Draft Report

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जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN

Parts of Bokaro, Ramgarh and Dhanbad Districts, Jharkhand

राज्य एकक कार्यालय रांची

State Unit Office, Ranchi

CENTRAL GROUND WATER BOARD

Ministry of Water Resources, River Development & Ganga Rejuvenation

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REPORT ON NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN IN PARTS OF BOKARO, RAMGARH AND DHANBAD DISTRICTS(PHASE –II) JHARKHAND STATE

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SUO, RANCHI

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JHARKHAND STATE

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1.0 INTRODUCTION

1.1 OBJECTIVES, SCOPE OF THE STUDY, APPROACH & METHODOLOGY

The National aquifer mapping studies visualizes integration of information available on geomorphology, geology, hydrogeology, hydrochemistry, cropping pattern, irrigation statistics, soil cover, forest cover etc on a GIS platform and formulation of the ground water management plan for individual units of optimal size in accordance with the nature of the aquifer, water quality, sustainability and stress on the resource. Evolving aquifer management plans based on issues related to groundwater quantity and quality and projected scenarios and suggests suitable strategies for implementation of aquifer management plan.

Aquifer mapping study was carried out in 13 blocks (OE-3, Semi-critical-1, Safe-9) in parts of Dhanbad, Bokaro and Ramgarh districts covering an area about 3958 sq. km. *(fig.1)* During aquifer mapping studies it is approached to know the aquifer geometry of the aquifers, geophysical survey has been carried followed by exploratory drilling to decipher the aquifer orientation. Data gap analysis was carried out for the whole area and accordingly data gap report was prepared. Exploratory drilling was done as per findings to know the behavior of groundwater, disposition of aquifers, and availability of groundwater. Water samples were taken from shallow as well as deeper aquifers to know about ground water quality.2-D and 3-D sections were also prepared for aquifer disposition. Long term trend of Water level of HNS wells were drawn to have an idea about declining or rising trend. As per Resources of 2011, the management plan was finalized.

1.2 AREA DETAILS & DEMOGRAPHY (Location, Extent and Accessibility)

The study area covers parts of Ramgarh, Bokaro and Dhanbad districts. Ramgarh has one sub-division namely Ramgarh and four block's namely Ramgarh, Gola, Mandu and Patratu. The present boundary of Ramgarh district is in North – Hazaribagh district, South – Ranchi district, East – Ranchi and West - Bokaro district. The district headquarter is at Ramgarh town. It is situated on National Highway 33 and 46 Km away from state's capital, Ranchi on Northern side and 52 Km away from Hazaribagh on southern side. The total area of Ramgarh district is 1341 sq.km. The total area of Bokaro district covered during NAQUIM studies were 2356 sq. km. The blocks included in studies are chas, chandankiyari, Jaridih, Peterbar, Kasmar, Gomia and Bermo. In Dhanbad district only two blocks namely Dhanbad and Jharia were taken up in NAQUIM Phase II studies of aquifer mapping covering an area of 261 sq. km. The administrative set up of Phase II area is given in *Table 1.*

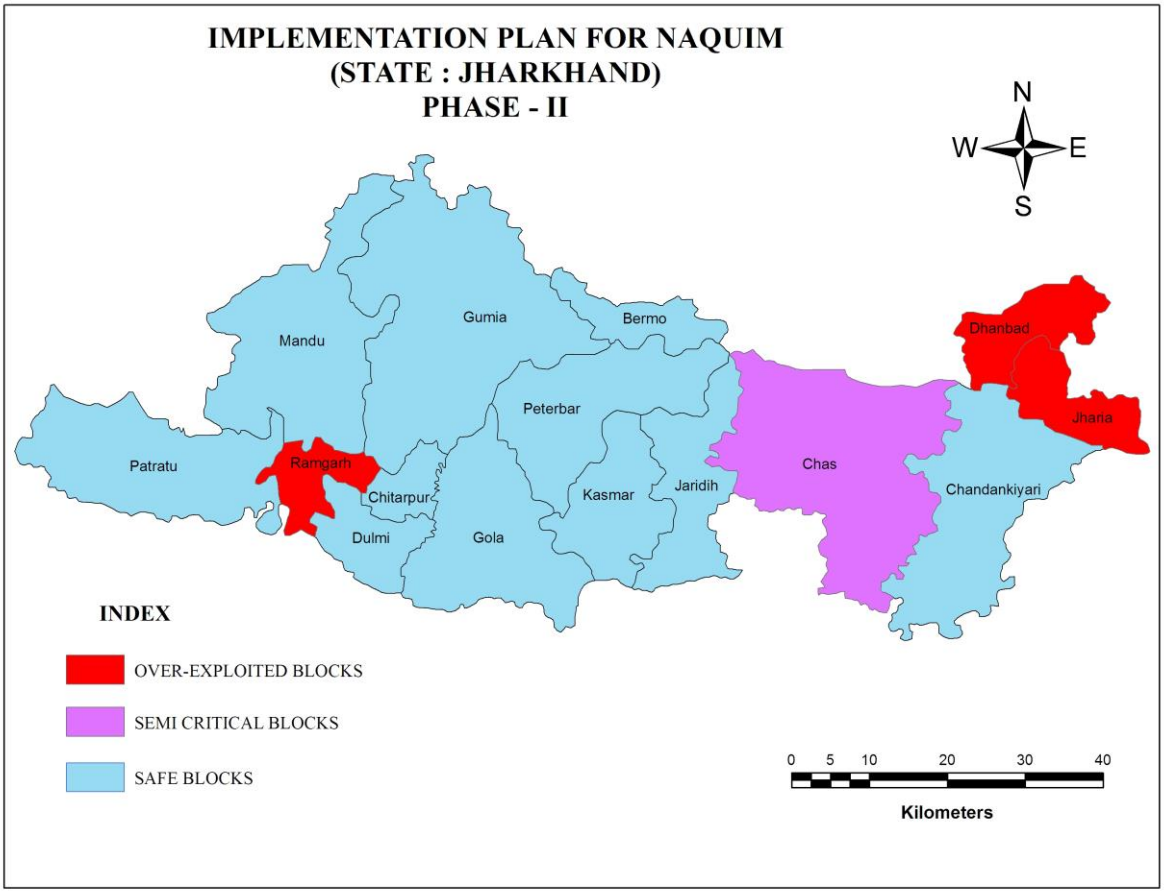


Fig.1 Aquifer Mapping Area of Phase II

Table – 1 Administrative set up of Phase II area

S.No.	District Name	Geographical area (Sq. Km)	Gram Panchayats	Village	No. of Tehsil	Name of Tehsil	No. of Blocks
North Chhotanagpur division							
1.	Bokaro	2356	251	635	8	Gumia, Petarwar, Jaridih, Chas, Chandankyari, Kasmar, Bermo, Nawadih	8
2.	Dhanbad & Jharia	261	181	1348	8	Dhanbad Sadar, Jharia, Baghmara, Nirsa, Gobindpur, Balipur, Tundi & Topachachi	8
3.	Ramgarh	1341	257	315	6	Gola, Mandu, Patratu, Chitarpur, Ramgarh & Dulmi	6

The census report 2011 states that total population of phase II area has 56,96,260 whereas rural population is 27,33,267 and urban population is 29,62,993. Based on the census -2011 District wise population details is given in *Table 2.*

Table-2 District- wise population details

Sl. No.	District	Male	Female	Rural	Urban	Total
1.	Bokaro	1,072,807	989,523	1,078,686	983,644	2062330
2	Ramgarh	494,230	455,213	530,488	418,955	949443
3	Dhanbad & Jharia	1,405,956	1,278,531	1,124,093	1,560,394	2684487
Total		2972993	2723267	2733267	2962993	5696260

1.3 DATA AVAILABILITY, DATA GAP ANALYSIS & DATA GENERATION

Data availability, data gap analysis and data generation and targets as per EFC norms and actual achievements are given below in *Table 3*. There is no aquifer-wise data available from State or any other agencies.

Table-3 Data availability, data gap analysis and data generation

No of Blocks	***13***		
	Existing	As per EFC norms Required	Actual achievements
Area in sq.km	3958		
Preparation of Sub-surface Geology (area in sq.km)	3958		Existing data inadequate
Geo-morphological analysis (area in sq.km)	3958		Layer received
Land use pattern (area in sq.km)	3958		Layer received
Vertical electrical Sounding (VES) (Nos)	30	141	58
Bore Hole Logging (Nos)		Need based	Need based
2-D Imaging (Line Km)			
Ground TEM (Nos)			
Heliborne TEM & Gravity (Line km)			
Preparation of Drainage Map (area in Sq.km)	3958		Layer received
Demarcation of water bodies (area in sq.km)	3958		Layer yet to be received
Soil infiltration studies (Nos)			1
Rainfall data analysis for estimation of recharge to ground water (area in sq.km)	3958		Monthly data yet to be received
Canal flow, impact of recharge structures analysis, surface water-ground water interaction studies etc (area in sq.km)	3958		
Water level monitoring (No of stations* frequency) (No of monitoring stations)	97*4*3		1164
Exploratory Wells	29		9
Observation Wells			6
Slug test (Nos)			
Specific Yield test (Nos)			

Micro-level hydro-geological data Acquisition including Quality Monitoring			
Water Quality (sampling and Analysis) for Basic Constituent, Heavy Metals etc	80		45
Analysis of Ground water for Pesticides, Bacteriological contamination in Ground water (Nos)			
Carbon dating (Nos)	-		-
Isotopic studies (Nos)	-		-
Core drilling (Nos)		Need based	

1.4 RAINFALL

Average Rainfall of the study area varies from 1200-1300 mm. Normal rainfall of Ramgarh district is 1040 mm and 80 percent of rainfall is from south west monsoon in the month of June-September. Normal rainfall of Bokaro & Dhanbad district is 1259 mm & 1295 mm respectively. Details of rain fall data of last five years for Ramgarh, Bokaro and Dhanbad districts is given in Table 4,5, and 6 respectively.

Table -4 Rain fall data of Ramgarh district for last five years (mm)

YEAR	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct.	Nov.	Dec.
2010	0.0	0.0	0.2	0.0	0.0	35.0	230	184	194	90	9.6	27
2011	0.3	0.0	7.5	0.0	17.8	427	93	503	270	37	0.0	0.0
2012	23.6	6.4	4.4	8.6	2.8	70.8	348	419	183	129	104	14
2013	0.0	1.2	0.0	7.8	95.8	157.6	240	282	105	385	0.0	0.0
2014	10.8	52.4	25.6	3.6	107.6	155.2	232	270	159	121	0.0	0.0

Table-5 Rain fall data of Bokaro district for last five years (mm)

YEAR	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct.	Nov.	Dec.
2010	0.6	24.8	0.0	18.2	73.0	58	304.5	245	263	77.8	3.4	27
2011	7.8	2.4	29.2	32.4	26.4	402	185.9	488	202	73.1	0.0	0.0
2012	60	15.5	3.1	2.4	4.9	81	299.4	325	222	26.1	43.1	12.1
2013	0	26.7	2.7	34.7	139.7	179	223.5	310	122	372	0.0	0.0
2014	17	40	34.2	5.2	135.5	124	394.5	259	183	31.2	0.0	0.0

Table -6 Rain fall data of Dhanbad & Jharia district for last five years (mm)

YEAR	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct.	Nov.	Dec.
2010	7.0	0.0	0.0	4.6	28.1	152.8	171	171	253	49	3.7	38
2011	0.9	0.0	13.4	3.0	29.9	313	180	470	285	18	0.0	0.0
2012	13.4	1.9	1.2	17.5	13.5	80.1	326	264	336	21	54	9.1
2013	0.0	24.0	0.4	13.6	112	167	172	300	197	284	0.0	0.0
2014	10.3	35.1	16.3	2.0	86.6	113	277	249	161	30	0.0	0.0

(Source IMD)

1.5 PHYSIOGRAPHY

Physiographically the study area represents that overall slopping towards the eastern part (figure 2). Minimum elevation is 73 m from above mean sea level in the eastern part of the Jharia Block of Dhanbad district and the Maximum elevation occurs in the north-western and the south-western part of the study area of phase-II is 1073m above from the mean sea level.

