केन्द्रीय भूमि जल बोर्ड

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विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

NAYAGARH DISTRICT
ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

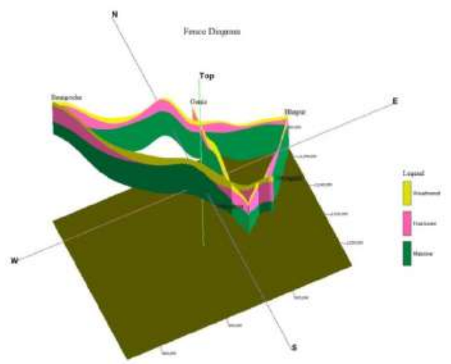
South Eastern Region, Bhubaneswar

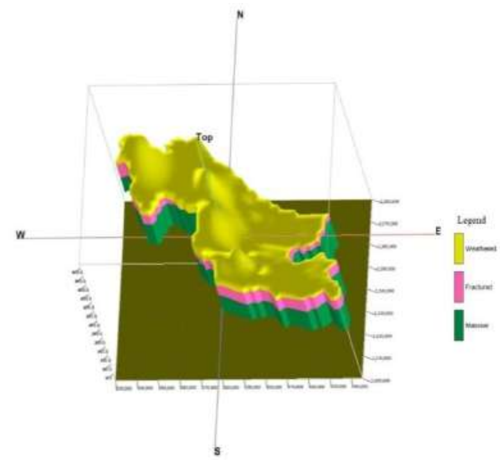
Government of India

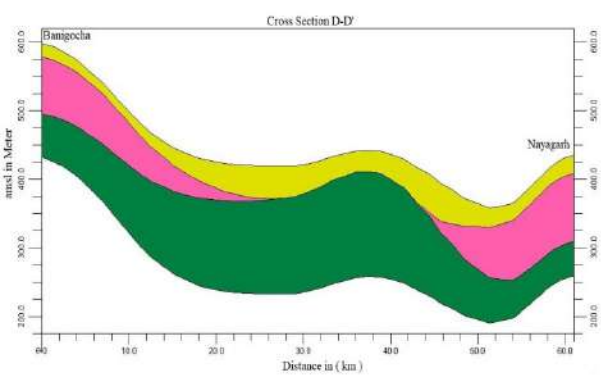
MINISTRY OF JAL SHAKTI, DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

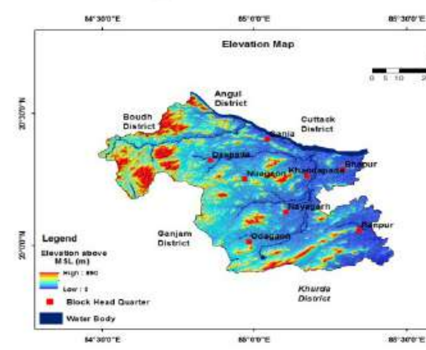
REPORT ON

AQUIFER MAPPING AND MANAGEMENT PLAN IN NAYAGARH DISTRICT, ODISHA









CENTRAL GROUND WATER BOARD
South Eastern Region, Bhubaneswar
June-2022

FOREWORD

Nayagarh is a new district carved out of Puri in 1993 during a major district reorganisation process in the State. Puri was divided into Puri, Khordha and Nayagarh. As a part of the erstwhile Puri district, Nayagarh enjoyed the taste of ancient cultural heritage of Puri dating back from 3rd century B.C. It borders Angul district and Cuttack district in North West, Kandhamal in West, Ganjam in South and Khordha in the East having a geographical cover area of 3890 sq. km. Major portions of the district are covered with hilly terrain and high-land dense forest.

The district is endowed with vast natural resources and is one of the agriculturally developed districts of Odisha. The district is underlain mostly by hard crystalline formations of Eastern Ghat Supergroup. The river Mahanadi and its tributaries are the main surface water sources which provide water to the district. However, large part of the district still lacks surface water irrigation facility. The agrarian development of the district can be boosted by tapping the ground water resources through dug wells and medium-deep bore wells.

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.

The hard crystalline rocks of the district form two distinct aquifer systems. The shallow aquifer is formed by the weathered mantle where water is stored under phreatic condition. The deeper aquifer is formed by fracture zones, joints etc where water occur in semi-confined condition. Granitic hardrock aquifers have water yielding fracture zones and have average success rate with 2-5 lps of discharge. Borewells in charnockites and khondalites have very poor yield. The places where weathering thickness is more and condition is favourable, the phreatic aquifer attains good yield potential and large diameter dug wells are suitable structures to extract water from them.

The present stage of ground water development is only 42.18 %, 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.

Based on present studies, available data and the earlier hydrogeological studies taken up in 8 blocks of the district viz. Bhapur, Dasapalla, Gania, Khandapada, Nayagarh, Nuagaon, Odogaon and Ranpur covering 3890 Sq. Km. area, 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. **Smt. Mausumi sahoo, Scientist-'B'**, has prepared the present report on **"Aquifer Mapping and Management Plan in Nayagarh District, Odisha"**. Her sincere efforts in preparation of the report will no doubt be very useful and benefit the state. It is hoped that it will help 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: 10th June 2022

10/6/22
(P K Mohapatra)
Regional Director

CONTRIBUTORS PAGE

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Overall Supervision		Shri P. K. Mohapatra, Regional Director

District at a glance

SL. NO	ITEMS	STATISTICS
1.	**GENERAL INFORMATION**	
	a) Geographical area (Sq.Km)	3,890
	b) Administrative Division	
	Number of Tehsil/Block	8 Tehsils/8 Blocks
	Number of GramPanchayats(G.P)/villages	194 G.Ps, 1702 villages
	c) Population (As on 2011 census)	962789
2.	**GEOMORPHOLOGY**	
	Major physiographic units	Structural Hills, Denudational Hills, Residual Hills, Lateritic uplands, Alluvial plains, Intermontane Valleys
	Major Drainages	The Mahanadi, Burtanga, Kuanria, Kamai&Kusumi
3.	**LAND USE (Sq. Km)**	
	a) Forest area:	1900
	b) Net area sown:	980
4.	**MAJOR SOIL TYPES**	Alfisols, Ultisols
5.	**IRRIGATION BY DIFFERENT SOURCES**	
	(Areain Ha)	
	Dug wells	3989
	Shallow Tube wells	1351
	Deep Tube wells	1577
6.	**NUMBERS OF GROUND WATER MONITORING WELLS**	41 (DW & PZ)

7. PREDOMINANT GEOLOGICAL FORMATIONS

Precambrian: Granite Gneiss, Khondalite, Charnockite

Recent: Alluvium

8. HYDROGEOLOGY

- Major water bearing formation — Consolidated &Unconsolidated formations
- Premonsoon depth to water level during 2020(in mbgl) — Min- 0.5; Max- 10.8
- Post-monsoon Depth to water level during 2020(in mbgl) — Min –0.33; Max- 6.9

9. GROUND WATER EXPLORATION BY CGWB(AS ON 31.03.2007)

No. of wells drilled(EW, OW)	21
Depth Range (m)	56.40 to 200m
Discharge (litre/second)	Negligible to 13.5

10. DYNAMIC GROUND WATER RESOURCES (2020) IN HAM

Annual Extractable Ground Water	35898.01
Gross Annual Ground Water Draft	14123.95
Ground Water Available for Future Use	21461.6
Stage of Ground Water development	42.18%

CONTENTS

List of Figures

List of Tables

1. INTRODUCTION

1.1 Objective

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

The activities under NAQUIM are aimed at identifying the aquifer geometry, aquifer characteristics their yield potential along with the quality of water occurring at various depths, aquifer-wise assessment of ground water resources and development. Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater.

With these aims, Aquifer Mapping was carried out in the hard rock terrain of Nayagarh district in Odisha covering all eight blocks of the district namely Bhapur, Khandapada, Nayagarh, Gania, Dasapalla, Nuagaon, Odogaon and Ranapur.

1.2 Scope of the Study

An administrative District of Odisha, Nayagarh District was created in 1st April 1993 when the erstwhile Puri District was split into three distinct Districts. The District is bounded by Cuttack District on the North, Kandhamal District on the West, Ganjam District on the South and Khordha District on its East. Birth history of Nayagarh District in around the thirteenth century and is considered as an important part in the political history of Odisha. King Suryamani of Baghela dynasty came to Puri on a pilgrimage from Madhya Pradesh and established his kingdom at Nayagarh. Nayagarh District consists of the four Garjat states of ex-states Ranpur, Nayagarh, Khandapara and Daspalla. The aboriginal Savaras and Kandhas are the indigenous people of Nayagarh District. Nayagarh District with an area of 3890 Sq Km lies between 19^0 53' 52" and $20^0$34' 46" N and longitudes 84^0 29' 26" and 85^0 27' 22"East Longitude and falls in the Survey of India toposheets No. 73 D, H, E & A. The District is situated on the hilly ranges in the West and its North Eastern parts have formed small well cultivated fertile valleys intersected by small streams. It's in the higher altitude than the sea level and above flood level. The River Mahanadi flows in the Eastern boundary.

Nayagarh District Covering a geographical area of 3890 sq km consists total 962789 population as per 2011 census. The total male population of the District is 502636 and female population is 460153. As per administrative concern, the district has one sub division namely Nayagarh. There are 8 Tahasils, 8 Blocks, 14 Police stations, 194 gram panchayats and 1702 villages functioning in the District.

With the increasing development of ground water resources to meet rising demands and consequent adverse environmental impacts, issues of ground water over-exploitation, contamination and other related issues, Aquifer Mapping and Management Programme had taken up during Annual Action Plan 2020-21. The study is aimed in assessing the prevailing hydrogeological condition, ground water potential, level of development and management of ground water in the district. Under this initiative, management plans for each aquifer system have been prepared suggesting various interventions to optimize ground water withdrawal and identifying aquifers with potable groundwater for drinking purpose in quality affected areas. The management options also includes identification of feasible area for artificial recharge to ground water and water conservation which help in arresting declining water levels besides demand side management option including crop diversification, increasing water use efficiency etc. For this purpose 100 dug wells, which are distributed throughout the district have been established to know the behavior of phreatic water table during pre and post monsoon period. The purpose of this report is to bring out the overall ground water scenario of the district and its socio-economic implication. Perusal of the report will give an overall idea regarding the availability of water in time and space within the natural framework of the study area as well as suitable methods for its extraction. The necessity of ground water recharge by artificial means has also been highlighted in the report.

1.3 Methodology

1.3.1 Approach and Methodology

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

1.3.2 Compilation of Existing Data and Identification of Data Gaps

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

1.3.3 Hydrogeological Investigations

Review of background information will help to carry out further studies in the field, where various techniques can be applied to determine the three-dimensional extent and aquifer characteristics of the significant water-bearing formations. For this purpose key wells, which are distributed throughout the study area have to be established to know the behavior of the phreatic water table during pre and post monsoon period. Well inventory and collection of relevant data is to be carried out to strengthen the data base. The analysis of the data has to be carried out for preparation of thematic maps.

1.3.4 Geo –hydrochemical Investigations

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

1.3.5 Generation of Thematic Layers Using GIS

- Drainage
- Soil
- Land use and land cover
- Geomorphology
- Geology

- Hydrogeological map
- Aquifer disposition
- Ground water quality

1.3.6 Development of Aquifer-Wise Management Plan

The dimension and disposition of the aquifer is figured out on the basis of integrated study of the geologic, hydrogeological, hydrological, geochemical and geophysical information. Determining aquifer potential and characteristics are essential for their effective management and sustainable development. Local ground water related issues should be identified and studied in detail to make plans to address them.

1.4 Study Area

An administrative District of Odisha, Nayagarh District was created in 1st April 1993 when the erstwhile Puri District was split into three distinct Districts. The District is bounded by Cuttack District on the North, Kandhamal District on the West, Ganjam District on the South and Khordha District on its East. Nayagarh District with an area of 3890 Sq Km lies between 19 degree 54’ to 20 degree 32’ North Latitude and 84 degree 29’ to 85 degree 27’ East Longitude and falls in the Survey of India toposheets No. 73 D, H, E &A.Nayagarh District Covering a geographical area of 3890 sq km consists total 962789 population as per 2011 census. The total male population of the District is 502636 and female population is 460153. As per administrative concern, the district has one sub division namely Nayagarh. There are 8 Tahasils, 8 Blocks, 14 Police stations, 194 gram panchayats and 1702 villages functioning in the District. The index map of the study area is presented in **Fig.1.1** while an administrative map is presented as **Fig. 1.2**.The study area is part of Mahanadi basin. The Mahanadi river flows along the eastern boundary of the district and separates it from Cuttack district. The district headquarter Nayagarh is connected by all weather metalled road from capital city Bhubaneswar (90 km) through SH-1.It is also connected by rail with the capital city. The details regarding the administrative divisions of the study area are given in **Table 1.1**. The block-wise demographic details are shown in **Table-1.2**.

Table 1.1 Block-wise Areas Covered Under NAQUIM in Nayagarh District

Sl No	Block Name	Area (sq.km)	GPs	Villages
1	Bhapur	229.85	20	119
2	Dasapalla	913.18	20	416
3	Gania	409.3	8	114
4	Khandapara	359.59	22	201
5	Nayagarh	290.27	29	150
6	Nuagaon	584.49	22	232
7	Odogaon	501.02	36	220
8	Ranapur	602.3	37	250
Total		**3890**	**194**	**1702**

Table 1.2 Block-Wise Demographic Details in Nayagarh District

Sl No	Block	Population (2011)			Sex Ratio	Literacy Rate		
		Rural	Urban	Total		Person	Male	Female
1	Bhapur	125616	0	125616	914	81.77	90.15	72.66
2	Dasapalla	70654	6906	77560	954	73.27	83.1	62.95
3	Gania	38506	0	38506	919	79.27	88.09	69.73
4	Khandapara	77995	18219	96214	904	79.87	88.37	70.57
5	Nayagarh	43006	17030	60036	881	80.42	88.16	72.05
6	Nuagaon	48514	44739	93253	922	83.62	90.58	75.81
7	Odogaon	110626	5401	116027	904	79.34	86.73	71.27
8	Ranapur	129054	21865	150919	940	82.54	89.23	75.49

Fig 1.1 Index Mapof Study Area

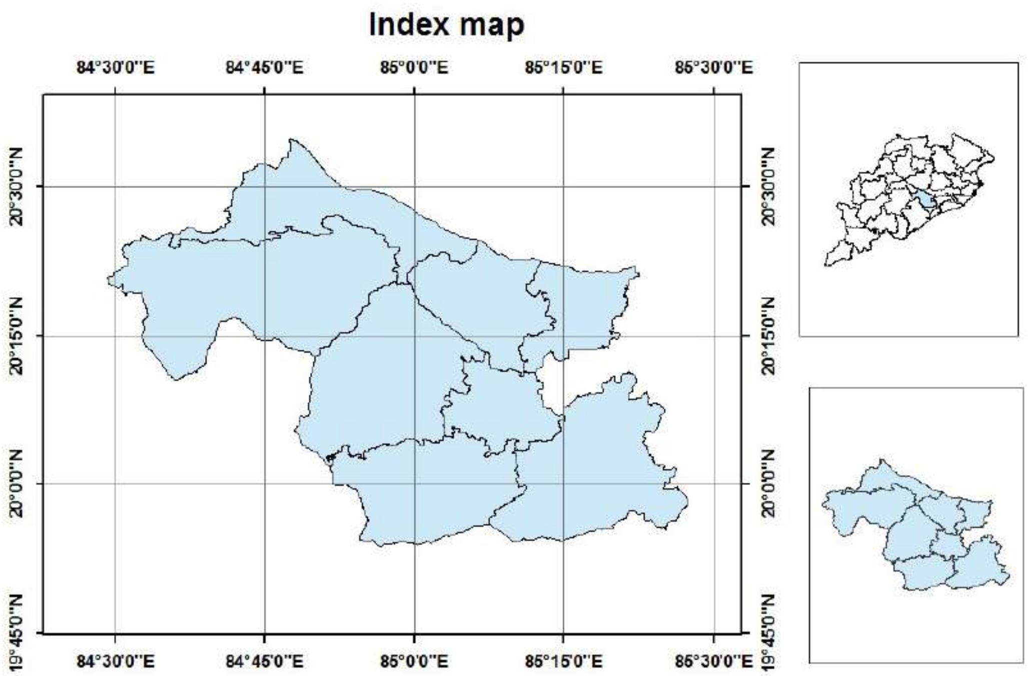
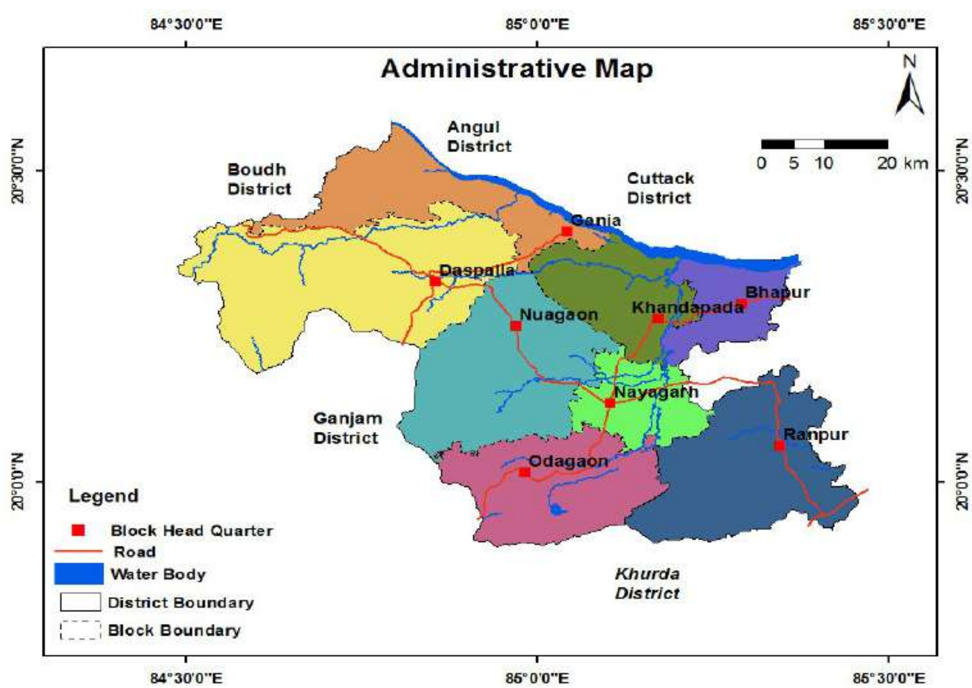


Fig 1.2 Administrative Map of Study Area



2. Rainfall and Climate

Rainfall:

The study area enjoys a humid sub-tropical climatic condition characterized by three distinct seasons viz: summer, rain and winter. The district receives an average annual rainfall of around 1400 mm. About 80 % of the annual rainfall occurs during monsoon period between June to September. Generally south-western monsoon breaks in the middle of June and continues till the end of October, which forms the rainy season. Dasapalla & Ranpur receives a maximum and minimum rainfall of around 1762.8 and 1131.2 mm respectively. The Isohyetal map shows a typical rainfall distribution pattern with rain reducing smoothly from north-west to south central region and north east to south central region i.e. towards Nayagarh block. This can be attributed to the rain shadow zone existing on the lee side of the Eastern Ghat mountain range present south west of the District. Maximum rainfall generally occurs during the month of July followed by June and August. A good amount of pre-monsoonal rainfall also occurs during Late April and May which comes as a relief to the district. The result of long term analysis of rainfall is presented in Table 2.2.

Rainfall is generally heavy during the monsoons, which occur during the months of June and early October (Fig. 2.1).About 80 % of the annual rainfall occurs during monsoon period between June to September. South West monsoon is primarily responsible for the rainfall in this District. Average rainfall of the district is presented in Fig. 2.2.

Fig 2.1 Monthly Average Rainfalls in Nayagarh District

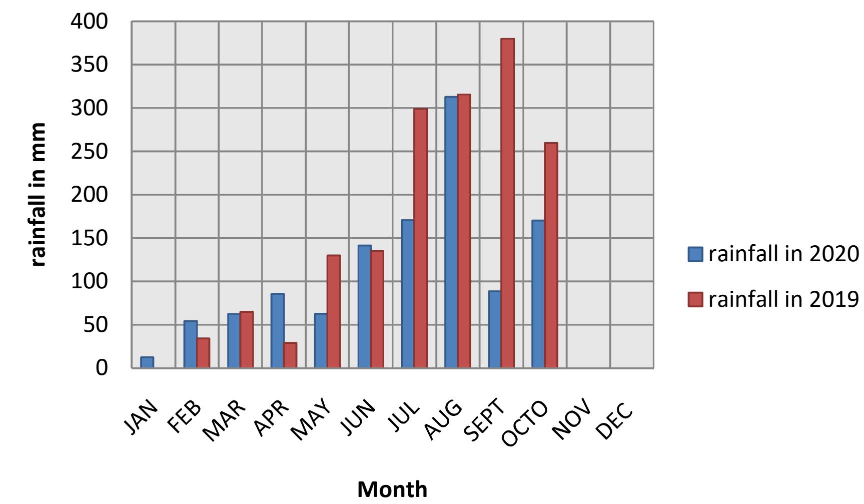
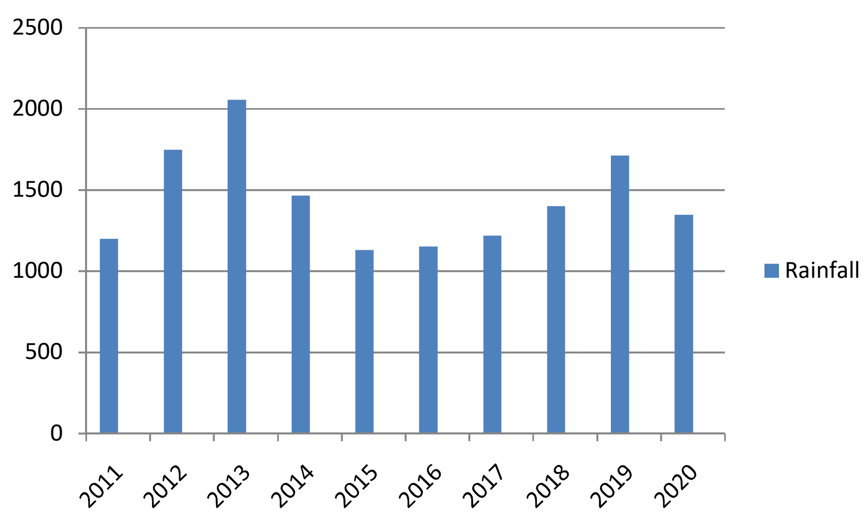


Fig 2.2 Average Annual Rainfalls in Nayagarh District



Blockwise rainfall data for ten years (2011-2020) are presented in **Table 2.1**.The isohyetal map of the district has been prepared on the basis of the average rainfall of ten years and presented in **Fig 2.3**.The north eastern, southern and western parts of the district receive maximum rainfall which gradually dwindles towards western, central and eastern part of the district.The blockwise annual rainfall varies from 1131.2mm to 1762.8mm.The statistical analysis of rainfall data has been carried out to see the variation of rainfall pattern with time (**Table 2.2 &Fig 2.3).** A perusal of the frequency of occurrence of droughts in Nayagarh district suggests that the district has been spared from severe drought. However mild to moderate drought has occurred in almost all blocks.

Table 2.1 Block wise Rainfall Data of Nayagarh District

Year	Bhapur	Daspalla	Gania	Khandapara	Nayagarh	Nuagaon	Odagaon	Ranpur
2011	1354.2	1202.21	1042	1791	1077.2	765	1172.2	1200.544
2012	1975	1978	1492	2318.4	1626.2	1408	1522.1	1672.8
2013	2144.2	1860.3	1632.8	3058.1	1923.3	1399.8	2150.9	2282.5
2014	1579	1472.8	1153.8	2231.7	1545.4	1182.9	1312.8	1258.5
2015	1155	1455.3	874	1530.1	1204.9	637.9	1145	1047.2
2016	1290	1054.2	929.4	1695.8	1134.4	746.2	1415.8	950.7
2017	1544.9	1310.5	885.5	1397.4	1253.2	914.6	1286.6	1164.5
2018	1448.1	1364.7	1393.6	1291.4	1595.4	1263.2	1368	1481.7
2019	1647.8	1477.6	1610	1743.2	2053	1366.5	1563.2	2247.2
2020	1162.4	1762.8	1418	1227	1475.5	1177.6	1432.3	1131.2

Table 2.2 Long-term Rainfall Analysis of Nayagarh District

Year	Normal Rainfall	Actual Rainfall	Departure from Normal	Percentage Departure from Normal (in %)	Remark
2000	1400	1264.57	135.43	9.67	Normal
2001	1400	1883.94	-483.94	-34.57	Moderate Drought
2002	1400	1147.59	252.41	18.03	Normal
2003	1400	1576.77	-176.77	-12.63	Mild Drought
2004	1400	1197.14	202.86	14.49	Normal
2005	1400	1768.05	-368.05	-26.29	Moderate Drought
2006	1400	1382.37	17.63	1.26	Normal
2007	1400	1458.21	-58.21	-4.16	Deficit-Normal
2008	1400	1588.74	-188.74	-13.48	Deficit-Normal
2009	1400	1566.76	-166.76	-11.91	Deficit-Normal
2010	1400	1191.29	208.71	14.91	Normal
2011	1400	1200.54	199.46	14.25	Normal
2012	1400	1749.06	-349.06	-24.93	Moderate Drought
2013	1400	2056.49	-656.49	-46.89	Moderate Drought
2014	1400	1467.11	-67.11	-4.79	Deficit-Normal
2015	1400	1131.18	268.83	19.20	Normal
2016	1400	1152.06	247.94	17.71	Normal
2017	1400	1219.65	180.35	12.88	Normal
2018	1400	1400.76	-0.76	-0.05	Deficit-Normal
2019	1400	1713.56	-313.56	-22.40	Moderate Drought
2020	1400	1348.35	51.65	3.69	Normal

Fig. 2.3 Rainfall Analysis with percent Departure from normal

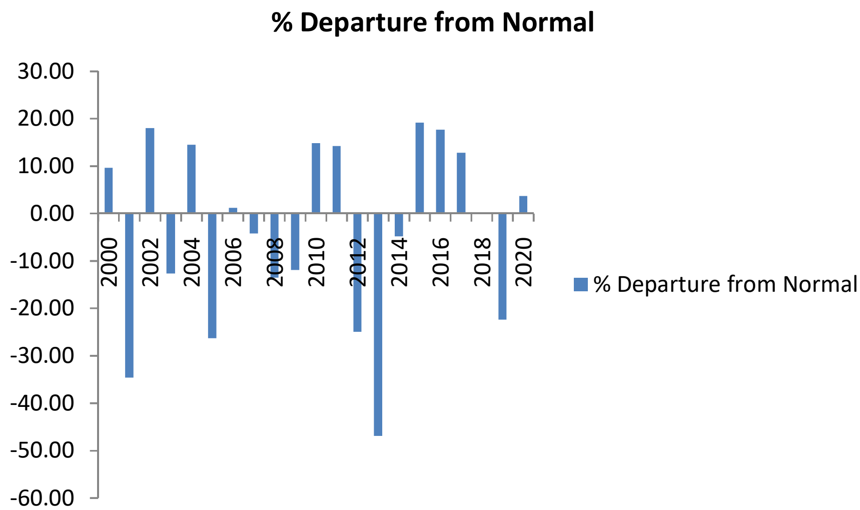
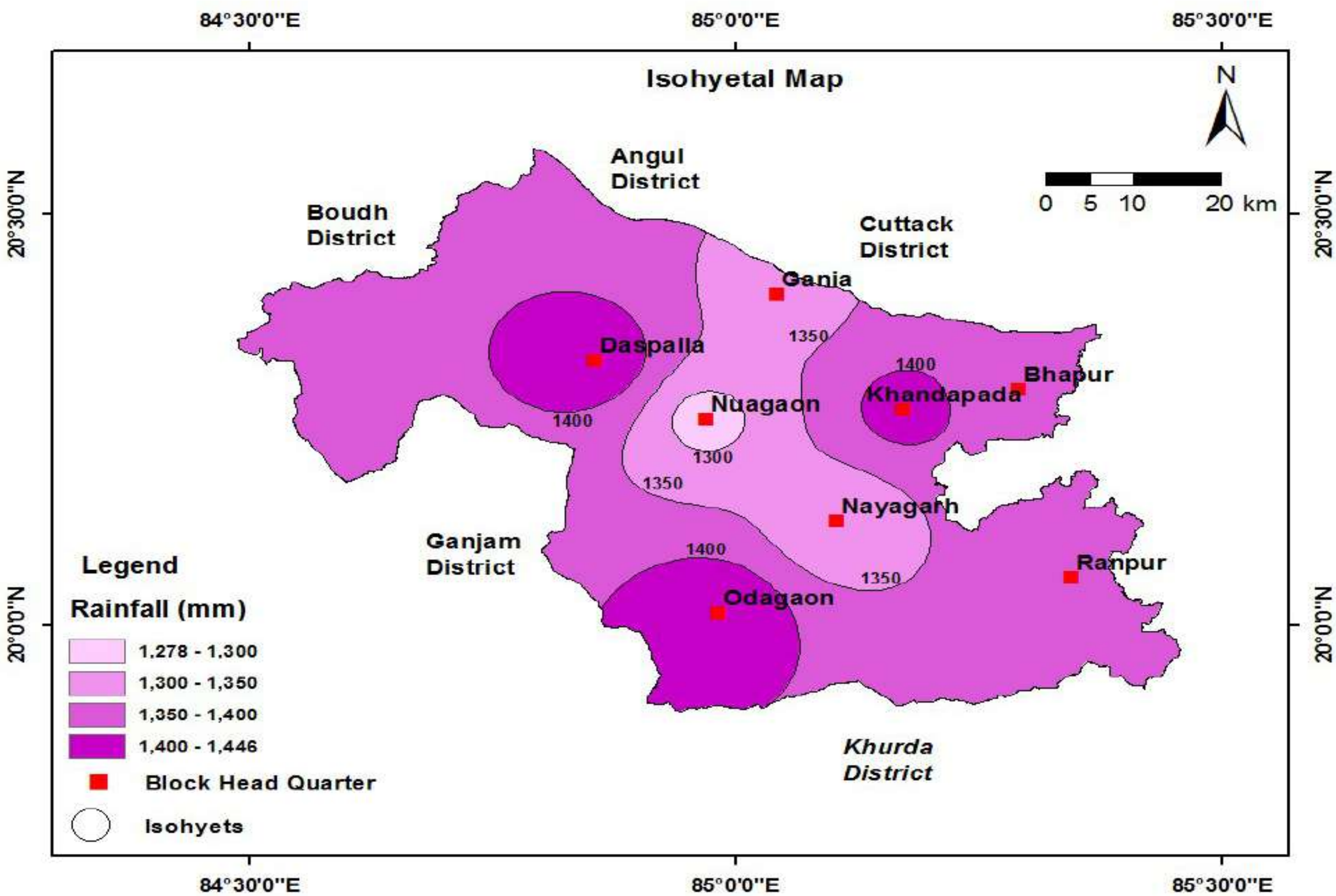


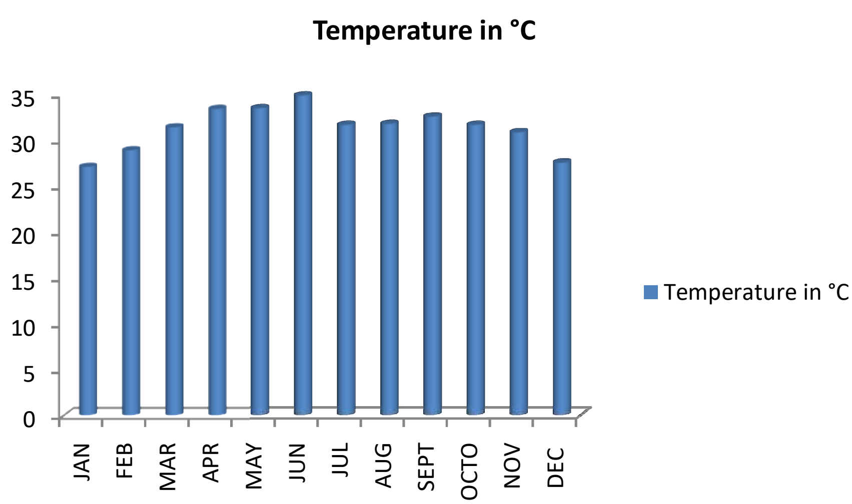
Fig 2.4 Iso-hyetal Map of Nayagarh District



Temperature:

The mean maximum daily temperature rises to 44°C during May and falls to 10°C during December. The maximum temperature is experienced during the month of May. The summer is very severe in Nayagarh, Khandapada, Gania andMahipur areas. The temperature is comparatively less severe in Daspalla and Banigochha areas. During the months from March to May, the summer is hot throughout the study area. The monthly variation of temperature is presented in **Fig. 2.4**.

Fig 2.5 Monthly Temperature Variations in Nayagarh District



Humidity:

Heavy fall of dew even in late March indicates the high humid climate prevalent in the division. The presence of moisture loving plants along the banks of River Mahanadi, Brutanga, Kuanria, Duanta and in the valleys are a witness to the existence of high humidity in the atmosphere. High relative humidity due to presence of mist and dew is helpful in prolonging of humid conditions. The relative humidity is generally high in monsoon and post monsoon period. High humidity is particularly found inBirigarh, Kathapatani, Chadiapalli and Banigochha areas where wide varieties of vegetation are observed. In such localities the presence of *Diospyrosembryopteris*(MankadaKendu), *Strychnosnuxvomica*(Kochila) and

Syzigiumcuminii(Jamun) and their semi-evergreen associate species indicate that the soil and humidity conditions are conducive for the resultant crop.

Special weather Conditions:

Occasional hailstorms and depressions occur during the monsoon season and in October which is accompanied with high force winds. Thunderstorms occur mostly in the afternoons in summer months. Winds usually blow from the South West and North West direction in the monsoon season. In summer, the winds vary in direction and magnitude depending upon the depression in the Bay of Bengal. Flash floods are a normal feature during heavy rain in the areas of hilly terrains, where the vegetative cover in the hill is fast depleting and at times the communication to the interior areas of the division are often disrupted.

Natural Calamities:

Flash floods are seen annually during the rainy season in the riverine tracts especially in the Mahanadi, Brutanga, Kuanria and its tributaries. Most of the tributary streams remain in spate throughout the rainy season especially after a good rainfall since most are hill streams. Major floods uproot trees on the banks of such streams during spate. Lot of soil erosion takes place along slopes as a result of such floods, boulders and rocks are exposed. In the peak summer months when there is a period of scarcity of water in the forests due to the drying up of streams, the wildlife become easy prey for the poachers near the water holes. Heat waves accompanied with sunstroke, deaths and injuries have also become serious problems in this area since 1998. Cyclones in this area are not a regular phenomenon, but the super cyclone on 30.10.1999 left a major impact by damaging the forest growth especially in Odagaon, Mahipur and Daspalla ranges. The occurrence of different types of natural calamities in Nayagarh district is furnished. Droughts also occur in different parts of the district due to want of rain for agriculture during the rainy season.

3. Geomorphology

Physiography and landforms:

The district has a rectangular shape stretching from northwest to south east direction. This district is situated in the hilly ranges in the West and its North Eastern parts has formed a small well cultivated fertile valleys intersected by small streams. River Mahanadi flows through the district and other small rivers like Kusumi, Brutanga, Malaguni, Kuanria, Dahuka and Buddhabuddhiani also flows through the district. These rivers make the district a fertile area. The geomorphology of the area is shown in **Fig. 3.5.**Hydrogeomorphological setup of the area has been identified based on interpretation of landsat image and in the field. The delineation of hydrogeomorphological units aimed at demarcation of discharge & recharge zone and favorable area for groundwater development. Important characteristics of different hydro geomorphic units are described in brief in the following paragraphs and are depicted in Plate.

Structural Hills:

Structural hills are formed by granites, khondalite, and charnockite group of rocks, occupying the major portion of the study area. They are structurally controlled with complex folding, faulting and incised by numerous crisscross joints and fractures which facilitate some infiltration. But this hydro-geomorphic unit mostly acts as run off zone. The infiltrated water at places gives rise to springs in the valleys and hill slopes.

Residual Hills:

This unit mainly consists of small residual masses of granites, khondalites and charnockites. The residual hills occur scattered in the pediment zone. This unit has poor infiltration characteristics and behaves as runoff zone.

Denudational Hills:

These are formed by jointed and fractured granites, khondalites and charnockites. The structurally weak planes favour some rain water infiltration. The percolating water comes out in the form of springs in the topographic lows. These units generally act as runoff zones. The denudational hills have restricted occurrences, and are mostly seen in Nuagaon, Nayagarh and Dasapalla blocks.

Lateritic Upland:

The lateritic uplands are developed over granitic, khondalitic and charnockitic basement rocks. The laterite appears to form duricrust along the mountain slopes. The thickness of laterite varies from 3 to 15 meters. The lateritic uplands are characterized by moderate rainfall infiltration and considerable water table fluctuation. Groundwater potential in this unit is moderately good. Lateritic uplands are seen in parts of Ranapur and Nayagarh blocks.

Intermontane valleys:

These valleys are mostly structurally controlled and found in the mountainous western and north western tracts in the study area. These valleys are underlain by colluvial deposits and shallow buried pediments. Sometimes streams issue from the high hill ranges and deposit lot of detritus sediments in the narrow depressions giving rise to valley fill deposits. Infiltration takes place in the upper pediment zones which percolates down to the valley areas. Springs are generally formed in such intermontane valleys. Ground water potential is moderately good in this zone. These areas represent the discharge zones.

Surface water bodies:

The mapable surface water bodies represent reservoirs of medium and minor irrigation projects.

Valley Fill:

Valley fills are promising zones of ground water occurrences. These fracture and joint controlled valleys are receptacles of sand-silt-clay-pebble and boulder deposits. Ground water potential of these zones is good. These zones behave as ground water discharge zones.

Shallow Buried Pediment:

These hydro geomorphic units are seen along the periphery of the hills and hillocks. These are formed from low grade weathering of the underlying granites and khondalite-charnockite group of rocks. Consequently the weathered mantle is thin, ranging between 5 to 10 m. These zones represent both run off, recharge and discharge zones. Groundwater generally occurs at moderate to deeper levels.

Moderately Buried Pediment:

These areas represent moderate level of weathering of underlying rocks. Thickness of weathered mantle generally vary from 5 to 15 m. Infiltration in this unit is moderately good.

Deep Buried Pediment:

These hydro geomorphic units represent deep seated weathering of the underlying crystalline rocks. The thickness of the weathered mantle generally varies from 10 to 20 m. In this unit the infiltration characteristic is good. The thick weathered overburden favour a good amount of water to circulate before reaching the deeper fractured zones.

Alluvial plains:

It is the most potential hydro geomorphic unit. It occurs in the eastern part of the study area.., extending from north to south along the courses of Kusumi, Dahuka, Kamai Rivers and in a small patch along Mahanadi river. It is built up of a sequence of sand-silt and clay. The alluvial plains form parts of the flood plains of the rivers, occupying topographic lows and hence constitute the groundwater discharge zones.

Lineament:

These are long linear features, and especially represent the long thrust or fault zones. Such structurally weak planes allow ground water to percolate to the deeper horizons, forming potential aquifers. Such trends are identifiable from satellite image and in the field where its surface expression may be long narrow depressions,

Physiographically, the study area is composed of three distinct physiographic units, i.e.

i. High hill ranges in the north-western part in the form of Baishipalli and Chadiapalli ranges in Gania and Daspalla block respectively with Burtangariver following the intermontane valley between the two. This region has a land elevation ranging from 200 m to 800 m above mean sea level with a steep slope except in wide intermontanevalleys.TheBurudhani (726 m), Balimunda Parbat (855 m),Mungula Parbat (784 m) and Palba (730 m) are some of the hill peaks in the region. Rivers flowing in these hill ranges follow angular drainage pattern, which is the characteristics of structural weak zones like joints, fractures and faults.

ii. Gently sloping plain with isolated hills and mounds having a general land elevation varying from 40 to 200 meter above mean sea level is seen the rest of the study area. This unit is characterized by dendritic and rectangular drainage pattern with both structure and slope playing important role for its development. However some isolated hill ranges like Hatimunda and Suliya on the northern and southern side of Nayagarh with peaks between 575 and 682 m above mean sea level also deserves mention. Another 30 kilometer long structural hill trending along NE-SW direction in the southern part of the district is seen truncating near Ranpur town.

Drainage and Morphometric Features:

There are 10 numbers of rivers with their tributaries flowing in this district. Floods, in this district normally occur from June to September due to heavy rainfall in the catchment areas of the rivers and release of water from Hirakud Dam through Mahanadi.

The drainage system of the area can be broadly divided into two groups:

(a) Mahanadi – Burtanga – Kuanria – Kamai – Kusumi drainage systems which is following from south and west to north and north east

(b) Mahanadi and its tributaries forming a drainage system, which flows towards east.

Mahanadi:

The Mahanadi enters this district at Kuturi of Badasilinga G.P. under Gania Block and takes an easterly course along Gania,Khandapara and Bhapur Blocks for about 55 Kms. The portion of its course from Boudh border to Baramul is known as Satakosia Gorge. The river here discharges a large volume of water in narrow channel flanked by high precipitous hills. During the flood, Mahanadi overflows its banks and floods the adjoining G.Ps. of Gania ,Khandapara and Bhapur Blocks.

Brutanga:

River Brutanga a tributary of river Mahanadi rises from the hilly areas of Phulbani and Bhanjanagar and carries large volumes of water to the river Mahanadi. During high flood in river Mahadnadi the flood water of Brutanga River inundates the low lying areas of Gania Block being not discharged to river Mahanadi.

Kusumi:

It rises from Panchabati in Bhanjanagar Sub-Division of Ganjam District and takes its winding course. It meets with Duanta and Dahuka near Khandapara border and flows through Khandapara Tahasil area and merges into Mahanadi near Kantilo. The excess water discharges from Budhabudhiani project combined with water of Duant and Lunijhara also cause flood in Nayagarh Block area.

Malaguni:

This river emanates from the hills of Ranpur Tahasil and takes its winding course and merges in Chilika Lake passing through the areas of Khurda District.

Other Rivers:

Budhabudhiani, Kuanria and Dahuka are other rivers where medium Irrigation projects have been constructed.

The variation in land elevations above MSL is shown in **Fig. 3.1**.The drainage map of the area is shown in **Fig. 3.3.**

Figure-3.1 3-D Elevation Map of Nayagarh District

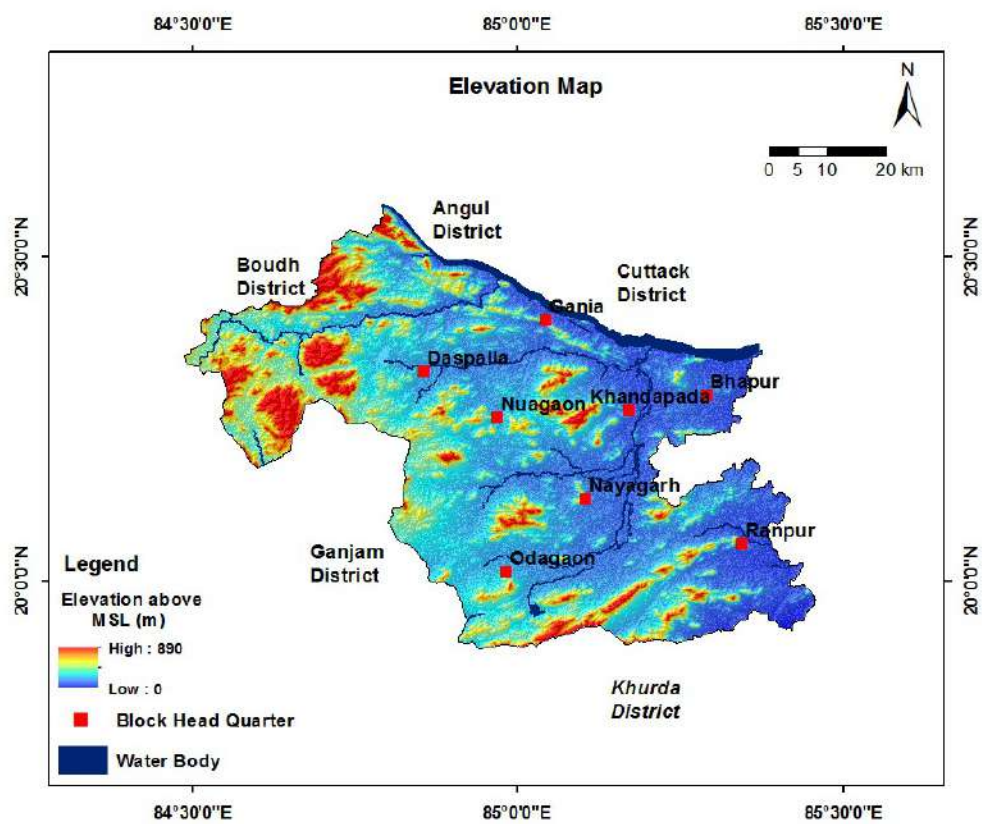


Figure-3.2 Elevation Map of Nayagarh District

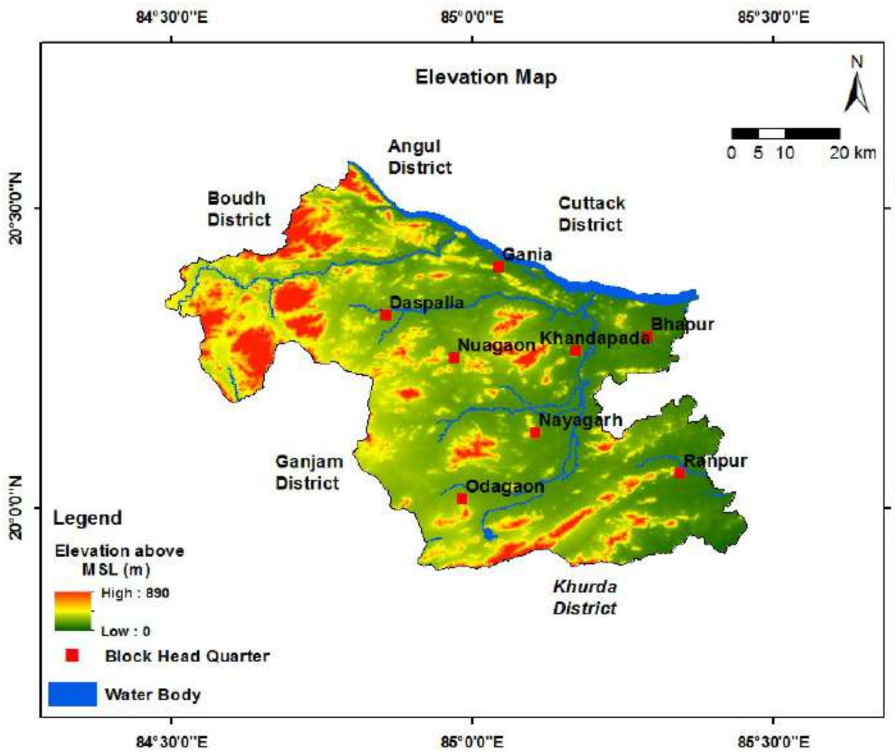


Figure-3.3 Drainage Map of Nayagarh District

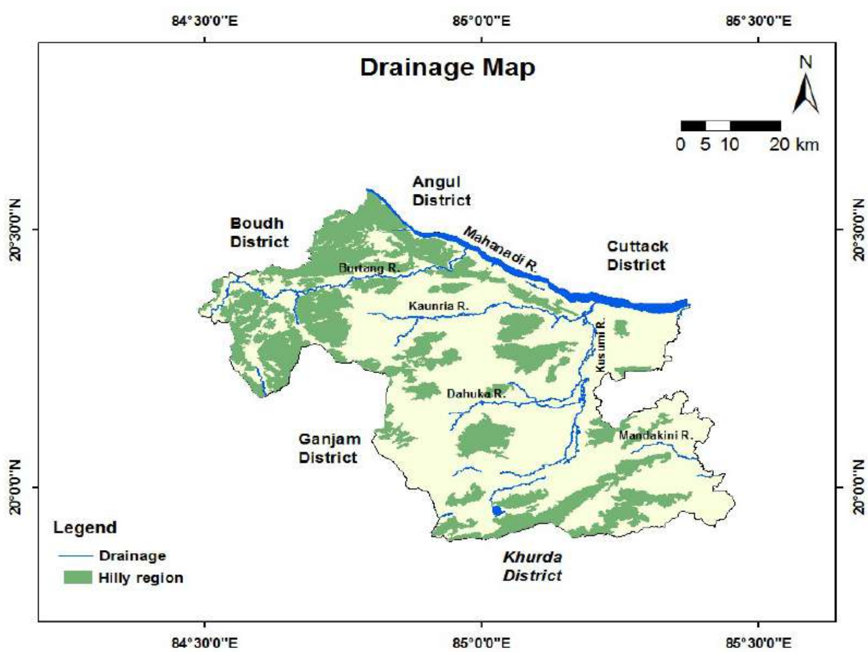


Figure-3.4 Slope Map of Nayagarh District

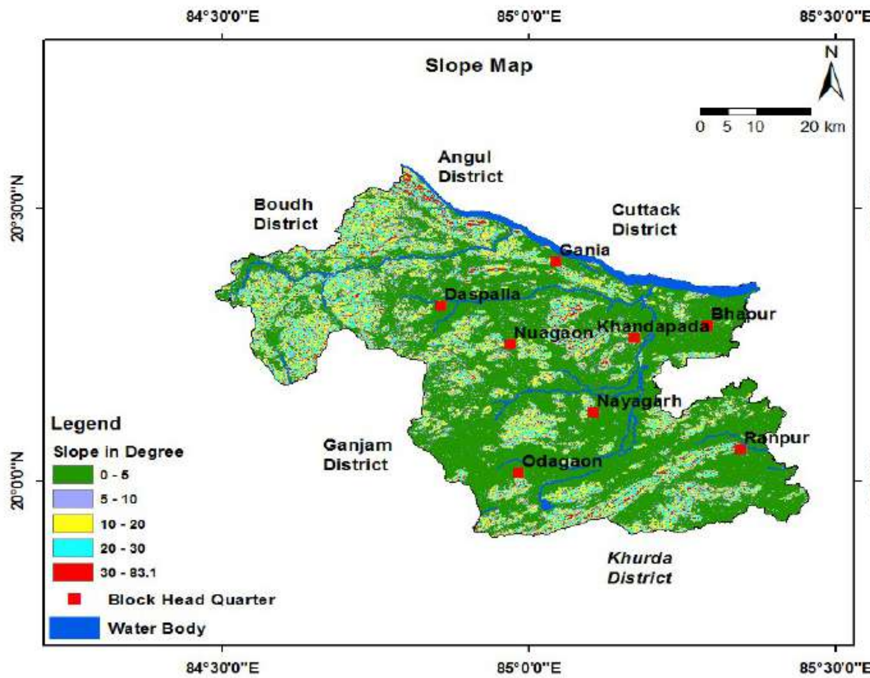
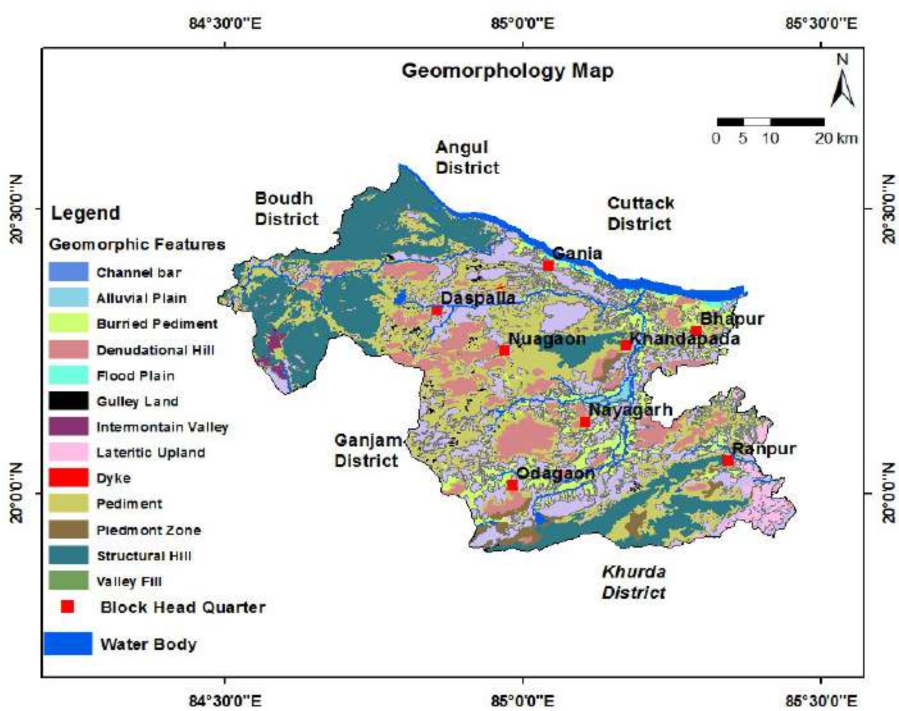


Figure-3.5 Geomorphology Map of Nayagarh District



4. Soil and Land Use

Soil:

Soils are classified by the kind and number of horizons or layers that have developed in them. The horizons are distinguished by texture, kind of minerals present and presence of salts and alkalis.

