केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

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

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

BARAMKELA BLOCK, RAIGARH DISTRICT, CHHATTISGARH

उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर

North Central Chhattisgarh Region, Raipur

Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development & Ganga Rejuvenation
CENTRAL GROUND WATER BOARD

Aquifer Mapping and Management Plan in Baramkela block, Raigarh District, Chhattisgarh

By
Sh. A K Biswal (Scientist-D)

Type of Study	**Officer engaged**
Data compilation, Data Gap Analysis & Data Generation	Sri R.K.Tripathy,Scientist-B (AAP-2016-17)
Data Interpretation, Integration, Aquifer Mapping, Management Plan & Report writing	Sri A. K. Biswal, Scientist-D

North Central Chhattisgarh Region
Raipur
2020

BLOCK AT A GLANCE

BARAMKELA BLOCK, RAIGARH DISTRICT, CHHATTISGARH

1.	**GENERAL INFORMATION**	
	i) Geographical area (Sq. km)	781.34
	ii) Administrative Divisions (As on 2017)	
	a) Number of Villages	248
	iii) Population as on 2011 Census	24739
	iv) Average Annual Rainfall	971.88 mm
2.	**GEOMORPHOLOGY**	
	i) Major Geomorphological Units	Structural hills & valleys, flood plain
	ii) Major Drainages	Mahanadi Basin (Mand ,Kurket & Borai)
3.	**LAND USE (ha) As on 2016-17**	
	i) Forest Area	576
	ii) Net Area Sown	46264
	iii) Double cropped Area	3347
4.	**MAJOR SOIL TYPES**	Ultisols- Red & Yellow and Alfisols- Red sandy soil
5.	**AREA UNDER PRINCIPAL CROPS, in ha (As on 2016-17)**	Paddy-34943, Wheat-474, Pulses-2119, Tilhans-2440, Fruits and vegetables- 93
6.	**IRRIGATED AREA BY DIFFERENT SOURCES in ha (As on 2016-17)**	
	i) Dug wells	30
	ii) Tube wells/Bore wells	11911
	iii) Canals	3339
	iv)Tanks	1115
	v) Other sources	1406
	vi) area Irrigated more than once	9692
7.	**NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on March'2019)**	
	i) No of Dug wells	8
	ii) No of Piezometers	2
8.	**PREDOMINANT GEOLOGICAL FORMATIONS**	
	Chhattisgarh Supergroup (Sandstone, shale)	
	Basement Crystallines (Granites, Gneiss, Schists & metamorphic)	

9.	**HYDROGEOLOGY**	
	i) Major Water Bearing Formations	Weathered & fractured sandstone, shale, siltstone, and Granite gneisses.
	ii) Pre-monsoon Depth to Water Level	4.70 to 25.50 mbgl
	iii) Post-monsoon Depth to Water Level	0.5 to 6.6 mbgl
	iv) Long Term Water Level Trend for 10 yrs (2008-2017 Vs 2018) in m/yr	appreciable change in water level with significant falling trend both in pre-monsoon and post monsoon period to the tune of 17 cm per year
10.	**GROUND WATER EXPLORATION BY CGWB (As on March'2019)**	
	i) No of Wells Drilled	EW: 5, , PZ: 2
	ii) Depth Range (m)	35-200
	iii) Discharge (litres per second)	Neg to 19.5
11.	**GROUND WATER QUALITY**	
	i) Presence of Chemical Constituents	EC for Shallow aquifer is 82 to 737 and for deeper aquifer is 290 to 1128 µS/cm at 25°C, PH- 7 to 8.47, All the chemical constituents are well within permissible limit .
	ii) Type of Water	Calcium-Magnesium-Bicarbonate (Ca-Mg-HCO_3) and Calcium-Sulphate (Ca-SO_4) type for shallow aquifer & Calcium-Bicarbonate (Ca-HCO_3) type for deeper aquifer respectively.
12.	**DYNAMIC GROUND WATER RESOURCES in Ham (Estimated as on March'2013)**	
	i) Annual Extractable Ground Water Recharge	6464.93
	ii) Total Annual Ground Water Extraction	5024.43
	iii) Ground Water Resources for Future use	1342.84
	iv) Stage of Ground Water Development	77.72 %
	v) Category	**Semi-Critical**
13.	**AWARENESS AND TRAINING ACTIVITY**	Nil
14.	**EFFORTS OF ARTIFICIAL RECHARGE & RAIN WATER HARVESTING**	
	i) Projects Completed by CGWB (No & Amount spent)	Nil
	ii) Projects Under Technical Guidance of CGWB (Numbers)	Nil

16. MAJOR GROUND WATER PROBLEMS AND ISSUES

i. High stage of ground water development of due to over exploitation of resource.
ii. Poor Sustenance of wells due to Inherent character of aquifers having low yield.
iii. Growing of high water consuming crops in-spite of semi-critical stage of GW development.
iv. Declining of water levels.

CONTENTS

ABBREVIATIONS

a msl	above mean sea level
BDR	Basic Data Report
CGWB	Central Ground Water Board
Dia	Diameter
DTW	Depth To Water
EC	Electrical Conductivity
EW	Exploratory Wells
GW/ gw	Ground Water
ham	Hectare meter
lpcd	litres per capita per day
lpm	litres per minute
lps	liters per second
m bgl	meter below ground level
MCM/mcm	Million Cubic Meter
NCCR	North Central Chhattisgarh Region
NHNS/ NHS	National Hydrograph Network Stations
OW	Observation Well
PZ	Piezometre

FOREWORD

Groundwater resources are being developed over years in order to meet domestic, irrigation and industrial requirements. The spatial distribution of availability of ground water resources however, is uneven and is being indiscriminately exploited by various users thereby creating relentless pressure. On the other hand rapid urbanization, industrialization and land use changes has resulted decline of water levels in many parts of the country.

There is an urgent need for scientific approach for proper management of the available ground water resources for sustainability of this precious natural resource for present and future generation.

Central Ground Water Board has been in the forefront of activities for occurrence, development, and management of this resource through various scientific studies and techniques. Over the last four decades CGWB, NCCR, Raipur has gathered a huge amount of data regarding ground water resources of Chhattisgarh. Based on this experience aquifer mapping of Baramkela block was prepared with the vast amount of data generated and available with North Central Chhattisgarh Region. The report embodies all the features of ground water and related aspects of the study area including physiography, meteorological conditions, hydrology, drainage, geomorphology, geology, hydrogeology, ground water resources, hydrochemistry, geophysics, ground water problems etc.

The report titled " A REPORT ON AQUIFER MAPPING & MANAGEMENT PLAN IN BARAMKELA BLOCK, RAIGARH DISTRICT, CHHATTISGARH" " is prepared by Sh. A.K.Biswal, Scientist-D (CGWB,NCCR,Raipur) and is the result of untiring efforts Sh. R.K.Tripathy, Scientist-B, (CGWB,SER,Bhubaneswar). It was a Herculean job and required hard working. I appreciate the concerted efforts put by the author to make it possible to bring the report in its present shape. I hope this report will no doubt be useful and worthy for the benefit of Raigarh block and would be a useful document for academicians, administrators, planners and all the stakeholders in ground water.

Though utmost care has been taken to minimize the errors, some errors may have inadvertently crept in. It is expected that these mistakes will be taken in the proper spirit.

Dr. Santanu Samanta
(REGIONAL DIRECTOR (I/C))

EXECUTIVE SUMMARY

The Baramkela block covers a geographical area of 781.34 sq. km. It is situated in the southern part of the Chhattisgarh lying between 21.3405 degree and 22.7024 degree North latitudes and 83.2217degree and 83.4712 degree East longitudes comprising 95 village panchayats and 248 villages . According to 2011 census record the total population of the block is 24739. About 51.43 % of the net sown area is irrigated by all sources. Ground water contributes nearly 57% of the net irrigated area.

Baramkela block experiences Sub-tropical climate characterized by extreme cold in winter and extreme hot in summer. The average annual rainfall is 971.88 mm (average of last five years i.e 2012-2017). The annual temperature varies from 10^{0}C in winter to 46^{0}C in summer. The relative humidity Varies from 85 % in rainy season to 35-40 % during winter. The block is mainly drained by the rivers- Mand, Kelo, which are perennial in nature. The drainage system in Baramkela block originate at the southern part and flow in N and to NE direction before joining the Mahanadi river.

Geomorphologically the Baramkela block is characterized by structural hills and valleys and flood plains, structural plain on Gondwana rocks, pediment and pediplain.. The general elevation of the plain ranges between 190 and 240m amsl. The elevation in case of structural hills ranges from 200 to 300 m amsl. This region has a general slope towards the north.

Geologically Baramkela block is mainly covered by rocks of Archaean to Cretaceous age. Based on the water bearing property, the rocks of the block is comprising of hard rock crystalline and metamorphic and consolidated sedimentary rock of Chhattisgarh Super group .

The aquifer material controlling ground water flow in the block can be broadly divided into two major media (1) Porous media (Shallow Aquifer) and (2) Fractured media (Deeper Aquifer). The major aquifer groups in Baramkela block are (i) Basement crystalline and metamorphic, (ii) Chhattisgarh Super group (Chandrapur Group ,Raipur group, Raigarh formation).

Hydrogeologically, the shallow aquifers both in hard and semi-consolidated rock in the block are wide spread and largely in use. The shallow aquifers are being tapped through dug wells, dug cum bore wells or shallow bore wells drilled to a depth of 60 m. The weathered mantle and shallow fractures mainly constitute the shallow aquifers. The thickness of weathered mantle varies from 5 to 25m bgl. The average yield of Granite gneiss is 1.42 lps with transmissivity of 1-12 m²/day & average drawdown is 26.15 m. One to two sets of potential fracture zone mostly lie beyond 100 m depth. The average yield of Gunderdih shale is 6.41 lps with avg transmissivity of 14.58 m²/day & average drawdown is 13.91 m. One to three sets of potential fracture zone mostly lie within 100 m depth in Gunderdih shale. Similarly the average yield of Chandrapur sandstone is 4.79 lps with a range from 0.85 to 12.5 lps with an average transmissivity of 2.3 m²/day and average drawdown is 21.46 m. One to two sets of most potential fracture zone lies within 100 m depth.

*11 nos. of observation wells were established and monitored in pre & post monsoon period to access the ground water regime of the block including the national hydrograph stations. The water level analysis data indicates that the static water level of phreatic aquifer in the block during pre monsoon period is 4.70 to 25.50 mbgl with an average of 12.38 mbgl and during post-monsoon period it ranges from 0.5 to 6.6 mbgl with an average of 2.51 mbgl. The fluctuation ranges from 2.8 to 19.50 m with an average fluctuation of 7.77 m. The long term ground water level trend indicates that there is appreciable change in water level with significant falling trend both in pre-monsoon and post monsoon period to the tune of 17 cm per year and is categorized as "**Semi-Critical**" block. The average weathered thickness of the phreatic aquifer is around 17.66 m.*

The regional ground water flow direction is towards south-west and towards east. It may also be seen that the flow of ground water is mostly towards the major drainage suggesting that the base flow is towards the drainage system.

As per resource estimation March 2017, the Net Annual Extractable Ground Water Recharge (Ham) in Baramkela block is 6464.93 ham. The Net Ground Water Availability for future use is 1342.84 ham. Current Annual Ground Water Extraction for all purposes is 5024.43 ham out of which 4615.03 ham is for irrigation. The overall Stage of Ground Water Extraction in the block is 77.72 %. The Annual GW Allocation for domestic Use as on 2025 is 507.06 ham. As per the NAQUIM study in the block, 81 nos. of Percolation tank , 271 nos of Nalas bunding cement plug/ check dam, 650 nos. of recharge shaft and 485 nos. of Gully plugs /Gabbion structures may be constructed throughout the block that can recharge 35.4 mcm water to underground to sustain the ground water resources in a long term basis.