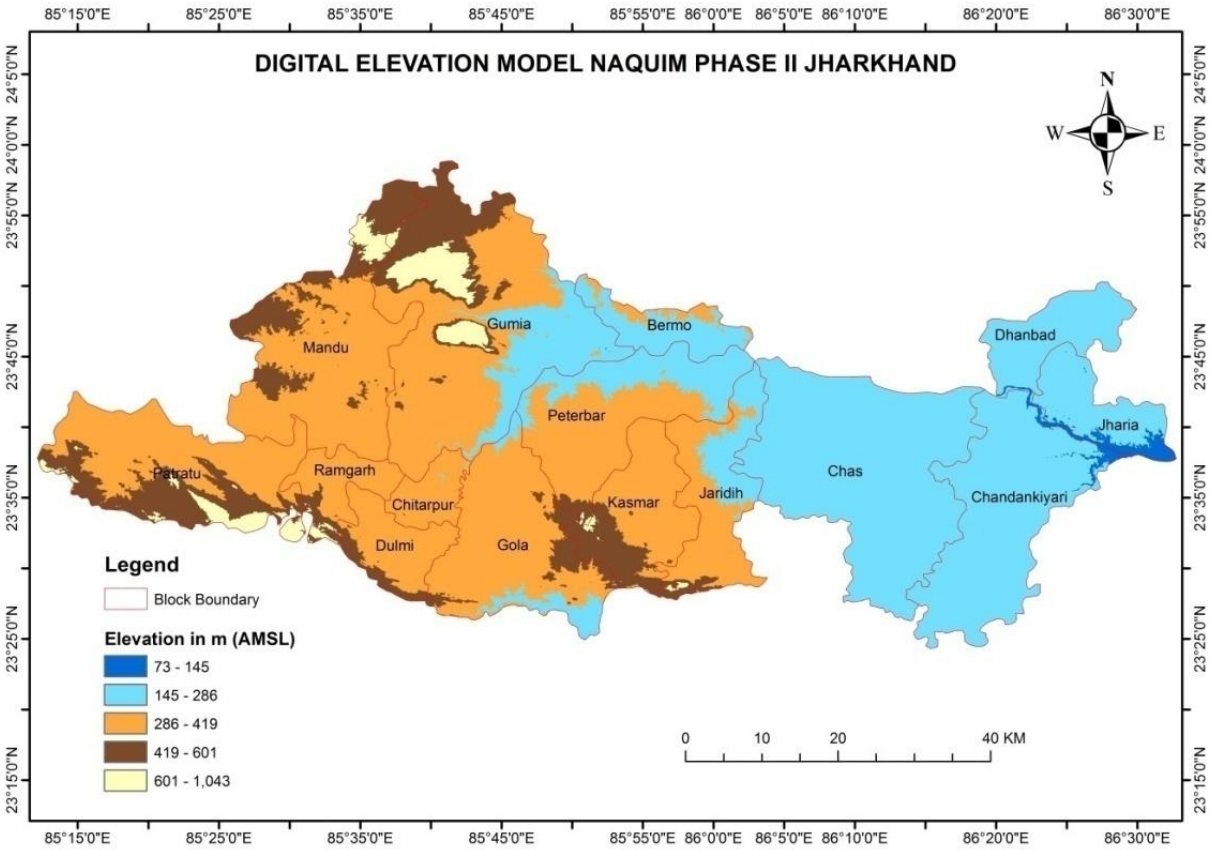


Fig.2 Physiography of NAQUIM Phase II

Dhanbad district is a topographically lower plateau having relatively little undulations. The district consists of two district physical units. Northern area is hilly with forest while southern area provides appearance of plain. The highest peak in the area is Dhangipahar. The general slope is from north-west to south-east. Geologically the area is comprised with Archean granites and gneisses. In southern part Gondwana rock formation occur in patches. The important rivers, flowing in the district are Damodar and the Barakar. The Ramgarh district is a part of Chotanagpur plateau. Important physiographic regions of the district are Damodar valley. Major area of the district comes under Damodar valley. Damodar Valley is bounded by Hazaribagh plateau in north and Ranchi plateau in south. Ranchi and Hazaribagh plateau is separated by east–west running Damodar Valley. BarkaPahar (Marang Buru)1049 meters high above sea level located along the Ramgarh-Ranchi border is probably the highest peak, and it also separates the districts. The Bokaro district have average altitude of the land is 210 meter from mean sea level. The district has a maze of valleys and sub-valleys formed by the river Damodar and its tributaries.

1.6 GEOMORHOLOGY

Geomorphology of the study area is undulating and has piedmont alluvium in central part, pediplain weathered in western part, dissected pediment in eastern part, pediplain weathered in north –west and southern part. Other structures like upland dissected, structural hills, denudation hills, etc. are also found in scattered form in phase II area. The detail of geomorphology is shown in figure.

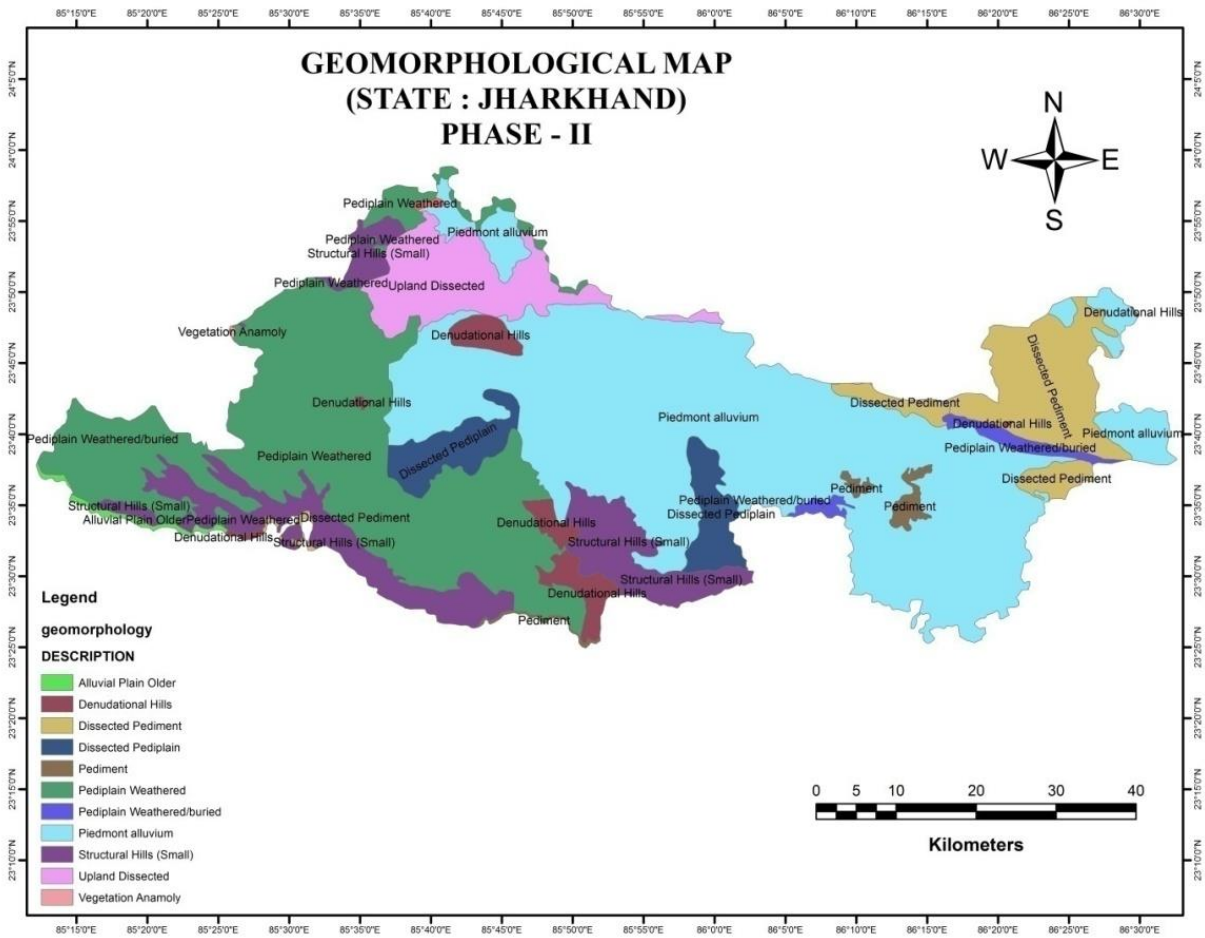


Fig. 3 Geomorphological map

The main geomorphic features and landforms are as follows.

Alluvial Plains: - These are found near the river tracts and consist of gravels, sands, silt, etc.

Structural Hills: - These are linear or arcuate hills showing definite trend lines and covered with thick forests developed. Found in southern-eastern part of Gola, Dulmi, Kasmar, Jaridih and some part of Mandu block.

Pediplain (W):- These are developed over granite gneiss and Meta sediments. High frequencies of lineaments are found. These are found in Ramgarh, Gola, Mandu and Petarwar block.

Dissected Pediment:- Dissected pediments are developed over Gondwana formations. Found in Jharia and Dhanbad areas.

1.7 LAND USE

The total geographical area of study area is 3958 sq km where 509 sqkm area falls in forest/ hilly area. Gross cropped area is 1138 sqkm whereas net sown area is 1049 sqkm. Details of land use pattern is given below in Table 7 and land use map is shown in *figure 4.*

Table 7 – Details of Land use

Land use classification	Area (sqkm)
Total geographical area	3958
Forest	509
Gross cropped area	1138
Net sown area	1049.6
Cropping intensity	110-114%

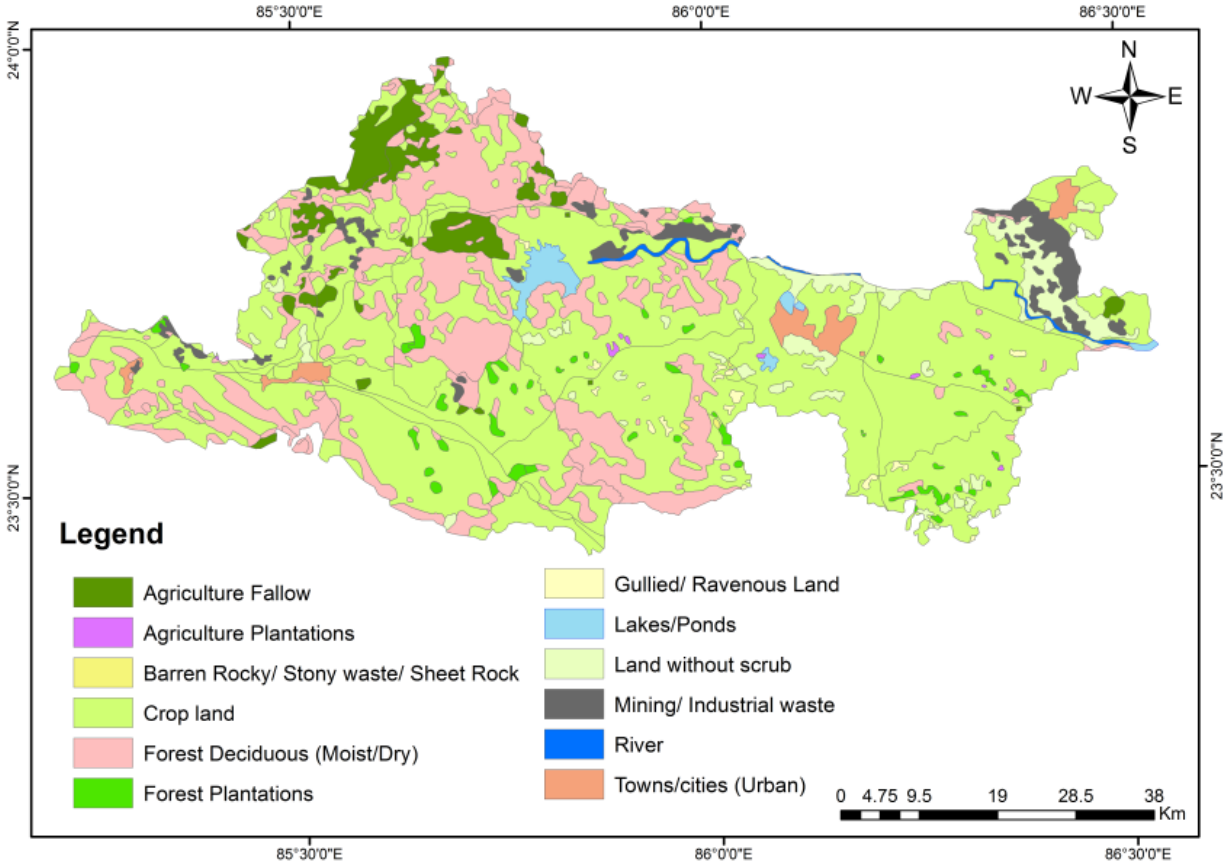


Fig.4 Land use Map

1.8 SOIL

The soil of the study area can be broadly grouped into different formation like granite gneiss of archean age, sand stone and shales of lower gondwana and alluvial plain. Texturally the soils of phase II area have been classified into four classes as :-

Stony and Gravelly: These are low grade soils having a large admixture of cobbles, pebbles and gravels generally found at the base of the hills.

Sandy Soils: It is found near the stream beds containing 60% sand and are easily drained. These are poor in respect of fertility and require heavy maturing.

Loamy Soils: These consist mostly of detritus of decomposed rocks and vegetables matter. It is suitable for cultivation. Normally these are found in valleys near the hills.
Clayey Soils: These soils are found near tank beds. It is sticky soils. Their water bearing capacity is very high. The area is very fertile but yielding capacity improved with addition of sand, lime and organic manures etc.

