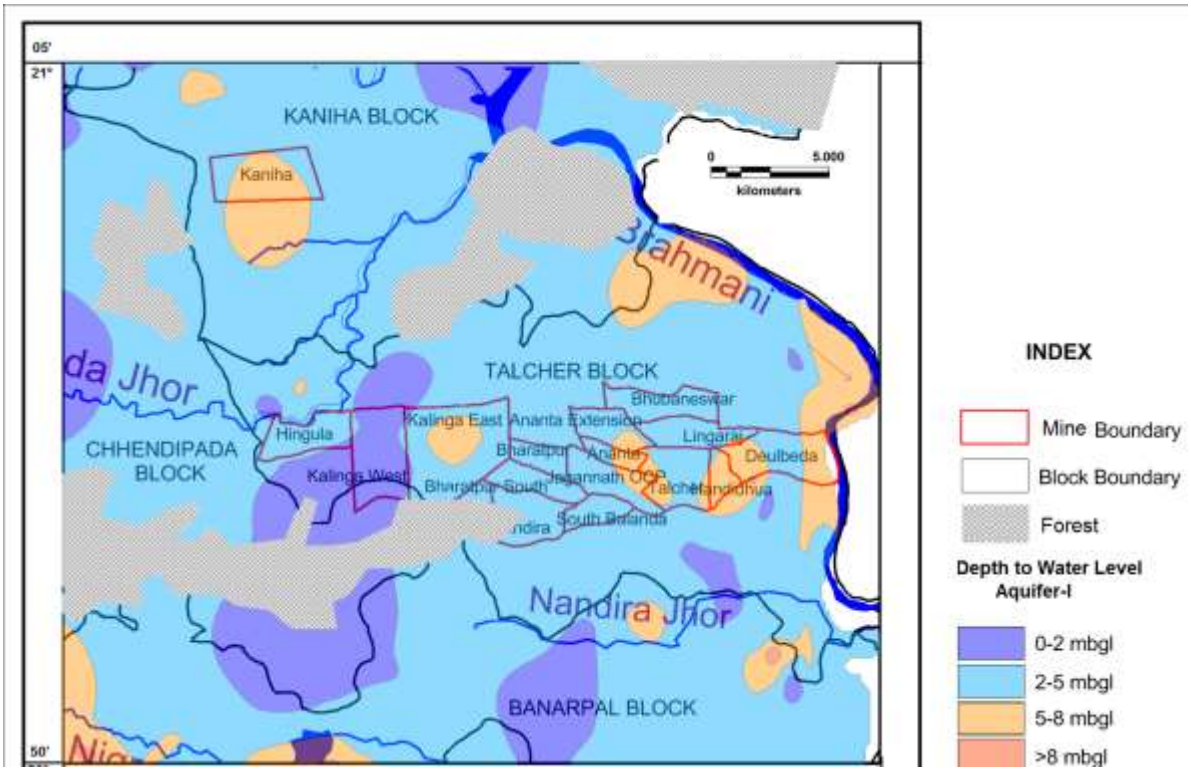


Fig. 8.2: Depth to Water Level (2015) in Aquifer-I in Talcher Coal Field, Angul District.

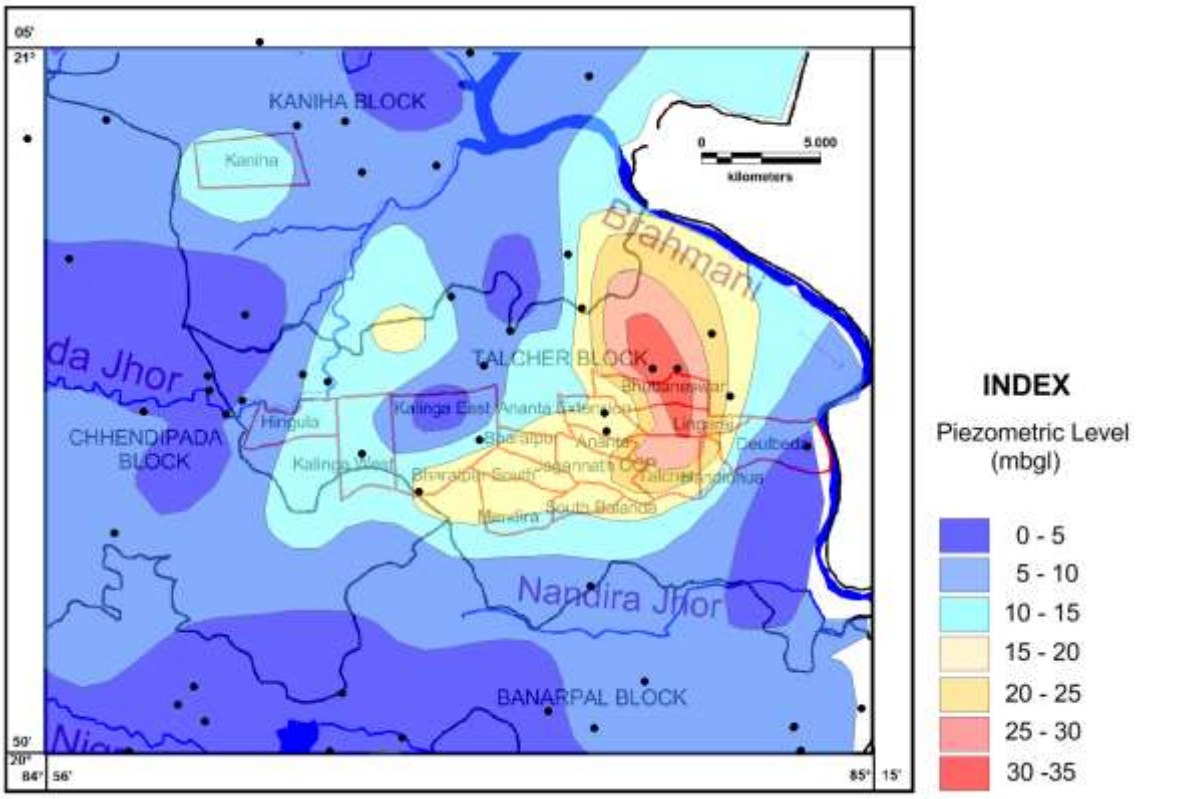


Fig. 8.3: Piezometric Head of Aquifer-II in Talcher Coal Field, Angul District.

8.1.2 Fluoride in Ground Water

It has already been found that higher concentration of fluoride has been observed in the ground water in shallow as well as deeper aquifer. The State Pollution Control Board (SPCB), Odisha has already reported excess fluoride in the soil samples from 11 villages surrounding the Nalco smelter plant area in Banarpal block. But as per the findings of studies carried out by CGWB on different occasion, the occurrence of higher fluoride in isolated locations (details in Section-5) and does not show any pattern. Also any adverse effect of effluent discharged from mining and industries, on the ground water quality has not been noticed yet.

8.2 Management Plan

8.2.1 Management Plan for Mine Dewatering

The discharge of large quantum of ground water by the mine dewatering has created a ground water trough in the Talcher coal mining area. The maximum piezometric head is around 35 mbgl however outside the mining areas the piezometric head is within the range of 3-7 mbgl. From this it's evident that the cone of depression of pumping is low due to poor transmissivity of the aquifers.

As per the information available, about 50% of ground water discharged from the mines is used in domestic and industrial purpose in the Mining area and in the surroundings. The remaining unused ground water which is normally discharged to the nearby drainage channels can be collected and used for recharge purpose. By recharging water through injection wells in the form of garland recharge wells along the periphery of ground water trough, to create a boundary of ground water mound which will check further spreading of the effect of mine dewatering as a result of which the ground water regime beyond the coal mining area will remain unaffected from pumping within the mines. The garland recharge well concept is shown in **Fig.8.4**.

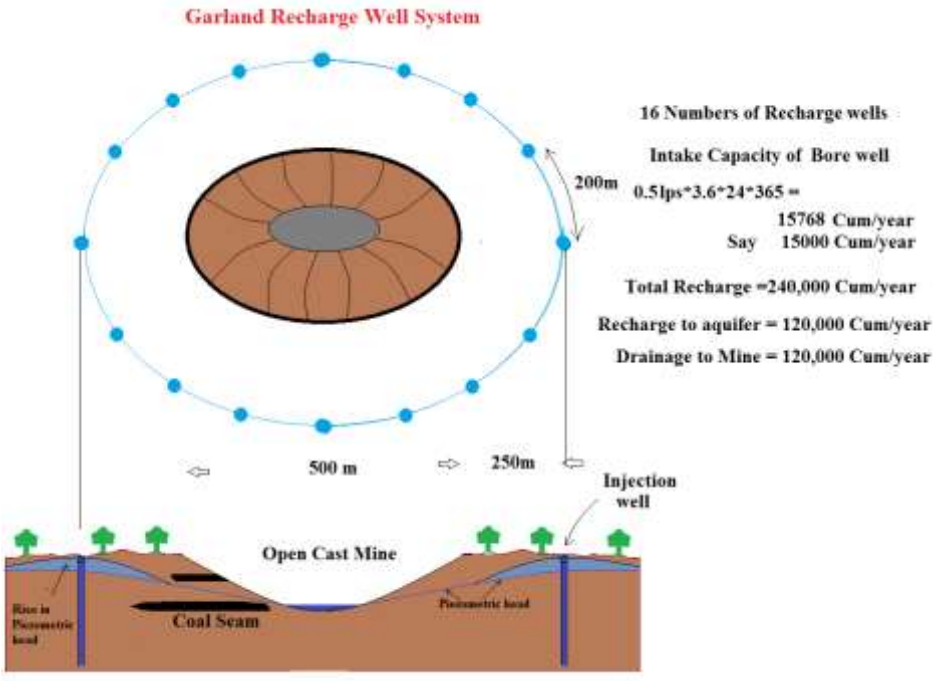


Fig. 8.4: Garland Recharge Well System to Reduce the Effect of Mine Water Dewatering.

8.2.2 Management Plan for Fluoride in Ground Water

Fluoride higher than permissible limit of drinking has been found in the NAQUIM area in shallow as well as deeper aquifers. Drinking water sources like dugwells, borewells and hand pumps, once found to be of high F, should be immediately marked unsuitable and informed to the public to prohibit the use of such sources for drinking. The occurrence of fluoride is known to be a local phenomenon and in none of the village, fluoride is found everywhere and in all ground water sources. Hence it's advisable to make suitable arrangement for providing alternate, safe and hygienic source for drinking water in those fluoride affected villages.

8.2.3 FutureGround Water Development Potential

From the ground water resource estimation carried out for the Aquifer-I in 2011, the present ground water development ranges from24.07 % in Pallahara Block to maximum 52.05% in Talcher block. This includes ground water usage for all usage domestic, industrial as well as irrigation. However the percentage of area irrigated by ground water is the area is mere 2% of total irrigation area. Taking ground water development safely up to 60% of the resource available, the ground water potential for further development is calculated, which is about 5660 Ham in the NAQUIM

area with minimum 231.7 Ham in Talcher block and maximum 1998.34 Ham in Banarpal block. The details of the same are shown in **Table 8.2**.

Table 8.2: Ground Water Development Potential in Angul District.

Block	Total Area irrigated (Ha)	Area irrigated by Ground Water (Ha)	% of Area Irrigated by Ground Water	Net Annual Ground Water Availability (Ham)	Existing Gross Ground Water Draft for all uses (Ham)	60% of Annual Resource Available (Ham)	Further Ground Water development potential (Ham)
Angul	2810.32	0	0	6220	2013.68	3732	1718.32
Banarpal	4160.01	0	0	7728	2638.46	4636.8	1998.34
Chhendipada	3229.29	226	6.9	6377	2973.34	3826.2	852.86
Kaniha	767.49	24.12	3.1	6033	2760.98	3619.8	858.82
Pallahara	2006.88	177.63	8.85	6468	1556.81	3880.8	2323.99
Talcher	1097.87	0	0	2913	1516.10	1747.8	231.7
TOTAL	**14071.86**	**427.75**	**3.03**	**35739**	**13459.37**	**21443.4**	**7984.03**

9 Summary and Recommendations

9.1 Summary

National Aquifer Mapping Programme (NAQUIM) were taken up for detailed hydrogeological investigation, data-gap analysis and Aquifer Mapping in Angul district covering an area of 4283 sq. km., during the period 2012-2019. The following are the summarised details.

1 Data gap analysis was carried out in the area and further data acquisition is planned accordingly.

2 The study area exposes rocks of Iron-Ore Super Group, Easternghat Super Group and Gondwana Super Group. Besides these laterites and alluvial deposits of Quaternary Period also occurs at places.

3 Ground Water Occurs in Phreatic condition in weathered portions generally down to a depth of about 30 mbgl.

4 Ground water occurs under semiconfined to confined condition in fractured formation down to maximum depth of about 200 mbgl.

5 The area receives a good rainfall the annual average rainfall between 1988-2017 ranges from 1079.4 mm (Banarpal) to 1820.3 mm (Pallahara).

6 The average pre-monsoon water level in the area is within 6 mbgl.

7 The estimated dynamic ground water resource shows that the stages of development of ground water range from 34.7 to 68.8 %, therefore sufficient scope still exists for further ground water usage.

8 The quality of ground water is potable and good except some isolated cases of excessive fluoride.

9 Huge quantum of ground water are being pumped out from the ground water reservoir due to the coal mine dewatering which is impacting the ground water regime by lowering of water table and piezometric head in and around the coal mining area.

9.2 RECOMMENDATIONS

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. In view of the above, the present study 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 As the current average stage of ground water withdrawal is within 50%, utilization of ground water resource for the socio-economic development is feasible. Annually about 6000 Ham of ground water can be withdrawn safely for further usage. The phreatic aquifer in Chhendipada block, covering the Kamthi formation, have very high and sustainable ground water potential.

2 Drinking water sources like dugwells, borewells and hand pumps, once found to be of high F, they should immediately be marked unsuitable and informed to the public to prohibit the use of such sources for drinking. Moreover it's advisable to make suitable arrangement for providing alternate, safe and hygienic source for drinking water in those fluoride affected villages.

3 The effect of large scale ground water pumping from the coal mining areas can be arrested by using the unused pumped ground water for creating a recharge front around the mining area through the proposed Garland Recharge Well concept.

4 Artificial recharge through construction of Percolation tank and check dams are feasible where source water is available.The check dams should be constructed on 2^{nd} and 3^{rd} order drainages. Further details such as aquifer wise storage potential, source water availability etc. are discussed in Part-II of the report.

Ground Water Exploration Data of Angul District.

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
1	Angul	Kukudang	EW	20.8922	85.1417	153.85	Granite Gneiss	6.00	9.45-10.45	5.32	<1	>24	-	
2	Angul	Kumarsingha	EW	20.7692	85.0764	112.15	Granite Gneiss	14.00	10-105	6.53	2.9	18.9	2.99	
3	Angul	Kangula (Godisahi)	EW	20.7939	85.1253	142.7	Garnetiferous Granite Gneiss	8.50	14.60, 114.20, 141.70	4.60	12	36.98 (3)		
4	Angul	Kangula (Godisahi)	OW	20.7936	85.1250	141.7	Gneiss Hard	9.30	12.10, 106.10, 138.60	4.20	11	29		
5	Angul	Angarbandha	EW	20.7767	85.1489	200	Biotite granite gneiss	13.50	76.6	5.70	0.5	-		
6	Angul	Kangula	EW	20.7967	85.1314	123.4	Granite gneiss	11.15	24.8	8.65	0.5			
7	Angul	Kusumpat	EW	20.7417	84.9833	22.5	Khondalite	5.36	13.31,15.50	4.7	4.4	4.7		-
8	Angul	Nisa	EW	21.0578	84.9558	292	Gondwana-Shale-Sandstone		55-67, 77-87	7.21	1.83	11.29	3.34	-
9	Banarpal	Tubey(Tasara)	EW	20.8500	84.9833	153.85	Fractured Granite Gneiss	11.00	9 to 11	0.99	< 1			
10	Banarpal	Rantalai	EW	20.8333	85.0417	106	Fractured Granite Gneiss	19.00	1 to 30	6.04	< 1			
11	Banarpal	Khandsar	EW	20.8583	85.1625	153.85	Fractured Granite Gneiss	8.90	18-18.5	6.00	1.5	3		
12	Banarpal	Turanga	EW	20.8458	85.1250	117.25	Shale, Granite Gneiss	18.00	33-34, 93-95		2.126			
13	Banarpal	Banarpal	EW	20.8333	85.2222	129.45	Granite Gneiss	13.65	36-37, 78-79	5.42	4.54	9.08	20.54	
14	Banarpal	Banarpal	OW	20.8336	85.2225	141.65	Granite Gneiss	25.75	134-136	4.95	4	3.5		
15	Banarpal	Apartipur	EW	20.8500	85.2250	150.75	Granite Gneiss	15.00	16-18		2.5			
16	Banarpal	Pandarbharania	EW	20.8747	85.2542	105.05	Granite Gneiss	17.55	74, 99		23			
17	Banarpal	Bauligarh	EW	20.8583	85.2378	150.75	Granite Gneiss	5.50	Dry		Dry			
18	Banarpal	Gaudsai	EW	20.8417	85.1431	150.75	Granite Gneiss	14.50	13.5-16.5	3.47	0.2	-	-	
19	Banarpal	Chainpur-GRIDCO	EW	20.8836	85.2208	153.85	Lwr Gondwana sandstone, shale, coal seams	12.00	13-14	-	-	-	-	

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
20	Banarpal	Nuapada-CESU	EW	20.8422	85.2200	86.75	Fractured Granite Gneiss	22.25	23.65-24.65, 44.05-45.05	4.77	4.36	15.84	-	
21	Banarpal	Nuapada-CESU	OW	20.8419	85.2197	68.45	Fractured Granite Gneiss	22.80	24-25, 31-32, 60-61	5.07	12.03	15.74	-	
22	Banarpal	Motanga	EW	20.8006	85.2303	80.7	Fractured Granite Gneiss	8.85	73.5-74.6, 79.6-80.7	6.75	12	-	-	
23	Banarpal	Tentulihata	EW	20.8486	85.2458	202.7	Fractured Granite Gneiss	18.00	16-18	6.95	1	-	-	
24	Banarpal	Phulpara	EW	20.7514	85.1564	200	Biotite granite gneiss	10.50	72.5	11.10	1	-		
25	Banarpal	Turanga	EW	20.8478	85.1256	111.2	Garnetiferous Granite Gneiss	14.00	14.6	3.05	5	4.75		
26	Banarpal	Turanga	OW	20.8478	85.1256	111.2	Garnetiferous Granite Gneiss	13.60	14.6, 52.2	2.80	6	10.0		
27	Banarpal	Benagadia	EW	20.8542	85.0464	123.4	Garnetiferous Granite Gneiss	14.00	14.6	0.25	1.9	-		
28	Banarpal	Golabandha	EW	20.8442	84.9936	153.9	Garnetiferous Granite Gneiss	15.00	16.6	2.8	2			
29	Banarpal	San-Kerjang	EW	20.8564	84.9894	153.6	Granite gneiss	7.80	20.4	6.3	1	-		
30	Banarpal	Mahidharpur	EW	20.6911	85.2022	150	Granite Gneiss	11.54	105,111	4.31	negligible			
31	Banarpal	Tentulihata	EW	20.8450	85.2369	150	Shale	19.60			negligible			
32	Banarpal	Karadagadia	EW	20.8375	85.0683	150	Granite Gneiss	13.50	19.6,36.9,100		4.9			
33	Banarpal	Karadagadia	OW	20.8383	85.0694	150	Gneiss	14.85		5.8	2.5	5.81		
34	Banarpal	Paratara	EW	20.8453	85.0550	150	Gneiss	8.00						
35	Banarpal	Gadasantri	EW	20.8017	85.1969	150	Gneiss			3.95	0.78	6.65		
36	Chhendipada	Koshala	EW	21.1753	84.9419	152.75	Lwr Gondwana Sandstone with coal seams	25.30	All through contact with sandstone	6.65	3.35	2.85	46.13	
37	Chhendipada	Chhendipada	EW	21.0819	84.8778	153.85	Lwr Gondwana Sandstone with coal seams	23.65	All through contact with sandstone	8.40	2.9	6.5	10.94	

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
38	Chhendipada	Balipata	EW	20.9833	84.8417	153.85	Lwr Gondwana Sandstone with coal seams	19.65	All through contact with sandstone	3.00	3	6		
39	Chhendipada	Jarpada	EW	20.8667	84.8667	50.15	Fractured Granite Gneiss	10.15	13-14	2.97	10			
40	Chhendipada	Jarpada	EW	20.8669	84.8669	38.07	Fractured Granite Gneiss	5.80	6 -1 3	2.95	8			
41	Chhendipada	Koshala	EW	21.1750	84.9417	153.85	Gondwana Sandstone	22.08	23-25, 50-60	7.00	5	13.3		
42	Chhendipada	Santrabandh	EW	21.0557	85.0290	310.66	Gondwana-Shale-Sandstone	20.00		14.31	0.43	7.98	1.09	
43	Chhendipada	Kosala	EW	21.0083	84.9417	54.38	Sand Stone	52.50	Slotted 3.00-7.04, 11.50-32.00, 36.70-38.50	3.5	1	40.50 - 52.00		
44	Chhendipada	Kartada	EW	20.9103	84.8274	150	Granite gneiss	18.00	20	6.1	1.5	13.92	12.69	
45	Chhendipada	Ugi	EW	20.8501	84.8831	105.7	Granite gneiss	20.50	24, 74, 75-84, 84-99.6	10.17	14	6.79	60.05	
46	Chhendipada	Ugi	OW	20.8501	84.8831	93.5	Granite gneiss		24-26, 65-69, 72-73, 80-82	11.05	20.3	7.75	51.3	4.23E-04
47	Chhendipada	Tukuda	EW	20.8692	84.8984	150	Granite gneiss	9.00	20.2	0.73	0.44	25.87	2.67	
48	Chhendipada	Santrapur	EW	20.8334	84.9647	150	Granite gneiss	6.30	25-40	2.85	2.132	24.98	16.49	
49	Chhendipada	Anturia	EW	20.8024	84.8149	150	Granite gneiss	20.50	40-50	1.49	0.6	18.06	0.59	
50	Chhendipada	Jerang Dehuri Sahi	EW	20.8982	84.8556	150	Charnockite	6.50		1.3	0			
51	Chhendipada	Jamunali	EW	20.9335	84.7829	81.3	Granite gneiss	12.00	32.5-38.6, 75.2-81.3	4.9	10	12.05	7.06	
52	Chhendipada	Jamunali	OW	20.9335	84.7829	67	Granite gneiss	9.50	50.8-67	5.24	8.5	15.35	4.89	
53	Chhendipada	Kankarai	EW	20.9616	84.9953	150	Gondwana	9.50	20.3-26.4, 38.6-50.8, 63-75.2, 105.7-111.8, 133.1-142.3	6.4	1.8	20.7	5.67	

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
54	Chhendipada	Raijharan	EW	20.9542	84.9701	150	Gondwana	22.00	38.6-44.7, 56.9-99.6, 105.7-117.9, 136.2-142.3	6.33	1.8			
55	Chhendipada	Matigharia	EW	20.9554	84.8629	150	Gondwana	12.50	10.1-37.6, 49.8-150	4.37	3.38	9.28	10.49	
56	Chhendipada	Koroda	EW	20.9513	84.8913	150	Gondwana	17.50	5-150	3.89	4.5	13.58	13.2	
57	Chhendipada	Barpada	EW	20.9925	84.9046	130.1	Gondwana	20.00	50.8-84.3, 114.8-130.1	1.34	8.5	20.13	42.77	
58	Chhendipada	Tentulisahi (Korada)	PZ	20.9540	84.9055	63	Gondwana	18.00	21-57	4.62	4			
59	Chhendipada	Kuskila (Pz)	PZ	20.9873	84.8866	63	Gondwana	18.20		5.53				
60	Chhendipada	Durgapur (Pz)	PZ	20.9197	84.8921	63	Gondwana	33.50		2.05				
61	Chhendipada	Brahmanbil	EW	21.0511	84.9256	150	Gondwana	1.21		6.54	2	17.60	23.46	
62	Chhendipada	Patakumanda	EW	21.1447	84.8236	153.7	Gondwana	1.10		-0.1	2.5	28.75	28.28	
63	Chhendipada	Tentulia	PZ	21.0344	84.8653	62.2	Gondwana	0.45		9.86				
64	Chhendipada	Changuria	EW	21.1083	84.9528	153.7	Gondwana	19.90	140.5-143.5	4.7	2	15.1	17.59	
65	Chhendipada	Prasbania	EW	21.0083	84.8708	153.7	Gondwana	18.00	37.70-40.7,125.8-153.70	3.48	1.25	24.27	15.21	
66	Chhendipada	Kushakila	PZ	20.9881	84.8869	63	Gondwana	18.20	38.6-44.7	6.6	0.2			
67	Kaniha	Jarada	EW	21.0414	85.0825	124.35	Gondwana-Shale-Sandstone	18.30		9.9	0.6	18.27	0.84	
68	Kaniha	Badahira	EW	21.1067	85.0094	150	Gondwana	18.70	25.6 - 26.59	10.3	0.3			
69	Kaniha	Samal	EW	21.0733	85.1411	93	Granite Gneiss	24.10	48 - 50, 62.2-65.2	9.14	18	2		
70	Kaniha	Kamarei	EW	21.0614	85.0658	150	Gondwana	36.40			0.15			
71	Kaniha	Belpada	EW	21.0328	85.1786	150	Gondwana	26.00			0.2			
72	Kaniha	Bada Gunduri	EW	21.0781	84.9906	150	Gondwana	20.40			0.5			
73	Kaniha	Dandasingha	EW	21.0656	85.0781		Gondwana							
74	Kaniha	Deranga	EW	21.1153	84.9917	153.6	Gondwana	25.65		5.53	0.1			