The quality of ground water in the phreatic zone is well within permissible limit of BIS standards and is suitable for drinking, irrigation and industrial purposes. The ground water of Baramkela block in overall is calcium-magnesium-bicarbonate (Ca-Mg-HCO3) and calcium-sulphate (Ca-SO4) type for shallow aquifer & calcium-bicarbonate (Ca-HCO3) type for deeper aquifer respectively.

ACKNOWLEDGEMENT

The author is grateful to Shri G C Pati, Chairman, Central Ground Water Board for giving opportunity for preparation of the National Aquifer Mapping & Management report of Baramkela block, Raigarh district, Chhattisgarh. I express my sincere gratitude to Shri G.L.Meena, Member (WQ & WTT) & Sh. S.Marwaha, Member (Scientific), CGWB for giving valuable guidance, encouragement and suggestions during the preparation of this report. The author is thankful to Dr. S.K.Samanta, Head of the Office, Central Ground Water Board, NCCR, Raipur extending valuable guidance and constant encouragement during the preparation of this report. The author is also thankful to Sh. A.K.Patre, Sc.D; Sh. J.R.Verma, Sc.D; Smt.Priyanka Sonbarse , Sc-B; Sh.R.K.Dewangan, Sc-B & Sh. Uddeshya Kumar, Sc-B and other officers and officials of all the sections of the office for the help rendered & for providing the needful data during the preparation of this report on "AQUIFER MAPPING & MANAGEMENT PLAN IN BARAMKELA BLOCK, RAIGARH DISTRICT, CHHATTISGARH".

A.K.Biswal

Scientist-D

AQUIFER MAPPING AND MANAGEMENT PLANS IN BARAMKELA BLOCK, DISTRICT-RAIGARH, CHHATTISGARH

CHAPTER-1
INTRODUCTION

1.1 Objectives:

The groundwater is the most valuable resource for the country. The demand for ground water for various types of use is increasing day by day; consequently indiscriminate development of ground water has taken place and the ground water resource has come under stress in several parts of the country. On the other hand, there are also areas where adequate development of ground water resources has not taken place. These facts underscore the need for micro-level study of the aquifer systems of the country. Central Ground Water Board (CGWB) is involved in hydrogeological investigations covering major part of the country and as per requirement; the reappraisal of ground water regime is being taken up in priority areas to generate the background data on regional scale. CGWB has also carried out ground water exploration in different phases with prime objective of demarcating and identifying the potential aquifers in different terrains for evaluating the aquifer parameters and also for developing them in future. The reports and maps generated from the studies are mostly based on administrative units such as districts and blocks and depict the subsurface disposition of aquifer on regional scale. However, due to paradigm shift in focus from development to management of ground water in last one decade, the need for more reliable and comprehensive aquifer maps on larger scale has been felt for equitable and sustainable management of the ground water resources at local scale. Volumetric assessment of ground water and strategies for future development and management are the primary objective of aquifer mapping.

1.2 Scope of the study:

The aquifer maps are the maps depicting aquifer disposition, giving lateral and vertical extension. The maps will also provide information on the quantity and quality. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological and quality data is integrated to characterize the quantity, quality and movement of ground water in aquifers.

It explains the components of the Aquifer Classification System, outlines the assumptions underlying the map information presented and also summarizes the content of an aquifer classification map. The goal is to help the map users understand the strengths and limitations of the information contained on the aquifer classification maps so that they can apply that information appropriately to their particular water and land management needs. The system and maps are designed to be used together and in conjunction with other available information as a screening tool for setting groundwater management priorities. They provide a way of comparing aquifers within a consistent hydrogeological context and prioritizing future actions at various planning levels. The maps may provide some background information for site-specific projects. However, the maps are not to be used for making site-specific decisions. The classification of an aquifer reflects the aquifer as a whole and at a specific time. Groundwater conditions, such as the degree of vulnerability and water quality, can vary locally and over time respectively. This variability in the data sometimes requires subjective decision-making and generalising of information for an entire aquifer. As such the Baramkela block was studied under NAQUIM program in 2016-17.

1.3 Methodology:

The activities under the aquifer project can be summarized as follows:

i) Data Compilation & Data Gap Analysis: One of the important aspect of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by the Central Ground Water Board and various other government organizations with a new set of data generated that broadly describe an aquifer system. The data were compiled, analysed, synthesized and interpreted from available sources. These sources were predominantly non-computerised data that were converted into computer based GIS data sets. On the basis of these available data, Data Gaps were identified.

ii) Data Generation: It was evident from the data gap that additional data should be generated to fill the data gaps in order to achieve the objective of the aquifer mapping programme. This was done by multiple activities like exploratory drilling, hydro-chemical analysis, use of geophysical techniques as well as detail hydrogeological surveys. About 5 nos. of exploratory wells & observation wells were drilled by CGWB and through outsourcing in various periods in different formation, 11 nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 19 nos of ground water samples from different sources representing shallow as well as deeper aquifers were studied carefully and analysed before preparing the aquifer map and management plan.

iii) Aquifer map Preparation: On the basis of integration of data generated through various hydrogeological and geophysical studies, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out the Characterization of Aquifers. These maps may be termed as Aquifer Maps depicting spatial (lateral and vertical) variation of the aquifers existing within the study area, quality, water level and vulnerability (quality and quantity).

iv) Aquifer Management Plan: Based on the integration of these generated, compiled, analysed and interpreted data, the management plan has been prepared for sustainable development of the aquifer existing in the area.

1.4 Salient Information:

The Baramkela Block of Raigarh District is situated in the southern part of Raigarh district of Chhattisgarh and is bounded on the north by Janjgir Champa district and pussore block of Raigarh District, in the west by Sarangarh block, in the south by Mahasamund district and in the East by Odisha state. The area lies between 21.3405 degree and 21.7024 degree N latitudes and 83.2217 degree and 83.4712 degree E longitudes. The geographical extension of the study area is 781.34 sq.km representing around 11.4 % of the district's geographical area. The area is served by a good road network from the District Headquarter Raigarh. Administrative map of the block is shown in map-1. Kenkamdi river flowing north and joining Mahanadi flowing west forms the major drainage system of the block. The drainage system of the block is a part of Mahanadi basin. Drainage map is shown in map-2.

1.5 Population:

The total population of Baramkela block as per 2011 Census is 24739 out of which rural population is 23225 living in 248 nos of villages while the urban population is 1514. The decadal growth rate of the block is 15.49 as per 2011 census.The population detail is given in table-1 .

Table- 1: Population Break Up

Block	Total population	Rural population	Urban population	Nos of Villages/ village panchayats
Baramkela	24739	23225	1514	248/95

Source: CG Census, 2011

1.6 Rainfall:

The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall in the study area is (Average of the last five years i.e. 2012 to 2017) 1316.14 mm with 50 to 60 rainy days. The rainfall detail is presented in table-2.

Table-2: Annual Rainfall (mm) in Baramkela block for the years (2012-2017)

Block	Rainfall in mm				
	2012-13	2013-14	2014-15	2015-16	2016-17
Baramkela	576	6506	4894	1769	46264
Average	971.88				

Source: Land and Revenue Department, Raigarh district

1.7 <u>Agriculture and Irrigation</u>:

Agriculture is practiced in the area during kharif and Rabi season every year. During the Kharif, cultivation is done through rainfall while during the Rabi season; it is done through ground water as well as partly through surface water like canals and other sources. The groundwater abstraction structures are generally dug wells, Bore wells /tube wells. The principal crops in the block are Paddy, Wheat and pulses. In some areas, double cropping is also practiced. The landuse (agricultural) pattern, cropping pattern and details of area irrigated in Baramkela block is given in Table 3 (A, B, C, D).

Table-3 (A): Land use pattern in Baramkela block during the year 2016-17(in ha)

Blocks	Revenue forest area	Area not available for cultivation	Non agricultural & Fallow land	Agricultural Fallow land	Net sown area	Double cropped area	Gross cropped area
Baramkela	576	6506	4894	1769	46264	3347	*42058*

Source: District Statistical Book-2017

Table-3 (B): Cropping pattern in Baramkela block during the year 2016-17(in ha)

Blocks	Kharif	Rabi	Cereal				Pulses	Tilhan	Fruits /Vegetables	Mirch Masala	Sugar-cane
			Rice	Wheat	Jowar & Maize	Others					
Baramkela	32216	9842	34943	474	35	254	2119	2440	93	238	243

Table-3 (C): Area irrigated by various sources in Baramkela block during the year 2016-17(in ha)

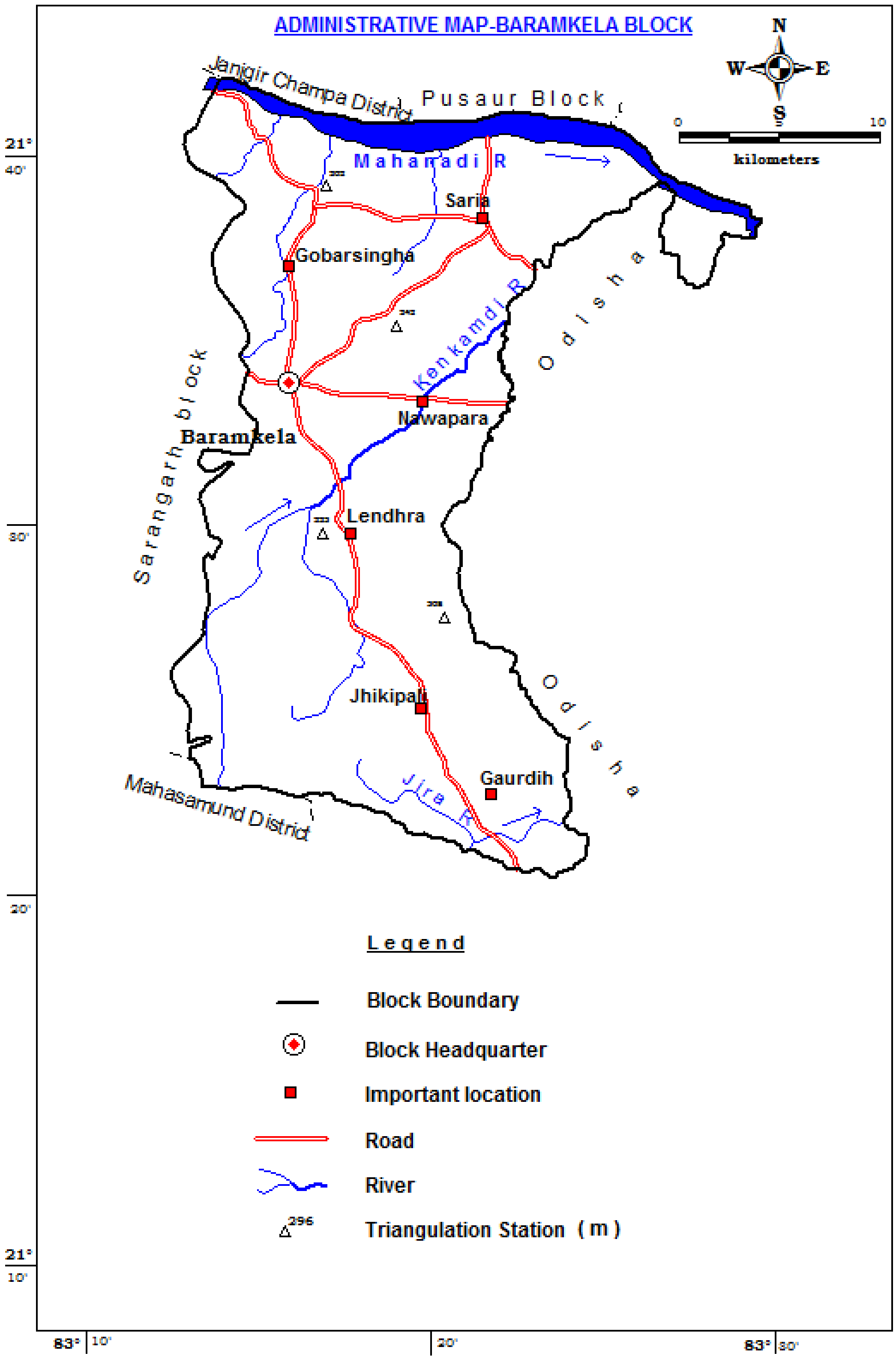
Blocks	Canal (private and Govt.)		Bore wells/ Tube wells		Dug wells		Talabs		Irrigated area by other sources	Irrigated area by GW sources	Net Irri-gated area	Irrigated area more than once	Gross irrigated area	% of Net irrigated area to. Net area sown
	Nos	Irrigated area (ha)	Nos	Irrigated area	Nos	Irrigated area	Nos	Irrigated area						
Baramkela	6	3339	3426	11911	278	30	601	1115	1406	11941	20953	9692	21633	51.43