As per the US soil taxonomy only two soil types namely Vertisol and Ultisol have been found in the study area. The soil orders in US soil taxonomy and their Indian equivalents, which are found in the study area are shown in **Table 4.1**:

Table 4.1 Soil Profile in Nayagarh District

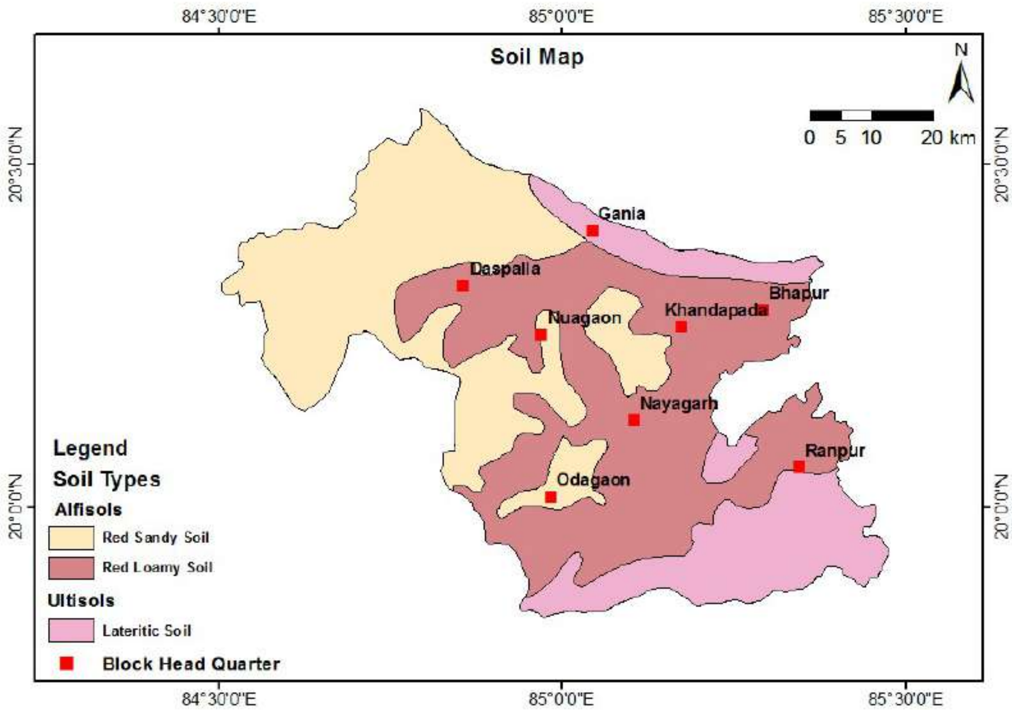
Sl. No.	US soil taxonomy	Indian equivalents
1	Alfisol	Deep black soil
		Red loamy/sandy/gravelly soil
2	Ultisol	Lateritic soil
		Red and yellow soil

Alfisols: These include red gravelly soil, red sandy and red loamy soils. The red sandy soil is having vast aerial extent covering major portions of Daspalla, Nuagaon and Gania blocks. Besides red sandy and loamy soils are also occupying large areas of Nayagarh, Bhapur, Khandapara blocks. This soil is more pervasive and occurs in all blocks. Red gravelly soils are seen only in small parts of Nayagarh, Bhapur and and Ranapur blocks. The red soils are light textured and devoid of lime concretions & carbonates. These soils are generally deficient in nitrogen, phosphate, organic matter and lime. These soils are suitable for the cultivation of paddy and other crops. By the application of proper fertilizers and with good irrigation facility, large variety of crops can be grown in this soil.

Ultisols: These include the laterite and lateritic soils found only in the southern part of the district. These are characterized by a compact to vesicular mass in the sub soil horizon, composed usually a mixture of hydrate oxides of iron and aluminum. Chemically alkaline and alkaline earth metals are absent in this soil. These soils are poor in nitrogen, phosphate, potassium and organic materials with pH ranges from 4.5 to 6.0. Due to its hard nature, cultivation is done immediately after rain.

A considerable portion of the study area is hilly and forest and is mainly confined to Daspalla, Nuagaon and Gania blocks. Agriculture is practiced mainly in the eastern blocks of the district due to good soil and less undulated terrain condition. The soil map of the Nayagarh districts is shown in **Figure. 4.1**

Fig. 4.1 Soil Map of Nayagarh District



Land Utilisation:

Bio-geographically Nayagarh district covers the forest under Nayagarh Division, Khordha Division, Mahanadi Wildlife Division and Kendu Leaf Division of Phulbani (Kandhamal). The Nayagarh Forest Division has 1063.16 sqkm of Forest of which more than 80 percent is reserve forest. Only a small part of the district, i.e.Ranpur forest area comes under Khordha Forest Division. The Mahanadi Wildlife Division covers Baisipalli Wildlife Sanctuary of 166 sqkms. Phulbani Kendu Leaf Division covers Daspalla, Nuagaon, part of Ranpur range.

A considerable portion of the district is covered by hills and forests. The pediment and alluvial areas are used for cultivation. About 36% of the total geographical area of the district is cultivated. Only 21% of the total geographical area is irrigated. The total land of the district is 3,89,000 hectre of which 1,33,540 ha is cultivated and, 208,000 ha is forest covered. The district is covered with hills and forests. The river Mahanadi flows on the north eastern boundary and the small streams like Kuannia, BudhaBudhiani and Dahuka traverse the mid part of the district. **Table 4.2 and Table 4.3** show the distribution of total geographical area for land use and agriculture. The thematic map on land use is shown in **Figure. 4.2**

Fig. 4.2 Land Use Map of Nayagarh District

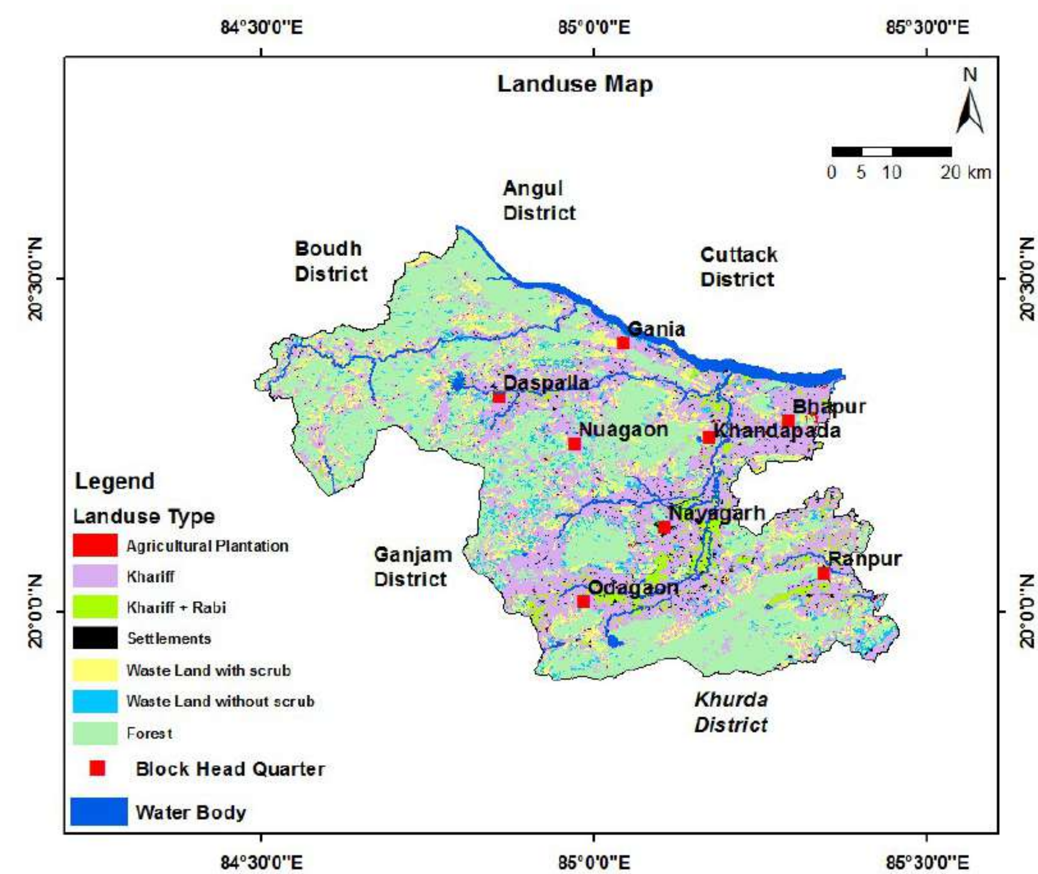


Table: 4.2 Land Utilisation Pattern in Nayagarh District

Land Utilisation Pattern	**Area in Ha**
Geographical Area	389000
Forest Area	190083
Misc. Trees and Grooves	6000
Permanent Pasture	4000
Cultivable Waste	5000
Land under Non-agriculture	25000
Barren and uncultivable	6000
Current Fallow	13000
Other Fallow	1000

Cropping Pattern:

Agriculture is the main occupation of the people in the district. However the hills and forests occupy considerable areas restricting the availability of land for cultivation purposes. The principal crops grown in the district are paddy, maize, barley and other millets, pulses such as red gram, green gram, and black gram, oilseeds such as groundnut, till sunflower, mustard and castor. Sugarcane is the major cash crop grown in irrigated areas. Paddy is the predominant crop. Pulses come next in importance.

District is situated on the hilly ranges in the West and its North Eastern parts have formed small well cultivated fertile valleys intersected by small streams. Out of total geographical area of 3, 89,000 ha, the cultivated area is 1, 38,917 ha with cropping intensity of 166%. In summer most of the agricultural area remains fallow due to non-availability of required amount of irrigation water. The crop wise details shows a total cropping of 1, 33,540 ha in *Kharif* and 92,364 ha in *Rabi* season. Out of which 54,190 ha in *Kharif* and 26,629 ha in *Rabi* are irrigated. An area of 26,786 ha covered under 3 medium irrigation project has assured irrigation in *kharif*, whereas, the rest of the irrigated area i.e. 27,404 ha is under protective irrigation. 79,350 ha are under rainfed cropping.

Table: 4.3 Crop Wise Irrigation Status

Crop Type	Kharif (Area in Ha)			Rabi(Area in Ha)			Total Area in Ha		Horticulture and Plantation Crops (Area in Ha)		
	Irrigated	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Total**
Cereals	46130	57129	103259	720		720	46850	57129			
Coarse Cereals		730	730					5925			
Pulses		10340	10340	7390	63530	70920	7390	73870			
Oil Seeds		4100	4100	1850	2475	4325	1850	6575			
Fibre		735	735					735			
Vegetable	4820	5248	10068	10909		10909	15729	5248			
Sugarcane	3240		3240	4500		4500	7740				
Any Other Crops		1068	1068	1260		1260	1260	1250		142	
District Total	**54190**	**79350**	**133540**	**26629**	**66005**	**92634**	**80819**	**145537**			

Table: 4.4 Block wise Land Utilisation Pattern (Ha)

Sl No	Block	Forest	Land under non Agricultural use	Barren and Non Cultivable land	Permanent Pastures and other grazing land	Land under misc. trees and crops not included in net sown area	Cultivable waste	Old fallows	Current fallows	Net Area Sown
1	Bhapur	1053	5828	2123	380	293	784	428	566	9601
2	Dasapalla	16832	5314	7284	2236	563	1116	4334	5545	11508
3	Gania	3279	3229	3554	397	116	165	1019	1263	2984
4	Khandapara	2542	3446	3043	702	705	1439	1699	454	9412
5	Nayagarh	756	1997	158	528	661	136	266	259	14777
6	Nuagaon	5292	5329	2946	1617	1783	2752	2713	2331	14283
7	Odogaon	4075	3158	2324	1712	720	2091	1256	1210	19441
8	Ranapur	2667	3953	2349	4227	3475	295	2013	856	16087

5. Drainage and Irrigation

Irrigation:

District is situated on the hilly ranges in the West and its North Eastern parts have formed small well cultivated fertile valleys intersected by small streams. Nayagarh district was created in 1993.Previously Nayagarh Subdivision was under Khordha Irrigation Division. This process continued till January, 2015 when Nayagarh Irrigation Division was constituted bifurcating it from the Khordha Irrigation Division. There are three medium irrigation projects in the district. They are Kuanria irrigation project near Daspalla, BudhaBudhiani irrigation project near Sarankul and Dahuka irrigation project near Balugaon. The district has limited irrigation facilities with only 36% of the total cropped area irrigated at present. There is no major irrigation project in the district. Ground water contributes 30% of the total irrigation potential in the district through various ground water abstraction structures. Nayagarh District being situated in Mahanadi and Rusikulya basin has an abundant potential for flow irrigation from different river and tributaries of River Mahanadi. Prominent rivers in Nayagarh district are Mahanadi, Brutang, Kuanria, Dahuka, Kusumi,, Mandakini, Lunijharaa Kamei and Duanto. Though there is no major irrigation project in this district, three medium irrigation projects, viz. Kuanria Irrigation Project, Budhabudhiani Irrigation Project and Dahuka irrigation project are functioning covering an ayacut of 5688 ha, 5540 ha and 2278 ha respectively. Besides the three medium projects, two more proposals are under active consideration; Brutanga Irrigation Project over River Brutanga near Daspalla and a barrage project near Sunanati over river Kusumi. Besides this minor and lift irrigation projects including river lift points are covering an area of 19376 ha and 18167 ha. Though the irrigation potential of most of the minor irrigation projects is very low yet, they have significantly transformed the cropping pattern of the district and economic condition of the people. Pani Panchayat as a facility to provide water to paddy field came in the year 2003. Its duty is to see less loss of water, better irrigation and maintenance of water courses. It intends to help the cultivators. 59 numbers of Pani Panchayats are working in the district. Detais regarding irrigation has been shown in **table 5.1.**The irrigation schemes in the district is given in **table 5.3.**

Figure: 5.1 Drainage Map of the Study Area under NAQUIM

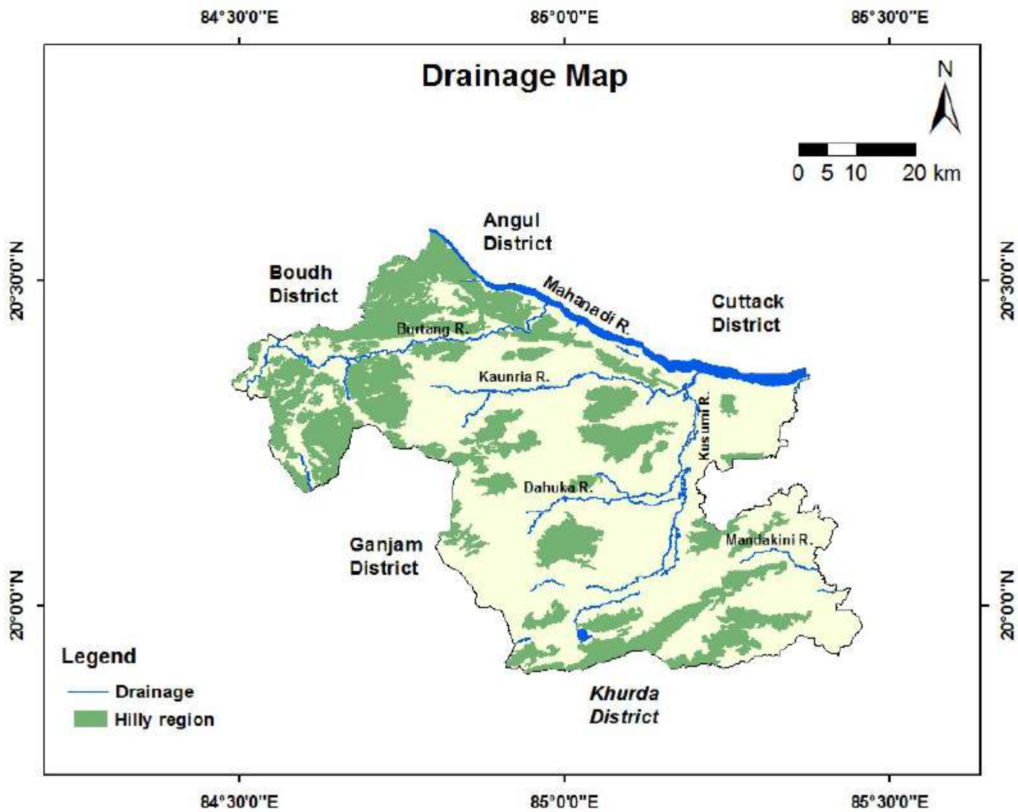


Table: 5.1 Block wise Irrigation Classifications

Sl No	Name of theBlock	Irrigated Area (Ha)		Rainfed Area (Ha)	
		Net Irrigated Area (Kharif)	Net Irrigated Area (Rabi)	Partially Irrigated/Protective Irrigation	Un Irrigated or Totally Rainfed
1	Bhapur	2855	2018		8921
2	Daspalla	8703	3675	4923	13326
3	Gania	1826	1337		6576
4	Khandapada	7925	3874	7740	6733
5	Nayagarh	8267	3989	6174	6716
6	Nuagaon	3996	2595		17317
7	Odogaon	12857	5731	8567	12093
8	Ranapur	7761	3410		13045
	Total	**54190**	**26629**	**27404**	**84723**

Three numbers of medium irrigation projects such as Budhabudhiani, Kuanria and Dahuka are there in the district. Construction of new projects such as Kusumi Barrage Project at Sunalati-Krushnaprasad of Nayagarh block, Dhusuma Barrage Project in Odogaon block and Gunthuni Check dam in Khandapara block have been proposed. Details are given in the table no 5.2 and table 5.3.

Table 5.2 Details of MIPs in Nayagarh District

Sl. No.	District	Name of Project	Type	Ayacut Area (Ha)		
				Kharif	Rabi	Total
1	Nayagarh	Budhabudhiani Irrigation Project	Reservoir	4290	1250	5540
2	Nayagarh	Kuanria Irrigation Project	Reservoir	3780	1908	5688
3	Nayagarh	Dahuka Diversion Weir Project	Diversion Weir	2278	0	2278
	Total			10348	3158	13506

Table 5.3 Details of Additional Potential under proposed projects

Sl. No.	Block	Name of Project	AdditionlIrrigtionPotentil to be Created (in ha)
1	Nayagarh	Kusumi Smart Irrigation Project	3500
2	Odagaon	Dhusuma Barrage Project	400
3	Khandapara	Gunthuni Check Dam	154
4	Nayagarh	Extension of Jadupur minor	300.26

Table: 5.4 Details of Irrigation Schemes in Nayagarh District

Sl No	District	Block	No of villages	Total No of Schemes								
				Ground Water					Surface Water			Grand Total
				Dug Well	Shallow Tubewell	Medium Tubewell	Deep Tubewell	Total	Surface flow scheme	Surface lift scheme	Total	
1	Nayagarh	Bhapur	119	874	1	1	3	879	1	1	2	881
2	Nayagarh	Dasapalla	416	1301	2	0	0	1303	11	13	24	1327
3	Nayagarh	Gania	114	578	12	3	0	593	26	3	29	622
4	Nayagarh	Khandapara	196	1060	43	4	1	1108	6	44	50	1158
5	Nayagarh	Nayagarh	149	912	61	163	12	1148	10	48	58	1206
6	Nayagarh	Nuagaon	232	1237	5	64	3	1309	56	30	86	1395
7	Nayagarh	Odagaon	220	820	27	33	6	886	71	70	141	1027
8	Nayagarh	Ranpur	249	1509	23	43	20	1595	90	334	424	2019
Total			1695	8291	174	311	45	8821	271	543	814	9635

Table 5.5 Source wise Irrigation Potential in Nayagarh District

Sl No	Block	Medium Irrigation		Minor Irrigation(ha)		Lift Irrigation(ha)		Water bodies including RWH structures(ha)		Total surface water(ha)		Open well(ha)		Deep Tube well(ha)		Shalow Tube well(ha)		Total Ground water(ha)	
		Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
1	Bhapur	0	0	383	0	1180	1072	1030	684	2593	1756	154	154	73	73	35	35	262	262
2	Dasapalla	3780	1500	2280	243	568	560	1730	955	8286	3258	348	348	69	69	0	0	417	417
3	Gania	0	0	458	243	580	528	647	425	1685	1196	130	130	11	11	0	0	141	141
4	Khandapar a	185	0	3808	810	1992	1737	1293	680	7278	3227	133	133	360	360	154	154	647	647
5	Nayagarh	2093	0	2368	264	976	1050	895	740	6332	2054	779	779	461	461	695	695	1935	1935
6	Nuagaon	0	0	823	41	1110	1004	1289	776	3222	1821	596	596	128	128	50	50	774	774
7	Odogaon	4290	1000	3556	116	1559	1443	1505	1225	10910	3784	1228	1228	345	345	374	374	1947	1947
8	Ranapur	0	0	4055	0	1454	1354	1458	1262	6967	2616	621	621	130	130	43	43	794	794
	total	10348	2550	17659	171 7	9419	8748	9847	6747	47273	19712	3989	3989	1577	1577	1351	1351	6917	6917

Table 5.6 Source wise Irrigation Structures in Nayagarh District

Sl No	Block	Surface Irrigation					Ground Water						Other sources including traditional WHS	Total
		Canal based		Tanks/Ponds/Reservoirs			Tube wells		Open wells		Bore wells			
		Govt.	Pvt.	Community ponds	Individual ponds	Govt. Reservoirs/Dams	Govt.	Pvt.	Govt.	Pvt.	Govt.	Pvt.		
1	Bhapur	6	0	0	0	45	0	30	0	154	0	71		306
2	Dasapalla	24	0	0	0	28	0	0	0	348	0	69		461
3	Gania	9	0	0	0	21	0	0	0	130	0	11		171
4	Khandapara	14	0	0	0	94	0	144	0	133	0	362		747
5	Nayagarh	26	0	0	0	58	0	680	0	779	0	455	2	2000
6	Nuagaon	19	0	0	0	59	0	45	0	596	0	132	0	851
7	Odogaon	27	0	0	0	68	0	364	0	1228	0	392	8	2097
8	Ranapur	34	0	0	0	62	0	37	0	621	0	229	9	992
	Total	159	0	0	0	435	0	1300	0	3989	0	1721	29	7633

6. Geology

Major part of the study area is underlain crystalline rocks of archaean age. Recent alluvium occurs as narrow discontinuous patches forming the valley fills and flood plains of Dahuka, Kusumi, Kaunria, Burtang and Mahanadi rivers. Laterites occur as capping over the crystalline rocks and are abundant in the eastern and south-eastern part of the district. The generalized stratigraphic sequence is given below:

Table 6.1: **Generalized Stratigraphic Sequence in Nayagarh District**

Group/Formation	**Lithology**	**Age**
Recent	Alluvium	Sand, silt, clay, pebble & boulder in varying proportions Laterite and Lateritic gravels
---Unconformity---		
Archaeans	Granitic Suite	Pegmatite & Quartz veins Porphyroblastic granite gneiss Biotite granite Garnetiferous granite gneiss
	Charnockite Suite	Hypersthene granite & gneiss Pyroxene granulite Amphibolite
	Khondalite Suite	Quartz-feldspar-garnet-sillimanite-schist & gneiss Garnetiferous quartzite Calc-silicates

Khondalite Suite: This suite of rocks consists mainly of quartz-garnet-sillimanite-graphite-schist and gneisses, garnetiferous quartzite and calc-silicate rocks which generally form steep hills. Khondalites are grayish to reddish brown in colour containing garnet and flakes of graphite. The calc silicate rocks are light grey to white in colour, fine grained and compact. The Khondalite suite of rocks is less dominant in the area than the granitic suite of rocks. Khondalites are mainly exposed in the eastern and south eastern tracts of the district.

Charnockite Suite: These suites of rocks consist of hypersthene granite and gneisses, pyroxene granulites, amphibolite. Hypersthene granites are fine to medium grained, light grey to gray in colour, hard and compact. Amphibolites occur in places as inclusion in garnetiferous granite gneiss and dark coloured, medium grained having incipient schistocity. Pyroxene granulites are dark coloured and medium grained, occur as bands, lenses in acid charnockites. This suite has limited extent, generally exposed in the western part of the district and are shown along with khondalites.

Granitic Suite: This suite consists of variants of granites and granite gneisses and is the most predominant rock type in the district. These rocks form both high hill ranges and also undulating plains (pediments). The granitic rocks are also seen to form structural, residual and denudational hills and are also present as domal mounds. They are generally gray to light gray in colour and medium to coarse grained.

Pegmatites and quartz veins: The older archaean country rocks are intruded by numerous veins of quartz and pegmatites. Pegmatites are usually coarse grained, comprising mainly of quartz, feldspar and mica. Quartz veins generally intruded the country rock along the fracture planes.

Laterites and lateritic gravels: Laterite occurs as thin and discontinuous capping over the older formations. These are ferruginous in character and highly porous in nature. The thickness of laterite usually varies from 3 to 15 meter. These are generally seen in the south eastern and eastern parts of the district especially in Ranpur and Nayagarh and Odogaon blocks.

Alluvium and valley fills: Recent alluvium occurs in the flood plains and as channel fills forming discontinuous patches along the courses of the Duant, Dahuka, Kusumi, Kaunria and Burtang and along the Mahanadi River. The alluvium comprises sand, silt and clay layers of varying thickness. The valley fill sediments consist of sand, silt, clay, pebble, and boulder.

Structure: The area is a part of the Eastern Ghats orogenic province. Among the structural elements joints/fractures and foliations form the prominent conduits for ground water movement. The structures generally trend NE-SW(Eastern Ghat Trend) with a dip varying from 70° to 80° towards east. The trend of foliations sometimes veers to E-W, dipping toward north. Four sets of joints are generally encountered in the area trending N-W, E-W, NE-SW and NW-SE with dips varying from 60° to near vertical. The joint opening varies from 1 to 1.5cm. The fracture opening dies out with depth. Geology of the study area is shown in figure 6.1.

Figure: 6.1 Geological Map of Nayagarh District

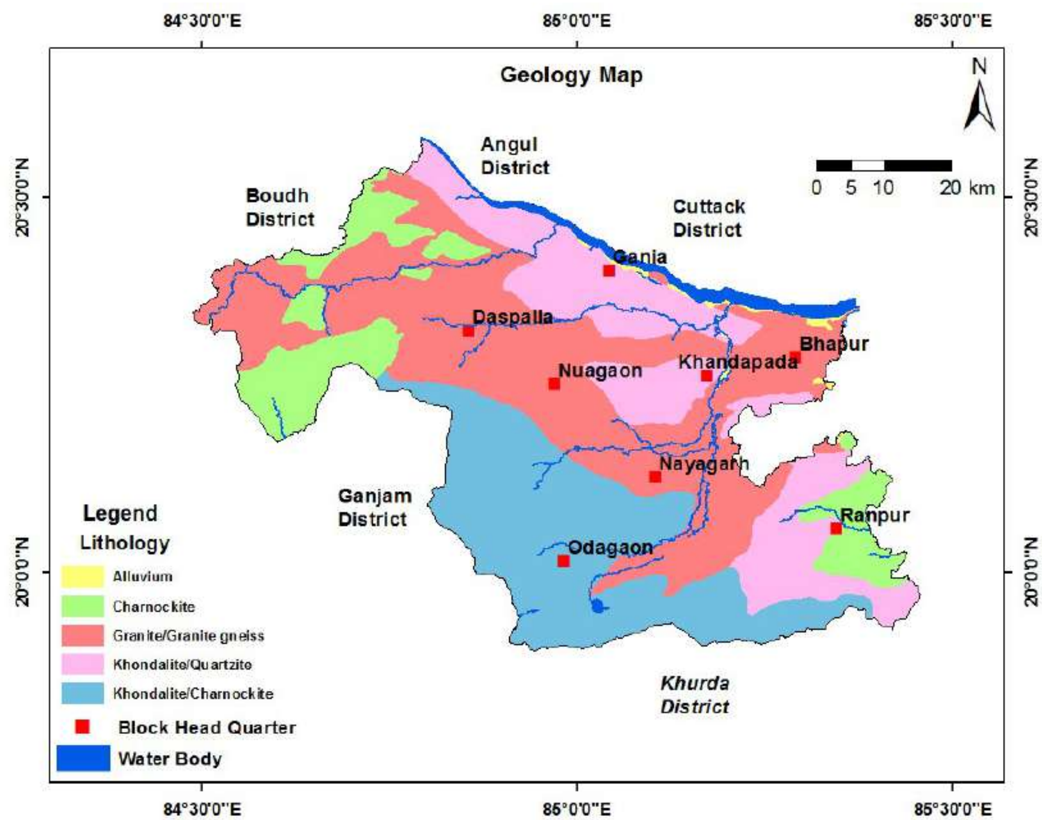
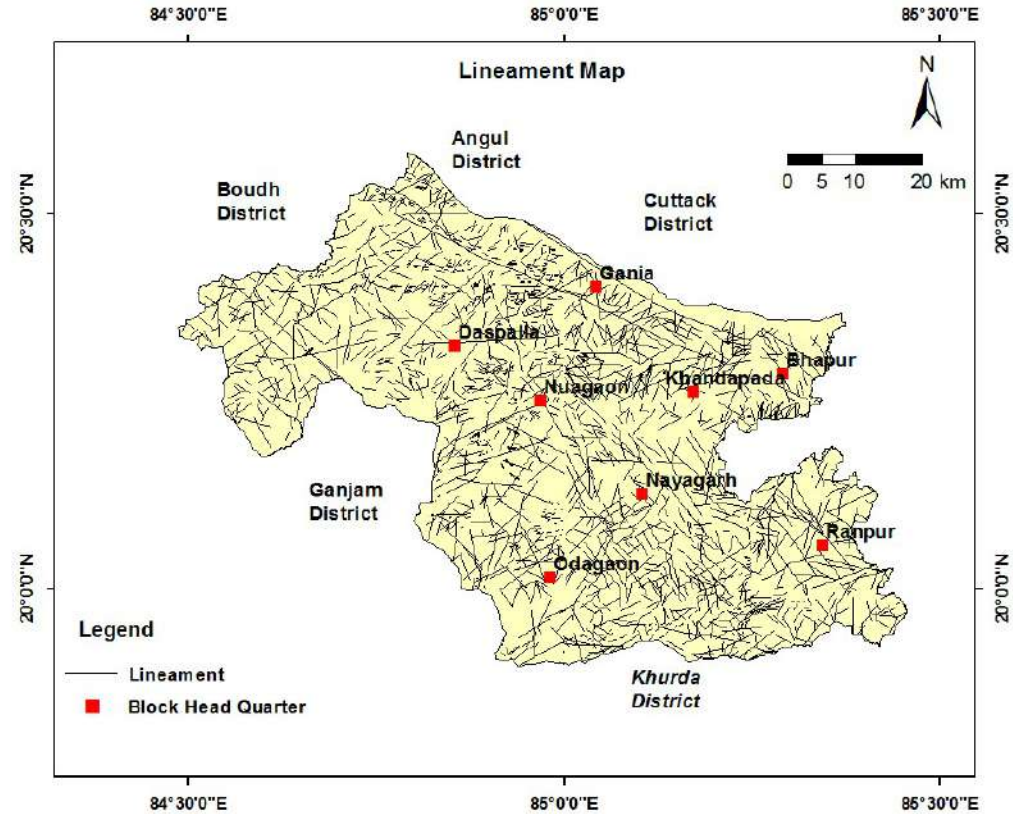


Figure: 6.2 Lineament Map of Study Area



7. Hydrogeology

Ground water occurrence

The geological set up and geomorphology play a dominant role over the occurrence and movement of ground water in an area. The archaean crystallines crop out in the major part of in the form of weathered pediments with ridges, scarps, tors, isolated hills and mounds. These archaean crystallines are devoid of primary porosity except when weathered and fractured. Alluvium and valley fills deposits of recent and sub-recent age occur in small patches along with main rivers and stream courses. Based on water bearing and water yielding characteristics of the rock groups, the district can be broadly sub-divided into two hydrogeological units.

1. Areas underlain by consolidated formation
2. Areas underlain by unconsolidated formation

Consolidated formation

The consolidated formations comprise mainly granites and granitic gneisses, khondalite and charnockites. These hard crystalline rocks do not possess primary porosity. However these formations are capable of holding and transmitting water through the secondary pore spaces developed by fracturing and weathering. The hydrogeological properties of the weathered mantle of the crystalline rocks vary considerably depending on the nature of the weathered material and degree of weathering. In these rocks ground water generally occurs under water table to semi-confined condition and circulates through the underlying joints and fractures. Such joints at places open in the intermontane valleys or notches on hill slopes giving rise to springs.

Water bearing properties of the major Litho Units:-

Granite and granite gneisses: The granites and granite gneisses occupying the undulating plains (Pediment areas) form the most potential aquifers in the hard rock terrain. They are very much prone to weathering except on high hills and produces porous and permeable weathered mass rich in kaolin and quartz. The porphyroblastic granite gneisses form comparatively thicker weathered mantle than its other variants. These rocks are generally well jointed and fractured and hence giving rise to deep weathered zones. The weathered and fractured mantle serves as good pheratic aquifer, where ground water remains under unconfined condition. This weathered residuum is generally shallow on hill slopes and deep to very deep in pediment and buried pediment areas with thickness varying between 10 to 30 meters & more than 40m weathering in parts of Ranapur blocks. This aquifer is commonly being exploited by means of dug wells. The dug wells with yield 30 to 50 m^3/day can be extracted from deep large diameter dug wells. However it was found that dug wells are not penetrated to the optimum weathering depth that is why giving a maximum yield upto 10 – 15 cubm/day. Bore wells are also productive in these formations, but high discharge is only obtained in specific locations which are underlain by deep and productive fractures. Drilling carried out at Bhapur, Kantilo & Baunsiapada sites shows the presence of good and productive fractures within 100 meter of depth with discharges varying from 3 to 14 lps.

Khondalite and Charnockite: These formations are generally exposed in the north-western and central hilly tracts of the study area are generally massive with weathering not so pronounced. Joints and fractures are also not well developed. The thickness of the weathered residuum varies from 10 to 20 meters. Dug wells are the common ground water abstraction structures feasible in these formations. These formations are generally devoid of deeper fractures and hence bore wells are not feasible in these formations. The maximum yield from deeper aquifer is limited to 2 lps.

Khondalite: Khondalite generally form high hill ranges, although they also occur in the undulating pediment areas in the east. Joints and fractures are moderately well developed in khondaliteswhere asshistosity is the main planar structure in this rock unit. Because of high foliated nature, weathering is generally pronounced in these rocks. Dug wells can yield from 10 to 30 m^3/day. However due to non penetration of the entire aquifer in the region, it was found from the field visit and pumping test that the maximum yield of the dug wells vary from 5-10 m^3/day. The bore well data of the Nayagarh Sugar Factory indicates that the potential fracture zone occurs in the depth range of 27 to 87 m and the yield of bore wells varies from 1.5 to 5 lps. Dug cum bore wells in these hydrogeological units may yield up to 5 lps under favourable hydrogeological condition.

Unconsolidated formation

Alluvium: The alluvial strip along the Dahuka, Kusumi, Kamai and Mahanadi rivers & southern parts of the study area mainly in Ranapur block constitute the most potential aquifers in the study area due to their high porosity and permeability. The alluvium consists of sand, gravel, silt and clay and their admixture in varied proportions. From the drilling data of the tube-wells drilled by Orissa lift Irrigation Corporation (OLIC) in the flood plains of Dahuka and Kusumi river, it is observed that the alluvial thickness extends down to a depth of 45 meters. A cumulative thickness of 5 to 15 meters of saturated granular zones has been encountered. The water level is shallow and the yield varies from 5 to 15 liters/ second.

Valley fill deposits: The valley fill deposits of Kuanria, Burtunga, kusumi & Dahuka rivers consists of an admixture of sand, silt, clay, gravel and boulder. At places the presence of good granular zones proves to be highly potential for ground water extraction. Generally the thickness of these deposits restricted to 15 meters of depth. Dug wells are the most feasible ground water abstraction structure with yield varies from 3 to 5 liters/second.

Figure: 7.1 Hydrogeological Map of Nayagarh District

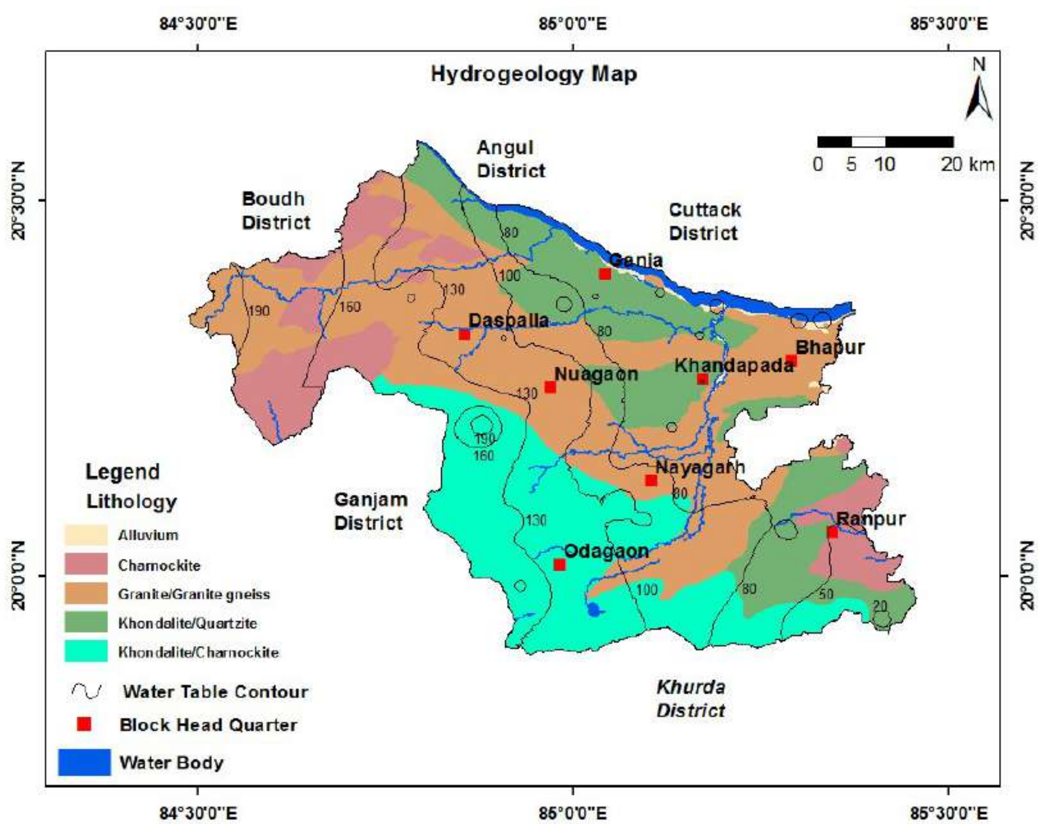
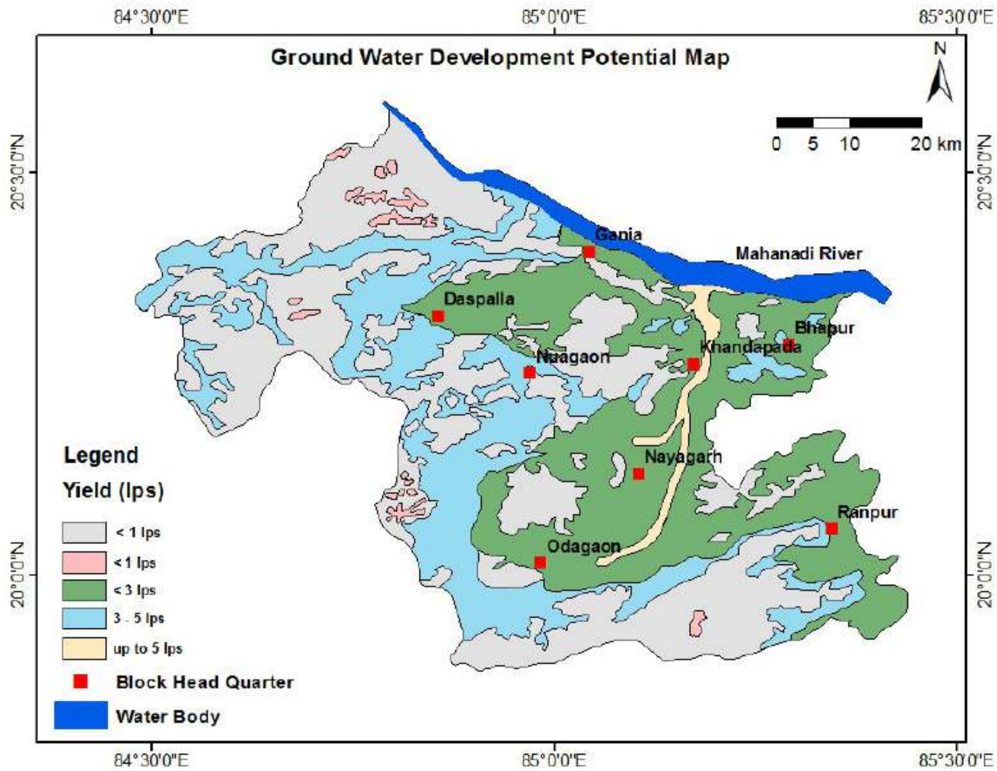


Figure: 7.2 Ground Water Development Potential Map of Nayagarh District



8. Ground Water Exploration

The Nayagarh district occupies the central part of eastern Orissa and is underlain by hard rocks which include khondalite-charnockite suit of rocks and granitic rocks. The granitic rocks are most extensive and occur as both the garnetiferous and non-garnetiferous varieties. Thekhondalites generally form hills and ridges.

A total of 20 exploratory and 6 observation wells were drilled in the district. The depth of these wells varied from 56.40 to 200.37m and the yield varied from negligible to 13.5 lps. One to three sets of saturated fractures were encountered and in the majority of the cases fractures were found to restrict within 100m depth. The deeper (>100m) saturated fractures are mostly found to be low yielding. The static water levels vary from 1.92 to 12.67m below ground level. The drawdowns are generally restricted within 20m. The moderately high discharge wells are located at Madhyakhand (4 lps), Gania (3.5 lps), Kantilo (7.2 lps), Khedpada (5.25 lps). The high yielding well is located at Bhapur (13.5 lps). It is noted that the northern part of the district along Madhekhand-Gania- Kantilo – Bhapur area potential saturated fractures occur. In other parts the yield is generally low.

Aquifer Characteristics:

Phreatic Aquifer

The pumping tests were conducted on selected dugwells representing different hydrogeological units and the aquifer characteristics was evaluated in terms of Specific Capacity Index i.e. flow of ground water per metre depression of head over unit cross sectional area of inflow offered by the aquifer. The **Table-8.1** summarises the aquifer characteristics of the phreatic aquifers. The wide range of yield and specific capacity is due to very much heterogeneous nature of the weathered zone in lateral extension as well as variation of thickness of this zone.

Deeper Aquifer

Unlike phreatic aquifer, ground water occurs under confined to semi-confined condition in the deeper aquifer. The deeper aquifer comprises of the jointed and fractured consolidated or crystalline formations. In general it's confined on top by weathered formations and bottom by massive rocks. Generally 1 to 4 potential fracture zones are encountered within the depth range of 200 m. The first promising zone occurs in the depth range of 15 to 35 m., which is just below the zone of weathering. The depth range of prime importance is from 40 to 100 m. Normallythe fracture zones in this depth range have high water yielding capacities and majority of successful bore wells in the study area tapped zones within this depth range. The other potential fracture zones are found at the depth ranges of 40-65, 70-75, 95-115, 135-155 and 170-195 mbgl. Granite suites rocks have more promising aquifers in comparison to other rocks like Charnockites and Khondalites. However the success of bore wells is site specific and depends on topographic and hydrogeological conditions.The details of the exploratory wells are given in **Table-8.2.**

Table-8.1: Aquifer Characteristics of Major Hydrogeological Units in Nayagarh District

Sl. No	Hydrogeological Unit	Specific Capacity Index
1	Weathered Granite Gneiss	0.50 to 4
2	Weathered Charnockite	1 to 3
3	Khondalites	0.80 to 4
5	Valley Fills	3.0 to 40.0
6	Alluvium	4 to 9

Figure: 8.1 Locations of Exploratory Wells drilled by CGWB in Nayagarh District

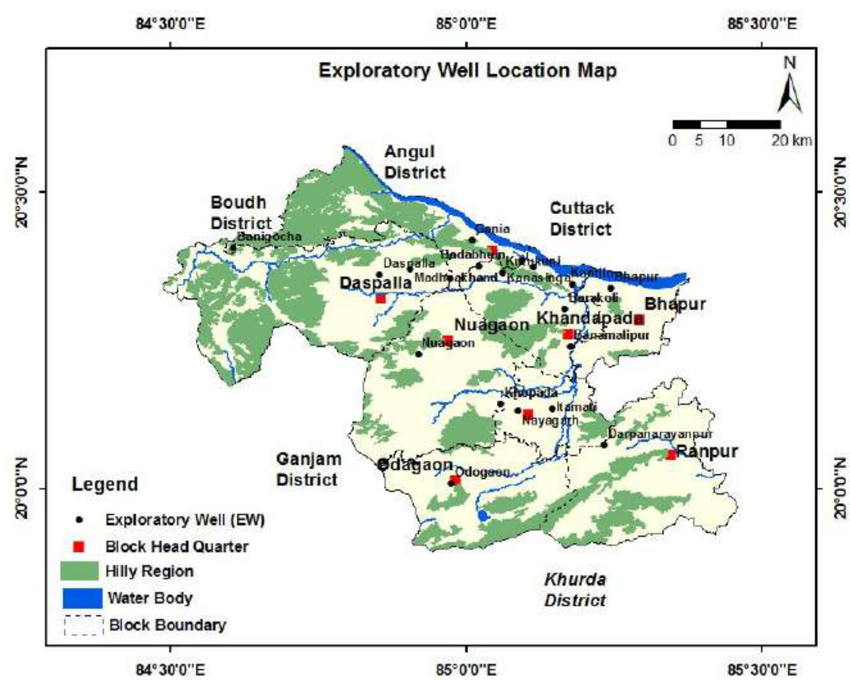


Figure: 8.2 Yield Map of the Fractured Aquifer in the Study Area

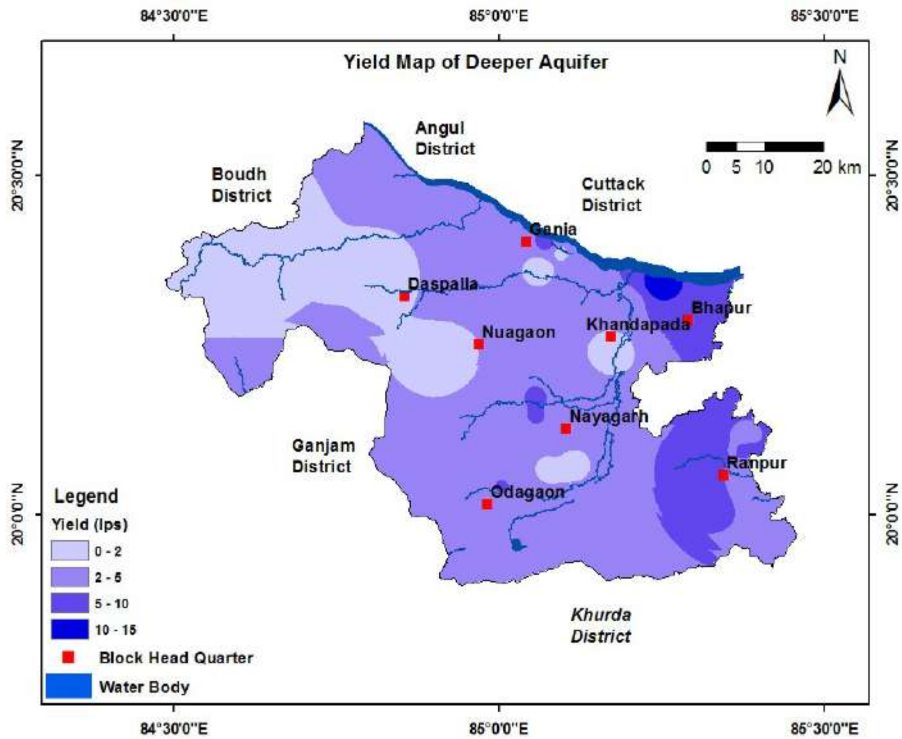


Figure: 8.3 Depth to Water Level in Fractured aquifer during Pre Monsoon

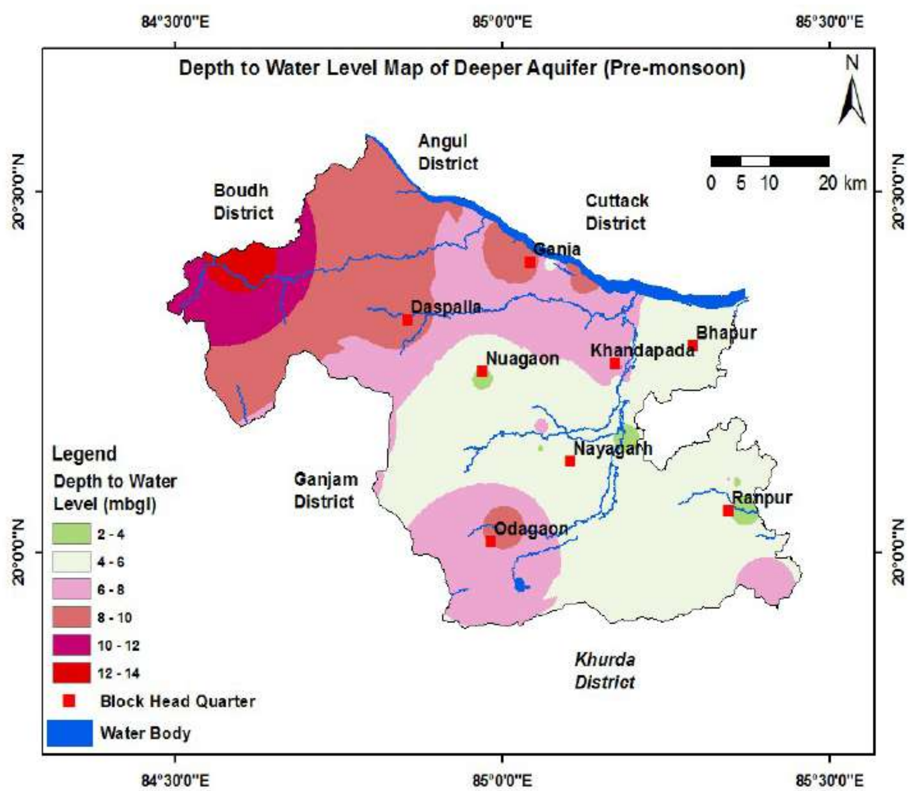


Figure: 8.4 Depth to Water Level in Fractured aquifer during Post Monsoon

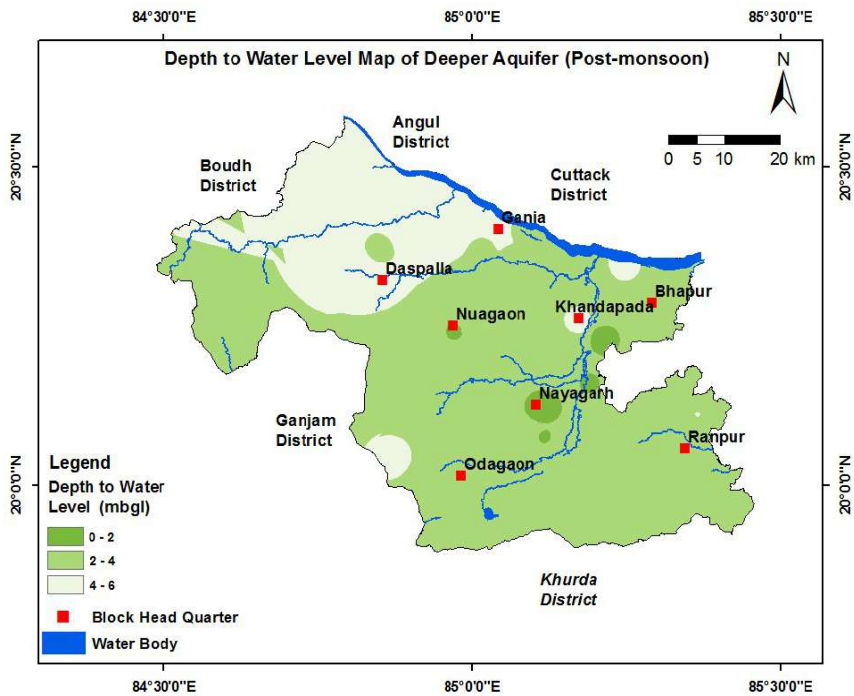


Figure: 8.5 Seasonal Fluctuation in Water Level in Fractured aquifer

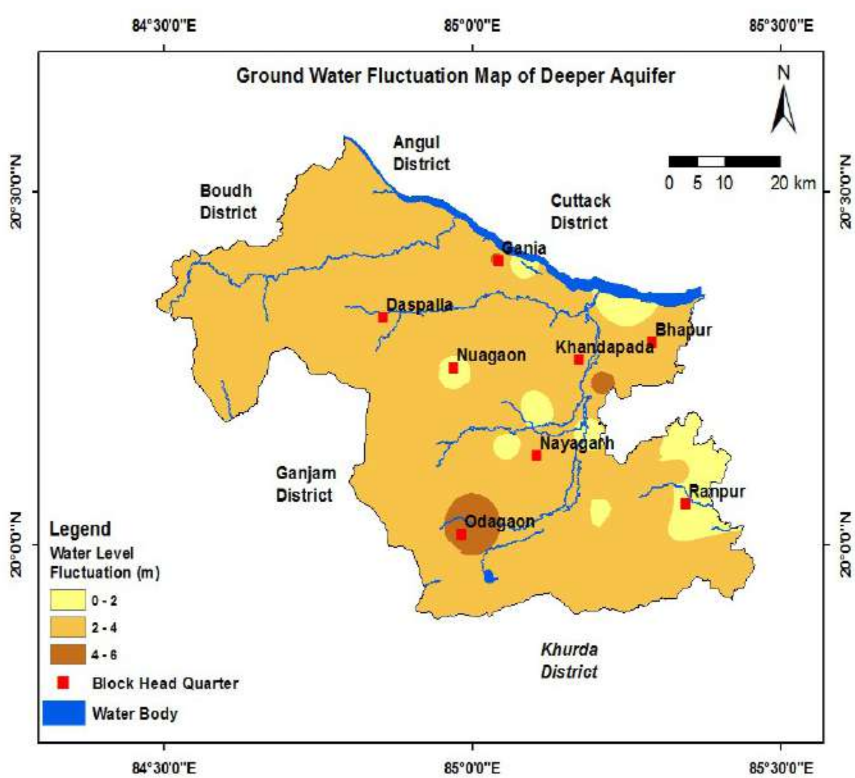


Table 8.2 Basic Data of Exploratory Wells Drilled by CGWB in Nayagarh District

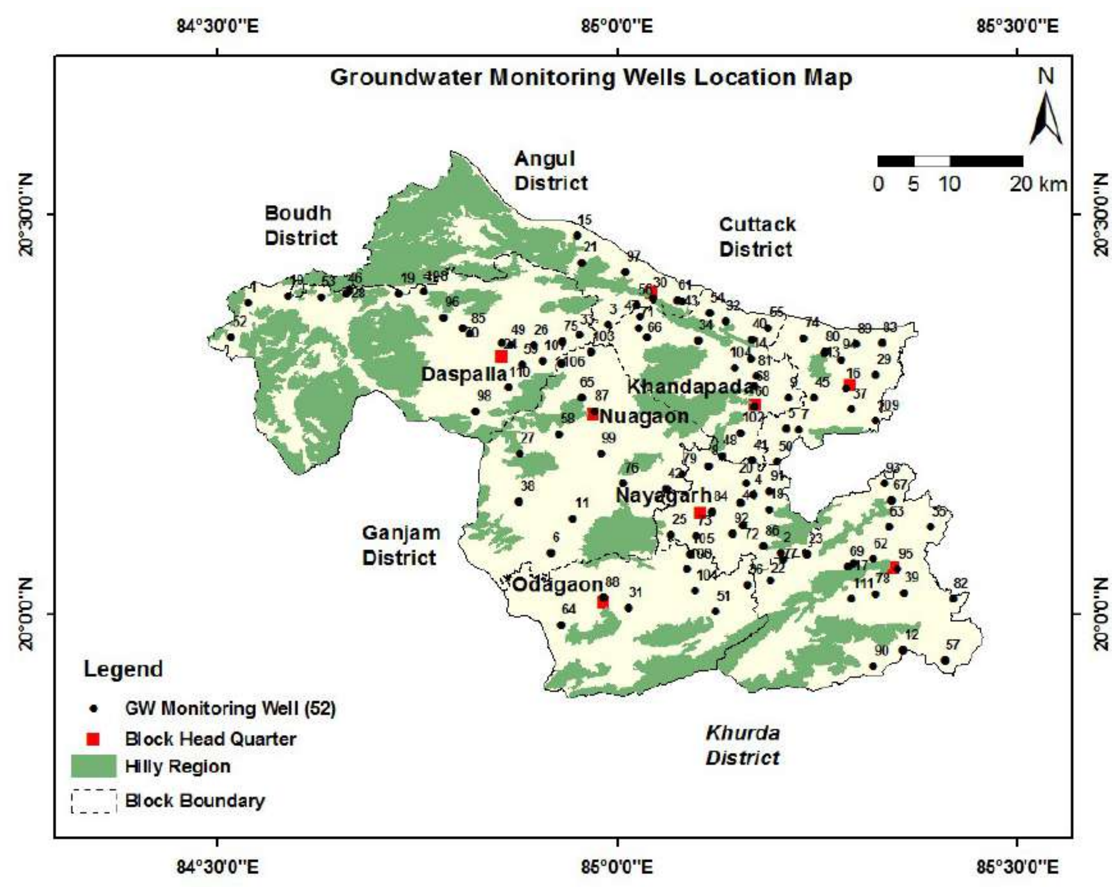
Sr.No	District	Block	Location	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing Depth(mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Discharge (lps)	Drawdown (m)
1	**Nayagarh**	Nayagarh	Nayagarh	20.0676	85.0742	182.50	Granite gneiss	29.88	153	3.48	1.50	
2	**Nayagarh**	Khandapara	Banamalipur	20.2413	85.1757	196.70	Granite gneiss	10.87		5.75	0.2	
3	**Nayagarh**	Nuagaon	Nuagaon	20.2288	84.9205	185.70	Granite gneiss	10.94		2.20	0.5	
4	**Nayagarh**	Gania	Gania	20.4211	85.0108	200.37	Granite gneiss	19.50	21,99,149	4.20	3.5	17.2
5	**Nayagarh**	Daspalla	Madhyakhand	20.3724	84.9053	193.80	Granite gneiss	12.20	78	4.5	4.0	19.5
6	**Nayagarh**	Daspalla	Madhyakhand	20.3724	84.9053	79.80	Granite gneiss	9.88	76	4.40	4.2	
7	**Nayagarh**	Daspalla	Kantilo	20.4012	85.0739	176.80	Granite gneiss	18.95	19,40,50	3.60	6.00	
8	**Nayagarh**	Daspalla	Kantilo	20.4012	85.0739	76.75	Granetiferous Gr. gneiss	12.90	40.25, 51.45,65.65	4.90	7.20	
9	**Nayagarh**	Khandapada	Khepada	20.1451	85.0584	158.10	Granetiferous Gr. gneiss	25.9	78,102	2.92	4.75	
10	**Nayagarh**	Nayagarh	Khedpada			154.0	Granetiferous Gr. gneiss	28.0	7,81,33,142	2.60	5.25	
11	**Nayagarh**	Daspalla	Daspalla	20.3624	84.8543	190.60	Granetiferous Gr. gneiss	22.60		3.59	0.50	
12	**Nayagarh**	Daspalla	Banigocha	20.4074	84.6073	166.20	garnetiferrous Gr. gneiss &Charnockit	21.37	63, 104	12.67	1.0	