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
75	Talcher	Talchir College	EW	20.9417	85.2250	150.75	Lwr Gondwana sandstone, shale, coal seams	22.00	all through contacts	3.97	0.136	-	-	
76	Talcher	Kheranali	EW	20.9884	85.0091	305	Gondwana-Shale-Sandstone	24.84		2.70 agl	2	25.52	2.2	
77	Talcher	Ekdal	EW	21.0100	85.1329	164.95	Gondwana-Shale-Sandstone			3.07	0.62	16.03		
78	Talcher	Anantabereni	EW	21.0392	85.0539	70.35	Gondwana-Shale-Sandstone	20.00		6.90	5.91	19.65	34.75	
79	Talcher	Maliabandh	EW	20.9581	85.0079	177.09	Gondwana-Shale-Sandstone	48.77	24.38-30.48	1.07	2.43	18.00	16	4.5E-04
80	Talcher	Sanatribeda	EW	20.9111	84.9591	307.7	Gondwana-Shale-Sandstone		-	7.52	-	0.92		
81	Talcher	Kumunda	EW	20.9704	85.1008	289	Gondwana-Shale-Sandstone		100-110, 114.122, 131-137, 151-156, 186-195, 207-214, 231-238, 247-254, 262-268, 282-286	Ground level	1.83	28.21	2.71	
82	Talcher	Naraharipur	EW	20.9694	85.1750	29	Gondwana Shale, Sstone, Coal	10.48	21.46	4.28	0.36	1.9		
83	Talchir	Karnapur	EW	20.8956	85.1189	150	Shale	17.00			negligible			
84	Pallahara	Hathigincha		21.45	85.1603	21.02	Granite gneiss	8.22	6.00-8.00	3.09	0.7	10.41		
85	Pallahara	Baliposi		21.4472	85.1592	21	Granite Gneiss	15.15	12.96,14.85	6.02	0.75	7.78		
86	Pallahara	Jimmiripali		21.4167	85.1667	9.53	Granite Gneiss	6.67	5.07-6.42	4.21	0.033	5		
87	Pallahara	Dimisia		21.4083	85.1583	15.5	Granite Gneiss	13.27	13.31-12.91	5.02	0.22	6.42		
88	Kishorenagar	Bamur	EW	21.0117	84.4861	153.85	Granite	9.97	92-94					
89	Kishorenagar	Ichhapur	EW	20.9561	84.7436	32.1	Leptynitic rock	4.8	15.44,17.93					

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
90	Kishorenagar	Boinda	EW	20.9083	84.7333	32.43	Biotite Gneiss	4.6	10.47					
91	Athamalik	Karadabahali	EW	20.8536	84.6464	163	Granite Gneiss	11.5	19.3-22.3, 62.0-65.0	0.84	3.5	7.28	38.47	
92	Athamalik	Ambsarmunda	EW	20.8622	84.5800	155	Granite Gneiss	10	24.0, 30.0, 89.4-92.5	5.28	3.66	24.82	7.93	
93	Athamalik	Amsarmunda (OW)	OW	20.8622	84.5800	110.8	Granite Gneiss	11.5		6.28				
94	Athamalik	Talamaliha	EW	20.8650	84.5708	182	Granite Gneiss	9.5			0.25			
95	Athamalik	Thakurgarh	EW	20.8111	84.6231	182	Granite Gneiss	18.2	25.4, 58.0, 101.6	7.07	3.74	4.21	82.3	4.39E-06
96	Athamalik	Thakurgarh (OW)	OW	20.8111	84.6231	56	Granite Gneiss	15	16.2-19.3, 28.4-31.5	6.97	7	4.13	68.9	
97	Athamalik	Taleipatahar (Kundajhari)	EW	20.8100	84.6847	165.7	Granite Gneiss	9	83.2, 150.4		2			
98	Athamalik	Banamalipur	EW	20.8397	84.6314	180	Granite Gneiss	4			Negl.			
99	Athamalik	Anandpur (Salapada College)	EW	20.8258	84.6403	170	Granite Gneiss, Basic Intrusive	11.5	19, 95.5	6.75	5	23.38	29.09	3.90E-04
100	Athamalik	Anandpur (Salapada College) OW	OW	20.8258	84.6403	104.7	Granite Gneiss, Basic Intrusive	11.5	19.3, 71.10	6.62	2.5	3.2	59.94	
101	Athamalik	Maimura	EW	20.7725	84.6956	170.8	Granite Gneiss	11.5			1.25			

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
102	Athamalik	Kutulusingha	EW	20.7850	84.6822	165.7	Granite Gneiss	14.8	90.4		1.2			
103	Athamalik	Mandarbahal	EW	20.8725	84.6647	175	Granite Gneiss	11.5	60		0.25			
104	Athamalik	Tileshwar	EW	20.8831	84.6219	175	Granite Gneiss	11.5	19.3		0.25			
105	Athamalik	Bidising	EW	20.8122	84.7478	170	Granite Gneiss	13	7.1, 92.5		0.5			
106	Athamalik	Olatha	EW	20.6561	84.6228	180	Granite Gneiss	6	30.5		1			
107	Athamalik	Aida	EW	20.6664	84.6108	200	Granite Gneiss, Silicified Clay	19.5			Negl.			
108	Athamalik	Ramgarh	EW	20.8586	84.7686	165	Granite Gneiss, Basic Intrusive	12.5	34.5		0.5			
109	Athamalik	Paiksahi	EW	20.8317	84.7611	180	Granite Gneiss	12.5			Negl.			
110	Athamalik	Tapdhol	EW	20.8083	84.7908	170.8	Granite Gneiss	9	18	3.3	1.25	13.92	8.05	
111	Athamalik	Jhilimunda	EW	20.8736	84.7103	180	Granite Gneiss	7.5			Negl.			
112	Athamalik	Sapaghara	EW	20.8586	84.7569	170	Granite Gneiss	17.5			0.25			
113	Kishorenagar	Angapada	EW	20.9292	84.5625	175	Granite Gneiss	5.5	25, 47, 102		0.5			
114	Kishorenagar	Urukula	EW	20.9183	84.6025	170	Granite Gneiss	23.3	52.8	1.52	5.5	16.97	7.82	9.94E-05
115	Kishorenagar	Urukula OW	OW	20.9183	84.6025	79.3	Granite Gneiss	28	51.0, 63.0	1.89	5.05	13.21	7.13	
116	Kishorenagar	Bhejigoth	EW	20.9044	84.6847	180	Granite Gneiss	21	28	2.35	0.44	24.53	0.217	

Sl. No	Block	Location	Type	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing (mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Dis-charge (lps)	Draw-down (m)	T (m^2/day)	S
117	Kishorenagar	Gaon Boinda	EW	20.9153	84.7397	175	Granite Gneiss	8.5	51.40, 52.0	3.39	5	27.75	1.86	6.18E-05
118	Kishorenagar	Gaon Boinda OW	OW	20.9153	84.7397	175	Granite Gneiss	6.5	51.40, 52.0	3.01	5	17.79	1.79	
119	Kishorenagar	Papasara	EW	20.9211	84.6700	175	Granite Gneiss	21	149		0.25			
120	Kishorenagar	Gunthapada (Luhamunda)	EW	20.9450	84.7239	185	Granite Gneiss	17.9	103.7		0.25			
121	Athamalik	Bandhagaon	EW	20.8522	84.5581	155	Granite Gneiss, Charnockite	14.2	40, 47	4.1	6	3.89	53.62	2.10E-03
122	Athamalik	Bandhagaon OW	OW	20.8522	84.5581	155	Granite Gneiss, Charnockite	11.5	54.0, 142.0	4.5	3	0.68	174.63	
123	Kishorenagar	Brahmanidei	EW	20.8761	84.5144	196.2	Granite Gneiss	6.5	23.0, 60.0		Negl.			
124	Kishorenagar	Chudakhai	EW	20.9294	84.5181	165.8	Granite Gneiss	11.6	109		6			
125	Kishorenagar	Chudakhai OW	OW	20.9294	84.5181	153.5	Granite Gneiss	10	54, 122, 136		1.48			
126	Kishorenagar	Dhadarapal	EW	20.9472	84.5417	170	Granite Gneiss	8.1			Negl.			
127	Kishorenagar	Himitira	EW	20.9300	84.4911	185	Granite Gneiss	9.1	13-14		0.77			
128	Kishorenagar	Ghanapur	EW	20.9047	84.6082	185	Granite Gneiss	17.6	61	6.5	2.5	16.8		
129	Kishorenagar	Ambamunda	EW	20.9386	84.6369	200	Granite Gneiss	17.7			0.25			
130	Kishorenagar	Kuajhari	EW	20.9356	84.6447	190.1	Granite Gneiss	11.5			0.25			

Details of Key Observation Wells and National Hydrograph Network Stations (NHS) inAngul District.

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
1	Kalandi Prasad	KW	Kaniha	73G/4	Gondwana	85.18417	21.00528	0.3	5.3	1.75	4.45	3.45	1
2	Siriguda	KW	Kaniha	73G/4	Gondwana	85.21750	21.01347	0.7	11.3	1.6	8.75	4.8	3.95
3	Gurujanga	KW	Kaniha	73G/4	Gondwana	85.19417	21.01722	0.6	10.25	1.85	9.1	5.55	3.55
4	Godibandha	KW	Kaniha	73G/4	Gondwana	85.16981	21.02000	0.5	11.15	1.8	9.8	6.9	2.9
5	Ekgharia	KW	Kaniha	73G/4	Gondwana	85.16194	21.04444	0.4	7.7	2.2	4.82	3.6	1.22
6	Samal	KW	Kaniha	73G/4	Gondwana	85.12861	21.06722	0.5	6.05	2	2.6	2.1	0.5
7	Dangarbeda	KW	Kaniha	73G/4	Pre-cambrian	85.14528	21.08389	0.35	8.1	2.8	6.75	4.05	2.7
8	Hariharpur	KW	Kaniha	73G/4	Gondwana	85.14583	21.01431	0	9.3	3	3.7	3.88	-0.18
9	Jadunathpur	KW	Kaniha	73G/4	Gondwana	85.11036	21.02547	0.55	10.75	2.8	8.75	3.75	5
10	Khairanali	KW	Kaniha	73G/4	Gondwana	85.07833	21.04306	0.25	7	2.4	5.86	4.15	1.71
11	Nakanaka	KW	Kaniha	73G/4	Gondwana	85.08908	21.06333	0.4	6.7	2	4.65	3.05	1.6
12	Godashila	KW	Kaniha	73G/4	Pre-cambrian	85.08967	21.09322	0.5	7.92	1.9	2.3	1.55	0.75
13	Patharmunda	KW	Kaniha	73G/4	Gondwana	85.06303	21.08833	0.55	9.95	2	8.65	4.9	3.75
14	Jarada	KW	Kaniha	73G/4	Gondwana	85.04597	21.07125	0.1	8.3	3	7.15	2.9	4.25
15	Chhelia	KW	Kaniha	73G/4	Gondwana	85.04778	21.05222	0.55	10	2.2	6	3.9	2.1
16	Sana Hara	KW	Kaniha	73G/4	Gondwana	85.04389	21.02417	0.8	6.4	3.1	5.75	3.6	2.15
17	Harichandanpur	KW	Kaniha	73G/4	Gondwana	85.02989	21.04233	0.2	11.35	1.9	8.67	6.8	1.87
18	Badagunduri	KW	Kaniha	73G/4	Gondwana	85.00250	21.07944	0.5	8.9	1.65	4.9	3.9	1
19	Kansamunda	KW	Kaniha	73G/4	Gondwana	85.01861	21.08611	0.45	9.55	1.9	7.25	4.4	2.85
20	Masunihata	KW	Kaniha	73G/4	Gondwana	85.04778	21.10667	0.65	9.9	1.4	4.5	3.4	1.1
21	Takua	KW	Kaniha	73G/4	Pre-cambrian	85.03917	21.11806	0.25	9.35	2	2.95	3.65	-0.7
22	Khajuria	KW	Kaniha	73G/4	Pre-cambrian	85.02733	21.13736	0.4	8.9	2.5	7.25	3.3	3.95
23	Sapakata	KW	Kaniha	73G/4	Pre-cambrian	85.00667	21.17653	0.48	5.57	2.4	2.62	1.82	0.8
24	Hanumanpur	KW	Kaniha	73G/4	Pre-cambrian	85.06028	21.14544	0.2	10.35	2.9	6.15	1.7	4.45
25	Brahmanidei	KW	Kaniha	73G/4	Pre-cambrian	85.05836	21.17614	0.5	7.7	2	3.55	1.55	2

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
26	Khalapala	KW	Kaniha	73G/4	Pre-cambrian	85.01658	21.22461	0.5	7.6	1.6	5.6	3.35	2.25
27	Bajrakota	KW	Kaniha	73G/4	Pre-cambrian	85.04661	21.21286	0.3	8.7	1.6	6.25	3.8	2.45
28	Denali	KW	Kaniha	73G/4	Pre-cambrian	85.03917	21.23750	0.25	9.1	1.9	7.9	5.8	2.1
29	Nalama	KW	Kaniha	73G/4	Pre-cambrian	85.10261	21.17794	0.5	8.6	1.9	6.45	4.55	1.9
30	Dalaka	KW	Kaniha	73G/4	Pre-cambrian	85.09683	21.15906	0.5	8.5	1.7	4.35	3.1	1.25
31	Talapada	KW	Kaniha	73G/4	Pre-cambrian	85.13419	21.14503	0.3	8.3	3	7.8	5.1	2.7
32	Kiajhara	KW	Kaniha	73G/4	Pre-cambrian	85.09167	21.13833	0.55	8.35	1.9	5.6	3	2.6
33	Baruan	KW	Kaniha	73G/4	Pre-cambrian	85.12278	21.09472	0.3	4.98	1.8	4.05	1.1	2.95
34	Gahama	KW	Kaniha	73G/4	Pre-cambrian	85.14786	21.12083	0.25	6.5	1.6	4.85	4.9	-0.05
35	Viru	KW	Kaniha	73G/4	Pre-cambrian	85.18389	21.12333	0.25	7.35	2.2	3.9	3.65	0.25
36	Bulajhara	KW	Kaniha	73G/4	Pre-cambrian	85.20528	21.09944	0	6.6	3	6.2	3.85	2.35
37	Balijharana	KW	Kaniha	73G/4	Pre-cambrian	85.23333	21.09167	0.5	6.2	3.1	5.2	3.53	1.67
38	Deragola	KW	Kaniha	73G/4	Pre-cambrian	85.23914	21.15039	0.32	6.93	3	5.48	3.43	2.05
39	Mahidharpur	KW	Kaniha	73G/4	Pre-cambrian	85.20111	21.14619	0.5	7	2.8	6.3	4.2	2.1
40	Gangadharpur	KW	Kaniha	73G/4	Pre-cambrian	85.20906	21.17778	0.35	7.75	3.2	6.4	2.4	4
41	Sipur	KW	Kaniha	73G/4	Pre-cambrian	85.15458	21.16556	0.4	8.6	3.05	8	5.1	2.9
42	Arkil	KW	Kaniha	73G/4	Pre-cambrian	85.12528	21.19750	0.3	8.15	1.85	6.95	4.2	2.75
43	Kulabir	KW	Kaniha	73G/4	Pre-cambrian	85.07792	21.19542	0.1	6.6	1.6	4.1	2.5	1.6
44	Gengutia	KW	Kaniha	73G/4	Pre-cambrian	85.07222	21.25278	0.2	5.4	2.1	3.3	2.05	1.25
45	Rengali	KW	Kaniha	73G/4	Pre-cambrian	85.02583	21.25583	0.25	11.1	2.95	4	4.15	-0.15
46	Jamujhori	KW	Kaniha	73C/16	Gondwana	84.98762	21.04363	0.45	8.3	1.9	5.2	3.3	1.9
47	Sana Santrabandha	KW	Kaniha	73C/16	Gondwana	84.95258	21.09028	0.35	7.7	2.4	6.86	3.21	3.65
48	Boinda	KW	Kaniha	73C/16	Gondwana	84.98483	21.07768	0.5	7.4	2.5	6.95	4.41	2.54
49	Bada Changudia	KW	Kaniha	73C/16	Gondwana	84.96375	21.10261	0.4	9.73	2.3	9.11	2.38	6.73
50	Kakudia	KW	Kaniha	73C/16	Gondwana	84.97282	21.10415	0.45	10.15	1.8	8.7	1.52	7.18
51	Balipeta	KW	Kaniha	73C/16	Gondwana	84.98877	21.10940	0.55	10.75	2.05*2	8.55	2.74	5.81
52	Derang	KW	Kaniha	73C/16	Gondwana	84.98433	21.11530	0.6	13.7	2.8	9.62	5.18	4.44

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
53	Ghantianali	KW	Kaniha	73C/16	Gondwana	84.97155	21.13225	0.4	6.9	3.95	4.25	2.98	1.27
54	Kaladama	KW	Kaniha	73C/16	Pre-cambrian	84.92743	21.24393	0.5	7.7	3.1	6.22	2.18	4.04
55	Katarpali	KW	Kaniha	73C/16	Pre-cambrian	84.95393	21.24283	0.5	8.25	2	5.55	3.61	1.94
56	Barapada	KW	Kaniha	73C/16	Pre-cambrian	84.97868	21.24037	0.35	7.45	4.7	5.47	4.87	0.6
57	Nialu	KW	Kaniha	73C/16	Pre-cambrian	84.98247	21.19878	0.5	8.5	2.25	6.18	4.32	1.86
58	Luhamunda	KW	Kaniha	73C/16	Gondwana	84.99792	21.09019	0.52	10.15	1.8	8.41	5.75	2.66
59	Sansamura	KW	Kaniha	73C/15	Pre-cambrian	84.90594	21.25697	0	7.75	1.9	4.11	2.61	1.5
60	Kusumpal	KW	Talchir	73H/1	Gondwana	85.01897	20.95775	0.6	10.15	2	7.45	4.02	3.43
61	Solarha	KW	Talchir	73H/1	Gondwana	85.06967	20.97297	0.65	8	1.5	2.6	1.16	1.44
62	Lakeiposi	KW	Talchir	73H/1	Gondwana	85.09633	20.96358	0.2	10.1	1.5	6.74	6.42	0.32
63	Daunara	KW	Talchir	73H/1	Gondwana	85.09744	20.94369	0.5	10.3	2.1	6.22	3.25	2.97
64	Chauliakata	KW	Talchir	73H/1	Gondwana	85.22208	20.95361	0.4	10	2.4	5.35	3.61	1.74
65	Kankili	KW	Talchir	73H/1	Gondwana	85.22944	20.99250	0.5	9.7	1.7	5.65	1.52	4.13
66	Madanmohanpur	KW	Talchir	73H/1	Gondwana	85.18758	20.96650	0.5	11.8	1.55	7.55	3.13	4.42
67	Jilinda	KW	Talchir	73H/1	Gondwana	85.16236	20.98539	0.5	8.1	1.5	5.92	4.5	1.42
68	South balanda	KW	Talchir	73H/1	Gondwana	85.15944	20.92781	0.8	10.25	2.65	4.8	3.97	0.83
69	Gobara	KW	Talchir	73H/1	Gondwana	85.14222	20.90981	0.65	9.5	1.9	1.99	3.04	-1.05
70	Chalagarh	KW	Talchir	73H/1	Gondwana	85.18731	20.92522	0.7	5.9	1.5	2.58	1.55	1.03
71	Lingakata	KW	Talchir	73H/1	Gondwana	85.22728	20.87667	0.4	4.9	2.15	1.7	1.23	0.47
72	Santhapada	KW	Talchir	73H/1	Gondwana	85.23472	20.91610	0.6	12	2.9	6.02	3.85	2.17
73	Scotlandpur	KW	Talchir	73H/1	Gondwana	85.22167	20.98119	0.6	9.4	2.2	3.95	3.63	0.32
74	Ghantapada	KW	Talchir	73H/1	Gondwana	85.18889	20.93530	0.75	14.85	2.9	8.35	4.77	3.58
75	Talchir	KW	Talchir	73H/1	Gondwana	85.21250	20.94940	0.8	11.5	1.9	7.59	9.28	-1.69
76	Gurujanguli	KW	Talchir	73H/1	Gondwana	85.22103	20.89797	0.4	7.2	1.8	3.3	2.07	1.23
77	Teheranpur	KW	Talchir	73H/1	Gondwana	85.18472	20.90190	0.6	11.8	1.82	7.76	2.84	4.92
78	Kandhal	KW	Talchir	73H/1	Gondwana	85.18944	20.97811	0.35	9.1	1.5	3.4	2.07	1.33
79	Bantol	KW	Talchir	73H/1	Gondwana	85.20856	20.92372	0.52	9	2	5.94	2.32	3.62

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
80	Dera	KW	Talchir	73H/1	Gondwana	85.16844	20.95353	1.1	7.5	1.7	5.88	5.27	0.61
81	Kandhabareni	KW	Talchir	73H/1	Gondwana	85.09261	21.00042	0.4	10.25	1.5	5.08	2.25	2.83
82	Ekdal	KW	Talchir	73H/1	Gondwana	85.13750	20.99044	0.4	11.4	1.3	5.62	3.84	1.78
83	Joragarhia	KW	Talchir	73H/1	Gondwana	85.10464	20.98286	0	8.75	1.4	6.03	2.78	3.25
84	Tentulei	KW	Talchir	73H/1	Gondwana	85.17639	20.91940	0.6	8.09	2.1	3.98	3.54	0.44
85	Kalamchuin	KW	Talchir	73H/1	Gondwana	85.06667	20.96030	0.3	8.65	2	1.56	1.17	0.39
86	Gopal prasad	KW	Talchir	73H/1	Gondwana	85.04306	20.97080	0.25	4.3	2.8	2.99	3.54	-0.55
87	Shendhogram	KW	Talchir	73H/1	Gondwana	85.23333	20.89030	0.43	7.9	2.03	6.02	5.39	0.63
88	Jagannathpur	KW	Talchir	73H/1	Gondwana	85.20142	20.92083	0.5	6.48	1.9	3.25	1.76	1.49
89	Baghuabola	KW	Talchir	73H/1	Gondwana	85.21772	20.94300	0.35	4.6	1.1	3.81	1.61	2.2
90	Hariharpur	KW	Talchir	73H/1	Gondwana	85.24881	20.97542	0.33	11.72	2.4	10.04	8.01	2.03
91	Kumunda	KW	Talchir	73H/1	Gondwana	85.02647	20.97661	0.35	7.45	2.2	2.6	1.83	0.77
92	Chittalpur	KW	Talchir	73H/1	Gondwana	85.03467	20.98142	0.4	8.93	2.6	7.24	5.12	2.12
93	Mallibandha	KW	Talchir	73H/1	Gondwana	85.02869	20.95075	0.5	7.27	2.1	2.52	1.81	0.71
94	Bhalugadia	KW	Talchir	73H/1	Gondwana	85.01011	20.95814	0.35	9.1	1.9	6.35	3.78	2.57
95	Karnapur	KW	Talchir	73H/1	Gondwana	85.12236	20.89619	0.5	9.6	1.9	7.24	2.81	4.43
96	Bhagalkata	KW	Chhendipada	73C/16	Gondwana	84.92835	21.03233	0.55	14.65	1.85	5.6	2.25	3.35
97	Brahmanbil	KW	Chhendipada	73C/16	Gondwana	84.93255	21.04640	0.5	10.3	1.5	8.3	4	4.3
98	Santrabandha_A	KW	Chhendipada	73C/16	Gondwana	84.94575	21.07402	0.45	7.75	2.8	4.9	1.53	3.37
99	Santrabandha_B	KW	Chhendipada	73C/16	Gondwana	84.94473	21.08608	0.55	8.3	1.75	7.6	1.85	5.75
100	Takua	KW	Chhendipada	73C/16	Gondwana	84.96887	21.07135	0.5	9.65	2.75*2	8.9	4.52	4.38
101	Jamujhori	KW	Chhendipada	73C/16	Gondwana	84.98762	21.04363	0.45	8.3	1.9	7.05	2.79	4.26
102	Chakundapal	KW	Chhendipada	73C/16	Gondwana	84.90230	20.99987	0.6	10.1	1.8	5.8	1.68	4.12
103	Dubanali	KW	Chhendipada	73C/16	Gondwana	84.87187	21.00575	0.45	10.6	1.55	9.95	4.6	5.35
104	Tentulei	KW	Chhendipada	73C/16	Gondwana	84.86600	21.03378	0.3	7.6	120*1.	6.8	4.48	2.32
105	Handigurha	KW	Chhendipada	73C/16	Gondwana	84.83877	21.04423	0.35	10.65	1.8	7.6	5.25	2.35
106	Deulijharan	KW	Chhendipada	73C/16	Gondwana	84.98762	21.04363	0.15	6.25	1.5	4.85	3.37	1.48