Source: District Statistical Book-2017

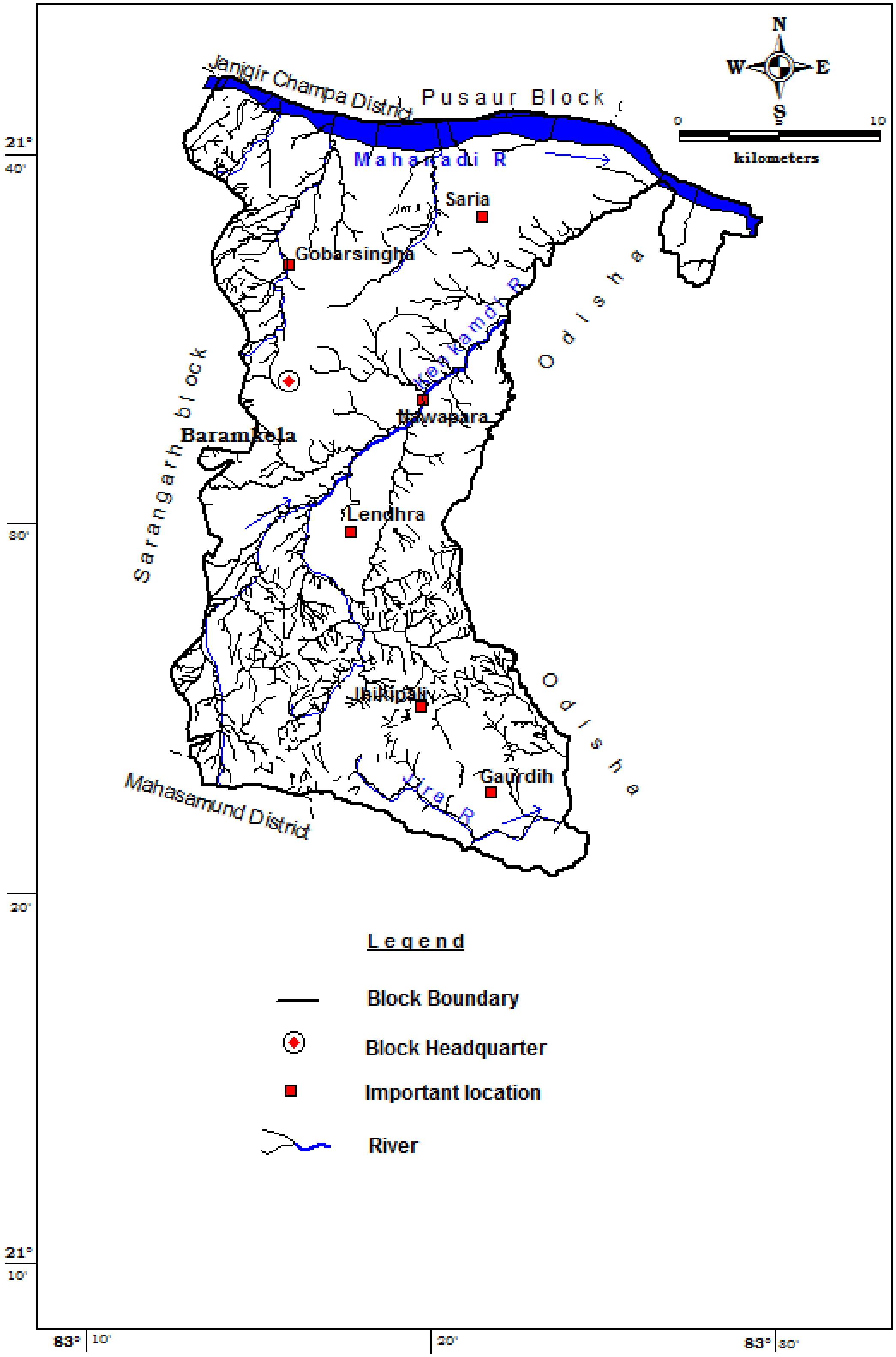
Table 3 (D): Statistics showing Agricultural land Irrigated

Block	Net Irrigated Area	Net Irrigated Area by ground water	Percentage of Area Irrigated by ground water
Baramkela	20953	11941	57 %

Map-1: Administrative map of Baramkela block



Map-2: Drainage map of Baramkela block



CHAPTER-2

DATA COLLECTION & GENERATION

2.1 Introduction:

About 5 nos. of exploratory wells drilled by CGWB and through outsourcing in various periods in different formation (table-4), 11 nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 19 nos of ground water samples collected from different sources representing shallow as well as deeper aquifers were studied carefully and analysed before preparing the aquifer map and management plan of Baramkela block.

Table-4: Status of exploration (EW) in Kharsia block (formation wise)

Block	Gondwana formation	Gunderdih Shale	Charmuria Limestone	ChandrapurS andstone	Crystallines	Total
Baramkela	-	4	1	-	-	5

2.2 Exploration:

Hard and soft rocks need separate well design. Since Baramkela block is mostly covered by hard rock, so well construction is relatively an easy job. With the help of high capacity DTH rigs, 200 m deep wells can be constructed within 10-12 hrs in hard rock areas. In these wells of hard rock, casing the initial weathered thickness is a bit time taking. Once the weathered zone is sealed with casing, drilling through massive formation is just a matter of time. The penetration rates (depth drilled per minute) are high in general. During the exploration, cutting materials are collected in every 3 m interval of depth and kept in a wooden box prepared for the sample collection. These rock cutting materials are observed carefully and accordingly a litholog is prepared which represents the depth wise rock type at that point. The aquifer parameter of various shallow and deeper aquifers were calculated based on long term (1000 minutes) pumping tests, preliminary yield test and slug test of bore/tube wells during exploratory drilling. The details of the exploratory well is given in **Annexure-I.**

2.2.1 Well design:

Hard and soft rocks need separate well design. Since Baramkela block is mostly covered by hard rock, so well construction is relatively an easy job. With the help of high capacity DTH rigs, 200 m deep wells can be constructed within 10-12 hrs in hard rock areas. In these wells of hard rock, casing the initial weathered thickness is a bit time taking. Once the weathered zone is sealed with casing, drilling through massive formation is just a matter of time. The penetration rates (depth drilled per minute) are high in general. PVC casing is preferred where ever ferric oxide problem persist in ground water of hard rock (Fig-1).

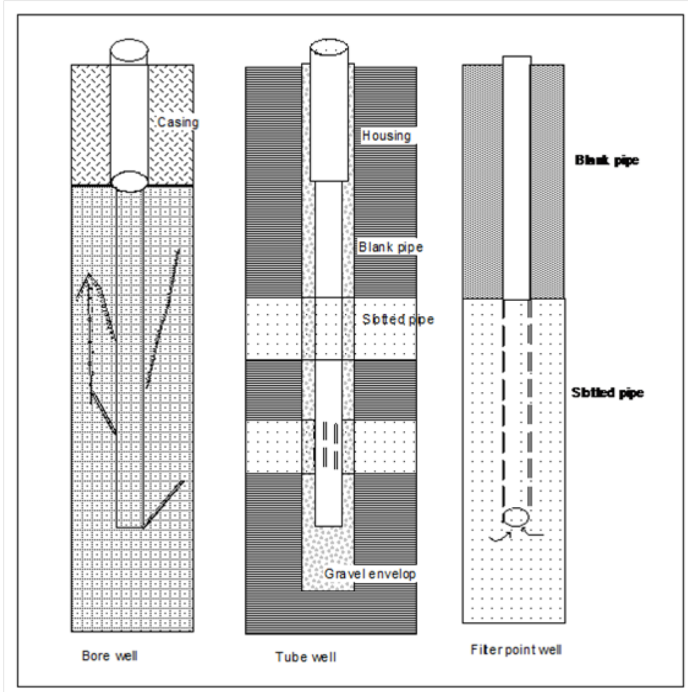


Fig-1: Well Design in hard rock

2.3 Water Level data:

Ground water is a dynamic system. It always remains under the influence of time dependant recharging and discharging factors. Due to this continuous influence, water level of the aquifer system fluctuates and the range depends on the period of influence. The recharge to the ground water system is controlled by many factors such as rainfall, seepage from reservoirs, lakes, ponds, rivers and irrigation, etc. The output from the ground water system includes ground water withdrawal, natural seepage to rivers and sea, evaporation from shallow water table and transpiration through vegetation. To study the ground water behavior, CGWB has established some dug wells and piezometers as observation wells known as national Hydrograph station (NHS) which are monitored regularly with respect to static water level and quality from 1969 onwards. The density of observation wells was increased year after year. During the present survey 11 nos of observation wells including NHS were monitored. The NHS are monitored four times in a year and the newly established key observation wells were monitored two times (Pre-monsoon & Post-monsoon). The time period of monitoring is as follows:

May -	20^{th} to 30^{th} of the month - represents Pre-monsoon water level
August -	20^{th} to 30^{th} of the month - represents peak monsoon water level.
November -	1^{st} to 10^{th} of the month- represents water level of Post-monsoon period.
January -	1^{st} to 10^{th} of the month- represents the recession stage of water level.

The water samples from these wells were collected in pre-monsoon period and were analysed to ascertain the chemical quality. Ground water levels, observed over a period, provides valuable information on the behavior of ground water regime, which is constantly subjected to changes due to recharge and discharge. The difference between these two factors results in the decline or rise in the ground water storage. When the recharge exceeds discharge there will be rise in the ground water storage whereas decline in the storage will be observed when recharge is less than discharge. The response of these factors is ultimately reflected on the water level of the area and their fluctuation. The phreatic water table of an area is the subdued replica of surface topography, which is regionally controlled by the major river basins and locally controlled by the watersheds. This is termed as phreatic aquifer in the report which represents the weathered formation of the area. Since all the developmental activities are listed by administrative unit in the state hence the block wise water level data is needed for planning developmental activity. On the basis of analysis of water level data, the changes in the ground water regime have been discussed. For every set of measurement the data was analyzed and maps like Pre and post-monsoon depth to water level, Water level fluctuation and Long term (decadal) water level trend have been prepared. The historical water level data available were analyzed to have long-term trend in water level behavior of all the basins within the state. The water level trends were analyzed to understand the ground water regime variation in long-term basis. The details of the water level data is given in **Annexure-II**.

2.4 Hydrochemical data:

The hydrochemical analysis of the ground water of the block was based mostly on the analysis of 19 ground water samples collected during the survey and exploration from key observation wells as well as exploratory wells (**Annexure-III A & B**). The parameters analysed were EC, pH, Ca^+, Mg^+, Na^+, K^+, CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--}, NO_3^- and F^-. During the year 2016, ground water samples from ground water monitoring wells of CGWB in Baramkela block were analysed for Arsenic. Further, a special study has been taken up by CGWB to assess the Uranium contamination in ground water in the year 2019 where ground water samples were analysed in the chemical laboratory of CGWB, Chandigarh.