Sr.No	District	Block	Location	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Casing Depth(mbgl)	Aquifer zones tapped (mbgl)	SWL (mbgl)	Discharge (lps)	Drawdown (m)
							e					
13	**Nayagarh**	Odogaon	Odogaon	20.0102	84.9750	166.20	Pink Granite &charnockite	18.0	39,53,60.5	2.20	2.02	
14	**Nayagarh**	Nayagarh	Itamati	20.0751	85.1161	160.30	Charnockite & Gr. gneiss	22.66	24.8, 44.9	1.92	1.50	24.86
15	**Nayagarh**	Bhapur	Bhapur	20.3399	85.2450	56.40	Khondalite (leucocratic Granite)	16.02	15.8, 18.8,27.0, 35.1, 40.2, 46.3	5.38	13.50	
16	**Nayagarh**	Bhapur	Bhapur	20.3399	85.2450	180.5	Highly altered Granite	16.30	50.5	4.70	2	
17	**Nayagarh**	Khandapada	Barakoli	20.3046	85.1675	200	Granite	19				
18	**Nayagarh**	Khandapada	Sidhamula	20.3976	85.1151	200	Granite	30	35-36	10.2	0.5	
19	**Nayagarh**	Khandapada	Sidhamula	20.3976	85.1151	191	Granite	25				
20	**Nayagarh**	Khandapada	Kanasinga	20.3754	85.1136	200	Granite	7				
21	**Nayagarh**	Khandapada	Badabhuin	20.3767	85.0213	200	Granite	21	22-23	3.7	5.54	14.86
22	**Nayagarh**	Khandapada	Badabhuin	20.3767	85.0213	151	Granite	19	27-28	3.5	4.36	
23	**Nayagarh**	Khandapada	Kutukuni	20.3659	85.0617	171	Granite	10.65	99-100	3.9	0.5	
24	**Nayagarh**	Gania	Khalisara	20.3872	85.0940	200	Granite	21.1	23-24	7.4	1.2	
25	**Nayagarh**	Khandapada	Gokulanandapitha	20.3988	85.1156	125	Granite	13	17-18	9	2.5	
26	**Nayagarh**	Gania	Paturia	20.4025	85.0960	172.5	Granite	16.4				

9. Ground Water Monitoring

The nature of occurrence and movement of ground water were studied through ground water monitoring wells during pre-monsoon and post-monsoon period. Under NAQUIM, the ground water regime of the phreatic aquifer was monitored during pre- and post-monsoon periods in 2020-21 in 41 National Hydrograph Network Stations (NHNS) and 70 Key Observation wells (dug wells). The details of the monitoring wells are shown in **Table 9.1** and the locations of the monitoring stations are shown in **Fig. 9.1**. The chemical quality of ground water in the district is monitored annually on a routine basis by CGWB through its National Hydrograph Network Stations. During the NAQUIM programme, 127 water samples were collected and results of their chemical analysis is given in **Table 11.2 and 11.3.**

Figure: 9.1 Locations of Ground Water Monitoring Stations in Nayagarh District



9.1 Shallow Aquifer

Ground water occurs in phreatic condition in shallow aquifers and is utilized by means of dug wells or shallow tube wells. The depth of the dug wells used as observation points vary from 5.7 to 15.2 mbgl and their diameter ranges from 0.7 m to4.00 m. The wells are generally lined to the total depth.

9.1.1 Pre monsoon depth to Water level

Depth to water level in pre-monsoon period (May 2020) varies from 1.2mbgl to 10.8mbgl the average being 4.97 m bgl. In general, the study area has the depth to water level in between 3 to 7 mbgl during the pre-monsoon. Water logging conditions found nowhere during the pre-monsoon. Shallower water level of 0-4mbgl is observed in some parts of Khandapara and Nuagaon block and in some isolated patches of Nayagarh, Bhapur, Ranpur, Gania and Dasapalla blocks. Deeper water levels (>6mbgl) are found mostly in Dasapallablock and in patches of Odogaon, Ranpur and Bhapur block. The locations where the depth to water level is more than 8 m bgl are Banamalipur (8.5), Khandapada(8.5) in Khandapada block and Gadavanivalo (9.4), Krishnachandrapur (9.45) in Ranpur block, Sakini(9.0), Buguda (10.80) in Dasapalla block. The pre-monsoon depth to water level map is shown in **Fig. 9.2(A)** and water table contour map is shown in **Fig. 9.2(B)**

Figure: 9.2(A)Depth to Water Level in Phreatic Aquifer during Pre monsoon

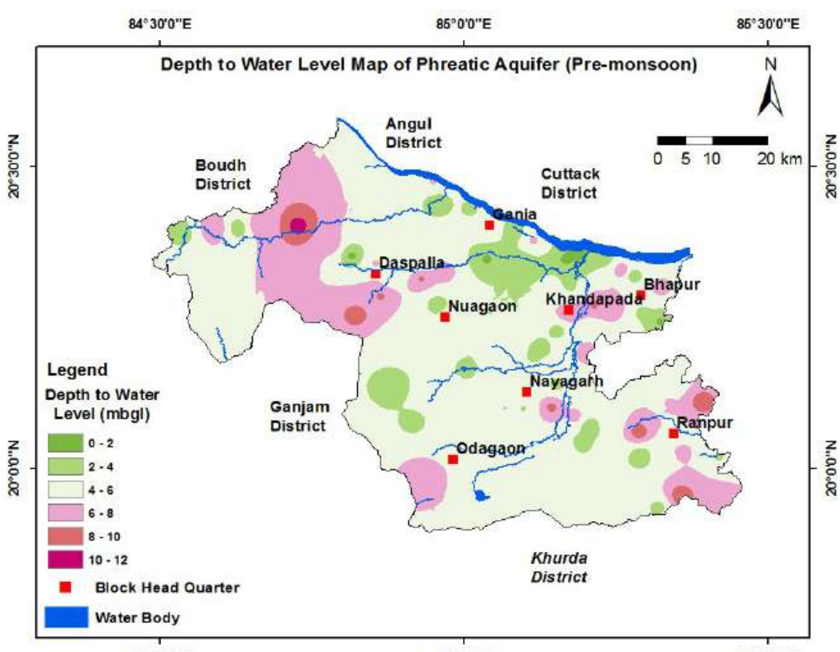
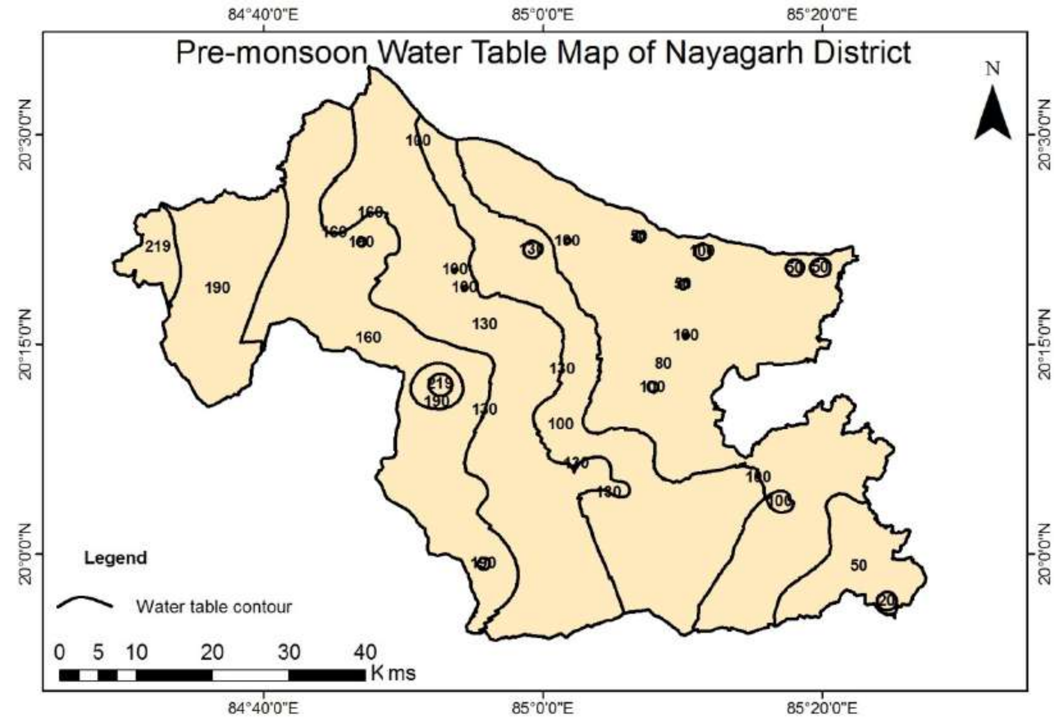


Figure: 9.2(B)Water Table Contour Map of Phreatic Aquifer during Pre monsoon



9.1.2 Post monsoon depth to Water level

Depth to water level in post-monsoon period (Nov 2020) varies from 0.3 mbgl (Kuanria) to 6.9 (Buguda) mbgl, the average being 2.12 m bgl. The depth to water level of the study area during Nov 2020 is in general within 3 mbgl. The areas where water level is less than 2 mbgl are found mostly in Khandapada, Nayagarh and Ranpur block. Almost the entire district shows a shallow water level (<4 mbgl) during post monsoon except few isolated patches in Dasapalla, Odogaon and Ranpur blocks. The locations where the depth to water level is more than 4.5 m bgl are Soroda (4.85), Subalaya (4.97), Takara (5.15) in Dasapalla block and Tarabalo (5.6) in Bhapur block and Yosodapur (6.9mbgl) in Ranpurblock.The post-monsoon depth to water level map is shown below in **Fig. 9.2(B)**.

Figure: 9.3(A)Depth to Water Level in Phreatic Aquifer during Post monsoon

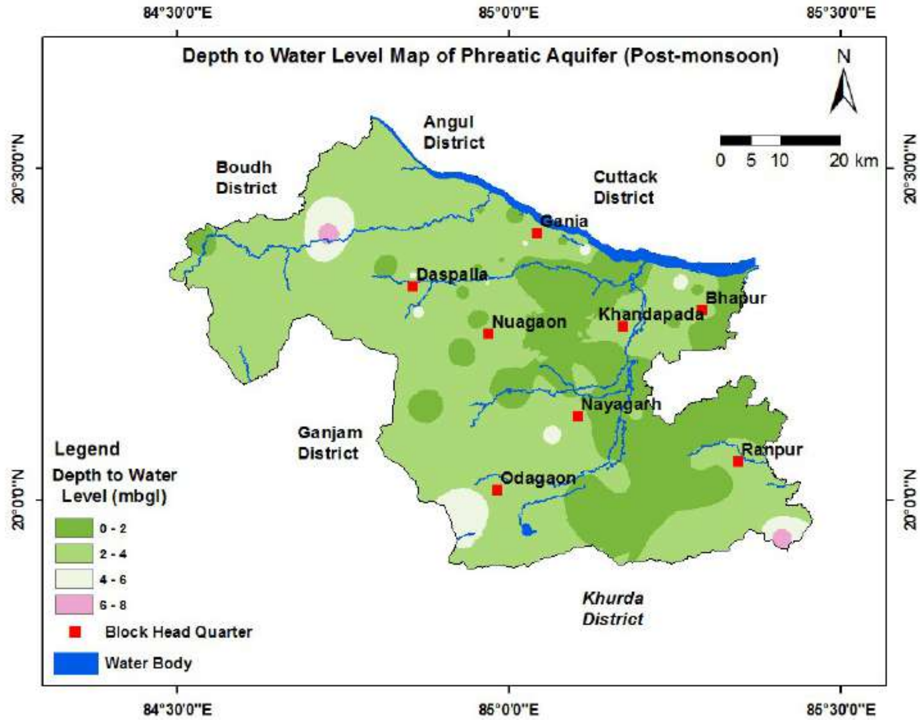
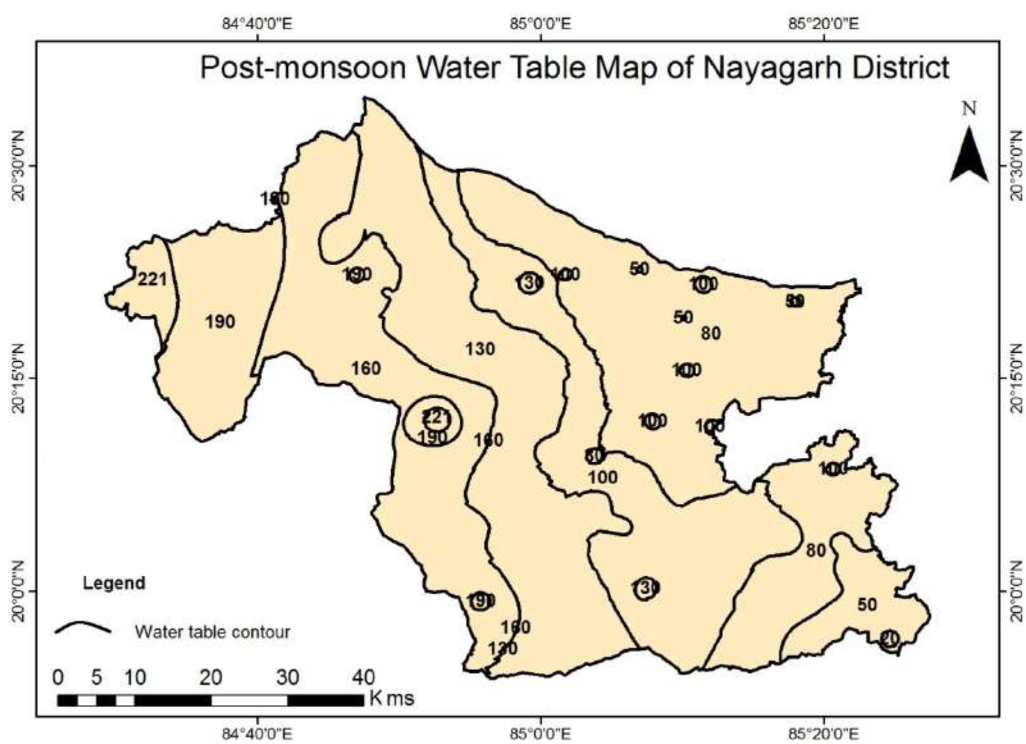


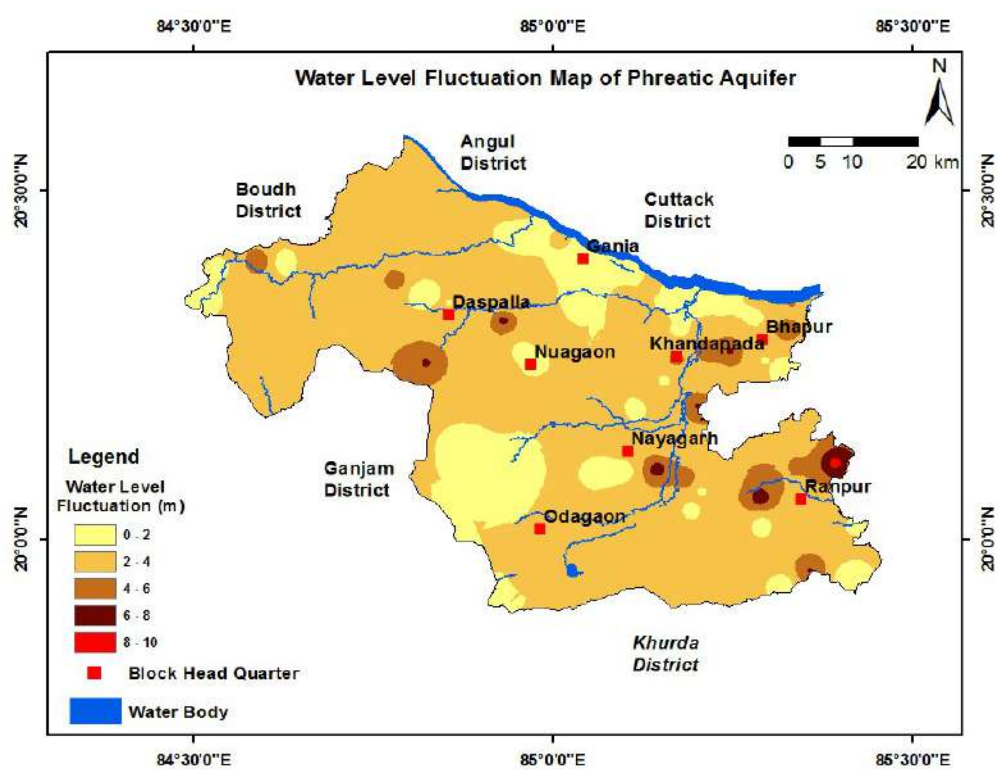
Figure: 9.3(B)Water Table Contour Map of Phreatic Aquifer during Post monsoon



9.1.3 Seasonal Fluctuation of Water Level

Fluctuation of ground water table between pre and post monsoon period in the study area varies from 0.4 to 8.45 m, the average being 2.85 m. The general range of fluctuation in water level in the study area is between 1-3m. The locations where the fluctuation of water level is more than 5 m bgl are Banigochha (5.05), Jamusahi (6.35),Soroda (6.55) in Dasapalla block, Banamalipur (5.1) in Khandapada block, Fatehgarh (5.28),Kaduapada (6.15) in Bhapur block and Rajapatna (7.15) in Nayagarh block and Krishnachandrapur (7.15) and Gadavanivalo (8.45) in Ranpur block. The shallow post-monsoon water level along with fluctuation pattern indicates that the annual replenishment of phreatic aquifer due to monsoon rainfall is adequate in the district but deeper summer level is due to rapid dewatering of the phreatic aquifer due to steep gradient towards the Mahanadi river which surroundsnorthern boundary of the district.The seasonal fluctuation of water level of Aquifer-I is shown in **Fig. 9.4**. Some hydrographs of different locations in the district showing water level trend are given below.

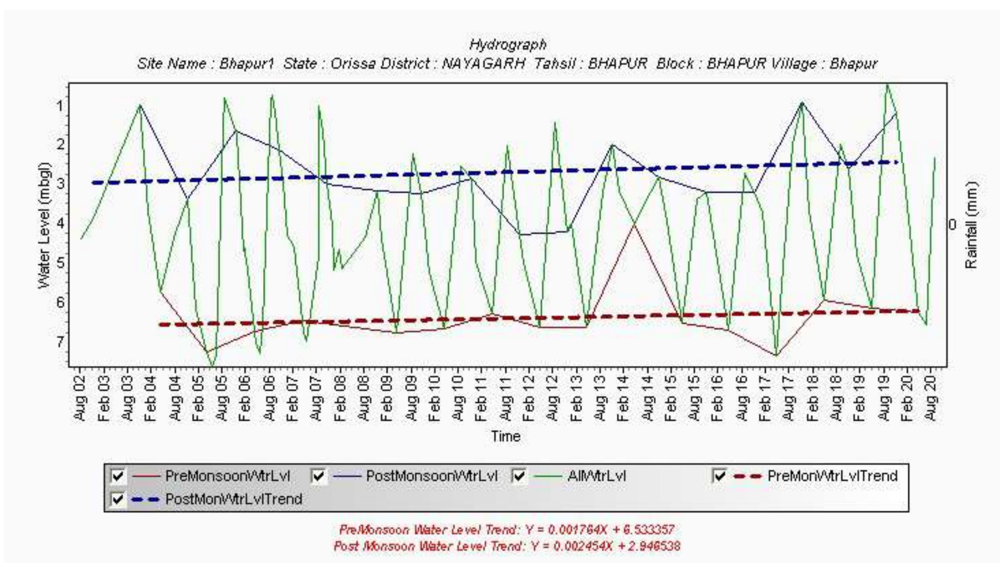
Figure: 9.4 Seasonal Fluctuation of Water Level in Phreatic Aquifer

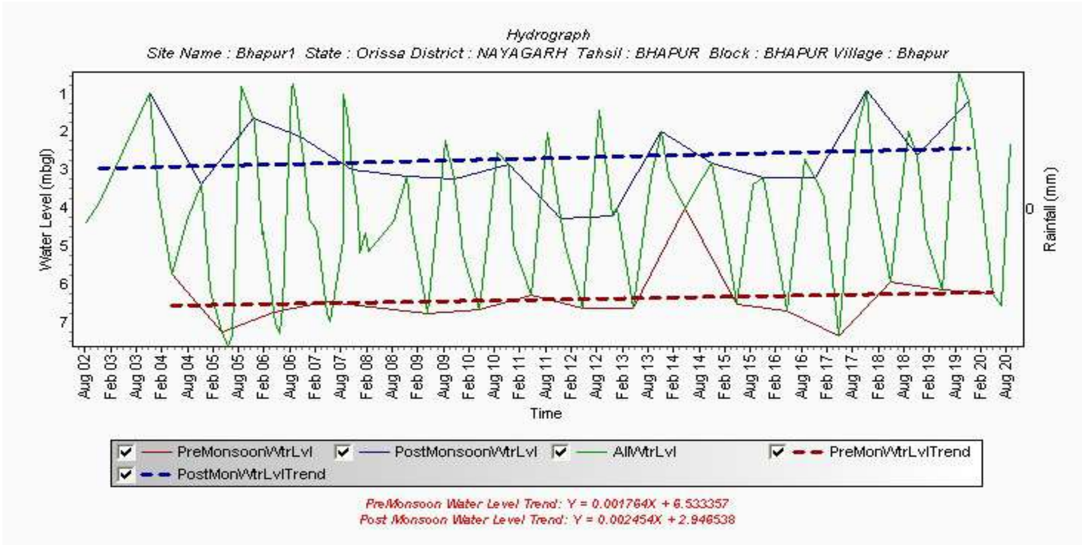


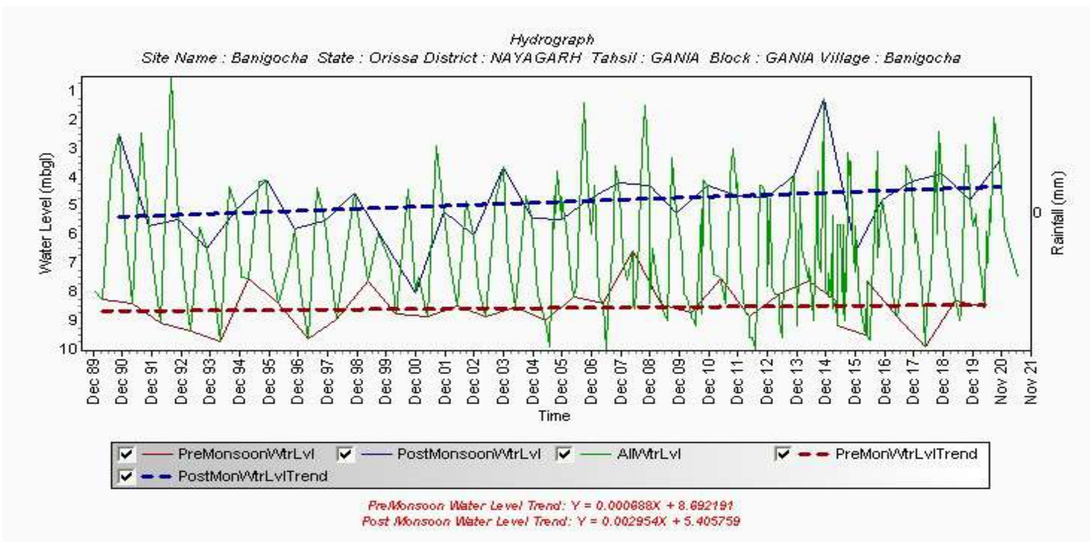
9.1.4 Hydrograph Analysis

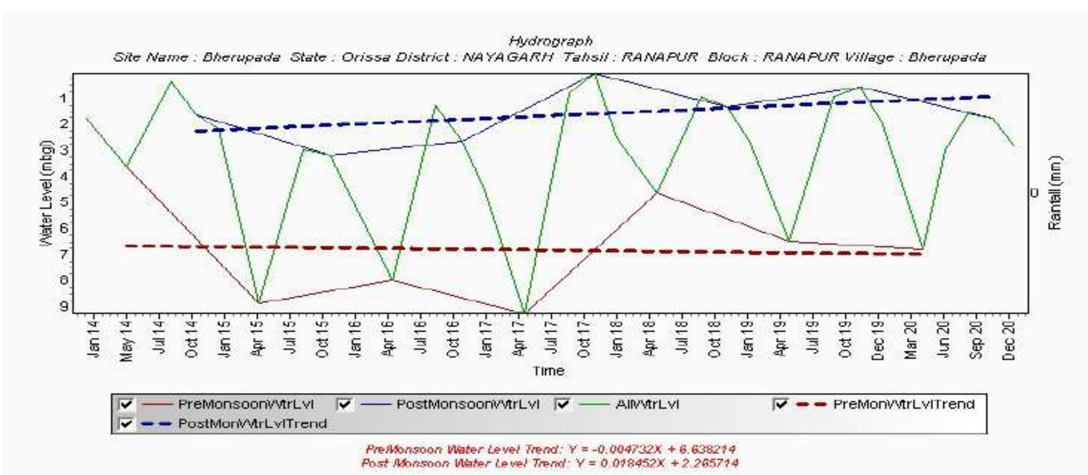
The hydrographs of 41 ground water monitoring stations were analysed. The variation in short term and long-term water level trends may be due to variation in natural recharge due to rainfall and withdrawal of groundwater for agricultural activity, domestic requirement and mining & industrial needs.

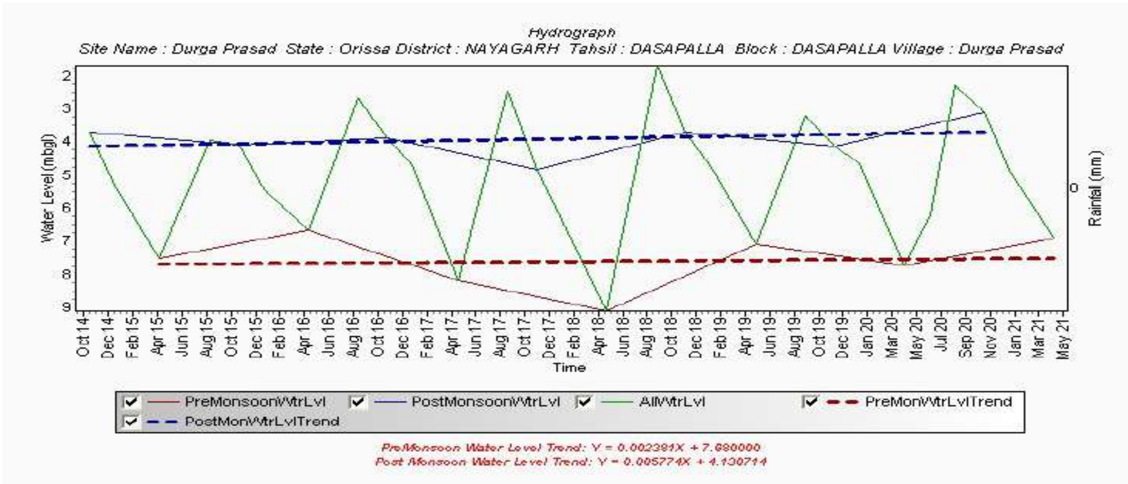
The water level hydrographs of selected National Hydrograph Network Stations (NHNS) are shown below. An annual rising limb in hydrographs, indicate the natural recharge of groundwater regime due to monsoon rainfall, as the monsoon rainfall is the only source of water. However, the groundwater draft continuously increases as indicated by the recessionary limb. The groundwater resources where not replenished / recharged fully, the groundwater levels come under continuous stress and deplete.

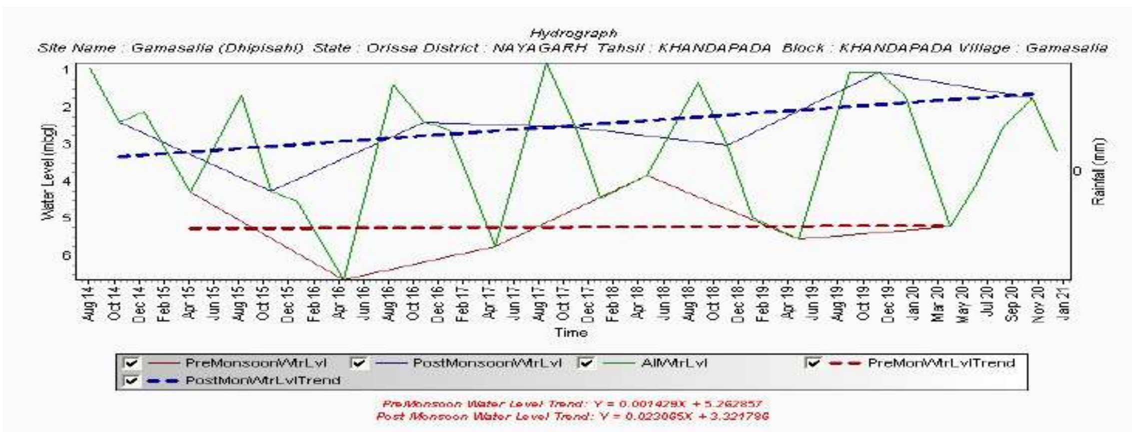


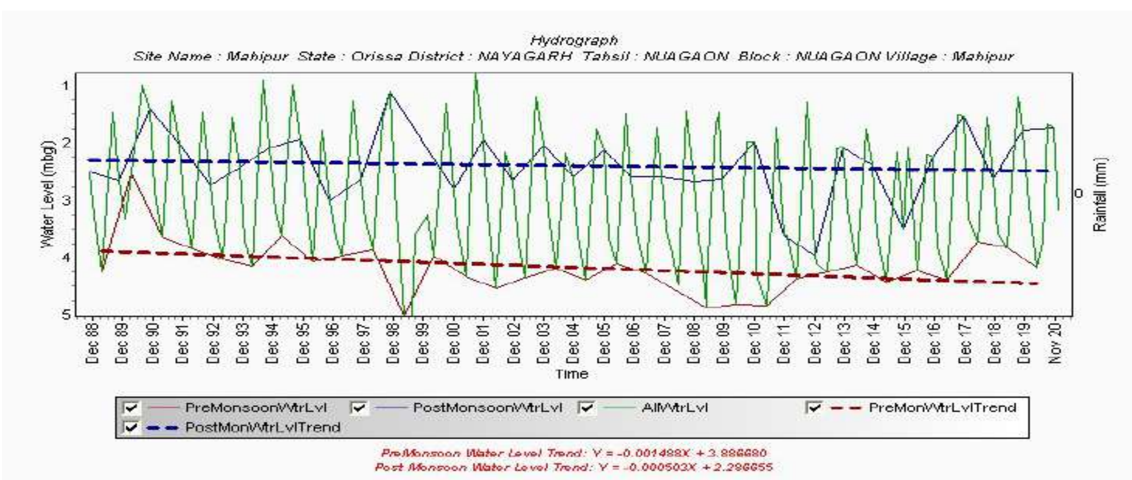

Hydrograph
Site Name : Bhapur1 State : Orissa District : NAYAGARH Tahsil : BHAPUR Block : BHAPUR Village : Bhapur
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001764X + 6.533357
Post Monsoon Water Level Trend: Y = 0.002454X + 2.946538

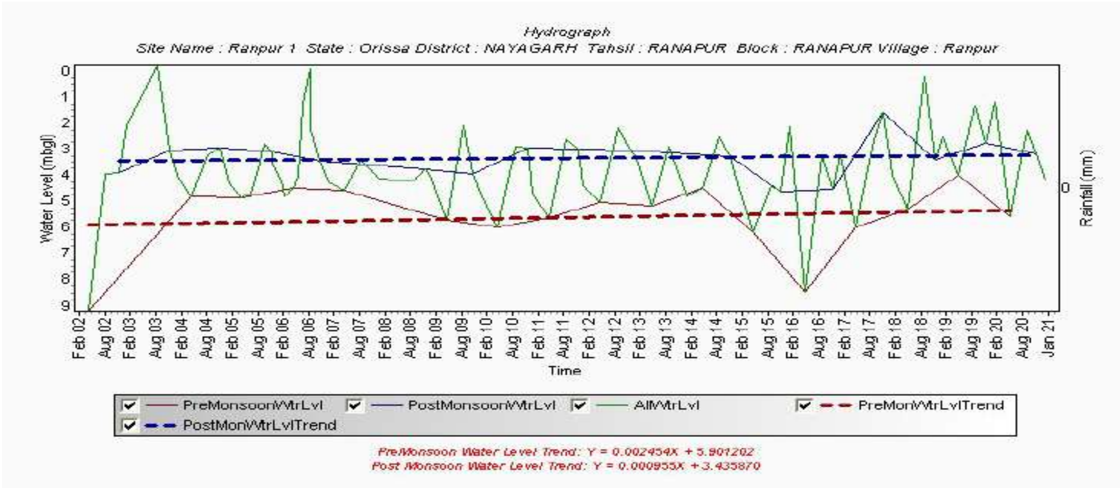

Hydrograph
Site Name : Banigocha State : Orissa District : NAYAGARH Tahsil : GANIA Block : GANIA Village : Banigocha
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.000688X + 8.692191
Post Monsoon Water Level Trend: Y = 0.002954X + 5.405759

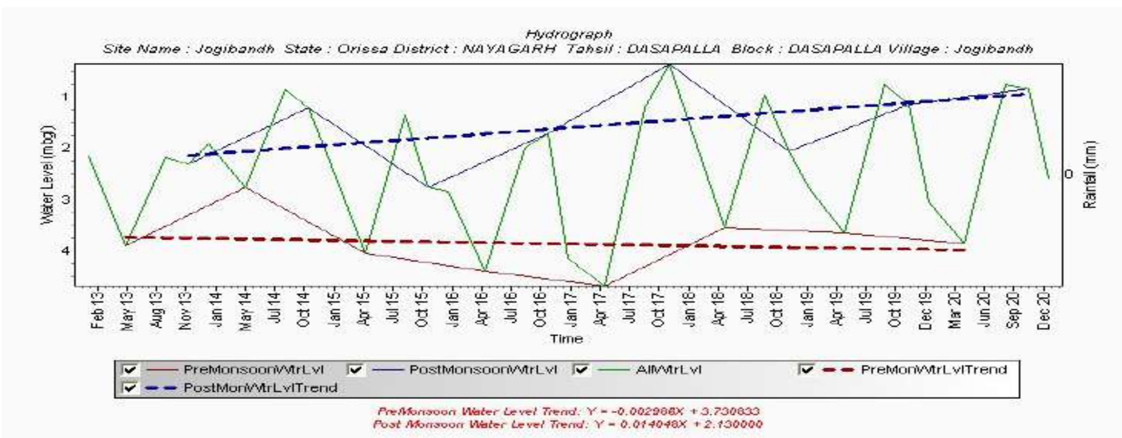

Hydrograph
Site Name : Bherupada State : Orissa District : NAYAGARH Tahsil : RANAPUR Block : RANAPUR Village : Bherupada
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.004732X + 6.638214
Post Monsoon Water Level Trend: Y = 0.018452X + 2.265714

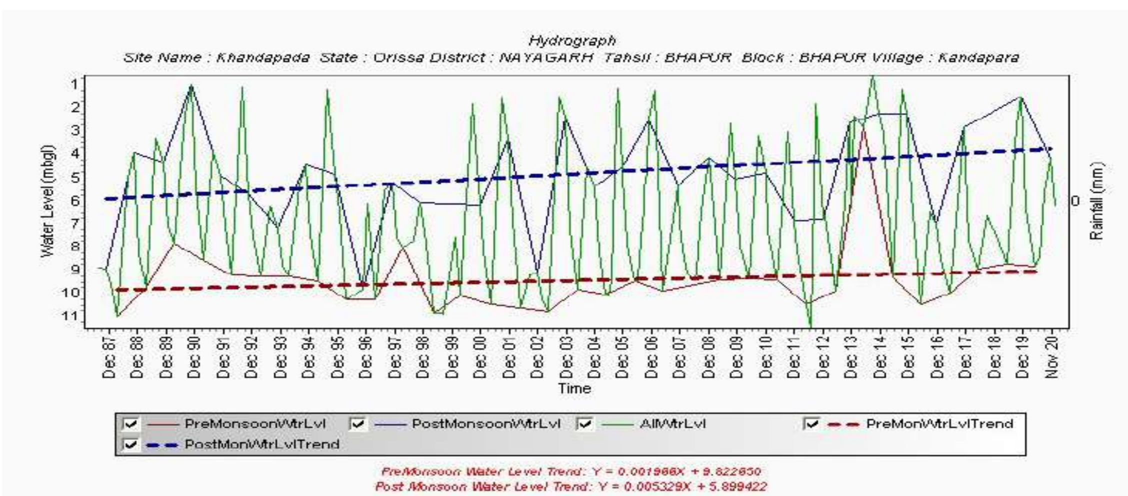

Hydrograph
Site Name : Durga Prasad State : Orissa District : NAYAGARH Tahsil : DASAPALLA Block : DASAPALLA Village : Durga Prasad
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.002381X + 7.680000
Post Monsoon Water Level Trend: Y = 0.005774X + 4.130714

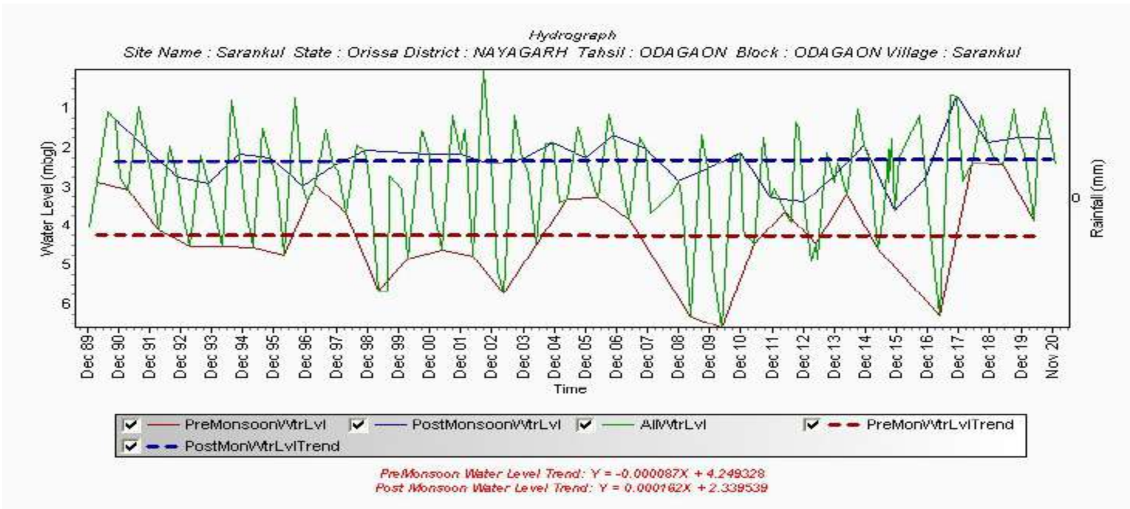

Hydrograph
Site Name : Gamasalia (Dhipisahi) State : Orissa District : NAYAGARH Tahsil : KHANDAPADA Block : KHANDAPADA Village : Gamasalia
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001429X + 5.262857
Post Monsoon Water Level Trend: Y = 0.023065X + 3.321796

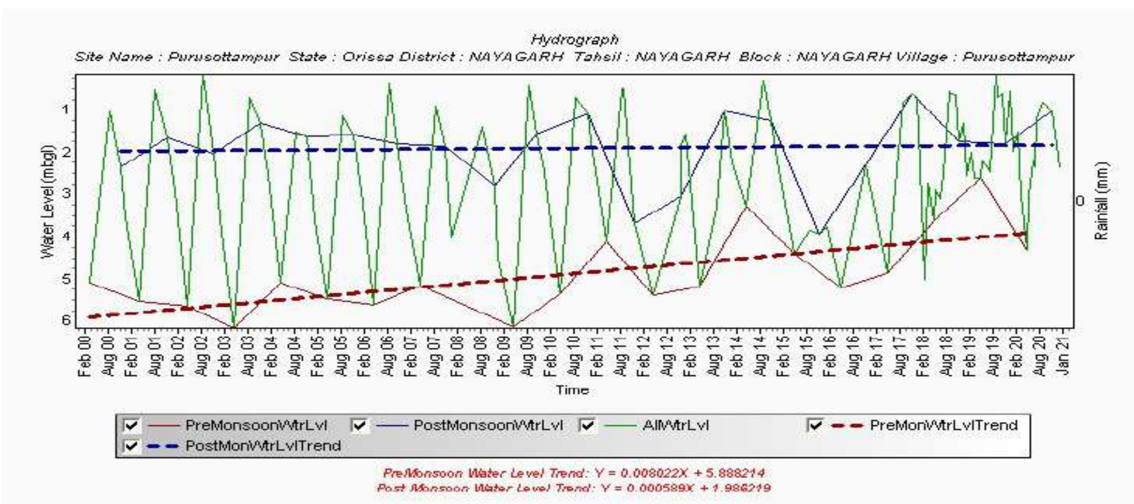

Hydrograph
Site Name : Mahipur State : Orissa District : NAYAGARH Tahsil : NUAGAON Block : NUAGAON Village : Mahipur
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.001488X + 3.886680
Post Monsoon Water Level Trend: Y = -0.000503X + 2.296655

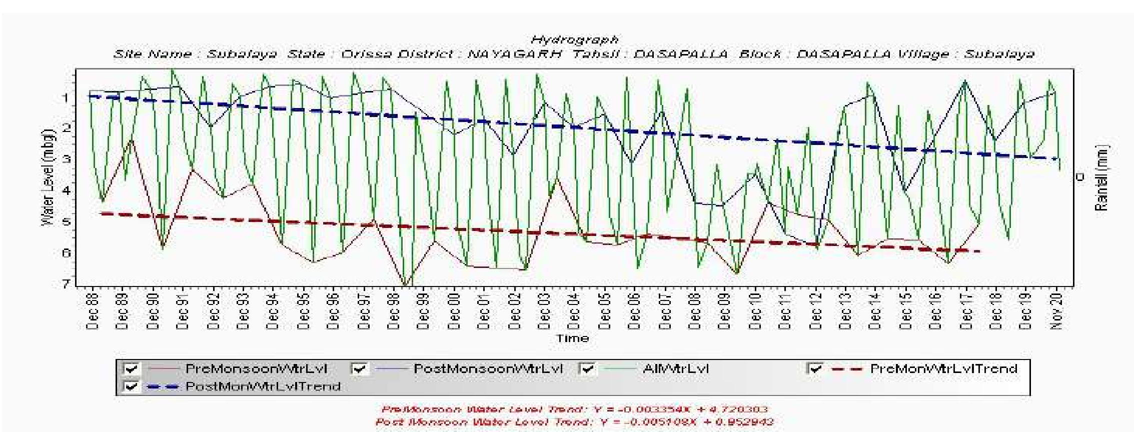

Hydrograph
Site Name : Ranpur 1 State : Orissa District : NAYAGARH Tahsil : RANAPUR Block : RANAPUR Village : Ranpur
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.002454X + 5.901202
Post Monsoon Water Level Trend: Y = 0.000955X + 3.435870


Hydrograph
Site Name : Jogibandh State : Orissa District : NAYAGARH Tahsil : DASAPALLA Block : DASAPALLA Village : Jogibandh
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.002988X + 3.730833
Post Monsoon Water Level Trend: Y = 0.014048X + 2.130000


Hydrograph
Site Name : Khandapada State : Orissa District : NAYAGARH Tahsil : BHAPUR Block : BHAPUR Village : Kandapara
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001966X + 9.822650
Post Monsoon Water Level Trend: Y = 0.005329X + 5.899422


Hydrograph
Site Name : Sarankul State : Orissa District : NAYAGARH Tahsil : ODAGAON Block : ODAGAON Village : Sarankul
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.000087X + 4.249328
Post Monsoon Water Level Trend: Y = 0.000162X + 2.339539


Hydrograph
Site Name : Purusottampur State : Orissa District : NAYAGARH Tahsil : NAYAGARH Block : NAYAGARH Village : Purusottampur
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.008022X + 5.888214
Post Monsoon Water Level Trend: Y = 0.000589X + 1.988219


Hydrograph
Site Name : Subalaya State : Orissa District : NAYAGARH Tahsil : DASAPALLA Block : DASAPALLA Village : Subalaya
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.003354X + 4.720303
Post Monsoon Water Level Trend: Y = -0.005108X + 0.952943

9.1.5 Decadal Water Level Trend

A total no. of 42stations were considered for analysis of long-term decadal trend for the period 2011-2020. Out of 45 stations, 9 stations were showing rising trend and the remaining 36 stations showing no change during pre-monsoon. Similarly during post monsoon 31 stations were showing rising trend remaining 14 stations showing no change. The decadal trend of water level for both pre-monsoon and post-monsoon periods was analyzed. The results are presented in Fig. 9.5 (A) & (B).There is no significant falling trend in any area in the district. The details are presented in table no. 9.2.