1.9 HYDROLOGY AND DRAINAGE

The hydrological condition of the study area is governed by two major river basin or sub-basins, which is mentioned below:

S. no.	Name of River Basin/Sub Basin
1.	Damodar River Basin
2.	Barakar River sub-basin

Damodar River Basin:
Damodar River basin plays a vital role for ecological balance and provides the life supporting system of large number of flora and fauna since millions of years. From prehistoric time human civilization evolved along this river basin. The main tributary of Damodar is Barakar which also originates in Hazaribagh District in Chotanagpur plateau. These two rivers form large upper catchment of the basin with an area of 17500 Sq KM in the undulating plateau with their numerous drainage networks. The relatively smaller lower catchment (around 25%) of the total basin area is in the Gangetic plain formed by sediments carried by Damodar and its tributaries. DRB is recognized by mainly two types of land features – The upper catchment in upland plateau region with forest and mineral resources at the north and west and the lower catchment with fertile alluvium plain land at the east and south.

Barakar River sub-basin:
The total geographic area of the basin is 7026 sq km, of which 453.23 sq km falls in Bokaro and 695.7 sq km in Dhanbad district. The Barakar river originates from the hills of Hazaribagh and runs almost parallel to river Damodar in about 200km length in the eastern direction and join the river Damodar near dishergarh town. The important tributaries of the river Barakar are the saghar, the barkar sakri, barsati khero, usri chikri .

The study area has dendritic drainage pattern. The flow direction of drainage pattern is towards eastern part. Major river in this part is Damodar and Barakar. Drainage map of the area is shown in *figure-5.*

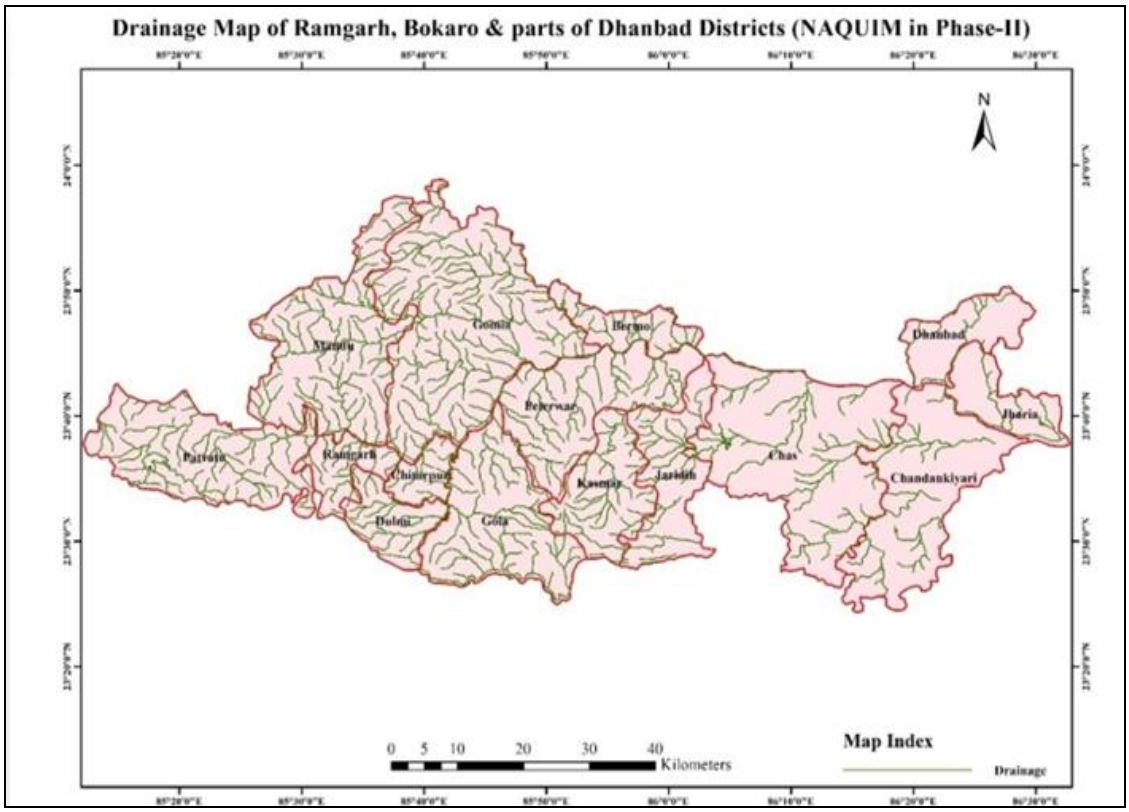


Fig.5 Drainage map of study area

1.10 IRRIGATION

The study area has poorly developed irrigation facilities. According to the fourth minor irrigation census data of Dhanbad & Jharia, Chas and Ramgarh block total 2623 ha is irrigated by minor irrigation schemes whereas 813 ha is irrigated by ground water schemes and 1810 ha is irrigated through surface water schemes. The details of total numbers of sources and area irrigated by different schemes is given in *(Table 8 &9)*

Table 8 Details of irrigation sources

Total Number of Sources							
Ground Water				Surface Water			Grand Total
Dug well	Shallow Tube well	Deep Tube well	Total	S. Flow Scheme	S. Lift Scheme	Total	
1514	2		1516	441	113	554	2070

Table 9 Details of area irrigated by minor irrigation schemes

Area Irrigated by Ground Water Schemes (Ha)					Area Irrigated by Surface Water Schemes (Ha)				
Kharif	Rabi	Perennial	Others	Total	Kharif	Rabi	Perennial	Others	Total
340	396	61	16	813	1081	625	55	49	1810

1.11 CROPPING PATTERN

Agriculture and coal mining is the main occupation of the people residing in study area. The cropping pattern is generally influenced by varied soil type and different climatic conditions. The principal crop of the area is Paddy, maize, pea, green gram, groundnut, urd, wheat, chickpea and arhar. The horticulture crops are Cauliflower, cabbage, tomato, Brinjal, L. finger, cucumber etc.

2.0 DATA COLLECTION & GENERATION

2.1 GEOLOGICAL STUDIES

Geologically the area is comprises with Archean rocks of meta-sediments, limestone, Phyllites, Chotanagpur granite gneisses. In eastern, northern and western part has Gondwana rock formation of occur in patches. Major part of the area covers granite gneiss and Gondwana rocks. Ground water is occurs in unconfined in the weathered zone of the granitic gneiss and semi-confined to unconfined in the shale, sand and coal bearing area of Gondwana rocks formations. Geological map of the area is shown in figure 6.

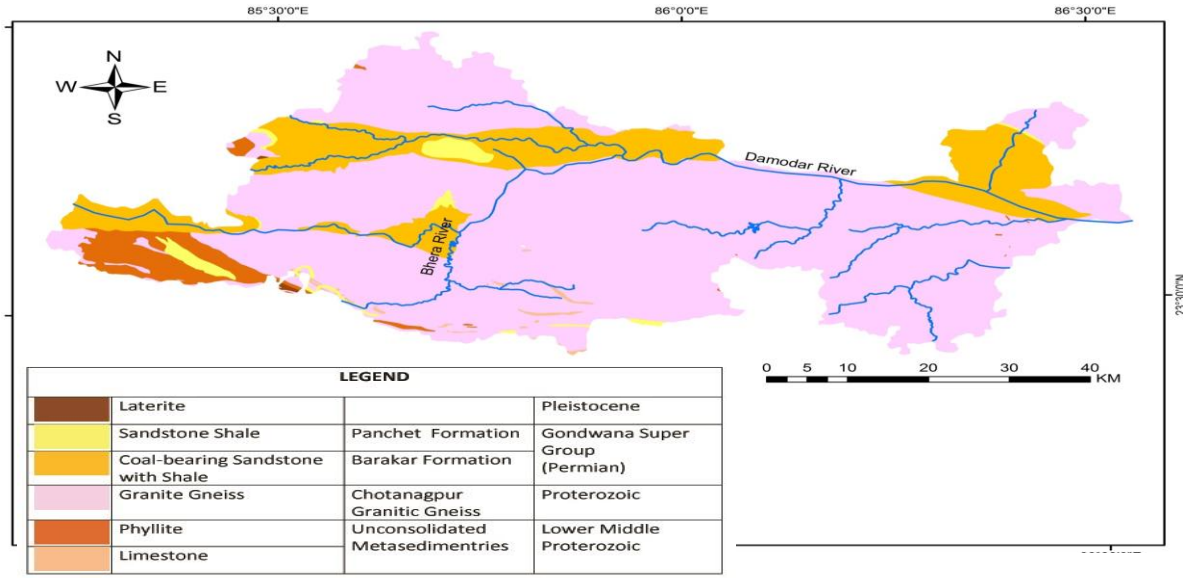


Fig.6 Geological Map

The geological set up of the area governs occurrence and movement of ground water in the area. Influent seepages from canal, streams and other surface water bodies, contributes to the Ground water in the study area. The hydrogeological condition of the district is very complicated due to wide variability of geology, topography, drainage and mining activity. Based on the degree of consolidation the fissured formation can be further sub divided into two groups:-

a) Consolidated Formation
b) Semi-consolidated Formation

Consolidated Formation:
Ground water occurs in the study area under confined to semi confined conditions. The fractured lineaments are found to be an effective factor in facilitating Ground Water movement and storage.
Semi Consolidated Formation: Ground water occurs in this formation under confined to Semi Confined condition. These are found in the Central part of the district.

The whole area is occupied by consolidated formations comprising granite-gneisses and quartzites of Chotanagpur series and some unclassified rocks such as mica-schists, phyllites and amphibolites etc belonging to Precambrian age. These rocks are very hard and compact and lack primary porosity. Ground water is stored mainly in the secondary porosity resulting from weathering and fracturing of the rocks. The aquifer materials are highly heterogeneous in character showing both vertical and lateral variations .The weathered residuum form the main repository of ground water, which occurs under water table conditions and circulates through deeper fractures and fissures. Ground Water occurs under unconfined condition in phreatic aquifers and semi confined to confined conditions in the deeper fractures zones. The water yielding capacity of fractured rocks largely depend on the extent of fracturing, openness and size of fractures and extent of their interconnections into the near surface weathered zone .These interconnected joints and fractures in the underlying hard rocks facilitate circulation of ground water and in turn form deeper aquifers. Bokaro district, Dhanbad and Jharia block has the oldest geological formations are a group of crystalline metamorphic of Archean (Dharwar) age which forms the basement. The lower gondwana groups of sedimentary strata including the coal bearing beds were deposited over Archean rocks in slowly sinking faulted trough (basins).

The generalized stratigraphic succession of the Bokaro/Dhanbad district is as follows:-

Quaternary		Soil/Alluvium
Triassic To Lr. Carboniferous	Lower Gondwana group	Raniganj sub-group or upper coal measures ironstone shales subgroup or Barren measures Barakar sub-group or lower coal measures Talchirs

Later post-Dharwar injection Complex	Streaky, injection, augen and sillimanite gneisses. Rapakiwi textured gneisses and epidiorites.
Earlier post-Drarwar Intrusives	Granites, pegmatites, aplites and some quartz veins. Meta-dolerites and meta-norites with or without olivine
Dharwar	Gneisses, amphibolites, epidiprites and hornblends – schists. Quartzites (granulite and schistone), granulites and calc gneisses. Micaceous schists

2.1.1Hydrogeology

Aquifer geometry-The aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, the surface and subsurface geophysical studies in the district covering all geological formations. The aquifer can be divided into two zones – shallow and deeper aquifer.

(i) Shallow aquifer – The shallow aquifers are being taped through dug wells, dug cum bore wells or shallow bore wells drilled to the depth of 60 m. The weathered mantle and shallow fractures constitute the shallow aquifers. The thickness of weathered mantle varies from 5 to 25 mbgl. The well inventory data suggest that the maximum depth of dug well in granite gneiss and Gondwana is 17 m and 25 m respectively. Exploration in granite gneiss indicates that shallow fractures are less productive. Many dug wells and hand pumps get dried up during summer.

(ii)Deeper aquifers-:

Achaeans meta-sedimentary, the granites, intrusive metabasics and the Lower Gondwana sedimentary constitute the productive aquifer. The first three come under consolidated Formation and the last one under semi consolidated Formation.