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
107	Shimlipal	KW	Chhendipada	73C/16	Gondwana	84.78425	21.06047	0.5	9.05	1.5	8.4	3.62	4.78
108	Patraparha	KW	Chhendipada	73C/16	Gondwana	84.77220	21.07987	0.3	8.55	1.55	7.1	2.97	4.13
109	Piplibahal	KW	Chhendipada	73C/16	Gondwana	84.78428	21.10582	0.4	9.7	1.31	6.4	2.21	4.19
110	Khamar	KW	Chhendipada	73C/16	Gondwana	84.79918	21.10687	0.55	7.4	1.8	5.45	1.27	4.18
111	Bagedia	KW	Chhendipada	73C/16	Gondwana	84.82162	21.10323	0.7	8.4	1.7	7	1.59	5.41
112	Podapada	KW	Chhendipada	73C/16	Gondwana	84.84155	21.09030	0.35	11.95	1.6	9.65	3.47	6.18
113	Chhendipada	KW	Chhendipada	73C/16	Gondwana	84.86910	21.08075	0.5	10.35		6.1	2.08	4.02
114	Gopinathpur	KW	Chhendipada	73C/16	Gondwana	84.89288	21.05077	0.35	12.4	2.9	11.85	5.1	6.75
115	Kunjabiharipur	KW	Chhendipada	73C/16	Gondwana	84.90360	21.03665	0.45	9.25	1.5	7.85	2.67	5.18
116	Jalatap	KW	Chhendipada	73C/16	Gondwana	84.97493	21.01785	0.6	6	1.55	5.05	2.75	2.3
117	Kukurpeta	KW	Chhendipada	73C/16	Gondwana	84.88945	21.02670	0.5	6.6	3	5.25	1.65	3.6
118	Karadabahal	KW	Chhendipada	73C/16	Gondwana	84.90922	21.05043	0.15	7.4	2.35	7.05	2.1	4.95
119	Sanchangudia	KW	Chhendipada	73C/16	Gondwana	84.95390	21.10473	0.4	9.8	2.35	9.3	2.38	6.92
120	Kakudia	KW	Chhendipada	73C/16	Gondwana	84.97282	21.10415	0.45	10.15	1.8	9.55	1.2	8.35
121	Campashala	KW	Chhendipada	73C/16	Gondwana	84.94975	21.14545	0.3	8.7	3.65	7.9	2.05	5.85
122	Badaberana	KW	Chhendipada	73C/16	Gondwana	84.93280	21.12902	0.3	7.6	2.1	6.05	1.75	4.3
123	Andharikata	KW	Chhendipada	73C/16	Gondwana	84.93058	21.14562	0.55	9.8	1.65	7.85	3.26	4.59
124	Gambharipal	KW	Chhendipada	73C/16	Gondwana	84.90003	21.15793	0.2	7.55	2	7	0.92	6.08
125	Nuaparha	KW	Chhendipada	73C/16	Gondwana	84.88307	21.14520	0.6	8.5	1.92	7.15	1.93	5.22
126	Charbati	KW	Chhendipada	73C/16	Gondwana	84.86922	21.12088	0.4	9.95	1.55	5.4	1.17	4.23
127	Rugudisahi	KW	Chhendipada	73C/16	Gondwana	84.86452	21.10703	0.6	12.6	1.4	4.3	3.18	1.12
128	Bahalsahi	KW	Chhendipada	73C/16	Gondwana	84.87938	21.09720	0.6	9.95	3	7.8	2.54	5.26
129	Golagadia	KW	Chhendipada	73C/16	Gondwana	84.89425	21.11452	0.2	6.05	3.85	4.7	0.7	4
130	Dahibar	KW	Chhendipada	73C/16	Gondwana	84.90300	21.09415	0.5	10.65	2.5	8.9	2.24	6.66
131	Kankurpal	KW	Chhendipada	73C/16	Gondwana	84.93310	21.11077	0.3	7.85	1.95	4.2	1.57	2.63
132	Mandua	KW	Chhendipada	73C/16	Pre-cambrian	84.98333	21.15657	0.85	9.2	2	5.8	2	3.8
133	Baramancha	KW	Chhendipada	73C/16	Gondwana	84.84493	21.14693	0.4	5	1.2	3.8	1.11	2.69

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
134	Sarapal	KW	Chhendipada	73C/16	Gondwana	84.81712	21.13427	0.35	9.35	2.1	8.1	2.36	5.74
135	Machhakuta	KW	Chhendipada	73C/16	Gondwana	84.83723	21.07210	0.35	7.55	2.15	4.55	1.93	2.62
136	Bhatpal	KW	Chhendipada	73C/16	Gondwana	84.74820	21.10527	0.82	5.4	1.54	2.6	1.14	1.46
137	Nuagaon	KW	Chhendipada	73C/12	Gondwana	84.71985	21.11290	0.55	6	1.96	2.78	3.13	-0.35
138	Marudhip	KW	Chhendipada	73C/12	Gondwana	84.70573	21.11155	0.43	7.91	1.54	6.14	2.75	3.39
139	Kanloi	KW	Chhendipada	73C/12	Gondwana	84.69772	21.10087	0.6	12.73	1.9	9.4	1.81	7.59
140	Jarasingha	KW	Banarpal	73H/1	Gondwana	85.06257	20.85634	0.5	8.7	2.2	4.75	3.55	1.2
141	Golabandha	KW	Banarpal	73D/13	Pre-cambrian	84.99738	20.85387	0.2	5.52	2	6.5	4.25	2.25
142	Sana Kerjung	KW	Banarpal	73D/13	Pre-cambrian	84.98732	20.85637	0.3	7.8	1.95	7.5	5.2	2.3
143	Bada Kerjung	KW	Banarpal	73D/13	Pre-cambrian	84.96939	20.86564	0.3	8.39	1.6	6.9	3.2	3.7
144	Jamunda	KW	Banarpal	73D/13	Pre-cambrian	84.92657	20.86759	0.38	12.42	1.58	10.9	9.2	1.7
145	Kanjara	KW	Banarpal	73D/13	Gondwana	84.92545	20.84978	0.3	9.48	1.49	4.95	3.45	1.5
146	Jaruda	KW	Banarpal	73D/13	Pre-cambrian	84.95383	20.84989	0.3	9.65	2.04	10.2	8.2	2
147	Bimalbeda	KW	Banarpal	73D/13	Pre-cambrian	84.93299	20.84620	0.35	8.17	1.87	5.05	2.55	2.5
148	Santrapur	KW	Banarpal	73D/13	Pre-cambrian	84.95955	20.83474	0.3	5.86	1.55	4.7	3	1.7
149	Dudhiabeda	KW	Banarpal	73D/13	Pre-cambrian	84.97348	20.84547	0.3	8.28	1.5	8	5	3
150	Tubey	KW	Banarpal	73D/13	Pre-cambrian	84.99257	20.81768	0.35	6.83	1.98	4.85	3.2	1.65
151	Partara	KW	Banarpal	73H/1	Pre-cambrian	85.04850	20.84540	0.5	9.51	2.06	9.05	8.4	0.65
152	Kusasingha	KW	Banarpal	73H/1	Pre-cambrian	85.06206	20.84603	0.55	9	1.72	7.7	6.3	1.4
153	Kadagadia	KW	Banarpal	73H/1	Pre-cambrian	85.07760	20.83229	0.5	7.38	1.38	6.5	5.4	1.1
154	Kurudol	KW	Banarpal	73H/1	Pre-cambrian	85.13640	20.87059	0.55	6.78	2	2	0.75	1.25
155	Ekagharia	KW	Banarpal	73H/1	Gondwana	85.15928	20.90272	0.25	9.16	1.9	5.95	4.3	1.65
156	Tentoi	KW	Banarpal	73H/1	Gondwana	85.17198	20.89573	0.45	10.95	1.75	9.35	8	1.35
157	Tentolei	KW	Banarpal	73H/1	Gondwana	85.17197	20.88969	0.5	6.9	2.82	5.95	4.6	1.35
158	Balaramprasad	KW	Banarpal	73H/1	Pre-cambrian	85.16911	20.86190	0.45	7.78	1.8	4	4.1	-0.1
159	Pingua	KW	Banarpal	73H/1	Gondwana	85.17949	20.88003	0.5	7.13	1.62	2.7	2.35	0.35
160	Kendupalli	KW	Banarpal	73H/1	Gondwana	85.19974	20.89811	0.3	4.95	1.5	3.4	2	1.4

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161	Gotmara	KW	Banarpal	73H/1	Pre-cambrian	85.21498	20.85439	0.35	9.18	1.42	6.75	4.6	2.15
162	Girang Chhak	KW	Banarpal	73H/1	Pre-cambrian	85.16022	20.84763	0.5	5.51	1.63	2.5	2.9	-0.4
163	Kandasar	KW	Banarpal	73H/1	Pre-cambrian	85.13239	20.84285	0.35	7.58	0.9	3.4	1.75	1.65
164	Banarpal Village	KW	Banarpal	73H/1	Pre-cambrian	85.20070	20.84103	0.35	11.17	1.68	3.65	3.4	0.25
165	Budhapanka	KW	Banarpal	73H/1	Gondwana	85.24168	20.86363	0.5	7.23	1.7	6.6	4.05	2.55
166	Tentulihata	KW	Banarpal	73H/1	Gondwana	85.24821	20.84657	0.2	8.36	2	8.25	4.5	3.75
167	Nuahata	KW	Banarpal	73H/1	Pre-cambrian	85.23039	20.83247	0.4	7.1	2.26	7.6	3.8	3.8
168	Pirhasahi	KW	Banarpal	73H/1	Pre-cambrian	85.21108	20.80742	0.45	7.29	2.2	5.95	4.15	1.8
169	Gadasantri	KW	Banarpal	73H/1	Pre-cambrian	85.20161	20.79641	0	8.04	1.77	7.7	6.25	1.45
170	Arahat	KW	Banarpal	73H/1	Pre-cambrian	85.18087	20.77106	0.3	6.8	2.38	5.8	4.65	1.15
171	Purikia	KW	Banarpal	73H/1	Pre-cambrian	85.17789	20.77447	0.75	7.98	1.98	7.97	6.1	1.87
172	Kainchabahala	KW	Banarpal	73H/2	Pre-cambrian	85.17702	20.74320	0.55	7.37	2.3	6.45	4.85	1.6
173	Phulpada	KW	Banarpal	73H/1	Pre-cambrian	85.16641	20.75327	0.4	7.1	1.82	6	5.2	0.8
174	Gadatalmul	KW	Banarpal	73H/2	Pre-cambrian	85.19394	20.73089	0.4	9.52	1.3	7.05	5.8	1.25
175	Serenabeda	KW	Banarpal	73H/2	Pre-cambrian	85.17568	20.68198	0.45	7.05	2	6.8	4.8	2
176	Khandanali	KW	Banarpal	73H/2	Pre-cambrian	85.17408	20.71120	0.25	6.15	3.25	5.75	3.1	2.65
177	Sankhamur	KW	Pallahara	73G/3	Pre-cambrian	85.1667	21.2556	0.52			6.09	1.92	4.17
178	Bankhol	KW	Pallahara	73G/3	Pre-cambrian	85.1028	21.3278	0			6.45	0.51	5.94
179	Sahargurujang	KW	Pallahara	73G/3	Pre-cambrian	85.1069	21.3639	0.5			6.19	3.35	2.84
180	Srirampur	KW	Pallahara	73G/3	Pre-cambrian	85.1542	21.3917	0.5			8.33	3.52	4.81
181	Kantala	KW	Pallahara	73G/3	Pre-cambrian	85.2472	21.4458	0.5			9.5	6.96	2.54
182	Jamirdihi	KW	Pallahara	73G/7	Pre-cambrian	85.2583	21.4958	0.59			7.1	2.7	4.4
183	Chasa Gurujang	KW	Pallahara	73G/3	Pre-cambrian	85.0917	21.4417	0.75			8.03	4.89	3.14
184	Mahidharpur	KW	Pallahara	73G/3	Pre-cambrian	85.0458	21.4208	0.5			7.2	4.37	2.83
185	Dimiria	KW	Pallahara	73G/3	Pre-cambrian	85.1514	21.4194	0.57			7.69	4.27	3.42
186	Korarha	KW	Pallahara	73G/3	Pre-cambrian	85.1958	21.3792	0			2.2	2.07	0.13
187	Korarhapal	KW	Pallahara	73G/3	Pre-cambrian	85.1569	21.3472	0.6			6.65	3.8	2.85

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188	Ghenakani	KW	Pallahara	73G/3	Pre-cambrian	85.1889	21.3111	0.85			6.57	3.06	3.51
189	Badasarha	KW	Pallahara	73G/3	Pre-cambrian	85.2083	21.3083	0.48			7.56	4.64	2.92
190	Nuagaon	KW	Pallahara	73G/3	Pre-cambrian	85.2417	21.2625	0.57			8.11	4.77	3.34
191	Biralmunda	KW	Pallahara	73G/7	Pre-cambrian	85.2694	21.2972	0.7			4.23	2.17	2.06
192	Munderibeda	KW	Pallahara	73G/8	Pre-cambrian	85.2500	21.2458	0.45			6.95	3.5	3.45
193	Kunjam	KW	Pallahara	73G/8	Pre-cambrian	85.2528	21.2056	0.65			8.39	4.6	3.79
194	Injirih	KW	Pallahara	73G/8	Pre-cambrian	85.2958	21.1958	0.55			7.31	3.93	3.38
195	Kantiaposhi	KW	Pallahara	73G/4	Pre-cambrian	85.1722	21.2083	0.55			7.1	3.95	3.15
196	Khamar	KW	Pallahara	73G/3	Pre-cambrian	85.2000	21.2667	0.79			6.78	4.23	2.55
197	Dhuliapada	KW	Athmalik	73D/5	Pre-cambrian	84.2869	20.8897	0.1	8.9	1.8	8.52	3.4	5.12
198	Tasarbeda	KW	Athmalik	73D/5	Pre-cambrian	84.3056	20.9325	0.3	10.18	1.5	10.1	6.2	3.9
199	Kadapada	KW	Athmalik	73D/5	Pre-cambrian	84.3322	20.8706	0	6.7	3.4	5.7	4.8	0.9
200	Kandhapada	KW	Athmalik	73D/5	Pre-cambrian	84.3972	20.8069	0.6	7.16	2.1	6.73	5.8	0.93
201	Nilakanthapada	KW	Athmalik	73D/5	Pre-cambrian	84.4589	20.7594	0	7.6	4.8	5.87	3.2	2.67
202	Athmalik	KW	Athmalik	73D/10	Pre-cambrian	84.5389	20.7225	0.55	5.71	1.5	3.5	2.2	1.3
203	Pataka	KW	Athmalik	73D/10	Pre-cambrian	84.6347	20.6489	0.95	10.35	2.2	10.15	2.55	7.6
204	Jamudoli	KW	Athmalik	73D/10	Pre-cambrian	84.7056	20.6289	0.35	4.65	3.2	3.05	1.75	1.3
205	Thakurgarh	KW	Athmalik	73D/9	Pre-cambrian	84.6281	20.8128	0.5	8	8.75	6.8	1.9	4.9
206	Kundajhari	KW	Athmalik	73D/9	Pre-cambrian	84.6833	20.8108	0.65	9.1	2	7.95	4.8	3.15
207	Bidising	KW	Athmalik	73D/9	Pre-cambrian	84.7419	20.8103	0.45	7.1	2.3	7	3.65	3.35
208	Tapdhol	KW	Athmalik	73D/13	Pre-cambrian	84.7872	20.8114	0.6	8.2	2	6.4	3.36	3.04
209	Kutasingha	KW	Kishornagar	73C/8	Pre-cambrian	84.4589	21.0494	0.65	10.2	2.1	8.7	6.3	2.4
210	Kishorenagar	KW	Kishornagar	73D/5	Pre-cambrian	84.4706	20.9622	0.45	9.4	2.1	8.37	5.2	3.17
211	Talapadar	KW	Kishornagar	73D/5	Pre-cambrian	84.4269	20.9736	0.5	6	2	5.5	3.3	2.2
212	Angapada	KW	Kishornagar	73D/9	Pre-cambrian	84.5472	20.9333	0.5	7.95	2.1	6.92	2.75	4.17
213	Bhimpur	KW	Kishornagar	73D/5	Pre-cambrian	84.4178	20.9228	0.25	8.85	2.65	8.75	4.75	4
214	Tusar	KW	Kishornagar	73D/5	Pre-cambrian	84.3556	20.9089	0.3	9.45	2	5.15	3.75	1.4

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
215	Raniakata	KW	Kishornagar	73D/5	Pre-cambrian	84.4406	20.8908	0.8	5.3	2.15	4.8	2.55	2.25
216	Sanjamura	KW	Kishornagar	73D/9	Pre-cambrian	84.5011	20.8844	0.5	4.55	3.6	3.27	1.9	1.37
217	Talamaliha	KW	Athmalik	73D/9	Pre-cambrian	84.5686	20.8656	1.3	5.4	2.5	4.1	1.45	2.65
218	Navdippur	KW	Athmalik	73D/9	Pre-cambrian	84.5997	20.8383	0.5	11.2	2.2	9.4	5.45	3.95
219	Pedipathar	KW	Athmalik	73D/9	Pre-cambrian	84.6983	20.8869	0.25	10.15	1.9	9.65	4.9	4.75
220	Gunduri	KW	Athmalik	73D/9	Pre-cambrian	84.6625	20.8406	0.7	8.9	2	8.7	4.8	3.9
221	Ranibandha	KW	Athmalik	73D/9	Pre-cambrian	84.6689	20.7875	0	6.15	3.1	5.9	3.5	2.4
222	Ghanajodi	KW	Athmalik	73D/9	Pre-cambrian	84.7114	20.7636	0.35	6.05	1.85	4.75	3.65	1.1
223	Kantapada	KW	Athmalik	73D/13	Pre-cambrian	84.7514	20.7750	0.65	10	1.8	8.4	5.65	2.75
224	Ambanali	KW	Athmalik	73D/13	Pre-cambrian	84.7686	20.8625	0.9	7.2	1.9	3.6	2	1.6
225	Bantul	KW	Athmalik	73D/9	Pre-cambrian	84.7456	20.8497	0.8	8.3	1.9	7.75	5.45	2.3
226	Jhilimunda	KW	Athmalik	73D/9	Pre-cambrian	84.7103	20.8725	0.2	7.8	2	5.95	3.6	2.35
227	Adikata	KW	Kishornagar	73D/9	Pre-cambrian	84.5844	20.9383	0.5	8.75	2.3	6.95	4.2	2.75
228	Dehurisahi	KW	Kishornagar	73D/9	Pre-cambrian	84.6400	20.9386	0.3	7.5	3	7.17	4.15	3.02
229	Urukula	KW	Kishornagar	73D/9	Pre-cambrian	84.6028	20.9178	0.2	8.2	1.8	7.25	4.15	3.1
230	Damabahal	KW	Kishornagar	73D/9	Pre-cambrian	84.6222	20.8725	0.6	6.45	1.9	5.15	1.45	3.7
231	Karadabahal	KW	Athmalik	73D/9	Pre-cambrian	84.6489	20.8531	0.45	8.85	1.8	7.85	5.85	2
232	Mandarbahal	KW	Athmalik	73D/9	Pre-cambrian	84.6636	20.8808	0.55	7.95	1.5	7.7	4.1	3.6
233	Bileinali	KW	Athmalik	73D/9	Pre-cambrian	84.6628	20.9039	0.5	7.3	2.1	6.33	3.5	2.83
234	Asrubahal	KW	Kishornagar	73D/13	Pre-cambrian	84.7911	20.9586	0.5	5.65	3.4	3.75	3.5	0.25
235	Anlaberini	KW	Kishornagar	73D/13	Pre-cambrian	84.7625	20.9872	0.4	10.9	2	10.1	7.75	2.35
236	Laxmipriyapur	KW	Kishornagar	73C/12	Pre-cambrian	84.7314	21.0128	0.3	9.3	1.6	7.3	6.25	1.05
237	Bhagirathipur	KW	Kishornagar	73D/9	Pre-cambrian	84.6103	20.8294	0.25	8.35	1.8	4.65	2.55	2.1
238	Bantala	NHS (DW)	Angul	73 H/2	Pre-cambrian	85.06306	20.74306	0.55	8.5	1.21	5.93	2.90	3.03
239	Bantala-Ii	NHS (BW)	Angul	73 H/2	Pre-cambrian	85.06556	20.74167	0.5	0	0	4.86	3.00	1.86
240	Barhabahal	NHS (DW)	Angul	73 H/1	Pre-cambrian	85.1	20.755	0.6	7.92	1.9	8.72	7.63	1.09
241	Derjung	NHS (BW)	Angul	73 H/1	Pre-cambrian	85.03556	20.83833	0.5	0	0	6.91	4.08	2.83

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
242	Jagannathpur	NHS (DW)	Angul	73 D/14	Pre-cambrian	84.86944	20.72111	0.59	8.27	1.2	5.63		5.63
243	Jarpada	NHS (BW)	Angul	73 H/1	Pre-cambrian	85.16778	20.88	0.5	0	0	3.60	1.36	2.24
244	Maratira	NHS (BW)	Angul	73 D/13	Pre-cambrian	84.97361	20.82528	0.5	0	0	8.57	3.90	4.67
245	Panchmahala	NHS (DW)	Angul	73 H/1	Pre-cambrian	85.05917	20.82278	0.6	11	1.5	7.85	4.34	3.51
246	Panchmahala-Ii	NHS (BW)	Angul	73 H/1	Pre-cambrian	85.00778	20.80333	0.5	0	0	6.84	4.86	1.98
247	Purnakot	NHS (DW)	Angul	73 D/14	Pre-cambrian	84.83611	20.64583	0.49	9.08	3.5	5.23	1.06	4.17
248	Tikarpara	NHS (DW)	Angul	73 D/14	Pre-cambrian	84.7875	20.59833	0.69	10.75	2.35	3.55	1.85	1.7
249	Tikarpara-ii	NHS (DW)	Angul	73 D/14	Pre-cambrian	84.7875	20.59833	1.31	10.1	2.02	6.25	2.09	4.16
250	Tubey	NHS (DW)	Angul	73 D/13	Pre-cambrian	84.99944	20.81389	0.7	7.9	1.86	5.94	2.87	3.07
251	Amna	NHS (DW)	Banarpal	73 H/1	Pre-cambrian	85.16889	20.84889	0.59	9	1.93	7.05	3.20	3.85
252	Angul1	NHS (DW)	Banarpal	73 H/1	Gondwana	85.09944	20.83889	0.66	13.95	2.1	8.11	2.83	5.28
253	Banarpal1	NHS (DW)	Banarpal	73 H/1	Gondwana	85.21611	20.84167	0.55	9.5	1.45	5.46	2.08	3.38
254	Bhogabereni	NHS (DW)	Banarpal	73 H/1	Gondwana	85.21389	20.89167	0.69	9.93	1.93	4.66	1.86	2.8
255	Kuio	NHS (DW)	Banarpal	73 H/1	Pre-cambrian	85.08111	20.89083	0.34	10.72	1.6	6.32	3.67	2.65
256	Kukurang	NHS (DW)	Banarpal	73 H/1	Pre-cambrian	85.14833	20.89722	0.34	10	1.74	8.69	3.54	5.15
257	Kulnara1	NHS (DW)	Banarpal	73 H/1	Pre-cambrian	85.16944	20.83611	0.48	7.5	1.86	5.31	1.91	3.4
258	Mahidharpur	NHS (DW)	Banarpal	73 H/2	Gondwana	85.18556	20.6875	0.71	14.59	1.22	4.25	1.43	2.82
259	Tulsipal	NHS (DW)	Banarpal	73 H/1	Gondwana	85.18667	20.80361	0.44	8.16	2.57	5.76	2.96	2.8
260	Bagharia	NHS (DW)	ChhendipadaA	73 C/16	Gondwana	84.81583	21.10694	0.8	8.25	1.54	6.16	2.35	3.81
261	Chendipada1	NHS (DW)	Chhendipada	73 C/16	Pre-cambrian	84.87167	21.08167	0.64	9.87	1.21	5.52	4.13	1.39
262	Durgapur 1	NHS (DW)	Chhendipada	73 D/13	Pre-cambrian	84.88278	20.91806	0.5	8.3	1.8	5.00	2.50	2.5
263	Jharpada	NHS (DW)	Chhendipada	73 D/13	Gondwana	84.88194	20.87639	0.78	8.5	1.25	5.80	1.83	3.97
264	Katada	NHS (DW)	Chhendipada	73 D/13	Gondwana	84.82056	20.90667	0.6	8	3	3.92	2.22	1.7
265	Kosala1	NHS (DW)	Chhendipada	73 C/16	Gondwana	84.94889	21.0075	0.45	8.31	0	2.73	1.10	1.63
266	Nisa	NHS (DW)	Chhendipada	73 H/1	Pre-cambrian	85.00417	20.92639	0.48	7.21	1.86	9.98	7.13	2.85
267	Paranga	NHS (DW)	Chhendipada	73 H/1	Pre-cambrian	85.03056	20.87917	0.7	7.9	1.86	8.70	3.47	5.23
268	Ugi	NHS (DW)	Chhendipada	73 D/13	Pre-cambrian	84.87917	20.84667	0.5	11.9	1.5	7.29	4.02	3.27

Sl No	Village	Type	Block	Toposheet	Lithology	Longitude	Latitude	MP	Depth	Dia	PreWL (mbgl)	PostWL (mbgl)	Fluctuation (m)
269	Goribandha	NHS (BW)	Kaniha	73 G/4	Gondwana	85.17444	21.0175	0.5	0	0	4.43	3.78	0.65
270	Pabitranagar pz	NHS (BW)	Kaniha	73 G/4	Gondwana	85.16778	21.13944	0.5	0	0	11.80	9.15	2.65
271	Samal	NHS (DW)	Kaniha	73 G/4	Gondwana	85.14167	21.07222	0.37	6.55	1.99	10.05	6.85	3.2
272	Seepur	NHS (BW)	Kaniha	73 G/4	Gondwana	85.15639	21.17556	0.5	0	0	2.50	1.62	0.88
273	Sipur	NHS (DW)	Kaniha	73 G/4	Gondwana	85.15694	21.16667	0.45	9.85	1.25	5.97	5.17	0.8
274	Balanda	NHS (DW)	Talcher	73 H/1	Gondwana	85.15778	20.9275	0.92	10.25	2.78	9.02	7.00	2.02
275	Chainpal	NHS (BW)	Talcher	73 H/1	Gondwana	85.21917	20.88667	0.5	0	0	11.8	9.15	2.65
276	Godibandha	NHS (DW)	Talcher	73 G/4	Gondwana	85.16944	21.01944	0.3	12.1	2.1	10.05	6.85	3.2
277	Kumunda 1	NHS (DW)	Talcher	73 H/1	Gondwana	85.02639	20.97639	0.35	7.5	2.25	2.5	1.62	0.88
278	Sendhogram	NHS (DW)	Talcher	73 H/1	Gondwana	85.23333	20.92556	0.43	8.02	2.03	5.97	5.17	0.8
279	Talcher1	NHS (DW)	Talcher	73 H/1	Gondwana	85.21444	20.94861	0.8	11	1.9	9.02	7	2.02
280	Tentulai	NHS (DW)	Talcher	73 H/1	Gondwana	85.17306	20.91944	0.48	8.14	2.38	3.77	0	3.77
281	Khamar	NHS (DW)	Pallahara	73G/3	Pre-cambrian	85.19667	21.26611						
282	Srirampur	NHS (DW)	Pallahara	73G/3	Pre-cambrian	85.15111	21.39444						
283	Pallahara	NHS (DW)	Pallahara	73G/3	Pre-cambrian	85.19583	21.43167						
284	Jamdihi	NHS (DW)	Pallahara	73G/7	Pre-cambrian	85.25722	21.50056						
285	Tileswar	NHS (DW)	Athamallik	73D/9	Pre-cambrian	84.61056	20.88528		7		6.52	3.62	2.9
286	Bamur	NHS (DW)	KishorenagarAR	73D/4	Pre-cambrian	84.48056	21.01167		6.63		5.47	3.71	1.76
287	Handpa	NHS (DW)	KishorenagarAR	73D/9	Pre-cambrian	84.67778	20.95056		7.61		6.21	2.37	3.84
288	Thakurgarh 1	NHS (DW)	Athamallik	73D/9	Pre-cambrian	84.63194	20.81333		6.58		5.97	3.02	2.95
289	Athamallik 2	NHS (DW)	Athamallik	73D/10	Pre-cambrian	84.50194	20.72194		8		5.14	1.8	2.9
290	Handpa-Ii	NHS (BW)	Kishorenagar	73D/9	Pre-cambrian	84.6889	20.9506		45.0			3.76	
291	Boinda-Ii	NHS (BW)	Kishorenagar	73D/9	Pre-cambrian	84.7336	20.9103		42.0			2.6	

Results of Chemical Analysis of Water Samples From Aquifer-I (Shallow/Phreatic)in Angul District.