Figure: 9.5(A) Decadal Trend of Water Level in Phreatic Aquifer during Pre monsoon

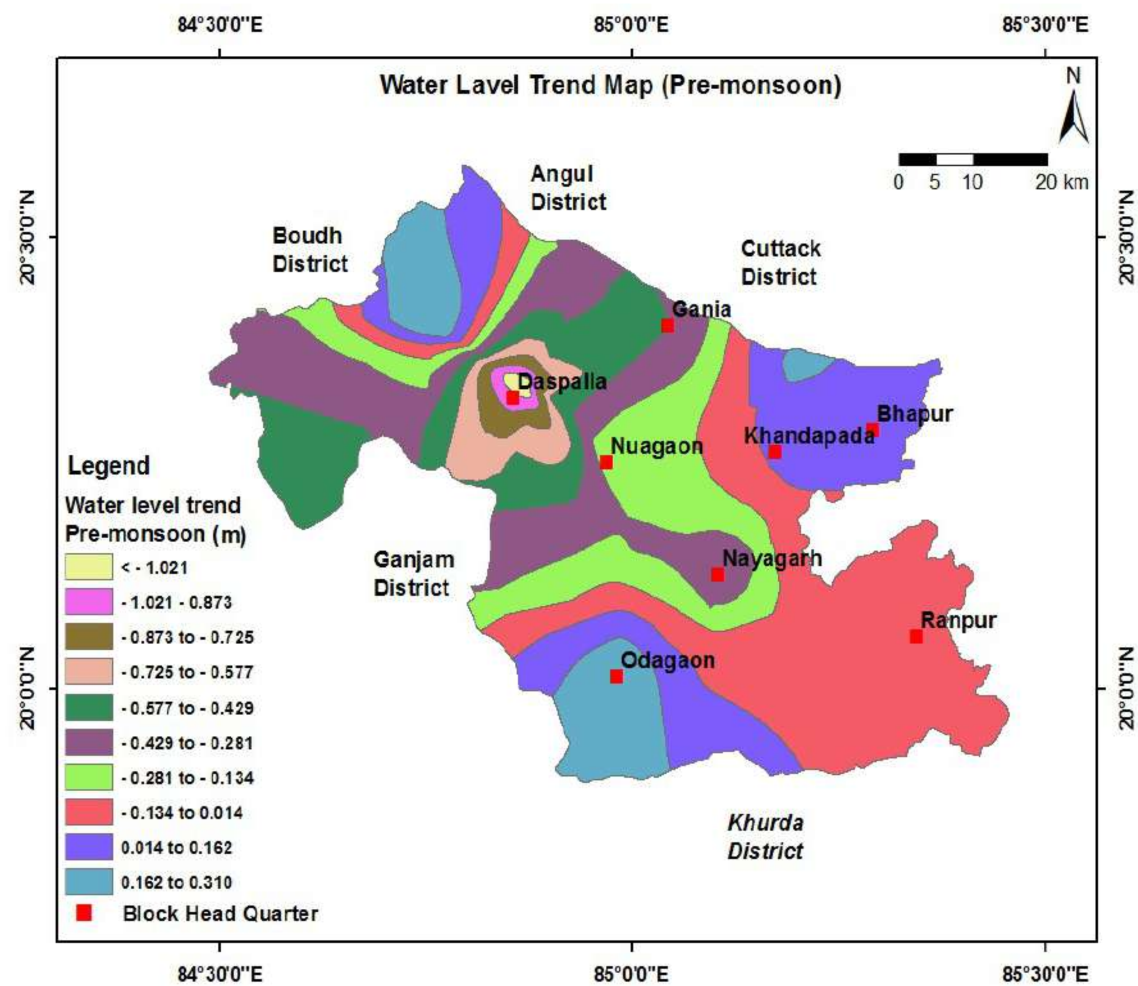
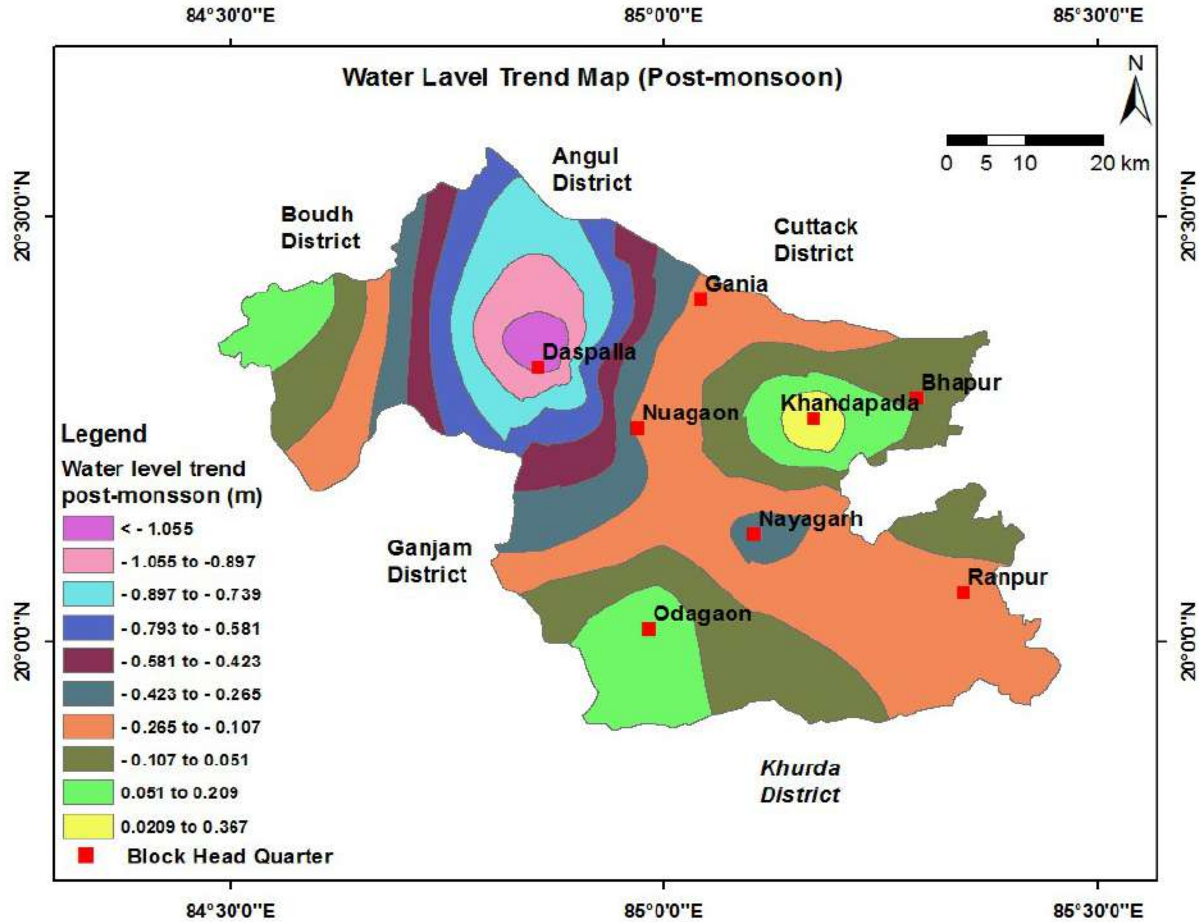


Figure: 9.5(B) Decadal Trend of Water Level in Phreatic Aquifer during Post monsoon



9.1.5 Aquifer Characteristics of Phreatic Aquifer

The pumping tests were conducted on selected dug wells representing different hydrogeological units and the aquifer characteristics was evaluated in terms of Specific Capacity Index i.e. flow of ground water per metre depression of head over unit cross sectional area of inflow offered by the aquifer. The **Table-9.1** summarises the aquifer characteristics of the phreatic aquifers. The wide range of yield and specific capacity is due to very much heterogeneous nature of the weathered zone in lateral extension as well as variation of thickness of this zone

9.2 Deeper Aquifer

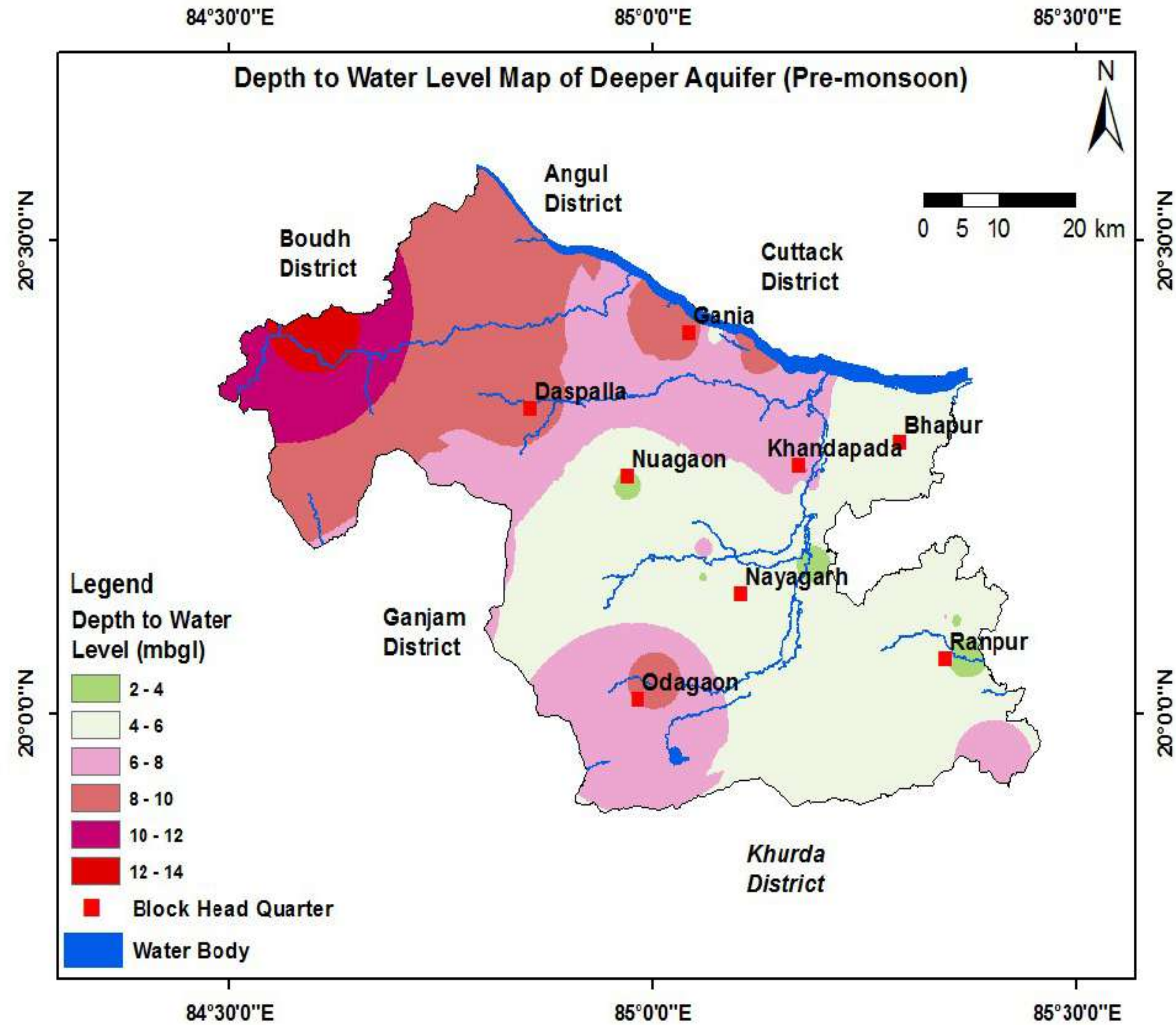
Unlike phreatic aquifer, ground water occurs under confined to semi-confined condition in the deeper aquifer. The deeper aquifer comprises of the jointed and fractured consolidated or crystalline formations as well as the semi-consolidated formations such as Gondwanas. In general it's confined on top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

CGWB has constructed 20 EW and 6 OW in Nayagarh district through its Ground Water Exploration Programme, whose depths range from 56.30 m bgl (Bhapur) to 200.37 m bgl (Gania). The static water level varies from 1.92 m bgl (Itamati) to 10.2 m bgl (Sidhamula). The discharge of successful borewells varies from 0.20 lps (Banamalipur) to a maximum of 13.5lps (Bhapur)). The drawdown varies from 14.86 m (Badabhuin) to 24.86 m (Itamati). The details of the exploratory wells are given in **Table-8.2.**Generally 1 to 4 potential fracture zones are encountered within the depth range of 200 m. The first promising zone occurs in the depth range of 15 to 35 m., which is just below the zone of weathering. The depth range of prime importance is from 40 to 100 m. Normallythe fracture zones in this depth range have high water yielding capacities and majority of successful bore wells in the study area tapped zones within this depth range. The other potential fracture zones are found at the depth ranges of 40-65, 70-75, 95-115, 135-155 and 170-195 mbgl. Granite suites rocks have more promising aquifers in comparison to other rocks like Charnockites and Khondalites. However the success of bore wells is site specific and depends on topographic and hydrogeological conditions.

9.2.1 Pre Monsoon Depth to Water Level

Depth to water level in pre-monsoon period (May 2020) varies from 3.4mbgl to 9.7mbgl the average being 5.92 m bgl. In general, the study area has the depth to water level in between 3 to 8mbgl during the pre-monsoon. Shallower water level of 0-6mbgl is observed in east and central part of the district Bhapur, Nayagarh, Nuagaon and Ranpur blocks. Deeper water levels (> 6 mbgl) are found mostly in Dasapalla, Gania, Khandapada and Odogaon blocks. The locations where the depth to water level is more than 8 m bgl are Khandapada(8.15),Dasapalla (8.85) and Gania (9.7).The pre-monsoon depth to water level map is shown in **Fig. 9.6(A)**.

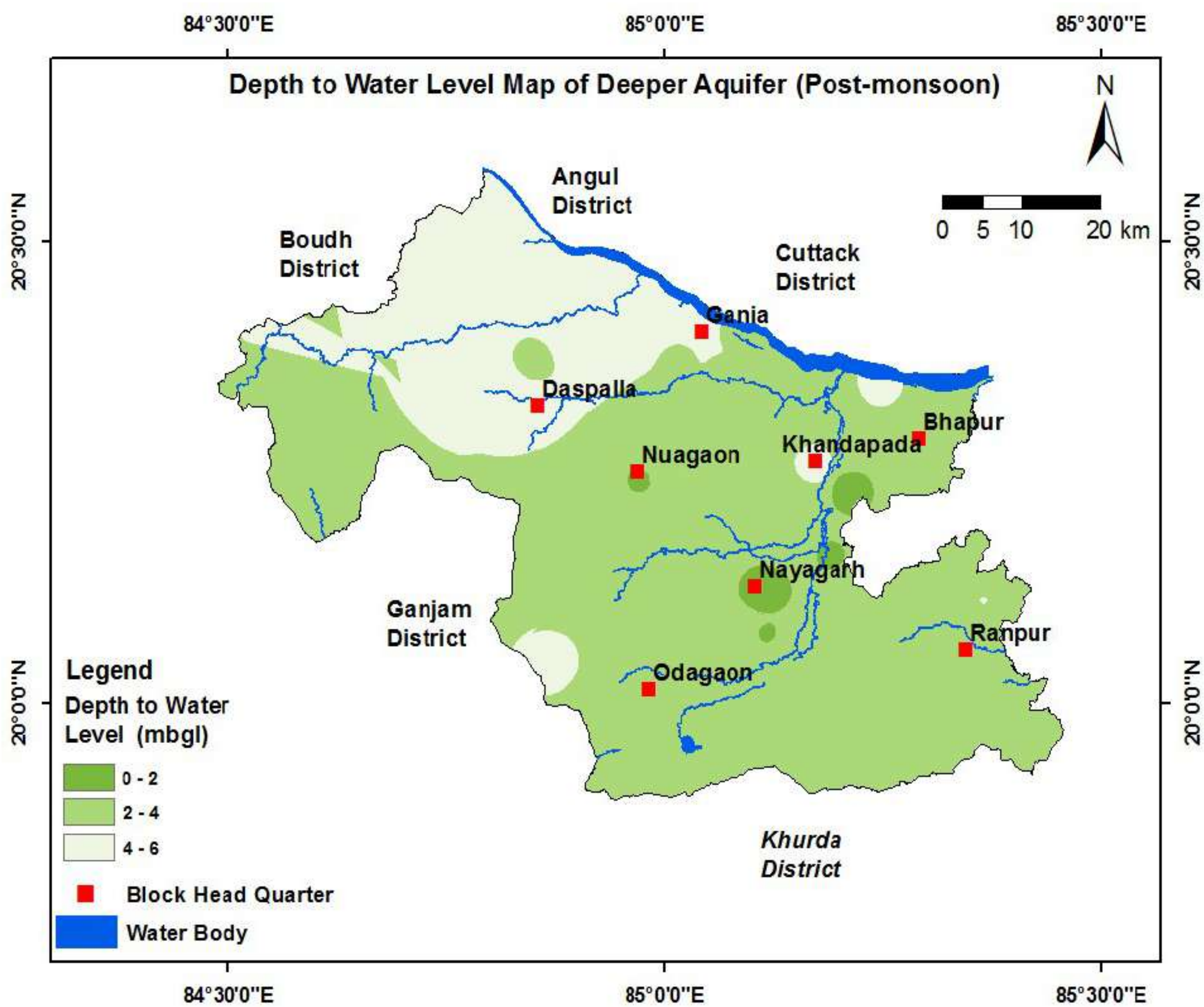
Figure: 9.6(A) Depth to Water Level in Fractured aquiferduring Pre Monsoon



9.2.2Post Monsoon Depth to Water Level

Depth to water level in post-monsoon period (May 2020) varies from 0.43mbgl to10.2mbgl the average being 4.05 m bgl. In general, the study area has the depth to water level in between 2 to 4mbgl during the post-monsoon. Shallower water level upto 4mbgl is observed in all blocks covering the entire district except nort-western part of the district. Deeper water levels (> 6 mbgl) are found mostly in Dasapalla and Gania blocks. The locations where the depth to water level is more than 8 mbgl is Sidhamula(10.2).The post-monsoon depth to water level map is shown in **Fig. 9.6(B)**.

Figure: 9.6(B) Depth to Water Level in Fractured aquifer during Post Monsoon



9.2.3 Seasonal Fluctuation of Water Level

Fluctuation of ground water table between pre and post monsoon period in the study area varies from 1.54 to 5.43m, the average being 2.99 m. The general range of fluctuation in water level in the study area is between 2-4m. The locations where the fluctuation of water level is more than 4 m bgl are Gania (4.22), Baghuapalli (5.43).The seasonal fluctuation of water level of Aquifer-I is shown in **Fig. 9.7**.

Figure: 9.7 Seasonal Fluctuation in Water Level in Fractured aquifer

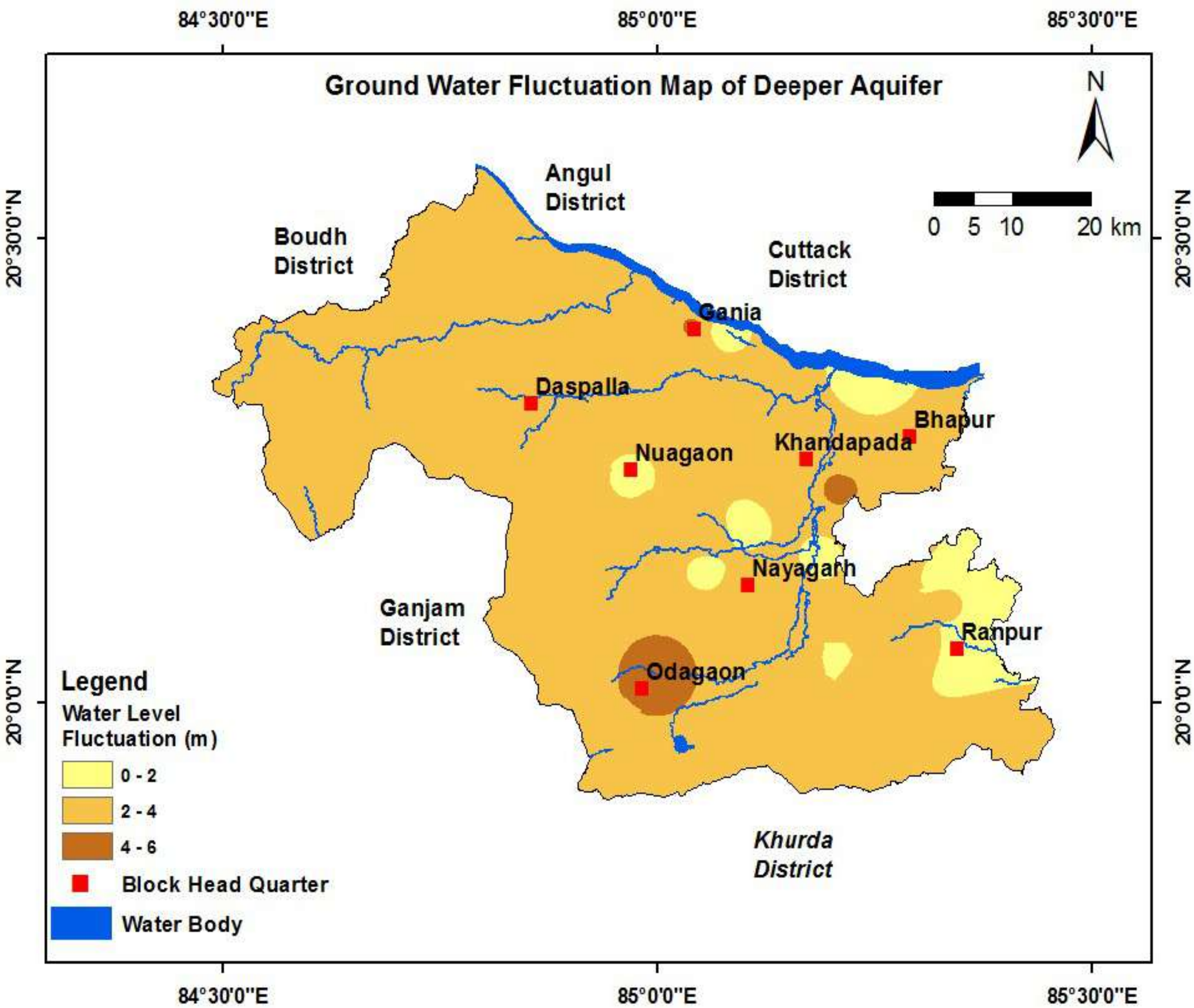


Table 9.1 Details of Monitoring Wells in Nayagarh District

Sl No	Block	Location	Type of Well	Longitude	Latitude	Pre monsoon DTWL (mbgl)	Post monsoon DTWL (mbgl)	Elevation(m amsl)
1	DASPALLA	Ambalimba	KW	84.5382	20.3905	3.2	1.45	194.11
2	NAYAGARH	Anandapalli	KW	85.2050	20.0772	4.25	0.6	87
3	GANIA	Arhakota	NHS	84.9887	20.3631	4.32	1.97	124.91
4	NAYAGARH	Badapandusar	KW	85.1703	20.1503	3.8	1.1	65
5	BHAPUR	Baghuapalli	KW	85.2118	20.2334	4.6	2	61.17
6	NUAGAON	Bahajdola	KW	84.9169	20.0772	3.7	2.1	148.31
7	BHAPUR	BaldiaNuagaon	KW	85.2279	20.2316	6	2.7	63.05
8	NAYAGARH	Balugaon	KW	85.1151	20.1861	3.7	2.91	74.96
9	KHANDAPARA	Banamalipur	KW	85.2142	20.2712	8.5	3.4	63.72
10	DASPALLA	Banigochha	NHS	84.5895	20.3984	7.9	2.85	189.45
11	NUAGAON	Bantala	KW	84.9451	20.1198	4.5	3	113.94
12	RANPUR	Barapalli	KW	85.3575	19.9559	9.6	3.5	34.54
13	NAYAGARH	Baunsabati	KW	85.2594	20.3275	5.6	2	65
14	KHANDAPARA	Benagadia	NHS	85.1678	20.3209	3.5	1.55	48.3
15	GANIA	Bentapada	KW	84.9498	20.474	6.1	3.45	60.37
16	BHAPUR	Bhapur	NHS	85.2853	20.284	5.3	2.5	75.37
17	RANPUR	Bherupada	NHS	85.2956	20.0653	6.3	1.25	86
18	NAYAGARH	Biruda	KW	85.1897	20.1312	5.3	2.2	63.4
19	DASPALLA	Buguda	KW	84.7276	20.4014	10.8	6.9	106.18
20	NAYAGARH	Champatipur	KW	85.1611	20.1654	5.5	1.95	60.73
21	GANIA	Charamula	KW	84.9561	20.4399	2.9	1.94	58.72
22	RANPUR	Damasahi	KW	85.191	20.0432	3.2	1.85	99.92

Sl No	Block	Location	Type of Well	Longitude	Latitude	Pre monsoon DTWL (mbgl)	Post monsoon DTWL (mbgl)	Elevation(m amsl)
23	RANPUR	Darpanarayanpur	NHS	85.2376	20.0758	4.4	0.95	110.33
24	DASPALLA	Dasapalla	NHS	84.8559	20.3398	6.1	4.14	102.83
25	NAYAGARH	Dianpada	KW	85.0672	20.1	6.02	4.85	101.55
26	DASPALLA	Dihagaon	KW	84.8953	20.3379	4.2	2.2	95.49
27	NUAGAON	Dimiria	KW	84.8785	20.2017	4.92	2.2	136.93
28	NAYAGARH	Durgaprasad	KW	84.6661	20.4056	7.2	2.6	172
29	BHAPUR	Fategarh	KW	85.3229	20.3001	7.05	1.77	77.92
30	GANIA	Gania	NHS	85.0442	20.3963	5.11	3.2	62.43
31	ODAGAON	Gasisevipur	NHS	85.0139	20.0089	3.9	0.95	123
32	KHANDAPARA	Ghanasaila	NHS	85.1354	20.3669	4.2	1.2	50.84
33	DASPALLA	Gholahandi	NHS	84.9528	20.3498	4.95	1.87	136.77
34	KHANDAPARA	Girhipalli	KW	85.1014	20.3429	3.4	0.4	44.39
35	RANPUR	Godbanivalo	KW	85.3916	20.11	9.4	0.95	54.67
36	ODAGAON	Godipada	KW	85.1638	20.038	5.3	2.6	87
37	BHAPUR	Golapokhori	KW	85.2936	20.2583	3.25	1.35	64.36
38	NUAGAON	Goomy	KW	84.8778	20.1418	2.7	1.6	159.79
39	RANPUR	Gopalpur	KW	85.3585	20.0272	6.4	3.55	43.08
40	KHANDAPARA	Gopinathpur	KW	85.1685	20.3453	1.2	0.73	47.08
41	KHANDAPARA	Gunthuni	KW	85.169	20.1931	5.2	1.95	59.64
42	NAYAGARH	Hatdwar	KW	85.0619	20.1569	5.78	2.78	79.7
43	GANIA	Indipata	KW	85.0815	20.3916	3.2	1.87	56.83
44	NAYAGARH	Itamati	NHS	85.1543	20.1402	3.1	0.65	39.29
45	BHAPUR	Jamusahi	KW	85.2462	20.2715	8	1.65	63.53
46	DASPALLA	Jamusahi	KW	84.6619	20.402	7	3.1	141.84
47	GANIA	JhadaGadia	NHS	85.0292	20.3733	4.9	2.1	78

Sl No	Block	Location	Type of Well	Longitude	Latitude	Pre monsoon DTWL (mbgl)	Post monsoon DTWL (mbgl)	Elevation(m amsl)
48	KHANDAPARA	Jogiapalli	KW	85.1311	20.1984	3.25	1.15	84.04
49	NAYAGARH	Jogibandh	NHS	84.8669	20.3375	3.3	0.33	113
50	BHAPUR	KaduaJagannath	KW	85.2006	20.1919	7.3	1.15	68.18
51	ODAGAON	Kajalipallisasan	KW	85.1233	20.0052	4.2	1.4	103
52	DASPALLA	Kajumendhi	KW	84.5176	20.347	4.2	2.5	223.28
53	DASPALLA	Kalurkumpa	NHS	84.6296	20.3981	2.8	2.15	162.45
54	KHANDAPARA	Kanasingha	NHS	85.1156	20.3775	6.5	4.97	50.22
55	KHANDAPARA	Kantillo	NHS	85.1895	20.359	0.5	0.7	52.57
56	GANIA	Kararhpada	KW	85.0243	20.3869	5.1	4.17	63.75
57	RANPUR	KerandaTangi	KW	85.4099	19.9439	7.3	6.8	29.95
58	NUAGAON	Khalamela	KW	84.9281	20.2265	4.3	1.6	133.86
59	DASPALLA	Khamarsahi	KW	84.8816	20.313	5.25	2.95	110.74
60	KHANDAPARA	Khandapada	NHS	85.1714	20.2599	8.5	3.88	83.16
61	GANIA	Kishoreprasad	KW	85.0753	20.3931	6.85	2	68
62	ODAGAON	Klyanpur	KW	85.3197	20.0708	3.4	1.6	111
63	RANPUR	Koilma	NHS	85.3395	20.11	6.1	2	63.77
64	ODAGAON	Komand	KW	84.9297	19.988	7.2	5.15	166
65	NUAGAON	Korada	KW	84.9561	20.2717	2.9	1.5	99.77
66	KHANDAPARA	Koska	KW	85.0368	20.348	1.2	0.7	79.22
67	RANPUR	Kotagad	KW	85.3432	20.1428	4.6	1.55	89.08
68	KHANDAPARA	Kotapokhori	KW	85.1718	20.2865	4.9	1.94	46
69	RANPUR	Krishnach.pur	KW	85.2886	20.0609	9.45	2.3	93.83
70	DASPALLA	Kuaria	KW	84.8075	20.3594	3.7	0.4	146
71	KHANDAPARA	Kumbharpada	NHS	85.0278	20.3595	3.5	1.65	84.29
72	NAYAGARH	Lathipada	KW	85.1575	20.1119	6.2	2.9	74

Sl No	Block	Location	Type of Well	Longitude	Latitude	Pre monsoon DTWL (mbgl)	Post monsoon DTWL (mbgl)	Elevation(m amsl)
73	NAYAGARH	Lenkujipada	KW	85.0987	20.099	3.9	2.7	84.29
74	BHAPUR	Madhapur	KW	85.233	20.3467	3.2	2.6	84.29
75	DASPALLA	Madhyakhanda	NHS	84.9322	20.3418	4.2	1.95	84.29
76	NUAGAON	Mahipur	NHS	85.0078	20.165	3.67	1.22	84.29
77	RANPUR	Mahulia	KW	85.2068	20.0697	2.6	0.85	82.03
78	RANPUR	Majhiakhanda	KW	85.3226	20.0259	4.6	1.1	67.69
79	NUAGAON	Malisahi	KW	85.0814	20.1764	4.5	1.17	45.98
80	BHAPUR	Marada	KW	85.2598	20.3284	7.5	5.6	76.59
81	KHANDAPARA	Mardarajpur	KW	85.1749	20.2986	3.4	2.55	50.6
82	RANPUR	Mayurjhalia	KW	85.4195	20.0204	3.85	2.2	33.68
83	BHAPUR	Nandabara	KW	85.331	20.3399	5.8	1.7	38.68
84	NAYAGARH	Nayagarh	KW	85.1186	20.1286	2.7	0.8	92
85	DASPALLA	Neliguda	KW	84.8166	20.3523	1.6	1.1	133.94
86	NAYAGARH	Notara	KW	85.1837	20.0864	6.7	1.7	72.36
87	NUAGAON	Nuagaon	NHS	84.971	20.2542	4.4	2.9	102.69
88	ODAGAON	Odagaon	KW	84.9833	20.0217	4.15	1.7	142
89	BHAPUR	Padmabati	KW	85.2986	20.3396	5.25	2.05	42.27
90	RANPUR	Patia	KW	85.3204	19.9357	3.5	2.3	36.93
91	KHANDAPARA	Purusottampur	KW	85.1903	20.1550	4	0.72	64
92	NAYAGARH	Rajapatana	KW	85.1449	20.1013	8.7	1.55	37.8
93	RANPUR	RajSunakhela	NHS	85.335	20.165	4.2	1.62	70.4
94	BHAPUR	Rakama	KW	85.2806	20.3194	2.55	1.52	76.65
95	RANPUR	Ranapur	NHS	85.35	20.057	5.3	2.89	59.68
96	DASPALLA	Rangamatia	NHS	84.7837	20.3714	6.85	2.3	160.09
97	GANIA	Rasanga	KW	85.0104	20.4284	3.8	1.67	59.51

Sl No	Block	Location	Type of Well	Longitude	Latitude	Pre monsoon DTWL (mbgl)	Post monsoon DTWL (mbgl)	Elevation(m amsl)
98	DASPALLA	Sakhini	KW	84.8235	20.2541	9	2.85	160.67
99	NUAGAON	Sampada	KW	84.9797	20.2025	5.46	0.7	113
100	RANPUR	Sanagada	KW	85.0881	20.0572	5.7	1.25	79
101	ODAGAON	Sarankul	KW	85.0967	20.0306	3.6	1.5	108
102	KHANDAPARA	Sikharpur	KW	85.1549	20.2277	3.2	1.55	67.17
103	NUAGAON	Sikrida	KW	84.9673	20.3285	8	4.1	78.12
104	KHANDAPARA	Singhapada	KW	85.1475	20.3091	4.4	1.33	55.48
105	ODAGAON	Solapata	KW	85.0922	20.0761	3	0.9	98
106	NUAGAON	Soroda	KW	84.9308	20.3141	8.3	1.75	98.17
107	DASPALLA	Subalaya	KW	84.9069	20.3172	5.2	0.8	102
108	DASPALLA	takara	KW	84.7594	20.4044	5.8	2.72	120
109	BHAPUR	Tarobalo	KW	85.3226	20.2433	1.75	1.35	37.79
110	DASPALLA	Tendabari	KW	84.864	20.2846	8.25	4.3	129.89
111	RANPUR	Yosadapur	KW	85.2924	20.0211	2.3	1.4	84.09

Table-9.2: Decadal Water Level Trend Analysis of CGWB NHS (period 2011-2020) in Nayagarh District

Water Level Trend during Pre Monsoon						Water Level Trend duringPost Monsoon					
Sl No	Location	Data points	Rise(m/year)	Fall(m/year)	Intercept	Sl No	Location	Data points	Rise(m/year)	Fall(m/year)	Intercept
1	Adakata	7				1	Adakata	8	0.1292		
2	Andapali	3				2	Andapali	6			
3	Badabhuin	0				3	Badabhuin	1			
4	Bada-Pandeswar	5				4	Bada-Pandeswar	6			
5	Banigocha	22			0.0106	5	Banigocha	12			0.0044
6	Benagadia	3				6	Benagadia	4			
7	Bherupada	7				7	Bherupada	8	0.2245		
8	Darpa-Narayanpur	0				8	Darpa-Narayanpur	2			
9	Daspalla	18			0.3552	9	Daspalla	11	0.1098		
10	Durga Prasad	7				10	Durga Prasad	8	0.0515		
11	Gamasalia	6				11	Gamasalia	8	0.3093		
12	Gania	18			0.0180	12	Gania	11	0.0663		
13	Gasisevipur	7				13	Gasisevipur	7	0.1552		
14	Ghholahandi	8				14	Ghholahandi	8	0.2561		
15	Itamati	7				15	Itamati	9	0.1204		
16	Jogibandh	8				16	Jogibandh	9	0.1833		
17	Kalyanpur	1				17	Kalyanpur	5			
18	Kana Singhi	8				18	Kana Singhi	8	0.0010		
19	Kantilo	17	0.0383			19	Kantilo	11	0.1490		
20	Khandapada	19	0.0963			20	Khandapada	10	0.1556		
21	Kishore Prasad	4				21	Kishore Prasad	8	0.2437		

Water Level Trend during Pre Monsoon						Water Level Trend duringPost Monsoon					
Sl No	Location	Data points	Rise(m/year)	Fall(m/year)	Intercept	Sl No	Location	Data points	Rise(m/year)	Fall(m/year)	Intercept
22	Koilama	7				22	Koilama	8	0.2593		
23	Kuanria	6				23	Kuanria	8	0.1764		
24	Kuluru Kumpa	8				24	Kuluru Kumpa	9	0.0953		
25	Lathipada	0				25	Lathipada	2			
26	Madhyakhand	3				26	Madhyakhand	7	0.3270		
27	Mahipur	19	0.0173			27	Mahipur	11	0.1848		
28	Mali Bareni	0				28	Mali Bareni	1			
29	Nayagarh	19			0.1045	29	Nayagarh	9	0.1418		
30	Nuabausabati	7				30	Nuabausabati	9	0.0508		
31	Nuagaon	18			0.0350	31	Nuagaon	10	0.1703		
32	Odagaon	18	0.1297			32	Odagaon	11	0.1833		
33	Purusottampur	19	0.1075			33	Purusottampur	11	0.2117		
34	Raj Sunakhala	0				34	Raj Sunakhala	4			
35	Rangamatia	7				35	Rangamatia	8	0.4065		
36	Ranpur	18	0.0798			36	Ranpur	10	0.0825		
37	Sampada	8				37	Sampada	9	0.2234		
38	Sanagada	3				38	Sanagada	6			
39	Sarankul	18	0.0558			39	Sarankul	11	0.2169		
40	Solopata	6				40	Solopata	7	0.4365		
41	Subalaya	17	0.0241			41	Subalaya	11	0.3949		
42	Takara	20	0.0968			42	Takara	11	0.0787		

10. Ground Water Resource

Estimation of Ground Water Resources has been carried out based on the methodology recommended by the Groundwater Estimation Committee (GEC'2015). A ground water resource of the entire state has been computed by CGWB (CGWB, SER, 2020) for the year 2019-2020. Salient features of the estimation of ground water resources are described below. The present computations pertain to the ground water year 2019-20. The resources have been computed block wise. Areas having slope more than 20 % were excluded from recharge computations. Ground water recharge and draft were computed separately for command and non-command areas.

Ground Water Recharge in various Seasons

Recharge from monsoon rainfall has been estimated separately for command and non-command areas. Recharge has been computed using both water level fluctuation method as well as rainfall infiltration factor method. For comparison of figures obtained from the above two methods, percent deviation has been computed and the recharge has been calculated according to the recommended methodology. Recharge from rainfall during non-monsoon period has been computed by Rainfall Infiltration Factor Method only.

Table 10.1:Specific yield and rainfall infiltration factors of different rock types in the study area

Sl. No.	Rock type	Specific Yield	Rainfall Infiltration Factor
1	Granite	0.02	0.01
2	Charnockite	0.02	0.05
3	Khondalite	0.02	0.02

Besides rainfall, the other sources which contribute towards recharge of ground water resources are seepage from canal, return flow from irrigation (both surface as well as ground water), recharge from tanks and ponds, recharge from water conservation structures etc. The recharge from such sources has been computed based on the data supplied by the state agencies. As per the recommended methodology the recharge has been computed separately for monsoon and non-monsoon periods. The factors for computation of return flow from irrigation, seepage from canals, recharge from tanks and ponds and water conservation structures have been taken as those recommended by GEC'2015 (Table 10.2).

Table 10.2: Norms used for Recharge from Other Sources

1	**Recharge Due to Seepage From Canals**	
	Formation	**Canal Seepage factor ham/day/ million square meters of wetted area**
	Unlined canals in normal soils with some clay content along with sand	10-20
	Lined canals in normal soils with some clay content along with sand	5
	All canals in hard rock area	3.5
2	**Recharge Due to Irrigation by Surface Water**	
	Crop type	**Recharge as a percentage of applied water**
	Paddy	50%
	Non-paddy	30%
3	**Recharge Due to Irrigation by Ground Water**	
	Crop type	**Recharge as a percentage of applied water**
	Paddy	45%
	Non-paddy	25%
4	**Recharge due to Tanks & Ponds**	
	Seepage from Tanks & Ponds	1.4 mm / day
5	**Recharge due to Water Conservation Structures**	
	Season	**Recharge as a percentage of gross storage**
	Monsoon	20%
	Non-monsoon	20%

Table 10.3: Block wise groundwater recharge in different seasons

(Figures are in Ham)

Sl. No.	Block	Monsoon		Non Monsoon		Total Recharge
		Rainfall	Other Sources	Rainfall	Other Sources	
1	BHAPUR	2471.59	148.27	470.35	237.2	3327.41
2	DASPALLA	3763.96	1121.47	964.07	1473	7322.5
3	GANIA	1717.76	158.95	370.92	306.54	2554.17
4	KHANDAPADA	2014.07	234.95	551.23	376.97	3177.22
5	NAYAGARH	1865.92	865.25	430.27	1060.11	4221.55
6	NUAGAON	4416.24	253.13	710	403.19	5782.56
7	ODOGAON	2994.05	1432.8	812.94	1577.07	6816.86
8	RANAPUR	3743.6	328.39	913.91	530.14	5516.04

Ground Water Draft for Various Purposes

Ground water draft for domestic use has been estimated based on block-wise population. The annual average per capita consumption has been taken as 22.5 m^3 (60 litres per day) assuming 100% dependence on ground water. Drafts during monsoon and non-monsoon periods have been estimated separately. Ground water draft for irrigation was estimated based on the number of structures and the unit draft (Table 10.4) of different types of structures. Ground water draft for industrial use is negligible and has not been included while assessing the ground water draft.

Table 10.4:Unit Draft of different types of structures

Sl. No.	Type of structure	Average annual draft (ha m/structure)	
		Monsoon	Non-monsoon
1	Dug well with Pump	0.075	0.675
2	Shallow bore well	0.200	1.800
3	Dug well	0.040	0.360

Table 10.5: Block wise ground water draft for various uses

(Figures are in Ham)

Sl. No.	Block	Draft for domestic use	Draft for irrigation	Draft for all uses
1	BHAPUR	299.63507	490.16	789.79507
2	DASPALLA	292.733285	1194.36	1487.0933
3	GANIA	108.237465	1010.49	1118.7275
4	KHANDAPADA	361.57849	1160.57	1522.1485
5	NAYAGARH	619.0814275	2082.6	2701.6814
6	NUAGAON	261.179765	1075.02	1336.1998
7	ODOGAON	470.9815825	2292.45	2763.4316
8	RANAPUR	794.2624475	1590.71	2384.9724

Level of Development and Categorisation

Net annual ground water availability has been computed by deducting the unaccounted natural discharge from the total annual recharge. Unaccounted natural discharge has been taken as 5% of the total annual recharge as per the criteria recommended by GEC'2015.

Stage of ground water development has been computed using the relation:

$$Stage of ground water development = \frac{Gross ground water draft for all uses}{Annual available ground water resource} \times 100$$

The block-wise resource of the aquifer mapping blocks as on 2020 is given below in **Table 10.6.**

Table 10.6 Dynamic Ground Water Resources of Aquifer-I in Nayagarh District. (2020)

Sl No	District	Block	Annual Extractable GW (Ham)	Gross Draft (Ham)	GW Available for Future Use (Ham)	Stage of Extraction
1	Nayagarh	Bhapur	2994.67	789.79	2182.81	26.38
2	Nayagarh	Daspalla	6590.26	1487.09	5095.22	28.63
3	Nayagarh	Gania	2426.46	1118.72	1300.59	46.11
4	Nayagarh	Khandapada	2859.5	1522.15	1322.23	53.23
5	Nayagarh	Nayagarh	3942.1	2721.58	995.05	66.05
6	Nayagarh	Nuagaon	5493.43	1336.2	4140.65	24.32
7	Nayagarh	Odogaon	6351.35	2763.44	3569.79	47.19
8	Nayagarh	Ranapur	5240.24	2384.98	2855.26	45.51
		Total	35898.01	14123.95	21461.6	42.18

The combined net ground water available is **35898.01**ham and gross annual draft is **14123.95**ham. The stage of ground water development is minimum for Nuagaon block which is 24.32 %. The highest ground water development is in kantamal block that is 60.75 % and all the blocks are in safe category.

The ground water resource can be aquifer wise divided into Dynamic and Static resource. The dynamic resource is the part of resource within the water level fluctuation zone which is also the annual replenishable resource. The resource below the water level fluctuation zone is termed as the In-storage (Static) resource. Mainly the water level fluctuation method was adopted for calculation of recharge.The in-storage resources are calculated separately for aquifer-i and ii. However the semi-confined to confined deeper aquifers have linkage to the unconfined aquifer through the fractures and receive continuous recharge. The in-storage ground water resources of aquifer-i are given in table 10.7 and the total resources of aquifer-i in table 10.8 below.

Table 10.7 In-storage Ground Water Resources of Aquifer-I in Nayagarh District

Sl No	Block	Assessment Area	Bottom Depth of Aquifer	Average Pre-monsoon Water Level	Total Effective Saturated Thickness 5% of (2-3)	Average Specific Yield	In Storage Ground Water Resources [(1)*(4)*(5)]
		(Ha)	(mbgl)	(mbgl)	(m)		(Ham)
		1	2	3	4	5	6
1	Bhapur	23973	16.16	5.16	11	0.02	5274.06
2	Daspalla	88792	16.31	5.61	10.7	0.02	19001.49
3	Gania	44119	18.75	4.67	14.08	0.02	12423.91
4	Khandapada	35107	18.08	4.05	14.03	0.02	9851.02
5	Nayagarh	23544	26.84	5.23	21.61	0.02	10175.72
6	Nuagaon	65207	10.94	4.77	6.17	0.02	8046.54
7	Odogaon	49043	18	4.4	13.6	0.02	13339.70
8	Ranapur	61256	26.9	5.44	21.46	0.02	26291.08
	Total	391041					104403.51

Table 10.8 Total Ground Water Resources in Aquifer-I in Nayagarh District (2020)

Sl No	Block	Dynamic Resource (Ham)	In Storage Resource (Ham)	Total Ground Water Resource (Ham)
1	Bhapur	2994.67	5274.06	8268.73
2	Daspalla	6590.26	19001.49	25591.748
3	Gania	2426.46	12423.91	14850.3704
4	Khandapada	2859.5	9851.02	12710.5242
5	Nayagarh	3942.1	10175.72	14117.8168
6	Nuagaon	5493.43	8046.54	13539.9738
7	Odogaon	6351.35	13339.70	19691.046
8	Ranapur	5240.24	26291.08	31531.3152
	Total	35898.01	104403.51	140301.5244

The in-storage ground water resource in Aquifer- II i.e. the semi-confined to confined aquifer is shown in Table 10.9.

Table 10.9 In-storage Ground Water Resources of Aquifer-II in Nayagarh District

Sl No	Block	Assessment Area	Top Depth of Aquifer	Bottom Depth of Aquifer	Total Satu-rated Thickness	Productive Zone	Avg. Sp. Yield	In Storage Ground Water Resources
		(Ha)	(mbgl)	(mbgl)	(m)	(5% of Total Thickness)		(Ham)
						(m)		
		1	2	3	(4)=(3-2)	5	6	(7)=(1*5*6)
1	Bhapur	23973	16.16	200	183.84	9.192	0.015	3305.40
2	Daspalla	88792	16.31	200	183.69	9.1845	0.015	12232.65
3	Gania	44119	18.75	200	181.25	9.0625	0.015	5997.43
4	Khandapada	35107	18.08	200	181.92	9.096	0.015	4790.00
5	Nayagarh	23544	26.84	200	173.16	8.658	0.015	3057.66
6	Nuagaon	65207	10.94	200	189.06	9.453	0.015	9246.03
7	Odogaon	49043	18	200	182	9.1	0.015	6694.37
8	Ranapur	61256	26.9	200	173.1	8.655	0.015	7952.56

Irrigation Potential that can be created:

Irrigation potential of ground water resources is the area that can be irrigated from available ground water resources. In this report block-wise irrigation potentials have been computed considering both 70% and 90% of the available resources as exploitable within safe limits. Since the principal irrigated crop in the district is paddy, the irrigation potential has been computed considering the crop waterrequirement of paddy for Odishai.e. 0.125 m.

The computational procedure followed is given below.

1. Considering 70% stage of development: $P_i = ((0.7 \times R_a) - D_G^{\,i} - D^d_{2025}) / \Delta$
2. Considering 90% stage of development: $P_i = ((0.9 \times R_a) - D_G^{\,i} - D^d_{2025}) / \Delta$
3. Ultimate irrigation potential: $P_i = R_a - D^d_{2025} / \Delta$

Where,

P_i = Irrigation potential in ha

R_a = Available ground water resources (Total Resources – Natural losses) in ha m

D_G^i = Gross ground water draft for irrigation in ha m

D^d_{2025} = Allocation for domestic and industrial use in the year 2025 in ha m

Δ = Crop water requirement in m (here it is 0.125 m)

Present ground water development:

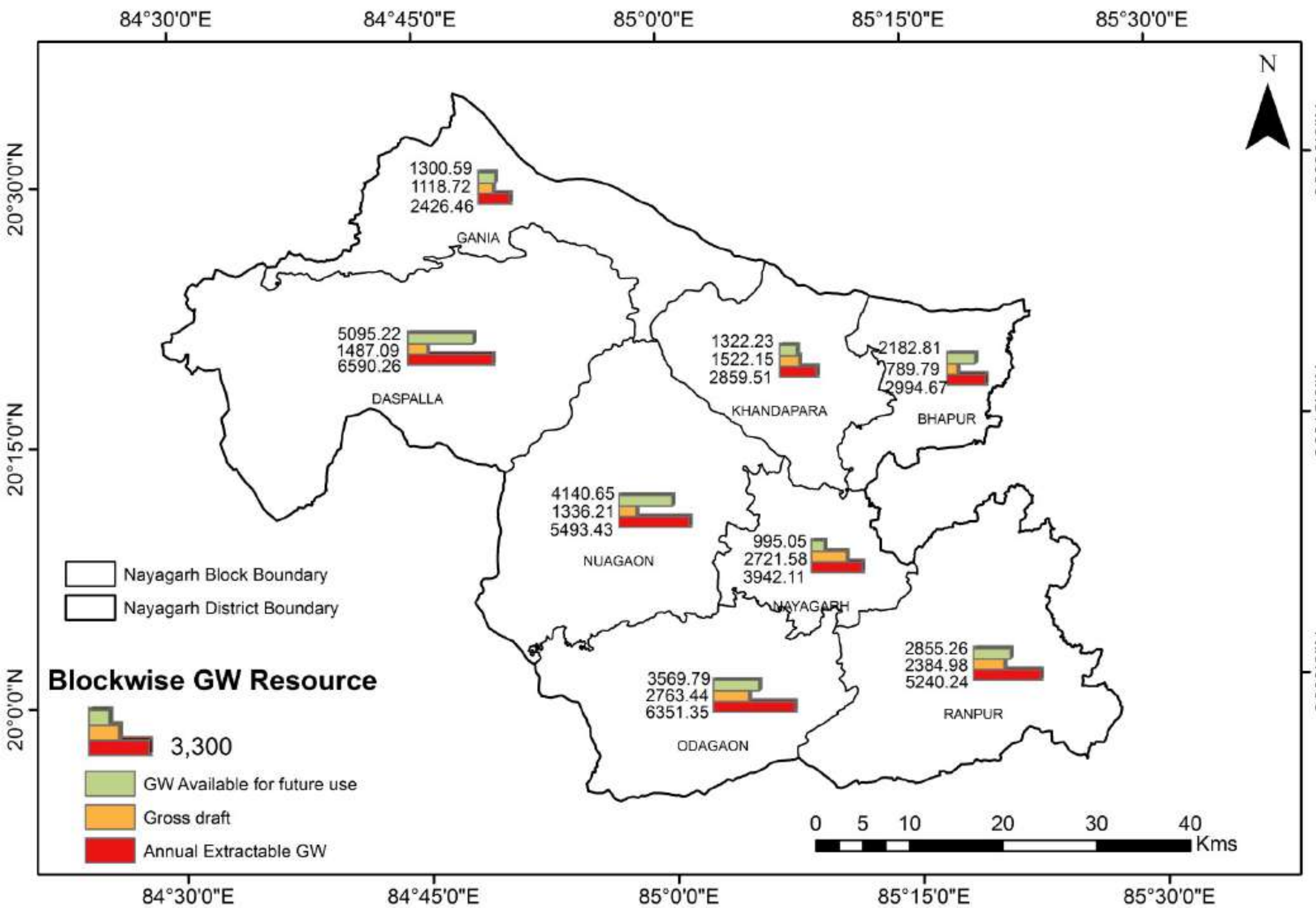
The present Ground Water Development in the district has been calculated for each block. All the blocks in the study area have been categorized as safe from ground water abstraction point of view.

The overall ground water development in the study area is moderate except for the Nayagarh block which has a higher stage of development. This may be attributed to the high stage of development in the Nayagarh urban area. The ground water development in the entire study area is 42.18 %. The study area as a whole and each individual blocks are safe from ground water development point of view.

Table 10.10:Block wise irrigation potentials

Sl. No.	Block	Net Annual Extractable Ground Water	Natural losses	allocation for domestic and industrial use in the year 2025	Gross draft for irrigation	Irrigation potential (assuming 70% development)	Irrigation potential (assuming 90% development)
		(ha m)	(ha m)	(ha m)	(ha m)	(ha)	(ha)
1	Bhapur	2994.67	332.74	321.71	490.16	8411.848	12670.94
2	Daspalla	6590.26	732.24	300.68	1194.36	20844.59	30217.42
3	Gania	2426.46	127.71	115.39	1010.49	3865.96	7543.96
4	Khandapada	2859.5	317.72	376.7	1160.57	1935.808	6002.656
5	Nayagarh	3942.1	279.45	844.55	2082.6	2906.36	2953.88
6	Nuagaon	5493.43	289.13	277.76	1075.02	18321.84	26648.72
7	Odogaon	6351.35	465.51	489.1	2292.45	10708.3	20125.65
8	Ranapur	5240.24	275.8	5425.45	1590.71	28328.42	20385.31
	Total	35898.01	2820.3	8151.34	10896.36	95323.13	126548.5

Fig 10.1 Dynamic Ground Water Resources of Nayagarh District (2020)



11. Ground Water Quality

Chemical quality of ground water has been assessed on the basis of chemical analysis of ground water samples collected during ground water monitoring and hydrogeoogical survey. Quality of ground water from deeper aquifers was assessed during the exploration activities like drilling and pumping tests. The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water. The chemical quality of ground water in the district is monitored annually on a routine basis by CGWB through its National Hydrograph Network Stations. During the NAQUIM programme, 127 water samples were collected from the shallow and deeper aquifers and results of their chemical analysis is given in Table 11.2 and Table 11.3.No quality problem was reported from the study area. Aquifer-wise ranges of chemical constituents are given in Table 11.1.

Ground Water Suitability for Various Uses:

All the analysed parameters, in all stations fall well within safe limits for drinking as well as irrigation purpose as prescribed by the BIS (Annexure). The pH value ranges from 6.08 to 8.13 and is within the prescribed limit by BIS. The Electrical Conductivity (EC) value ranges from 149 to 2640 micro siemens/. All of the samples have EC value well within the range. The Cl^- varies from 25 mg/l to 447 mg/l. F^- varies from 0.01 mg/l to 1.62 mg/l. The Total Hardness (TH) value ranges from 45 mg/l to 600 mg/l. The Ca^{+2} values vary from 10 mg/l to 166 mg/l and Mg^{+2} values vary from 1 mg/l to 123 mg/l. Almost all the values of the analysed parameters fall under the safe category for both drinking and irrigation purpose. The iso-conductivity map of phreatic and deeper aquifers of the district has been prepared and presented as Fig.11.2 (A) and Fig.11.2(B)respectively. The chloride and fluoride concentration in shallow and deeper aquifer of the study area are shown in Fig. 11.3(A) & (B) and Fig. 11.4(A) & (B). The quality of ground water is generally good with EC ranging from 149 to 2640 µs/cm.

The analysed results are presented in the form of piper trilinear diagram in order to have an idea about similarity and difference in composition of the ground water in different geological and hydrogeological environment. Fig. 11.5(A) and Fig. 11.5(B)show the trilinear plot of various chemical parameters. From the figure it may be seen that the ground water in the area is of no predominant type. This shows clearly that the ground water is not much evolved and by and large it is within the potable limits.

The sodium absorption ratio (SAR) is calculated and is plotted against EC value and is presented in Fig. 11.6(A) and Fig. 11.6(B)as US salinity diagram. The SAR values indicate the degree to which irrigation water tends to enter into cation exchange reaction with soil. High value of SAR indicates a hazard of sodium replacing already absorbed Ca and Mg in the soil, which in turn leads to damaging soil structure. From the figure it may be seen the ground water is falling under medium to high salinity hazard zone.

The predominant USSL classes of the water samples fall within C2S1 and C3S1 classes. The water samples represent Mg-HCO_3type to mixed facies of Ca-Mg-Na-HCO_3-Cltypes as shown in the Piper diagram in Fig. 11.5(A) and Fig. 11.5(B). This indicates a transitional or mixing environment between the younger water and resident water.