2.2 Depth to water levels:

Ground water regime is monitored through 46 ground water monitoring wells that includes 42 dug wells and 4 purposes built Piezometers established in the study area. With the field data, maps were prepared for visual interpretation of the behaviors of the ground water levels. Depth to ground water level were demarcated into various zones in the ranges of less than 2 m, 2-5 m, 5-10 m, 10-20 m, 20-40 m, and more than 40 m. The description of depth to water levels during pre-monsoon and post monsoon is as follows:

2.2.a Depth to Water level May 2015:

Depth to ground water level during May 2015 ranges from 3.54 mbgl to11.6 mbgl. Minimum depth to water level 3.54 mbgl recorded at Bermo/Phusro in Bokaro district and maximum depth to water level 11.6 mbgl recorded at Chas block in Bokaro district. Depth to water level map May 2015 is shown in *figure 7.*

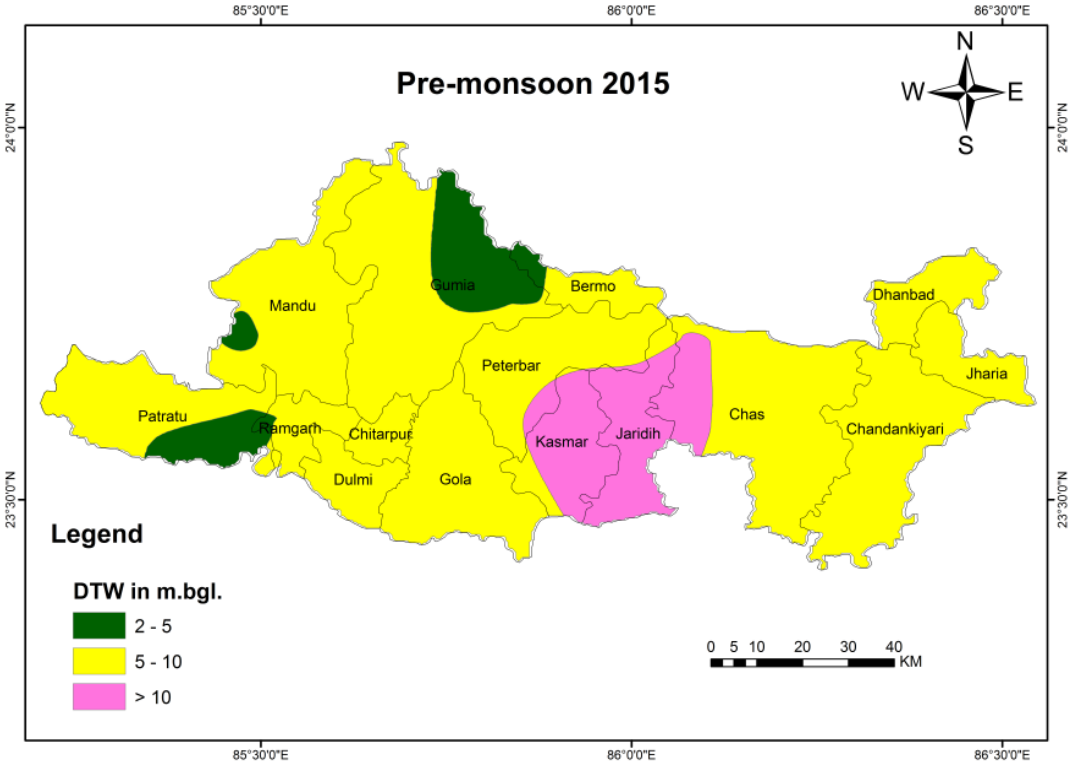


Fig.7 Depth to water level Map (pre-Monsson-2015)

2.2.b Depth to Water level November 2015:

During month of November 2015 (post-monsoon) depth to water level varied from 2.2 m bgl to 8.7 m bgl. Minimum depth to water level 2.2 mbgl recorded at Thakurgora, in Mandu block of Ramgarh district and maximum depth to water level 8.7 mbgl recorded at Jaina-mohr, Chas block of Bokaro district. Depth to water level map November 2015 is shown in *figure 8.*

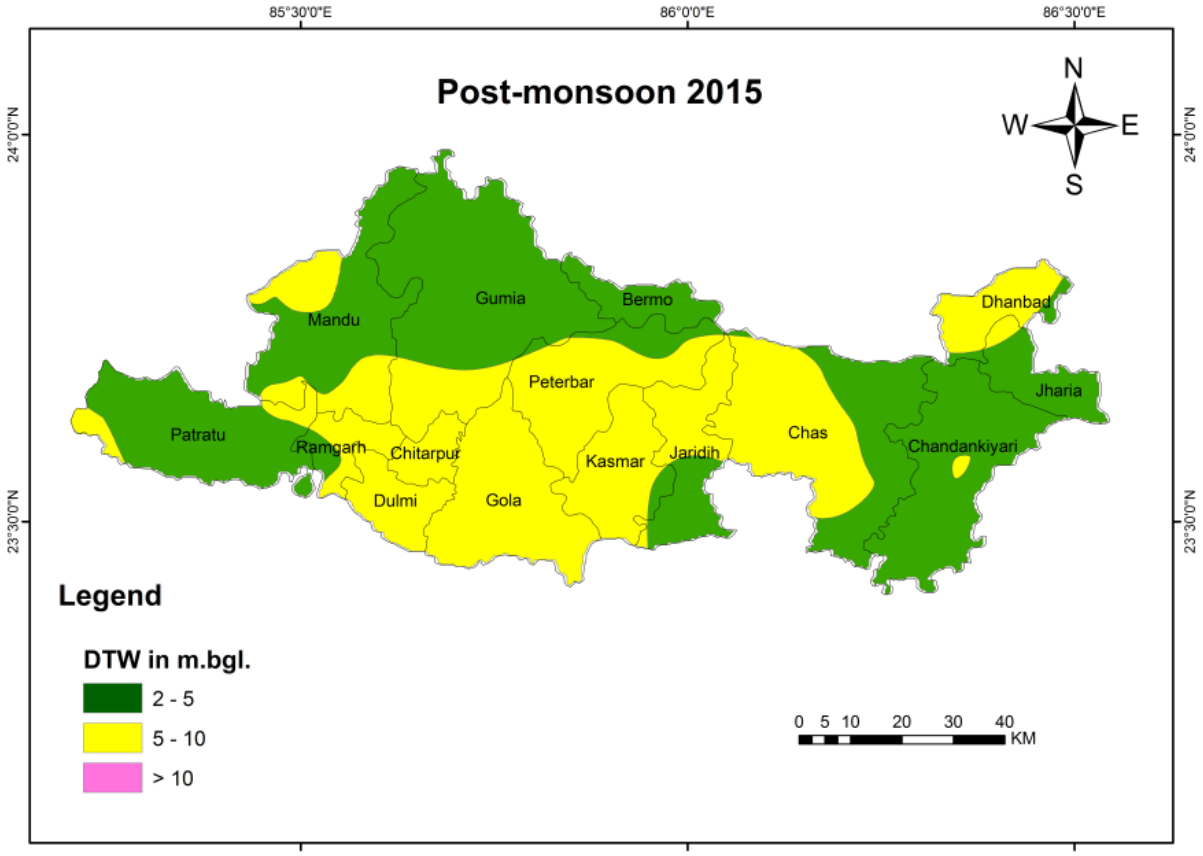


Fig.8 Depth to water level Map (post-Monsoon-2015)

2.3 SOIL INFILTERATION TEST

Soil infiltration test carried out in village - SAYAL (Near Kali Temple), Patratu block, Ramgarh district. The details of soil infiltration test is given in Table10

Table10 Details of soil infiltration test in Sayal, Patratu

Time (in minutes)	water level reading (in mm)	Infiltration (in mm)	Infiltration rate (mm/ min.)	Infiltration rate (mm/ hour)
0	153	0	0	0
10	134	19	1.9	114
20	125	28	0.9	54
30	120	33	0.5	30
40	117	36	0.3	18
50	114	39	0.3	18
60	111	42	0.3	18
70	108	45	0.3	18
80	105	48	0.3	18
90	101	52	0.4	24
100	98	55	0.3	18
110	98	55	0.3	18
120	97	56	0.1	6
130	97	56	0.1	6
140	93	60	0.4	24
150	91	62	0.2	12
160	88	65	0.3	18
170	86	67	0.2	12
180	84	69	0.2	12
190	82	71	0.2	12
200	80	73	0.2	12

2.4 HYDROCHEMICAL STUDIES

2.4.1Water Quality Monitoring:

Water quality was being monitored through 93 monitoring wells which includes 45 hydrograph stations (dug wells) existing in the area. During the study additional 48 samples were collected in 2015-16 through newly established key wells for analysis of general chemical parameters. However, the data collected shows water quality of phreatic (weathered) aquifer only. There is no water quality data for fractured aquifer separately. Chemical quality of key wells and bore wells tapping individual aquifer is awaited. The ground water is contaminated with fluoride in chas block, the spot representation of fluoride occurrences is shown in *Figure 9.*

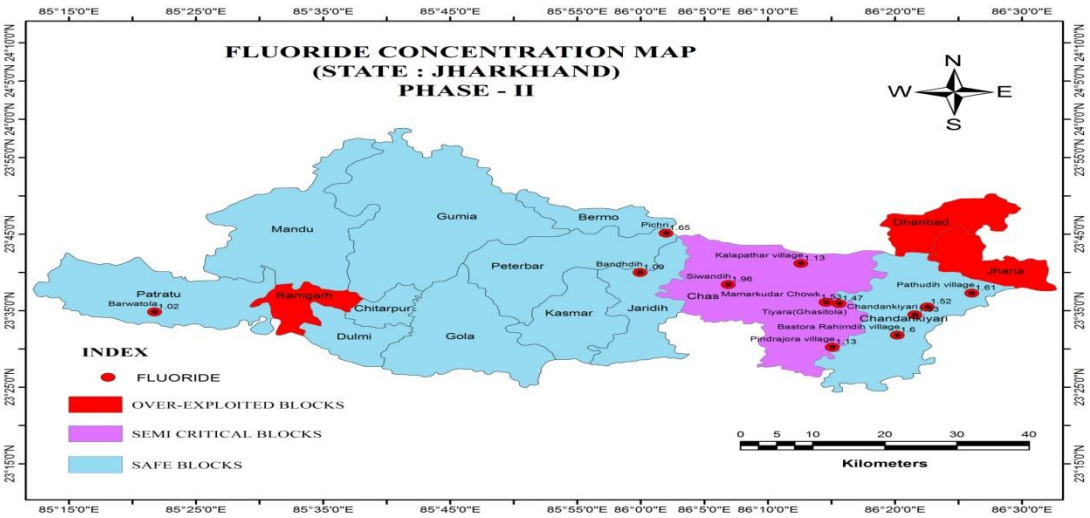


Fig.9 Fluoride concentration map

2.5 GEOPHYSICAL STUDIES

Under aquifer mapping studies 58 VES were conducted in Ramgarh and Bokaro district. Out of the 58 VES, 8 VES were conducted in chas block of Bokaro district and 50 VES were conducted in Granitic terrain and Gondwana terrain of Ramgarh district.

2.5.1 GEOPHYSICAL RESULTS

In Bokaro district total 8 VES were conducted in connection with site selection for exploratory drilling. Out of 8 VES, 4 VES were conducted in Govt. Mahila polytechnic campus , Bokaro. After gradient resistivity profiling, the VES no. 2 was recommended for exploratory drilling at the site. The interpreted result reveals that the first layer thickness is 4.5m and resistivity 78 Ohm-m which is surface soil. The second layer is weathered formation having resistivity of 129 Ohm-m and thickness 14m .The third and fourth layers resistivities are very hard and compact. The fracture deciphered at the depth of148-151m. The drilling has been carried out and the discharge was found 6cm in V notch plate. Another 4 VES were carried out in Govt. boys polytechnic campus, Khutri , Bokaro, after gradient resistivity profiling. The VES no. 3 was found suitable for drilling. The interpreted result reveals the four-Geoelectric layers at this point. The first layer thickness and resistivity is 1.5m and 135 Ohm-m respectively. The second layer thickness is 4.55m and resistivity 61.5 Ohm-m reveals the weathered formation. The third layer resistivity is 205 Ohm-m and thickness 12m indicates semi weathered formation. The fourth layer is very hard and compact. At this point drilling has been carried out but found very low discharge.

Total 50 VES were conducted in Ramgarh district. Out of the 50 VES, 26 VES were conducted in Granitic terrain and 24 VES were conducted in Gondwana terrain.

The interpreted VES results of Granitic terrain indicate, the top soil resistivity varies from 50.0-512ohm.m with thickness 0.8-3.3m.This is followed by highly weathered / weathered layer with resistivity 20 to 108ohm.m with thickness 3.0 to 22.3m.This is underlain by fractured /minor fractured rock with resistivity 117 to 585ohm.m with thickness 14.7 to 37.5m. This is followed by 870ohm.m to very high resistivity layer indicating massive formation and this is expected at a depth range of 12.0-43.0 m. At places within the massive rock fractures / minor fractures also expected as a low resistivity layer expected below the very high resistivity layer.

The interpreted VES results of Gondwana terrain indicate, the top soil resistivity varies from 47.0-784ohm.m with thickness 0.75-5.3m.This is followed by highly weathered/ weathered layer with resistivity 4to 99ohm.m with thickness 1.3 to 46.9m.This is underlain by fractured/minor fractured rock with resistivity 112 to 188ohm.m with thickness 14.2 to

109.7m. This is followed by 328ohm.m to very high resistivity layer indicating massive formation and this is expected at a depth range of 7.6-121.8 m. At places within the massive rock fractures / minor fractures also expected as a low resistivity layer expected below the very high resistivity layer.