Lab Id	Location	Block	Longitude	Latitude	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F	SAR
						µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
2014-15/1521	Jamunali	Banarpal	85.0376	20.7608	7.8	1785	943	590	320	156	49	133	10.1	0	390	390	13	0.35	2.4
2014-15/1522	Salagadia	Banarpal			7.8	**4007**	1951	**1355**	65	**340**	**123**	226	15.5	0	79	**1127**	80	0.31	2.7
2014-15/1523	Serenabeda	Banarpal	85.1757	20.6820	8.3	485	231	200	205	24	34	18	0.3	3	244	28	3	0.65	0.6
2014-15/1524	Narendrapur	Banarpal	85.1335	20.5867	8.4	580	324	235	275	24	43	52.8	1.1	3	329	18	20	0.96	1.5
2014-15/1525	Amantapur	Banarpal	84.9539	20.8343	7.9	938	447	215	150	36	30	156	1.6	0	183	85	48	1.03	4.6
2014-15/1526	Nuahati	Banarpal	85.1357	20.6230	8.25	965	369	310	175	36	53	94.2	0.5	0	214	71	9	0.61	2.3
2014-15/1527	Balarampasad II	Banarpal	85.1691	20.8619	8.2	390	238	150	135	32	17	27.2	0.8	0	165	11	69	0.64	1.0
2014-15/1528	Angarbandha	Banarpal	85.1489	20.7767	8.1	932	427	335	200	52	50	46.4	1.1	0	244	92	65	0.56	1.1
2014-15/1529	Jukubu	Banarpal	85.0063	20.5753	8.1	465	268	145	105	24	21	36.7	1.4	0	128	35	87	0.20	1.3
2014-15/1530	Jhanjhribahal	Banarpal	85.1196	20.6113	8.3	667	303	225	245	40	30	28.3	1	3	293	21	35	0.68	0.8
2014-15/1531	Martira	Banarpal	84.9736	20.8253	7.8	1750	907	490	380	132	39	145.6	25.9	0	464	266	71	0.20	2.9
2014-15/1532	Subarnapur	Banarpal	85.0333	20.7502	8.2	522	242	180	145	40	19	30.5	1.6	0	177	35	29	0.43	1.0
2014-15/1533	Ekagharia	Banarpal	85.1593	20.9027	7.9	2058	939	**675**	175	120	91	120.5	1.8	0	214	418	82	0.36	2.0
2014-15/1534	Tentulihata	Banarpal	85.2458	20.8486	8.2	883	432	175	160	22	29	104.7	1	0	195	124	55	0.38	3.4
2014-15/1535	Kuio	Banarpal	85.0811	20.8908	7.9	1367	618	530	125	138	45	37.9	2.4	0	153	284	35	0.28	0.7
2014-15/1536	Bondai	Banarpal	85.1174	20.6295	8.26	1090	537	150	225	26	21	98.8	65.4	0	275	121	70	0.27	3.5
2014-15/1537	Purkia	Banarpal	85.1779	20.7745	7.8	1880	809	500	80	130	43	119.2	13.5	0	98	425	30	0.23	2.3
2014-15/1538	Derjang	Banarpal	85.0356	20.8383	8.1	**2365**	1144	**775**	260	160	91	160.6	6	0	317	461	110	0.49	2.5
2014-15/1539	Banarpal village	Banarpal	85.2007	20.8410	8.2	705	345	145	115	38	12	81.2	2.8	0	140	92	50	0.56	2.9
2014-15/1540	Tubey I	Banarpal	84.9994	20.8139	8.1	958	420	265	125	50	34	63.7	1.7	0	153	145	50	0.40	1.7
2014-15/1541	Gotmara	Banarpal	85.2150	20.8544	7.9	730	318	210	100	56	17	39.1	2.1	0	122	99	45	0.39	1.2
2014-15/1542	Jungle Jamunda	Banarpal	84.9341	20.8734	8.2	997	518	270	320	28	49	98.8	0.8	0	390	99	50.2	0.89	2.6
2014-15/1543	Benagadia	Banarpal	85.0464	20.8542	7.9	570	346	235	150	54	24	28.8	1.1	0	183	53	95	0.33	0.8
2014-15/1544	Kendupali	Banarpal	85.1997	20.8981	8.1	546	290	180	130	36	22	32.7	1	0	159	53	67	0.50	1.1
2014-15/1545	Bada Hinsor	Banarpal	84.9259	20.8349	8.46	1765	810	330	420	14	72	201	0.9	0	512	227	43	**1.20**	4.8
2014-15/1546	Girinka Chhak	Banarpal	85.1602	20.8476	8.05	560	298	190	85	44	19	31.8	0.3	0	104	82	70	0.25	1.0
2014-15/1547	Tubey I I	Banarpal	84.9926	20.8177	8	1043	453	280	150	42	43	78.1	6.6	0	183	191	2.4	0.37	2.0
2014-15/1548	Kukudang	Banarpal	85.1483	20.8972	7.9	1353	714	425	300	30	85	110	8.1	0	366	195	106	0.78	2.3
2014-15/1549	Partara	Banarpal	85.0550	20.8453	8.2	1016	495	345	265	40	60	63.5	0.8	0	323	131	41	0.63	1.5
2014-15/1550	Arahat	Banarpal	85.1809	20.7711	7.8	1480	671	545	100	120	60	47.7	2.1	0	122	308	73	0.28	0.9
2014-15/1551	Pingua	Banarpal	85.1795	20.8800	8.2	670	307	140	125	38	11	66.4	3.6	0	153	92	20	0.58	2.4
2014-15/1552	Balarampasad I	Banarpal	85.1691	20.8619	8.05	1347	590	385	150	54	61	98.8	1.3	0	183	266	19	0.58	2.2

Lab Id	Location	Block	Longitude	Latitude	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F	SAR
						µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
2014-15/1553	Kadagaria	Banarpal	85.0776	20.8323	8.15	1132	528	200	205	38	26	143.7	1.2	0	250	163	33	0.57	4.4
2014-15/1554	Kusasingha	Banarpal	85.0621	20.8460	8.18	1340	514	350	185	46	57	80.1	3.7	0	226	195	20.8	0.28	1.9
2014-15/1555	Kanjra	Banarpal	84.9254	20.8498	8.44	715	401	125	280	20	18	112.7	1.5	0	342	25	55	1.00	4.4
2014-15/1556	Golabandha	Banarpal	84.9974	20.8539	8.1	915	439	275	100	68	26	53.3	2.9	0	122	160	69	0.28	1.4
2014-15/1557	Tentoloi	Banarpal	85.1720	20.8897	8.26	677	311	210	215	28	34	44.4	1	0	262	57	18	0.55	1.3
2014-15/1558	Badakerjang	Banarpal	84.9694	20.8656	8	1930	883	**640**	85	130	77	112.1	0.8	0	104	500	12	0.30	1.9
2014-15/1559	Kandasar	Banarpal	85.1324	20.8429	7.93	1641	863	495	50	136	38	121.3	0.8	0	61	401	136	0.25	2.4
2014-15/1560	Amalpeda	Banarpal	85.0586	20.6524	8.14	580	307	210	140	34	30	30.6	0.3	0	171	43	85	0.48	0.9
2014-15/1561	Budhapanka	Banarpal	85.2417	20.8636	8.21	620	294	190	135	36	24	42.9	0.3	0	165	57	52	0.45	1.4
2014-15/1562	Fulpada	Banarpal	85.1564	20.7514	8.22	796	407	215	180	32	33	73.6	1.7	0	220	99	60	0.25	2.2
2014-15/1563	Kudol	Banarpal	85.0832	20.7183	8.24	655	344	155	160	26	22	56.1	37	0	195	74	33	0.47	2.0
2014-15/1564	Banusahi	Banarpal	84.9347	20.8491	8.24	1290	638	335	275	30	63	141.4	1.6	0	336	191	45	0.94	3.4
2014-15/1565	Bonda II	Banarpal	85.1175	20.6277	8.3	1038	571	115	235	22	15	90.5	120.9	3	281	106	75	0.50	3.7
2014-15/1566	Nuapal	Banarpal	85.0805	20.7056	8.3	818	414	285	255	40	45	54.6	3.3	3	305	85	33	0.86	1.4
2014-15/1567	Burhapanka-2	Banarpal	85.2417	20.8636	8.1	491	224	160	115	40	15	22.2	3.2	0	140	43	31	0.58	0.8
2014-15/1568	Jarasingha	Banarpal	85.0626	20.8563	7.9	700	312	240	165	34	38	38.2	1.9	0	201	99	2	0.58	1.1
2014-15/1569	Nuahata	Banarpal	85.2304	20.8325	7.9	1045	526	315	320	30	58	90.4	0.3	0	390	135	21	0.62	2.2
2014-15/1497	Dumuduma	Kaniha	85.1597	21.0149	7.37	1120	611	400	90	108	32	71.83	10.4	0	110	326	9	0.55	1.6
2014-15/1498	Rangapur	Kaniha	85.1547	21.0150	7.56	250	131	80	90	24	5	14.42	9.37	0	110	21	3	0.51	0.7
2014-15/1499	Bolangi	Kaniha	85.0913	21.0399	7.82	460	228	185	140	38	22	20.91	1.41	0	171	60	2	0.30	0.7
2014-15/1500	Julibandh	Kaniha	85.0803	21.0524	7.54	780	401	245	145	46	32	67.7	1	0	177	121	46	0.45	1.9
2014-15/1501	Dandasingha-2	Kaniha	85.0804	21.0648	7.96	480	261	190	150	52	15	16.41	18.35	0	183	50	20	0.33	0.5
2014-15/1502	Jarada-2	Kaniha	85.0478	21.0645	7.81	430	227	160	135	42	13	29.61	5.01	0	165	53	3	0.62	1.0
2014-15/1503	Badatribida	Kaniha	85.0507	21.0420	7.74	500	247	200	150	30	30	22.41	2.91	0	183	71	1	0.13	0.7
2014-15/1504	Shradhapur	Kaniha	85.0099	21.0487	7.89	1180	596	440	320	86	55	70.82	2.6	0	390	167	23	0.18	1.5
2014-15/1505	Badagunduri-2	Kaniha	85.0025	21.0794	7.8	300	167	80	90	24	5	34.89	0.61	0	110	35	13	0.05	1.7
2014-15/1506	Kaniha	Kaniha	85.0487	21.0882	7.84	670	339	240	205	26	43	42	5.08	0	250	74	26	0.69	1.2
2014-15/1507	Jharaberini	Kaniha	85.0390	21.1294	7.59	880	478	250	180	44	34	82.1	2.4	0	220	131	76	0.48	2.3
2014-15/1508	Boudbeda	Kaniha	85.0586	21.1791	7.42	180	87	40	70	6	6	19.42	0.49	0	85	7	7	0.00	1.3
2014-15/1509	Bajrakota-3	Kaniha	85.0363	21.2127	7.53	1560	822	270	325	34	45	241	1.8	0	397	301	4	0.74	6.4
2014-15/1510	Bajrakota-2	Kaniha	85.0429	21.2161	7.54	1250	636	470	320	76	68	57.1	25.2	0	390	213	5	0.35	1.1
2014-15/1511	Denali-2	Kaniha	85.0380	21.2427	8.3	620	295	220	260	24	39	35.6	1.32	0	317	35	3	0.95	1.0
2014-15/1512	Rengali	Kaniha	85.0258	21.2558	8.14	880	440	290	180	40	46	51	27.72	0	220	128	39	0.32	1.3
2014-15/1513	Ranjana	Kaniha	85.0809	21.1820	7.82	520	259	200	100	36	27	24	3	0	122	85	24	0.20	0.7

Lab Id	Location	Block	Longitude	Latitude	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F	SAR
						µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
2014-15/1514	Sunakhani	Kaniha	85.1633	21.0158	7.9	250	110	90	75	16	12	12	0.8	0	92	21	3	0.23	0.5
2014-15/1515	Kulei	Kaniha	85.1277	21.0856	7.86	490	250	190	140	30	28	18.77	1.3	0	171	53	35	0.25	0.6
2014-15/1516	Pabitra Nagar	Kaniha	85.1660	21.1347	7.63	370	190	135	90	34	12	22.1	0.39	0	110	67	1	0.08	0.8
2014-15/1517	Siling	Kaniha	85.1568	21.1602	7.86	930	487	140	360	16	24	143.5	3	0	439	71	14	0.66	5.3
2014-15/1518	Gandmula	Kaniha	85.0730	21.1974	7.79	490	241	145	215	18	24	44.14	4.15	0	262	18	3	0.70	1.6
2014-15/1519	Bhaliberha	Kaniha	85.0704	21.2291	7.58	540	268	195	180	24	33	28.6	3.1	0	220	57	14	0.49	0.9
2014-15/1520	Burukuna	Kaniha	85.2113	21.1454	7.59	790	410	290	165	60	34	46	6.4	18	165	149	16	0.33	1.2
2014-15/1033	Kalandi Prasad	Kaniha	85.1842	21.0053	8.21	700	267	250	165	60	24	6.6	0.8	0	201	60	17	0.22	0.2
2014-15/1034	Dangarbeda	Kaniha	85.1453	21.0839	8.28	520	109	110	80	24	12	1.75	0.9	0	98	21	1	0.39	0.1
2014-15/1035	Khairanali	Kaniha	85.0783	21.0431	8.08	1560	494	365	115	68	47	47.48	1.08	0	140	230	32	0.26	1.1
2014-15/1036	Chhelia	Kaniha	85.0478	21.0522	8.06	2150	589	400	100	68	56	58.21	10.97	0	122	259	77	0.30	1.3
2014-15/1037	Badagunduri	Kaniha	85.0025	21.0794	8.28	500	153	160	130	26	23	1.8	0.5	0	159	21	1	0.96	0.1
2014-15/1038	Kansamunda	Kaniha	85.0186	21.0861	8.2	380	154	155	110	38	15	1.8	0.6	0	134	32	0	0.42	0.1
2014-15/1039	Takua	Kaniha	85.0392	21.1181	8.11	680	270	215	105	66	12	15.65	0.5	0	128	53	60	0.31	0.5
2014-15/1040	Brahmanidei	Kaniha	85.0584	21.1761	8.29	720	261	175	170	56	9	36.75	1.16	0	207	46	10	0.45	1.2
2014-15/1041	Khalapala	Kaniha	85.0166	21.2246	8.13	440	166	140	125	40	10	10.4	0.8	0	153	28	2	0.37	0.4
2014-15/1042	Denali-2	Kaniha	85.0392	21.2375	8.07	760	295	290	165	60	34	1	0.6	0	201	96	4	0.46	0.0
2014-15/1043	Talapada	Kaniha	85.1342	21.1450	8.27	500	210	210	175	42	26	3.4	0.4	0	214	32	1	0.26	0.1
2014-15/1044	Kiajhara	Kaniha	85.0917	21.1383	8.21	1600	447	425	315	66	63	12.43	0.09	0	384	43	74	0.55	0.3
2014-15/1045	Baruan	Kaniha	85.1228	21.0947	8.28	600	380	370	75	70	47	5.26	0.8	0	92	206	6	0.21	0.1
2014-15/1046	Bulajhara	Kaniha	85.2053	21.0994	8.15	460	183	170	105	36	19	5.43	0.7	0	128	43	16	0.46	0.2
2014-15/1047	Balijharana	Kaniha	85.2333	21.0917	8.23	640	221	225	200	24	40	8	0.4	0	244	28	0	0.61	0.2
2014-15/1048	Arkil	Kaniha	85.1253	21.1975	8.08	1540	500	490	125	86	67	16.06	0.8	0	153	216	39	0.36	0.3
2014-15/1049	Kulabir	Kaniha	85.0779	21.1954	8.44	870	292	275	245	48	38	13.07	0.5	30	238	43	2	0.95	0.3
2014-15/1050	Gengutia	Kaniha	85.0722	21.2528	8.48	1400	568	305	290	46	46	112.25	0.5	54	244	156	32	1.10	2.8
2014-15/1051	Rengali	Kaniha	85.0258	21.2558	8.65	900	402	205	360	20	38	92.4	0.8	66	305	32	2	**1.40**	2.8
2014-15/1445	Jamujhori	Kaniha	84.9876	21.0436	7.36	660	334	325	160	62	41	3.21	1.46	0	195	89	41	0.74	0.1
2014-15/1446	Sana	Kaniha	84.9526	21.0903	7.76	740	376	360	85	76	41	2.67	0.1	0	104	174	31	0.91	0.1
2014-15/1447	Boinda	Kaniha	84.9848	21.0777	8.11	680	343	330	175	68	39	2.76	4.41	0	214	99	24	0.39	0.1
2014-15/1448	Bada Changudia	Kaniha	84.9638	21.1026	8.28	700	328	345	265	46	56	1.93	1.39	0	323	53	10	0.86	0.0
2014-15/1449	Kakudia	Kaniha	84.9728	21.1042	8.21	600	307	285	140	60	33	3.51	3.99	0	171	74	48	0.69	0.1
2014-15/1450	Balipeta	Kaniha	84.9888	21.1094	8.27	530	267	255	165	64	23	1	5.33	0	201	53	22	0.41	0.0
2014-15/1451	Derang	Kaniha	84.9843	21.1153	8.21	520	264	255	75	50	32	1.81	0.1	0	92	117	18	0.15	0.0
2014-15/1452	Ghantianali	Kaniha	84.9716	21.1323	8.26	780	394	365	190	84	38	11.05	0.1	0	232	121	26	0.92	0.3

Lab Id	Location	Block	Longitude	Latitude	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F	SAR
						µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
2014-15/1453	Kaladama	Kaniha	84.9274	21.2439	8.21	530	272	260	100	64	24	2.38	0.1	0	122	113	8	0.35	0.1
2014-15/1454	Katarpali	Kaniha	84.9539	21.2428	8.18	940	492	360	125	82	38	48.2	3.64	0	153	209	36	0.71	1.1
2014-15/1455	Barapada	Kaniha	84.9787	21.2404	8.23	750	355	365	225	36	67	4.31	0.1	0	275	89	23	0.92	0.1
2014-15/1456	Nialu	Kaniha	84.9825	21.1988	8.18	820	415	390	210	84	44	4.54	7.21	0	256	121	28	0.39	0.1
2014-15/1457	Luhamunda	Kaniha	84.9979	21.0902	8.12	400	201	200	165	64	10	1	0.1	0	201	21	5	0.90	0.0
2014-15/1458	Sansamura	Kaniha	84.9059	21.2570	8.26	760	365	365	250	60	52	3.91	7.33	0	305	82	10	0.43	0.1
2014-15/1459	Kusumpal	Talcher	85.0190	20.9578	8.11	280	140	140	90	44	7	1	0.8	0	110	25	8.2	0.16	0.0
2014-15/1460	Solarha	Talcher	85.0697	20.9730	8.21	1060	562	485	160	108	52	12.03	5.94	0	195	195	92.5	0.79	0.2
2014-15/1461	Lakeiposi	Talcher	85.0963	20.9636	8.23	420	205	205	130	42	24	2.11	0.1	0	159	46	12.2	0.55	0.1
2014-15/1462	Daunara	Talcher	85.0974	20.9437	8.21	570	287	275	155	66	27	3.64	0.1	0	189	67	29.5	0.66	0.1
2014-15/1463	Chauliakata	Talcher	85.2221	20.9536	8.03	280	136	135	100	24	18	1	0.1	0	122	25	7.6	0.19	0.0
2014-15/1464	Kankili	Kaniha	85.2294	20.9925	8.21	1650	861	**650**	240	124	83	79.8	0.65	0	293	390	39	0.96	1.4
2014-15/1465	Madanmohanpur	Kaniha	85.1876	20.9665	8.22	980	523	465	115	156	18	9.46	3.2	0	140	213	54	0.20	0.2
2014-15/1466	Jilinda	Kaniha	85.1624	20.9854	8.24	680	348	325	165	82	29	4.51	4.49	0	201	117	12	0.41	0.1
2014-15/1467	South Balanda	Kaniha	85.1594	20.9278	8.15	570	302	275	150	80	18	2.99	0.24	0	183	43	68	0.23	0.1
2014-15/1468	Gobara	Kaniha	85.1422	20.9098	8.2	790	452	390	175	144	7	2.42	0.26	0	214	64	128	0.90	0.1
2014-15/1469	Chalagarh	Kaniha	85.1873	20.9252	8.26	570	282	280	155	60	32	1.08	0.1	0	189	43	53	0.46	0.0
2014-15/1470	Lingakata	Kaniha	85.2273	20.8767	8.47	460	221	230	170	64	17	1.01	0.1	0	207	28	8	0.85	0.0
2014-15/1471	Santhapada	Kaniha	85.2347	20.9161	8.1	1690	930	**835**	120	**206**	78	8.45	3.99	0	146	351	210	0.23	0.1
2014-15/1472	Scotlandpur	Kaniha	85.2217	20.9812	8.49	800	362	385	220	32	74	4.05	0.17	0	268	99	20	0.96	0.1
2014-15/1473	Ghantapada	Kaniha	85.1889	20.9353	8.59	660	343	310	185	88	22	3.31	7.83	0	226	74	37	0.41	0.1
2014-15/1474	Talchir	Kaniha	85.2125	20.9494	8.48	250	127	125	95	40	6	1	0.1	0	116	21	2	0.26	0.0
2014-15/1475	Gurujanguli	Kaniha	85.2210	20.8980	8.69	1670	868	**770**	435	182	77	19.31	18.05	0	531	206	105	0.92	0.3
2014-15/1476	Teheranpur	Kaniha	85.1847	20.9019	8.52	1580	813	**740**	190	112	**112**	16.51	0.75	0	232	347	110	0.91	0.3
2014-15/1477	Kandhal	Kaniha	85.1894	20.9781	8.48	400	187	190	135	42	21	1	0.1	0	165	28	14	0.56	0.0
2014-15/1478	Bantol	Talcher	85.2086	20.9237	8.09	1020	562	475	85	120	43	10.43	1.46	0	104	213	123	0.41	0.2
2014-15/1479	Dera	Talcher	85.1684	20.9535	8.22	450	223	220	125	42	28	1	0.1	0	153	57	19.4	0.22	0.0
2014-15/1480	Kandhabareni	Talcher	85.0926	21.0004	8.2	790	394	390	220	82	45	1.6	2.41	0	268	110	21.2	0.38	0.0
2014-15/1481	Ekdal	Talcher	85.1375	20.9904	8.3	630	317	300	145	62	35	3.87	5.29	0	177	99	24.3	0.67	0.1
2014-15/1482	Joragarhia	Talcher	85.1046	20.9829	8.19	960	502	460	175	104	49	8.1	2.2	0	214	170	63.3	0.81	0.2
2014-15/1483	Tentulei	Talcher	85.1764	20.9194	8.21	2210	1164	**1050**	220	114	**186**	19.03	10.96	0	268	518	184.2	0.11	0.3
2014-15/1484	Kalamchuin	Talcher	85.0667	20.9603	8.3	1160	654	555	195	162	36	6.89	0.44	0	238	60	272	0.53	0.1
2014-15/1485	Gopal Prasad	Talcher	85.0431	20.9708	8.28	1140	623	525	185	128	50	13.71	10.23	0	226	124	184	**2.21**	0.3
2014-15/1486	Shendhogram	Talcher	85.2333	20.8903	8.23	1620	886	320	345	42	52	226.08	0.1	0	421	238	120	**1.30**	5.5