Table 11.1 Aquifer-wise Ranges of Chemical Constituents in Nayagarh District

Parameter	Unit	Shallow (Aquifer-I)		Deep (Aquifer-II)	
		Minimum	Maximum	Minimum	Maximum
pH	-	6.08	8.13	6.95	8.2
EC	µS/	149	2640	250	1900
TDS	mg /L	-	-	159.1	927.88
TH	mg/	45	660	82	714
TA	mg/ L	-	-	90	460
Ca^{++}	mg/	10	166	14	110
Mg^{++}	mg/	1	123	6	104
Na^{+}	mg/	3	298	11	180
K^{+}	mg/	1	307	1	144
$CO_3^{=}$	mg/	0	0	0	0
HCO_3^{-}	mg/	37	549	110	561
NO_3^{-}	mg/	0	271	0	48
Cl^{-}	mg/	25	447	7	478
$SO_4^{=}$	mg/	2	201	1	75
F^{-}	mg/	0.01	1.62	0.015	2.17

Fig.11.1 Water Quality Sampling Locations in Nayagarh District

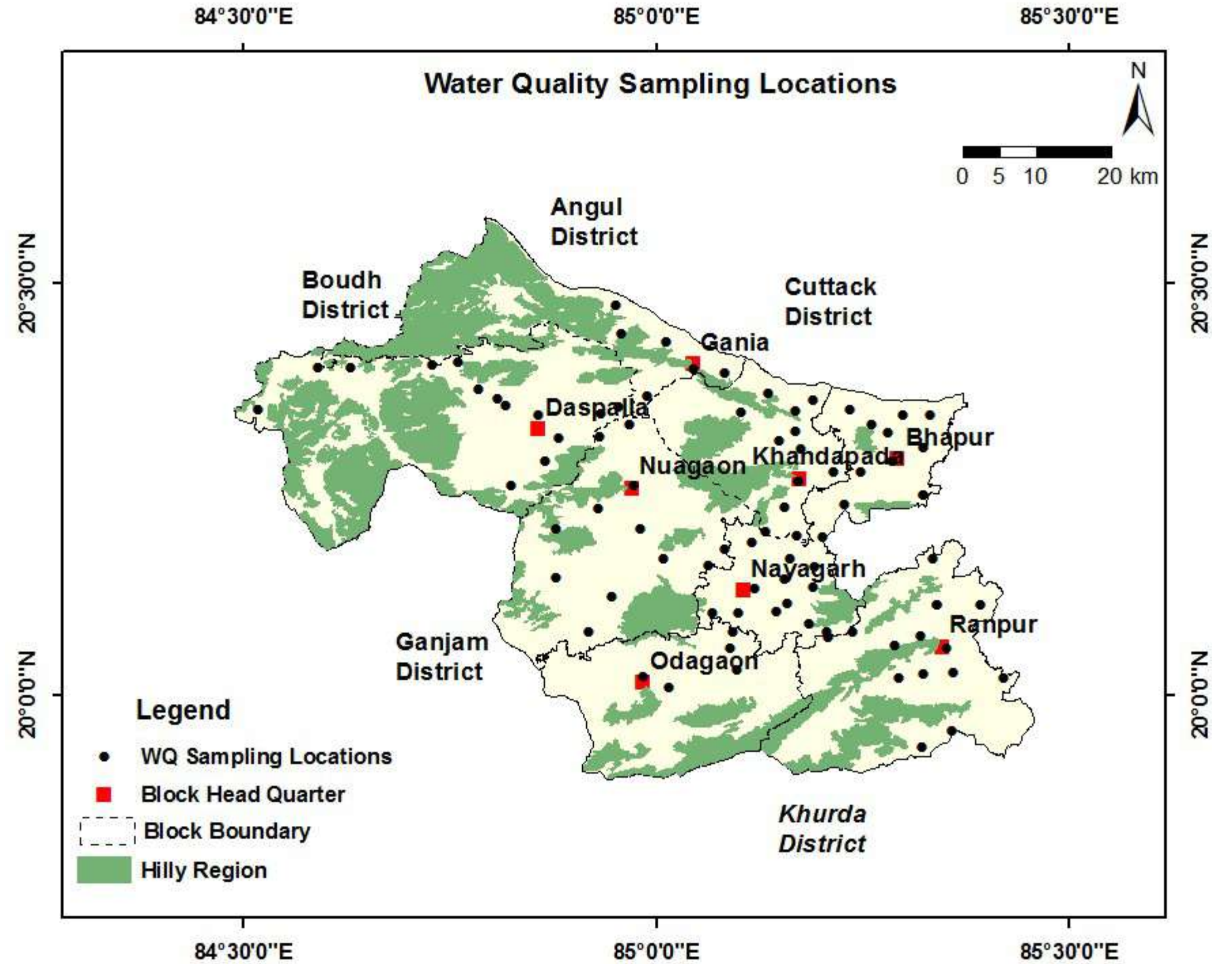


Fig.11.2 (A) Iso-Conductivity Map of Phreatic Aquifer

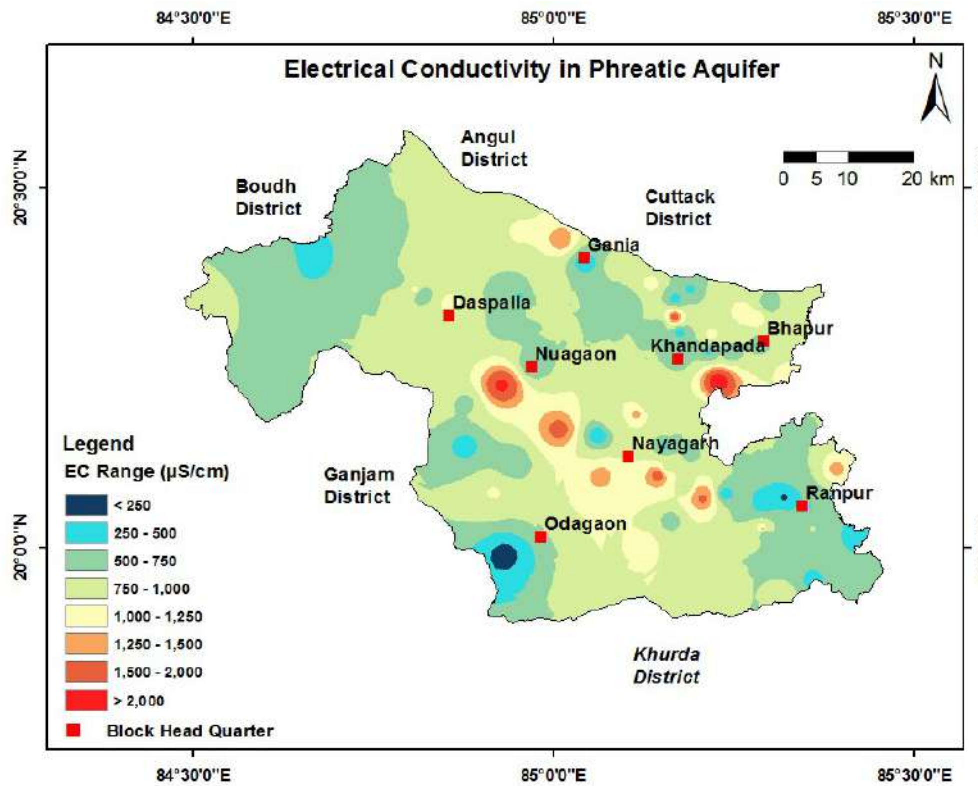


Fig.11.2 (B) Iso-Conductivity Map of Fractured (Deeper) Aquifer

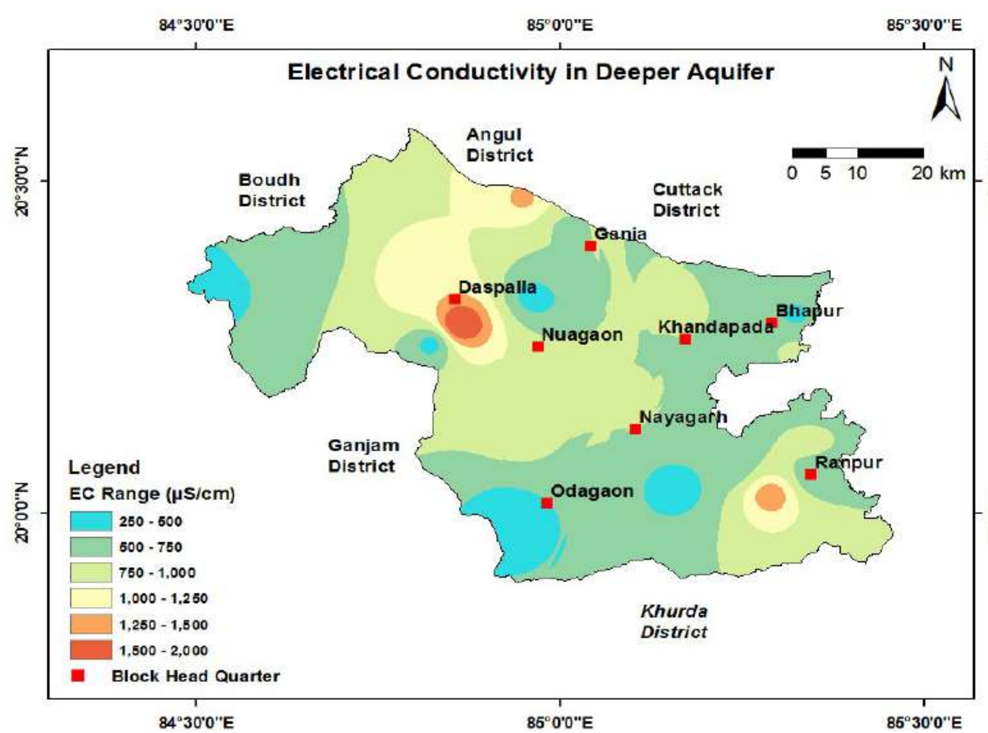


Fig.11.3 (A)Chloride Concentration in Phreatic Aquifer

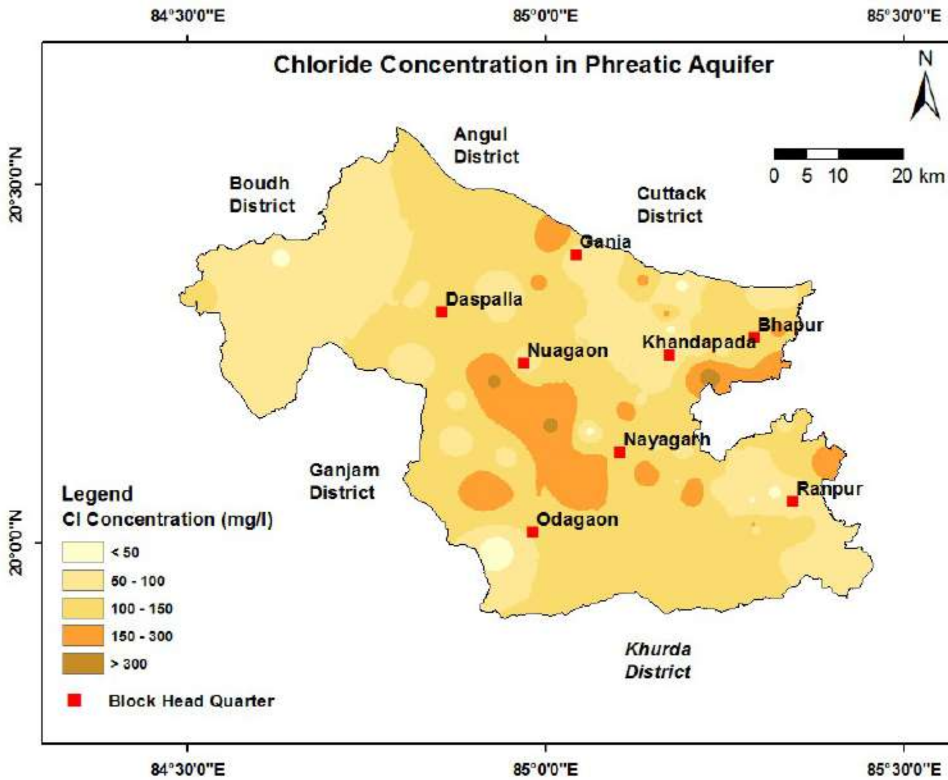


Fig.11.3 (B)Chloride Concentration in Fractured Aquifer

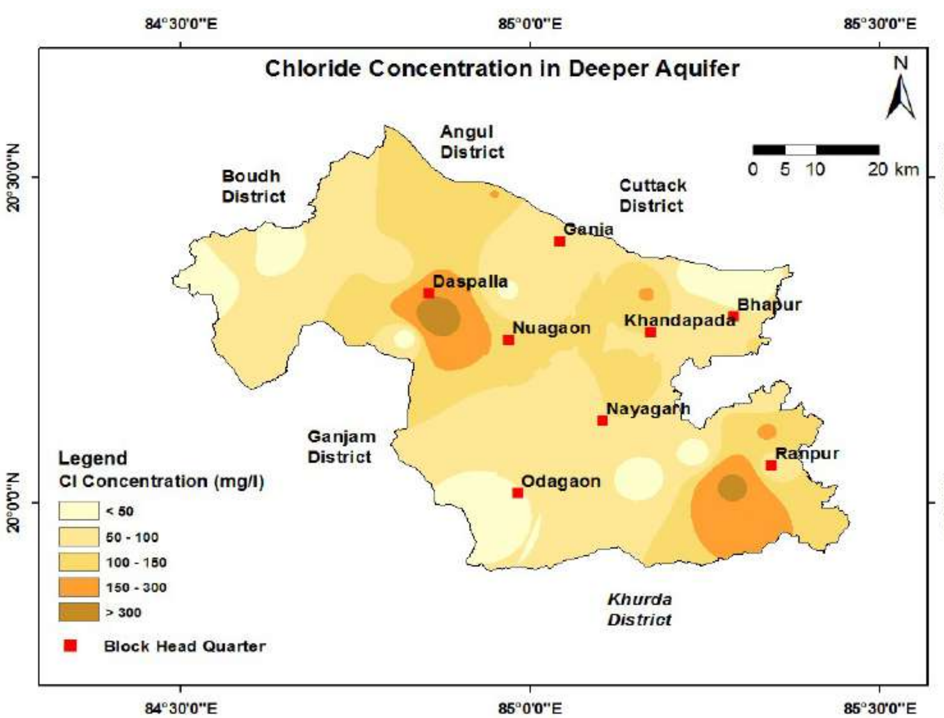


Fig.11.4 (A) Fluoride Concentration in Phreatic Aquifer

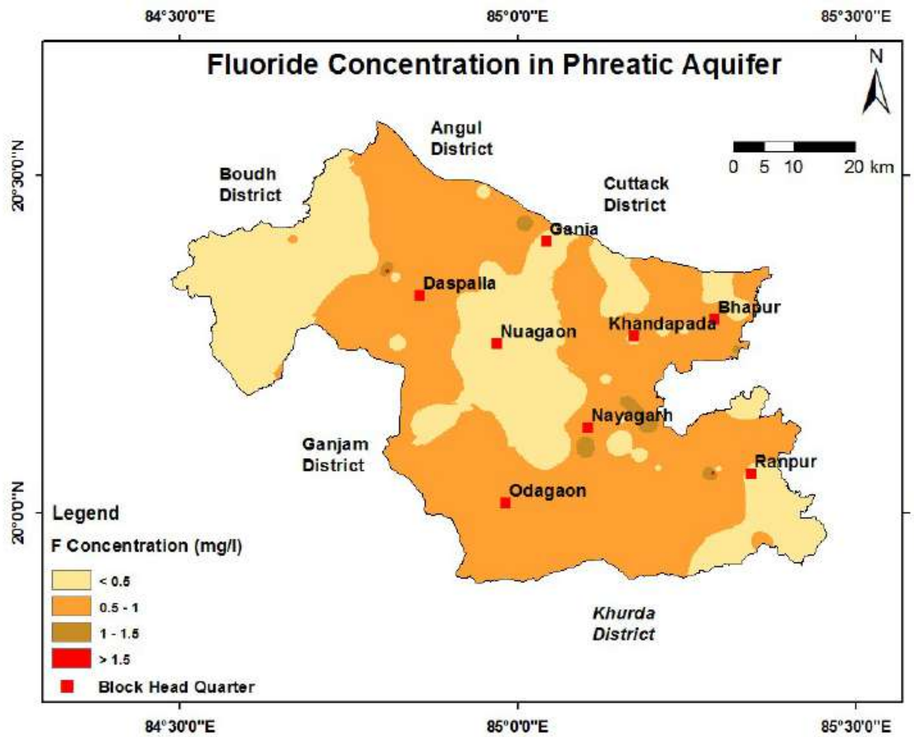


Fig.11.4 (B)Fluoride Concentration in Fractured Aquifer

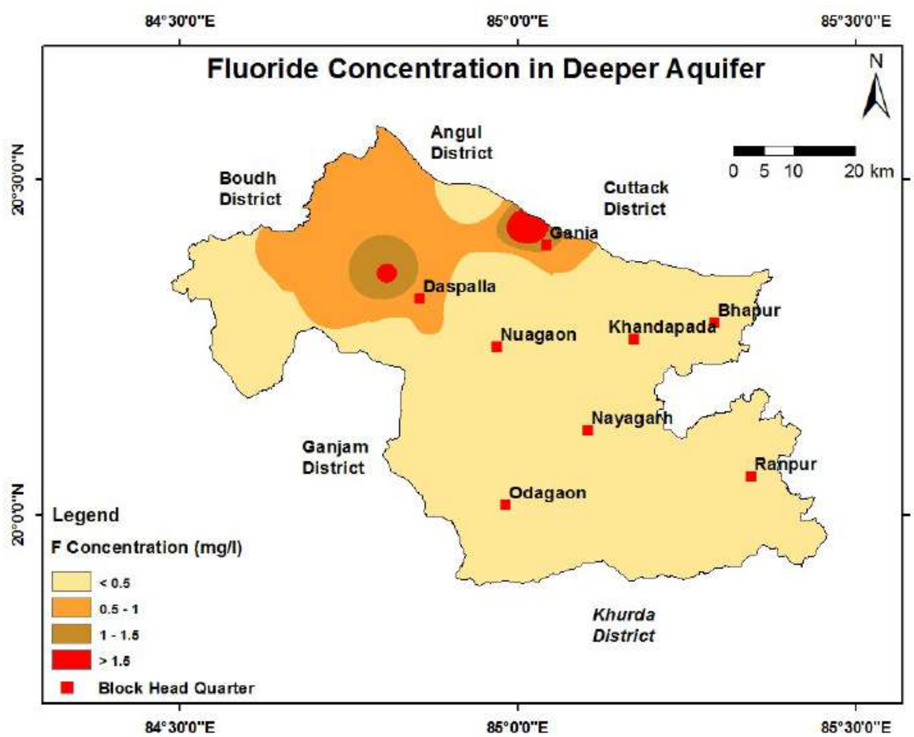


Fig. 11.5(A) Piper Diagram of Phreatic Water Samples

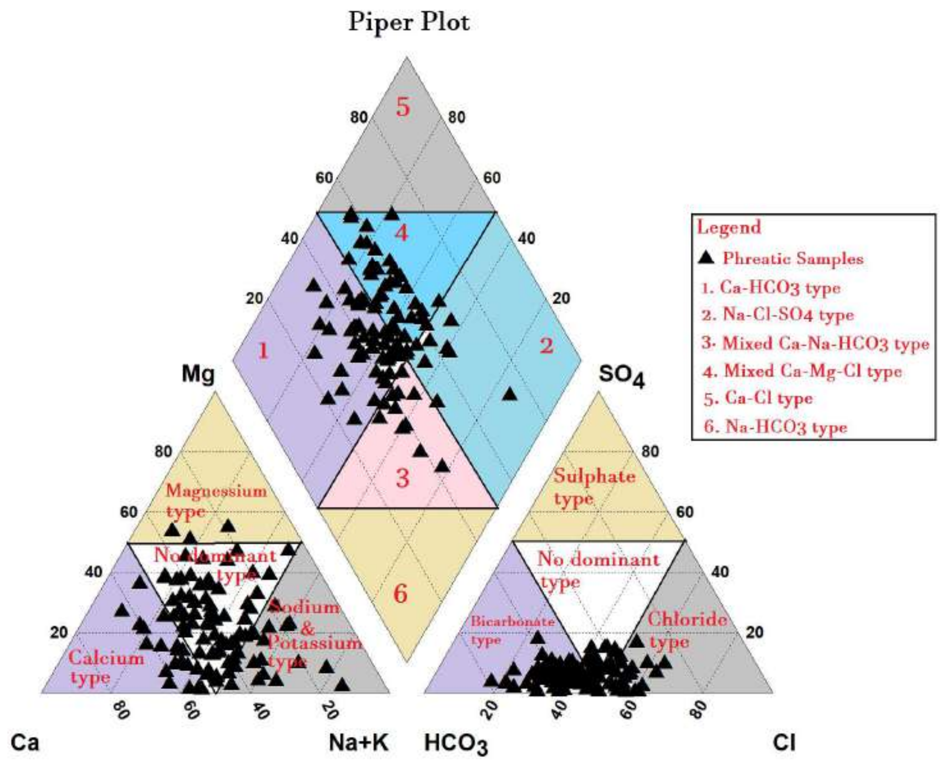


Fig. 11.5(B) Piper Diagram of Deeper Water Samples

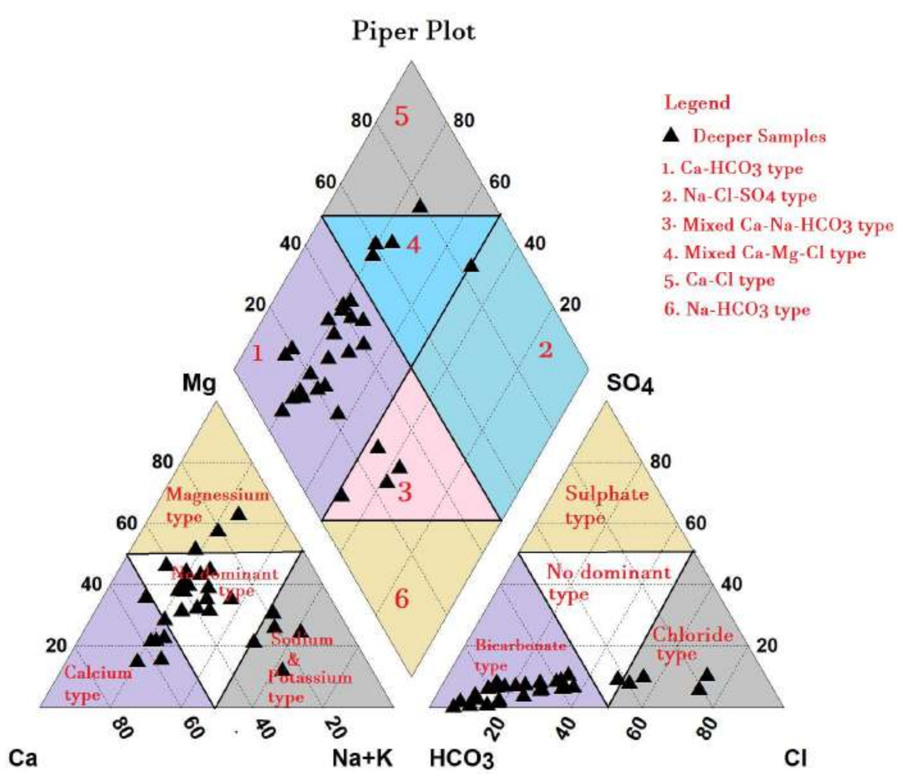


Fig. 11.6(A) US-Salinity Diagram of Phreatic Aquifer

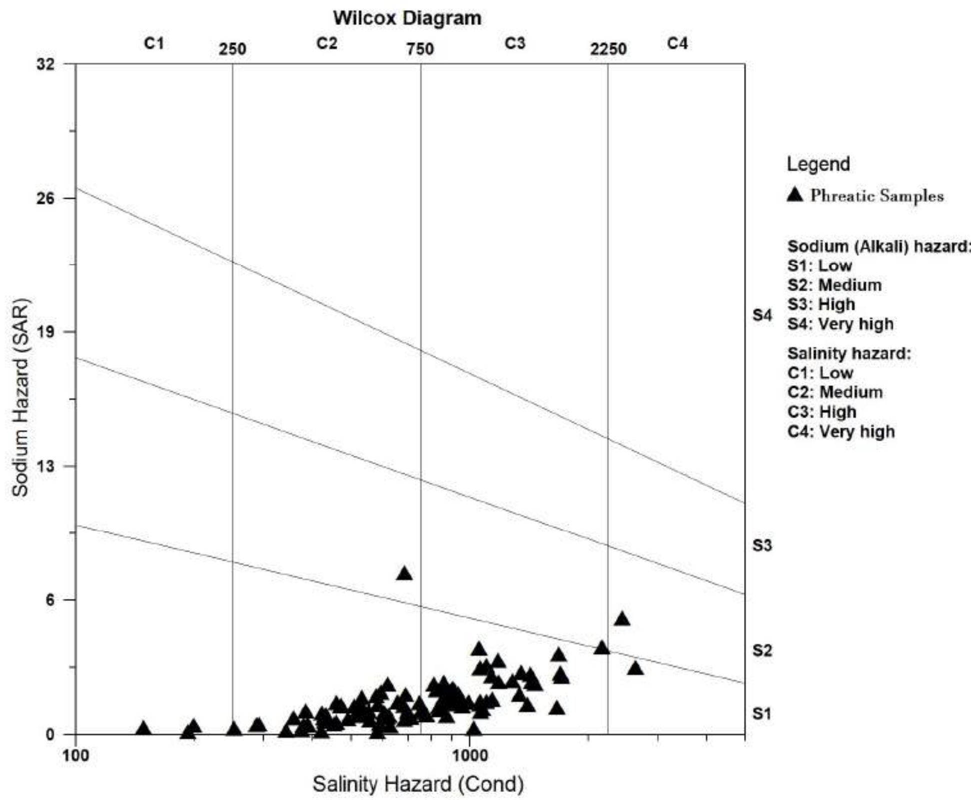


Fig. 11.6(B) US-Salinity Diagram of Deeper Aquifer

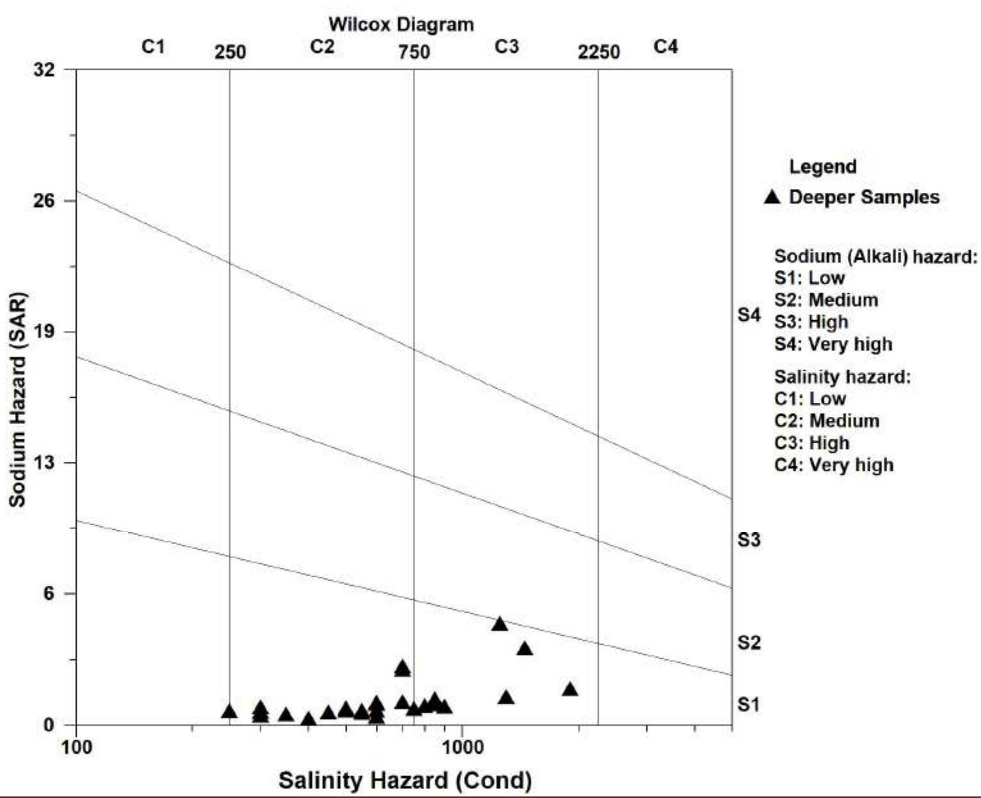


Table 11.2 Chemical Analysis Results of Samples from Phreatic Aquifer																
SL No	DISTRICT	LOCATION	pH	EC in µs/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
1	Nayagarh	Andapali	7.2	1429	390	84	44	130	39	0	445	199	58	12	1.0
2	Nayagarh	Adakata	7.26	995	320	100	17	63	18	0	214	170	24	59	0.5
3	Nayagarh	Bada-Pandeswar	7.45	695	190	36	24	35	66	0	146	128	23	20	1.2
4	Nayagarh	Bahajdola	7.1	1024	460	128	34	15	12	0	256	199	19	16	0.6
5	Nayagarh	BaldiaNuagaon	7.26	2640	520	92	71	167	307	0	476	426	93	271	0.8
6	Nayagarh	Balugaon	7.5	1341	340	108	17	80	114	0	366	199	35	95	0.5
7	Nayagarh	Banamalipur	7.61	459	120	44	2	38	22	0	140	78	14	7	0.5
8	Nayagarh	Banigochha	7.42	618	230	72	12	29	16	0	195	85	14	22	0.3
9	Nayagarh	Bantala	7.51	526	180	60	7	28	28	0	183	78	15	13	0.6
10	Nayagarh	Barapalli	7.54	430	160	36	17	18	15	0	140	71	4	7	0.6
11	Nayagarh	Benagadia	8.13	1704	340	120	10	123	190	0	549	163	59	143	0.3
12	Nayagarh	Bentapada	7.8	935	280	36	46	75	21	0	281	135	30	10	0.5
13	Nayagarh	Bhapur	7.52	583	270	64	27	5	14	0	146	114	7	4	0.7
14	Nayagarh	Bherupada	7.7	390	140	32	15	13	22	0	146	53	3	18	0.26
15	Nayagarh	Biruda	7.56	624	250	60	24	32	1	0	256	71	4	4	1.34
16	Nayagarh	Buguda	7.54	630	260	56	29	15	15	0	159	92	3	62	0.16
17	Nayagarh	Champatipur	7.78	828	230	88	2	75	14	0	244	135	11	17	1.2
18	Nayagarh	Charamula	7.55	1060	330	84	29	61	46	0	317	121	35	64	0.89
19	Nayagarh	Darpanarayanpur	6.74	343	150	32	17	6	13	0	79	71	2	24	0.7
20	Nayagarh	Dasapalla	7.12	1103	270	64	27	124	13	0	458	121	15	1	0.84
21	Nayagarh	Dianpada(Patharakata)	6.88	1402	480	68	75	72	49	0	384	227	37	42	0.11
22	Nayagarh	Dimiria	7.1	685	250	68	19	26	37	0	238	85	16	42	0.67
23	Nayagarh	Durgaprasad	7.4	292	110	28	10	12	14	0	61	57	2	17	0.52
24	Nayagarh	Fategarh	7.18	895	240	72	15	52	58	0	226	163	32	1	0.41
25	Nayagarh	Gania	7.44	289	100	28	7	11	16	0	79	57	4	5	0.15

26	Nayagarh	Gasisevipur	7.37	432	130	44	5	24	19	0	116	78	7	11	0.24
27	Nayagarh	Ghanasaila	7.28	1106	300	116	2	62	87	0	329	163	26	48	0.2
28	Nayagarh	Gholahandi	7.4	472	130	40	7	36	14	0	153	64	8	7	0.34
29	Nayagarh	Giridipalli	7.42	609	170	60	5	32	52	0	195	92	10	13	0.99
30	Nayagarh	Godbanikilo	7.54	1352	230	80	7	103	162	0	372	206	42	65	0.6
31	Nayagarh	Godipada	7.62	595	120	40	5	51	57	0	122	121	8	46	0.57
32	Nayagarh	Gohiriapada	7.42	1080	360	136	5	54	60	0	397	135	13	33	0.55
33	Nayagarh	Goomy	7.58	375	160	28	22	7	17	0	98	78	2	1	0.46
34	Nayagarh	Gopalpur	7.37	760	260	80	15	46	13	0	201	114	10	40	0.25
35	Nayagarh	Gopinathpur	7.65	379	140	32	15	12	14	0	98	71	3	6	0.36
36	Nayagarh	Gunthuni	7.5	874	270	84	15	34	75	0	281	128	33	4	0.63
37	Nayagarh	Hatdwar(Simlisahi)	6.08	253	100	10	18	7	16	0	85	39	5	8	0.38
38	Nayagarh	Indipata	6.64	812	225	24	40	83	8	0	293	78	51	1	0.52
39	Nayagarh	Itamati	6.43	426	150	28	19	22	11	0	165	64	4	1	0.4
40	Nayagarh	Jamusahi	6.54	534	140	48	5	37	12	0	159	71	13	11	0.48
41	Nayagarh	Jogiapalli	6.78	827	175	36	21	64	53	0	299	85	36	0	0.44
42	Nayagarh	KaduaJagannath	6.71	840	245	66	19	43	56	0	214	121	43	31	0.6
43	Nayagarh	Kajalaipallisasan	6.79	1068	415	68	60	52	15	0	226	121	53	200	0.81
44	Nayagarh	Kajumendhi	7.05	916	220	52	22	72	50	0	268	107	44	50	0.4
45	Nayagarh	Kalurkumpa	7.02	555	185	22	32	35	11	0	238	43	22	7	0.06
46	Nayagarh	Kalyanpur	7.09	1181	275	42	41	134	10	0	415	149	38	6	0.5
47	Nayagarh	Kantillo	7.18	453	165	52	9	15	11	0	214	36	9	9	0.81
48	Nayagarh	Khalameda	7.24	2170	560	22	123	226	7	0	458	330	133	128	0.45
49	Nayagarh	Khamarsahi	7.26	905	225	56	21	76	39	0	134	149	36	115	0.78
50	Nayagarh	Khandapada	7.06	585	190	48	17	45	7	0	275	53	8	1	0.48
51	Nayagarh	Koilma	7.14	422	135	30	15	27	8	0	92	71	24	18	1.19
52	Nayagarh	Komand	7.02	149	45	16	1	5	8	0	37	25	7	1	0.67
53	Nayagarh	Koska	7.08	580	140	48	5	50	26	0	220	64	14	1	0.31
54	Nayagarh	Kotagad	7.2	1064	315	72	33	65	52	0	305	163	41	24	0.54

55	Nayagarh	Kotapokhori	7.27	523	165	40	16	35	19	0	171	57	23	29	1.12
56	Nayagarh	Krishnach.pur	7.19	384	125	30	12	29	6	0	140	46	8	3	1.62
57	Nayagarh	Kuanria	7.17	1063	275	80	18	121	7	0	262	138	72	101	1.58
58	Nayagarh	Lathipada	7.32	921	250	70	18	68	44	0	214	117	36	105	0.28
59	Nayagarh	Lenkujipada	7.45	1057	215	36	30	139	12	0	403	117	36	22	1.48
60	Nayagarh	Madhapur	7.3	960	350	70	43	58	6	0	275	114	45	64	0.65
61	Nayagarh	Madhyakhanda	7.5	591	250	38	38	19	7	0	232	60	25	5	0.87
62	Nayagarh	Mahipur	7.2	1670	660	136	78	76	9	0	268	330	53	103	0.41
63	Nayagarh	Mahulia	7.55	1682	190	46	18	121	304	0	519	181	63	126	0.39
64	Nayagarh	Malisahi	7.68	897	250	74	16	69	37	0	299	131	19	4	0.33
65	Nayagarh	Marada	7.62	1143	300	82	23	67	88	0	281	138	24	137	0.57
66	Nayagarh	Mardarajpur	7.59	387	150	44	10	12	7	0	153	36	7	3	0.34
67	Nayagarh	Mayurjhalia	7.67	358	130	28	15	21	11	0	104	57	19	0	0.01
68	Nayagarh	Nandabara	7.5	862	225	56	21	85	12	0	348	85	29	5	0.6
69	Nayagarh	Nayagarh	7.47	2440	545	166	32	298	32	0	445	447	201	20	0.94
70	Nayagarh	Neliguda	7.63	533	160	44	12	51	7	0	201	64	18	0	0.23
71	Nayagarh	Notara(Tangipatnasahi)	7.68	748	185	60	9	47	72	0	262	96	11	17	0.35
72	Nayagarh	Nuagaon	7.57	459	190	40	22	18	6	0	159	64	14	0	0.04
73	Nayagarh	Odagaon	7.6	492	185	46	17	23	11	0	116	75	20	45	0.26
74	Nayagarh	Padmabati	7.52	558	205	40	26	23	10	0	171	60	24	33	0.29
75	Nayagarh	Patia	7.58	879	200	48	19	70	73	0	226	131	42	43	0.04
76	Nayagarh	Purusottampur	7.72	840	295	100	11	48	34	0	305	71	76	1	0.36
77	Nayagarh	Rajaballavapur	7.84	1287	325	88	26	106	45	0	433	156	49	11	0.63
78	Nayagarh	Rajapatana	7.7	1714	355	104	23	119	173	0	506	209	68	96	0.32
79	Nayagarh	RajSunakhela	7.65	620	145	54	2	66	16	0	146	96	46	28	0.07
80	Nayagarh	Rakama(Adiapada)	7.73	1185	180	48	15	77	177	0	415	128	38	36	0.47
81	Nayagarh	Ranapur	7.59	472	140	48	5	38	21	0	159	64	15	19	0.29
82	Nayagarh	Rangamatia	7.43	710	270	72	22	31	7	0	134	85	41	112	0.19
83	Nayagarh	Rasanga	7.28	1465	445	126	32	118	8	0	293	213	91	114	1.14

84	Nayagarh	Sakhini	7.55	834	290	56	36	52	9	0	250	78	39	75	0.47
85	Nayagarh	Sampada	7.57	193	90	26	6	3	9	0	55	36	9	8	0.31
86	Nayagarh	Sarankul	7.36	682	225	52	23	48	15	0	268	71	29	1	1.03
87	Nayagarh	Sidhamula	7.58	421	190	30	28	5	9	0	159	43	13	15	0.26
88	Nayagarh	Sikharpur	7.55	852	295	56	38	64	7	0	421	53	19	2	0.93
89	Nayagarh	Sikrida	7.5	778	290	76	24	36	15	0	177	103	27	100	0.27
90	Nayagarh	Singhapada	7.69	656	180	64	5	47	46	0	244	82	22	2	0.3
91	Nayagarh	Solopata	7.7	1140	325	60	43	115	7	0	537	92	21	1	1.48
92	Nayagarh	Soroda	7.75	511	150	46	9	38	23	0	116	99	16	24	0.19
93	Nayagarh	Takara	7.65	756	255	80	13	39	27	0	275	82	24	10	0.4
94	Nayagarh	Tarobalo	8.11	685	50	16	2	125	9	0	104	149	33	2	1.57
95	Nayagarh	Tarobalo(HP)	7.5	1440	400	62	60	115	63	0	384	220	53	51	0.5
96	Nayagarh	Tendabari	7.48	948	280	108	2	64	47	0	256	128	47	52	0.76
97	Nayagarh	Yosadapur	7.6	524	175	46	15	31	11	0	159	82	14	1	0.69
98	Nayagarh	Sanagada	7.67	200	65	16	6	8	9	0	43	36	6	6	0.71
99	Nayagarh	Majhiakhanda	7.61	689	170	52	10	57	32	0	159	124	34	6	0.56

Table 11.3 Chemical Analysis Results of Samples from Deeper Aquifer

SL NO	DISTRICT	VILLAGE	pH	ECµmh/cm	TDS	TH	TA	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3	F -
1	Nayagarh	Adakata	7.38	300	175.8	107	90	22	12	21	2.9	0	110	37	10	6	0.0414
2	Nayagarh	Balugaon	7.7	1450	748.9	372	115	84	39	167	2.3	0	140	372	75	46	0.068
3	Nayagarh	Banigocha	7.75	1900	927.88	714	190	110	104	109	4.2	0	232	478	57	45	0.551
4	Nayagarh	Bantala	7.8	750	386.97	321	150	57	43	34	1.3	0	183	142	31	41	0.034
5	Nayagarh	Benagadia	7.8	900	485.88	362	190	70	45	41	1.2	0	232	156	43	15	0.1
6	Nayagarh	Bentapada	7.85	850	448.29	327	140	90	24	45	1.5	0	171	160	41	34	0.015
7	Nayagarh	Darpanarayanpur	7.9	850	424.9	321	295	20	64	43	6.5	0	360	72	17	27	0.033
8	Nayagarh	Fategarh	7.9	500	236.44	204	210	41	24	25	1	0	256	19	11	6	0.75

SL NO	DISTRICT	VILLAGE	pH	ECµmh/cm	TDS	TH	TA	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3	F -
9	Nayagarh	Godipada	7.93	700	352.75	168	250	29	23	86	1.3	0	305	51	25	10	2.17
10	Nayagarh	Kajumendhi	7.93	800	422.52	321	220	33	57	39	1.2	0	268	104	27	40	0.254
11	Nayagarh	Kalukumpa	7.94	300	159.1	112	115	35	6	17	2.5	0	140	19	3	32	0.023
12	Nayagarh	Komand	8	600	309.66	260	175	53	30	27	3.8	0	214	74	20	48	0.035
13	Nayagarh	Kotagad	8	450	216.41	179	130	51	12	20	1.5	0	159	49	19	13	0.0421
14	Nayagarh	Kuanria	8	850	501.58	163	280	43	13	38	144	0	342	67	31	11	0.0524
15	Nayagarh	Madhapur	8	550	263.33	230	170	33	35	22	1.9	0	207	53	16	16	0.077
16	Nayagarh	Malisahi	8.1	600	299.62	219	220	39	29	38	1.3	0	268	30	24	23	0.371
17	Nayagarh	Nayagarh	8.11	350	181.69	143	140	41	10	15	5.9	0	171	23	5	4	0.045
18	Nayagarh	Odagaon	8.11	500	244.44	194	210	33	27	27	1	0	256	21	8	1	0.601
19	Nayagarh	Padmabati	8.12	300	194.49	128	140	41	6	13	2.7	0	171	7	1	0	0.09
20	Nayagarh	Rajaballavapur	8.14	1250	630.89	250	460	35	39	180	1	0	561	77	44	41	1.59
21	Nayagarh	Rajsunakhala	8.14	550	299.38	224	190	43	28	25	6.7	0	232	58	17	15	0.229
22	Nayagarh	Ranapur	8.16	600	295.51	270	245	63	27	16	1	0	299	33	4	35	0.161
23	Nayagarh	Rasanga	8.17	600	270.67	219	150	47	24	36	5	0	183	65	29	45	0.612
24	Nayagarh	Sakhini	8.2	700	369.75	260	225	51	32	43	11	0	275	67	29	42	0.041
25	Nayagarh	Sarankul	8.2	500	260.38	204	215	51	18	24	1	0	262	19	3	2	0.135
26	Nayagarh	Sikrida	8.2	700	426.1	184	320	27	28	85	1	0	390	19	9	3	0.252
27	Nayagarh	Tarobalo	8.2	400	190.85	179	160	33	23	11	1.3	0	195	19	13	15	0.073
28	Nayagarh	Tendabari	8.24	1300	621.86	500	380	115	51	72	2.5	0	464	151	59	47	0.039

12. Aquifer Groups and their Disposition

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

Aquifer- I (Unconfined Aquifer): Unconfined aquifer occurs in entire area except rocky outcrops, formed by the weathered mantle atop all crystalline 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.12.8.

Aquifer-II(Semi-Confined to Confined Aquifer):Semi-confined to confined aquifer occurs as fracture zone aquifers in the entire area irrespective of rock types. However the aquifer properties, the yield of bore wells constructed in them depends on the rock type. In general, most of the fracture zones are encountered within 0 to 150 mbgl and seldom beyond that. Thus the maximum depth for the Aquifer-II has been taken as 200 mbgl.
The characteristics of the aquifer groups are summarized in **Table 12.1**

Table 12.1: Characteristics of Aquifer Groups in Nayagarh District

Type of Aquifer Group	Formation	Depth range (mbgl)	Yield	Aquifer parameter	Suitability for drinking/ irrigation
Aquifer-I (Phreatic)	**Unconsolidated and Weathered** **Recent**: Soil, Alluvium & Laterite **Pre-cambrian**: Granite Gneiss, Charnockite, Khondalite,	0-30	10-50m^3/day	Specific Capacity Index: 0.5-40 lpm/m/m^2	Yes for both
Aquifer-II (Semi-confined to Confined)	**Fractured** Granite Gneiss, Charnockite, Khondalite	30-200	Negl.-13.5lps	Transmissivity: 0.95-50.11	Yes for both

Aquifer Disposition:

The ground water exploration data has been used to generate the 3D disposition of the aquifer system. It comprises of all existing litho-units and the zones tapped during the ground water exploration forming an aquifer. Based on the ground water exploration and micro-level hydrogeological survey data and aquifer delineation method, a schematic 3-D aquifer disposition is prepared and shown in **Fig. 12.1.** Four 2D schematic sections were drawn along lines A-A', B-B', C-C' and D-D' which are shown in plain view in **Fig.12.2** and the corresponding 2D schematic sections are shown in **Fig. 12.4**, **12.5, 12.6,** and **12.7**.A 3D Fence diagram is shown in **Fig. 12.2**.

Fig.12.1 Schematic 3D Aquifer Disposition in Nayagarh District

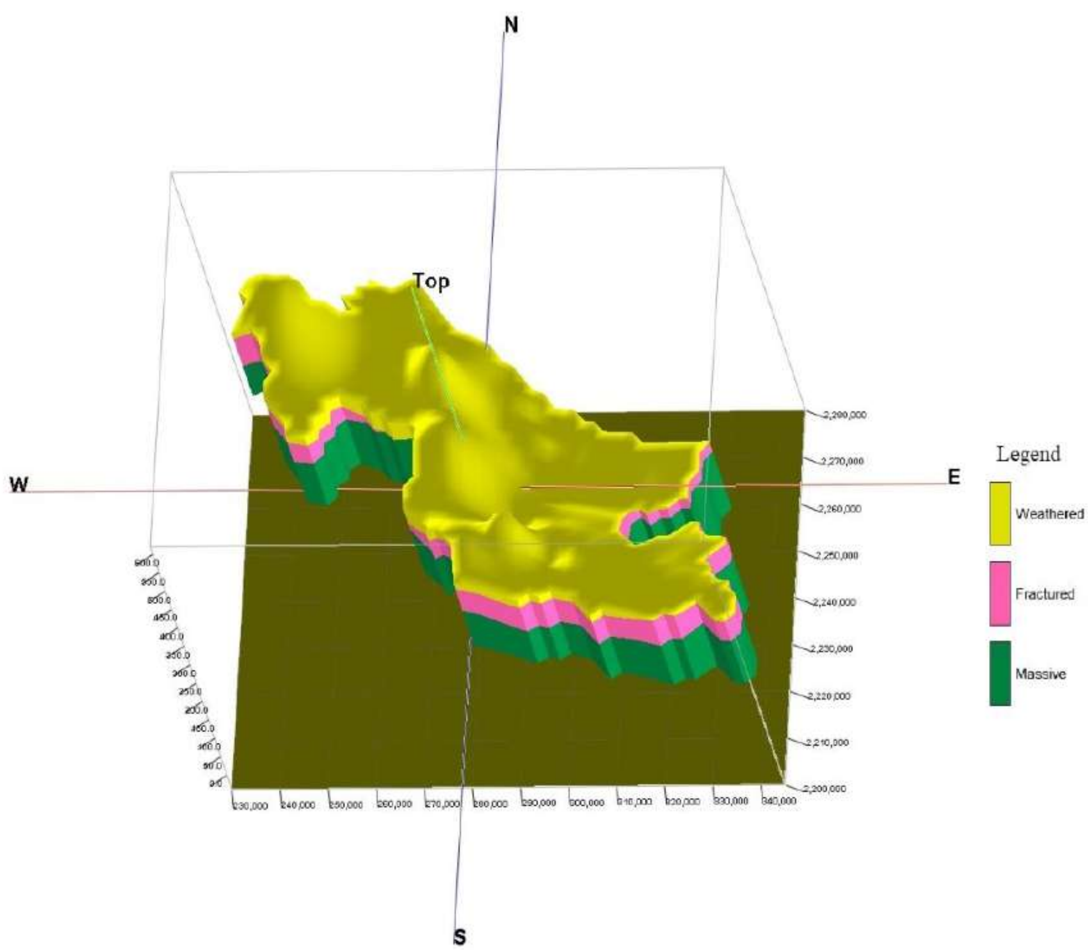


Fig.12.2 Aquifer 2D Section Lines along A-A', B-B', C-C', D-D'

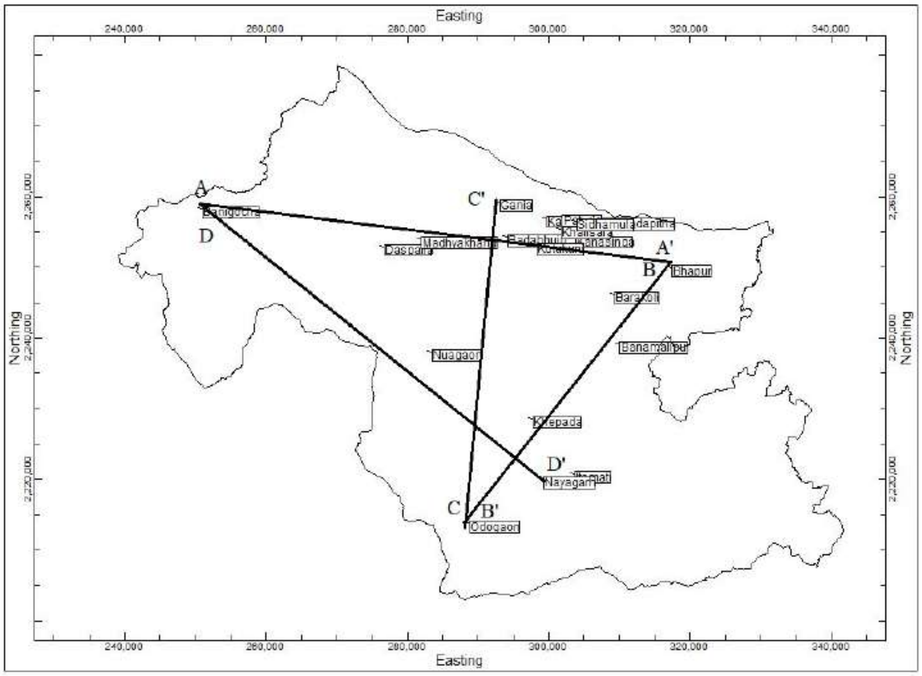


Fig. 12.3 Schematic 3D-Fence Diagram in Nayagarh District

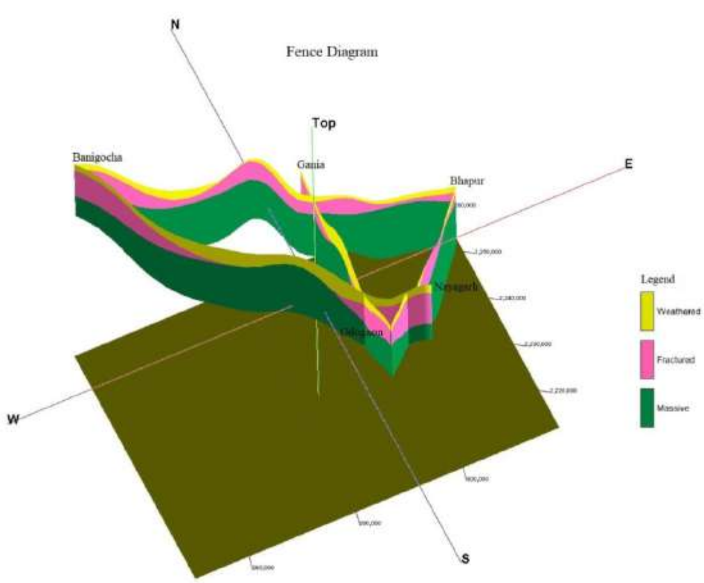


Fig. 12.4 Schematic Aquifer Cross Section along A-A'

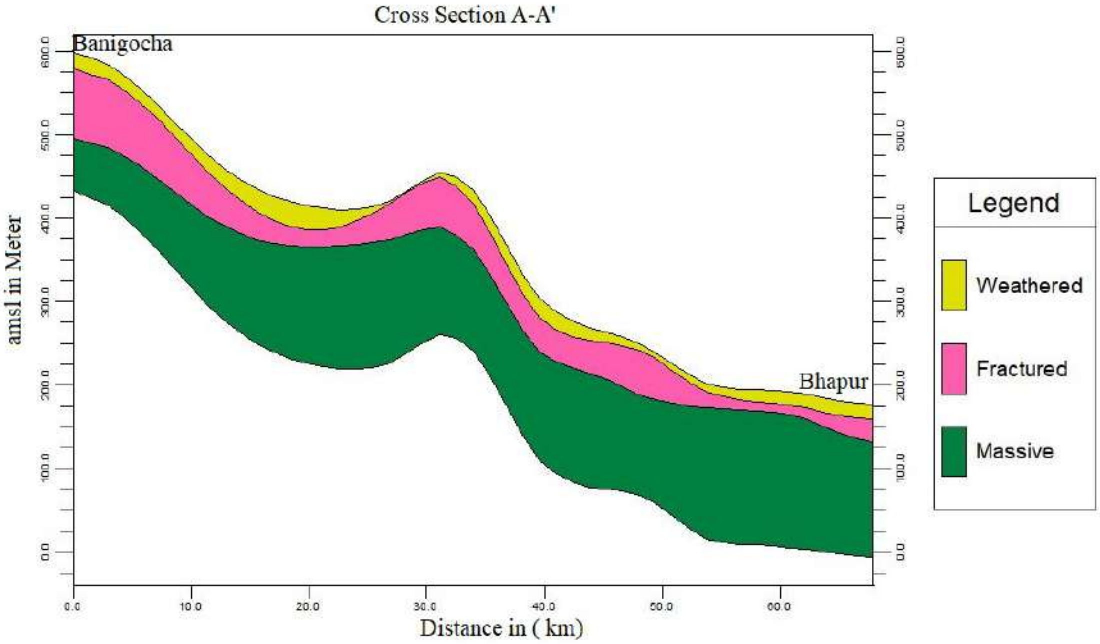


Fig. 12.5 Schematic Aquifer Cross Section along B-B'