2.6 EXPLORATORY DRILLING:

CGWB has drilled 48 no. of exploratory well in the NAQUIM Phase II area Location map is shown in the figure 10. It is observed that in granite gneiss weathered zones depth ranges between 1-30 mbgl considering first aquifer, depth to water level ranges 4.2- 11 mbgl, yield of the well ranges 0.45 to 5 lps. Fractured zones are encountered within the depth 30-200 mbgl. In sandstone depth to water level ranges between 11-37 mbgl and yield ranges 2.6 to 5.5 lps**.** Majority of fractures are encountered within 100 mbgl in Granite gneiss and Gondwana Rocks. In Granite gneiss few fractures are encountered within 100-150 mbgl. The exploration details are given in *annexure I*

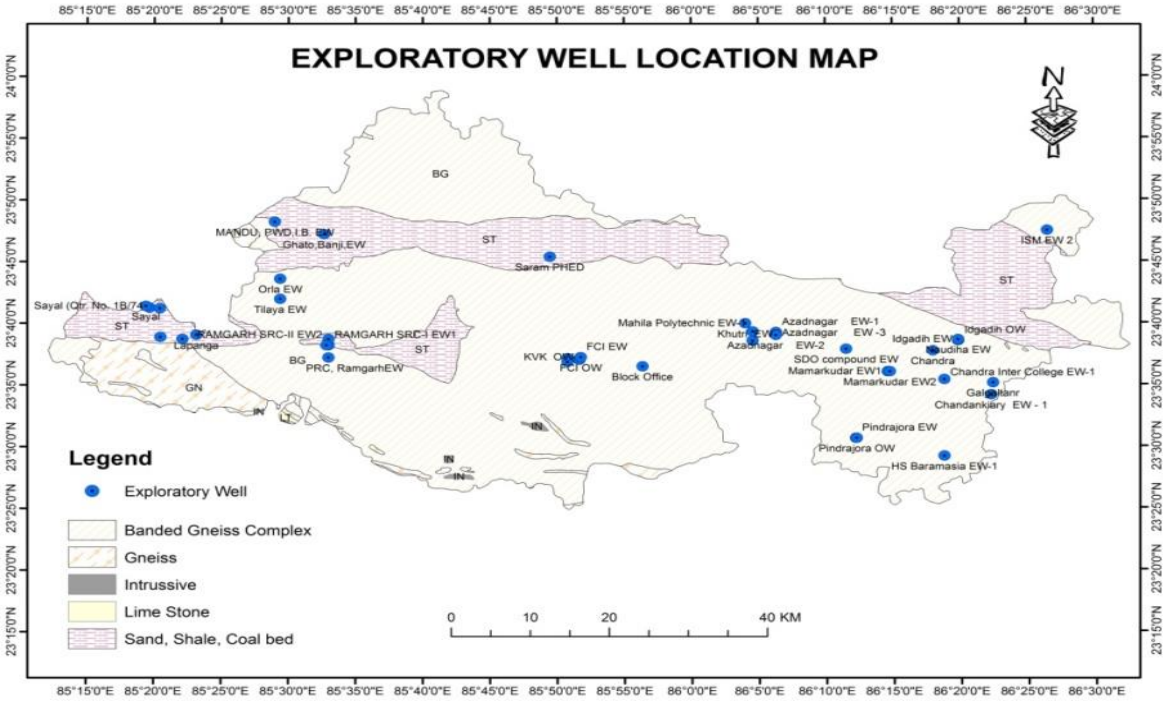


Fig.10 Exploratory well Location map in NAQUIM Phase-II

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Based on exploratory wells data, Geophysical studies, 2-D and 3-D sections have been prepared. Two types of major formations are in the study area i.e. Granite gneiss and Lower gondwana. In granite-gneiss terrain lithological section A-A' which is along orla EW to Potamdaga exploratory well having minimum one and maximum two fractures were encountered which is shown in *figure 11-A* while in section B-B' prepared in between patel nagar Ew to galgaltanr Ew here two Ew constructed in gondwana formation and rest nine ew constructed in granite gneiss having minimum one and maximum four fractures were encountered which is shown in figure 11-B. Maximum numbers of fractures are encountered in gondwana formation. In section C-C' all the wells drilled in granitic rock terrain of Bokaro district wherein D-D' section one ew drilled in gondwana formation having four number of weathered zones are rest five wells drilled in granitic rock having

one and two fractures which is shown in *figure 12-A &B.* In section E-E' & F-F' all the wells drilled in gondwana rock terrain of Ramgarh district having one to four number of weathered zones encountered which is shown in *figure 13-A &B.*

Lithological section A-A' & B-B'

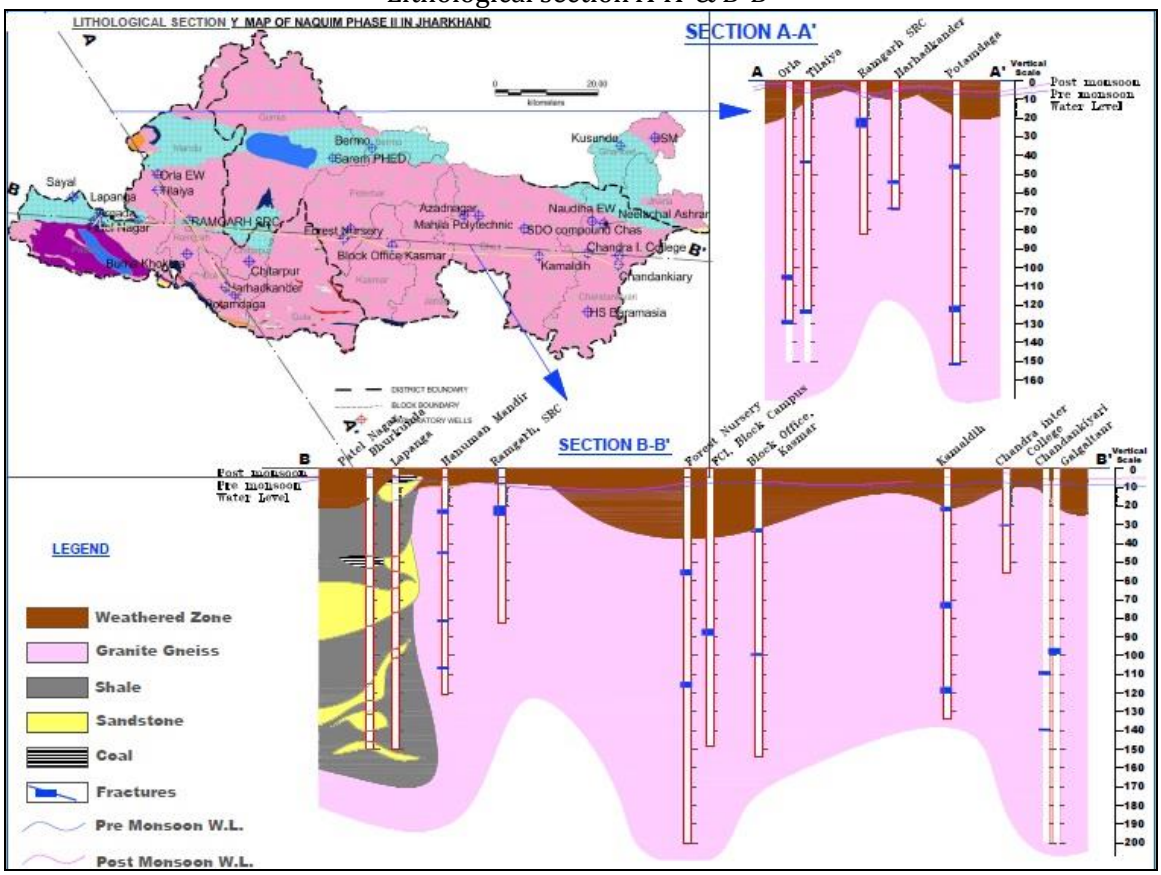


Fig.11- Lithological section A-A' & B-B'

Lithological Section C-C’ & D-D’

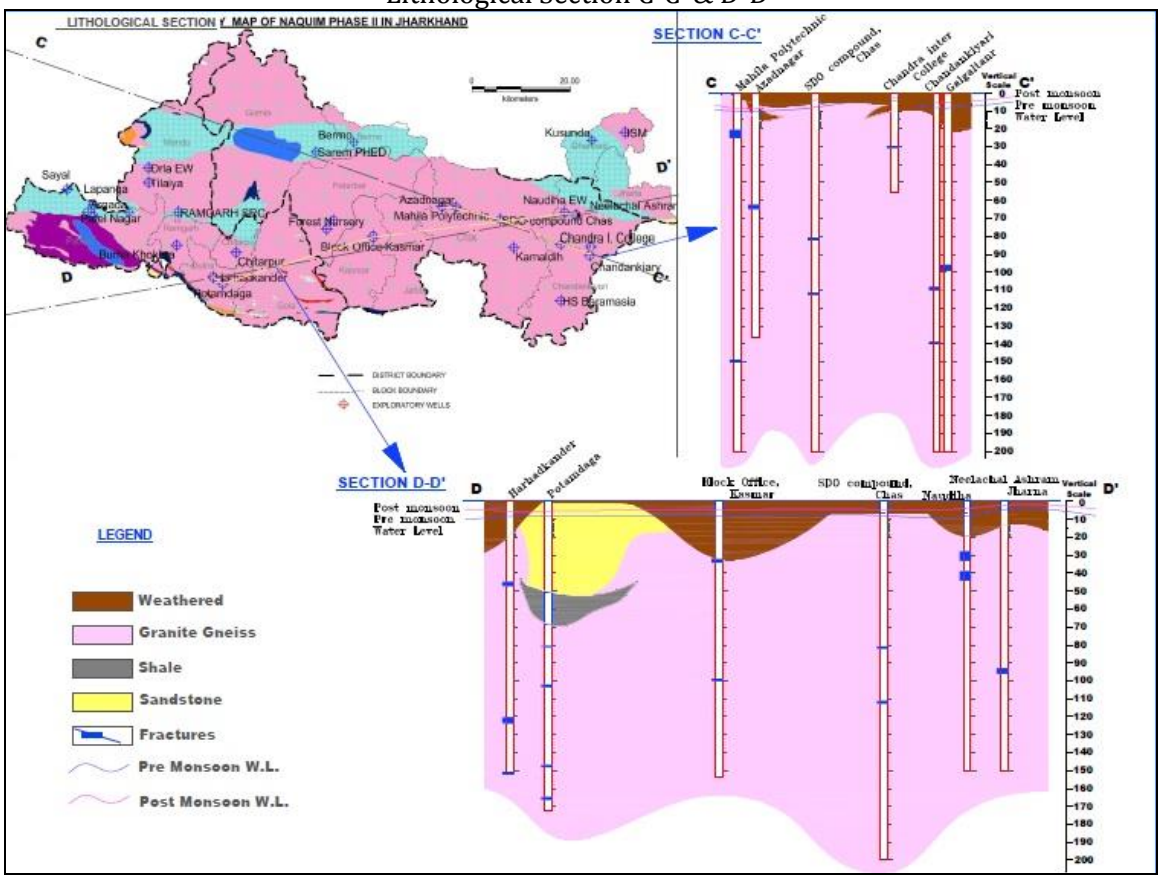


Fig.12- Lithological section C-C’ & D-D’

Lithological Section E-E’ & F-F’

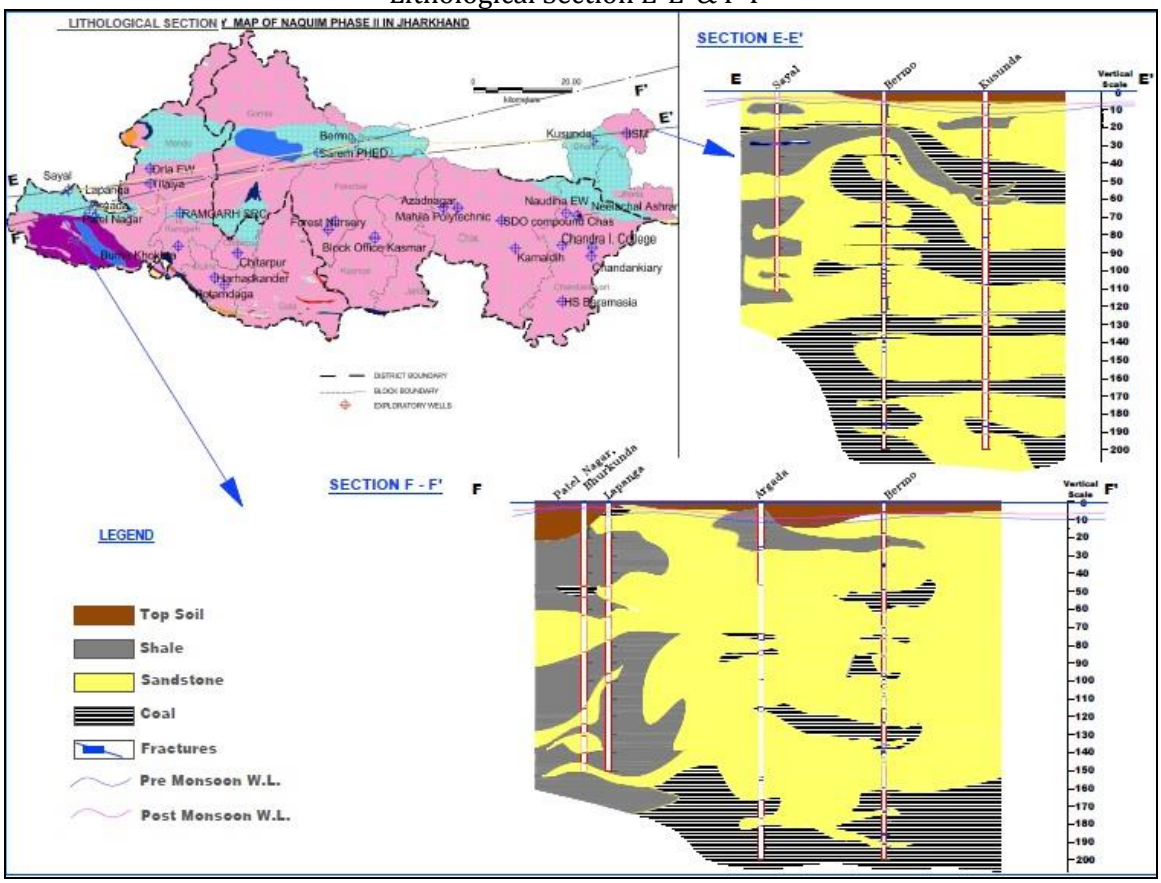


Fig.13- Lithological section E-E’ & F-F’

Based on exploratory bore well, 3D lithological model has been generated. Model and lithology encountered in the bore wells are shown in *figure14.* The model depicts that weathered and fracture granite is observed of limited thickness.