Lab Id	Location	Block	Longitude	Latitude	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F	SAR
						µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
2014-15/1487	Jagannathpur	Talcher	85.2014	20.9208	8.26	1120	544	435	375	116	35	60.58	0.63	0	458	92	15.1	0.16	1.3
2014-15/1488	Baghubola	Talcher	85.2177	20.9430	8.27	800	373	380	165	42	67	8.69	0.19	0	201	142	14.3	0.49	0.2
2014-15/1489	Hariharpur	Talcher	85.2488	20.9754	8.25	550	261	275	145	50	36	1	0.1	0	177	74	12.9	0.50	0.0
2014-15/1490	Kumunda	Talcher	85.0265	20.9766	8.29	1050	547	490	170	54	86	10	4.96	0	207	167	122.8	0.33	0.2
2014-15/1491	Chittalpur	Talcher	85.0347	20.9814	8.13	720	367	340	145	62	45	6.69	3	0	177	117	46.5	0.33	0.2
2014-15/1492	Mallibandha	Talcher	85.0287	20.9508	8.09	1070	577	420	265	120	29	44.8	8.75	0	323	131	84.4	0.37	1.0
2014-15/1493	Bhalugadia	Talcher	85.0101	20.9581	8.25	1170	625	425	170	84	52	54.2	17.15	0	207	234	82.4	0.24	1.1
2014-15/1494	Karnapur	Talcher	85.1224	20.8962	8.12	**2630**	1350	**1210**	140	160	**197**	18.03	6.89	0	171	691	192.4	0.44	0.2
2012-13/740	Bhogabareni	Talcher	85.2139	20.8917	7.8	890	509	280	325	48	39	86	5	0	397	103	30	1.07	2.2
2012-13/741	Balanda	Talcher	85.1578	20.9275	8.1	550	306	170	135	54	9	39	6	0	165	39	77	0.15	1.3
2012-13/743	Talcher	Talcher	85.2144	20.9486	7.9	450	259	85	125	26	5	65	6	0	153	75	6	0.07	3.1
2012-13/744	Samal	Kaniha	85.1417	21.0722	8.1	570	298	170	230	40	17	35	28	0	281	25	13	**1.70**	1.2
2012-13/745	Sipur	Kaniha	85.1569	21.1667	8.4	350	179	135	140	38	10	16	6	6	159	21	3	0.24	0.6
2012-13/750	Sendogram	Talcher	85.2333	20.9256	8.3	600	319	90	125	16	12	88	3	0	153	117	6	**3.80**	4.0
2012-13/751	Tentulai	Talcher	85.1731	20.9194	7.9	1055	550	315	275	28	60	85	8	0	336	96	106	0.95	2.1
2012-13/752	Kukuranga	Banarpal	85.1483	20.8972	8.6	1900	1059	250	560	40	36	330	1	12	659	192	118	0.58	9.1
2012-13/753	Tubey	Banarpal	84.9994	20.8139	8.5	680	335	240	265	44	32	36	3	9	305	36	23	0.33	1.0
2012-13/754	Jarpada	Angul	85.1678	20.8800	8	1400	689	530	355	32	**109**	55	5	0	433	199	72	0.96	1.0
2012-13/755	Kartada	Chhendipada	84.8206	20.9067	7.9	1050	525	415	315	60	64	44	7	0	384	107	51	0.28	0.9
2012-13/761	Chendipada	Chhendipada	84.8717	21.0817	8.1	670	328	185	250	42	19	54	4	0	305	39	17	0.32	1.7
2012-13/762	Bagdia	Chhendipada	84.8158	21.1069	7.8	1300	605	425	185	92	47	56	7	0	226	213	77	0.23	1.2
2012-13/763	Kosala	Chhendipada	84.9489	21.0075	8.2	400	173	120	105	38	6	14	8	0	128	36	7	0.20	0.6
2012-13/764	Nisa	Chhendipada	85.0042	20.9264	8.1	990	533	280	265	64	29	60	67	0	323	107	45	0.53	1.6
2012-13/765	Parang	Chhendipada	85.0306	20.8792	8	530	313	235	275	46	29	31	8	0	336	21	10	0.14	0.9
2012-13/766	Panchamahal	Angul	85.0078	20.8033	8	1300	680	390	310	72	51	94	6	0	378	185	83	0.30	2.1
2012-13/767	Purunnakot	Angul	84.8361	20.6458	8.4	520	282	215	140	38	29	19	4	9	153	99	7	0.47	0.6
2012-13/768	Tikarapada	Angul	84.7875	20.5983	8.4	420	267	190	180	46	18	13	7	9	201	67	6	0.24	0.4
2012-13/769	Jagannathpur	Angul	84.8694	20.7211	8	800	404	275	255	36	45	36	6	0	311	99	26	0.18	0.9
2012-13/770	Bantala	Angul	85.0631	20.7431	8.6	2050	1136	160	**660**	16	29	370	10	12	781	256	53	**2.23**	12.7
2012-13/771	Badabahal	Angul	85.1000	20.7550	8.3	2000	1001	**675**	**610**	40	**140**	97	5	0	744	280	67	**2.32**	1.6
2012-13/772	Mohidharpur	Banarpal	85.1856	20.6875	7.9	630	320	200	205	54	16	32	3	0	250	71	19	0.55	1.0
2012-13/773	Tulsipal	Banarpal	85.1867	20.8036	8.1	1100	638	215	475	44	26	95	7	0	580	124	52	1.03	2.8
2012-13/774	Kuio	Banarpal	85.0811	20.8908	8	1600	729	555	240	116	64	58	7	0	293	234	103	**1.20**	1.1
2012-13/775	Angul	Angul	85.0994	20.8389	8	1100	540	340	130	112	15	40	6	0	159	227	61	0.50	0.9

Lab Id	Location	Block	Longitude	Latitude	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F	SAR
						µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
2012-13/776	Banarpal	Banarpal	85.2161	20.8417	7.9	750	383	275	225	88	13	25	7	0	275	71	41	0.25	0.7
2012-13/746	Khamar	Pallahara	85.1967	21.2661	8.1	550	331	200	160	44	22	40	16	0	195	103	9	0.24	1.2
2012-13/747	Srirampur	Pallahara	85.1511	21.3944	8.3	470	224	150	130	28	19	27	8	0	159	60	2	0.07	1.0
2012-13/748	Pallahara	Pallahara	85.1958	21.4317	8	350	195	115	75	22	15	29	7	0	92	71	6	0.07	1.2
2012-13/749	Jamdihi	Pallahara	85.2572	21.5006	7.8	60	49	40	40	6	6	4	1	0	49	7	0	0.03	0.3
2018-19/1180	Dhuliapada	Athmalik	84.2869	20.8897	7.84	570	289	275	142	70	24	3	0.6	0	173	78	28	0.22	0.1
2018-19/1181	Tasarabeda	Athmalik	84.3056	20.9325	7.62	440	222	205	133	40	26	3	3.7	0	162	50	20	0.17	0.1
2018-19/1182	Kodapada	Athmalik	84.3322	20.8706	8.06	1410	718	650	479	104	95	23	2.6	0	584	134	72	1.26	0.4
2018-19/1183	Kandhapada	Athmalik	84.3972	20.8069	8.19	660	357	305	265	90	19	4	12.9	0	323	54	18	0.34	0.1
2018-19/1184	Nilakanthapada	Athmalik	84.4589	20.7594	7.78	830	440	370	250	82	40	18	2.1	0	305	94	54	0.93	0.4
2018-19/1185	Athmalik	Athmalik	84.5389	20.7225	7.77	930	471	430	224	85	53	13	2.2	0	273	131	52	1.04	0.3
2018-19/1186	Pataka	Athmalik	84.6347	20.6489	8.11	860	428	390	230	66	55	15	2.1	0	281	129	22	1.47	0.3
2018-19/1187	Jamudih	Athmalik	84.7056	20.6286	7.93	650	309	305	235	34	53	9	0.9	0	287	49	21	1.17	0.2
2018-19/1188	Thakurgarh	Athmalik	84.6281	20.8128	8.21	490	234	225	179	34	34	6	3.8	0	218	27	21	0.91	0.2
2018-19/1189	Kundajhari	Athmalik	84.6831	20.8108	7.74	640	327	300	168	64	34	7	0.7	0	205	89	31	0.59	0.2
2018-19/1190	Bidising	Athmalik	84.7419	20.8103	8.17	780	396	370	214	72	46	7	3.4	0	261	84	55	0.33	0.2
2018-19/1191	Tapdhol	Athmalik	84.7872	20.8114	7.75	1010	526	465	158	94	56	16	2.7	0	193	193	69	0.57	0.3
2018-19/1192	Kutasingha	Kishornagar	84.4592	21.0494	7.83	800	432	295	314	70	29	5	70.7	0	383	64	5	0.66	0.1
2018-19/1193	Kishorenagar	Kishornagar	84.4706	20.9622	8.06	500	240	235	189	60	21	3	3.5	0	231	22	17	0.55	0.1
2018-19/1194	Talapadar	Kishornagar	84.4269	20.9736	7.7	620	323	295	184	56	38	5	1.3	0	224	84	28	0.95	0.1
2018-19/1195	Angapada	Kishornagar	84.5472	20.9333	7.78	860	428	400	189	70	55	11	1.6	0	231	144	33	0.48	0.2
2018-19/1196	Bhimpur	Kishornagar	84.4178	20.9228	8.28	540	251	260	234	48	34	3	1.5	0	285	20	4	0.84	0.1
2018-19/1197	Tusar	Kishornagar	84.3556	20.9089	8.15	980	464	450	230	52	78	13	4.6	0	281	168	10	0.65	0.3
2018-19/1198	Raniakata	Kishornagar	84.4406	20.8908	7.82	740	396	270	173	62	28	8	62.6	0	211	97	35	0.44	0.2
2018-19/1199	Sanjamura	Kishornagar	84.5011	20.8844	7.89	300	152	140	133	36	12	3	0.5	0	162	12	9	0.41	0.1
2018-19/1200	Talamaliha	Athmalik	84.5686	20.8656	7.98	530	248	182	180	20	32	37	0.8	0	220	32	17	1.71	1.2
2018-19/1201	Navdippur	Athmalik	84.5997	20.8383	7.82	680	327	288	270	55	37	21	1.7	0	330	47	3	0.46	0.5
2018-19/1202	Pedipathar	Athmalik	84.6983	20.8869	7.38	690	359	212	160	40	27	60	1	0	195	89	46	0.56	1.8
2018-19/1203	Gunduri	Athmalik	84.6625	20.8406	8.18	550	274	222	156	36	32	22	0.8	0	190	45	44	0.78	0.6
2018-19/1204	Ranibandha	Athmalik	84.6689	20.7875	8.24	620	279	253	279	36	40	23	2.6	0	340	7	3	0.91	0.6
2018-19/1205	Ghanajodi	Athmalik	84.7114	20.7636	7.87	440	214	182	189	34	24	15	0.5	0	231	15	12	0.59	0.5

Lab Id	Location	Block	Longitude	Latitude	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F	SAR
						µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
2018-19/1206	Kantapada	Athmalik	84.7514	20.7750	7.89	630	317	258	195	45	35	26	1.3	0	238	47	46	0.33	0.7
2018-19/1207	Ambanali	Athmalik	84.7686	20.8625	8.08	620	329	197	165	34	27	43	12.6	0	201	72	42	0.39	1.3
2018-19/1208	Bantul	Athmalik	84.7456	20.8625	7.97	970	515	333	300	73	37	38	49.7	0	366	92	46	0.27	0.9
2018-19/1209	Jhilimunda	Athmalik	84.7103	20.8725	7.68	410	191	152	165	22	24	22	0.6	0	201	10	13	0.81	0.8
2018-19/1210	Adikata	Kishornagar	84.5844	20.9383	7.7	1230	640	369	275	36	68	110	4.2	0	336	183	73	0.93	2.5
2018-19/1211	Daharisahi	Kishornagar	84.6400	20.9386	7.93	670	350	247	179	47	31	33	11.6	0	218	79	41	0.29	0.9
2018-19/1212	Urukula	Kishornagar	84.6028	20.9178	7.96	490	237	217	195	40	28	11	0.9	0	238	27	13	0.49	0.3
2018-19/1213	Damabahal	Kishornagar	84.6222	20.8725	8.2	790	393	283	265	59	33	34	26.7	0	323	35	46	0.56	0.9
2018-19/1214	Karadabahal	Athmalik	84.6489	20.8531	8.06	500	244	197	196	28	31	22	1.5	0	239	22	21	0.89	0.7
2018-19/1215	Mandarbahal	Athmalik	84.6636	20.8808	7.73	800	414	283	210	45	41	52	2.8	0	256	97	50	0.73	1.3
2018-19/1216	Bileinali	Athmalik	84.6628	20.8808	7.99	570	288	222	175	36	32	21	9.9	0	213	59	25	0.32	0.6
2018-19/1217	Asrubahal	Kishornagar	84.7911	20.9586	7.73	520	289	152	149	34	16	24	40.8	0	182	54	31	0.4	0.8
2018-19/1218	Anlaberini	Kishornagar	84.7625	20.9872	7.31	430	214	152	163	30	19	22	7.2	0	199	27	11	0.17	0.8
2018-19/1219	Laxmipriyapur	Kishornagar	84.7314	21.0053	7.47	150	74	56	55	12	6	5	3.8	0	67	10	4	0.11	0.3
				MIN	**7.31**	**60**	**49**	**40**	**40**	**6**	**5**	**1**	**0**	**0**	**49**	**7**	**0**	**0.03**	**0.0**
				MAX	**8.69**	**4007**	**1951**	**1355**	**660**	**340**	**197**	**370**	**121**	**66**	**781**	**1127**	**272**	**3.80**	**12.7**
				AVG	**8.07**	**864**	**424**	**304**	**193**	**59**	**38**	**44**	**6**	**1**	**234**	**120**	**40**	**0.57**	**1.2**

Results of Chemical Analysis of Water Samples From Aquifer-II (Deeper/Fractured)in Angul District.

Sl No	Site Name	Block	Latitude	Longitude	pH	EC	TDS	TH	Alkalinity	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	SO_4^{-}	NO_3	F	SAR
1	Karadabahali	Athamalik	20.8536	84.6464	7.58	660	342	160	192	26	23	76.5	3.5	0	234	37	62		1.03	2.6
2	Ambsarmunda	Athamalik	20.8622	84.5800	7.81	900	453	165	333	8	35	126.3	8.1	0	407	12	63		**2.01**	4.3
3	Amsarmunda (OW)	Athamalik	20.8622	84.5800	7.79	970	489	165	354	12	33	140.8	8.9	0	431	34	49		**2.38**	4.8
4	Talamaliha	Athamalik	20.8650	84.5708	7.93	1200	586	323	398	19.9	66	105.5	4	0	486	99	53		**3.1**	2.6
5	Thakurgarh	Athamalik	20.8111	84.6231	7.83	420	199	139	153.6	23.8	19	30	3	0	187	27	3		1.24	1.1
6	Thakurgarh (OW)	Athamalik	20.8111	84.6231	7.78	400	185	154	139	37.8	14.5	18	2	0	170	27	2		1.2	0.6
7	Karadabahali	Athamalik	20.8536	84.6464	7.26	510	280	153.6	31.8	18	15	3.4	154	0	278	17	22		0.66	0.1
8	Taleipatahar (Kundajhari)	Athamalik	20.8100	84.6847	7.68	820	405	189	26	15	114	2	122	0	231	69	66		**1.38**	0.1
9	Banamalipur	Athamalik	20.8397	84.6314	7.48	790	365	286	21	44	64	2	221	0	349	36	26		0.75	0.1
10	Anandpur (Solapada College)	Athamalik	20.8258	84.6403	7.59	860	434	398	24	53	87	0.84	268	0	485	17	14		**2.04**	
11	Kutulusingha	Athamalik	20.7850	84.6822	7.64	560	268	233	26	28	40	5	174	0	284	17	14		0.70	0.1
12	Tileshwar	Athamalik	20.8831	84.6219	7.4	1210	475	223	75	49	40	3	376	0	272	107	69		0.30	0.1
13	Bidising	Athamalik	20.8122	84.7478	7.61	420	195	146	28	18	22	2	141	0	178	14	24		0.21	0.1
14	Olatha	Athamalik	20.6561	84.6228	7.56	720	324	218	28	34	55	3	202	0	266	36	38		1.0	0.1
15	Tapdhol	Athamalik	20.8083	84.7908	7.84	380	180	228	34	26	38	7	183	0	187	17	2		0.71	0.2
16	Urukula	Kishorenagar	20.9183	84.6025	7.83	410	211	160	147	36	17	26	1	0	179	24	19		0.5	0.9
17	Urukula OW	Kishorenagar	20.9183	84.6025	7.83	400	206	150	147	36	15	26	0.1	0	179	22	20		0.48	0.9
18	Urukula	Kishorenagar	20.9183	84.6025	7.62	490	247	195	152	40	23	22	0.4	0	185	42	29		0.43	0.7
19	Bhejigoth	Kishorenagar	20.9044	84.6847	7.52	480	237	165	195	40	16	32	3.3	0	238	15	14		0.79	1.1
20	Gaon Boinda	Kishorenagar	20.9153	84.7397	7.9	680	342	270	223	48	36	36	5	0	272	66	17		0.46	1.0
21	Gaon Boinda OW	Kishorenagar	20.9153	84.7397	7.81	650	319	245	195	40	35	34	5	0	238	71	17		0.43	0.9
22	Papasara	Kishorenagar	20.9211	84.6700	7.59	500	250	110	214	20	15	65	3.4	0	261	15	4		0.36	2.7
23	Gunthapada (Luhamunda)	Kishorenagar	20.9450	84.7239	7.61	720	354	215	333	32	33	66	1.4	0	406	10	13		0.46	2.0
24	Bandhagaon	Athamalik	20.8522	84.5581	7.51	740	361	275	277	22	53	44	2	0	338	46	28		0.33	1.2
25	Bandhagaon OW	Athamalik	20.8522	84.5581	7.18	390	184	195	157	46	19	0	0	0	192	12	12		0.72	

26	Chudakhai	Kishorenagar	20.9294	84.5181	7.61	530	356	139	233	38	11	68	4	0	285	45	10		0.855	2.5
27	Chudakhai OW	Kishorenagar	20.9294	84.5181	8.23	910	436	124	242	30	12	130	5	0	296	105	50		1.0	5.1
28	Himitira	Kishorenagar	20.9300	84.4911	8.18	260	187	89	90	34	1	20	5	0	110	38	3		0.53	0.9
29	Ghanapur	Kishorenagar	20.9047	84.6082	8.19	500	282	178	195	30	26	45	5	0	238	48	35		0.55	1.5
30	Kuajhari	Kishorenagar	20.9127	84.6473	8.05	440	203	168	147	34	21	20	4	0	180	36	11		0.46	0.7
31	Angarbandh	Angul	20.7767	85.1489	7.4	1320				62	89	46	3	0	549	135		3.2	1	
32	Baghualata	Talcher	20.9398	85.2097	6.1	352		160		26	22	12	3	0	232	7		2		0.4
33	Bamur	Kishorenagar	21.0111	84.4831	7.6	246		105		16	16	31	2	0	165	22				1.3
34	Benagadia	Banarpal	20.8542	85.0464	7.76	510		210		18	40	32	21		238	19		33	0.98	1.0
35	Boinda	Kishorenagar	20.9083	84.7333	7.69	810		175		42	17	97	1	0	336	66				3.2
36	Golabandha	Banarpal	20.8442	84.9936	7.46	860		325		70	37	49	2	0	317	107		34	0.88	1.2
37	Gopinathpur	Talcher	20.8179	85.1503	7.61	370		125		28	13	39	3	0	219	29			0.36	1.5
38	Handapa	Kishorenagar	20.951	84.6862	7.61	729		250		66	21	65	2	0	275	92		0.3	0.6	1.8
39	Kandhal	Kishorenagar	20.9542	85.1883	8.2	426		155		46	22			0	146	43				
40	Kangula	Banarpal	20.7967	85.1314	7.68	390		120		28	12	25	16	0	195	24		0.5	0.5	1.0
41	Kangula Godisahi	Angul	20.7939	85.1253	7.79	1060		140		28	17	169	13	0	451	92		0.5	1.26	6.2
42	Khamar	Pallahara	21.2667	85.2	7.58	850		350		86	32	30	6	0	195	137		29.3	0.27	0.7
43	Kishoripal	Talcher	20.9759	85.2314	8.18	213		100		28	7	7	2	0	85	17			0.3	0.3
44	Mahidharpur	Banarpal	21.1462	85.2011	8.18	650		245		44	33	42	0.4	0	354	21	0		0.68	1.2
45	Nakchi	Kishorenagar	20.9667	84.608	7.54	309		135		40	9	26	4	0	171	14		1.14	0.75	1.0
46	Phapanda	Pallahara	21.4557	85.1413	7.7	460		140		36	12	25	5	0	195	39		4.1	0.67	0.9
47	Phulpada	Angul	20.7533	85.1664	7.86	830		205		38	27	80	11	0	397	43		0.5	1.08	2.4
48	Sana Kerjung	Banarpal	20.8564	84.9894	7.8	850		275		28	50	62	13	0	354	63		31	0.53	1.6
49	Santrabandh	Chhendipada	21.0822	84.953	7.55	563	366	125		20	10			0	140	39	0			
50	Talcher	Talcher	20.9417	85.2250	7.72	870		405		74	54	36	13	0	519	29		11	0.96	0.8
51	Talmul	Banarpal	20.7315	85.1953	7.78	930		270		54	33	79	9	0	525	22		0.5	0.75	2.1
52	Telesing	Kaniha	21.0784	85.0609	7.59	660		400		60	49	33	13	0	506	29		11	1	0.7
53	Thakurgarh	Athamalik	20.8111	84.6230	7.64	346		105		16	16	31	2	0	165	22				1.3
54	Turanga	Banarpal	20.8478	85.1256	7.33	1150		350		78	38	62	2	0	350	161		29.3	0.6	1.4
55	Kartada	Chhendipada	20.9103	84.8274	7.4	950	475	395	260	36	74	32	6.4	0	317	114	53		0.35	0.7
56	Ugi	Chhendipada	20.8501	84.8831	7.72	920	443	350		24	70.5	46.5	6.1	0	451	43	27		0.6	1.1

57	Ugi (OW)	Chhendipada	20.8501	84.8831	7.8	800	389	280	325	44	41	50	6	0	397	28	21		0.8	1.3
58	Tukuda	Chhendipada	20.8692	84.8984	7.79	870	436	300	155	76	26.7	44.4	3.8	0	189	138	52		0.38	1.1
59	Santrapur	Banarpal	20.8334	84.9647	8.43	1073	547	285	480	36	47.4	120	5.4	72	415	36	21		1.85	3.1
60	Anturia	Angul	20.8024	84.8149	8.44	700	361	200	300	36	26.7	65.2	2.4	36	293	36	12		0.55	2.0
61	Jamunali	Chhendipada	20.9335	84.7829	7.61	700	389	265		34	44	58	0.6	0	427	25	13		0.82	1.5
62	Jamunali (OW)	Chhendipada	20.9335	84.7829	7.48	760	406	285		38	46	61	0.1	0	433	28	16		0.76	1.6
63	Kankarai	Chhendipada	20.9616	84.9953	8.15	660	352	160		20	26.7	61	31	0	348	36	3		0.6	2.1
64	Raijharan	Chhendipada	20.9542	84.9701	7.72	830	447	275		58	31.6	51	30	0	281	103	33		0.3	1.3
65	Matigharia	Chhendipada	20.9554	84.8629	7.64	250	124	105		10	19.4	8	6	0	116	18	4		0.1	0.3
66	Koroda	Chhendipada	20.9513	84.8913	7.7	1500	780	465	450	96	55	121	8	0	549	170	55		1.7	2.4
67	Barpada	Chhendipada	20.9925	84.9046	7.2	650	335	210		20	38.9	30.5	38	0	311	36	16		0.4	0.9
68	Tentulisahi (Karoda) (Pz)	Chhendipada	20.954	84.9055	7.67	220	109	85	75	12	13	6.4	5	0	92	21	5		0.1	0.3
69	Kuskila	Chhendipada	20.9873	84.8866	6.56	410	202	145		14	27	21	4.5	0	153	25	34		0.33	0.8
70	Durgapur	Chhendipada	20.9197	84.8921	7.08	2010	972	615		286	24	85	42	0	122	508	14		0.78	1.5
71	Badagunduri	Kaniha	21.0781	84.9906	7.46	370	186	160		48	10	8	0	0	159	36	5		0.51	0.3
72	Badahira	Kaniha	21.1067	85.0067	7.67	750	361	280		30	50	42	0.8	0	275	99	2		0.52	1.1
73	Samal	Kaniha	21.0733	85.1411	7.81	550	263	230		30	38	20	0.2	0	232	53	5		0.71	0.6
				MIN	**6.1**	**213**	**109**	**85**	**21**	**8**	**1**	**1**	**0**	**0.00**	**85**	**7**	**0**	**0.3**	**0.10**	**0.1**
				MAX	**8.4**	**201**	**972**	**615**	**480**	**286**	**114**	**169**	**376**	**72.0**	**549**	**508**	**69**	**34.0**	**3.10**	**6.2**
				AVG	**7.6**	**680**	**346**	**220**	**185**	**40**	**33**	**45**	**32**	**1.50**	**283**	**55**	**23**	**12.0**	**0.78**	**1.4**

PART-II

BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN

1. BLOCK: ANGUL

1.1 Salient Information:

Mappable Area: 492 Sq. km
District/State: Angul / Odisha Total Geographic Area: 1146 Sq.km.