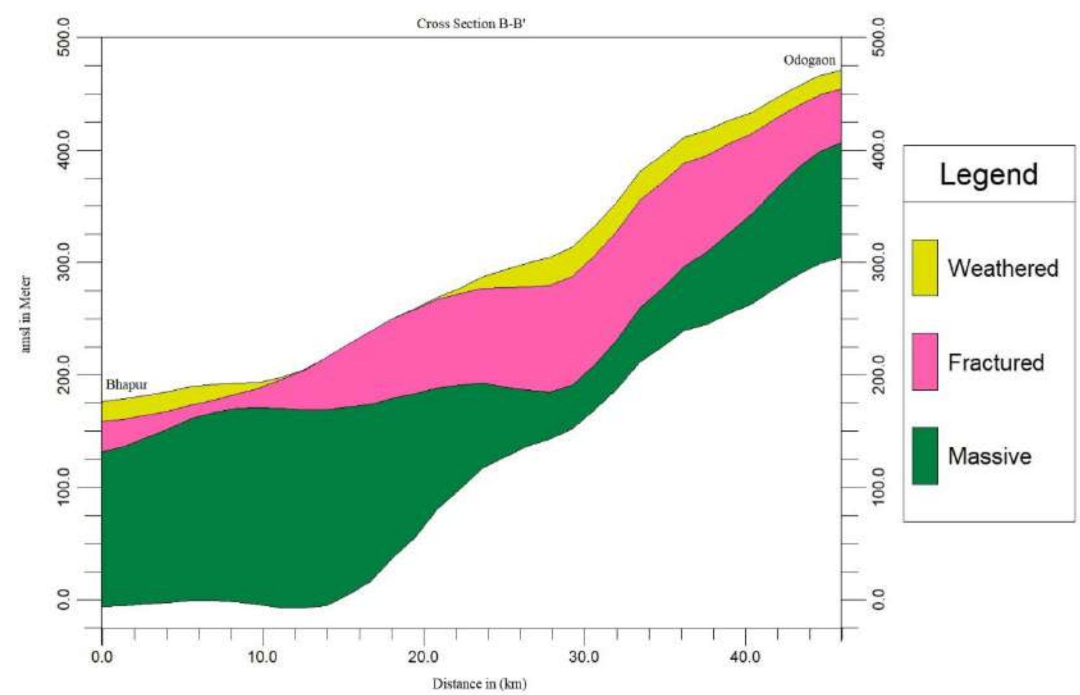


Fig. 12.6 Schematic Aquifer Cross Section along C-C’

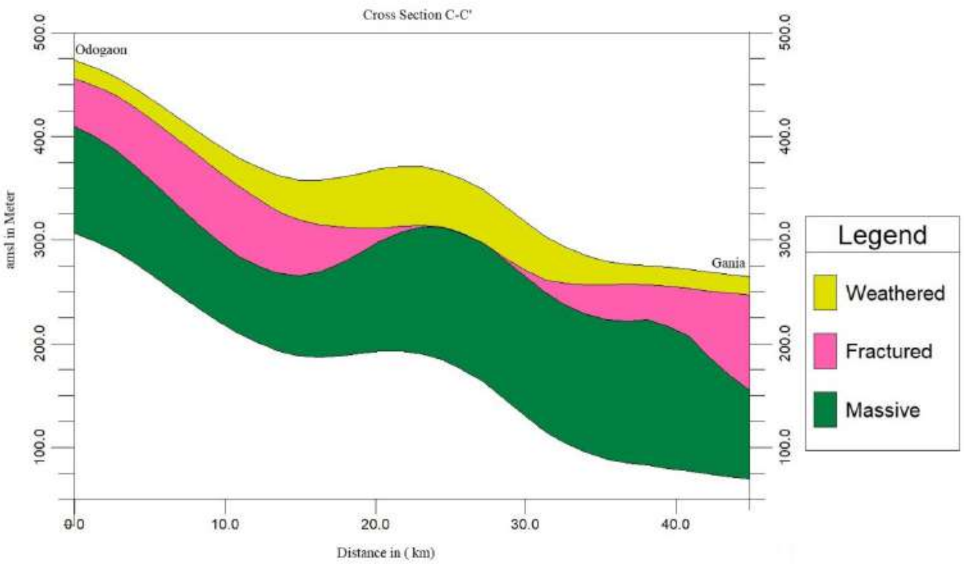


Fig. 12.7 Schematic Aquifer Cross Section along D-D’

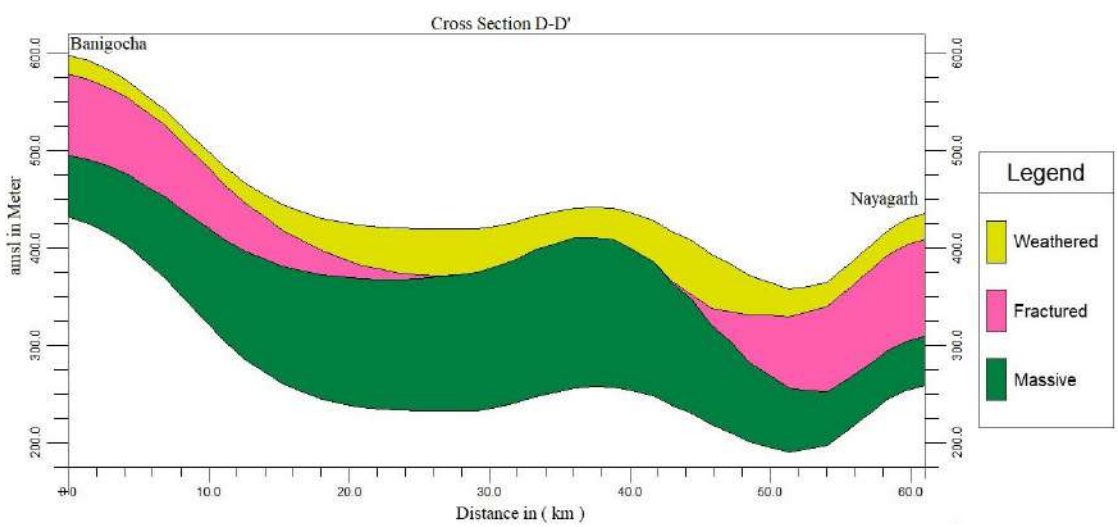
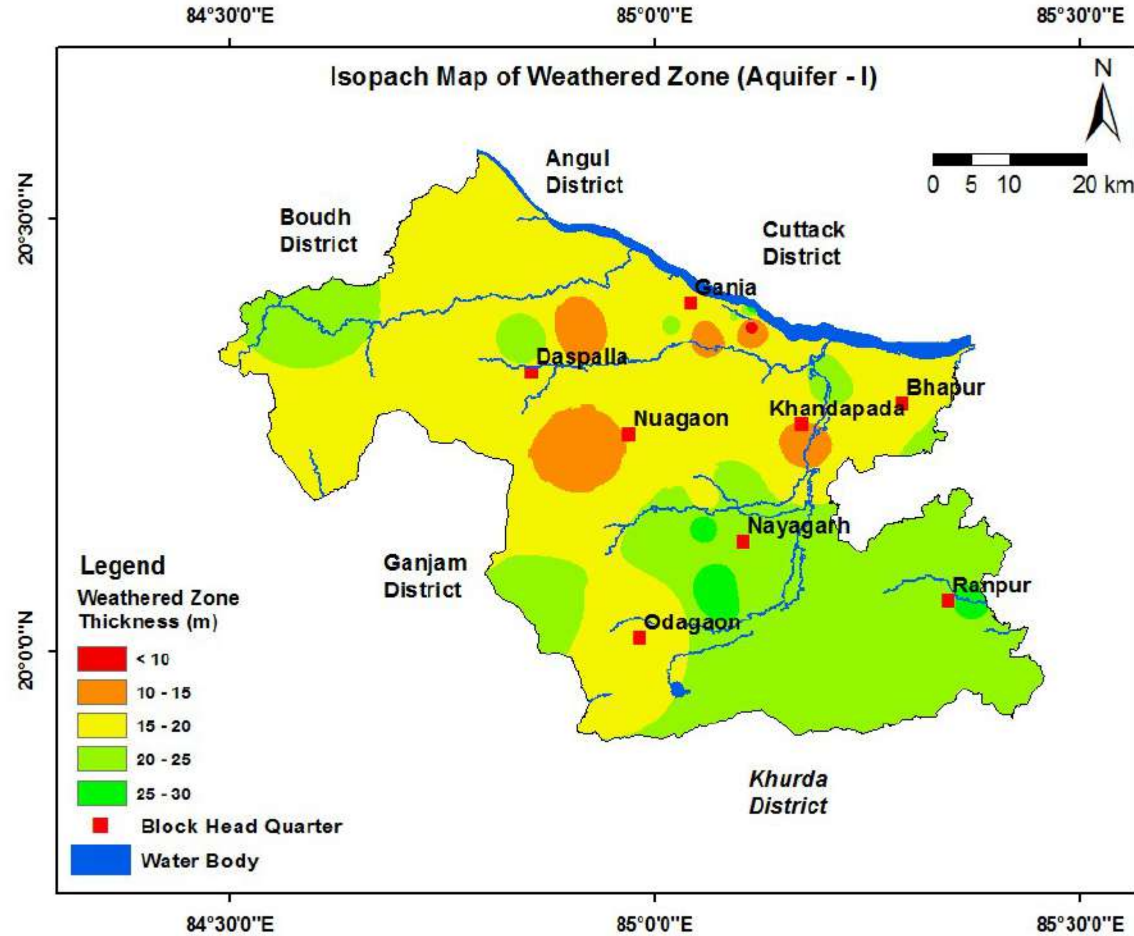


Fig. 12.8 Isopach of Weathered Zone (Aquifer-I) in Nayagarh District

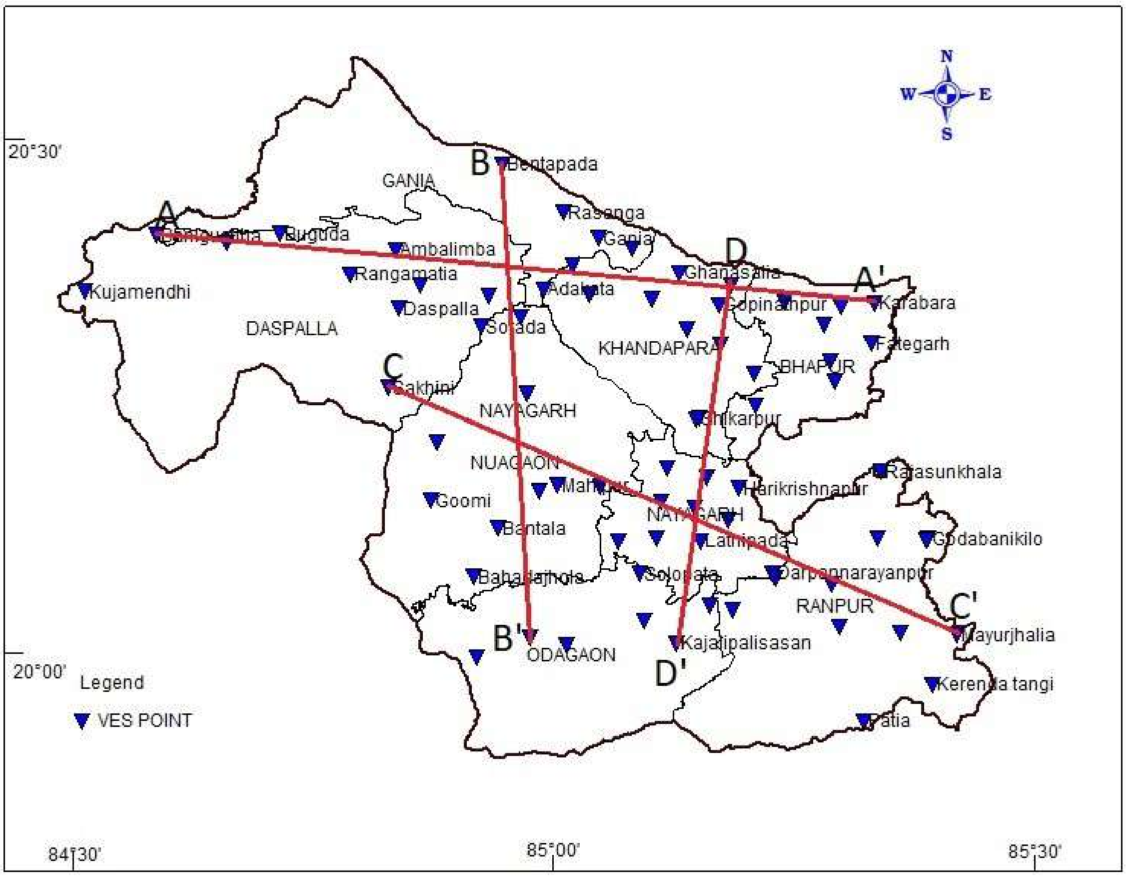


13. Geophysical Study

Electrical resistivity survey location

80 VES were conducted in around Ranpur, Gania, Nuagaon, Khandapara and Bhapur Blocks of Nayaghar District**,** Orissa State to study about Ground water availability in this area during Annual Action Plan 2020– 2021 usingSignal Stacking Resistivity Meter CRM 20 (Aquameter) of Anvic Systems**,** Pune**.** The VES locations are shown in Figure 13.1.

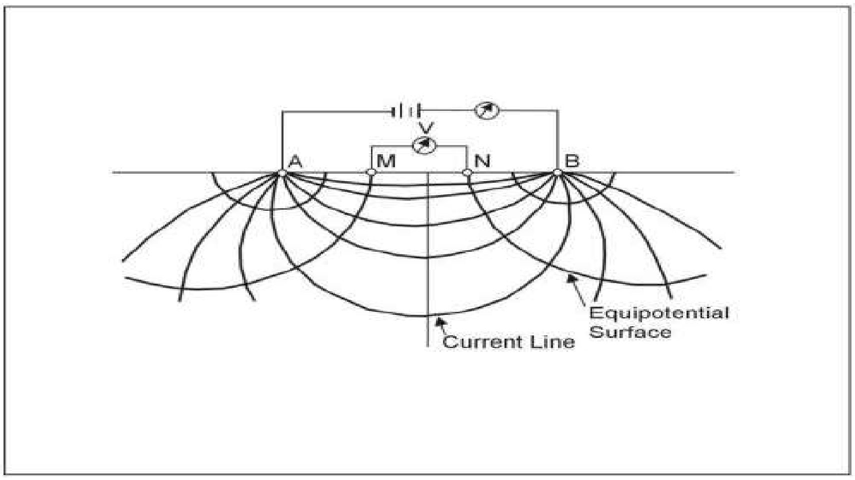
Figure 13.1 VES Location of Nayaghar District



METHODOLOGY

During the surface resistivity survey, CRM 20 resistivity meter (manufactured by Anvic System, Pune) was used. The instrument measures resistance i.e. ratio of potential differences and current in between two potential electrodes when current is sent through two current electrodes and there by apparent resistivity is calculated by multiplying the geometrical factor.Vertical Electrical Soundings (VES) using Schlumberger array were carried out at Eighty (80) stations.

Fig. 13.2Generalized form of the electrode configuration used in resistivity measurements.



The apparent resistivities are plotted in the double log graph paper and the types of the field curves are obtained as A, H, K, AH and AK. All the curves are interpreted with the help of partial curve matching technique and also by the resistivity sounding interpretation software programme IPI2WIN.

INTERPRETED VES RESULT

A total of 80 VES were carried out in Nayagarh distict. The VES locations are shown in Figure 13.1. Here only Seventy five (75) interpreted VES data results are given in Table 1 because five (5) VES data are not good for interpretation.

A. **Gania block:**

There are 7 VES Conducted in Gania block shown in figure 2,The resistivity of the 1stgeoelectrical layer denotes top soil varies between 5-50 Ωm and the thickness varies between 0-3m sometimes increases upto 5m.The resistivity of the 2ndgeoelectrical layer denotes the weather formation varies between 15-55Ωm and the thickness varies between 03-15m. The resisitivity of the 3rdgeoelectrical layer denotes the compact formation varies between 347-64775 Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 20-200m.

B. **Daspalla block:**

There are 10 VES Conducted in Daspalla block. There are 4th layers have presents, the resistivity of the 1stgeoelectric layer generalized as top soil varies from 8-70 Ωm and thickness varies from 0-2m..The resistivity of the 2ndgeoelectrical layer generalized as clay/silt varies from 6-24 Ωm and the thickness varies from 2-6m ,while depth ranges varies from 2-8m.The resistivity of the 3rdgeoelectric layer generalized as weather formation varies from 62-240 Ωm and thickness varies from 8-67m,while depth ranges varies from 8-75m.The 4th resistivity layer denotes as compact formation varies from 443-65496 Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 65-200m.

C. **Khandapada block:**

There are 12 VES Conducted in Khandapada block. There are 4th layers have presents ,the resistivity of the 1stgeoelectric layer generalized as top soil varies from 5-86 Ωm here thickness varies from 0-3m.The resistivity of the 2ndgeoelectrical layer generalized as clay/silt varies from 2-62 Ωm and the thickness varies from 3-8m ,while depth ranges varies from 3-11m.The resistivity of the 3rdgeoelectric layer generalized as weather formation varies from 6-358 Ωm and the thickness varies from 11-55m,while depth ranges varies from 11-66m.The 4th resistivity layer denotes as compact formation varies from 320-85936Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 66-190m.

D. Nuagaon block:

There are 09 VES Conducted in Nuagaon block. There are 4^{th} layers have presents ,the resistivity of the 1^{st}geoelectric layer generalized as top soil varies from 5-26 Ωm here thickness varies from 0-3m and the depth also varies from 0-3m occasionally exceeds to 5m.The resistivity of the 2^{nd}geoelectrical layer generalized as clay/silt varies from 3-7Ωm and the thickness varies from 3-8m ,while depth ranges varies from 3-11m.The resistivity of the 3^{rd}geoelectric layer generalized as weather formation varies from 11-133 Ωm and the thickness varies from 11-17m,while depth ranges varies from 11-28m.The 4^{th} resistivity layer denotes as compact formation varies from 45-23971Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 24-190m occasionally exceeds to 200m.

E. Nayagarh block:

There are 10 VES Conducted in Nayagarh block. There are 4^{th} layers have presents ,the resistivity of the 1^{st}geoelectric layer generalized as top soil varies from 6-510Ωm here thickness varies from 0-4m. The resistivity of the 2^{nd}geoelectrical layer generalized as clay/silt varies from 6-9Ωm and the thickness varies from 4-7m, while depth ranges varies from 4-11m.The resistivity of the 3^{rd}geoelectric layer generalized as weather formation varies from 12-144Ωm and the thickness varies from 11-39m, while depth ranges varies from 11-50m.The 4^{th} resistivity layer denotes as compact formation varies from 119-14172Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 50-200m.

F. Odagaon block:

There are 06 VES Conducted in Odagaon block. There are 4^{th} layers have presents, the resistivity of the 1^{st}geoelectric layer generalized as top soil varies from 5-57Ωm here thickness varies from 0-3. The resistivity of the 2^{nd}geoelectrical layer generalized as clay/silt varies from 4-15Ωm and the thickness varies from 3-8m, while depth ranges varies from 3-11m.The resistivity of the 3^{rd}geoelectric layer generalized as weather formation varies from

11-45Ωm and the thickness varies from 11-71m, while depth ranges varies from 11-82m.The 4th resistivity layer denotes as compact formation varies from 169-10187Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 80-180m.

G. <u>Bhapur block:</u>

There are 08 VES Conducted in Bhapur block. There are 4th layers have presents ,the resistivity of the 1stgeoelectric layer generalized as top soil varies from 5-86Ωm here thickness varies from 0-3m.The resistivity of the 2ndgeoelectrical layer generalized as clay/silt varies from 5-25Ωm and the thickness varies from 1-8m ,while depth ranges varies from 3-11m.The resistivity of the 3rdgeoelectric layer generalized as weather formation varies from 7-812Ωm and the thickness varies from 11-23m,while depth ranges varies from 11-34m.The 4th resistivity layer denotes as compact formation varies from 221-8482Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 34-190m.

H. <u>Ranpur block:</u>

There are 13 VES Conducted in Ranpur block. There are 4th layers have presents ,the resistivity of the 1stgeoelectric layer generalized as top soil varies from 3-69Ωm here thickness varies from 0-3m.The resistivity of the 2ndgeoelectrical layer generalized as clay/silt varies from 3-23Ωm and the thickness varies from 3-7m ,while depth ranges varies from 3-10m.The resistivity of the 3rdgeoelectric layer generalized as weather formation varies from 12-58Ωm and the thickness varies from 10-42m,while depth ranges varies from 10-52m.The 4th resistivity layer denotes as compact formation varies from 464-25786Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 52-200m.

The VES interpreted results are nearly same in all blocks in nayaghar districts. the resistivity of the 1stgeoelectric layer generalized as top soil varies from 6-510Ωm and thickness varies from 0-3m and the depth also varies from 0-3m occasionally exceeds to 5m.The resistivity of the 2ndgeoelectrical layer generalized as clay/silt varies from 5-20Ωm and the thickness varies from 3-4m ,while depth ranges varies from 3-7m.The resistivity of the 3rd geoelectric layer generalized as weather formation varies from 7-144Ωm and the thickness varies from 7-35m,while depth ranges varies from 7-60m.The 4th resistivity layer denotes as compact formation varies from 221-64775Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 55-200m shown in figure 4.

The VES location are Banigucha, Jamusahi, Madhapur, Padmabati & Karabara shown in figure 5.In place of Banigucha the top soil layer is depth 0-1m and the thickness is 1m.The clay layer depth is 1-3m, and the thickness is 2m .The Weather formation depth is 3-21m,while thickness is 18m .The last layer is present compact formation depth is 21-90m and the thickness is 69m.In place of jamusahi the top soil layer is depth 0-3m and the thickness is 3m.The clay layer depth is 3-6m, and the thickness is 3m .The Weather formation depth is 6-75m,while thickness is 69m .The last layer is present compact formation depth is 75-140m and the thickness is 65m. In place of Madhapur the top soil layer is depth 0-1m and the thickness is 1m.The clay layer depth is 1-2m, and the thickness is 1m .The Weather formation depth is 2-8m,while thickness is 6m .The last layer is present compact formation depth is 8-120m and the thickness is 112m. In place of Padmabati the clay layer depth is 0-3m, and the thickness is 2m .The Weather formation depth is 3-21m,while thickness is 18m .The last layer is present compact formation depth is 21-95m and the thickness is 74m. In place of Karabara the top soil layer is depth 0-1m and the thickness is 1m.The clay layer depth is 1-4m, and the thickness is 3m .The Weather formation depth is 4-34m,while thickness is 30m .The last layer is present compact formation depth is 34-80m and the thickness is 46m.

The VES point location are Bentapada, Nuagaon & Odagaon in 2D Cross section BB' in shown in Figure 6. In place of Bentapada the clay layer depth is 1-10m, and the thickness is 9m .The Weather formation depth is 9-10m,while thickness is 1m .The last layer is present compact formation depth is 10-200m and the thickness is 190m. In place of Nuagaon the top soil layer is depth 0-1m and the thickness is 1m.The clay layer depth is 1-7m, and the thickness is 6m .The last layer is present compact formation depth is 7-180m and the thickness is 173m. In place of Odagaon the top soil layer is depth 0-1m and the thickness is 1m.The Weather formation depth is 1-25m,while thickness is 24m .The last layer is present compact formation depth is 25-110m and the thickness is 85m.

The VES point location are Sakhini and the Mayurjhalia in 2D Cross section CC' in shown in Figure 7. In place of Sakhini the top soil layer is depth 0-2m and the thickness is 2m.The clay layer depth is 2-6m, and the thickness is 4m. The Weather formation depth is 6-34m,while thickness is 28m.The last layer is present compact formation depth is 34-150m and the thickness is 116m. In place of Mayurjhalia the top soil layer is depth 0-3m and the thickness is 3m. The clay layer depth is 3-18m, and the thickness is 15m.The Weather formation depth is 18-36m,while thickness is 18m .The last layer is present compact formation depth is 36-170m and the thickness is 134m.

The VES point location are Kantilo,Gutuni and the Kajalipalisasan in 2D Cross section DD' in shown in Figure 8. In place of Kantilo the top soil layer is depth 0-1m and the thickness is 1m.The clay layer depth is 1-5m, and the thickness is 4m. The Weather formation depth is 5-75m,while thickness is 70m.The last layer is present compact formation depth is 70-195m and the thickness is 125m. In place of Gutuni the top soil layer is depth 0-1m and the thickness is 1m. The clay layer depth is 1-5m, and the thickness is 4m.The Weather formation depth is 5-24m,while thickness is 17m .The last layer is present compact formation depth is 17-150m and the thickness is 133m. In place of Kajalipalisasan the top soil layer is depth 0-1m and the thickness is 1m. The clay layer depth is 1-11m, and the thickness is 10m.The last layer is present compact formation depth is 11-160m and the thickness is 149m.

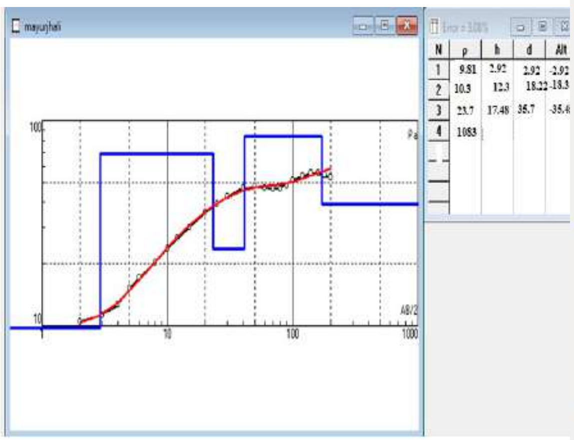
Conclusions and Recommendations:

In the surveyed area of Nayaghar district , the field curves are obtained as A,H,K,AH and AK, in general the top soil varies from 6-80Ωm here thickness varies from 0-3m and the depth also varies from 0-3m occasionally exceeds to 5m.

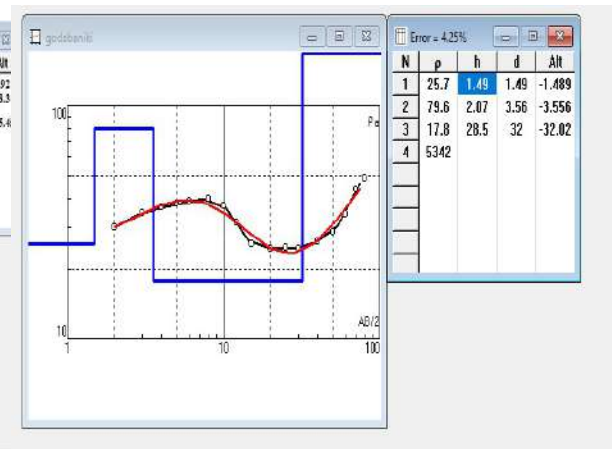
The resistivity of the 2ndgeoelectrical generalized layer as clay varies from 5-20Ωm occasionally exceeds to 5-26Ωm and the thickness varies from 5-10m ,while depth ranges varies from 5-15. The resistivity of the 3rdgeoelectric layer generalized as weather formation varies from 7-144Ωm and the thickness varies from 15-60m,while depth ranges varies from 15-75m.The 4th resistivity layer denotes as compact formation varies from 221-64775Ωm with an infinite depth. The depth to bottom of this layer, is general varies between 55-200m while thickness varies from 55-150m. On the basis of geoelectrical layer parameters some place of sites are recommended for borehole drilling.

INTERPRETATION OF VES CURVE

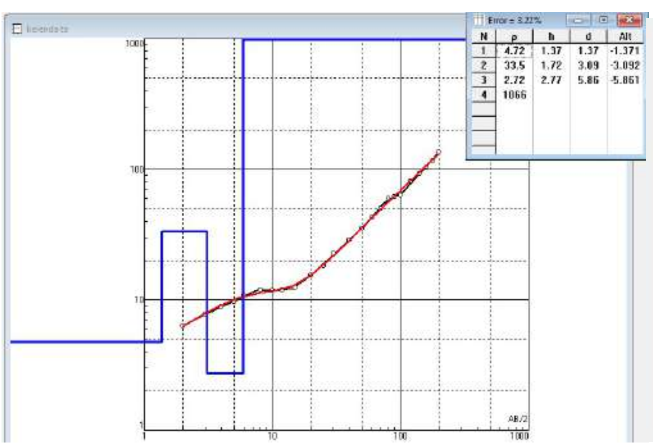
1.Mayurjhalia



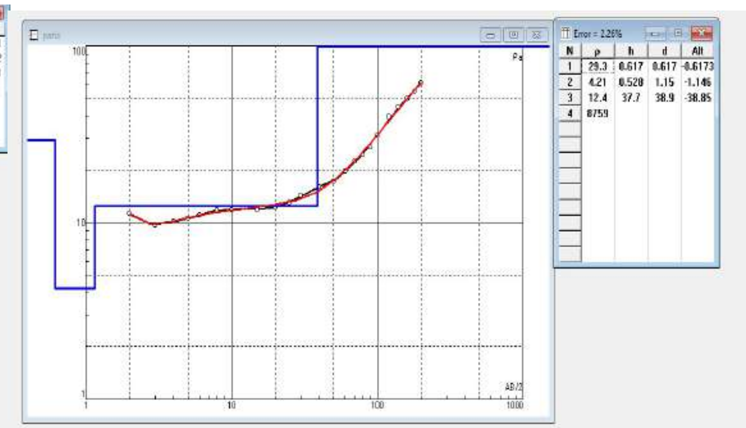
2.Godabanikilo



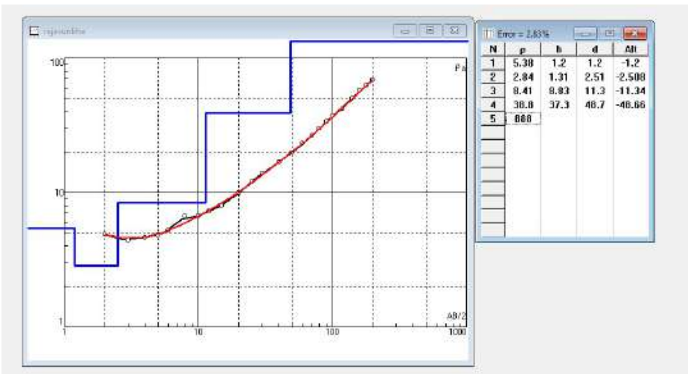
3.Kerenda tangi



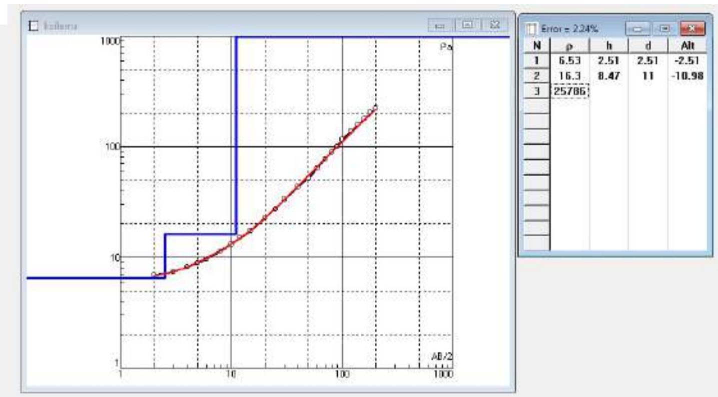
4.Patia



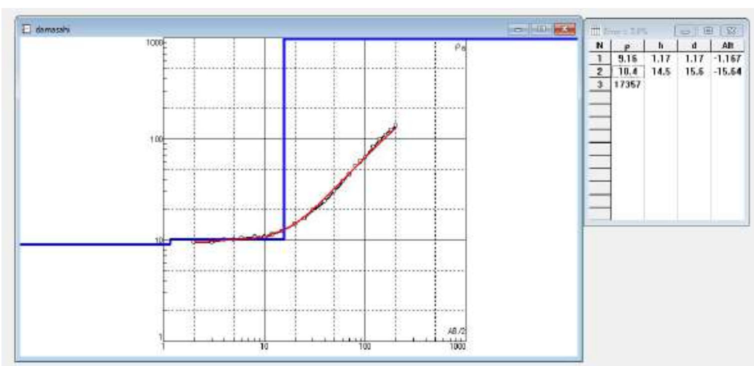
5.Rajasunkhala



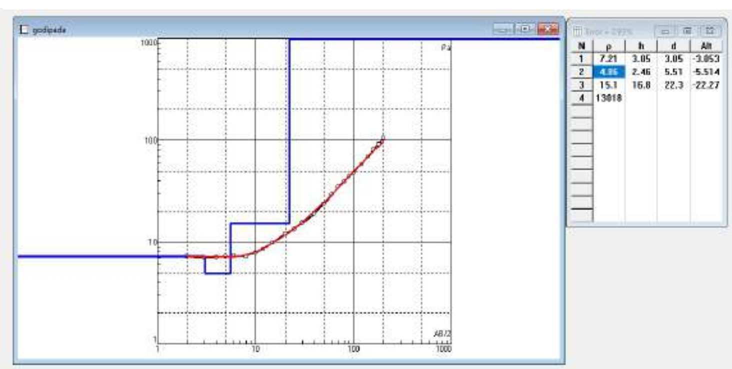
6.Koilama



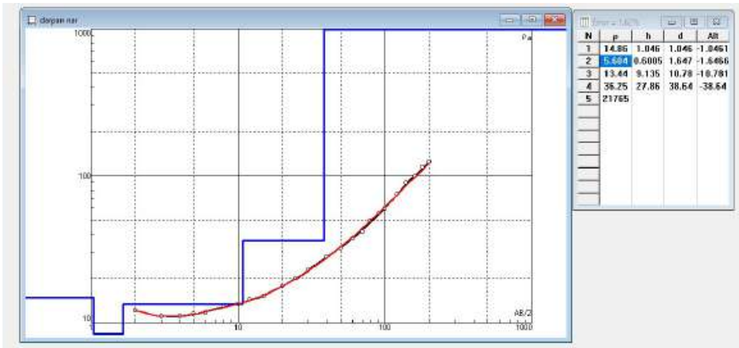
7.Damasahi



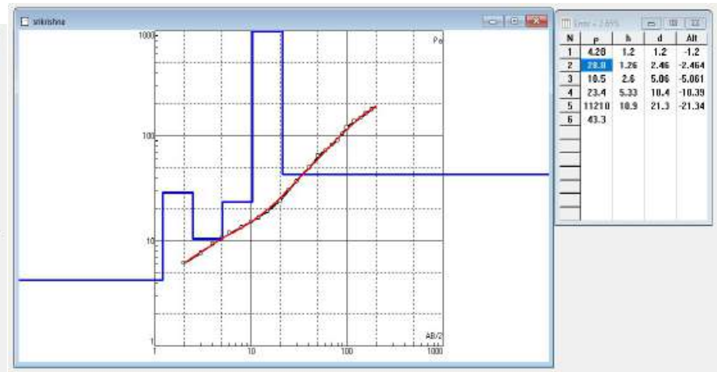
8.Godipada



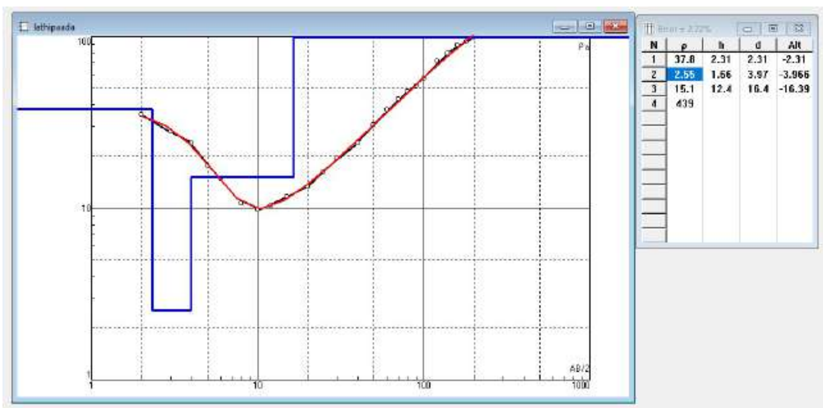
9.Darpanarayanpur



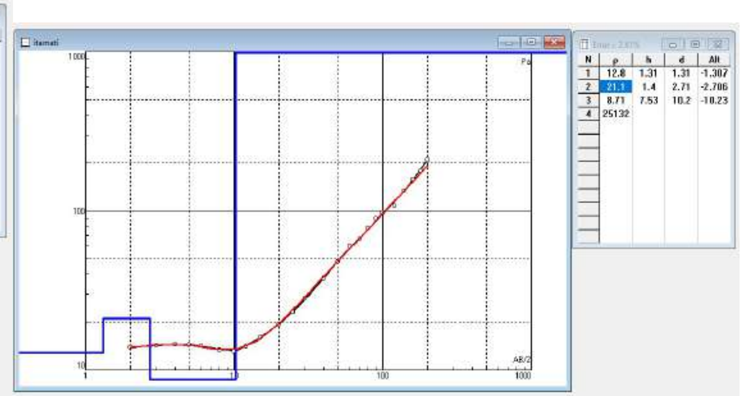
10.Srikrishnachandanpur



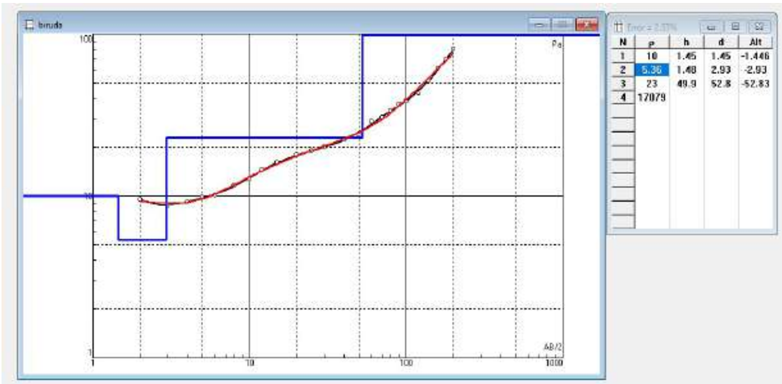
11.Lathipada



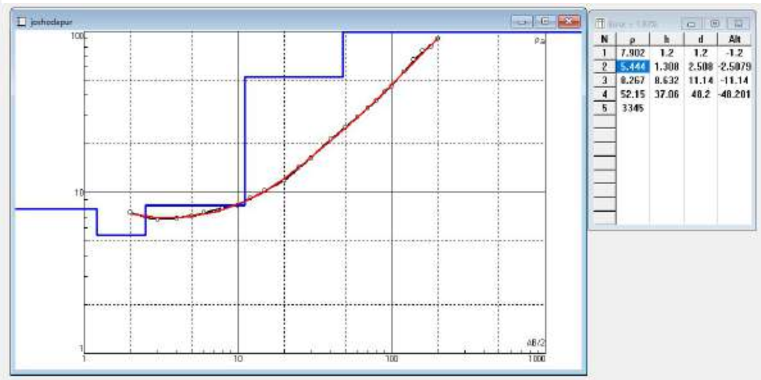
12.Itamati



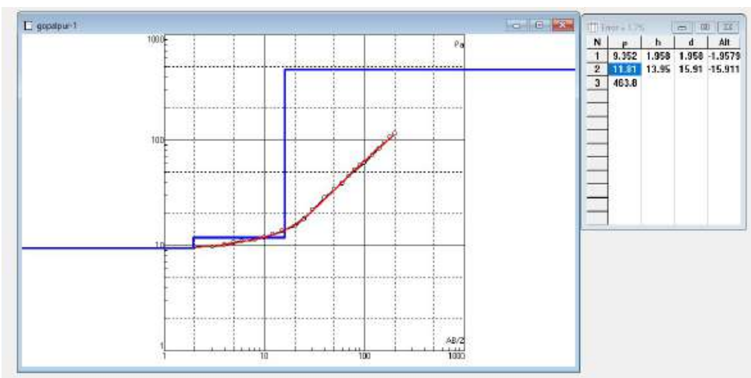
13.Biruda



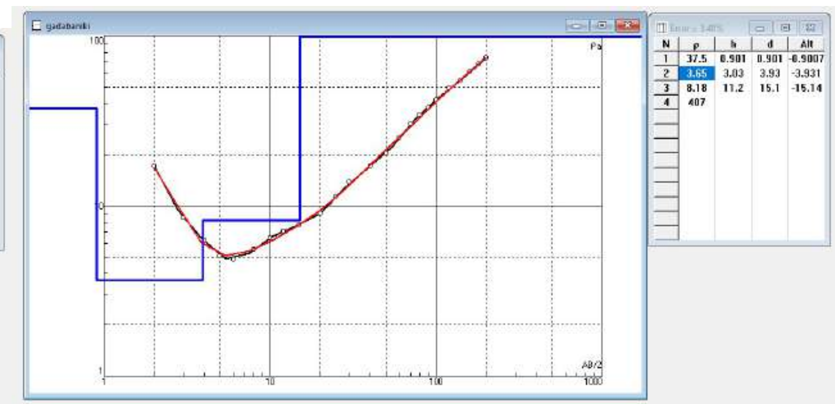
14.Joshodapur



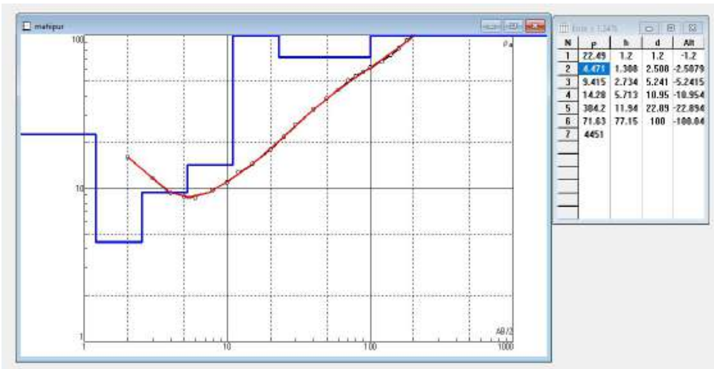
15.Gopalpur



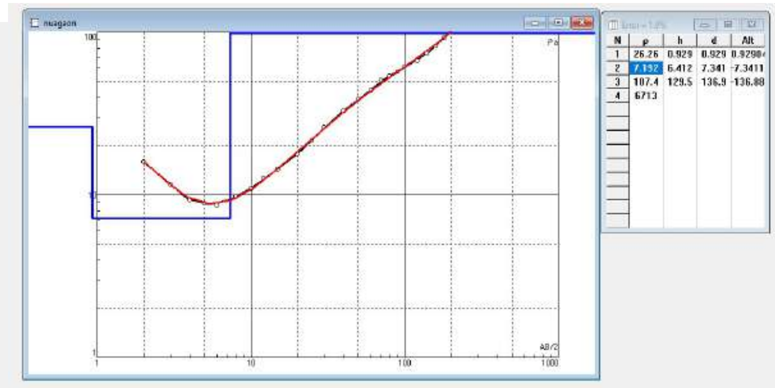
16.Gadabanikilo



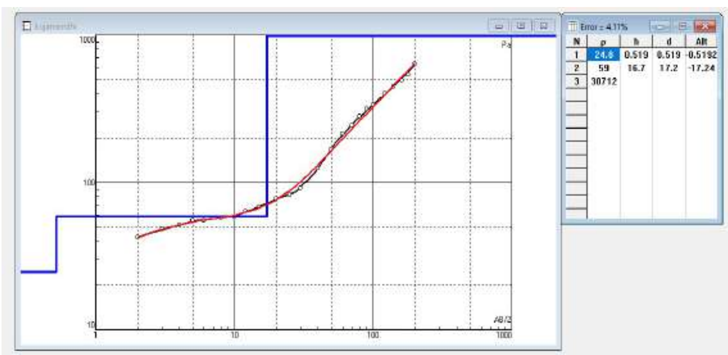
17.Mahipur



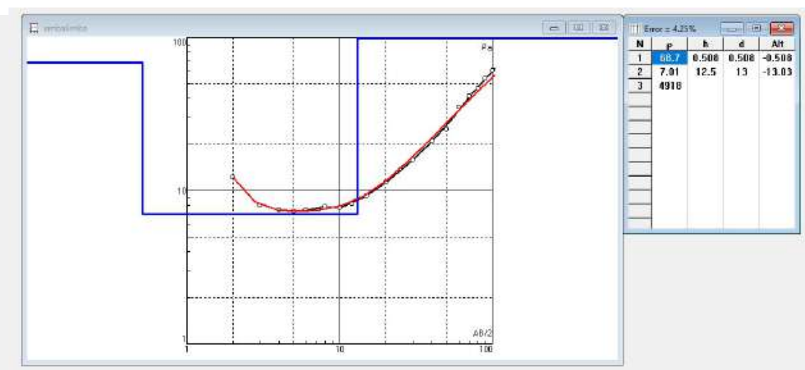
18.Nuagaon



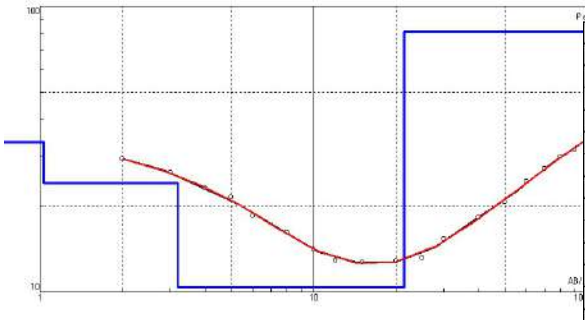
19.Kujamendhi



20.Ambalimba

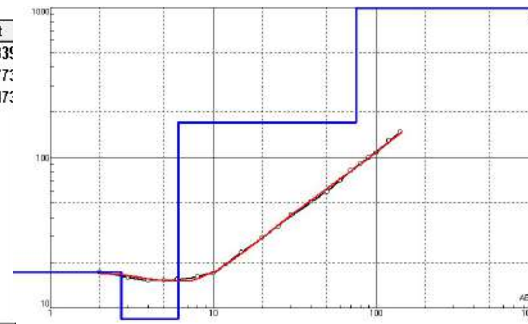


21.Baniguchha



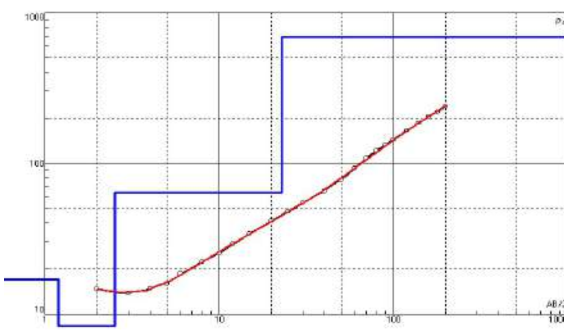
N	ρ	h	d	Alt
1	33.34	1.034	1.034	-1.0339
2	24.05	2.143	3.177	-3.1773
3	10.36	18.3	21.47	-21.473
4	81.12			

22. Jamusahi



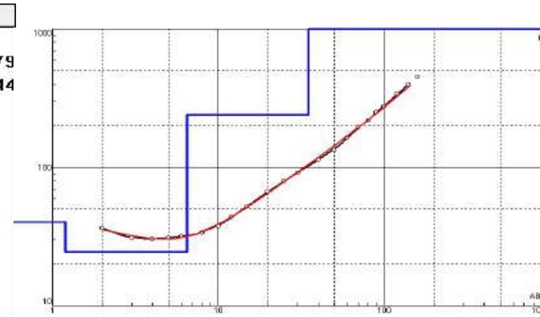
N	ρ	h	d	Alt
1	17.4	2.72	2.72	-2.721
2	8.01	3.4	6.12	-6.118
3	172	68.8	74.9	-74.94
4	5177			

23.Buguda



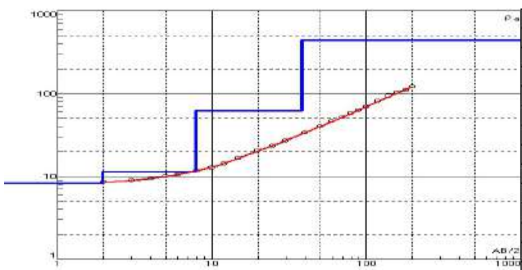
N	ρ	h	d	Alt
1	17.02	1.2	1.2	-1.2
2	6.796	1.308	2.508	-2.5079
3	64.15	20.44	22.94	-22.944
4	692.8			

24. Rangamatia



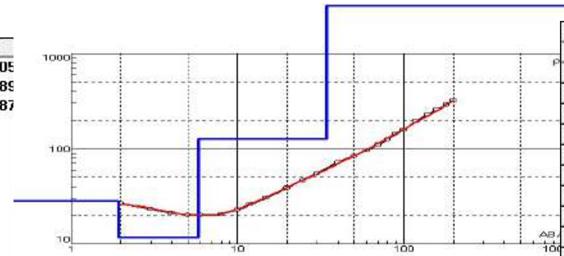
N	ρ	h	d	Alt
1	40.1	1.2	1.2	-1.2
2	24.3	5.24	6.44	-6.438
3	240	28.7	35.1	-35.13
4	65496			

25.Daspalla



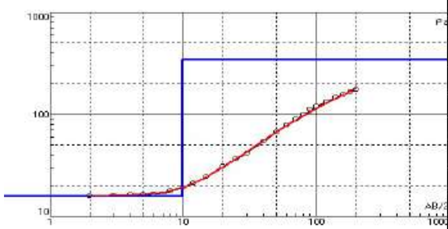
N	ρ	h	d	Alt
1	8.198	1.971	1.971	-1.9705
2	11.31	5.948	7.919	-7.9189
3	61.59	30.47	38.39	-38.387
4	443.1			

26. Sakhini



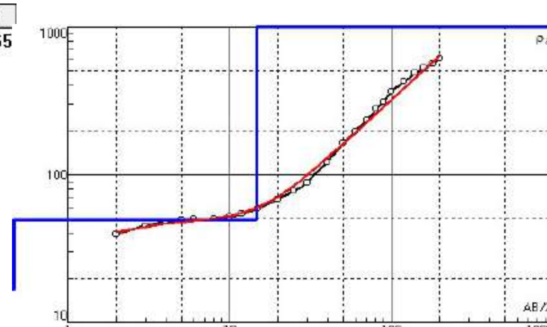
N	ρ	h	d	Alt
1	28.32	1.918	1.918	-1.9179
2	11.76	3.848	5.766	-5.7656
3	127.6	28.39	34.16	-34.159
4	29120			

27.Bentapada



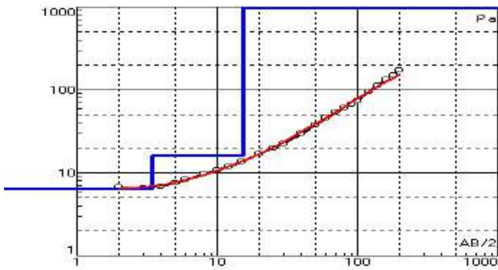
N	ρ	h	d	Alt
1	15.96	9.865	9.865	-9.865
2	347.1			

28. Rasanga



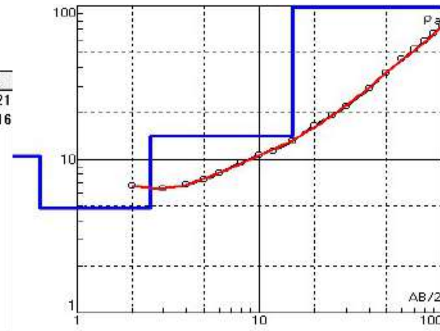
N	ρ	h	d	Alt
1	16.6	0.25	0.25	-0.2502
2	49.5	14.5	14.8	-14.78
3	64775			

29.Gania



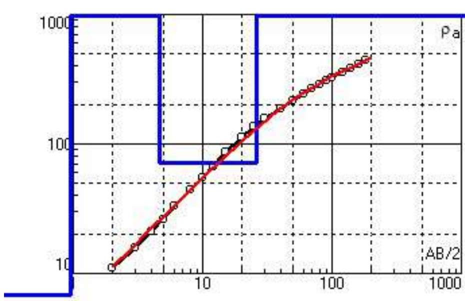
N	ρ	h	d	Alt
1	6.3	3.42	3.42	-3.421
2	15.9	11.7	15.2	-15.16
3	12219			

30.Adakata



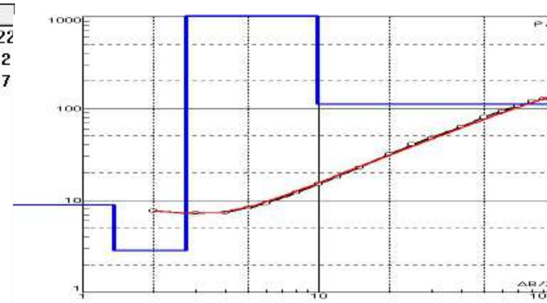
N	ρ	h	d	Alt
1	10.41	0.6265	0.6265	0.6265
2	4.852	1.876	2.502	-2.5024
3	14.13	12.66	15.17	-15.167
4	6220			

31.Sorada



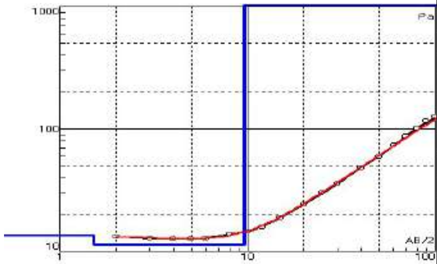
N	ρ	h	d	Alt
1	5.25	0.942	0.942	-0.9422
2	8221	3.73	4.67	-4.672
3	70.8	21.2	25.9	-25.87
4	6721			

32. Dimira



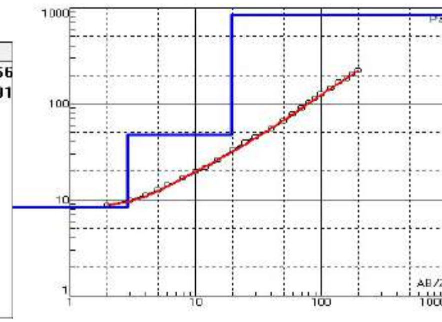
N	ρ	h	d	Alt
1	8.98	1.35	1.35	-1.351
2	2.85	1.38	2.73	-2.733
3	16731	7.09	9.82	-9.824
4	111			

33.Goomi



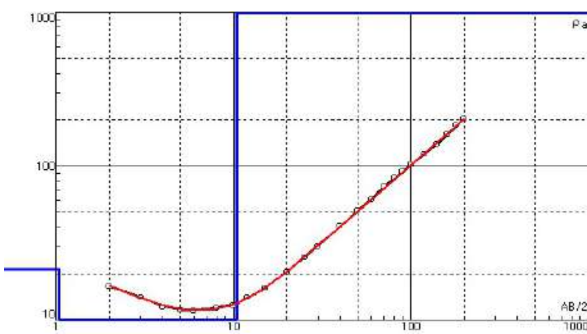
N	ρ	h	d	Alt
1	13.54	1.507	1.507	-1.5066
2	11.39	8.083	9.589	-9.5891
3	23971			