All the chemical analyses presented here have been carried out in the laboratory of CGWB, NCCR, Raipur. EC and pH were analysed using EC and pH meters respectively. Ca, Fe, CO3, HCO3 and Cl were analysed using titrimetric methods. K and Na were analysed by flame photometer, SO4 and F by Spectrophotometer, NO3 by UV Spectrophotometer and Arsenic was analyzed by AAS. The samples which were analyzed for major cation and anion species are balanced electrochemically within +10 percent. The obtained results give the overall existing scenario of the ground water hydrochemistry of Baramkela block. With respect to the results the suitability of ground water for drinking, agriculture and industrial purposes has been described. The result of the chemical analysis of ground water samples was compared with IS 10500 BIS: 2012 for the drinking purposes. The BIS standard mentions the acceptable limit and indicates its background. It recommends implementing the acceptable limit. Values in excess of those mentioned as "acceptable" render the water is not acceptable, but still may be tolerated in the absence of an alternative source but upto the limits indicates under "permissible limit" in the absence of alternate source, above which the sources will have to be rejected.

2.5 Achievement:

To understand the regional hydrogeological behavior of Baramkela block, this complex aquifer setup has been classified into aquifer system on the basis of their lithology and age. The aquifer characteristics, its extent and the ground water quality are analyzed on the basis of these broad classifications. However, for better delineation of the aquifer characteristics, the lithologs and pumping test results of same formation but in neighboring blocks are taken into consideration. Ground water flow pattern, long and short term dynamics is also studied block wise. Finally the Aquifer maps were prepared and accordingly Aquifer Management Plan has been formulated for Baramkela block.

CHAPTER-3

AQUIFER DISPOSITION

3.1 Principal & Major aquifer groups:

The aquifer material controlling ground water flow in Baramkela block can be broadly divided into two major media (1) Porous media (Phreatic Aquifer) and (2) Fractured media (Deeper Aquifer). The phreatic aquifer both in hard and soft rocks in the block is wide spread and largely in use. This aquifer is being tapped mainly through dug well upto a depth of 20 m broadly. The weathered mantle and shallow fractures mainly constitute the shallow aquifers. The thickness of weathered mantle varies from 5 to 20m bgl. Nearly 90% of dug wells are in the depth range between 5 and 15 mbgl. The hand pumps installed by PHED for drinking water taps the shallow fracture zone down to 60 m bgl. The deeper aquifers have been identified in both hard and soft rocks. From the data collected, the characteristic of different aquifers in the block are deciphered. The major aquifer groups in Baramkela block are (**Map-3**):

(i) Chhotnagpur Granite gneiss
(ii) Chandrapur Sandstone
(iii) Gunderdih Shale

(i) Chhotnagpur Granite Gneiss : These crystalline and metamorphic rocks mainly occur along the nort-western boundary of the block. The average yield of Granite gneiss is 1.42 lps with transmissivity of 1-12 m^2/day & average drawdown is 26.15 m. One to two sets of potential fracture zone mostly lie beyond 100 m depth. The specific capacity value for granites varies from 1.43 to 29 lpm/m. The distribution of ground water in these formations shows that the morphological low areas have better ground water prospect than the highs.

(ii) Chandrapur Sandstone : The central part of the block is occupied by Chandrapur Group which consists of Orthoquartzitic to subarkosic sandstone and black shale. The sandstone of Chandarpur is highly silicified and devoid of primary porosity. The low-lying Chandarpur sandstone covered area has phreatic aquifer. The distribution of ground water in Chandarpur group is poor and the movement of water is restricted along joints and fractures. The average yield of Chandrapur sandstone is 4.79 lps with a range from 0.85 to 12.5 lps with an average transmissivity of 2.3 m^2/day and average drawdown is 21.46 m. One to two sets of most potential fracture zone lies within 100 m depth.

(iii) Gunderdih Shale: The Gunderdih shale is calcareous in subsurface and many times gypsiferous, having good secondary porosity. The shally part of Raigarh Formation is represented by Gunderdih shale in the block. It is most wide spread mainly in soth-central parts of the block. The fracture zones are encountered in the depth range of 60 to 120 mbgl. However the potential fractures are mostly confined to within the depth of 100 m. The casing depth varies from 6 to 35.5 mbgl. The casing length also indicates thickness of the weathered formation. The discharge obtained from the wells drilled in the Gunderdih shale varies from 0.5 to 22.42 lps. The average yield of Gunderdih shale is 6.41 lps with avg transmissivity of 14.58 m^2/day & average drawdown is 13.91 m.

3.2 Ground Water Regime monitoring:

During the study, 11 nos. of wells both dug wells and hand pumps were established and monitored (Annexure-II) both in pre-monsoon and post-monsoon period. The water level analysis data indicates that the ground water level of phreatic aquifer during pre monsoon period ranges from 4.70 to 25.50 mbgl with an average of 12.38 mbgl and during post-monsoon period it ranges from 0.5 to 6.6 mbgl with an average of 2.51 mbgl. The fluctuation ranges from 2.8 to 19.50 m with an average fluctuation of 7.77 m. The long term ground water level trend indicates that there is appreciable change in water level with significant falling trend both in pre-monsoon and post monsoon period to the tune of 17 cm per year. The average weathered thickness of the phreatic aquifer is around 19.6 m. The water level map prepared for the district is presented in (**Map-4 A, B &C**).

3.2.1 Ground Water Level Trend:

The historical water level data from 2009 to 2019 were analyzed to have long-term trend in water level behavior in Baramkela block (Table-5). The post monsoon trend is important from the aquifer management point of view since it is related with the ground water extraction. The post-monsoon trend analysis indicates that the wells show declining trend to the tune of 0.01 to 0.02 m/yr. The hydrograph of some of the wells are presented in **Fig-2 A & B**. The declining trend in post-monsoon period indicates the declining trend in ground water recharge which may be attributed to the declining trend in rainfall as well as reducing trend in the area for ground water of recharge.

Table-5: Ground water level trend (2009-2019) in Post-monsoon period in Baramkela block

SN	Block	Site name	Longitude	Latitude	Trend (2010-2019) postmonsoon	Remarks
1	Baramkela	Baramkela	83.26	21.52	-0.024171	Declining
2	Baramkela	Saria1	83.3	21.56	-0.019395	Declining

3.2.2 Ground Water flow direction:

The regional ground water flow direction is towards south-west and towards east. It may also be seen that the flow of ground water is mostly towards the major drainage suggesting that the base flow is towards the drainage system.

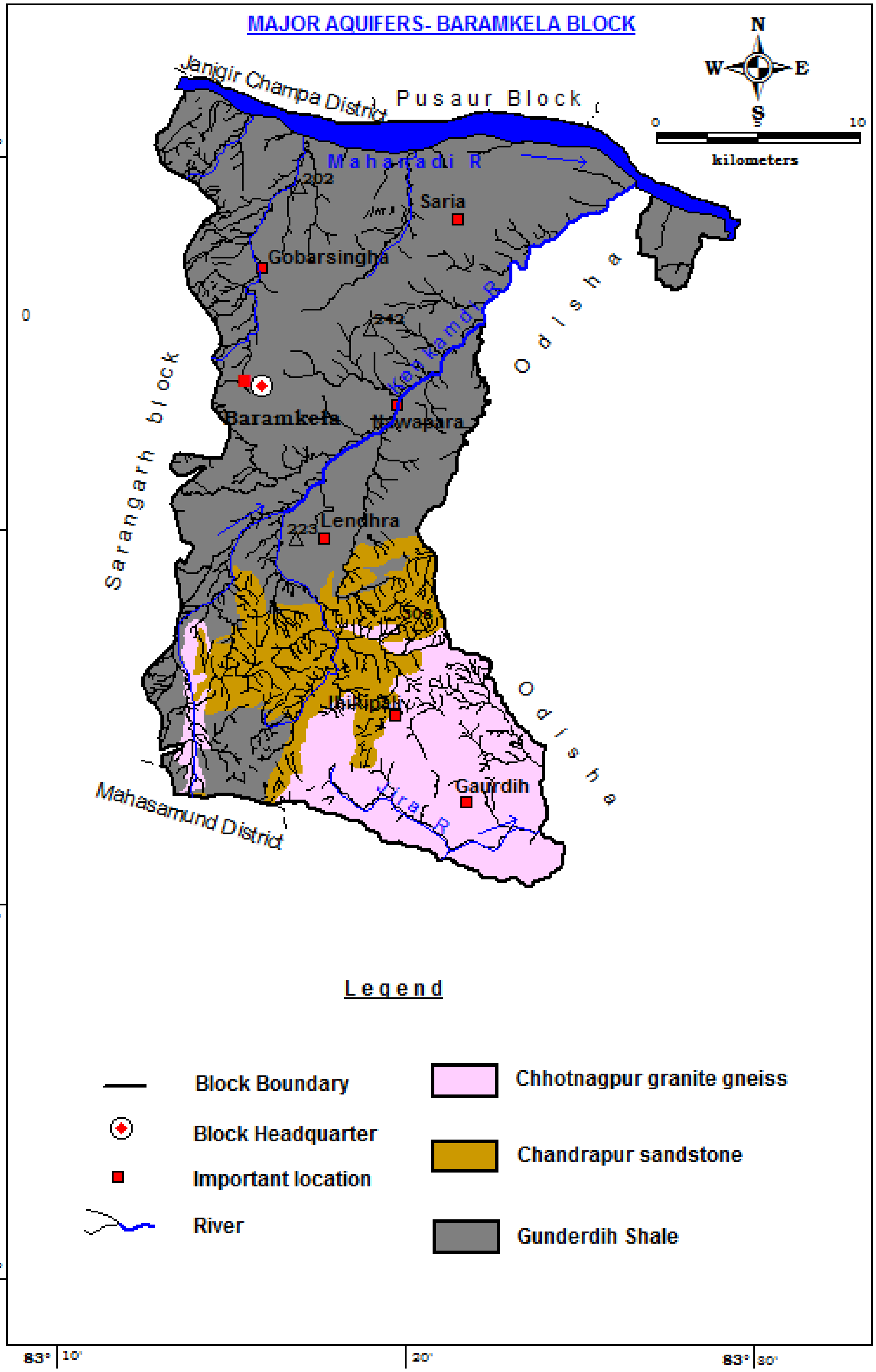
3.3 Ground Water Resources:

The ground water Resources of Baramkela block has been estimated on the basis of revised methodology GEC 2015. Ground water resources have two components – Replenishable ground water resources or Dynamic ground water resources and Static resources.