Population: The total population of Angul block as per 2011 Census is 166761 out of which rural population is 166761 & the urban population is 0.The population break up i.e. male- female, rural & urban is given below :

Table 1.1: Population Break Up, Angul Block.

Block	Total population	Male	Female	Rural population	Urban population
Angul	166761	84923	81838	166761	0

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is 15.18% as per 2001 census.

Rainfall: The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall (Average of the last 30 years i.e. 1998 to 2017) of Angul Block area is 1324.7 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 1.2: Rainfall Data in Angul Block in mm.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Monsoon rainfall	905.0	1477.2	1530.2	1080.4	1181.8	1273.4	1314.6	630.4	776.9	1037.5
Non-monsoon	266.6	112.6	1163.8	382.4	209.1	191.4	186.5	761.0	194.0	322.2
Annual Rainfall	1171.6	1589.8	2694.0	1462.8	1390.9	1464.8	1501.1	1391.4	970.9	1359.7
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	903.1	893.7	1005.9	1297.9	600.5	940.0	782.3	961.6	984.3	887.3
Non-monsoon	326.4	420.5	186.8	241.3	169.4	378.9	342.0	437.0	154.6	164.9
Annual Rainfall	1229.5	1314.2	1192.7	1539.2	769.9	1318.9	1124.3	1398.6	1138.9	1052.2
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1302.9	1008.0	842.8	1028.8	991.9	958.9	1086.5	1061.9	955.8	729.0
Non-monsoon	119.5	259.1	417.8	198.7	311.1	457.6	361.6	152.5	279.8	138.4
Annual Rainfall	1422.4	1267.1	1260.6	1227.5	1303.0	1416.5	1448.1	1214.4	1235.6	867.4

Agriculture and Irrigation: Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Angul block is given in **Table 1.3a** and **1.3b**.

Table 1.3a: Land Use Pattern (in ha), Angul Block.

Block	Forest Area	Misc. tree crops & groves not included in net area sown	Barren & Uncultivable land	Land put to non-agricultural use	Culturable waste	Permanent pastures and other grazing land	Current fallows	Other fallows	Net area sown
Angul	73176	537	727	3432	2755	2547	6209	5048	34182

Table 1.3b: Area Irrigated by Various Sources (in ha), Angul Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Angul	4874	1420	1098	115	3751	8740	2518

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the aquifer wise resource availability in Angul block upto 200 m depth is given in **Table 1.4**.

Table 1.4: Ground Water Resources of Angul Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Angul	6867	24225	9083	**40175**	**3479**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 2327 Ham while the same for domestic and industrial field is 1152 Ham. To meet the future demand for ground water, a total quantity of 6453 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre- monsoon water level: : In the pre-monsoon period, it has been observed that in Angul block, the minimum depth to water level is 3.55 mbgl at Tubey and the maximum water level is 8.57 mbgl at Panchamahala, the average water level is 6.18 mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 1.06 (Tikarpada) to 4.08 mbgl (Jagannathpur) with an average of 3.56 mbgl.

(iii) Seasonal water level fluctuation: The water level fluctuation data indicates that in Angul block, water level fluctuation varies from 1.70 (Tubey) to 4.84 m (purunakot) with an average fluctuation of 2.97 m.

(iv) The long term water level trend(2006-2015): During pre-monsoon out of 11 stations 8 show rising trend ranging from 0.039 to 0.205 m/yr and the rest 3 stations show falling trend with the range of -0.037 to -0.164 m/yr. In the post-monsoon season, only 2 stations show rising trend in the range of 0.04 to 0.081 m/yr and 9 stations show falling trend ranging from -0.055 to -0.411 m/yr.

1.2 Aquifer Disposition:

Number of Aquifers: There is only one aquifer system, formed by the crystalline rocks such a granite, granite gneisses, Charnockites and Khondalites of Proterozoic age, which has storage of ground water both in phreatic and fractured condition. The top phreatic aquifer has been classified as Aquifer-I the lower fractured aquifer as Aquifer-II.

Geology: Geologically the district exhibits lithology of Proterozoic age occupying Easternghat group of rocks comprising of Quartz-feldspar-garnet-sillimanite-graphite schist/gneiss (Khondalites), charnokite, pyroxene granulite and gneiss.

Aquifer-wise Characteristics :The **crystalline rocks** like granite, granite gneiss, khondalite, charnockite are devoid of any primary porosity. Secondary porosity in these rocks is developed due to intense weathering and fracturing, which forms good repository and passage for movement of groundwater. The thickness of the weathered zone is usually more in the topographic lows and undulating plains than in the highland areas. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the deeper fractured zones. The water-yielding capacity of the fractured rocks largely depends on the degree of fracturing, their horizontal extent as well as their interconnection.

Granite and Granite Gneiss: These are the most dominant rock types in the district, which are highly weathered and fractured. The thickness of the weathered zone varies from 5 m to 20 m, which form the repository of groundwater at shallow depth. Groundwater occurs under phreatic condition in this zone and can be developed through dug wells. The depth of dug wells varies from 4.5 to 14.0 m and the water level varies from 2.0 to 10.9 m below ground level during pre-

monsoon and from 0.75 to 9.2 m below ground level during post-monsoon period. The deep bore wells yield up to 12.0 litres per second depending upon the topographic setting, proximity to major lineaments, thickness of weathered zone and number as well as potential of saturated fracture zones. The result of wells constructed by CGWB in this district indicates that weathered as well as semi- weathered granite gneiss form moderately potential aquifer.

Khondalite: These rocks are restricted to higher elevations forming steep linear ridges and hence groundwater potential is limited although foliated nature of the rock facilitates deep weathering. In pediment areas, the thickness of the weathering varies widely. The average depth of dug wells is about 10m. The water level varies from 3.55 to 7.85 m below ground level during pre-monsoon and from 1.36 to 4.86 m below ground level during post-monsoon period.

Charnockite: It occurs as intrusive body and covers limited area. It is highly compact and owing to paucity of joints and fractures, is much less susceptible to weathering; hence, groundwater prospect is not good. The depth of dug wells ranges from 7.6 to 10.8 m. The depth to water level varies from 4.87 to 8.57 m below ground level during pre-monsoon and from 2.9 to 7.63 m below ground level during post- monsoon period.

1.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 1.4** where the total resource available in Angul block is 40175ham which is entirely crystalline granitic aquifer.

Table 1.5: Dynamic Ground Water Resources of Aquifer-I (Phreatic), Angul Block.

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Angul	6867	2327	1152	3479	1415	6453

Table 1.6: Stage of Ground Water Development and Categorisation of Angul Block.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Angul	50.7	Safe

Categorisation: The Angul block falls in safe category. The stage of Ground water development is 50.7%. The Net Ground water availability is 6867Ham. The Ground water draft for all uses is 3479Ham. The Ground water resources for future industrial and irrigation requirement for Angul block is 6453 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground water and Contamination**:** Throughout the study area, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The EC value for phreatic aquifer varies from 420 to 2050 micro Siemens per cm at 25^0c. The phreatic ground water has higher than permissible limit of F at two places Bantala (2.23 mg/l) and Badabahal (2.32 mg/l).

1.4 Ground Water Resource Enhancement:

Aquifer-wise Space Available for Recharge and Proposed Interventions : The volume of porous space available in the unsaturated zone of granitic aquifer up to a desirable depth (say 3 mbgl) is 50.55 x 10^6 m^3 assuming the specific yield of shale as 0.02, considering the void space depth 6.55 m and the assessment area of Angul block is 712 km^2 entirely covered by the granitic aquifer. This is summarised in **Table 1.7**.

Table 1.7: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Assessment Area (m^2)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Gondwana Sandstone	0	-	0.03	0
Precambrian Granitic	712x 10^6	3.55	0.02	50.55x 10^6

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of granitic aquifer may be recharged about 50.55 x 10^6 m^3, assuming the average annual rainfall as 1324.7 mm and the infiltration factor of granite is 0.05. This is summarised in **Table 1.8**.

Table 1.8: Details of Volume of Porous Space Available for Further Recharge (Aquifer-wise)

Formation	Assessment Area (m^2)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Gondwana Sandstone	0	-	0.08	-	-
Precambrian Granitic	712x 10^6	1.3247	0.05	50.55 x 10^6	3.39x 10^6

1.5 Other Issues:

Stage of ground water development in Angul block is only 50.7 % which is minimum in the NAQUIM blocks. There exists sufficient scope for ground water development for irrigational use.

1.5.1 Demand Side Interventions:

1. In Angul block district where stage of development is mere 50.7 %, no demand side intervention is required except increasing the utilisation of ground water for irrigation.
2. Also Artificial Recharge structures may be constructed in suitable locations especially in the areas where the water level remains more than 5 mbgl in the post-monsoon period in this block to arrest the huge non-committed run-off to augment the ground water storage in the area.

Table 1.9: Types of Artificial Structures Feasible in Angul Block.

Name of Block	Area Feasible for recharge (sq.km)	Volume of Unsaturated Zone available for recharge (m^3)	Types of Structures Feasible and their Numbers
Angul	28.13	3.39×10^6	The types of structures likely to be implemented are percolation tank, Nalla bund, check dam, recharge shaft and Gully plug/gabion structures. However their numbers are to be decided on the basis of formation and local geomorphology.

2. BLOCK: BANARPAL

2.1 Salient Information:

Mappable Area: 336 Sq. km

District/State: Angul / Odisha Total Geographic Area: 357 Sq. km

Population: The total population of Banarpal block as per 2011 Census is 209465 out of which rural population is 159438 & the urban population is 50037. The population break up i.e. male-female, rural & urban is given below -

Table 2.1: Population Break Up, Banarpal Block.

Block	Total population	Male	Female	Rural population	Urban population
Banarpal	209465	108550	100915	159438	50037

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is 16.19% as per 2001 census.

Rainfall: The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall(Average of the last 30 years i.e. 1988 to 2017) in Banarpal block is 1079.4 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 2.2: Rainfall Data in Banarpal Block in mm.

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Monsoon rainfall	657.0	707.0	666.3	727.0	675.0	730.0	997.0	105.0	658.0	1381.5
Non-monsoon	214.0	46.0	479.6	220.0	81.0	126.0	78.0	276.0	116.0	175.1
Annual Rainfall	871.0	753.0	1145.9	947.0	756.0	856.0	1075.0	381.0	774.0	1556.6
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	901.7	793.1	852.5	1294.5	524.0	1020.5	1175.6	823.8	1051.2	1049.2
Non-monsoon	269.5	423.6	80.2	164.5	155.4	275.3	253.0	300.5	111.0	213.0
Annual Rainfall	1171.2	1216.7	932.7	1459.0	679.4	1295.8	1428.6	1124.3	1162.2	1262.2
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1038.5	972.7	735.5	1097.6	1072.7	948.0	1164.5	846.0	862.2	666.6
Non-monsoon	175.7	216.0	239.4	155.2	226.4	401.5	247.2	57.6	224.8	187.0
Annual Rainfall	1214.2	1188.7	974.9	1252.8	1299.1	1349.5	1411.7	903.6	1087.0	853.6

Agriculture and Irrigation: Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Banarpal block is given in **Table 2.3a** and **2.3b**.

Table 2.3a: Land Use Pattern (in ha), Banarpal Block.

Block	**Forest Area**	**Misc. tree crops & groves not included in net area sown**	**Barren & Uncultivable land**	**Land put to non-agricultural use**	**Culturable waste**	**Permanent pastures and other grazing land**	**Current fallows**	**Other fallows**	**Net area sown**
Banarpal	1643	364	90	5005	940	2451	4076	4719	26896

Table2.3b: Area Irrigated by Various Sources (in ha), Banarpal Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Banarpal	7193	1980	342	0	3580	10773	2322

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the aquifer wise resource availability in Banarpal block up to 200 m depth is given in **Table 2.4**.

Table 2.4: Ground Water Resources of Banarpal Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Banarpal	3852	12336	4447	**19635**	**1924**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 1450 Ham while the same for domestic and industrial field is 474 Ham. To meet the future demand for ground water, a total quantity of 3769 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre- monsoon water level: In the pre-monsoon period, it has been observed that in Banarpal block, the minimum depth to water level is 2.0 mbgl at Kurudol and the maximum water level is 10.9 mbgl at Jamunda, the average water level is 6.24mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 0.75 (Kurudol) to 9.2 mbgl (Jamunda) with an average of 4.15 mbgl.

(iii) Seasonal water level fluctuation: The water level fluctuation data indicates that in Angul block, water level fluctuation varies from 0.25 (BanarpalVillage) to 5.28 m (Bhogaberini) with an average fluctuation of 2.09 m.

(iv) The long term water level trend(2006-2015): During pre-monsoon out of 9 stations 6 show rising trend ranging from 0.034 to 0.299 m/yr and the rest 3 stations show falling trend with the range of -0.091 to -0.328 m/yr. In the post-monsoon season, 6 stations show rising trend in the range of 0.004 to 0.354 m/yr and only 3 stations show falling trend ranging from -0.136 to -0.199 m/yr.

2.2 Aquifer Disposition:

Number of Aquifers: There are two major aquifers viz. (i) Crystalline rocks comprising of Khondalites and Charnockites (Easternghat) & (ii) Sandstone/Shale (Gondwana) both in phreatic and fractured condition serves as major aquifer system in Banarpal block.

Geology: Geologically the block exhibits lithology of Proterozoic to Cenozoic age.

Aquifer-wise Characteristics: (i)The **crystalline rocks** like khondalite, charnockite are devoid of any primary porosity. Secondary porosity in these rocks is developed due to intense weathering and fracturing, which forms good repository and passage for movement of groundwater. The thickness of the weathered zone is usually more in the topographic lows and undulating plains than in the highland areas. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the deeper fractured zones. The water-yielding capacity of the fractured rocks largely depends on the degree of fracturing, their horizontal extent as well as their interconnection.

Khondalite: These rocks are restricted to higher elevations forming steep linear ridges and hence groundwater potential is limited although foliated nature of the rock facilitates deep weathering. In pediment areas, the thickness of the weathering varies widely. The average depth of dug wells is about 10m.

Charnockite: It occurs as intrusive body and covers limited area. It is highly compact and owing to paucity of joints and fractures, is much less susceptible to weathering; hence, groundwater prospect is not good. The depth of dug wells ranges from 7.6 to 10.8 m. The depth to water level varies from 2.0 to 10.9 m below ground level during pre-monsoon and from 0.75 to 9.2 m below ground level during post- monsoon period.

(ii) The **semi-consolidated formation** are represented by rocks of *Gondwana* formation, which have faulted contact with the Pre-Cambrian rocks. It consists mainly of sandstone and shale. The friable and loosely cemented sandstone forms the aquifer. Ground water occurs in phreatic condition in the weathered zone and semi-confined to confined condition in deeper fractured and friable sandstone beds. The depth of dug well in these formations ranges from 7.20 to 10.50 m below ground level. The depth to water level varies from 3.4 to 9.35 mbgl during pre-monsoon and from 1.86 to 8.0 mbgl during post- monsoon period.The depth of drilled wells varies from 70 to 200 m and the yield ranges from 0.60 to 3.70 litres per second.

Table 2.5: Distribution of Principal Aquifer Systems in Banarpal Block.

Block	Phreatic and fractured crystalline (sq.km)	%	Phreatic and fractured Gondwanas (sq.km)	%	Total Assessment Area (sq.km)
Banarpal	283.9	81.4	64.9	18.6	348.8

2.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 2.4** where the total resource available in Banarpal block is 20635 ham out of which the resource available with sandstone (Gondwana)

area is 3838 ham and with charnockite/Khondalite (Precambrian) is 16796 ham. The dynamic resource of the block is 3852 ham out of which the sandstone area contributes 716 ham and the charnockite/Khondalite terrain contributes 3135 ham. The extraction details and the future scenario (2025) along with the categorisation is depicted in the **Table 2.6** & **2.7**.

Table 2.6: Dynamic Ground Water Resources of Aquifer-I (Phreatic) in Banarpal Block.

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Banarpal	3852	1450	474	1924	417	3769

Table 2.7: Stage of Ground Water Development and Categorization of of Banarpal Block.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Banarpal	49.9	Safe

Categorisation: The Banarpal block falls in safe category. The stage of Ground water development is 49.9%. The Net Ground water availability is 3852 Ham. The Ground water draft for all uses is 1924 Ham. The Ground water resources for future uses for Angul Block is 3769 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground Water and Contamination**:** Throughout the Banarpal block, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The EC value for phreatic aquifer varies from 390 to 4007 micro Siemens per cm at 25^0c and higher EC was observed at Salagadia (4007), Derjung (2350) and Ekagharia (2058). High fluoride content was observed at Bada Hinsor (1.2 mg/l) and Kuio (1.2 mg/l).

2.4 Ground Water Resource Enhancement:

Aquifer-wise Space Available for Recharge and Proposed Interventions: The volume of porous space available in the unsaturated zone of sandstone up to a desirable depth (say 3 mbgl) is 6.21 x $10^6 m^3$ assuming the specific yield of sandstone as 0.03, considering the void space depth 3.19 m and the area covered by Sandstone is 64.9 km^2 out of total assessment area of the block is 348.8 sq. km.

Similarly, the volume of formation available in the unsaturated zone of granite up to a desirable depth (say 3 mbgl) is 18.45 x 10^6 m^3 assuming the specific yield of granite as 0.02, considering the void space depth 3.25 m and granitic area is 283.9 sq. km. This is summarised in **Table 2.8**.

Table 2.8: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Assessment Area (m^2)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Gondwana Sandstone	64.9 x 10^6	3.19	0.03	6.21 x 10^6
Precambrian Granitic	283.9 x 10^6	3.25	0.02	18.45 x 10^6

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of sandstone may be recharged about 5.60 x 10^6 m^3 assuming the average annual rainfall as 1079.4 mm and the infiltration factor of sandstone is 0.08. Therefore the space left for recharge through other methods is only 0.61 x $10^6 m^3$.

Similarly it has been calculated that space left for the granitic terrain in the block for recharge is 3.14 x 10^6 m^3. This is summarised in **Table 2.9**.

Table 2.9: Details of volume of porous space available for further recharge (Aquifer-wise)

Formation	Area (m^2)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Gondwana Sandstone	64.9 x 10^6	1.079	0.08	5.60 x 10^6	0.61x 10^6
Precambrian Granitic	283.9 x 10^6	1.079	0.05	15.31 x 10^6	3.14x 10^6

2.5 Other Issues:

Stage of ground water development in Banarpal block is 49.9 % and hence there is sufficient scope for utilisation of ground water for irrigation.

2.5.1 Demand Side Interventions:

1. In Banarpal block of Angul district where stage of development is more than 60%, no demand side intervention is needed.
2. Also Artificial Recharge structures may be constructed in suitable locations especially in the areas where the water level remains more than 5mbgl in the post-monsoon period in this block to arrest the huge non-committed run-off to augment the ground water storage in the area.

Table 2.10: Types of Artificial Structures Feasible in Banarpal Block.

Name of Block	Area Feasible for recharge (sq.km)	Volume of Unsaturated Zone available for recharge (m^3)	Types of Structures Feasible and their Numbers
Banarpal	70.07	3.75×10^6	The types of structures likely to be implemented are percolation tank, Nalla bund, check dam, recharge shaft and Gully plug/gabion structures. However their numbers are to be decided on the basis of formation and local geomorphology.

3. BLOCK: CHHENDIPADA

3.1 Salient Information:

Mappable Area: 608 Sq. km
District/State: Angul / Odisha Total Geographic Area: 850 Sq. km

Population: The total population of Chhendipada block as per 2011 Census is 166751 out of which rural population is 166751 & the urban population is nil. The population break up i.e. male-female, rural & urban is given below -

Table 3.1: Population Break Up, Chhendipada Block.

Block	Total population	Male	Female	Rural population	Urban population
Chhendipada	166751	85300	81451	166751	0

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is 14.79% as per 2001 census.

Rainfall: The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall(Average of the last 30 years i.e. 1988 to 2017)of Chhendipada block is 1126.7 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 3.2: Rainfall Data in Chhendipada Block in mm.

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Monsoon rainfall	1015.0	953.6	1016.0	852.0	732.0	880.0	1627.0	415.0	824.0	1116.0
Non-monsoon	81.0	104.0	527.0	192.0	33.0	128.0	87.0	625.5	152.0	189.0
Annual Rainfall	1096.0	1057.6	1543.0	1044.0	765.0	1008.0	1714.0	1040.5	976.0	1305.0
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	522.0	907.0	508.0	1255.0	817.4	1142.5	820.9	1037.0	689.7	990.5
Non-monsoon	300.5	449.0	60.0	174.0	152.0	299.0	236.0	281.0	171.4	116.1
Annual Rainfall	822.5	1356.0	568.0	1429.0	969.4	1441.5	1056.9	1318.0	861.1	1106.6
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1394.3	915.2	477.9	1151.6	863.3	913.9	1052.7	791.7	858.7	768.2
Non-monsoon	104.8	206.6	246.2	199.4	275.4	350.0	215.4	166.0	182.8	187.6
Annual Rainfall	1499.1	1121.8	724.1	1351.0	1138.7	1263.9	1268.1	957.7	1041.5	955.8

Agriculture and Irrigation: Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Chhendipada block is given in **Table 3.3a**, **3.3b** and **3.3c**.

Table 3.3a: Land Use Pattern (in ha), Chhendipada Block.

Block	**Forest Area**	**Misc. tree crops & groves not included in net area sown**	**Barren & Uncultivable land**	**Land put to non-agricultural use**	**Culturable waste**	**Permanent pastures and other grazing land**	**Current fallows**	**Other fallows**	**Net area sown**
Chhendipada	32012	2359	205	5307	3607	2470	8103	6380	39665

Table3.3b: Area Irrigated by Various Sources (in ha), Chhendipada Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Chhendipada	1746	1383	648	0	3399	5145	2031

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the resource availability in aquifer wise in Chhendipada block upto 200 m depth is given in the **Table 3.4**.

Table 3.4: Ground Water Resources of Chhendipada Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Chhendipada	7398	26479	9760	**43637**	**3493**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 2554 Ham while the same for domestic and industrial use is 940 Ham. To meet the future demand for ground water, a total quantity of 6764 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre-monsoon water level: : In the pre-monsoon period, it has been observed that in Chhendipada block, the minimum depth to water level is 2.6 mbgl at Bhatpal and the maximum water level is 11.85 mbgl at Gopinathpur, the average water level is 6.55 mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 0.7 (Golagadia) to 7.13 mbgl (Ugi) with an average of 2.54 mbgl.

(iii) Seasonal water level fluctuation: The water level fluctuation data indicates that in Angul block, water level fluctuation varies from 1.12 (Rugudisahi) to 8.35 m (Kakudia) with an average fluctuation of 4.01 m.

(iv) The long term water level trend(2006-2015): During pre-monsoon out of 6 stations 3 show rising trend ranging from 0.099 to 0.386 m/yr and the rest 3 stations show falling trend with the range of -0.011 to -0.072 m/yr. In the post-monsoon season, only 2 stations show rising trend in the range of 0.008 to 0.037 m/yr and 4 stations show falling trend ranging from -0.055 to -0.411 m/yr.

3.2 Aquifer Disposition:

Number of Aquifers: There are two major aquifers viz. (i) Granitic terrain (Pre-cambrian) & (ii) Sandstone (Gondwana formation) both in phreatic and fractured condition serves as major aquifer system in Chhendipada block.

Geology: Geologically the block exhibits lithology of Archean to Cenozoic age occupying crystalline granitic terrain with Iron-ore Group of rocks comprising of mica-schists and quartzites, Easternghat Group of rocks comprising of Quartz-feldspar-garnet-sillimanite-graphite schist/gneiss (Khondalites), charnokite, pyroxene granulite, granite and gneiss and semi-consolidated granular rocks of Gondwana such as sandstone, Shale and Coal.

Aquifer wise characteristics: (i)The **crystalline rocks** like khondalite, charnockite, granite gneiss, phyllite and mica quartzites are devoid of any primary porosity. Secondary porosity in these rocks is developed due to intense weathering and fracturing, which forms good repository and passage for movement of groundwater. The thickness of the weathered zone is usually more in the topographic lows and undulating plains than in the highland areas. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the deeper fractured zones. The water-yielding capacity of the fractured rocks largely depends on the degree of fracturing, their horizontal extent as well as their interconnection.

Granite and Granite Gneiss: These are the most dominant rock types in the district, which are highly weathered and fractured. The thickness of the weathered zone varies from 5 m to 20 m, which form the repository of groundwater at shallow depth. Groundwater occurs under phreatic condition in this zone and can be developed through dug wells. The depth of dug wells varies from 4.5 to 14.0 m. The deep bore wells yield up to 12.0 litres per second depending upon the topographic setting, proximity to major lineaments, thickness of weathered zone and number as well as potential of saturated fracture zones. The result of wells constructed by CGWB in this district indicates that weathered as well as semi- weathered granite gneiss form moderately potential aquifer.

Khondalite: These rocks are restricted to higher elevations forming steep linear ridges and hence groundwater potential is limited although foliated nature of the rock facilitates deep weathering. In pediment areas, the thickness of the weathering varies widely. The average depth of dug wells is about 10m.

Charnockite: It occurs as intrusive body and covers limited area. It is highly compact and owing to paucity of joints and fractures, is much less susceptible to weathering; hence, groundwater prospect is not good. The depth of dug wells ranges from 7.6 to 10.8 m. The depth to water level varies from 5.0 to 9.8 mbgl during pre-monsoon and from 2.35 to 7.13 mbgl during post- monsoon period.

Quartzite, Phyllite, Mica Schist:These rocks also are less fractured and weathered and hence yield from these litho-units are limited, although fractured quartzite in the proximity to lineaments yield

good amount of water. The depth to water level ranges from 5.0 to 7.0 m below ground level during pre- monsoon and from 3.0 to 4.0 m below ground level during post- monsoon period.