34. Shikirida



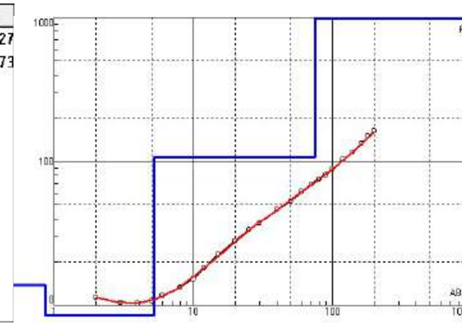
N	ρ	h	d	Alt
1	8.329	2.901	2.901	-2.901
2	47.65	16.58	19.48	-19.478
3	844.8			

35.Ghanasalia



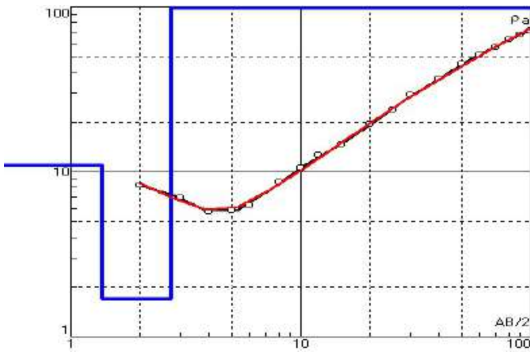
N	ρ	h	d	Alt
1	21.27	1.043	1.043	-1.0427
2	10.03	9.33	10.37	-10.373
3	15749			

36.Kantilo



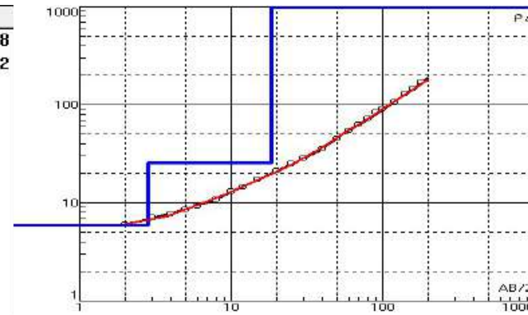
N	ρ	h	d	Alt
1	13.9	0.8601	0.8601	0.8601
2	8.545	4.337	5.197	-5.197
3	107.5	70.21	75.41	-75.409
4	8238			

37.Gopinathpur



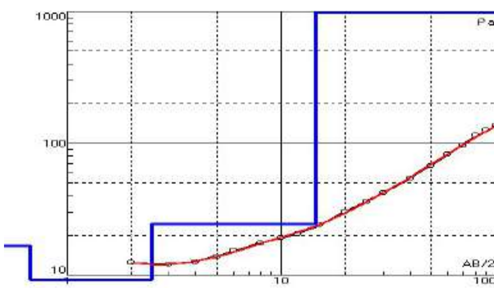
N	ρ	h	d	Alt
1	11	1.37	1.37	-1.368
2	1.71	1.37	2.74	-2.742
3	206			

38.Indipatta



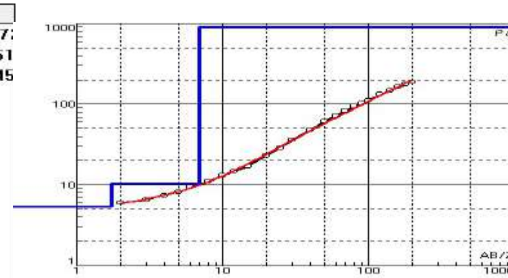
N	ρ	h	d	Alt
1	5.88	2.83	2.83	-2.833
2	25.4	15.5	18.3	-18.33
3	10794			

39.Madhyakhand



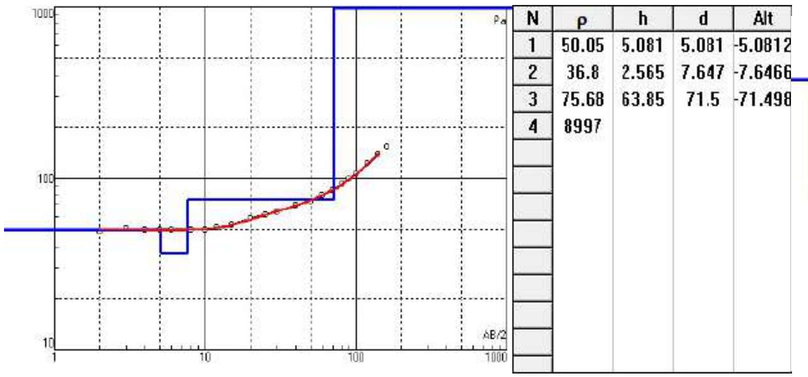
N	ρ	h	d	Alt
1	16.68	0.6777	0.6777	0.6777
2	9.233	1.797	2.475	-2.4751
3	24.56	11.97	14.44	-14.445
4	21072			

40.Kosaka



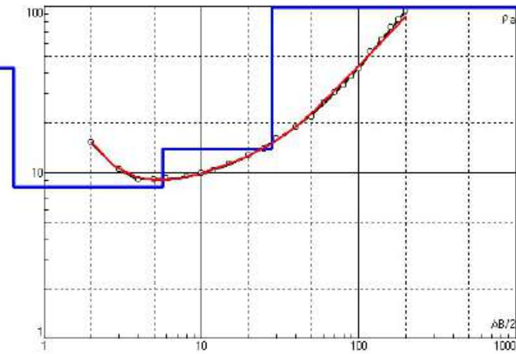
N	ρ	h	d	Alt
1	5.43	1.72	1.72	-1.723
2	10.5	5.15	6.88	-6.876
3	895			

41.Giridipalli



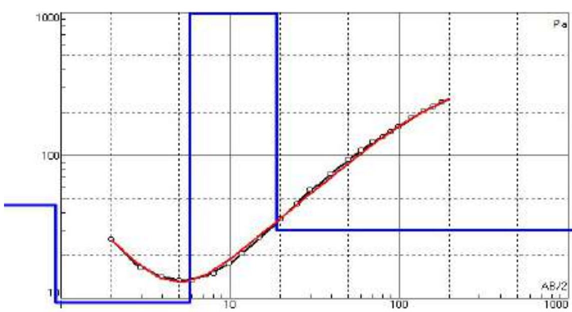
N	ρ	h	d	Alt
1	50.05	5.081	5.081	-5.0812
2	36.8	2.565	7.647	-7.6466
3	75.68	63.85	71.5	-71.498
4	8997			

42.Singhapada



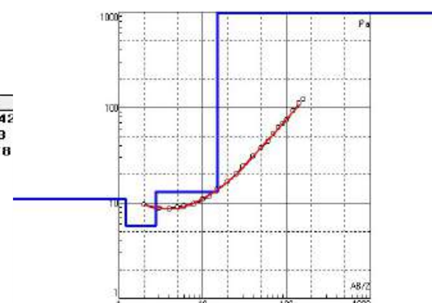
N	ρ	h	d	Alt
1	42.4	0.638	0.638	-0.6376
2	8.14	5.04	5.68	-5.675
3	13.8	22.3	28	-27.95
4	6099			

43.Badabhuin



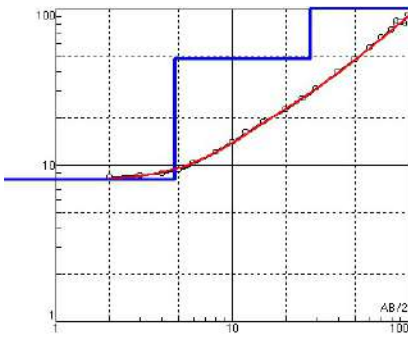
N	ρ	h	d	Alt
1	44.7	0.934	0.934	-0.9342
2	9.39	4.9	5.83	-5.83
3	8130	13	18.8	-18.78
4	30			

44.Bahadajhola



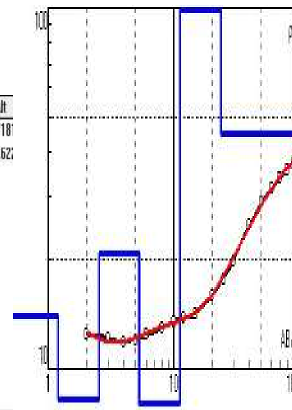
N	ρ	h	d	Alt
1	11.1	1.2	1.2	-1.2
2	5.79	1.58	2.78	-2.779
3	13.1	12.2	14.9	-14.94
4	17516			

45.Bantala



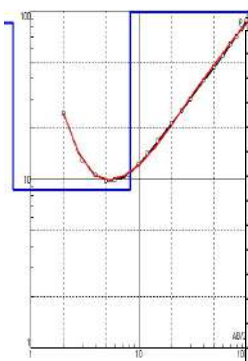
N	ρ	h	d	Alt
1	8.186	4.718	4.718	-4.718
2	48.33	22.9	27.62	-27.62
3	2477			

46.Mahipur



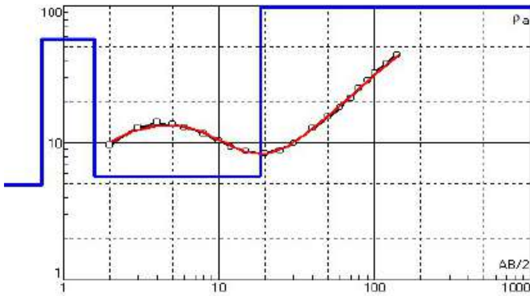
N	ρ	h	d	Alt
1	13.93	1.2	1.2	-1.2
2	8.223	1.33	2.53	-2.5301
3	20.78	2.804	5.335	-5.3345
4	7.032	5.913	11.25	-11.247
5	133	12.47	23.71	-23.714
6	44.87			

47.Gopinathpur



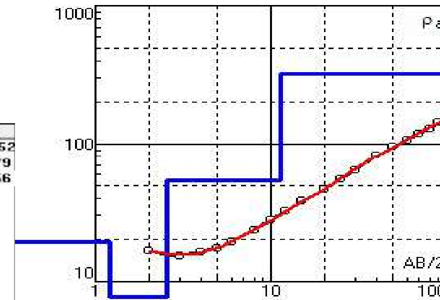
N	ρ	h	d	Alt
1	85.4	0.683	0.683	-0.683
2	8.67	7.66	8.34	-8.343
3	310			

48.Shikarpur



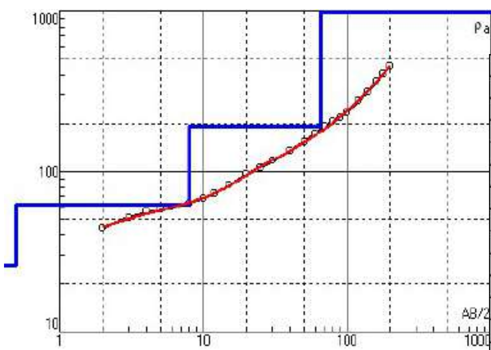
N	ρ	h	d	Alt
1	4.97	0.725	0.725	-0.7252
2	57	0.854	1.58	-1.579
3	5.66	17	18.6	-18.56
4	3144			

49.Mardarajpur



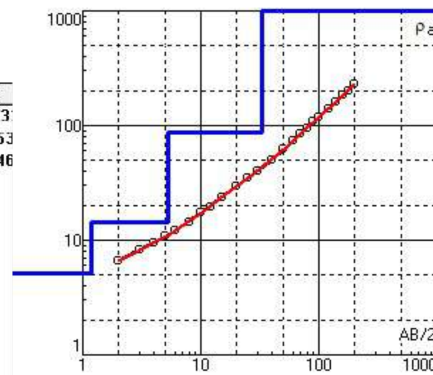
N	ρ	h	d	Alt
1	19.44	1.2	1.2	-1.2
2	7.798	1.33	2.53	-2.5301
3	54.21	8.754	11.28	-11.284
4	320.4			

50.Khanadapada



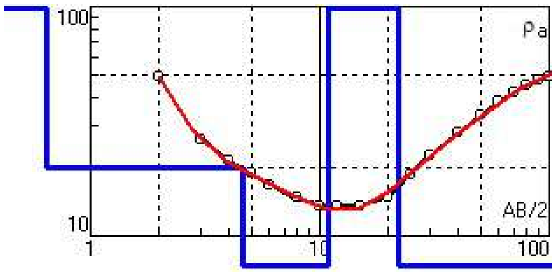
N	ρ	h	d	Alt
1	25.81	0.4973	0.4973	0.4973
2	61.74	7.508	8.005	-8.0053
3	191.5	57.84	65.85	-65.846
4	85936			

51.Baghuapalli



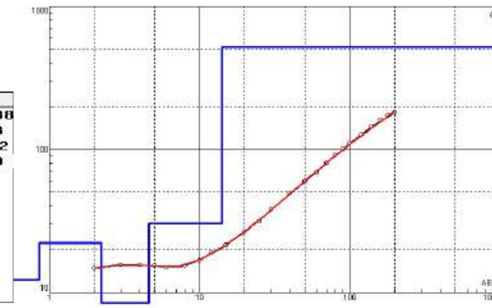
N	ρ	h	d	Alt
1	5.166	1.192	1.192	-1.1922
2	14.25	4.075	5.267	-5.2672
3	86	27.35	32.62	-32.619
4	4249			

52.Golapokhari



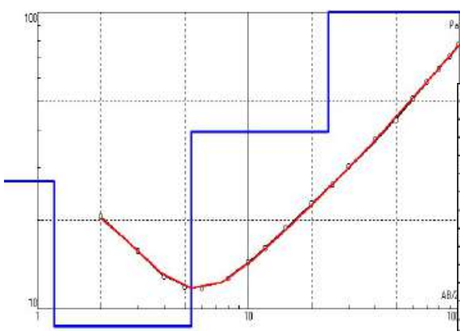
N	ρ	h	d	Alt
1	188	0.644	0.644	-0.6438
2	19.7	3.99	4.63	-4.63
3	5.92	6.29	10.9	-10.92
4	812	11	21.9	-21.9
5	5.2			

53.Bhapur



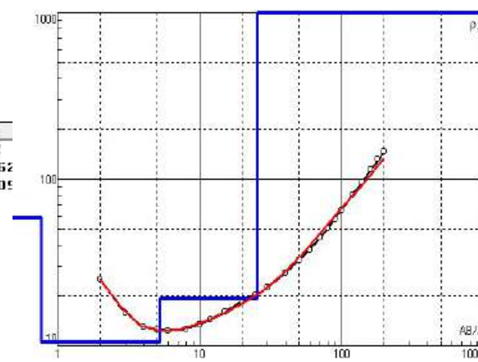
N	ρ	h	d	Alt
1	12.2	0.8607	0.8607	0.8607
2	22.23	1.356	2.216	-2.2164
3	7.761	2.408	4.625	-4.6246
4	30.32	9.42	14.04	-14.044
5	521			

54.Gutuni



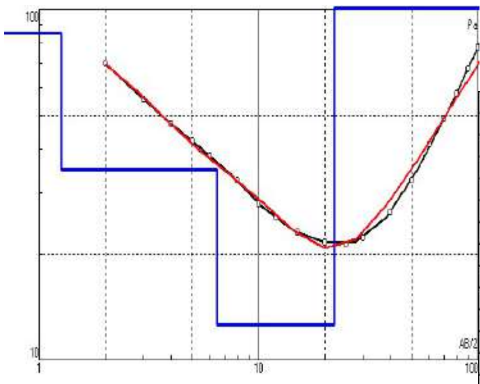
N	ρ	h	d	Alt
1	27	1.2	1.2	-1.2
2	8.293	4.136	5.336	-5.336
3	39.44	18.67	24.01	-24.00
4	300			

55. Banamalipur



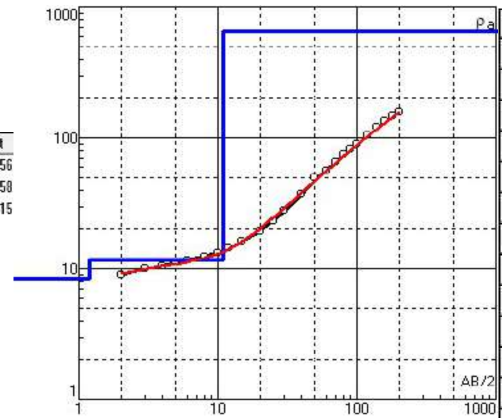
N	ρ	h	d	Alt
1	58.6	0.764	0.764	-0.7642
2	10.5	4.5	5.26	-5.264
3	19.4	20.2	25.5	-25.45
4	10179			

56.Banamalipur



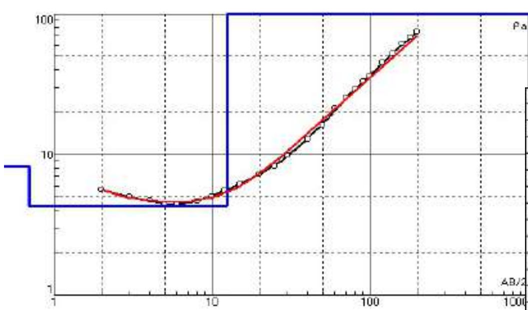
N	ρ	h	d	Alt
1	85.6	1.26	1.26	-1.256
2	34.9	5.2	6.46	-6.458
3	12.6	15.7	22.2	-22.15
4	4443			

57.Kajalipalisasan



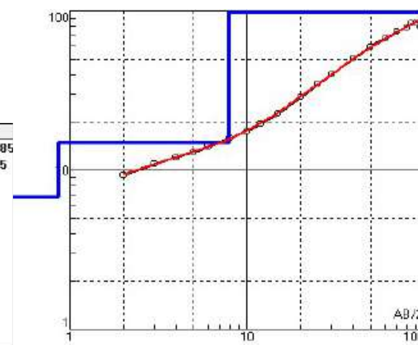
N	ρ	h	d	Alt
1	8.47	1.2	1.2	-1.2
2	11.7	9.8	11	-11
3	656			

58.Sarankul



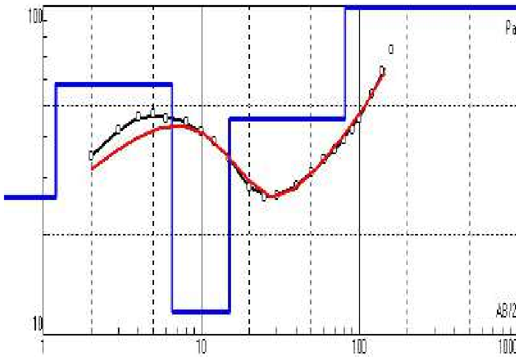
N	ρ	h	d	Alt
1	8.23	0.688	0.688	-0.6885
2	4.32	11.8	12.5	-12.5
3	10187			

59.Solopata



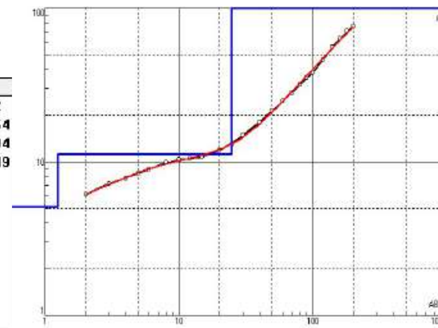
N	ρ	h	d	Alt
1	6.831	0.8616	0.8616	0.8615
2	14.89	7.037	7.899	-7.899
3	169.1			

60.Komand



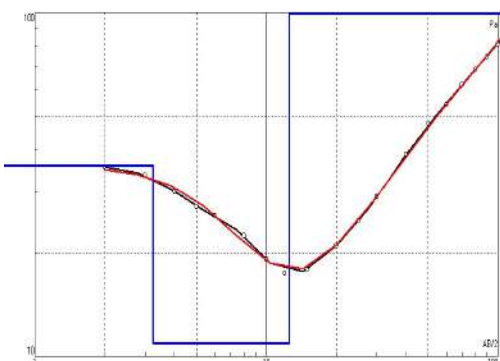
N	ρ	h	d	Alt
1	26.2	1.2	1.2	-1.2
2	57.9	5.36	6.56	-6.564
3	11.7	8.47	15	-15.04
4	45.3	66.5	81.5	-81.49
5	2798			

61.Odagaon



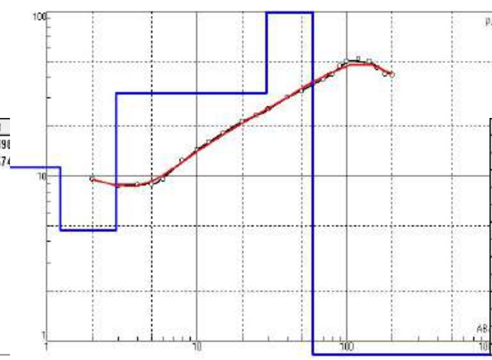
N	ρ	h	d	Alt
1	5.11	1.24	1.24	-1.241
2	11.2	23.4	24.7	-24.65
3	585			

62.Ghasadeipur



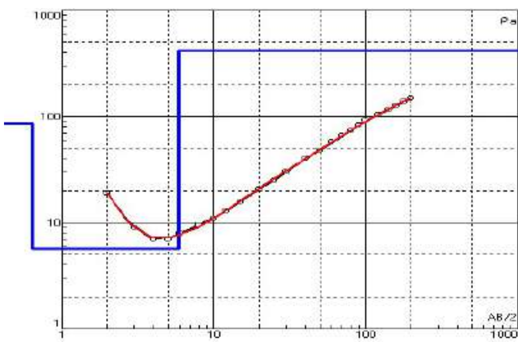
N	ρ	h	d	Alt
1	35.92	3.25	3.25	-3.249
2	10.92	9.324	12.57	-12.574
3	318			

63.Fateghar



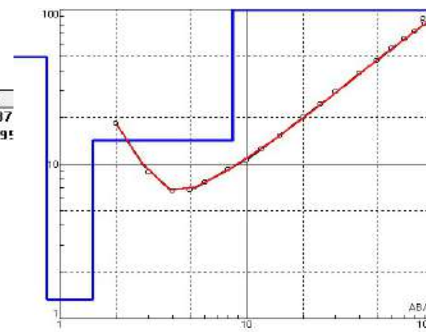
N	ρ	h	d	Alt
1	11.4	1.22	1.22	-1.224
2	4.63	1.65	2.88	-2.875
3	32.1	26.4	29.3	-29.31
4	221	30.1	59.4	-59.38
5	0.636			

64.Rakamma



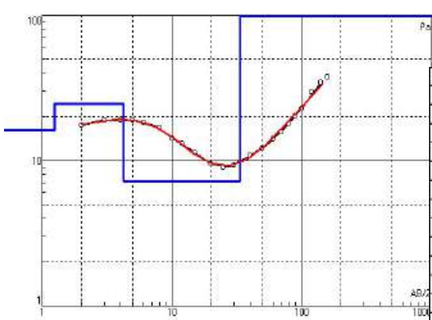
N	ρ	h	d	Alt
1	86.22	0.6437	0.6437	0.6437
2	5.721	5.186	5.829	-5.8295
3	416.8			

65.Madhapur



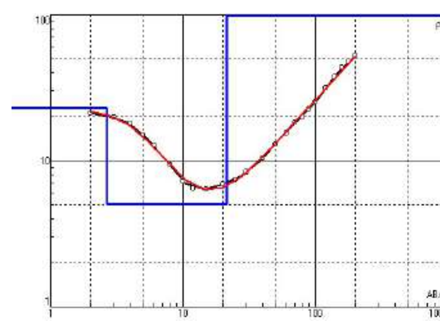
N	ρ	h	d	Alt
1	49.47	0.8558	0.8558	0.8557
2	1.326	0.6467	1.502	-1.5025
3	14.23	6.937	8.44	-8.4395
4	686.4			

66.Karabara



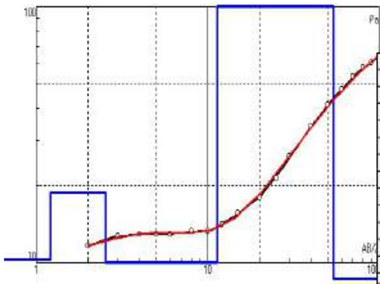
N	ρ	h	d	Alt
1	16.1	1.24	1.24	-1.235
2	24.7	3.01	4.25	-4.247
3	7.23	29.4	33.6	-33.64
4	7076			

67.Padmabati



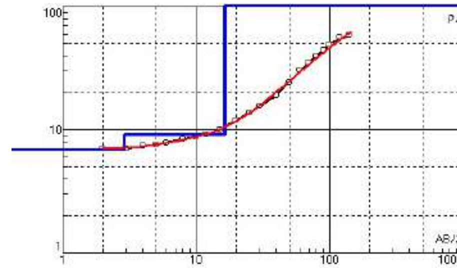
N	ρ	h	d	Alt
1	22.8	2.68	2.68	-2.676
2	5.04	18.6	21.3	-21.31
3	8482			

68.Shikarpur



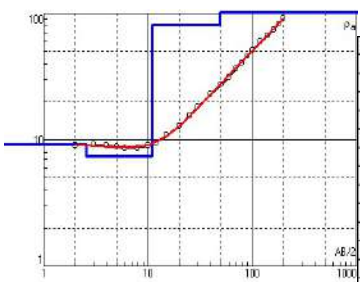
N	ρ	h	d	Alt
1	10.3	1.2	1.2	-1.2
2	18.75	1.33	2.53	-2.5301
3	10.02	8.727	11.26	-11.257
4	358.2	43.02	54.28	-54.278
5	6.217			

69.Harikrishnapur



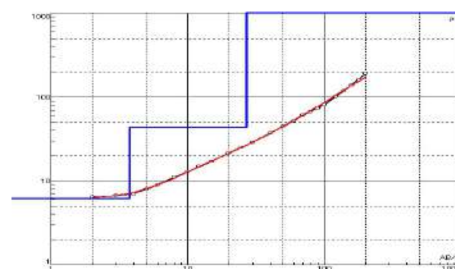
N	ρ	h	d	Alt
1	6.91	2.87	2.87	-2.875
2	9.2	13.4	16.3	-16.29
3	308			

70.Champtipur



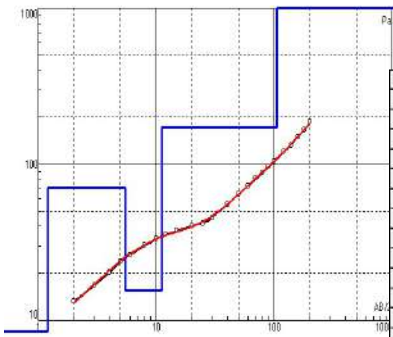
N	ρ	h	d	Alt
1	9.195	2.536	2.536	-2.5362
2	7.426	8.464	11	-11
3	81.38	38.07	49.08	-49.075
4	571.2			

71.Balugaon



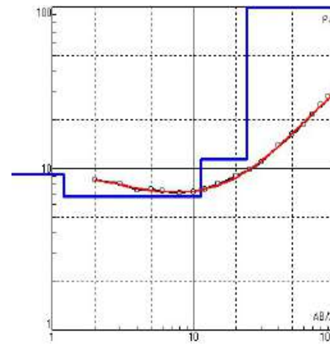
N	ρ	h	d	Alt
1	6.14	3.75	3.75	-3.748
2	43.7	23.1	26.8	-26.8
3	11637			

72.Shimlisahi



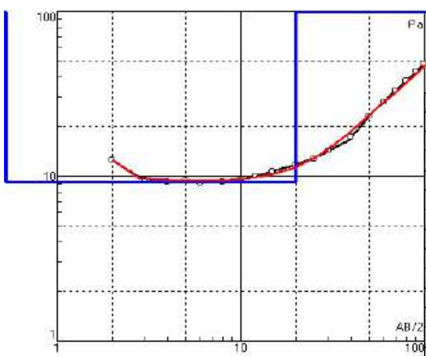
N	ρ	h	d	Alt
1	8.539	1.2	1.2	-1.2
2	70.28	4.269	5.469	-5.4685
3	15.55	5.713	11.18	-11.182
4	173.2	94.03	105.2	-105.21
5	16220			

73. Dianpada



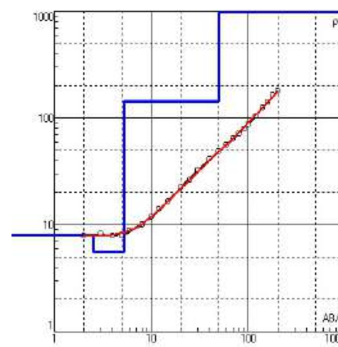
N	ρ	h	d	Alt
1	9.258	1.2	1.2	-1.2
2	6.742	10.06	11.26	-11.26
3	11.5	12.47	23.73	-23.727
4	119.3			

74.Railway station(Nayagharh)



N	ρ	h	d	Alt
1	510	0.338	0.338	-0.3383
2	9.18	19.7	20	-20.01
3	5052			

75.Nayagarh



N	ρ	h	d	Alt
1	7.99	2.51	2.51	-2.51
2	5.55	2.73	5.24	-5.244
3	144	44.2	49.5	-49.46
4	14172			

Table 13.1 VES Result in Nayagarh District

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
1	Mayurjhalia	Ranpur	1	334655	2214174	1	9.81	2.92	2.92	Top soil			
						2	10.3	12.3	18.22	Clay			
						3	23.7	17.48	35.7	Weather formation	Aquifer	18.22-35.7	potable
						4	1083.5			Compact formation			
2	Godabanikilo	Ranpur	2	331606	2224564	1	25.7	1.49	1.49	Top soil			
						2	79.6	2.07	3.56	Semi Weather formation			
						3	17.8	28.5	32	Weather formation	Aquifer	3.56-32	potable
						4	5342			Compact formation			
3	Kerendatangi	Ranpur	3	332015	2208810	1	4.72	1.37	1.37	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	33.5	1.72	3.09	Semi Weather formation			
						3	2.72	2.77	5.86	Weather formation	Aquifer	3.09-5.86	potable
						4	1066			Compact formation			
4	Patia	Ranpur	4	324383	2204952	1	29.3	0.617	0.617	Top soil			
						2	4.21	0.528	1.15	Clay			
						3	12.4	37.7	38.9	Weather formation	Aquifer	1.15-38.9	potable
						4	8759			Compact formation			
5	Rajasunkhala	Ranpur	5	326566	2231831	1	5.38	1.2	1.2	Top soil			
						2	2.84	1.31	2.51	Clay			
						3	8.41	8.83	11.3	Weather formation	Aquifer	2.5111.3	potable
						4	38.8	37.3	48.7	Weather formation	Aquifer	11.3-48.7	potable
						5	888			Compact formation			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
6	Koilama	Ranpur	6	326174	2224643	1	6.53	2.51	2.51	Top soil			
						2	16.3	8.47	11	Weather formation	Aquifer	2.51-11	potable
						3	25786			Compact formation			
7	Damasahi	Ranpur	7	310330	2217037	1	9.16	1.17	1.17	Top soil			
						2	10.4	14.5	15.6	Weather formation	Aquifer	1.17-15.6	Potable
						3	17357			Compact formation			
8	Godipada	Ranpur	8	307812	2217624	1	7.21	3.05	3.05	Top soil			
						2	4.86	2.46	5.51	Clay			
						3	15.1	16.8	22.3	Weather formation	Aquifer	5.51-22.3	Potable
						4	13018			Compact formation			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
9	Darpanarayapur	Ranpur	9	314980	2220490	1	14.86	1.046	1.046	Top soil			
						2	5.604	0.6005	1.647	Clay			
						3	13.44	9.135	10.78	Weather formation	Aquifer	1.647-10.78	Potable
						4	36.25	27.86	38.64	Weather formation	Aquifer	10.78-38.64	Potable
						5	21765			Compact formation			
10	srikrishnachandrapur	Ranpur	10	321187	2219688	1	4.28	1.2	1.2	Top soil			
						2	28.8	1.26	2.46	Clay			
						3	10.5	2.6	5.06	Clay			
						4	23.4	5.33	10.4	Weather formation	Aquifer	5.06-10.4	Potable
						5	11210	10.9	21.3	Compact formation			
						6	43.3			Weather formation			
11	Lathipada	Nayagharh	11	306916	2224579	1	37.8	2.31	2.31	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	2.55	1.66	3.97	Clay			
						3	15.1	12.4	16.4	Weather formation	Aquifer	3.97-16.4	Potable
						4	429			Compact formation			
12	Itamati	Nayagharh	12	306327	2228173	1	12.8	1.31	1.31	Top soil			
						2	21.1	1.4	2.71	Clay			
						3	8.71	7.53	10.2	Weather formation	Aquifer	2.71-10.2	Potable
						4	25132			Compact formation			
13	Biruda	Nayagharh	13	310018	2226771	1	10	1.45	1.45	Top soil			
						2	5.36	1.48	2.93	Clay			
						3	23	49.9	52.8	Weather formation	Aquifer	2.93-52.8	Potable
						4	17079			Compact formation			
14	Joshodapur	Ranpur	14	321897	2215104	1	7.982	1.2	1.2	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	5.444	1.308	2.508	Clay			
						3	8.267	8.632	11.14	Clay			
						4	52.15	37.06	48.2	Weather formation	Aquifer	11.14-48.2	Potable
						5	3345			Compact formation			
15	Gopalpur 1	Ranpur	15	328494	2214366	1	9.352	1.958	1.958	Top soil			
						2	11.81	13.95	15.91	Weather formation	Aquifer	1.958-15.91	Potable
						3	463.8			Compact formation			
16	Gadabanikilo 2	Ranpur	16	331440	2224341	1	37.5	0.901	0.901	Top soil			
						2	3.65	3.03	3.39	Clay			
						3	8.18	11.2	15.1	Weather formation	Aquifer	3.39-15.1	Potable
						4	407			Compact formation			
17	Mahipur	Nuagaon	17	291448	2230738	1	22.49	1.2	1.2	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	4.471	1.308	2.508	Clay			
						3	9.415	2.734	5.241	Clay			
						4	14.28	5.713	10.95	Weather formation	Aquifer	5.241-10.95	Potable
						5	304.2	11.94	22.89	Less compact formation			
						6	71.63	77.15	100	Semi Weather formation	Aquifer	22.89-100	Potable
						7	4451			Compact formation			
18	Nuagaon	Nuagaon	18	288281	2240710	1	26.269	0.929	0.929	Top soil			
						2	7.192	6.412	7.341	Clay			
						3	107.4	129.5	136.9	Less compact formation			
						4	6713			Compact formation			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
19	Kujamendhi	Daspalla	19	240368	2252352	1	24.8	0.519	0.519	Top soil			
						2	59	16.7	17.2	Weather formation	Aquifer	0.519-17.2	Potable
						3	30712			Compact formation			
20	Ambalimba	Daspalla	20	274243	2256353	1	68.7	0.508	0.508	Top soil			
						2	7.01	12.5	13	Weather formation	Aquifer	0.508-13	Potable
						3	4918			Compact formation			
21	Baniguchha	Daspalla	21	248233	2258306	1	33.34	1.034	1.034	Top soil			
						2	24.05	2.143	3.177	Clay			
						3	10.36	18.3	21.47	Weather formation	Aquifer	3.177-21.47	Potable
						4	81.12			Compact formation			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
22	Jamusahi	Daspalla	22	255817	2257474	1	17.4	2.72	2.72	Top soil			
						2	8.01	3.4	6.12	Clay			
						3	172	68.8	74.9	Semi Weather formation	Aquifer	6.12-74.9	Potable
						4	5177			Compact formation			
23	Buguda	Daspalla	23	261749	2258250	1	17.02	1.2	1.2	Top soil			
						2	6.796	1.308	2.508	Clay			
						3	64.15	20.44	22.94	Weather formation	Aquifer	2.508-22.94	Potable
						4	692.8			Compact formation			
24	Rangamatia	Daspalla	24	269184	2253792	1	40.1	1.2	1.2	Top soil			
						2	24.3	5.24	6.44	Clay			
						3	240	28.7	35.1	Weather formation	Aquifer	6.44-35.1	Potable
						4	65496			Compact formation			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
25	Daspalla	Daspalla	25	274491	2250052	1	8.198	1.971	1.971	Top soil			
						2	11.31	5.948	7.919	Clay			
						3	61.59	30.47	38.39	Weather formation	Aquifer	7.919-38.39	Potable
						4	443.1			Compact formation			
26	Sakhini	Daspalla	26	273156	2241506	1	28.32	1.918	1.918	Top soil			
						2	11.76	3.848	5.766	Clay			
						3	127.6	28.39	34.16	Weather formation	Aquifer	5.766-34.16	Potable
						4	29120			Compact formation			
27	Bentapada	Gania	27	285967	2265406	1	15.96	9.865	9.865	Clay			
						2	347.1			Semi Weather formation			
28	Rasanga	Gania	28	292535	2260138	1	16.6	0.25	0.25	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	49.5	14.5	14.8	Weather formation	Aquifer	0.25-49.5	Potable
						3	64775			Compact formation			
29	Gania	Gania	29	296305	2257337	1	6.3	3.42	3.42	Top soil			
						2	15.9	11.7	15.2	Weather formation	Aquifer	3.42-15.2	Potable
						3	12219			Compact formation			
30	Adakata	Gania	30	290148	2251884	1	10.41	0.6265	0.6265	Top soil			
						2	4.852	1.876	2.502	Clay			Potable
						3	14.13	12.66	15.17	Weather formation	Aquifer	0.6265-15.17	
						4	6220			Compact formation			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
31	Sorada	Gania	31	283322	2247961	1	5.25	0.942	0.942	Top soil			
						2	8221	3.73	4.67	Clay			
						3	70.8	21.2	25.9	Weather formation	Aquifer	4.67-25.9	Potable
						4	6721			Compact formation			
32	Dimiria	Nuagaon	32	278341	2235582	1	8.98	1.35	1.35	Top soil			
						2	2.85	1.38	2.73	Clay			
						3	16731	7.09	9.82	Compact formation			
						4	111			Semi weather formation			
33	Goomi	Nuagaon	33	277744	2229232	1	13.54	1.507	1.507	Top soil			
						2	11.39	8.083	9.589	Weather formation	Aquifer	1.507-9.589	Potable

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						3	23971			Compact formation			
34	Shikrida	Nuagaon	34	287631	2248964	1	8.329	2.901	2.901	Top soil			
						2	47.65	16.58	19.48	Weather formation	Aquifer	2.901-19.48	Potable
						3	844.8			Compact formation			
35	Ghanasalia	Nuagaon	35	304940	2253487	1	21.27	1.043	1.043	Top soil			
						2	10.03	9.33	10.37	Weather formation	Aquifer	1.043-10.37	Potable
						3	15749			Compact formation			
36	Kantilo	Khandapara	36	310557	2252055	1	13.9	0.8601	0.8601	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	8.545	4.337	5.197	Clay			
						3	107.5	70.21	75.41	Weather formation	Aquifer	5.197-75.41	Potable
						4	8238			Compact formation			
37	Gopinathpur	Khandapara	37	309194	2250020	1	11	1.37	1.37	Top soil			
						2	1.71	1.37	2.74	Clay			
						3	206			Weather formation			
38	Indipata	Gania	38	299883	2256224	1	5.88	2.83	2.83	Top soil			
						2	25.4	15.5	18.3	Weather formation	Aquifer	2.83-18.3	Potable
						3	10794			Compact formation			
39	Madhyakhand	Daspalla	39	284314	2251326	1	16.68	0.6777	0.6777	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	9.233	1.797	2.475	Clay			
						3	24.56	11.97	14.44	Weather formation	Aquifer	2.475-14.44	Potable
						4	21072			Compact formation			
40	Kosaka	Khandapara	40	295123	2251366	1	5.43	1.72	1.72	Top soil			
						2	10.5	5.15	6.88	Clay			
						3	895			Compact formation			
41	Giridipalli	Khandapara	41	301979	2250755	1	50.05	5.081	5.081	Top soil			
						2	36.8	2.565	7.647	Clay			
						3	75.68	63.85	71.5	Weather formation	Aquifer	7.647-71.5	Potable
						4	8997			Compact formation			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
42	Singhapada	Khandapara	42	305765	2247410	1	42.4	0.638	0.638	Top soil			
						2	8.14	5.04	5.68	Clay			
						3	13.8	22.3	28	Weather formation	Aquifer	5.68-28	Potable
						4	6099			Compact formation			
43	Badabhuin 1	Gania	43	293425	2254413	1	44.7	0.934	0.934	Top soil			
						2	9.39	4.9	5.83	Weather formation			
						3	8130	13	18.8	Compact formation			
						4	30			Weather formation			
44	Bahadajhola	Nuagaon	44	282227	2221003	1	11.1	1.2	1.2	Top soil			
						2	5.79	1.58	2.78	Clay			
						3	13.1	12.2	14.9	Weather formation	Aquifer	2.78-14.9	Potable

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						4	17516			Compact formation			
45	Bantala	Nuagaon	45	284926	2226203	1	8.186	4.718	4.718	Top soil			
						2	48.33	22.9	27.62	Weather formation	Aquifer	4.718-27.62	Potable
						3	2477			Compact formation			
46	Mahipur 2	Nuagaon	46	289406	2230109	1	13.93	1.2	1.2	Top soil			
						2	8.223	1.33	2.53	Clay			
						3	20.78	2.804	5.335	Clay			
						4	7.032	5.913	11.25	Weather formation	Aquifer	5.335-11.25	Potable
						5	133	12.47	23.71	Semi Weather formation	Aquifer	11.25-23.71	Potable
						6	44.87			Weather formation			
47	Gopinath	Daspalla	47	276874	2252480	1	85.4	0.683	0.683	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	8.67	7.66	8.34	Clay			
						3	310			Semi weather formation			
48	Shikarpur	Khanadapada	48	306538	2237709	1	4.97	0.725	0.725	Top soil			
						2	57	0.854	1.58	Clay			
						3	5.66	17	18.6	Weather formation	Aquifer	1.58-18.6	Potable
						4	3144			Compact formation			
49	Mardarajpur	Khanadapada	49	309263	2245763	1	19.44	1.2	1.2	Top soil			
						2	7.798	1.33	2.53	Clay			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						3	54.21	8.754	11.28	Weather formation	Aquifer	2.53-11.28	Potable
						4	320.4			Compact formation			
50	Khandapada	Khandapada	50	309714	2242763	1	25.81	0.4973	0.4973	Top soil			
						2	61.74	7.508	8.005	Weather formation			
						3	191.5	57.84	65.85	Semi Weather formation	Aquifer	8.005-65.85	Potable
						4	85936			Compact formation			
51	Baghuapalli	Bhapur	51	312978	2239075	1	5.166	1.192	1.192	Top soil			
						2	14.25	4.075	5.267	Clay			
						3	86	27.35	32.62	Weather formation	Aquifer	5.267-32.62	Potable
						4	4249			Compact formation			
52	Golapokhari	Bhapur	52	321749	2241590	1	188	0.644	0.644	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	19.7	3.99	4.63	Clay			
						3	5.92	6.29	10.9	Weather formation	Aquifer	4.63-10.9	Potable
						4	812	11	21.9	Compact formation			
						5	5.2			Weather formation			
53	Bhapur	Bhapur	53	321219	2243798	1	12.2	0.8607	0.8607	Top soil			
						2	22.23	1.356	2.216	Clay			
						3	7.761	2.408	4.625	Clay			
						4	30.32	9.42	14.04	Weather formation	Aquifer	4.625-14.04	Potable
						5	521			Compact formation			
54	Gutuni	Khandapara	54	308780	2233807	1	27	1.2	1.2	Top soil			
						2	8.293	4.136	5.336	Clay			
						3	39.44	18.67	24.01	Weather formation	Aquifer	5.336-24.01	Potable

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						4	300			Compact formation			
55	Banamalipur	Khandapara	55	312857	2242527	1	58.6	0.764	0.764	Top soil			
						2	10.5	4.5	5.26	Clay			
						3	19.4	20.2	25.5	Weather formation	Aquifer	5.26-25.5	Potable
						4	10179			Compact formation			
56	Banamalipur 2	Khandapara	56	312866	2242602	1	85.6	1.26	1.26	Top soil			
						2	34.9	5.2	6.46	Semi weather formation			
						3	12.6	15.7	22.2	Weather formation	Aquifer	6.46-22.2	Potable
						4	4443			Compact formation			
57	Kajalipalisasan	Odagaon	57	304092	2213576	1	8.47	1.2	1.2	Top soil			
						2	11.7	9.8	11	Clay			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						3	656			Compact formation			
58	Sarankul	Odagaon	58	300738	2216059	1	8.23	0.688	0.688	Top soil			
						2	4.32	11.8	12.5	Clay			
						3	10187			Compact formation			
59	Solopata	Odagaon	59	300294	2221081	1	6.831	0.8616	0.8616	Top soil			
						2	14.89	7.037	7.899	Clay			
						3	169.1			Weather formation			
60	Komad	Odagaon	60	282483	2212248	1	26.2	1.2	1.2	Top soil			
						2	57.9	5.36	6.56	Clay			
						3	11.7	8.47	15	Weather formation	Aquifer	6.56-15	Potable
						4	45.3	66.5	81.5	Weather formation	Aquifer	15-81.5	Potable

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						5	2798			Compact formation			
61	Odagaon	Odagaon	61	288192	2214408	1	5.11	1.24	1.24	Top soil			
						2	11.2	23.4	24.7	Weather formation	Aquifer	1.24-24.7	Potable
						3	585			Compact formation			
62	Ghasadeipur	Odagaon	62	292173	2213478	1	35.92	3.25	3.25	Top soil			
						2	10.92	9.324	12.57	Weather formation	Aquifer	3.25-12.57	Potable
						3	318			Compact formation			
63	Fategarh	Bhapur	63	325647	2245624	1	11.4	1.22	1.22	Top soil			
						2	4.63	1.65	2.88	Clay			
						3	32.1	26.4	29.3	Weather formation	Aquifer	2.88-29.3	Potable

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						4	221	30.1	59.4	Semi weather formation	Aquifer	29.3-59.4	Potable
						5	0.636			Sand saline			
64	Rakamma	Bhapur	64	320584	2247735	1	86.22	0.6437	0.6437	Top soil			
						2	5.721	5.186	5.829	Clay			
						3	416.8			Semi weather formation			
65	Madhapur	Bhapur	65	316334	2250281	1	49.47	0.8558	0.8558	Top soil			
						2	1.326	0.6467	1.502	Clay			
						3	14.23	6.937	8.44	Weather formation	Aquifer	1.502-8.44	Potable
						4	686.4			Compact formation			
66	Karabara	Bhapur	66	326022	2250014	1	16.1	1.24	1.24	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	24.7	3.01	4.25	Clay			
						3	7.23	29.4	33.6	Weather formation	Aquifer	4.25-33.6	Potable
						4	7076			Compact formation			
67	Padamabati	Bhapur	67	322347	2249696	1	22.8	2.68	2.68	Clay			
						2	5.04	18.6	21.3	Weather formation	Aquifer	2.68-21.3	Potable
						3	8482			Compact formation			
68	Shikarpur 2	Khandapara	68	306883	2237834	1	10.3	1.2	1.2	Top soil			
						2	18.75	1.33	2.53	Clay			
						3	10.02	8.727	11.26	Weather formation	Aquifer	2.53-11.26	Potable
						4	358.2	43.02	54.28	Semi weather formation	Aquifer	11.26-54.28	Potable
						5	6.217			Clay			
69	Harikrishnapur	Nayagarh	69	311070	2230182	1	6.91	2.87	2.87	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	9.2	13.4	16.3	Weather formation	Aquifer	2.87-16.3	Potable
						3	308			Semi weather formation			
70	Champtipur	Nayagarh	70	307643	2231360	1	9.195	2.536	2.536	Top soil			
						2	7.426	8.464	11	Weather formation	Aquifer	2.536-11	Potable
						3	81.38	38.07	49.08	Semi Weather formation	Aquifer	11-49.08	Potable
						4	571.2			Compact formation			
71	Balugaon	Nayagarh	71	303326	2232523	1	6.14	3.75	3.75	Top soil			
						2	43.7	23.1	26.8	Weather formation	Aquifer	3.75-26.8	Potable
						3	11637			Compact formation			
72	Similisahi	Nayagarh	72	296030	2230538	1	8.539	1.2	1.2	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	70.28	4.269	5.469	Semi weather formatio			
						3	15.55	5.713	11.18	Weather formation	Aquifer	5.469-11.18	Potable
						4	173.2	94.03	105.2	Less Compact formation			
						5	16220			Compact formation			
73	Dianpada	Nayagarh	73	297934	2224549	1	9.258	1.2	1.2	Top soil			
						2	6.742	10.06	11.26	Clay			
						3	11.5	12.47	23.73	Weather formation	Aquifer	11.26-23.73	Potable
						4	119.3			Semi weather formation			
74	Railway stNayagarh	Nayagarh	74	302721	2228847	1	510	0.338	0.338	Top soil			

Sl No	Location	Block	VES No	Esting	Northing	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Characteristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
						2	9.18	19.7	20	Weather formation	Aquifer	0.338-20	Potable
						3	5052			Compact formation			
75	Nayagarh 2	Nayagarh	75	302135	2224900	1	7.99	2.51	2.51	Top soil			
						2	5.55	2.73	5.24	Clay			
						3	144	44.2	49.5	Semi Weather formation	Aquifer	5.24-49.5	Potable
						4	14172			Compact formation			

14. Soil Infiltration Study

Soil infiltration is the process by which water on the ground surface enters into the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation water. Infiltration rate defined the volume flux of water flowing into the soil profile per unit of soil surface area and measured in inches per hour or millimeters per hour. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. The infiltrated water first meets the soil moisture deficiency, if any, and thereafter the excess water moves vertically downwards to reach the groundwater table. This vertical movement is called percolation. Infiltration is usually measured by the depth (generally in mm) of the water layer that can enter the soil in a specified time (generally one hour). Thus, an infiltration rate of 15 mm/hour means that a water layer of 15 mm on the soil surface will take one hour to infiltrate. The infiltration rate decreases as the soil becomes saturated. Infiltration rates decline to a steady or quasi-steady state as soil becomes increasingly moist over the period of a storm or experimental wetting. It also determines the rate at which water has to be applied to the fields, thereby controlling the advance rate of the overland flow and avoiding excessive deep percolation or excessive runoff. The infiltration or intake rate is defined as the rate at which water enters into the soil, usually expressed in mm/hr.

Infiltration rate usually shows a sharp decline with time from the start of the application of water. The constant rate approached after a sufficiently large time is referred as the steady- infiltration rate. In dry soil, water infiltrates rapidly. This is called the initial infiltration rate. As more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches to water table. This is called the basic infiltration rate or steady state infiltration rate. The infiltration rate decreases to a steady or quasi-steady state as the soil becomes saturated. Therefore, the infiltration rate curve shows a sharp decline with time. The constant rate approached after a sufficiently large time is referred as the steady-infiltration rate. Some water that infiltrates will remain in the shallow soil layer, where it will gradually move vertically and horizontally through the soil and subsurface material. Some of the water may infiltrate deeper, recharging groundwater aquifers.

This steady state is referred to as the basic infiltration rate, which is close to the value of the saturated hydraulic conductivity. When the basic infiltration rate is reached, the cumulative infiltration curve becomes a straight line and the basic infiltration rate curve becomes a horizontal line. The infiltration rates of soils are influenced, among others, by the soil texture. Heavy soils have low infiltration rates by virtue of their small pore sizes, while light soils have high infiltration rates because of larger pore sizes. The classification of infiltration rates for different soil types are given in Table 14.1.

Table14.1 Classification of Soil Infiltration Rate

S. No	Class	Rate of infiltration (mm/hour)	Remarks
1	Very Slow	<2.5	Soil in this group has very high percentage of clay.
2	Low	2.5 – 12.5	Most of these soils are shallow, high in clay and low in organic matter contents
3	Medium	12.5 – 25.0	Soils in this group are loams and silts
4	High	>25	These soils are deep sands, deep well aggregated silt loams and some tropical soils with porosity

Determination of infiltration rates is essential for reliable prediction of surface runoff, saturated hydraulic conductivity of the surface layer and groundwater recharge, and in developing or selecting the most efficient irrigation methods. Quantifying the soil infiltration capacity is of great importance to understanding and describing the hydrologic analysis and modeling. The use of efficient irrigation methods with reduced water losses is critical in most part of water scare regions of Indian subcontinent. In some areas that have a steep slope, surface material lying above a compacted layer may move in a mass, sliding down the slope because of saturated soil conditions. Decreases in infiltration or increases in saturation above a compacted layer can also cause nutrient deficiencies in crops. Either condition can result in anaerobic conditions which reduce biological activity and fertilizer use efficiencies. This makes studies on determination of infiltration rates of utmost importance. The measure of infiltration of water into the soil is an important parameter which helps in planning recharge interventions. In most cases, maintaining a high infiltration rate is desirable for a healthy environment. However, soils that transmits water freely throughout the entire profile need proper chemical management to ensure the protection of groundwater and surface water resources. Soils that have reduced infiltration can become saturated at the surface during rainfall. Saturation decreases soil strength, increases detachment of particles, and enhances the erosion potential.

FACTORS AFFECTING INFILTRATION PROCESS

The principles of infiltration and the factors affecting the process are imperfectly understood even after many years of investigation. Infiltration rates vary widely. It is dependent on the condition of the land surface (cracked, crusted, compacted etc), land vegetation cover, surface soil characteristics (grain size & gradation), storm characteristics (intensity, duration & magnitude), surface soil and water temperature, chemical properties of the water and soil.

The process of infiltration is affected by many different factors. Important factors are discussed below:

Soil properties

The type of soil and soil texture (sandy, silt, clay) can control the rate of infiltration. Soils that have stable strong aggregates as granular or blocky soil structure have a higher infiltration rate than soils that have weak, massive, or plate like structure. Soils that have a smaller structural size have higher infiltration rates than soils that have a larger structural size.

Residence time

The length of time that water remains on the surface depends on the slope, the roughness of the soil surface, and obstructions to overland flow, such as plant bases and litter. Consequently, plant communities with large amounts of basal area cover, such as grasslands tend to slow runoff more than communities with small amounts of basal cover,, such as shrub lands.