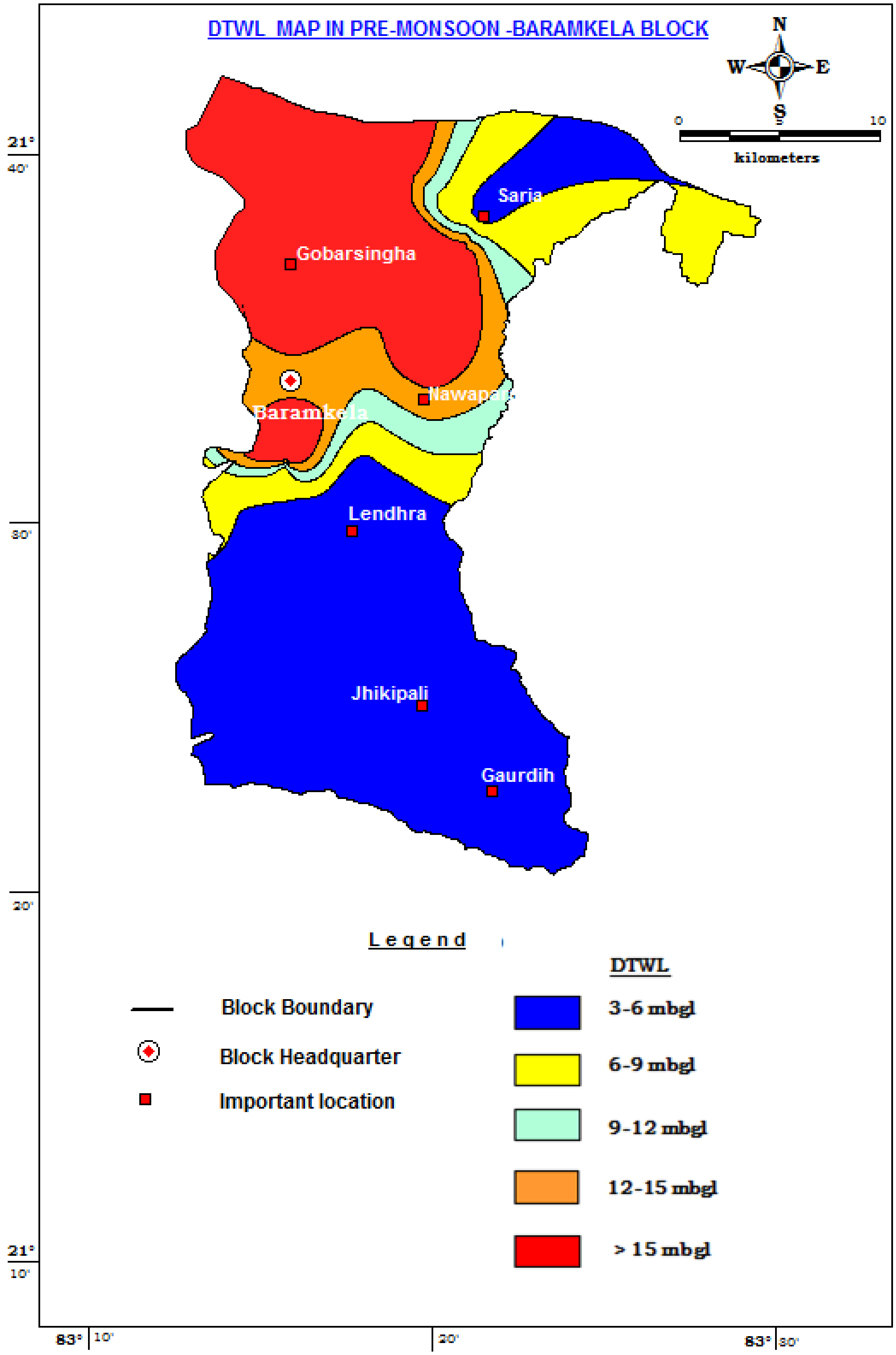
3.3.1 Replenishable ground water resources or Dynamic ground water resources:

As per resource estimation March 2017, the Net Annual Extractable Ground Water Recharge (Ham) in Baramkela block is 6464.93 ham. The Net Ground Water Availability for future use is 1342.84 ham. Current Annual Ground Water Extraction for all purposes is 5024.43 ham out of which 4615.03 ham is for irrigation. The overall Stage of Ground Water Extraction in the block is 77.72 %. The Annual GW Allocation for domestic Use as on 2025 is 507.06 ham. The block wise resource is presented in table 6.

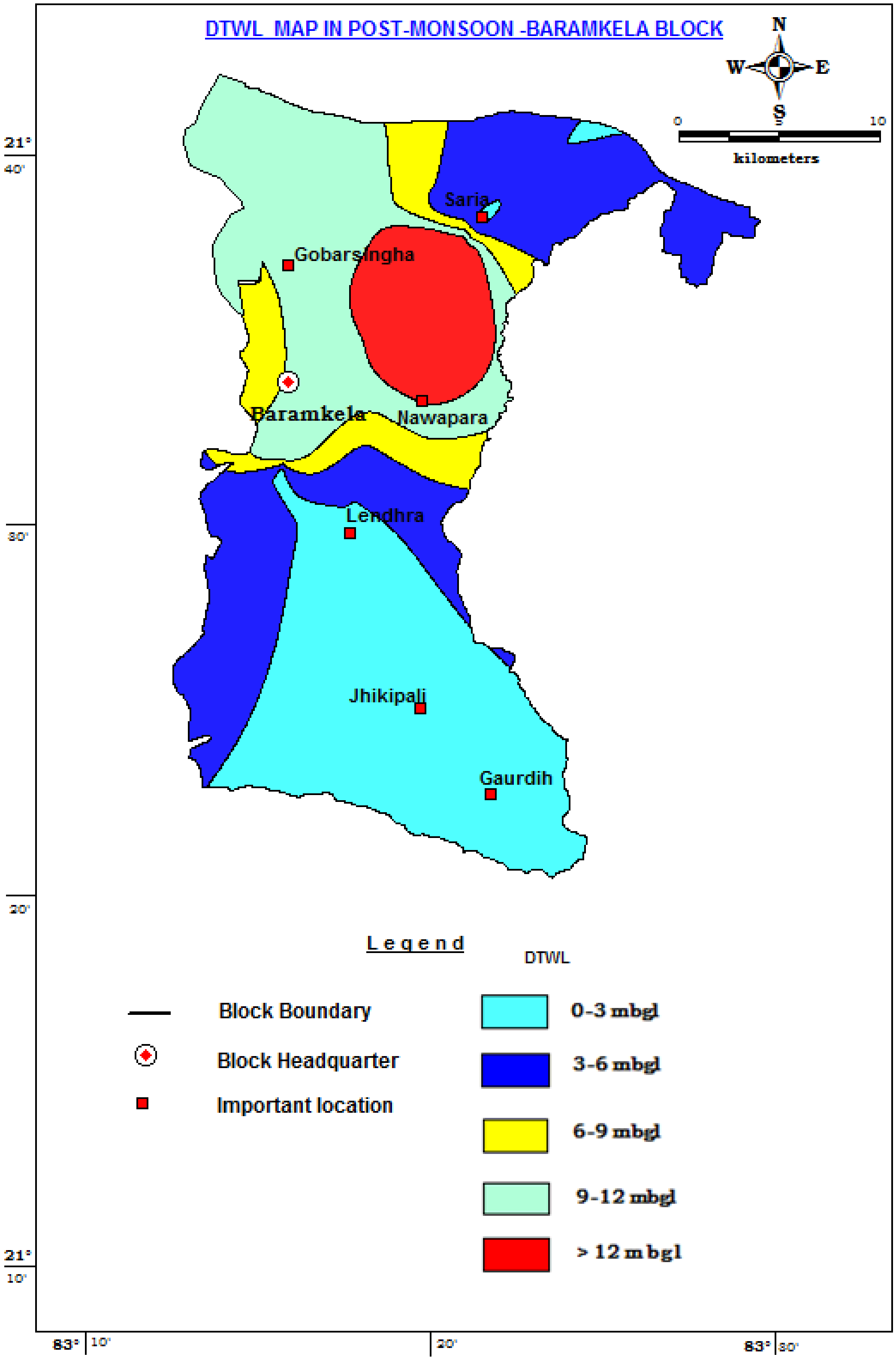
Map-3: Major Aquifer map of Baramkela



Map-4 (A): Pre-monsoon depth to water level map of Baramkela



Map-4 (B): Post-monsoon depth to water level map of Baramkela



Map-4 (C): Water level fluctuation map of Baramkela

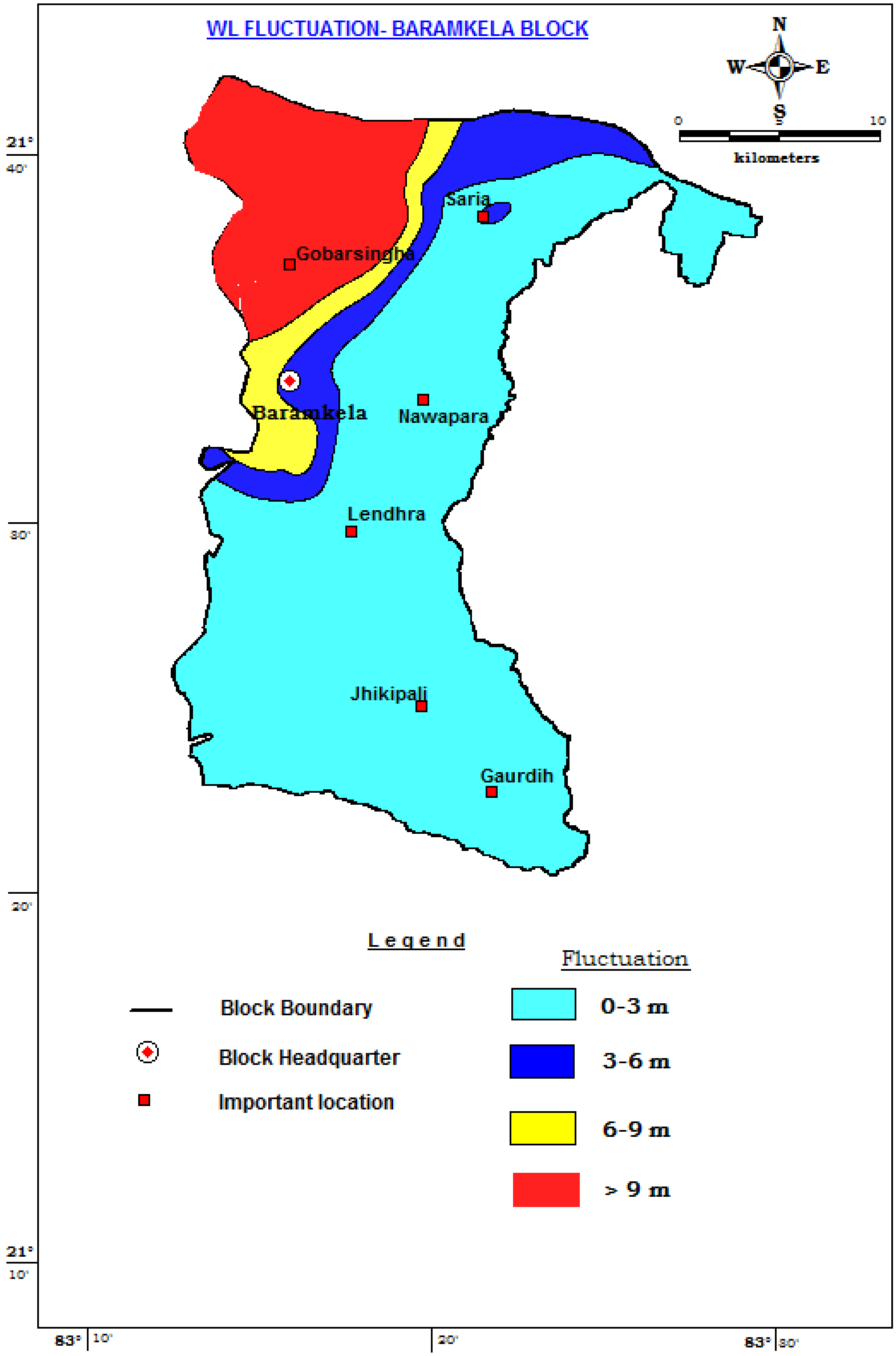


Table-6: Resources as estimated in 2017 of Baramkela block

Block	Annual Extractable Ground Water Recharge (Ham)	Current Annual Ground Water Extraction (Ham)				Annual GW Allocation for for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/ Semi critical/Safe)	Does the water Level Trend during Pre and Post Monsoon show a significant falling trend (Yes /No)	
		Irrigation use	*Industrial use*	*Domestic use*	*Total Extraction*					Yes/No	If Yes Value (cm/yr)
Baramkela	6464.93	4615.03	0	409.4	5024.43	507.06	1342.84	77.72	**Semi-Critical**	Yes	17

3.3.2 <u>Static Ground Water Resources:</u>

An attempt has been made to assess the Static Ground Water Resources Baramkela block which is the resource that remains available below the dynamic zone of water table fluctuation. This is not replenished every year and extracting this water is ground water mining. The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage. The following table-7 presents the ground water resources of Raigarh block.