(ii) The **semi-consolidated formations** are represented by rocks of *Gondwana* formation, which have faulted contact with the Pre-Cambrian rocks. It consists mainly of sandstone and shale. The friable and loosely cemented sandstone forms the aquifer. Ground water occurs in phreatic condition in the weathered zone and semi-confined to confined condition in deeper fractured and friable sandstone beds. The depth of dug well in these formations ranges from 5.0 to 14.65 mbgl. The depth to water level varies from 2.6 to 11.85 mbgl during pre-monsoon and from 0.7 to 5.25 mbgl during post- monsoon period.The depth of drilled wells varies from 70 to 200 m and the yield ranges from 0.60 to 3.70 litres per second.

Table 3.5: Distribution of Principal Aquifer Systems in Chhendipada Block.

Block	Phreatic and fractured crystalline	%	Phreatic and fractured Gondwanas	%	Total Assessment Area (sq.km)
Chhendipada	150	19.6	615.5	80.4	765.5

3.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 2.4** where the total resource available in Chhendipada block is 43637 ham out of which the resource available with sandstone (Gondwana) area is 35084 ham and with crystalline granitic aquifer is 8553 ham. The dynamic resource of the block is 7398 ham out of which the sandstone area contributes 5948 ham and the granitic terrain contributes 1450 ham. The extraction details and the future scenario (2025) along with the categorisation is depicted in the **Table 3.6** & 3.**7**.

Table 3.6: Dynamic Ground Water Resources of Aquifer-I (Phreatic), Chhendipada Block

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Chhendipada	7398	2554	940	3494	609	6764

Table 3.7: Stage of Ground Water Development and Categorisation of Chhendipada Block.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Chhendipada	47.2	Safe

Categorisation: The Chhendipada block falls in safe category. The stage of Ground water development is 47.2%. The Net Ground water availability is 7398Ham. The Ground water draft for all uses is 3494 Ham. The Ground water resources for future uses for Chhendipada Block is 6764 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground Water and Contamination**:** Throughout the study area, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The Chhendipada OCP is the only operational coal mine in the block which has no effect on ground water quality.

3.4 Ground Water Resource Enhancement:

Aquifer-wise Space Available for Recharge and Proposed Interventions: The volume of porous space available in the unsaturated zone of sandstone up to a desirable depth (say 3 mbgl) is 102.78 x 10^6 m^3 assuming the specific yield of sandstone as 0.05, considering the void space depth 6.34 m and the area covered by sandstone is 615.5 km^2 out of total block area 765.5 sq. km.

Similarly, the volume of formation available in the unsaturated zone of granitic aquifer to a desirable depth (say 3 mbgl) is 9.09x 106 m^3 assuming the specific yield of granite as 0.02, considering the void space depth 6.03 m and granitic area is 150 sq. km. This is summarised in **Table 3.8**.

Table 3.8: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Assessment Area (m^2)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Gondwana Sandstone	615.5 x 10^6	3.34	0.05	102.78 x 10^6
Precambrian Granitic	150 x 10^6	3.03	0.02	9.09 x 10^6

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of sandstone may be recharged about 55.47 x 10^6 m^3 assuming the average

annual rainfall as 1126.7 mm and the infiltration factor of sandstone is 0.08. So the volume left for recharge other than rainfall is 47.31 x 10^6 $m^{3.}$

Similarly it has been calculated that space left for the granitic terrain in the block for recharge other than rainfall is 0.64 x 10^6 m^3. The detail is summarised in **Table 3.9**.

Table 3.9: Details of Volume of Porous Space Available for Further Recharge (Aquifer-wise)

Formation	Assessment Area (m^2)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Gondwana Sandstone	615.5 x 10^6	1.1267	0.08	55.47 x 10^6	47.31 x 10^6
Precambrian Granitic	150 x 10^6	1.1267	0.05	8.45 x 10^6	0.64x 10^6

3.5 Other Issues:

1. Stage of ground water development in Chhendipada block is 47.2 % and it's potential for ground water development for irrigation.
2. Frequent borewell failure is common in Chhendipada block due to unstable & friable formation. On the otherhand dugwells in the block have good and sustainable yield. Therefore ground water development through dugwells is preferable.
3. Chhendipada OCP is the only operational coal mine in the block. In active coal-mining areas where huge quantity of groundwater is regularly pumped during mining affecting the ground water regime.

3.5.1 Demand Side Interventions:

1. In Chhendipada block where stage of development is only 47.2%, no demand side intervention is proposed.
2. Ground water coming out as mine dewatering can be utilised to control the impact of mine dewatering by creating garland recharge well system.
3. Also Artificial Recharge structures may be constructed in suitable locations especially in the areas where the water level remains more than 5 mbgl in the post-monsoon period in this block to arrest the huge non-committed run-off to augment the ground water storage in the area.

Table 3.10: Types of Artificial Structures Feasible in Chhendipada Block.

Name of Block	Area Feasible for recharge (sq.km)	Volume of Unsaturated Zone available for recharge (m^3)	Types of Structures Feasible and their Numbers
Chhendipada	41.15	47.95×10^6	The types of structures likely to be implemented are percolation tank, Nalla bund, check dam, recharge shaft and Gully plug/gabion structures. However their numbers are to be decided on the basis of formation and local geomorphology.

4. BLOCK: KANIHA

4.1 Salient Information:

Mappable Area: 453 Sq. km

District/State: Angul / Odisha Total Geographic Area: 723 Sq.km

Population: The total population of Kaniha block as per 2011 Census is 143109 out of which rural population is 133783 & the urban population is only 9326 .The population break up i.e. male-female, rural & urban is given below –

Table4.1: Population Break Up, Kaniha Block.

Block	Total population	Male	Female	Rural population	Urban population
Kaniha	143109	74791	68318	133783	9326

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is 4.81% as per 2001 census.

Rainfall:The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall(Average of the last 30 years i.e. 1988 to 2017) of Kaniha block is 1203.3 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 4.2: Rainfall Data in Kaniha Block in mm.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Monsoon rainfall	722.0	1309.0	994.0	1158.0	924.0	1253.0	1335.6	790.0	962.0	1061.0
Non-monsoon	220.0	77.0	497.0	272.0	100.0	71.0	162.0	580.0	67.5	163.3
Annual Rainfall	942.0	1386.0	1491.0	1430.0	1024.0	1324.0	1497.6	1370.0	1029.5	1224.3
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	886.5	1066.0	633.0	1137.0	688.7	1902.0	1259.0	1580.3	1066.0	881.0
Non-monsoon	211.5	329.0	86.0	186.0	52.0	318.0	66.0	426.0	165.0	145.0
Annual Rainfall	1098.0	1395.0	719.0	1323.0	740.7	2220.0	1325.0	2006.3	1231.0	1026.0
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1198.0	705.0	689.0	928.0	1025.7	873.8	935.0	890.0	537.0	508.4
Non-monsoon	171.0	219.0	205.0	159.0	229.0	423.8	228.0	164.0	94.0	115.0
Annual Rainfall	1369.0	924.0	894.0	1087.0	1254.7	1297.6	1163.0	1054.0	631.0	623.4

Agriculture and Irrigation: Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Kaniha block is given in **Table 4.3a**, **4.3b** and **4.3c**.

Table 4.3a: Land Use Pattern (in ha), Kaniha Block.

Block	Forest Area	Misc. tree crops & groves not included in net area sown	Barren & Uncultivable land	Land put to non-agricultural use	Culturable waste	Permanent pastures and other grazing land	Current fallows	Other fallows	Net area sown
Kaniha	27920	954	2369	7151	2003	1271	2473	2969	26410

Table4.3b: Area Irrigated by Various Sources (in ha), Kaniha Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Kaniha	814	1820	2042	0	2428	3242	3862

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the aquifer wise resource availability in Kaniha block upto 200 m depth is given in the **Table 4.4**.

Table4.4: Ground Water Resources of Kaniha Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Kaniha	7558	24125	8745	**40428**	**4569**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 4132 Ham while the same for domestic and industrial field is 437 Ham. To meet the future demand for ground water, a total quantity of 7489 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre- monsoon water level: : In the pre-monsoon period, it has been observed that in Kaniha block, the minimum depth to water level is 2.3 mbgl at Godashila and the maximum water level is 9.8 mbgl at Godibandha, the average water level is 6.08 mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 1.1 (Baruan) to 6.9 mbgl (Godibandha) with an average of 3.66 mbgl.

(iii) Seasonal water level fluctuation: The water level fluctuation data indicates that in Angul block, water level fluctuation varies from 0.25 (Viru) to 7.18 m (Kakudia) with an average fluctuation of 2.42 m.

(iv) The long term water level trend(2006-2015): During pre-monsoon out of 4 stations 3 show rising trend ranging from 0.105 to 0.418 m/yr and only1 station show falling trend of -0.086 m/yr. In the post-monsoon season, only 1 station show rising trend of 0.025 m/yr and 3 stations show falling trend ranging from -0.017 to -0.371 m/yr.

4.2 Aquifer Disposition:

Number of Aquifers: There are two major aquifers viz. (i) Granitic terrain (Pre-cambrian) & (ii) Sandstone/Shale (Gondwana formation) both in phreatic and fractured condition serves as major aquifer system in Kaniha block.

Geology: Geologically the block exhibits lithology of Archean to Cenozoic age occupying crystalline granitic terrain with Iron-ore Group of rocks comprising of mica-schists and quartzites, Easternghat Group of rocks comprising of Quartz-feldspar-garnet-sillimanite-graphite schist/gneiss (Khondalites), charnokite, pyroxene granulite, granite and gneiss and semi-consolidated granular rocks of Gondwana such as sandstone, Shale and Coal.

Aquifer-wise Characteristics:(i)The **crystalline rocks** like khondalite, charnockite, granite gneiss, phyllite and mica quartzites are devoid of any primary porosity. Secondary porosity in these rocks is developed due to intense weathering and fracturing, which forms good repository and passage for movement of groundwater. The thickness of the weathered zone is usually more in the topographic lows and undulating plains than in the highland areas. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the deeper fractured zones. The water-yielding capacity of the fractured rocks largely depends on the degree of fracturing, their horizontal extent as well as their interconnection.

Granite and Granite Gneiss: These are the most dominant rock types in the district, which are highly weathered and fractured. The thickness of the weathered zone varies from 5 m to 20 m, which form the repository of groundwater at shallow depth. Groundwater occurs under phreatic condition in this zone and can be developed through dug wells. The depth of dug wells varies from 4.5 to 8.6 m. The deep bore wells yield up to 12.0 litres per second depending upon the topographic setting, proximity to major lineaments, thickness of weathered zone and number as well as potential of saturated fracture zones. The result of wells constructed by CGWB in this district indicates that weathered as well as semi- weathered granite gneiss form moderately potential aquifer.

Khondalite: These rocks are restricted to higher elevations forming steep linear ridges and hence groundwater potential is limited although foliated nature of the rock facilitates deep weathering. In pediment areas, the thickness of the weathering varies widely. The average depth of dug wells is about 8m. The depth to water level varies from 4.1 to 6.45 mbgl during pre-monsoon and from 2.18 to 4.55 mbgl during post- monsoon period.

Charnockite: It occurs as intrusive body and covers limited area. It is highly compact and owing to paucity of joints and fractures, is much less susceptible to weathering; hence, groundwater prospect is not good. The depth of dug wells ranges from 5.4 to 11.1 m. The depth to water level varies from 3.3 to 7.9 mbgl during pre-monsoon and from 2.05 to 5.8 mbgl during post- monsoon period.

Quartzite, Phyllite, Mica Schist:These rocks also are less fractured and weathered and hence yield from these litho-units are limited, although fractured quartzite in the proximity to lineaments yield good amount of water. The depth of dug wells ranges from 4.98 to 10.35 m.The depth to water level ranges from 2.3 to 7.8 mbgl during pre- monsoon and from 1.1 to 5.1 mbgl.

(ii)The **semi-consolidated formations** are represented by rocks of *Gondwana* formation, which have faulted contact with the Pre-Cambrian rocks. It consists mainly of sandstone and shale. The friable and loosely cemented sandstone forms the aquifer. Ground water occurs in phreatic

condition in the weathered zone and semi-confined to confined condition in deeper fractured and friable sandstone beds. The depth of dug well in these formations ranges from 5.3 to 13.7 mbgl. The depth to water level varies from 2.6 to 9.8 mbgl during pre-monsoon and from 1.52 to 6.9 mbgl during post- monsoon period.The depth of drilled wells varies from 70 to 200 m and the yield ranges from 0.60 to 3.70 litres per second.

Table 4.5: Distribution of Principal Aquifer Systems in Kaniha Block.

Block	Phreatic and fractured crystalline	%	Phreatic and fractured Gondwanas	%	Total Assessment Area (sq.km)
Kaniha	484.2	70.6	201.6	29.4	685.8

4.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 4.4** where the total resource available in Kaniha block is 40428 ham out of which the resource available with sandstone (Gondwana) area is 11886 ham and with crystalline granitic aquifer is 28542 ham. The dynamic resource of the block is 7558 ham out of which the sandstone area contributes 2222 ham and the granitic terrain contributes 5336 ham. The extraction details and the future scenario (2025) along with the categorisation is depicted in the **Table 4.6**&4.**7**.

Table 4.6: Dynamic Ground Water Resources of Aquifer-I (Phreatic), Kaniha Block.

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Kaniha	7558	4132	437	4569	4569	7489

Table 4.7: Stage of Ground Water Development and Categorisation of Kaniha Block.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Kaniha	60.4	Safe

Categorisation: The Kaniha block falls in safe category. The stage of Ground water development is 60.4%. The Net Ground water availability is 7558Ham. The Ground water draft for all uses is

4569Ham. The Ground water resources for future uses for Kaniha block is 7489 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground Water and Contamination**:** Throughout the study area, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The EC value for phreatic aquifer varies from 180 to 2150 (Chhelia) micro Siemens per cm at 25^0c. High fluoride content was observed at Rengali (1.4) and Samal(1.7). Only one opencast mines is operational in the block i.e. Kaniha OCM of MCL near village Jarada. The NTPC power plant at Kaniha is the major industry having huge ash-pond as the main source of effluent. However any negative impact on ground water quality has not been established in the samples analysed.

4.4 Ground Water Resource Enhancement:

Aquifer-wise Space Available for Recharge and Proposed Interventions: The volume of porous space available in the unsaturated zone of sandstone up to a desirable depth (say 3 mbgl) is 30.74 x 10^6 m^3 assuming the specific yield of shale as 0.05, considering the void space depth 6.05 m and the area covered by Sandstone is 201.6 km^2 out of total block area of Kaniha 685.8 sq. km.

Similarly, the volume of formation available in the unsaturated zone of granitic rocks up to a desirable depth (say 3 mbgl) is 29.63 x 10^6 m^3 assuming the specific yield of granite as 0.02, considering the void space depth 6.06 m and area is 484.2 km^2. This is summarised in **Table 4.8**.

Table 4.8: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Area (m^2)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Gondwana Sandstone	201.6 x 10^6	3.05	0.05	30.74 x 10^6
Precambrian Granitic	484.2 x 10^6	3.06	0.02	29.63 x 10^6

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of sandstone may be recharged about 19.4 x 10^6 m^3 assuming the average annual rainfall as 1203.3 mm and the infiltration factor of sandstone is 0.08. Thus the volume left for recharge through other means is 11.34 x 10^6 m^3.

Similarly it has been calculated that the space left for the granitic terrain in the block for recharge through other means is 0.5 x 10^6 m^3. This is summarised in **Table 4.9**.

Table 4.9: Details of Volume of Porous Space Available for Further Recharge (Aquifer-wise)

Formation	Area (m^2)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Gondwana Sandstone	201.6×10^6	1.2033	0.08	19.4×10^6	11.34×10^6
Precambrian Granitic	484.2×10^6	1.2033	0.05	29.13×10^6	0.5×10^6

4.5 Other Issues:

1. Stage of ground water development in Kaniha block is 45.76 % and it's potential for further ground water development for irrigation.
2. Kaniha MCL is the only operational coal mine in the block. In active coal-mining areas where huge quantity of groundwater is regularly pumped during miningimpacting the ground water regime.

4.5.1 Demand Side Interventions:

1. In Kaniha block where stage of development is only 45.76 %, no demand side intervention is proposed.
2. Ground water coming out as mine dewatering can be utilised to control the impact of mine dewatering by creating garland recharge well system.
3. Also Artificial Recharge structures may be constructed in suitable locations especially in the areas where the water level remains more than 5 mbgl in the post-monsoon period in this block to arrest the huge non-committed run-off to augment the ground water storage in the area.

Table 4.10: Types of Artificial Structures Feasible in Kaniha Block.

Name of Block	Area Feasible for recharge (sq.km)	Volume of Unsaturated Zone available for recharge (m^3)	Types of Structures Feasible and their Numbers
Kaniha	26.98	11.84×10^6	The types of structures likely to be implemented are percolation tank, Nalla bund, check dam, recharge shaft and Gully plug/gabion structures. However their numbers are to be decided on the basis of formation and local geomorphology.

5 BLOCK: PALLAHARA

5.1 Salient Information:

Mappable Area: 797 Sq. km

District/State: Pallahara / Odisha Total Geographic Area: 1163 Sq. km

Population: The total population of Pallahara block as per 2011 Census is 129806 out of which rural population is 12457& the urban population is 5749. Pallahara is the only census town of the block. The population break up i.e. male- female, rural & urban is given below -

Table 5.1: Population Break Up, Pallahara Block.

Block	Total population	Male	Female	Rural population	Urban population
Pallahara	129806	66020	63786	124057	5749

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is 15.02% as per 2011 census.

Rainfall:The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall (Average of the last 30 years i.e. 1988 to 2017) of Pallahara blockis 1820.3 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 5.2: Rainfall Data in Pallahara Block in mm.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Monsoon rainfall	1335.2	1141.0	1291.5	1215.1	1271.8	2210.5	2273.9	1308.8	1782.5	1306.7
Non-monsoon	210.0	72.0	439.5	319.2	284.0	170.0	144.7	674.5	17.0	422.0
Annual Rainfall	1545.2	1213.0	1731.0	1534.3	1555.8	2380.5	2418.6	1983.3	1799.5	1728.7
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	1054.8	1515.9	951.6	1825.2	1272.5	2527.4	1933.7	2671.7	1456.5	1486.0
Non-monsoon	437.6	510.1	353.2	254.9	108.3	498.1	291.3	497.5	136.2	215.2
Annual Rainfall	1492.4	2026.0	1304.8	2080.1	1380.8	3025.5	2225.0	3169.2	1592.7	1701.2
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1607.5	1253.5	757.8	1721.7	1699.6	1882.0	1888.2	1088.0	1045.8	1161.8
Non-monsoon	195.0	204.1	251.0	197.0	258.3	596.0	256.8	214.0	216.2	227.8
Annual Rainfall	1802.5	1457.6	1008.8	1918.7	1957.9	2478.0	2145.0	1302.0	1262.0	1389.6

Agriculture and Irrigation: Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Kaniha block is given in **Table 5.3a** and **5.3b**.

Table 5.3a: Land Use Pattern (in ha), Pallahara Block.

Block	Forest Area	Misc. tree crops & groves not included in net area sown	Barren & Uncultivable land	Land put to non-agricultural use	Culturable waste	Permanent pastures and other grazing land	Current fallows	Other fallows	Net area sown
Pallahara	53825	231	2576	3795	1880	2622	2400	2379	37040

Table5.3b: Area Irrigated by Various Sources (in ha),Pallahara Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Pallahara	378	1020	2380	210	2880	3468	3400

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the aquifer wise resource availability in Talcher block upto 200 m depth is given in the **Table 5.4**.

Table 5.4: Ground Water Resources of Pallahara Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Pallahara	12443	30409	11371	**54223**	**4321**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 3956Ham while the same for domestic and industrial field is 365 Ham. To meet the future demand for ground water, a total quantity of 12409 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre- monsoon water level: : In the pre-monsoon period, it has been observed that in Pallahara block, the minimum depth to water level is 2.2 mbgl at Korarha and the maximum water level is 9.5 mbgl at Kantala, the average water level is 6.92 mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 0.51 (Bankhol) to 6.96 mbgl (Kantala) with an average of 3.66 mbgl.

(iii) Seasonal water level fluctuation: The data indicates that in Pallahara block, water level fluctuation varies from 0.13 (Korarha) to 5.94 m (Bankhol) with an average fluctuation of 1.73 m.

(iv) The long term water level trend (2006-2015): In the pre-monsoon season long term trend data available for only 2 stations, out of which Khamar-II shows arising trend of 0.041 m/yr and the other station namely Pallahara show falling trend of 0.370m/yr. During the post-monsoon, Khamar-II shows fallof 0.394 m/yr and Pallahara shows rise of 0.018 m/yr.

5.2 Aquifer Disposition:

Number of Aquifers: There is only one aquifer system, formed by the crystalline rocks such a granite, granite gneisses, Charnockites,BHQ/BHJ/BMQ, Volcanics, quartzite, shale and sandstones of Proterozoic age, which has storage of ground water both in phreatic and fractured condition. The top phreatic aquifer has been classified as Aquifer-I the lower fractured aquifer as Aquifer-II.

Geology: Geologically the district exhibits lithology of Proterozoic age occupying Easternghat Group, Iron Ore Group, Similipal Group and Kolhan Group of rocks comprising of granite, granite gneisses, Charnockites,BHQ/BHJ/BMQ, Volcanics, quartzite, shale and sandstones.

Aquifer-wise Characteristics: The **crystalline rocks** like granite, granite gneiss, charnockite etc. are devoid of any primary porosity. Secondary porosity in these rocks is developed due to intense weathering and fracturing, which forms good repository and passage for movement of groundwater. The thickness of the weathered zone is usually more in the topographic lows and undulating plains than in the highland areas. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the deeper fractured zones. The water-yielding capacity of the fractured rocks largely depends on the degree of fracturing, their horizontal extent as well as their interconnection.

5.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 5.4** where the total resource available in Pallahara block is 54223ham., which is entirely crystalline granitic aquifer. The dynamic resource of the block is 12443 ham. The extraction details and the future scenario (2025) along with the categorisation is depicted in the **Table 5.5** & **5.6**.

Table 5.5: Dynamic Ground Water Resources of Aquifer-I (Phreatic),Pallahara Block.

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Pallahara	12443	3956	365	4321	395	12409

Table 5.6: Stage of Ground Water Development and Categorisation of PallaharaBlock.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Pallahara	34.7	Safe

Categorisation: ThePallahara block falls in safe category. The stage of Ground water development is 34.7%. The Net Ground water availability is 12443 Ham. The Ground water draft for all uses is 4321 Ham. The Ground water resources for future uses for Pallahara Block is 12409 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground water and Contamination**:** Throughout the study area, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The EC value for phreatic aquifer varies from 60 to 550 micro Siemens per cm at 25^0c.

5.4 Ground Water Resource enhancement:

Aquifer wise space available for recharge and proposed interventions: The volume of porous space available in the unsaturated zone of sandstone up to a desirable depth (say 3 mbgl) is 40.3 x 10^6 m^3 assuming the specific yield of sandstone as 0.02, considering the void space depth 5.26 m and the block area 891.8 sq. km. This is summarised in **Table 5.7**.

Table 5.7: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Assessment Area (sq.m)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Precambrian Granitic	891.8x 10^6	2.26	0.02	40.3x 10^6

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of granitic aquifer can be fully recharged, assuming the average annual rainfall as 1820.3 mm and the infiltration factor of granite is 0.05. Thus slight intervention is required to augment the natural rainfall recharge through watershed management techniques. The details of recharge computation is summarised in **Table 5.8**.

Table 5.8: Details of Volume of Porous Space Available for Further Recharge (Aquifer-wise)

Formation	Area (sq.m)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Precambrian Granitic	891.8×10^6	1.8203	0.05	81.16×10^6	Nil

5.5 Other Issues:

Stage of ground water development in Pallahara block is only 34.7 %. There exists sufficient scope for ground water development for irrigational use.

5.5.1 Demand side interventions:

No demand side intervention is required except increasing the utilisation of ground water for irrigation.

6 BLOCK: TALCHER

6.1 Salient Information:

Mappable Area: 288 Sq. km

District/State: Angul / Odisha Total Geographic Area: 288 Sq. km

Population: The total population of Talcher block as per 2011 Census is 142622 out of which rural population is 98122 & the urban population is 44500 .The population break up i.e. male- female, rural & urban is given below -

Table 6.1: Population Break Up, Talcher Block.

Block	Total population	Male	Female	Rural population	Urban population
Talcher	142622	75022	67600	98122	44500

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is -0.06% as per 2001 census.

Rainfall:The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall (Average of the last 30 years i.e. 1988 to 2017) of Talcher block is 1143.8 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 6.2: Rainfall Data in Talcher Block in mm.

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Monsoon rainfall	1090.0	1338.0	972.0	1279.0	1028.0	1245.0	954.0	464.0	572.1	743.0
Non-monsoon	148.9	105.0	533.0	203.0	148.0	153.0	115.7	565.3	50.4	190.0
Annual Rainfall	1238.9	1443.0	1505.0	1482.0	1176.0	1398.0	1069.7	1029.3	622.5	933.0
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	488.2	596.0	513.0	939.8	526.6	1151.0	844.0	1179.3	969.0	988.5
Non-monsoon	207.0	225.6	43.0	104.0	72.0	200.0	243.0	410.0	170.0	176.0
Annual Rainfall	695.2	821.6	556.0	1043.8	598.6	1351.0	1087.0	1589.3	1139.0	1164.5
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1005.0	1073.0	608.0	1091.0	1226.0	684.0	1352.0	1104.0	980.0	635.0
Non-monsoon	175.0	225.0	213.0	205.0	288.0	408.1	331.0	170.0	266.2	332.0
Annual Rainfall	1180.0	1298.0	821.0	1296.0	1514.0	1092.1	1683.0	1274.0	1246.2	967.0

Agriculture and Irrigation: Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc. The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Kaniha block is given in **Table 6.3a** and **6.3b**.