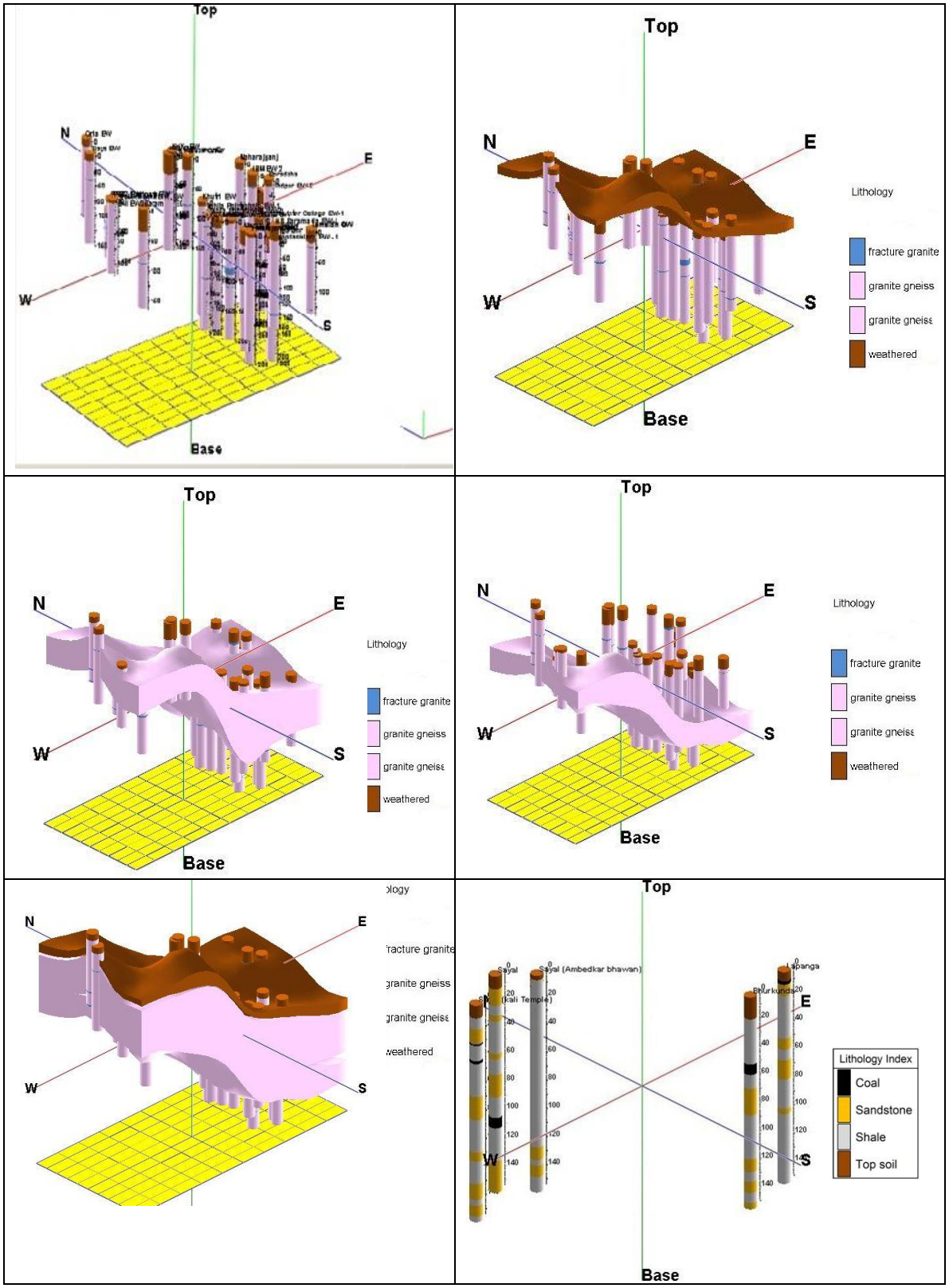
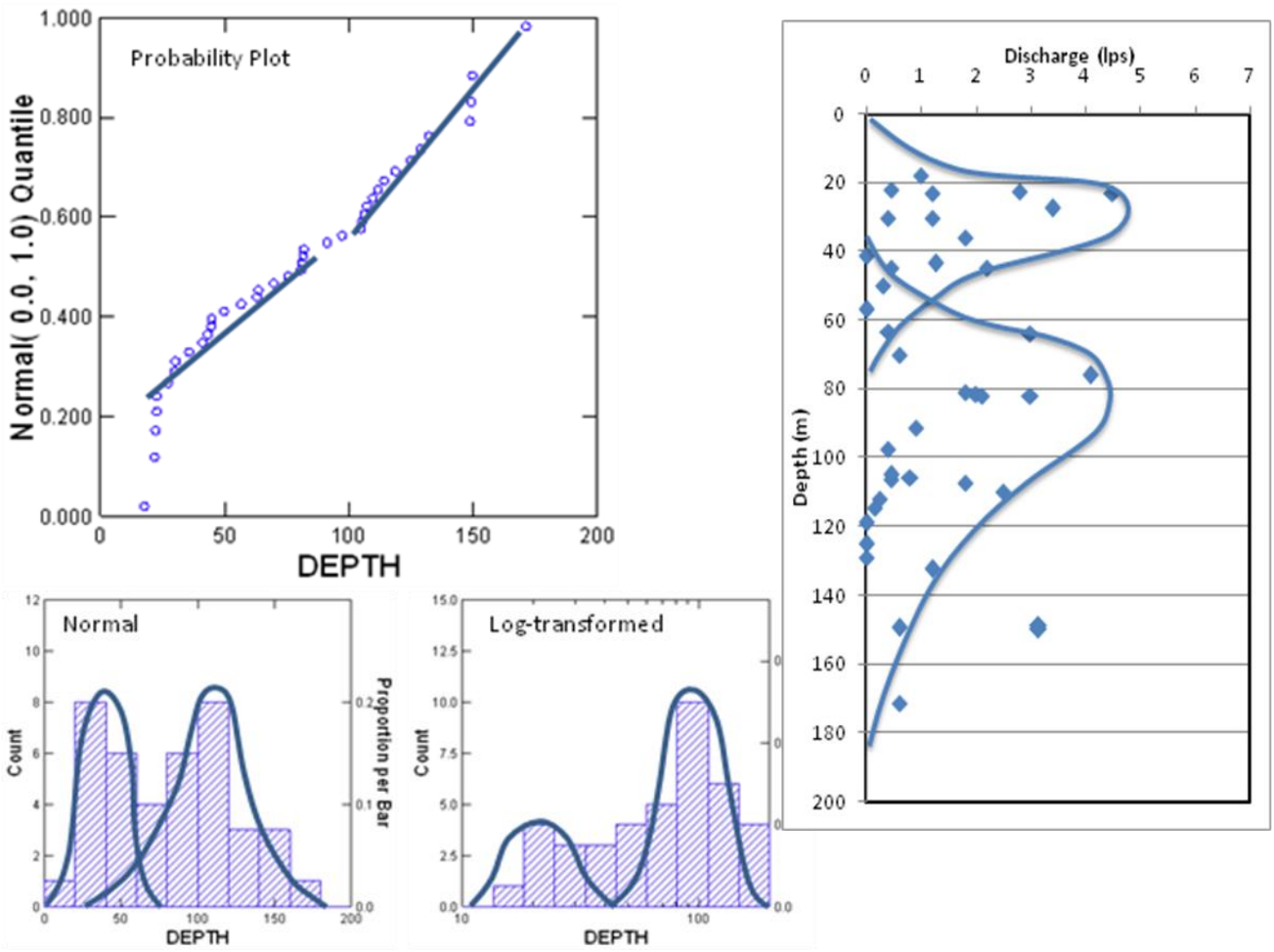


Fig.14 Three dimensional strip-log of EW drilled in granite and gondwana rocks

Statistical Analysis of Fracture System:

Statistical analysis of fracture system represents that there is two aquifer system lies in phase II study area, which is classified by its depth ranges i.e. Aquifer I & II. Depth of aquifer I is generally 0 to 30 mtr which is weathered and aquifer II fracture depth varies from 30 to 200 mbgl.

Majority of fractures are encountered within 120 mbgl in Granite gneiss as well as Gondwana Rocks. In Granite gneiss few fractures are encountered within 100-150 mbgl which is shown in *figure 15*



From (m)	To (m)	F	CF
0	25	5	5
25	50	9	14
50	75	4	18
75	100	7	25
100	125	8	33
125	150	6	39
150	175	1	40

Fig. 15 Statistical Analysis of Fracture System

4.0 GROUND WATER RESOURCES

Ground Water Resource of the area has been estimated for base year As on March-2011, on block wise basis. There are thirteen number of assessment units (blocks) in the study area where three blocks come under over-exploited namely Dhanbad, Jharia and Ramgarh. Chas block of Bokaro district is comes under semi-critical and nine blocks falls in safe categories. The net dynamic ground water availability in the area is 34556 ham and ground water draft for all uses is 15407 ham, making stage of ground water development 44% as a whole for the phase II area. After making allocation for future domestic and industrial water supply for next 25 years, balance available ground water for future irrigation development would be 18566 ham. The details of ground water resource of study area is given in table 11

Table 11 Ground Water Resource (As on March -2011)

S.No.	Items	Ramgarh district	Parts of Bokaro district	Parts of Dhanbad district
1	Area in ham	134100	235600	26100
2	Net Ground Water Availability in ham	12634	20132	1790
3	Existing Gross Ground Water Draft for Irrigation in ham	3237	4950	80.05
4	Existing Gross Ground Water Draft for Domestic and Industrial Water Supply in ham	1805	2192	2239
5	Existing Gross Ground Water Draft for all Uses in ham	5042	8045	2319
6	Net Ground Water Availability for future Irrigation Development in ham	7530	12016	-981
7	Stage of Ground Water Development (%)	39%	40%	129%

5.0 GROUND WATER RELATED ISSUES

5.1 Identification of Issues:

The major ground water related issues of the study area are grouped into following broad categories:

a. Area of intensive mining activities
b. Quantifying aspects
c. Quality aspects
d. Administrative issues

A variety of nature's factors affect the quantity and quality aspects of ground water over space and time. The major ground water related issues are discussed as follows;

5.1.a Area of intensive mining activities;

It is mainly associated with the mining activity with the intensive development of ground water. These are identified for the problem of depletion in the general water table and decline in the tube well discharge. Gondwana formation particularly the upper part of Barakar Sandstone support development of phreatic aquifers which extends from few meter below ground level to 30 mtr below land surface. Underground and opencast excavations behave as large sinks and create hydraulic gradient towards the mines. Mine water is pumped out for trouble free mining operations. Continuous withdrawal of water from coal mines for their mining activities is causing adverse impact on ground water

regime of the area which ultimately results in declining ground water levels, drying up of wells, dwindling of their discharge and sometimes land subsidence occurs. The main ground water problem in the mining area of coal is related with the dewatering of shallow and deep aquifer dewatering from open-cast and underground mining of the area. Continued pumping from various coal mines causes depletion of water levels.