Table-7: Ground water Resources of Baramkela block

Block	Recharge worthy Area (Ha)	Stage of Extraction in %	Static Resource in Ham	Dynamic Resource in Ham
Baramkela	90034	77.72	1560.109	6464.930

The table shows that the total static ground water resource of Baramkela block is 1560.1 Ham beside the dynamic ground water resource of 6464.93ham.

Fig- 2(A): Hydrograph of Sarai1, Baramkela block

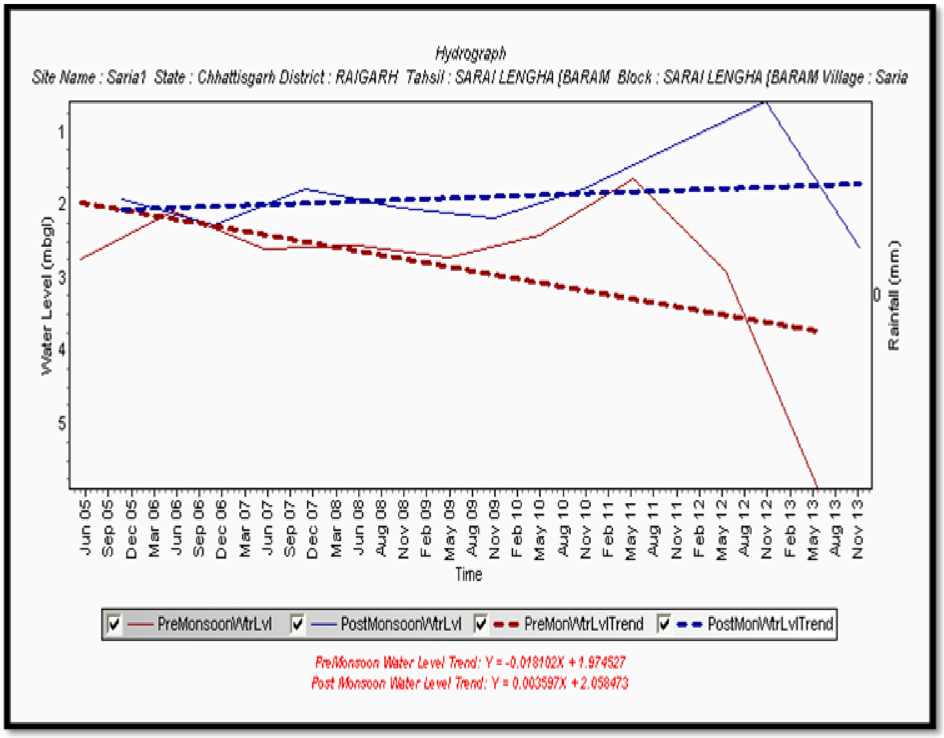
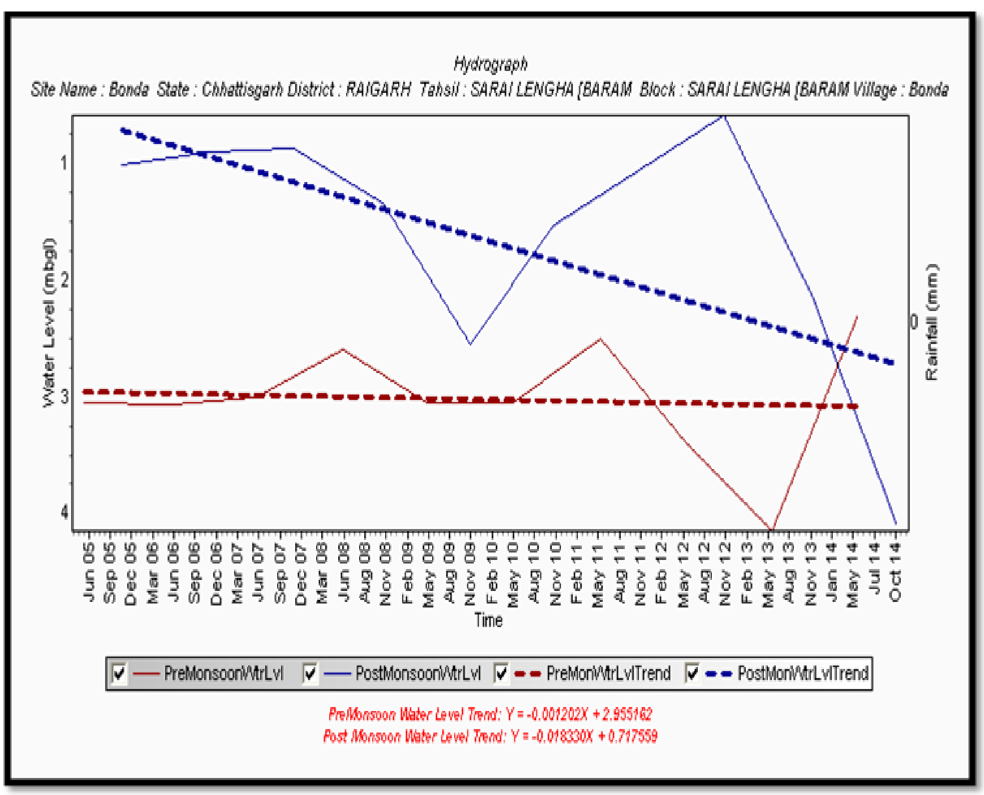


Fig- 2(B): Hydrograph of Bonda, Baramkela block



3.4 Ground Water Quality:

Ground water quality of shallow aquifer as well as deeper aquifer in Baramkela block for drinking, irrigation and industrial purposes is assessed on the basis of analysis of ground water samples collected from 24 nos. of observation wells for shallow aquifer & 11 exploratory wells for deeper aquifer (**Annexure-III A & B**). Apart from these, water samples were also analysed to assess the arsenic and uranium contamination respectively.

3.4.1 Water quality for all purposes: The concentrations of various parameters for both shallow & deeper aquifers are presented in the following table-8.

Table-8: Ground water quality data for shallow & deeper aquifer

Sl. No	Parameters (in ppm)	Shallow Aquifer		Deeper Aquifer	
		Min	Max	Min	Max
1	pH	7	7.5	7.7	8.47
2	EC(in µS/cm at 25° C)	82	737	290	1128
3	Total Alkalinity	40.16	195	69.67	340.16
4	HCO3	49	238	85	415
5	Cl	7	135	21	128
6	SO4	5	76	0	0
7	F	0.2	0.6	0	0
8	TH	50	305	25	190
9	Ca	4	56	4	42
10	Mg	7.2	60	4	25
11	Na	2.7	53.5	64	237
12	K	0.39	53	1.4	6.3

The above table-5.5 indicates that the ground water of Baramkela was found suitable for drinking purposes, irrigation as well as industrial purposes..

3.4.2 Arsenic contamination: No arsenic contamination in ground water is found in any ground water sample collected in Baramkela block.

3.4.3 Uranium contamination: The ground water in Baramkela block is safe from Uranium contamination point of view.

3.4.4 Type of Ground Water: The ground water of Baramkela block is calcium-magnesium-bicarbonate (Ca-Mg-HCO3) and calcium-sulphate (Ca-SO4) type for shallow aquifer & calcium-bicarbonate (Ca-HCO3) type for deeper aquifer respectively.

3.5 Ground Water Issues:

i. High stage of ground water development of due to over exploitation of resource.
ii. Poor Sustenance of wells due to Inherent character of aquifers having low yield.
iii. Growing of high water consuming crops in-spite of semi-critical stage of GW development.
iv. Declining of water levels.

CHAPTER-IV

AQUIFER MAPPING & MANAGEMENT PLAN

4.1 Aquifer Map:

Finally on the basis of above studies such as the aquifer characteristic of various aquifer groups & ground water level behavior in various seasons, the following maps for Baramkela block were prepared:

(i) Aquifer map 2-dimensionsl, (**Map-5)**

(ii) Aquifer map 3-dimensionsl (**Map-6)**

(iii) Ground water Development Potential & Artificial Recharge Prospect (**Map-7)**

4.2 Status of Ground Water Development Plan:

(i) The ground water development in the block is being done by dug wells and tube well/ bore wells. The dug well depth varies from 5 to 20 m and the diameter varies from 1 to 4 m. The bore wells drilled in the area are 60 to 150 m deep with diameter of 100 to 150 mm. Diesel or electric operated pumps of 1 to 5 HP or traditional tenda is used to lift the water from dug wells for irrigation purposes. The submersible electrical pumps of 3 to 5 HP are used for irrigation purpose in case of bore wells in the area. The bore wells in the area can irrigate an area of 0.5 to 2.5 ha for paddy.

(ii) The stage of ground water extraction for Baramkela block is 77.72 % and is categorized under **Semi-Critical**, there is need for artificial recharge structures in a long term basis to arrest the non-committed run-off to augment the ground water storage in the block. The details of artificial recharge structures to enhance ground water resource are presented in the table-8.

Table-8: Details of AR structures in Pusaur block

Block	Percolation tank recharge capacity 0.2192 mcm	Nalas bunding cement plug/ check dam recharge capacity 0.0326 mcm	Recharge shaft recharge capacity 0.00816mcm	Gully plugs Gabbion structures recharge capacity 0.0073 mcm	Total recharge in mcm
Baramkela	81	271	650	485	35.40

From the table 8, it is depicted that 81 nos. of percolation tank, 271 nos. of nala bunding/cement plug/check dams , 650 nos. of recharge shafts and 485 nos. of gully plug/gabion structures may be constructed at suitable locations that can enhance the ground water source to 35.40 mcm more.

(iii) The stage of ground water extraction in the block is 77.72 %. So there is needed to improve the ground water stressed condition to safe side that is to maintain the stage of ground water extraction less than 60%. Hence from the demand side of ground water management, change in cropping pattern from paddy to maize in Rabi season is an important aspect that can lead to improvement of stage of ground water extraction to 59.15 % from 77.72% if at least 3000 ha cultivated for paddy in Rabi season is cultivated for maize as explained in table-10.

Table-8: Details of change in cropping pattern in Baramkela block

Paddy culti vation area in Rabi season	Water requirement (m) per ha		Difference (m per ha)	Total saving of water (ham)	Existing gross ground water extraction for all uses in ham	Improved status of ground water extraction
	Paddy	Maize				
3000	0.9	0.5	0.4	1200	5024.43	59.15

(iv) Field to field irrigation (flooding method) should be replaced with channel irrigation in command area as there is about 30-40% conveyance loss in field irrigation. same amount of water can be saved through channel irrigation.

(v) Information, education and Communication (IEC) activities such as mass awareness programs to be organized to sensitize people on the issues of depleting groundwater resource, spacing criteria between ells, shifting from summer rice to Maize/ Ragi, to save ground water for future generation, advantages of taking such crops, crop methodology and its related aspects.

(vi) In command or non-command area wherever ground water has been used for field irrigation should be replaced immediately with micro irrigation methods such as sprinklers, drip irrigation etc.

(vii) Government should provide attractive incentives and subsidies to encourage farmers to take up alternative crops to paddy, which are equally profitable and adopt micro-irrigation practices such as drip and sprinkler irrigation.