Table 6.3a: Land Use Pattern (in ha), Talcher Block.

Block	**Forest Area**	**Misc. tree crops & groves not included in net area sown**	**Barren & Uncultivable land**	**Land put to non-agricultural use**	**Culturable waste**	**Permanent pastures and other grazing land**	**Current fallows**	**Other fallows**	**Net area sown**
Talcher	4187	376	577	3486	1083	551	2615	1724	15062

Table6.3b: Area Irrigated by Various Sources (in ha), Talcher Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Talcher	311	1350	374	0	2272	2583	1724

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the aquifer wise resource availability in Talcher block upto 200 m depth is given in the **Table 6.4**.

Table 6.4: Ground Water Resources of Talcher Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Talcher	2926	10184	3680	**16790**	**2012**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 1277 Ham while the same for domestic and industrial field is 735 Ham. To meet the future demand for ground water, a total quantity of 2862 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre- monsoon water level: : In the pre-monsoon period, it has been observed that in Talcher block, the minimum depth to water level is 1.56 mbgl at Kalamchuin and the maximum water level is 11.8 mbgl at Chainpal, the average water level is 5.45 mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 1.16 (Solarha) to 9.28 mbgl (Talchir) with an average of 3.72 mbgl.

(iii) Seasonal water level fluctuation: The data indicates that in Angul block, water level fluctuation varies from 0.32 (Lakeiposi, Scotlandpur) to 4.92 m (Teheranpur) with an average fluctuation of 1.73 m.

(iv) The long term water level trend(2006-2015): During pre-monsoon out of 5 stations 3 show rising trend ranging from 0.043 to 0.508 m/yr and the rest 2 stations show falling trend with the range of -0.29 to -0.355 m/yr. In the post-monsoon season, 2 stations show rising trend in the range of 0.043 to 0.1 m/yr and 3 stations show falling trend ranging from -0.025 to -0.502 m/yr.

6.2 Aquifer Disposition:

Number of Aquifers: There is only one major aquifer viz. Sandstone/Shale (Gondwana formation) both in phreatic and fractured condition serves as major aquifer system in Talcher block.

Geology: Geologically the block exhibits lithology of semi-consolidated granular rocks of Gondwana such as sandstone, Shale and Coal.

Aquifer-wise Characteristics: The **semi-consolidated formation**are represented by rocks of *Gondwana* formation, which have faulted contact with the Pre-Cambrian rocks. It consists mainly of sandstone and shale. The friable and loosely cemented sandstone forms the aquifer. Ground water occurs in phreatic condition in the weathered zone and semi-confined to confined condition in deeper fractured and friable sandstone beds. The depth of dug well in these formations ranges from 4.3 to 14.85 m. The depth to water level varies from 1.56 to 11.8 mbgl during pre-monsoon and from 1.16 to 9.28 mbgl during post- monsoon period.The depth of drilled wells varies from 70 to 200 m and the yield ranges from 0.60 to 3.70 litres per second.

Table 6.5: Distribution of Principal Aquifer Systems in Talcher block.

Block	Phreatic and fractured crystalline	%	Phreatic and fractured Gondwanas	%	Total Area (sq.km)
Talcher	0	0	288	100	288

6.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 6.4** where the total resource available in Talcher block is 11566 ham., which is entirely in the sandstone (Gondwana) area. The dynamic resource of the block is 2313 ham. The extraction details and the future scenario (2025) along with the categorisation is depicted in the **Table 6.6** & 6**.7**.

Table 6.6: Dynamic Ground Water Resources of Aquifer-I (Phreatic), Talcher Block.

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Talcher	2926	1277	735	2012	735	2862

Table 6.7: Stage of Ground Water Development and Categorisation of Talcher Block.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Talcher	68.8	Safe

Categorisation: The Talcher block falls in safe category. The stage of Ground water development is 68.8%. The Net Ground water availability is 2926 Ham. The Ground water draft for all uses is 2012 Ham. The Ground water resources for future uses for Talcher Block is 2862 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground water and Contamination**:** Throughout the study area, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The EC value for phreatic aquifer varies from 280 to 2630 micro Siemens per cm at 25^0c. Higher EC value was observed at Tentulei (2210) and Karnapur (2630). High fluoride content was found at Gopalprasad (2.21) and Sendhogram (1.3 & 3.8) mg/l.

The major open cast coal mines which are operating at present in Talcher block are Balanda, Jagannath, Ananta, Kalinga, Bharatpur, Lingaraj, Hingula, Bhubaneswari and the major underground coal mines operating are Nandira, Handidhua, Deulbera and Talcher**.** However there is no contamination of ground water both phreatic and deeper due to mining activities.

6.4 Ground Water Resource enhancement:

Aquifer wise space available for recharge and proposed interventions: The volume of porousspace available in the unsaturated zone of sandstone up to a desirable depth (say 3 mbgl) is 47.7 x 10^6 m^3 assuming the specific yield of sandstone as 0.03, considering the void space depth 5.2 m and the block area 288 sq. km. This is summarised in **Table 6.8**.

Table 6.8: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Area (sq.m)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Gondwana Sandstone	288 x 10^6	5.52	0.03	47.7 x 10^6
Precambrian Granitic	0	-	0.02	0

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of sandstone may be recharged about 26.35 x 10^6 m^3, assuming the average

annual rainfall as 1143.8 mm and the infiltration factor of sandstone is 0.08. Thus the space available for recharge through other means is 21.35 x 10^6 m^3. This is summarised in **Table 6.9**.

Table 6.9: Details of Volume of Porous Space Available for Further Recharge (Aquifer-wise)

Formation	Area (sq.m)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Gondwana Sandstone	288 x 10^6	1.1438	0.08	26.35 x 10^6	21.35 x 10^6
Precambrian Granitic	0	-	0.05	0	0

6.5 Other Issues:

1. Stage of ground water development in Talcher block is relatively high 68.8 % and is maximum among the NAQUIM blocks.
2. In active coal-mining areas where huge quantity of groundwater is regularly pumped during mining, it's impact on the ground water regime is appreciable in & around Talcher coal field.

6.5.1 Demand side interventions:

1. In Talcher block of Angul district where stage of development is 68.8 %, no demand side intervention is needed. There is further scope for ground water utilisation.
2. Ground water coming out as mine dewatering can be utilised to control the impact of mine dewatering by creating garland recharge well system.
3. Also Artificial Recharge structures may be constructed in suitable locations especially in the areas where the water level remains more than 5 mbgl in the post-monsoon period in this block to arrest the huge non-committed run-off to augment the ground water storage in the area.

Table 6.10: Types of Artificial Structures Feasible in Talcher Block.

Name of Block	Area Feasible for recharge (sq.km)	Volume of Unsaturated Zone available for recharge (m^3)	Types of Structures Feasible and their Numbers
Talcher	40.17	21.35 x 10^6	The types of structures likely to be implemented are percolation tank, Nalla bund, check dam, recharge shaft and Gully plug/gabion structures. However their numbers are to be decided on the basis of formation and local geomorphology.

7. BLOCK: ATHAMALLIK

7.1 Salient Information:

Mappable Area: 712 Sq. km

District/State: Angul / Odisha Total Geographic Area: 996 Sq. km

Population: The total population of Athamalik block as per 2011 Census is 110552 and the population break up i.e. male- female, rural & urban is given below –

Table 7.1: Population Break Up, Athamallik Block.

Block	Total population	Male	Female	Rural population	Urban population
Athamallik	110552	55236	55316	110552	0

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is 2.1 % as per 2001 census.

Rainfall:The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall (Average of the last 30 years i.e. 1988 to 2017) of Athamallik blockis 1387.2 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 7.2: Rainfall Data in Athamallik Block in mm.

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Monsoon rainfall	913.6	1210.6	982.1	1899.5	1138.2	928.8	1882.6	828.6	675.4	1900.8
Non-monsoon	239.5	75.3	484.5	190.0	71.4	104.6	109.4	568.2	45.0	211.2
Annual Rainfall	1153.1	1285.9	1466.6	2089.5	1209.6	1033.4	1992.0	1396.8	720.4	2112.0
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	800.8	1063.6	816.8	1940.1	826.2	1444.2	1038.0	1211.6	1731.3	1186.1
Non-monsoon	290.0	218.0	156.4	167.8	199.4	243.1	173.5	296.6	161.6	66.0
Annual Rainfall	1090.8	1281.6	973.2	2107.9	1025.6	1687.3	1211.5	1508.2	1892.9	1252.1
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1337.8	1397.4	754.0	976.4	1197.4	889.0	1647.6	835.8	958.4	940.9
Non-monsoon	183.6	105.8	191.4	243.4	211.4	521.2	215.4	134.8	223.0	162.1
Annual Rainfall	1521.4	1503.2	945.4	1219.8	1408.8	1410.2	1863.0	970.6	1181.4	1103.0

Agriculture and Irrigation:Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Kaniha block is given in **Table 7.3a** and 7.**3b**.

Table 7.3a: Land Use Pattern (in ha), Athamallik Block.

Block	Forest Area	Misc. tree crops & groves not included in net area sown	Barren & Uncultivable land	Land put to non-agricultural use	Culturable waste	Permanent pastures and other grazing land	Current fallows	Other fallows	Net area sown
Athamallik	49976	324	5200	8653	1876	2662	5664	4279	43825

Table 7.3b: Area Irrigated by Various Sources (in ha), Athamallik Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Athamallik	4783	964	848	135	1504	6422	1812

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the aquifer wise resource availability in Athamalik block upto 200 m depth is given in the **Table 7.4**.

Table 7.4: Ground Water Resources of Athamallik Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Athamallik	6100	25413	8634	**40147**	**2336**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 1970 Ham while the same for domestic and industrial field is 366 Ham. To meet the future demand for ground water, a total quantity of 6059 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre- monsoon water level: : In the pre-monsoon period, it has been observed that in Athamalik block, the minimum depth to water level is 3.05 mbgl at Jamudoli and the maximum water level is 10.15 mbgl at Pataka, the average water level is 6.87 mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 1.45 (Talamaliha) to 6.2 mbgl (Tasarbeda) with an average of 3.9 mbgl.

(iii) Seasonal water level fluctuation: The data indicates that in Angul block, water level fluctuation varies from 0.9 (Kadapada) to 7.6 m (Pataka) with an average fluctuation of 2.97 m.

(iv) The long term water level trend(2006-2015): During pre-monsoon only 1 station show rising trend of 0.5041 m/yr (Athamallik). In the post-monsoon season, the same station shows rising trend of 0.5662 m/yr.

7.2 Aquifer Disposition:

Number of Aquifers: There is only one aquifer system, formed by the crystalline rocks such a granite, granite gneisses, Charnockites,BHQ/BHJ/BMQ, Volcanics, quartzite, shale and sandstones of Proterozoic age, which has storage of ground water both in phreatic and fractured condition. The top phreatic aquifer has been classified as Aquifer-I the lower fractured aquifer as Aquifer-II.

Geology: Geologically the district exhibits lithology of Proterozoic age occupying Easternghat Group, Iron Ore Group, Similipal Group and Kolhan Group of rocks comprising of granite, granite gneisses, Charnockites,BHQ/BHJ/BMQ, Volcanics, quartzite, shale and sandstones.

Aquifer-wise Characteristics: The **crystalline rocks** like granite, granite gneiss, charnockite etc. are devoid of any primary porosity. Secondary porosity in these rocks is developed due to intense weathering and fracturing, which forms good repository and passage for movement of groundwater. The thickness of the weathered zone is usually more in the topographic lows and undulating plains than in the highland areas. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the deeper fractured zones. The water-yielding capacity of the fractured rocks largely depends on the degree of fracturing, their horizontal extent as well as their interconnection.

Table 7.5: Distribution of Principal Aquifer Systems in Athamallik block.

Block	Phreatic and fractured crystalline	%	Phreatic and fractured Gondwanas	%	Total Assessment Area (sq.km)
Athamallik	677	100	0	0	677

7.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 6.4** where the total resource available in Athamallik block is 11566 ham., which is entirely in the sandstone (Gondwana) area. The dynamic resource of the block is 2313 ham. The extraction details and the future scenario (2025) along with the categorisation is depicted in the **Table 7.6** & 7**.7**.

Table 7.6: Dynamic Ground Water Resources of Aquifer-I (Phreatic), Athamallik Block.

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Athamallik	6100	1970	366	2336	406	6059

Table 7.7: Stage of Ground Water Development and Categorisation of Athamallik Block.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Athamallik	38.3	Safe

Categorisation: The Athamalik block falls in safe category. The stage of Ground water development is 38.3%. The Net Ground water availability is 6100 Ham. The Ground water draft for all uses is 12336 Ham. The Ground water resources for future uses for Athamalik Block is 6059 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground water and Contamination**:** Throughout the study area, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The EC value for phreatic aquifer varies from 410 to 1410 micro Siemens per cm at 25^0c. Higher EC value was observed at Tapdhol (1010) and Kodapada (1410). High fluoride content was found at Thakurgarh (1.24), Ambsarmunda (2.01), Talamaliha (3.1), Anandpur (2.01) and Kundajhari (1.38) mg/l.

7.4 Ground Water Resource enhancement:

Aquifer wise space available for recharge and proposed interventions: The volume of porous space available in the unsaturated zone of Crystalline rocks up to a desirable depth (say 3 mbgl) is 51.45

x 10^6 m^3 assuming the specific yield of hard rocks as 0.02, considering the void space depth 6.8 m and the block area 677 sq. km. This is summarised in **Table 7.8**.

Table 7.8: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Area (sq.m)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Precambrian Granitic	677 x 10^6	3.8	0.02	51.45 x 10^6
Gondwana Sandstone	0	-	0.03	0

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of crystalline rocks may be recharged about 49.63 x 10^6 m^3, assuming the average annual rainfall as 1387.2 mm and the infiltration factor of granities is 0.05. Thus the space available for recharge through other means is 1.82 x 10^6 m^3This is summarised in **Table 7.9**.

Table 7.9: Details of Volume of Porous Space Available for Further Recharge (Aquifer-wise)

Formation	Area (sq.m)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Precambrian Granitic	677 x 10^6	1.3872	0.05	49.63 x 10^6	1.82 x 10^6
Gondwana Sandstone	0	-	0.08	0	0

7.5 Other Issues:

Stage of ground water development in Athamallik block is only 38.3 %. There exists sufficient scope for ground water development for irrigational use.

7.5.1 Demand side interventions:

1 In Athamallik block where stage of development is only 38.3 %, no demand side intervention is proposed.

2 Also Artificial Recharge structures may be constructed in suitable locations especially in the areas where the water level remains more than 5 mbgl in the post-

monsoon period in this block to arrest the huge non-committed run-off to augment the ground water storage in the area.

Table 7.10: Types of Artificial Structures Feasible in Athamallik Block.

Name of Block	Area Feasible for recharge (sq.km)	Volume of Unsaturated Zone available for recharge (m^3)	Types of Structures Feasible and their Numbers
Athamallik	75.9	1.82×10^6	The types of structures likely to be implemented are percolation tank, Nalla bund, check dam, recharge shaft and Gully plug/gabion structures. However their numbers are to be decided on the basis of formation and local geomorphology.

8. BLOCK: KISHORENAGAR

8.1 Salient Information:

Mappable Area: 597 Sq. km

District/State: Angul / Odisha Total Geographic Area: 852 Sq. km

Population: The total population of Kishorenagar block as per 2011 Census is 107821 and the population break up i.e. male- female, rural & urban is given below -

Table 8.1: Population Break Up, Kishorenagar Block.

Block	Total population	Male	Female	Rural population	Urban population
Kishorenagar	107821	54338	53483	107821	0

Source: Census, 2011

Growth Rate: The decadal population growth rate of the block is 11.4% as per 2001 census.

Rainfall: The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall (Average of the last 30 years i.e. 1988 to 2017) of Kishorenagar block is 1398.6 mm with 50 to 60 rainy days where as the normal rainfall of Angul district, as per IMD is 1421.1 mm.

Table 8.2: Rainfall Data in Kishorenagar Block in mm.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Monsoon rainfall	877.7	1194.0	950.0	1496.0	1383.8	1250.0	2220.1	856.5	719.8	1479.0
Non-monsoon	46.8	101.0	546.4	176.7	21.2	117.4	106.8	556.5	61.8	126.8
Annual Rainfall	924.5	1295.0	1496.4	1672.7	1405.0	1367.4	2326.9	1413.0	781.6	1605.8
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Monsoon rainfall	1064.7	1115.8	789.4	2169.2	927.3	1784.4	1013.5	1378.5	1554.0	1188.2
Non-monsoon	200.9	273.8	136.1	155.6	112.2	228.4	246.8	221.0	181.4	145.0
Annual Rainfall	1265.6	1389.6	925.5	2324.8	1039.5	2012.8	1260.3	1599.5	1735.4	1333.2
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Monsoon rainfall	1302.0	1213.3	783.4	1222.2	1153.0	921.8	1473.2	814.5	1217.0	759.1
Non-monsoon	66.0	164.6	192.0	184.4	248.0	324.8	197.6	93.4	253.4	201.0
Annual Rainfall	1368.0	1377.9	975.4	1406.6	1401.0	1246.6	1670.8	907.9	1470.4	960.1

Agriculture and Irrigation: Agriculture is practiced in the area during kharif and Rabi season every year. The **kharif** crops include paddy, maize, ragi, small millets, arhar, biri, mung, gound nut, til, castor, cotton, turmeric, ginger and vegetables like brinjal, tomato, and early cauliflower. On the other hand, **rabi** crops include paddy, wheat, maize, field pea, mung, biri, mustard, sunflower, safflower, niger, potato, onion, garlic, coriander, vegetables, tobacco, sugar cane etc.

The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Paddy, Wheat and Gram.

The Landuse pattern, area irrigated from different sources and contribution of ground water in irrigation of Kishorenagar block is given in **Table 8.3a** and 8.**3b**.

Table 8.3a: Land Use Pattern (in ha), Kishorenagar Block.

Block	Forest Area	Misc. tree crops & groves not included in net area sown	Barren & Uncultivable land	Land put to non-agricultural use	Culturable waste	Permanent pastures and other grazing land	Current fallows	Other fallows	Net area sown
Kishore nagar	44195	430	2657	2308	3678	2180	4529	3632	36380

Table 8.3b: Area Irrigated by Various Sources (in ha), Kishorenagar Block.

Block	Area Irrigated by Canal	Area Irrigated by Dugwell	Area Irrigated by Borewell	Area Irrigated by Tank	Area Irrigated by Other Sources	Total Area irrigated through Surface Water	Total Area irrigated through Ground Water
Kishorenagar	2543	776	1057	187	2390	5120	1833

Ground Water Resource Availability and Extraction: Based on the resource assessment made, the aquifer wise resource availability in Kishorenagar block upto 200 m depth is given in the **Table 8.4**.

Table 8.4: Ground Water Resources of Kishorenagar Block in Ham.

Block	Resource in Ham				Total Extraction in Ham
	Phreatic (Aquifer-I)		Fractured (Aquifer-II)	Total resource	
	Dynamic	In-storage	In-storage		
Kishorenagar	7555	25022	9124	**41701**	**2691**

Existing and Future Water Demand (2025): The existing draft for irrigation in the area is 2176 Ham while the same for domestic and industrial field is 515 Ham. To meet the future demand for ground water, a total quantity of 7302 ham of ground water is available for future use.

Water Level Behaviour: (i) Pre- monsoon water level: : In the pre-monsoon period, it has been observed that in Kishorenagar block, the minimum depth to water level is 3.27 mbgl at Sanjamura and the maximum water level is 10.1 mbgl at Anlaberini, the average water level is 6.48 mbgl.

(ii) Post- monsoon water level: In the post-monsoon period, it has been observed that the water level varies from 1.45 (Damabahal) to 7.75 mbgl (Anlaberini) with an average of 4.03 mbgl.

(iii) Seasonal water level fluctuation: The data indicates that in Angul block, water level fluctuation varies from 0.45 (Ashrubahal) to 4.17 m (Angapada) with an average fluctuation of 2.45 m.

(iv) The long term water level trend(2006-2015): During pre-monsoon, 4 existing stations show rising trend in the range of 0.0056 (Boinda1) to 0.1017 (Bamur) m/yr. In the post-monsoon season, the same 4 stations show rising trend with the range of 0.0066 m/yr (Handapa) to 0.0885 m/yr (Boinda1).

8.2 Aquifer Disposition:

Number of Aquifers: There is only one aquifer system, formed by the crystalline rocks such a granite, granite gneisses, Charnockites,BHQ/BHJ/BMQ, Volcanics, quartzite, shale and sandstones

of Proterozoic age, which has storage of ground water both in phreatic and fractured condition. The top phreatic aquifer has been classified as Aquifer-I the lower fractured aquifer as Aquifer-II.

Geology: Geologically the district exhibits lithology of Proterozoic age occupying Easternghat Group, Iron Ore Group, Similipal Group and Kolhan Group of rocks comprising of granite, granite gneisses, Charnockites,BHQ/BHJ/BMQ, Volcanics, quartzite, shale and sandstones.

Aquifer-wise Characteristics: The **crystalline rocks** like granite, granite gneiss, charnockite etc. are devoid of any primary porosity. Secondary porosity in these rocks is developed due to intense weathering and fracturing, which forms good repository and passage for movement of groundwater. The thickness of the weathered zone is usually more in the topographic lows and undulating plains than in the highland areas. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the deeper fractured zones. The water-yielding capacity of the fractured rocks largely depends on the degree of fracturing, their horizontal extent as well as their interconnection.

Table 8.5: Distribution of Principal Aquifer Systems in Kishorenagar block.

Block	Phreatic and fractured crystalline	%	Phreatic and fractured Gondwanas	%	Total Assessment Area (sq.km)
Kishorenagar	715.6	100	0	0	715.6

8.3 Ground Water Resource, Extraction, Contamination and Other Issues:

Aquifer wise resource availability is given in the **Table 8.4** where the total resource available in Kishorenagar block is 11566 ham., which is entirely in the sandstone (Gondwana) area. The dynamic resource of the block is 2313 ham. The extraction details and the future scenario (2025) along with the categorisation is depicted in the **Table 8.6** & 8**.7**.

Table 8.6: Dynamic Ground Water Resources of Aquifer-I (Phreatic), Kishorenagar Block.

District	Assessment Unit / Block	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic Water Supply in Ham	Net Ground Water Availability for Future Irrigation & Industrial Development in Ham
Angul	Kishorenagar	7555	2176	515	2691	325	7302

Table 8.7: Stage of Ground Water Development and Categorisation of Kishorenagar Block.

District	Block	Stage of Ground water development (%)	Categorisation
Angul	Kishorenagar	35.6	Safe

Categorisation: The Kishorenagar block falls in safe category. The stage of Ground water development is 35.6%. The Net Ground water availability is 7555 Ham. The Ground water draft for all uses is 2691Ham. The Ground water resources for future uses for Kishorenagar Block is 7302 Ham. Though there is scope for further Ground water development but it should be handled with a careful observation.

Chemical Quality of Ground water and Contamination**:** Throughout the study area, the water quality (phreatic aquifer) is good and all the parameters are within permissible limit. In conclusion it may be said that the groundwater in the block is suitable for drinking as well as for irrigation purposes. The EC value for phreatic aquifer varies from 150 to 1230 micro Siemens per cm at 25^0c. Higher EC value was observed at Adikata (1230).

8.4 Ground Water Resource enhancement:

Aquifer wise space available for recharge and proposed interventions: The volume of porousspace available in the unsaturated zone of sandstone up to a desirable depth (say 3 mbgl) is 49.8 x 10^6 m^3 assuming the specific yield of sandstone as 0.03, considering the void space depth 6.48 m and the block area 715.6 sq. km. This is summarised in **Table 8.8**.

Table 8.8: Summarised Details of Volume of Porous Space Available for Recharge (Aquifer-wise)

Formation	Assessment Area (sq.m)	Water Level (upto 3 mbgl in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m^3)
Precambrian Granitic	715.6 x 10^6	3.48	0.02	49.8 x 10^6
Gondwana Sandstone	0	-	0.03	0

Rain water being the only primary source for recharge, it has been calculated that unsaturated zone of granites may be recharged about 24.46 x 10^6 m^3, assuming the average annual rainfall as 1398.6 mm and the infiltration factor of sandstone is 0.08. It has been calculated that the space left for recharge with other means is 23.34 x 10^6 m^3. This is summarised in **Table 8.9**.

Table 8.9: Details of Volume of Porous Space Available for Further Recharge (Aquifer-wise)

Formation	Area (sq.m)	Annual average rainfall (m)	Infiltration Factor of the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Precambrian Granitic	715.6×10^6	1.3986	0.05	24.46×10^6	23.34×10^6
Gondwana Sandstone	0	-	0.08	0	0

8.5 Other Issues:

Stage of ground water development in Pallalahara block is only 35.6 %. There exists sufficient scope for ground water development for irrigational use.

8.5.1 Demand side interventions:

No demand side intervention is required except increasing the utilisation of ground water for irrigation.

Table 8.10: Types of Artificial Structures Feasible in Kishorenagar Block.

Name of Block	Area Feasible for recharge (sq.km)	Volume of Unsaturated Zone available for recharge (m^3)	Types of Structures Feasible and their Numbers
Kishorenagar	300	23.34×10^6	The types of structures likely to be implemented are percolation tank, Nalla bund, check dam, recharge shaft and Gully plug/gabion structures. However their numbers are to be decided on the basis of formation and local geomorphology.

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