5.1.b Quantity Aspects:

Ground water potential at any area mainly depends on the topography, rainfall, and geology. Because of plateau topography and Chotanagpur granitic gneiss complex as the litho-units occurring in the study area, the ground water potential is not uniform and it changes from one area to another. The salient features of ground water resources as on March-2011 is given in *Table 12.*

Table 12 Ground Water Resource (As on March -2011)

S.No.	Items	Ground water in ham
1	Total annual replenishable ground water resource	37395
2	Natural losses	2837
3	Net Dynamic Ground Water Availability	34556
4	Existing Gross Ground Water Draft for irrigation	8267
5	Existing Gross Ground Water Draft for Domestic and Industrial Water Supply	6237
6	Existing Gross Ground Water Draft for all Uses	15407
7	Provision for domestic and industrial requirement supply to next 25 years	7724
8	Net Ground Water Availability for future Irrigation Development	18565
9	Number of blocks	13
10	Number of semi-critical blocks	1
11	Number of critical blocks	0
12	Number of over-exploited blocks	3
13	Number of safe blocks	9
14	Stage of development	44%

Thus the availability of water resource is not uniformly distributed over space and time. This resource depletes often in summer, Therefore reduction of bore well's yield in lean period. The area is covered by Chotanagpur granite gneiss complexes where ground water potential of deeper aquifer is very less and limited thickness of fracture/joints are encountered in exploratory well drilling programme. In lower gondwana rock area weathered formation also possess low potential aquifers.

In Dhanbad and Jharia block of Dhanbad district, high dependency on ground water for Industrial and Domestic purposes. Existing ground water draft for Domestic and industrial ground water of Dhanbad and Jharia block is 2239 ham. Deeper aquifers of Dhanbad & Jharia Urban area is showing declining trend of water levels.

In Ramgarh block of Ramgarh districts and Chas block of Bokaro district high dependency on ground water is generally concise in Irrigation draft. The irrigation draft is 1052ham and 1441 ham respectively.

5.1.c Quality Aspects:

The ground water quality of the study area is potable and is suitable for irrigation, however at few localities contamination in ground water due to geogenic cause. The major problems and issues related to the quality is fluoride, iron, nitrate. The concentration of fluoride in the study area having more than permissible limit i.e 1.5 mg/l encountered in deeper aquifer in chas, chandankyari block of Bokaro district.

5.1.d Administrative Issues:

The study area experiences both very high as well low level of ground water development. In the north eastern part of the area the ground water resources are over utilized whereas western and some part of central part ground water resource is underutilized. Ground water related issues and problems are not getting scientific attention of the Government , planners and stakeholders. The plan and policy of the water resources department are mostly related to the surface water only. There is urgent need to pay attention towards ground water also. The laws of compulsory Rain Water harvesting should be enacted in Nagar Nigam /Nagar Palika's of the study area. A separate pricing policy for the bulk consumers of ground water in the area should be formulated.

5.2 Future demand scenario and stress aspects of the aquifer:

Ground Water Modeling is required to estimate the different scenario and stress aspects of the aquifer response. Few of the prospective scenarios is given in *Table13.*

Table 13 Future demand scenario and stress aspects of the aquifer

S,No,	Scenario (stress applied)	Aquifer-I Response	Aquifer-II Response	Remarks
1.	Existing Draft due to pumping			
2.	Ground water draft increased to 10% in next year			
3.	Draft increased 50% from the present level @ 5% annually from the present condition			
4.	Drought condition			

5.3 Participatory ground water management issues:

The public participation is an essential solicited in every for a yet in effect ground realities in all respect are ignored. At many places such activities amount of interference of alien culture or official imposition of hypothetic solutions. If corrective steps are not taken in time the present methodology adopted for people's participation will accelerate the loss of confidence among the people in their own capabilities.

6.0 MANAGEMENT STRATEGIES

Ground water management strategies for the study area, we have to prepare separate plan for over-exploited blocks, semi-critical blocks and safe blocks based on the ground water resource availability and draft condition of the area .

6.1 Management objective and option:

Prime Management objective is keeping in view of stage of development 70% and Management options are ;

- Proper utilization of mine water
- Implementation of Rain Water Harvesting & Artificial Recharge Techniques.
- Adoption of advance irrigation practices & Change in cropping pattern.

6.2 Management plan for Over-Exploited block:

In phase II area, Dhanbad, Jharia and Ramgarh block comes under over exploited blocks. In these three blocks Dhanbad and Jharia having intensive domestic and industrial draft, whereas irrigation draft is more in Ramgarh block. The ground water requirement pattern of these over-exploited blocks should be managed to keep stage of development 70%. The brief descriptions of block-wise management plan for OE blocks are discussed below;

Dhanbad & Jharia Block:

Ground Water requirement pattern to maintain stage of development at 70% of these blocks the volume of water required is given in *Table 14*

Table 14 Ground Water requirement Pattern in over-exploited blocks

S.No.	Items	Dhanbad	Jharia	Ramgarh
		Volume of water in ham		
1.	Net dynamic ground water availability	999	792	1897
2	Existing gross ground water draft for irrigation	59	21	1052
3	Existing gross ground water draft for domestic and industrial water supply	1370	869	944
4	Existing gross ground water draft for all uses	1429	891	1997
5	Proposed gross ground water draft for all uses	699	554	1328
6	Reduction in ground water draft from M & I for stage of development 70%	671	315	569

As per BCCL, Dhanbad coalfield area daily 31530 cubic mtr water is being pumped for trouble free mining operations. Out of 31530 cubic meter per day, 10340 cubic meter is utilized and 21190 cubic meter water per day goes as discharge runoff. These figure indicate that such a huge quantity of important ground water resource go as waste. The mine discharge of Dhanbad coalfield is given in Table15

Table 15Mine water discharge details of Dhanbad coalfield

Mine Discharge Utilized and Unutilised Mine Water in Respect of BCCL Mines In Dhanbad Block								
Cluster VI (Dhanbad)	Mines	M3/day	Actual discharge	Utilization (residential and related	Other uses	Manufacturing Requirement	Utilized	Unutilized
1	East Bassuriya OC	500		90	120	290	500	0
2	Bassuriya UG	1700		320	20	1360	1700	0
3	Gondudih Khas-Kusunda	1050		545	12	493	1050	0
4	Godhur UG&OC	900		250	187	463	900	0
	G.Total	**4150**		**1205**	**339**	**2606**	**4150**	**0**
Cluster XI (Dhanbad)								
1	Gopalichak UG	4100		565	70	870	1505	2595
2	Kanchi Balihari 10/12 pit UG	3780		410	30	710	1150	2630
3	Pootkee Balihari Project UG	4000		305	105	1320	1730	2270
4	Bhagaband UG	3900		700	75	635	1410	2490
5	Kendwadih UG (closed)	250		270			270	-20
6	Pootkee UG (closed)	5000		685			685	4315
7	Kanchi Balihari 5/6 pit UG (closed)	4500		290			290	4210
8	Moonidih UG	6000		1180	530	665	2375	3625
9	Moonidih Washery			525	400		925	-925
	G. Total	**31530**					**10340**	**21190**

In Jharia coal-field daily 9320 cubic meter water is being pumped for trouble free mining operations. Out of 9320 cubic meter per day, 5556 cubic meter is utilized and 3764 cubic meter water per day goes as discharge runoff. These figure indicate that such a huge quantity of important ground water resource go as waste. Details of mine discharge of Jharia coalfield is given in Table 16

Table16 Mine water discharge of Jharia coalfield

Table Showing Mine Discharge Utilized and Unutilized Mine Water in Respect of BCCL Mines In Jharia Blocks								
	Mines	M3/day	Actual discharge	Utilization (residential and related	Other uses	Manufacturing Requirement	UTILIZED	UNUTILIZED
Cluster X (Jharia)								
1	Bhowrah North UG	1485		328	328	0	656	829
2	Bhowrah North OC	640		329	329	0	658	-18
3	Bhowrah South UG	2300		330	330	0	660	1640
4	3 Pit OCP	620		331	331	0	662	-42
5	Chandan OCP (Bhowrah)	580		332	332	0	664	-84
6	Patherdih UG	2000		333	333	0	666	1334
7	Chandan OCP (Patherdih)	700		334	334	0	668	32
8	Sudamdih Incline UG	1160		335	335	0	670	490
9	Sudamdih (Shaft) UG	2340		336	336	0	672	1668
10	Amlabad Closed	0		337	337	0	674	-674
11	Sudamdih Coal Washery	0		338	338	0	676	-676
	G. Total	**11825**					**7326**	**4499**
Cluster IX (Jharia)								
1	N.T/S.T Expansion OCP (prop)	2330		636	0	1681	2317	13
2	Lodna UG	1600		723	360	203	1286	314
3	Bagdigi UG	2230		409	800	40	1249	981
4	Bararee UG	2050		425	500	56	981	1069
5	Joyrampur UG	1640		534	300	212	1046	594
6	Jealgora UG	1600		1600	0	0	1600	0
7	N.Tisra UG	1140		385	600	123	1108	32
8	Jeenagora OCP	700		300	100	300	700	0
9	N/S Tisra OCP	1745		950	135	660	1745	0
	G. Total	**15035**					**12032**	**3003**
Cluster VIII (Jharia)								
1	Bastacolla UG & OC	1840	1840	875	310		1185	655
2	Bera UG & OC	1470	1470	530	240		770	700
3	Dobari UG	1550	1550	595	120		715	835
4	Kuya UG & OC	1870	1870	782	325		1107	763
5	Goluckdih OCP	1180	1180	160	345		505	675
6	Ghanoodih OC	590	590	540	425		965	-375
7	Kujama OC	820	820	82	227		309	511
	Total	**9320**					**5556**	**3764**

Proposed Management Strategy for Dhanbad & Jharia :

The proposed management strategy for Dhanbad and Jharia is reduce ground water draft for Municipal and Industrial by using mine water seepage. Volume of mine water (ham) required to be used 671 ham for Dhanbad and 315 ham for Jharia. This amount of water is additionally required to maintain SOD 70% and it's already fulfilling through mine water seepage. Volume of mine water required to be used in given in Table17 and matching of demand and availability is given in Table18

Table.17 Volume of mine water required to be used

S.No.	Items	Dhanbad	Jharia
1	Existing ground water draft for municipal & Industrial Use in ham	1370	869
2	Proposed ground water draft for municipal & industrial use for maintain stage of development 70%	699	554
3	Additional water requirement to be met from mine water seepage for SOD 70%	671	315

Table 18 Matching of demand and availability

S.No.	Items	Dhanbad	Jharia
1	Unutilized mine water seepage (ham)	773	411
2	Requirement to be met from mine water seepage (ham)	671	315

From the matching of demand and availability scenario, it is clearly shows that unutilized mine water seepage is a huge reservoir itself to met the present requirement and to maintain stage of development 70%. Therefore strict water management practices should be adopted for the coal mining belt. Abandoned mines can be treated as a big rainwater harvesting and artificial recharge structure.

Roof-Top Rain Water Harvesting:

Implementation of Roof top rain water harvesting we can also enhance the ground water availability. A generalized plan for roof top rain water harvesting is given below:

- One rooftop having area 500 square feet = 45 square meters
- Rainwater that can be harvested from one roof with 75% efficiency = 34 cubic meters

  Considering urban households around 1 Lac, total rainwater that can be harvested =**3.4 million cubic meters (mcm)** can be recharge by roof top rain water harvesting system

Proposed Management Strategy for Ramgarh:

In the study area, Ramgarh block also come in overexploited block where existing gross ground water draft for domestic and industrial water supply is 944 ham and existing gross ground water draft for irrigation is 1052 ham. The total ground water draft for all uses is 1997 ham, making stage of ground water development 105.26%. When assessing the draft for Ramgarh block, it is observed that the irrigation ground water draft contribute towards higher as compared to the domestic and industrial draft.

To reduce irrigation draft and keep stage of development at 70% ground water draft is to be reduced to 1328 ham or adopt recharge practices of ground water. The ground water availability and its uses for different purposes has been given in *Table 19*

Table 19 Ground water requirement pattern in Ramgarh block

S.No.	Items	Volume of water (ham)
1	Net dynamic ground water availability	1897
2	Existing gross ground water draft for irrigation	1052
3	Existing gross ground water draft for domestic and industrial water supply	944
4	Existing gross ground water draft for all uses	1994
5	Net ground water availability for future irrigation development	- 377
6	**Proposed gross ground water draft for all uses**	**1328**
7	**Reduction in ground water draft for stage of development 70%**	**569**

6.2.a. Aquifer wise space available for recharge and proposed interventions

The computational procedure for computing the aquifer wise in-storage ground water resource comprising the following steps

- The area of the ground water assessment unit for which the static ground water resource is to be computed is obtained.
- The depth below ground level up to which the zone of water table fluctuation occurs is obtained. This can be taken as the maximum depth below ground level recorded during the pre-monsoon interval. An acceptable depth below ground level up to which ground water can be mined is obtained. This will be usually less than the maximum depth below ground level up to which the saturated aquifer formation extends.

The assessment of total availability of ground water resource has been carried out using following methodology.