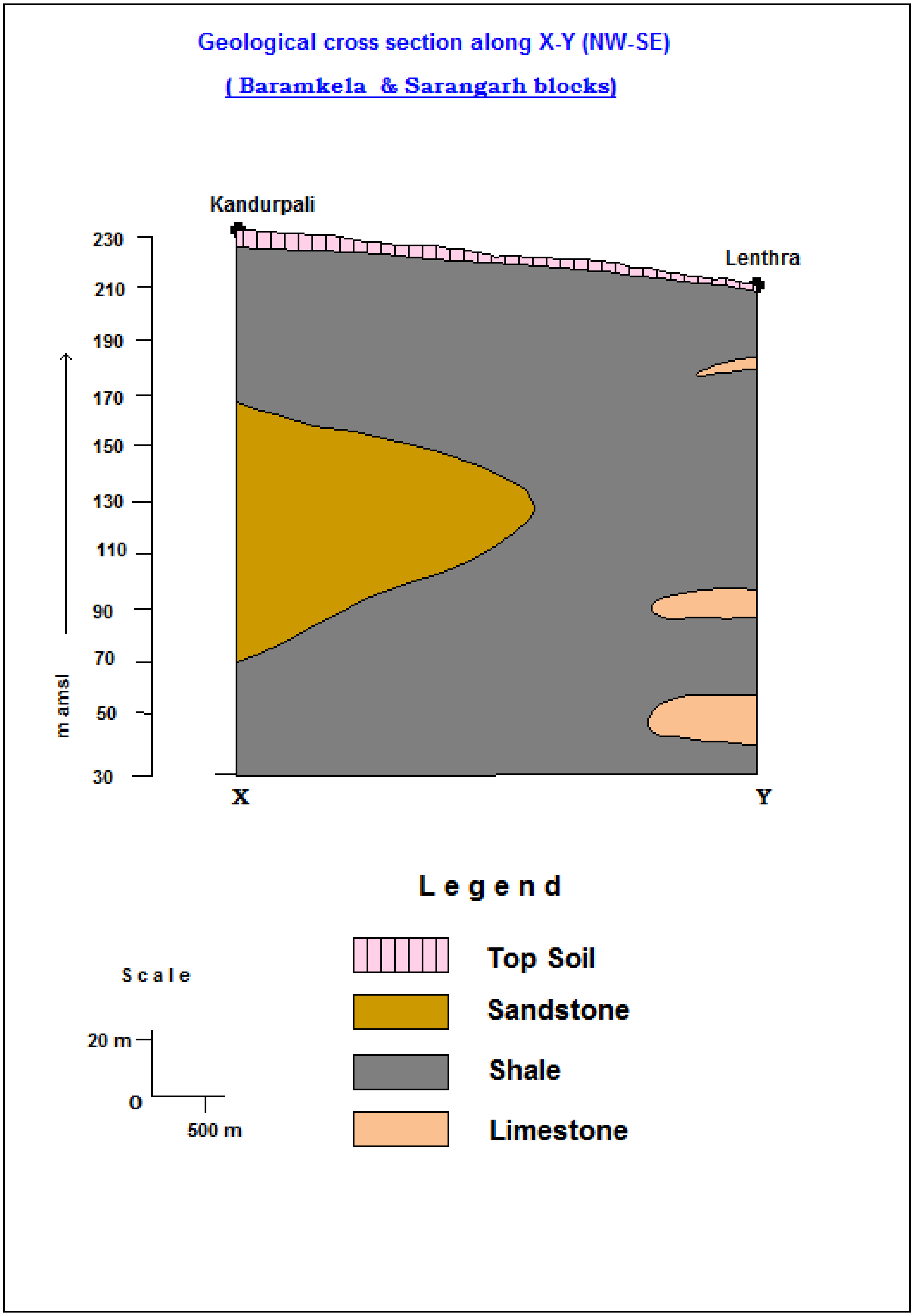
(ix) The practice of providing free electricity to operate irrigation borewells should be strictly monitored and put to an end in case of overconsumption.

(x) Even if farmers use solar pump or other method of ground water irrigation for summer paddy, it should not be flooding method. Proper pipes are to be used to transfer water from one plot to another.

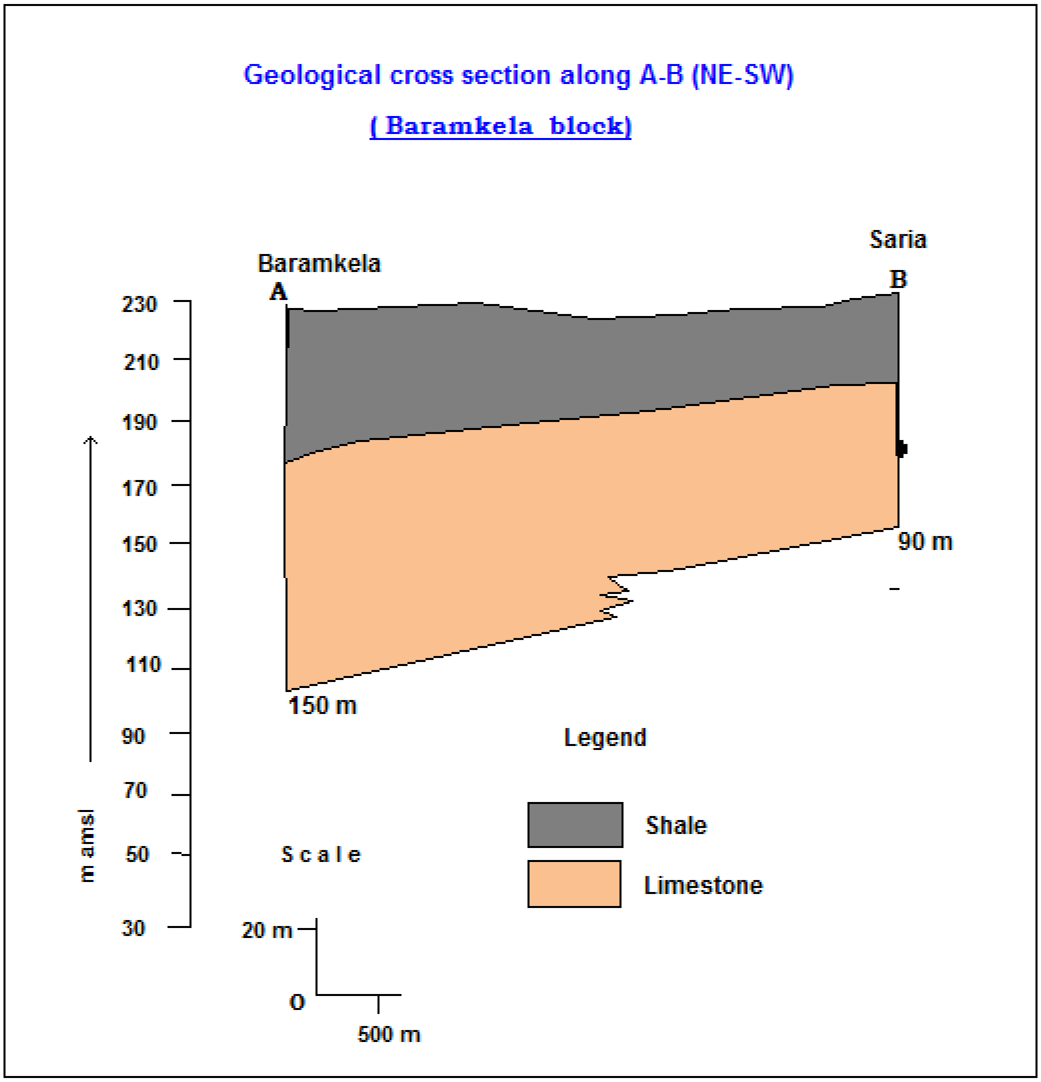
(xi) Govt. may set up network of grids to purchase electricity generated from solar panels. This will encourage the farmers not to waste electricity by extracting groundwater unnecessarily and also provide alternative income.

(xii) Furthermore, in order to strike a balance between the ground water draft and the available resource, suitable artificial structures at appropriate locations be constructed through successive phases after tentatively every 20nos of groundwater abstraction structures become operative.

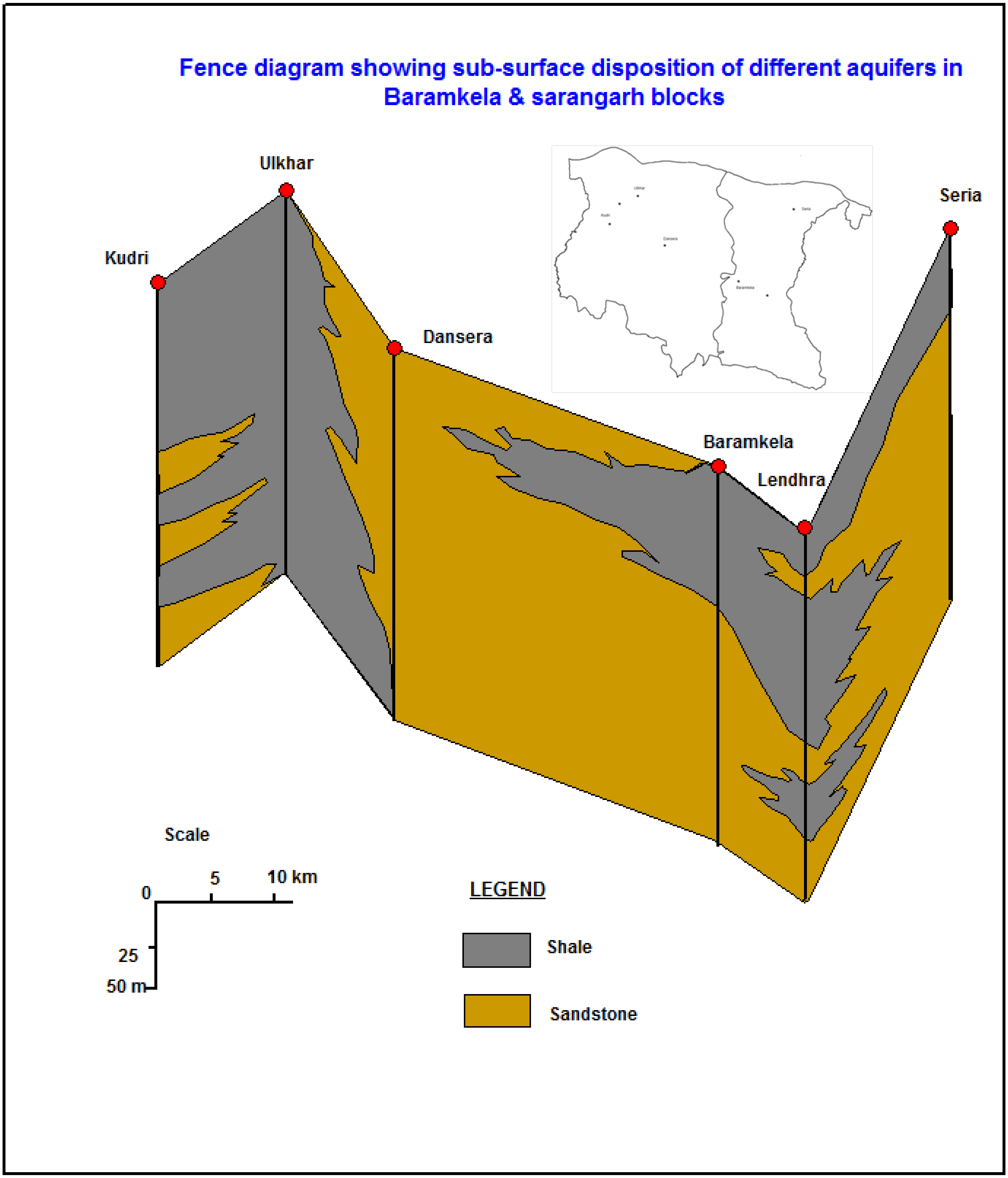
Map-5: Hydrogeological cross section in NE-SW direction