Vegetation

A high percentage of plant cover and large amounts of root biomass generally increase the infiltration rate. Different plant species have different effects on infiltration. The species that form a dense root mat can reduce the infiltration rate. In areas of semi arid rangeland, the infiltration limiting layer commonly is confined to the top few millimeters of the soil, particularly in the open spaces between plant canopies. These areas receive few inputs of organic matter, which build soil structure. Also, the impact of raindrops in these areas can degrade soil structure and form physical crusts.

Texture

Water moves more quickly through the large pores and spaces in a sandy soil than it does through the small pores in a clayey soil. Where the content of organic matter is low, texture plays a significant role in the susceptibility of the soil to physical crusting.

Depth

Soil depth controls how much water the soil can hold. When soil above an impermeable layer, such as bedrock, becomes saturated, infiltration ceases and runoff increases. The properties that affect infiltration and can be readily changed by management or a shift in vegetation.

Organic matter

Infiltration is affected by crop and land management practices that affect surface crusting, compaction, and soil organic matter. An increased amount of plant material, dead or alive, generally assists the process of infiltration. Organic matter increases the entry of water by protecting the soil aggregates from breaking down during the impact of raindrops. Particles broken from aggregates can clog pores and seal the surface and decrease infiltration during a rainfall event.

Aggregation and structure

Good soil structure improves infiltration. Soils with good structure have more pores for the movement of water than soils with poor structure. if aggregates are stable, the structure remains intact throughout a rainstorm.

Initial moisture content

The content or amount of water in the soil affects the infiltration rate of the soil. The infiltration rate is generally higher when the soil is initially dry and decreases as the soil becomes wet. As soil become wet, the infiltration rate slows down to the rate of permeability of the most restrictive layer.

Human activities on Soil surface

If the soil surface gets compacted due to construction of roads, operation of tractors and other farm implements and machinery the porosity of the soil is decreased. As a result, bigger pores are almost eliminated making soil impermeable. It reduces the infiltration rates appreciably. Soils with low infiltration can be responsible for runoff and flooding and can become saturated during rain events. This, in turn, decreases soil strength and increases erosion potential. It can also cause nutrient deficiencies in plants and generate anaerobic conditions. Soils that have reduced infiltration have an increase in the overall amount of runoff water. This excess water can contribute to local and regional flooding of streams and rivers of results in accelerated soil erosion of fields or stream banks.

Infiltration rate

The infiltration rate is generally highest when the soil is dry. As the soil becomes wet, the infiltration rate slows to the rate at which water moves through the most restrictive layer, such as a compacted layer or a layer of dense clay. Infiltration rates decline as water temperature approaches freezing. Little or no water penetrates the surface of frozen or saturated soils.

MEASUREMENTS OF INFILTRATION RATE

Infiltration is a very complex process, which can vary temporally and spatially. Selection of measurement techniques and data analysis techniques should consider these effects, and their spatial dimensions can categorize infiltration measurement techniques. There are two general approaches for the determination of infiltration rate. One of these approaches usually referred to as hydrograph analysis method and other method uses the infiltrometers. The infiltrometer always gives the infiltration capacity rate and the information from such infiltrometer tests at various locations in the area/basin may give a fairly satisfactory estimate of the average infiltration capacity rate for the entire area/basin as a whole (Youngs., 1991). Ring infiltrometers should be used to determine infiltration rates for inundated soils such as flood irrigation or pond seepage. In this area double ring infiltrometer has been used to measure the Infiltration rate.

A soil under given condition has an upper limit on its absorbing capacity. The infiltration capacity of soil under given conditions is defined as the maximum rate at which it is capable of absorbing water and is denoted by f. The actual infiltration observed in a given soil, f_a, will be equal to or less than its infiltration capacity f depending on whether or not the rate of source supply is more or less than the infiltration capacity. Specifically if i denotes the rate of rainfall, then

$$f_a = f, \text{ if } i \geq f \quad and$$

$$f_a = f, \text{ if } I \leq f$$

DOUBLE RING INFILTROMETER

This is the most commonly used flooding type infiltrometer. Infiltration is measured by observing the fall of water within the inner cylinder of two concentric cylinders, with a usual diameter of 30 and 60 m and a height of about 30 m, driven vertically into the soil surface layer as illustrated in Figure 3. The outer ring acts as a buffer preventing lateral seepage of water from the inner one. This allows infiltration measurement from the inner ring to be representative of infiltration from the large area. It consists of two concentric rings driven into soil to a depth of about 15 cm uniformly without tilt and disturbing the soil to the least. Drive the cylinder into the soil to a depth of approximately 15 cm by placing a driving plate over the cylinder, or placing heavy timber on top, and using a driving hammer. Rotate the timber every few pushes or move the hammer equally over the surface in order to obtain a uniform and vertical penetration.

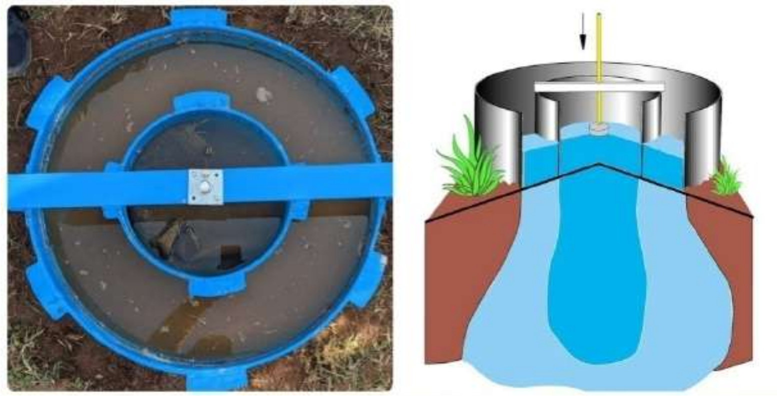
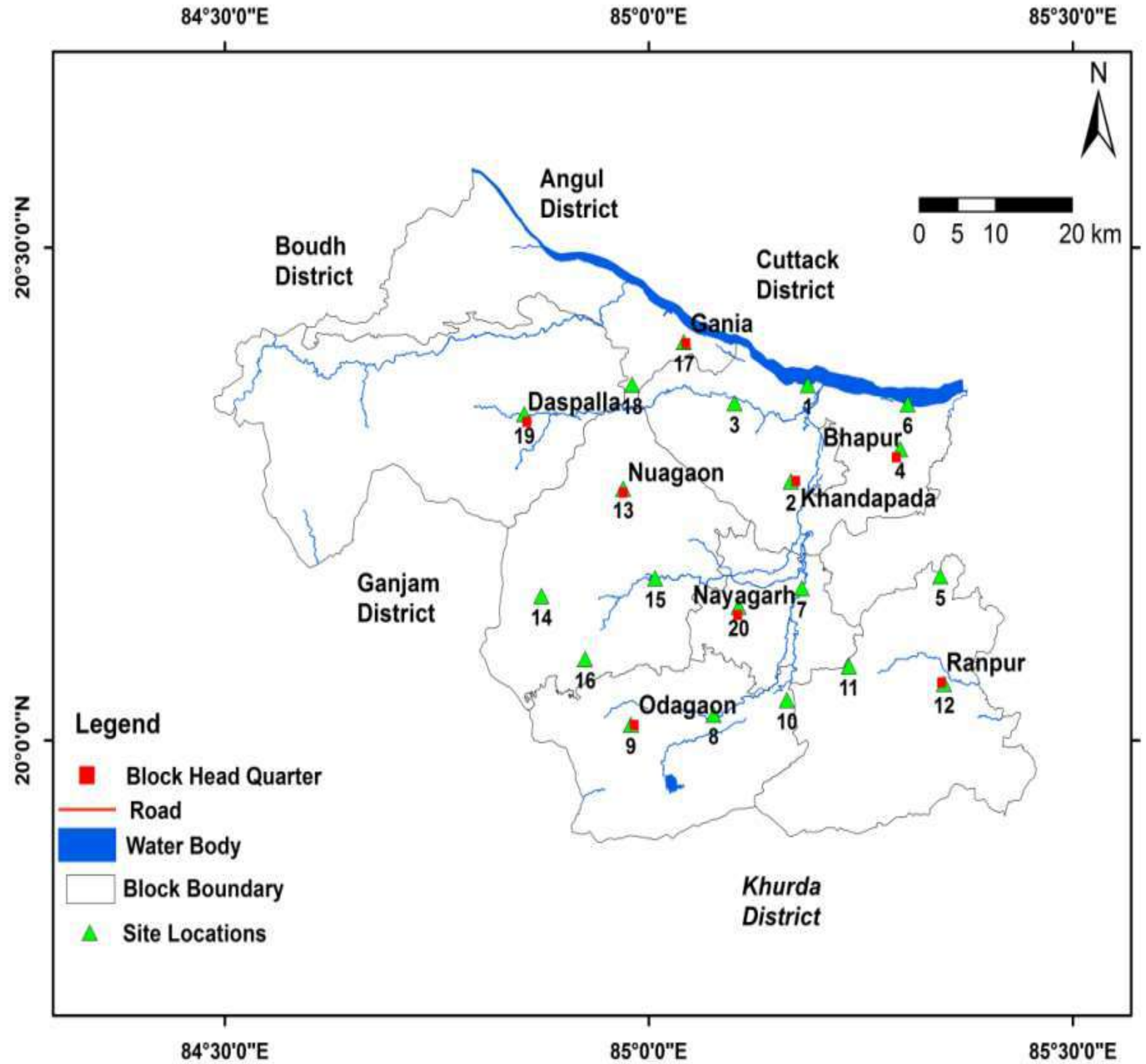


Figure 14.1 Double Ring Infiltrometer

Water is then applied in both the inner and outer rings to maintain a constant depth of about 5 cm. water is replenished after the level falls by 1 cm. The water depth in the inner and outer rings should be kept same during the observation period. Readings of volume of water added at successive time intervals to maintain constant depth of flooding in the inner ring are taken to facilitate the computation of infiltration rate. As the purpose of outer ring is to suppress the lateral percolation of water from the inner ring, the water added to it need not be measured through water is added to maintain the same depth as in the inner ring. The experiment has to be carried out till a constant infiltration rate is observed. The surface of the soil may be protected by a perforated disk of sheet metal so that the turbidity of surface water is kept at minimum.

Fix a gauge or any scale to the inner wall of the inner cylinder so that the changes in water level can be measured. Fill the outer ring with water to a depth approximately the same as will be used in the inner ring and also quickly add water to the inner cylinder till it reaches 100 mm on the gauge. Record the clock time immediately when the test begins and note the water level on the measuring rod. The initial infiltration will be high and therefore regular readings at short intervals should be made in the beginning, for example every minute, after which they can increase to 0, 2, 5, 10, 20, 30, 40, 60, 80, 100, 120, 150 and 180 minutes. The observation frequencies should be adjusted to infiltration rates. After a certain period infiltration becomes more or less constant (horizontal line). Then the basic infiltration rate is reached. After reading equal water lowering at equal intervals for about 2 or 3 hours, the test can stop. The infiltration during any time period can be calculated by subtracting the water level measurement before filling at the end of the period from the one after filling at the beginning of that same period. Soil infiltration tests using double ring infiltrometer were carried out at 21 locations in the Nayagarh District represented in the Figure.14.2.

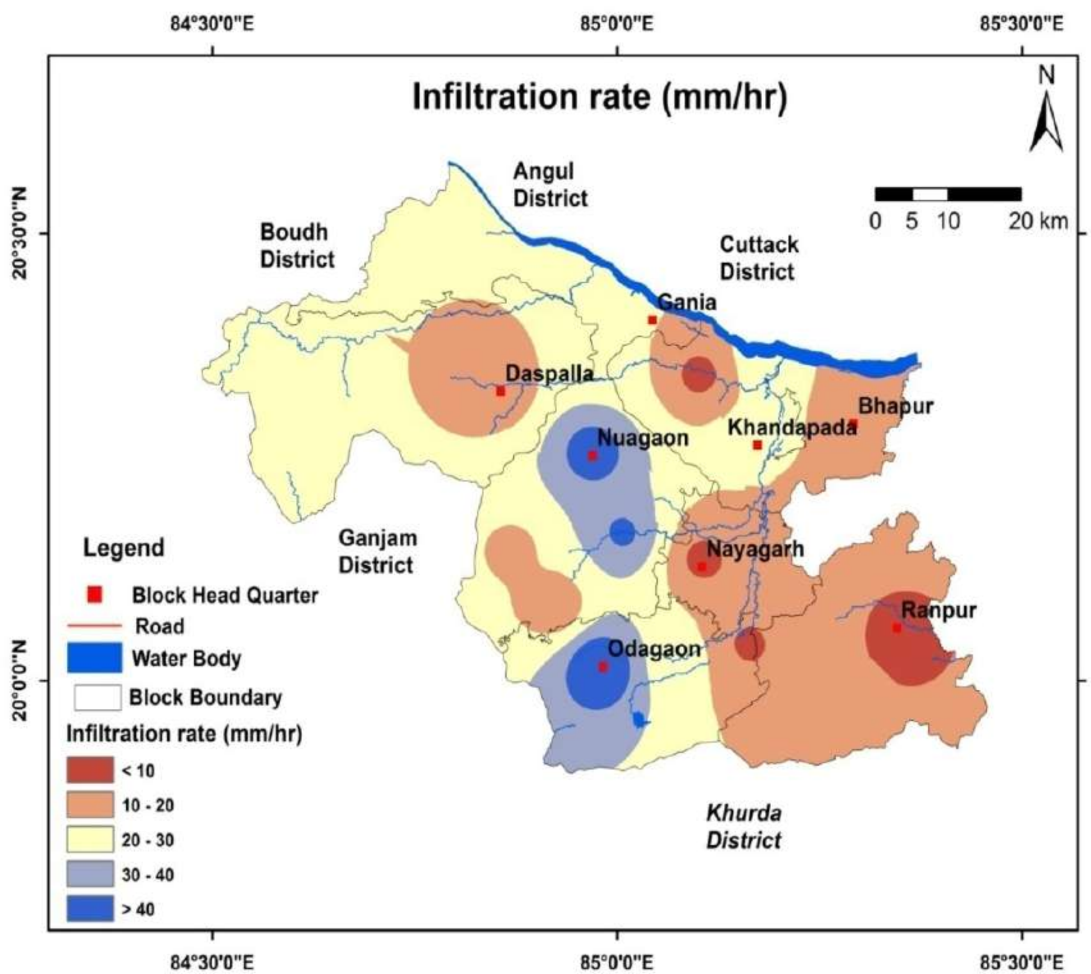
Figure.14.2 Locations of soil infiltration study sites in Nayagarh District



RESULTS

Wide variation in the infiltration rate has been observed in the entire area shown in figure.14.3. The initial infiltration rate in Nayagarh varies from 120 mm/hr to 1260 mm/hr and the final infiltration rate between 06 mm/hr and 54 mm/hr. The average initial and final infiltration rate for the Nayagarh found to be 373.5 mm/hr and 20.7 mm/hr respectively. The average infiltration rate for the Nayagarh District is estimated as 20.7 mm/hr. Site wise measured values of infiltration rates in Nayagarh Districts numbers of infiltration test conducted in each block are as given in Table14. 2.

Figure 14.3 Spatial distribution of soil infiltration rate in the Nayagarh District

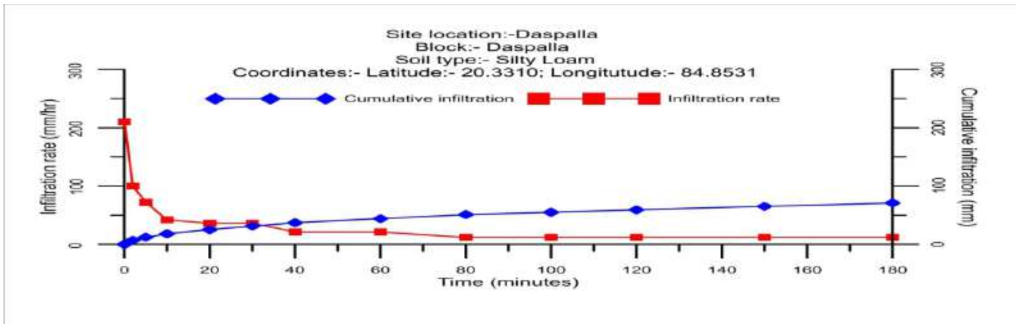


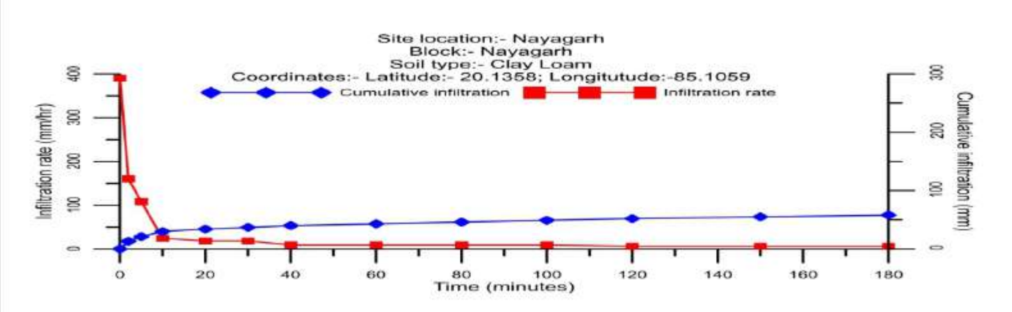
The observed low basic infiltration rates at certain sites indicate poor percolation of excess water through sub-surface due to presence of hard pan and ultimately causing water logging problem in the area. The clay percentage in the soil also influences the infiltration rate. Clay particles in the soil may swell as they become wet and thereby reduce the size of the pores and reducing the infiltration rate. Sandy loam soil is known to have high infiltration rates while clay loam and sandy clay soils are known to have very low infiltration rates. This explains why infiltration rates of sandy clay and loamy clay are lower than those of sandy loam soils. The higher infiltration rates at many sites indicate sandy nature of local soils. Sandy loam soil is known to have high infiltration rates while clay loam and sandy clay soils are known to have very low infiltration rates.

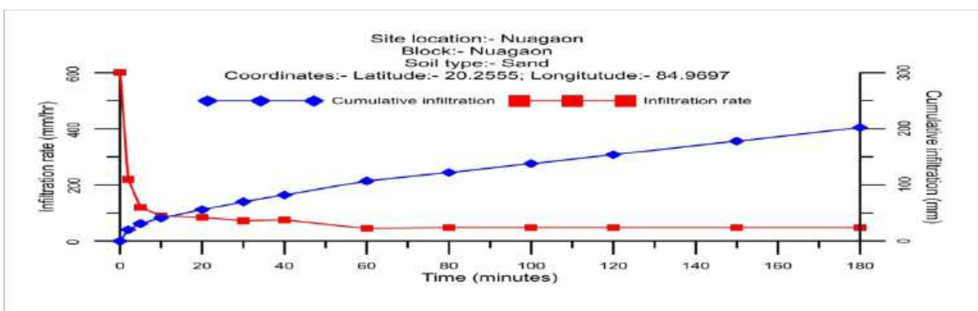
Table 14.2 Site wise measured values of infiltration rates in Nayagarh District

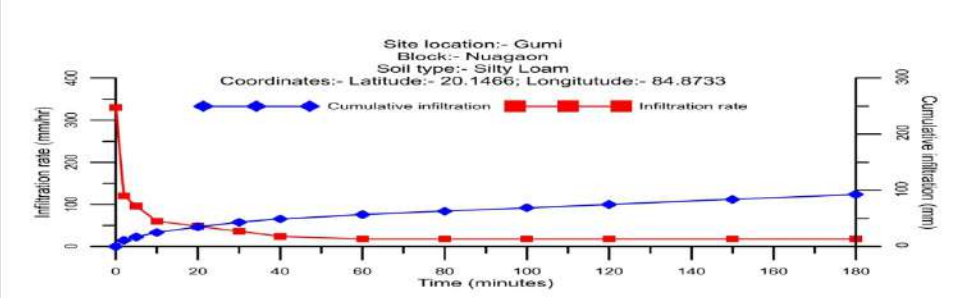
S. No	Site Location	Block	Soil Type	Longitude	Latitude	Infiltration rate (mm/hr)
1	Kantilo	Khandapada	Sandy Loam	85.18754	20.36073	30
2	Khadapada	Khadapada	Sandy Loam	85.16754	20.263	26
3	Giridipalli	Khadapada	Clay Loam	85.10119	20.34239	6
4	Bhapur	Bhapur	Sandy Loam	85.29648	20.29574	20
5	Rajsunakhala	Ranpur	Silty Loam	85.34368	20.16663	14
6	Padmabati	Bhapur	Silty Loam	85.30528	20.34131	12
7	Harikrishnapur	Nayagarh	Silty Loam	85.18049	20.15463	14
8	Sarankul	Odagaon	Sandy Loam	85.07638	20.02617	24
9	Odagaon	Odagaon	Sand	84.97883	20.01625	54
10	Godipada	Odagaon	Clay Loam	85.16285	20.04114	8
11	Darpanarayanpur	Ranapur	Silty Loam	85.23584	20.07542	18
12	Ranpur	Ranpur	Clay Loam	85.34812	20.05758	6
13	Nuagaon	Nuagaon	Sand	84.96974	20.25556	48
14	Gumi	Nuagaon	Silty Loam	84.87334	20.14665	18
15	Mahipur	Nuagaon	Sand	85.00752	20.16469	42
16	Bahadejhola	Nuagoan	Silty Loam	84.92477	20.08272	12
17	Gania	Gania	Sandy Loam	85.04134	20.40431	20
18	Adakata	Gania	Sandy Loam	84.98026	20.36102	24
19	Daspalla	Daspalla	Silty Loam	84.85314	20.33107	12
20	Nayagarh	Nayagarh	Clay Loam	85.10593	20.13587	6

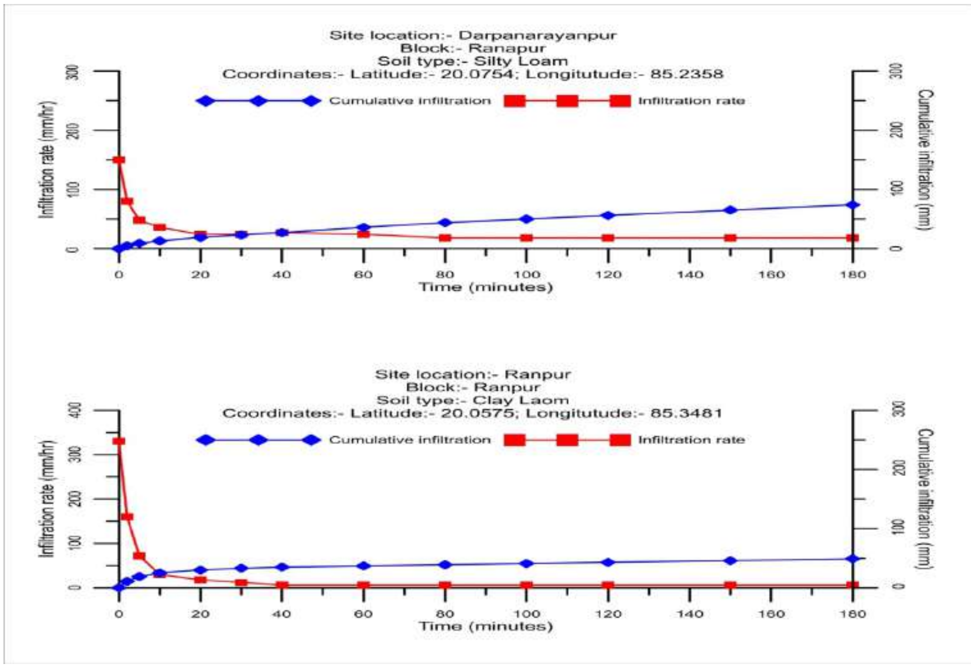
Infiltration rate and cumulative infiltration variation with time using double ring infiltrometer in some locations of Nayagarh District are given below.

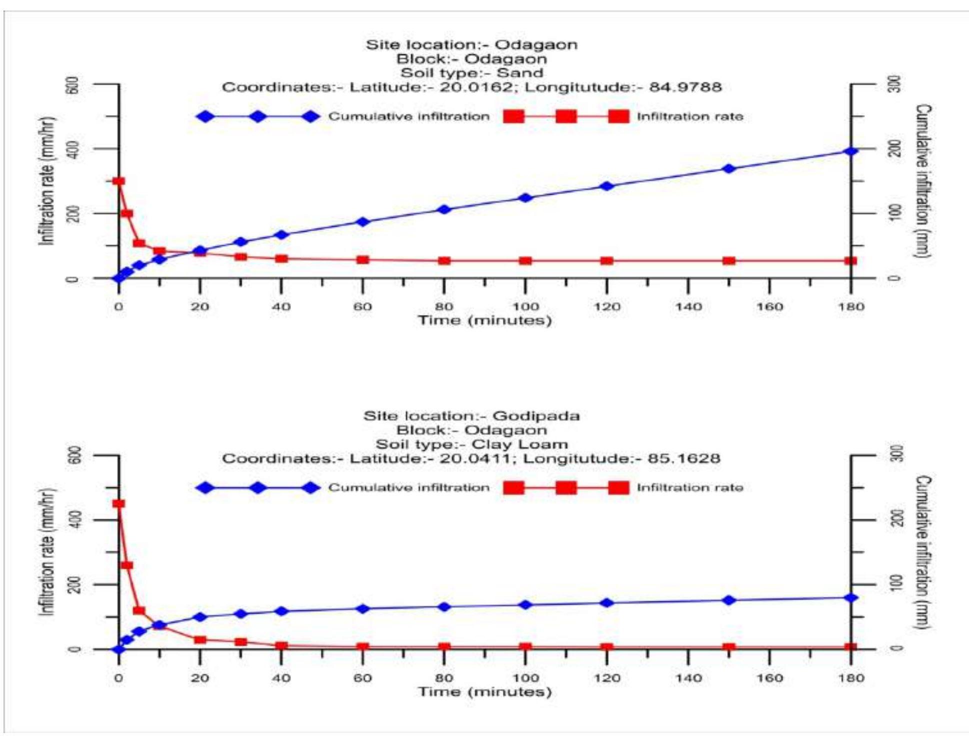


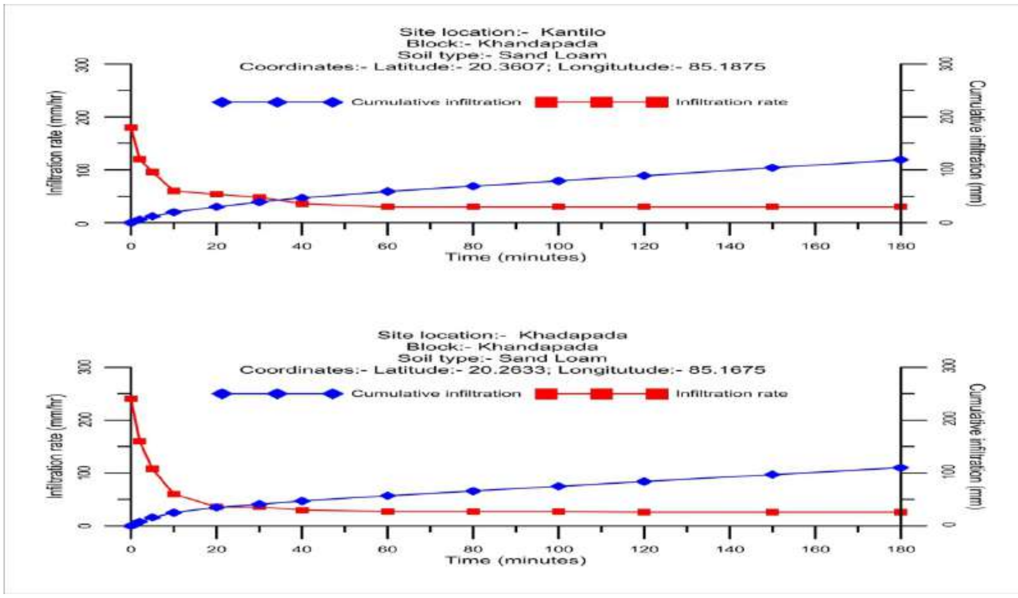


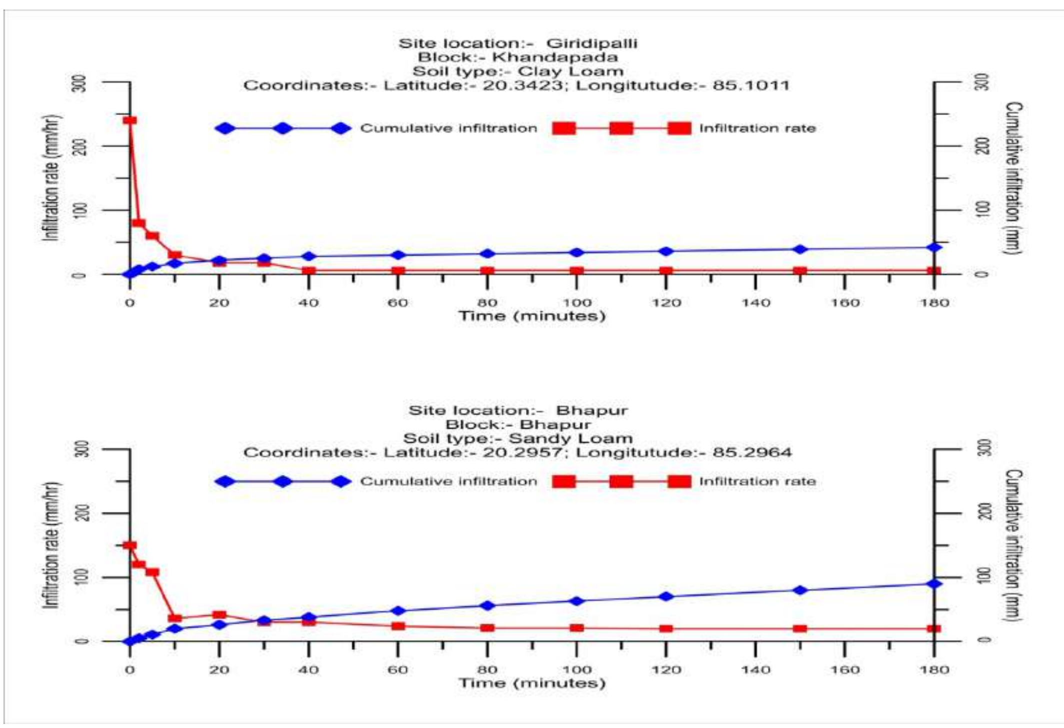


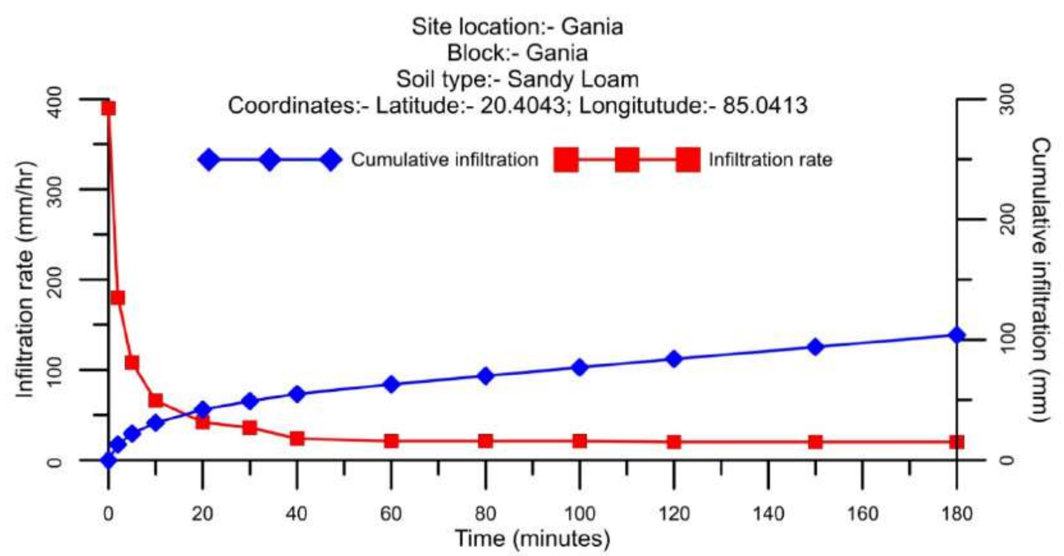


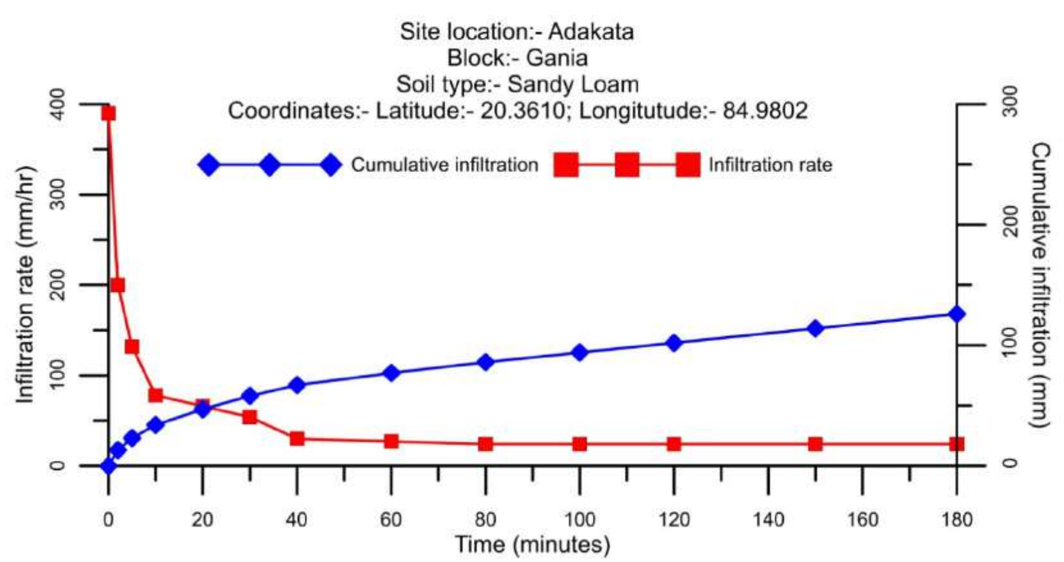

Site location:- Darpanarayanpur
Block:- Ranapur
Soil type:- Silty Loam
Coordinates:- Latitude:- 20.0754; Longitutude:- 85.2358
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)
Site location:- Ranpur
Block:- Ranpur
Soil type:- Clay Laom
Coordinates:- Latitude:- 20.0575; Longitutude:- 85.3481
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)


Site location:- Odagaon
Block:- Odagaon
Soil type:- Sand
Coordinates:- Latitude:- 20.0162; Longitutude:- 84.9788
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)
Site location:- Godipada
Block:- Odagaon
Soil type:- Clay Loam
Coordinates:- Latitude:- 20.0411; Longitutude:- 85.1628
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)


Site location:- Kantilo
Block:- Khandapada
Soil type:- Sand Loam
Coordinates:- Latitude:- 20.3607; Longitutude:- 85.1875
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)
Site location:- Khadapada
Block:- Khandapada
Soil type:- Sand Loam
Coordinates:- Latitude:- 20.2633; Longitutude:- 85.1675
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)


Site location:- Giridipalli
Block:- Khandapada
Soil type:- Clay Loam
Coordinates:- Latitude:- 20.3423; Longitutude:- 85.1011
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)
Site location:- Bhapur
Block:- Bhapur
Soil type:- Sandy Loam
Coordinates:- Latitude:- 20.2957; Longitutude:- 85.2964
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)


Site location:- Gania
Block:- Gania
Soil type:- Sandy Loam
Coordinates:- Latitude:- 20.4043; Longitutude:- 85.0413
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)
0
100
200
300
400
0
100
200
300
0
20
40
60
80
100
120
140
160
180


Site location:- Adakata
Block:- Gania
Soil type:- Sandy Loam
Coordinates:- Latitude:- 20.3610; Longitutude:- 84.9802
Cumulative infiltration
Infiltration rate
Infiltration rate (mm/hr)
Cumulative infiltration (mm)
Time (minutes)
0
100
200
300
400
0
100
200
300
0
20
40
60
80
100
120
140
160
180

15. Aquifer Management Plan

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

A. Ground Water Related Issues

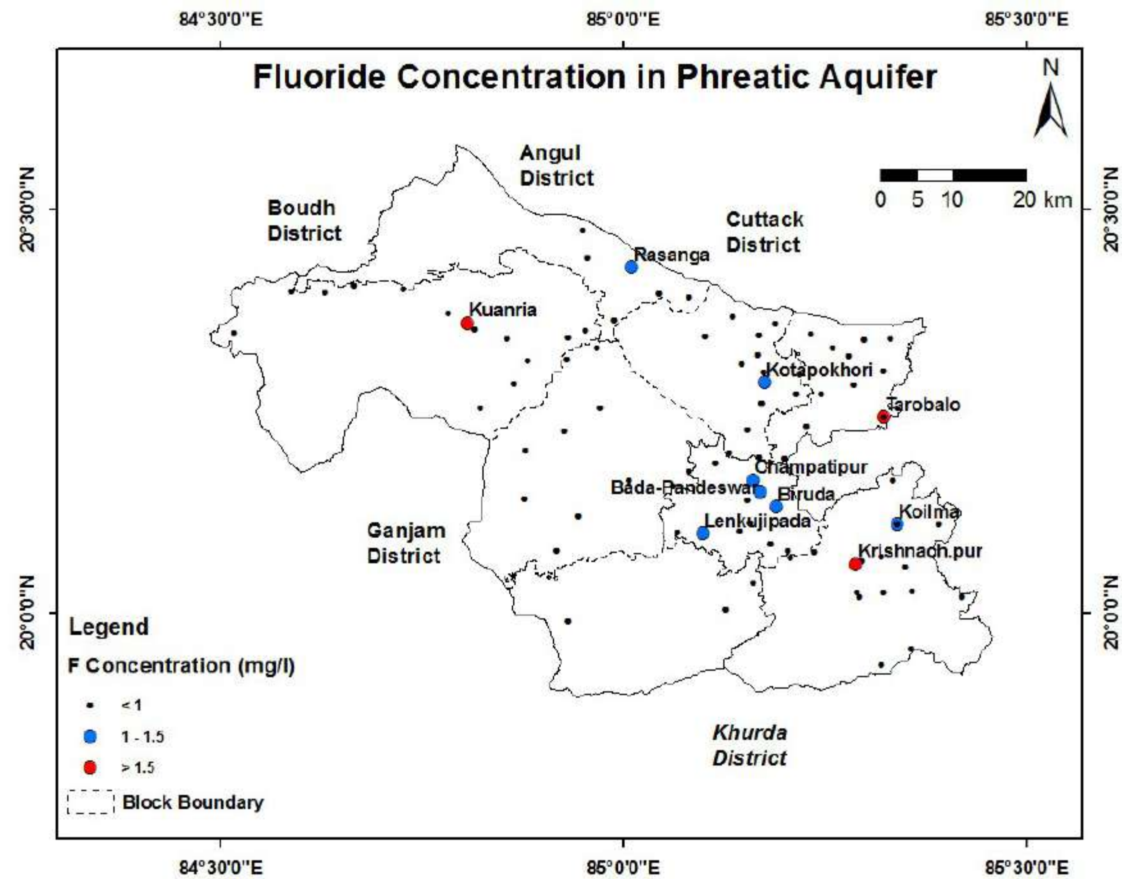
1. Fluoride in Ground Water

Incidence of high concentration of fluoride in ground water of Nayagarh district has been detected by CGWB during the past Reappraisal Hydrogeological Surveys. Chemical analysis of water sampling in Nayagarh district has revealed occurrence of fluoride in Dasapalla, Nayagarh, Gania and Bhapur block. The details of Fluoride concentration is shown in **Table 15.1** and depicted in **Fig. 15.1**.

Table 15.1 Fluoride point sourced locations in Nayagarh District

Sl	Block	Location	Source	Longitude	Latitude	Fluoride
1	Nayagarh	Bada-Pandusar	DW	85.1703	20.1503	1.2
2	Nayagarh	Biruda	DW	85.1897	20.1312	1.34
3	Nayagarh	Champatipur	DW	85.1611	20.1654	1.2
4	Ranpur	Koilma	DW	85.3395	20.11	1.19
5	Khandapara	Kotapokhori	DW	85.1718	20.2865	1.12
6	Ranpur	Krishnach.pur	DW	85.2886	20.0609	1.62
7	Dasapalla	Kuanria	DW	84.8075	20.3594	1.58
8	Dasapalla	Kuanria	BW	84.8075	20.3594	1.59
9	Nayagarh	Lenkudipada	DW	85.0987	20.099	1.48
10	Gania	Rasanga	DW	85.0104	20.4284	1.14
11	Gania	Rasanga	BW	85.0104	20.4284	2.17
12	Odogaon	Sarankul	DW	85.0967	20.0306	1.03
13	Odogaon	Solopata	DW	85.0922	20.0761	1.48
14	Bhapur	Tarobalo	DW	85.3226	20.2433	1.57

Fig. 15.1 Locations with High Fluoride Content in Ground Water in Nayagarh District



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

2. Under Utilisation of Ground Water Resources

As per the ground water resource estimated jointly by CGWB and State Govt. in 2020, the Annual Extractable Ground Water of the District is35898.01ham. The stage of ground water extraction of the districtis42.18%only.Blockwise the stage of ground water extractions are Bhapur(26.38%), Dasapalla(28.63%), Gania(46.11%), Khandapara(53.23%), Nayagarh(66.05%), Nuagaon(24.32%), Odogaon(47.19%), Ranpur(45.51%). Thus there is ample scope exists for further ground water development in the district.

3. Ground Water Problem in Hilly Areas

Nayagarh district receives adequate rainfall and the normal annual rainfall is 1423 mm. The western and south-western parts of the district are mainly of of hilly terrain and thus high run off zone. They act as recharge zones as well as good reservoir of ground water. Once they get saturated, during monsoon the excess water flows as run off and base flow. During the post-monsoon period, the thin weathered zones soon lose the entire storage water due to base flow. So there is scarcity of water in these areas in lean and summer season.

4. Less Productive Deeper Aquifer

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

5. Depleted Water Level in Phreatic Aquifer

Ground water level in the phreatic aquifer is found to be deep in many parts of Nayagarh district. Depth to water level during pre- and post-monsoon periods is deeper (>5m bgl) in Buguda of Dasapalla block,kerendaTangi in Ranpur block, Marada in Bhapur block and Komand on Odogaon block. The western parts of Dasapalla and Nuagaon block covering Buguda-Banigocha-Dasapalla-Durgaprasad-jamusahi-Sakeni-Soroda have deeper water level (>5mbgl) during pre-monsoon. Area between Soroda-Buguda-Durgaprasad-banigocha in Dasapalla block, Gadavanivalo-Rajapatna-Krisnachandrapur in Ranpur block and Banamalipur-Khandapara in Khandapara block have deeper water level (>7.5mbgl). The seasonal fluctuation in some of the villages in these areas indicates inadequate monsoon recharge which creates problems of water scarcity round the year.

B. Aquifer Management Plan

Management Plan for Higher Concentration of Fluoride

Though there are fluoride in many of the villages as discussed earlier, they are mostly found in shallow aquifers (dug wells) and medium deep bore wells mostly drilled by the state govt. agencies. The occurrence of fluoride are point specific and there are alternate sources available. Hence deeper aquifers form a better alternative source for the domestic use in this area.

Management Plan for Under-Utilization of Ground Water

Demand and Supply Scenario:The water demand and supply scenario of the district is depicted in **Table 15.2** where the demand figures were projected for year 2025 and the supply represents the existing water supply status.

Table 15.2: Water Demand and Supply Scenario in Nayagarh District

Block	Existing Water Availability (MCM)			Water Demand (MCM)		Water Gap (MCM)	
	Surface Water	Ground Water	Total	Present	Projected (2025)	Present	Projected (2025)
Bhapur	54.396	6.157	60.553	154.49	175.338	93.937	114.785
Daspalla	160.965	9.8	170.765	269.609	306.191	98.844	135.426
Gania	36.128	3.314	39.442	107.843	122.478	68.401	83.036
Khandapada	142.589	15.205	157.794	192.187	218.174	34.393	60.38
Nayagarh	119.131	45.473	164.604	226.511	257.078	61.907	92.474
Nuagaon	65.043	18.189	83.232	275.142	312.502	191.91	229.27
Odogaon	207.583	45.755	253.338	335.248	380.623	81.91	127.285
Ranapur	132.824	18.659	151.483	289.161	328.246	137.678	176.763
Total	918.659	162.552	1081.211	1850.191	2100.63	768.98	1019.419

Source: District Irrigation Plan of Nayagarh, March 2016

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

For the supply side intervention, further development of ground water resource is possible as there is sufficient scope for this is available in the district as the present ground water development ranges from 33.35 % to 60.75 % in the district. The quantum of water available for extraction from the phreatic aquifer is thus calculated, keeping the percentage of ground water development within 60%. The same is shown in the Table 15.3.

Table 15.3: Ground Water Development Potential of Nayagarh District

Block	Annual Extractable Ground Water (Ham)	Stage of Ground Water Extraction (% in 2020)	Present Ground Water Draft (Ham)	Ground Water draft at 60% Stage of Extraction (Ham) (1)*0.6	Surplus Ground Water at Present Stage of Extraction (Ham) (4)-(3)	Number of BW/ STW Recommended in Each block (assuming unit draft as 2.21 ham per structure per year) 50%	Number of DW Recommended in Each block (assuming unit draft as 0.26 ham per structure per year) 50%
	1	2	3	4	5	6	7
Bhapur	2994.67	26.38	789.79	1796.802	1007.012	228	1937
Daspalla	6590.26	28.63	1487.09	3954.156	2467.066	558	4744
Gania	2426.46	46.11	1118.72	1455.876	337.156	76	648
Khandapada	2859.5	53.23	1522.15	1715.7	193.55	44	372
Nayagarh	3942.1	66.05	2721.58				
Nuagaon	5493.43	24.32	1336.2	3296.058	1959.858	443	3769
Odogaon	6351.35	47.19	2763.44	3810.81	1047.37	237	2014
Ranapur	5240.24	45.51	2384.98	3144.144	759.164	172	1460

Structures Feasible: The feasible ground water structures and probable yield in different geological units in Nayagarh districtare given below:

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

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

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

Management Plan for Scarcity of Water in Hilly Areas

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

Management Plan for Less Productive Deeper Aquifer

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

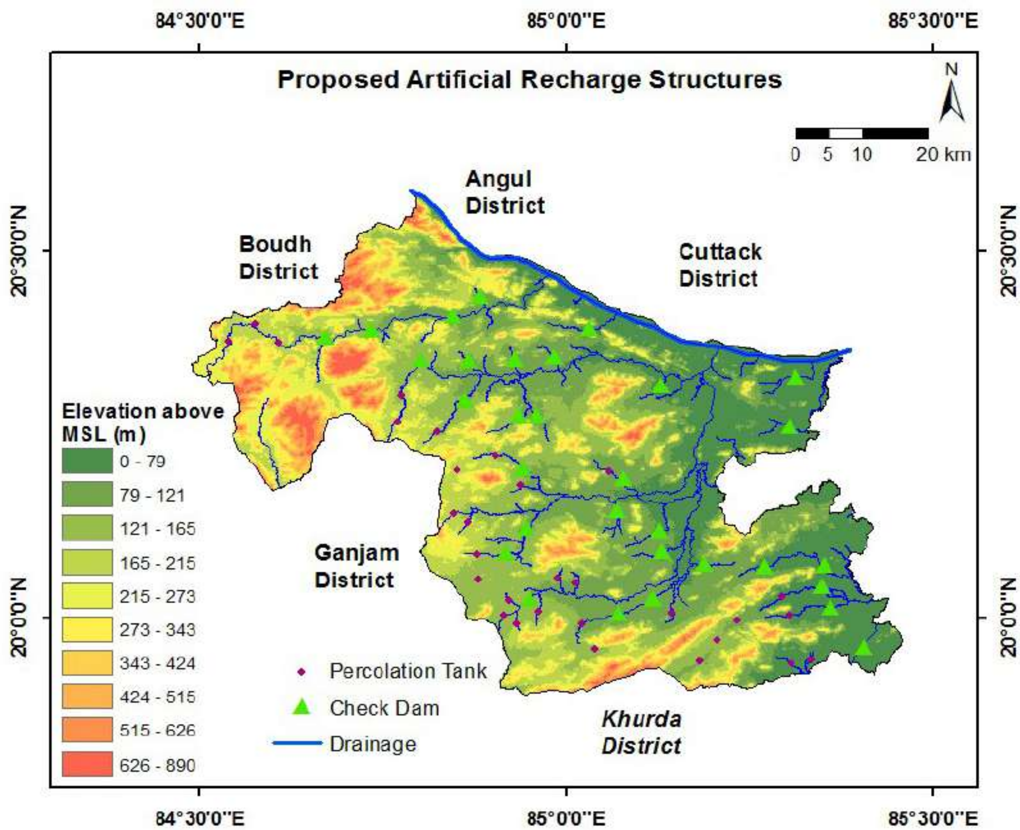
Management Plan for Depleted Water Level in Phreatic Aquifer

The problem of water level depletion in the phreatic aquifers can be addressed through artificial recharge and through various water conservation structures. As the deeper aquifer is usually less productive, injection wells are less feasible. Rather surface spreading techniques will be useful in these areas. Though there is no major irrigation project in this district, three medium irrigation projects, viz. Kuanria Irrigation Project, Budhabudhiani Irrigation Project and Dahuka irrigation project are functioning covering an ayacut of 5688 ha, 5540 ha and 2278 ha respectively.During the canal running days the phreatic aquifer gets adequate recharge from the canal water. Thus the foot hill areas to the south of the Main Canals are suitable areas for construction of recharge structures such as percolation tanks. Similarly 2nd and 3rd order drainages are suitable for the construction of check dams. For the mitigation of deeper water level areas in the district, the following measures can be taken up:

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

The proposed sites for artificial recharge structures are shown in **Fig. 15.2**.

Figure15.2: Tentative sites for Artificial Recharge Structures Proposed in Nayagarh District



16. Summary and Recommendations

Summary

National Aquifer Mapping Programme (NAQUIM) was taken up for detailed hydrogeological investigation, data-gap analysis and Aquifer Mapping and Management in Nayagarh district covering the blocks of Bhapur, Dasapalla, Gania, Khandapara, Nayagarh, Nuagaon, Odogaon and Ranpur covering an area of 3890 sq. km., during the period 2020-2021. The following are the summarised details.

1. The Nayagarh district lies between 19^0 53' 52" and $20^0$34' 46" N and longitudes 84^0 29' 26" and 85^0 27' 22"covering 3890sq. Km. under the SOI Toposheet Numbers 73D /10,11,12,14,15 &16, 73 H/3,4,7 & 8,, 74 E/1 & 5, 74 A/13 (1:50,000).
2. The district receives an average annual rainfall of around 1400 mm.
3. The area covered by forest in the district is 53.50% of total geographical area (3890 sq. km). The net area sown is 35.71% with cropping intensity of 166 %.
4. Two types of soil are found in the district viz. Alfisols and Ultisols.
5. The gross cropped area is 225904 Ha out of which 36% (80819 Ha) is irrigated and rest 64% area are rain fed.
6. There is no major irrigation project in the district. Three medium irrigation projects, viz. Kuanria Irrigation Project, Budhabudhiani Irrigation Project and Dahuka irrigation project are functioning covering an ayacut of 5688 ha, 5540 ha and 2278 ha respectively.
7. The district is underlain by Easternghat suite of rocks and alluvial formations.
8. The crystalline formations like Charnockite, Khondalite and Granite Gneiss are classified under consolidated water bearing formations. Here ground water exists in unconfined conditions in the weathered mantle and in semi-confined to confined conditions in deeper fractured aquifers. The feldspathic sandstones, conglomerate and shale constitute the Semi-consolidated water bearing formations. The alluvium on major river courses and valley fill deposits are classified under unconsolidated

formations.

9 CGWB has constructed 20 EWs and 6 OWs during the ground water exploration programme. For the monitoring of ground water level and quality CGWB has established 41 National Hydrograph Network Stations in the district.

10 Depth to water level in pre-monsoon period (May 2020) varies from 1.2 to 10.8mbgl, the average being 4.97 m bgl. Depth to water level in post-monsoon period (Nov 2018) varies from 0.3 to 6.9mbgl, the average being 2.12 m bgl. The seasonal fluctuation of ground water table between pre and post monsoon period in the study area varies from 0.4 to 8.45 m, the average being 2.85 m. There is no significant falling trend in the district.

11 The chemical quality of ground water both from shallow and deeper aquifers are good and can be suitably utilised for all purposes. Fluoride contamination has been detected in the district and it is revealed that higher fluoride concentration is restricted to shallow aquifers tapped by dugwells and shallow bore/tubewells. Deeper aquifer can provide alternative fluoride free source of water.

12 The estimated dynamic ground water resource is 35898.01 Ham and the stages of development of ground water range from 24.32% to 66.05%.The ground water development is maximum in the Nayagarh block and minimum in Nuagaon block.

RECOMMENDATIONS

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

1 Proper guidance has to be provided to the farmers for proper ground water abstraction structure in favourable hydro geological setting.
2 Priority should be given to the phreatic aquifer for extraction of ground water through large diameter dug wells and dug cum bore wells at hydro geologically suitable locations. Selection of proper site for drilling of bore wells, based on the favourable hydro geological conditions has to be done.
3 For the irrigation requirement in relatively water deficient areas, efficient irrigation techniques such as drip and sprinkler should be practiced.
4 The occurrence of fluoride are point specific and there are alternate sources available. Deeper aquifers form a better alternative source for the domestic use in this area.
5 In the foot hill regions, contour trenching, staggered trenching along with gabion structures should be constructed to arrest the surface runoff and improve rainfall recharge
6 Artificial recharge projects may be taken up in the district especially in hard rock areas for augmentation of ground water resources through construction of percolation tanks, check dams, farm ponds.
7 Rain water harvesting should be adopted in all govt. and public buildings.
8 The farmers should be educated through agricultural extension services for adopting suitable cropping patterns for optimal utilization of available ground water and surface water resources.

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