In- Storage Ground Water Resource Assessment:

Thickness of Aquifer (granular/productive zone) * Sp.yield * Area below zone of fluctuation water

Parameter used : Specific Yield
Depth of Assessment of in-storage Ground Water Resources
For Alluvial Area: Up to bed rock
For Hard rock area: Depth up to which the aquifer is commonly developed

6.2.b Aquifer wise ground water resource availability of Ramgarh block:

The over-exploited area comes under hard rock (Chotanagpur granite gneiss) as well as Lower Gondwana rock terrain therefore aquifer wise in-storage ground water resource availability were calculated separately for both the different formations is given below considering specific yield 1.5% for Granite gneiss and 3% for Gondwana rocks.

Aquifer wise statement for hard rock in Ramgarh block

Aquifer	Static Ground water resource
AQUIFER-I	49.95 mcm
AQUIFER-II	7.10 mcm

Aquifer wise statement for Gondwana rock in Ramgarh block

Aquifer	Static Ground water resource
AQUIFER-I	16.29 mcm
AQUIFER-II	2.31 mcm

Total Availability = Dynamic Ground Water Resource + In-Storage Ground Water Resource

Total Availability (Mcm) = 18.96 mcm + 75.65 mcm = 94.61 mcm

6.2.c Estimation of Available Sub Surface Storage Potential/Source Water requirement/availability for recharge, Types and number of Recharge structure

The thickness of unsaturated zones (below 3 mbgl) of above categories is estimated by considering the different range of water level. The total volume of unsaturated zone is calculated by considering the different water level zones and unsaturated thickness in different ranges of water level. This volume was multiplied by specific yield i.e. 1.5 % for hard rock or 3% for Gondwana on area specific basis to arrive at the net amount of water required which is to be recharged by artificial recharge to saturate the aquifer up to 3 mbgl. The details of sub surface storage potential and number of AR structures required in the study area is shown in *Table 20 & Table 21*

Table-20Details of sub surface storage space available & number of AR structures required for – Hard rock

	Sub surface storage available (mcm	Surface water required (mcm)	Runoff available (mcm)	Non-committed Runoff available (mcm)	Number of recharge shaft/ tube well/ NB/CD/CP/ percolation tank/ponds
Ramgarh	2.51	3.34	63.12	18.94	recharge shaft/ tube well- **33**
					percolation tank- **3**
					NB/CD/CP- **56**
					Pond -**17**

Table-21 Details of sub surface storage space available & number of AR structures required for-Gondwana rock

	Sub surface storage available (mcm	Surface water required (mcm)	Runoff available (mcm)	Non-committed Runoff available (mcm)	Number of recharge shaft/ tube well/ NB/CD/CP/ percolation tank/ponds
Ramgarh	.818	1.08	10.29	3.08	recharge shaft/ tube well- **10**
					percolation tank- **1**
					NB/CD/CP- **18**
					Pond -**5**

6.2.d Projected status of Ground Water Resources & Utilization:

After interventions of AR structure the following output comes in respect of stage of development. The details of output are given in *Table.22*

Table.22 Projected status of ground water resources and its utilisation in Ramgarh block

Block	Net Ground water availability	Additional recharge from water conservation &AR structure	Total net ground water availability after intervention	Existing Gross Ground water Draft for all uses	Net ground water draft after intervention	Present stage of ground water development	Projected stage of ground water development after
Ramgarh	Mcm	Mcm	Mcm	Mcm	Mcm	%	%
	18.96	3.328	**22.28**	19.96	19.96	**105.26**	**89.5**

6.2.e Demand side management:

In demand side intervention, the area proposed to be taken where intensive irrigation practices is going on especially in parts of Ramgarh. Principal crops of these areas are ;(Kharif)- Paddy, Maize, pea, , Green gram, Groundnut, Urd and (Rabi)- Wheat, Chickpea, Pea, Arhar. The volume of water expected to be conserved after taking 50% of the total area under advance irrigation practices is shown in *Table-23*.

Table -23 Advance irrigation practices

Type	Area proposed to be covered	Crop	Volume of water consumption before adoption of Advance irrigation practices (mcm)	Volume of water expected to be conserved i.e. 50% of Volume of water consumption before adoption of Advance irrigation practices is to be saved (mcm)
Sprinkler	156 ha	Wheat	0.4212	0.2106
Sprinkler	156ha	Mustard	0.2418	0.1209
Sprinkler	156ha	Linseed	0.29952	0.14976
Drip	78ha	Mustard	0.1209	0.06045
Drip	78ha	Linseed	0.14976	0.07488

Result: Micro irrigation practices are likely to reduce water abstraction for irrigation by 50 % (existing abstraction **1052 ham may come down to 550 ham)**

6.2.f Change in cropping pattern:

In the study area of phase II change in cropping pattern is adopted through replacement of Kharif crops by Kharif and Rabi crops replaced by Rabi crops. Total volume of water to be conserved if 50% change in the cropping pattern of the total area, expected volume of water to be saved is given in *Table-24*

Table 24.Change in cropping pattern

Area (Ha)	Area proposed to be covered	water require-ment (mm)	Total Consumption (ham)	Total Consumption (mcm)	Crop	Kharif/ Rabi	Proposed change	Volume of Water Saved (Mcm)
59 ha	50%	500mm	29.5	0.295	Paddy	Kharif	Paddy replaced by maize 50%	0.06254
59 ha	50%	394mm	23.246	0.23246	Maize	Kharif		
59 ha	50%	500mm	29.5	0.295	Paddy	Kharif	Paddy replaced by urd 50%	0.21653
59 ha	50%	113.9mm	7.847	0.07847	Urd	Kharif		
78 ha	50%	270 mm	21.45	0.2145	wheat	Rabi	Wheat replaced by mustard 50%	0.0936
78 ha	50%	155.7 mm	12.09	0.1209	Mustard	Rabi		
78 ha	50%	192 mm	14.976	0.14976	linseed	Rabi	Linseed replaced by mustard 50%	0.02886
78 ha	50%	155.7	12.09	0.1209	Mustard	Rabi		

Result: 50 % Change in cropping pattern results in saving of **40 ham** of water

6.3 Management Plan for Semi-Critical blocks:

Within the study area of phase II Chas block comes under semi-critical category where, intensive agricultural activities practiced. In Chas block irrigation ground water draft is more than domestic and industrial ground water draft. The ground water development pattern in semi-critical block should be managed to keep stage of development within 70%. The volume of water required is given in *Table 25*

Table 25 Ground water development pattern in Chas block

S.No.	Items	Volume of water (ham)
1	Net dynamic ground water availability	4031
2	Existing gross ground water draft for irrigation	1441
3	Existing gross ground water draft for domestic and industrial water supply	815
4	Existing gross ground water draft for all uses	3159
5	Net ground water availability for future irrigation development	1417
6	**Proposed gross ground water draft for all uses**	**2822**
7	**Reduction in ground water draft for stage of development to be remained within 70%**	**337**

6.3.1 Aquifer-wise availability of the semi-critical blocks;

The total availability of ground water resources (i.e. dynamic + in-storage resource) is computed for chas block and the computational procedure which is already discussed above in management plan of Ramgarh block. The ground water resource availability estimation for semi-critical blocks is shown in *Table 26*

Table 26-Aquifer wise availability in Chas block

S.No.	Block	Net dynamic ground water availability (mcm)	Aquifer I (mcm)	Aquifer II (mcm)	Total Ground water availability (mcm)
1	Chas	40.31	164.44	24.26	**229**

6.3.2 Augmentation plan of Ground Water resource through artificial recharge and water conservation

The details of sub surface storage space available and no of AR structures required in the study area is shown in *Table-27*

Table-27 Details of sub surface storage space available and number of AR structures required

	Sub surface storage available (mcm	Surface water required (mcm)	Runoff available (mcm)	Non-committed Runoff available (mcm)	Number of recharge shaft/ tube well/ NB/CD/CP/ percolation tank/ponds
Chas	25.26	33.9	287	86.34	recharge shaft/tube well- **34**
					percolation tank- **34**
					NB/CD/CP- **56**
					Pond/Dug Well -**170**

6.3.3 Projected status of Ground Water Resources & Utilization:

After interventions of AR structures the following result comes out in respect of stage of development. The details of output are given in *Table28.*

Table28-Projected status of GW resources its utilisation in Semi-critical block

Block	Net Ground water availability	Additional recharge from water conservation &AR structure	Total net ground water availability after intervention	Existing Gross Ground water Draft for all uses	Net ground water draft after intervention	Present stage of ground water development	Projected stage of ground water development after
	Mcm	Mcm	Mcm	Mcm	Mcm	%	%
Chas	40.31	25.26	**65.57**	31.59	31.59	**78.37**	**48**

6.4 Demand side management:

In demand side intervention, the area proposed to be taken where intensive irrigation practices is going on, especially in Chas block. Principal crops of these areas are ;(Kharif)- Paddy, Maize, pea, , Green gram, Groundnut, Urd and (Rabi)- Wheat, Chickpea, Pea, Arhar, black gram. The volume of water expected to be conserved after taking 50% of the total area under advance irrigation practices is shown in *Table-29*.

Table-29 Volume of water expected to be conserved in Chas Block

Type	Area proposed to be covered	Crop	Volume of water consumption before adoption of Advance irrigation practices (mcm)	Volume of water expected to be conserved (mcm)
Sprinkler	78 ha	Wheat	0.2106	0.1053
Sprinkler	78ha	Mustard	0.1209	0.06045
Drip	120ha	Blackgram	0.1356	0.0678

6.5 Change in cropping pattern:

In the study area of phase II change in cropping pattern is adopted through replacement of Kharif crops by Kharif and Rabi crops replaced by Rabi crops. Total volume of water to be conserved if 50% change in the cropping pattern of the total area, expected volume of water to be saved is given in *Table-30*

Table-30 Expected volume of water to be saved after adoption of cropping change

Block	Total volume of water to be conserved after 50% change in the cropping pattern of the total area

Chas	**0.27705**

6.6 Management plan for Safe blocks:

Management Strategies:

The following management strategies proposed to be adopted for safe blocks of phase II area.

- Ground water development and irrigation potential creation
- Ground water draft for irrigation may continue with same pace except kasmar block of Bokaro district.
- No change in Industrial and Domestic ground water draft.
- No change in cropping pattern.

6.6.1Plan for Ground Water Development:

The net dynamic ground water availability in the area is 34556 ham and ground water draft for all uses is 15407 ham, making stage of ground water development 44% as a whole for the phase II area .Although the ground water development in north-eastern, and Central part is more, there are ample scope of ground water development in some part of central and western part of the area. The Net ground water availability for future irrigation development and stage of ground water development of safe blocks are given in *Table 31*

Table-31 Net GW availability for future irrigation development and SOD

District	Assessment unit	Net ground water availability for future irrigation development in ham	Stage of ground water development (%)
Bokaro	Bermo	366	44
	Chandankyari	2374	18
	Gomia	5410	14.33
	Jaridih	547	58.32
	Kasmar	365	74
	Petarwar	1536	37.43
Ramgarh	Gola	2169	34.64
	Mandu	2870	25.41
	Patratu	2212	25.24

The average stage of ground water development is less than 50%. Out of 13 blocks, there are eight blocks having stage of development is less than 60% has been considered for further ground water development. District wise balance ground water for future irrigation potential is determined by deducting ground water draft for irrigation and allocation for next 25 years (up to year 2033). The ground water available for future irrigation is divided by an average depth of irrigation (∆), considering of 0.40m for Jharkhand, which ultimately gives irrigation potential *(Table.30).* Considering 70% of future irrigation potential as optimum utilization with .45 ha area for dug well and considering 60% for dug well, the numbers of proposed ground water abstraction structures are obtained which is shown in *Table 32*

Table 32 Future irrigation potential created and proposed number of dug wells

District	Assessment unit	Net ground water availability and future irrigation development (ham)	future irrigation potential available (ha)	70% of future irrigation potential created (ha)	Proposed number of ground water structure (Dug wells)
Bokaro	Bermo	366	915	641	855
	Chandankyari	2374	5935	4155	5540
	Gomia	5410	13525	9468	12624
	Jaridih	547	1367	957	1276
	Kasmar	365	912	638	851
	Petarwar	1536	3840	2688	3584
Ramgarh	Gola	2169	5422	3795	5060
	Mandu	2870	7175	5023	6697
	Patratu	2212	5530	3871	5161
Total		**17849**	**44621**	**31236**	**41648**

Development of ground water for the safe blocks in phase II area requires thorough understanding of the heterogeneity of the formations, e.g degree of weathering, thickness of fracture zones and depth of occurrences of the aquifer. The feasibility of different ground water structures together with yield prospects for the balance ground water resources for future irrigation use is given in **(***Table 33).*

Table 33.Proposed feasible GW abstraction structures based on balance potential

GW Balance to be utilized for irrigation (ham)	Type of structure	Depth range (m)	Diameter (m)	Probable yield range (lps)	Command/Non Command area (ham)	No of GW abstraction structure to be constructed
18742	Dug well	12 to 20	3 to 5.5	2 to 5	0.45	41648

Dug wells are feasible ground water structures for the study area. The construction of **41648** additional ground water abstraction structures would bring an additional area of **18742 ha** under assured irrigation.