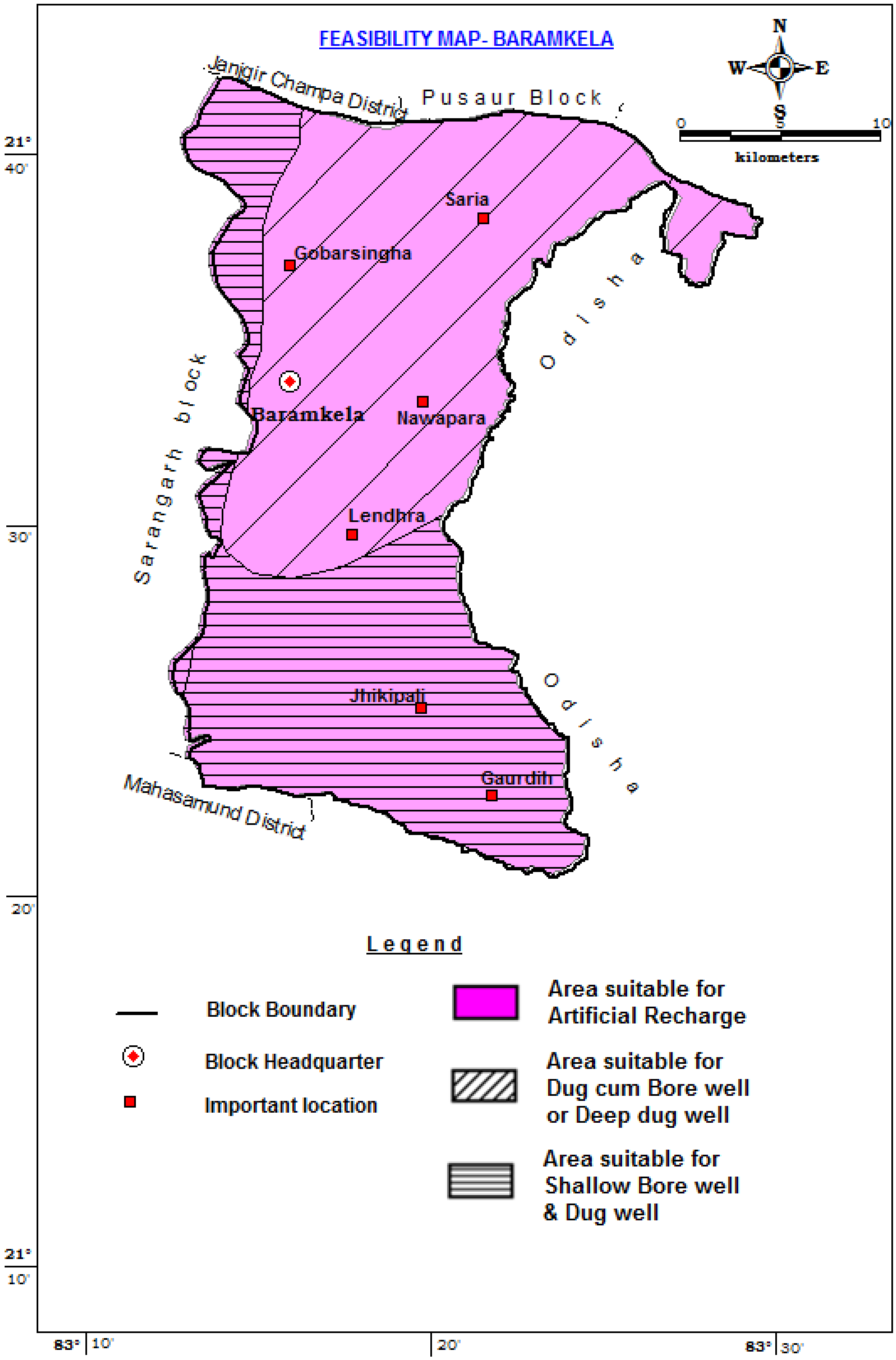
Map-5: Hydrogeological cross section in NE-SW direction



Map-6: 3-dimensional disposition of aquifer



Map-7: Ground Water Development prospect map of Baramkela block



CHAPTER-V

SUM UP

5.1 Conclusions:

Area: 781.34 sq.km taken for study. Average annual rainfall is 971.88 mm. 76% of the total irrigated area is irrigated by groundwater. The Principal Aquifer systems in the block are Chhotnagpur group, Raigarh Group & Chandrapur Group both in phreatic and fractured condition & the major aquifers are (i) Gunderdih Shale (ii) Chhotnagpur Granite Gneiss & (iv) Chandrapur Sandstone. Mahanadi, Kenkamdi and Jira river flowing towards north-east forms the major drainage system in the block. Paddy, Wheat and Gram are the major crops produced in the block.

The ground water level of phreatic aquifer during pre monsoon period ranges from 3.25 to 25.5 mbgl with an average of 11.6 mbgl and during post-monsoon period it ranges from 2.5 to 19.5 mbgl with an average of 7.32 mbgl. The fluctuation ranges from 0.3 to 14.75 m with an average fluctuation of 4.29 m. The long term ground water level trend indicates that there is appreciable change in water level with a falling trend of 17 cm/year both in pre-monsoon and post monsoon period. The average weathered thickness of the phreatic aquifer is around 19.6 m.

The average yield of Gunderdih shale is 6.41 lps with avg transmissivity of 14.58 m^2/day & average drawdown is 13.91 m. One to three sets of potential fracture zone mostly lie within 100 m depth in Gunderdih shale. The average yield of Granite gneiss is 1.42 lps with transmissivity of 1-12 m^2/day & average drawdown is 26.15 m. One to two sets of potential fracture zone mostly lie beyond 100 m depth. The average yield of Chandrapur sandstone is 4.79 lps with a range from 0.85 to 12.5 lps with an average transmissivity of 2.3 m^2/day and average drawdown is 21.46 m. One to two sets of most potential fracture zone lies within 100 m depth.

High stage of groundwater development, inherent character of aquifer giving low yield, growing water consuming crops in spite of critical stage of development and declining of water level are the major ground water issues in the block. Total Annual Extractable Ground Water Recharge 6464.93 ham and present stage of ground water extraction is 77.72 % and is under **semi-critical** category. In a long term sustainable basis, we have to go for artificial recharge, particularly to recharge the area of deeper water level by construction of Percolation Tank (81), Nala bund & Check dam (271), Recharge shafts (650) and gully plug/gabion structures (485) to recharge 35.40 mcm water to underground.

5.2 Recommendations:

- From supply side of ground water management, it is depicted that 81 nos. of percolation tank, 271 nos. of nala bunding/cement plug/check dams , 650 nos. of recharge shafts and 485 nos. of gully plug/gabion structures may be constructed at suitable locations that can enhance the ground water source to 35.40 mcm more.

- From the demand side of ground water management, change in cropping pattern from paddy to maize in Rabi season is an important aspect that can lead to improvement of stage of ground water extraction to 59.15 % from 77.72% if at least 3000 ha cultivated for paddy in Rabi season is cultivated for maize.

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ANNEXURE-I: Exploration details in Baramkela block

SL.NO	LOCATION	LAT	LONG	DEPTH (m)	CASING (m)	FORMATION	ZONE ENCOUNTERED (m)	YIELD (lps)	DRAWDOWN (m)
1	Kandurpali	21.538	83.2867	200	6.5	Gunderdih Shale	26-29,99-102	0.5	
2	Baramkela	21.525	83.258	92	28.55	Gunderdih Shale	18.4 -28, 46-50, 55-60	19.5	7.55
3	Gobar singa	21.6166	83.266	87.4	21.5	Gunderdih Shale	21-23, 34.8-36.8, 38-39, 85-87	16.8	9.9
4	Serla	21.641	83.356	53.2	30.56	Gunderdih Shale	27.5, 33-34,46-48,53-55	19	2.3
5	Bonda	21.654	83.3	35	26.8	Raigarh limestone	11-Aug	1	

ANNEXURE-II: Static Ground Water level details in Baramkela block

S.No	Village	Long	Lat	Source	Pre-Monsoon SWL (mbgl)	Post-Monsoon SWL (mbgl)	Fluctation (m)
1	Baramkela	83.2625	21.525	DW	9	2.9	6.1
2	Malda (B)	83.1956	21.5589	DW	9.95	4.00	5.95
3	Kapartunga	83.225	21.508	DW	6.7	4.5	2.2
4	Budeli	83.194	21.55	DW	6.6	3.1	3.5
5	Sanda	83.298	21.573	DW	4.7	4.4	0.3
6	Panchdhar	83.349	21.643	DW	6.65	4.7	1.95
7	Saria	83.3595	21.63896	DW	5.9	2.8	3.1
8	Paraskhol	83.264	21.532	HP	18.55	10.3	8.25
9	Sanda HP	83.298	21.573	HP	22.5	18.5	4
10	Barpali	83.346	21.615	HP	20.1	19.5	0.6
11	Kandola BW	83.296	21.648	HP	25.5	10.75	14.75

ANNEXURE-III (A): Chemical Quality details of Shallow aquifer in Baramkela block

S.NO.	Location	pH	TDS	EC	CO_3	HCO_3	Total Alkalinity	Cl	F	SO_4	Ca	Mg	Na	K	TH	PO_4	SiO_2	Fe
1	Kapartunga	7.17	213.6	356	0	98	80.33	57	0.49	16	16	17	32	0.78	110	0.00	5	0.159
2	Paraskhol	7.39	49.2	82	0	49	40.16	7	0.50	5	4	7.2	3.8	0.39	50	0.00	10	12.93
3	Budeli	7.28	176.4	294	0	110	90.16	28	0.41	20	12	7.2	43	5	60	0.00	11	0.128
4	Sanda	7.43	133.8	223	0	110	90.16	7	0.32	12	16	14	6.1	1.95	100	0.00	8	0.19
5	Barpali	7.36	154.2	257	0	110	90.16	7	0.37	18	12	7.2	4.3	53	60	0.00	7	0.065
6	Panchdhar	7.23	172.8	288	0	85	69.67	7	0.44	56	22	8.4	13	23	90	0.00	10	0.128
7	Kandola	7.37	151.8	253	0	122	100.00	7	0.41	54	18	25	9.2	27	150	0.00	5	0.472
8	Baramkela	7.5	301.8	503	0	226	185.25	21	0.6	9.3	40	27.6	3.9	1.9	215	0.14	10.4	
9	Bade Nawapara	7.2	324	540	0	98	80.33	85	0.2	29.2	42	15.6	26.9	1.4	170	0.14	8.3	
10	Lendra	7	372.6	621	0	104	85.25	99	0.2	27.8	52	27.6	15.5	0.6	245	0.09	7	
11	Jhikipali	7.2	442.2	737	0	128	104.92	135	0.2	43.9	56	20.4	53.5	1.1	225	0.13	22.4	
12	Mahuapali	7	249.6	416	0	171	140.16	21	0.3	43	30	25.2	10.9	2.1	180	0.1	6.3	
13	Kandola	7.3	396.6	661	0	238	195.08	18	0.3	76	22	60	8.3	2.8	305	0.11	6.1	
14	Barpali	7.2	280.2	467	0	201	164.75	11	0.2	16.6	20	36	2.7	2.5	200	0.11	6.1	

ANNEXURE-III (B): Chemical Quality details of deeper aquifer in Baramkela block

S.NO.	Location	pH	TDS	EC	CO_3	HCO_3	Total Alkalinity	Cl	F	SO_4	Ca	Mg	Na	K	TH	Fe	NO_3
1	Lendhra	8.2	642	1070	0	384	314.75	82		0	4	4	237	2.2	25	0	0
2	Resada	7.7	316.8	528	0	214	175.41	35		0	42	6	64	1.4	130	0	0
3	Chhichorumaria	8.2	676.8	1128	0	415	340.16	128		0	10	11	221	6.3	70	0	0
4	Kutela	8.1	174	290	0	85	69.67	35			40	5			120		
5	Baramkela	8.4	228	380	0	195	159.84	21			34	25			190		

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