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

GHARGHODA BLOCK, RAIGARH DISTRICT, CHHATTISGARH

उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर

North Central Chhattisgarh Region, Raipur

स्वच्छ जल : स्वच्छ भारत

केन्द्रीय भूमि जल बोर्ड

उत्तर मध्य छत्तीसगढ़ क्षेत्र

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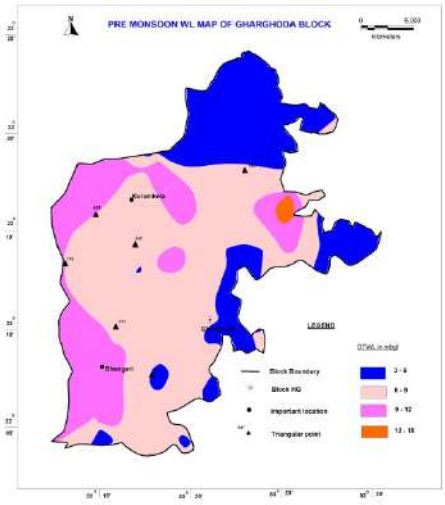
केन्द्रीय भूमि जल बोर्ड
CENTRAL GROUND WATER BOARD

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

By
Sh. A K Biswal (Scientist-D)



North Central Chhattisgarh Region
Raipur
2020

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

By
Sh. A K Biswal (Scientist-D)

Type of Study	**Officer engaged**
Data compilation, Data Gap Analysis & Data Generation	Sri S.Acharya, Scientist-D, (AAP-2015-16)
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

GHARGHODA BLOCK, RAIGARH DISTRICT, CHHATTISGARH

1.	**GENERAL INFORMATION**	
	i) Geographical area (Sq. km)	433.04
	ii) Administrative Divisions (As on 2017)	
	a) Number of Villages	83
	iii) Population as on 2011 Census	69970
	iv) Average Annual Rainfall	1358.82.48mm
2.	**GEOMORPHOLOGY**	
	i) Major Geomorphological Units	Structural plain on Gondwana rocks
	ii) Major Drainages	Mahanadi Basin (Mand ,Kurket & Korega)
3.	**LAND USE (ha) As on 2016-17**	
	i) Forest Area	4575
	ii) Net Area Sown	23877
	iii) Double cropped Area	1927
4.	**MAJOR SOIL TYPES**	Ultisols-Red sandy soil
5.	**AREA UNDER PRINCIPAL CROPS, in ha (As on 2016-17)**	Paddy-17310, Wheat-33, Pulses-3232, Tilhans-1406, Fruits and vegetables- 170
6.	**IRRIGATED AREA BY DIFFERENT SOURCES in ha (As on 2016-17)**	
	i) Dug wells	84
	ii) Tube wells/Bore wells	836
	iii) Canals	236
	iv)Tanks	91
	v) Other sources	407
	vi) Area Irrigated more than once	1233
7.	**NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on March'2019)**	
	i) No of Dug wells	11
	ii) No of Piezometers	3
8.	**PREDOMINANT GEOLOGICAL FORMATIONS**	
	Gondwana Supergroup (Sandstone, shale, coal)	

9. HYDROGEOLOGY

i) Major Water Bearing Formations	Weathered & fractured sandstone.
ii) Pre-monsoon Depth to Water Level	3.4 to 13.1 mbgl
iii) Post-monsoon Depth to Water Level	1.92 to 8.69 mbgl
iv) Long Term Water Level Trend for 10 yrs in m/yr	**Post-monsoon-**Fall: 0.002 to 0.017 Rise 0.001 to 0.002

10. GROUND WATER EXPLORATION BY CGWB (As on March'2019)

i) No of Wells Drilled	EW: 12, OW: 04
ii) Depth Range (m)	147 – 350.94
iii) Discharge (litres per second)	Neg to 7.8
iv) Transmissivity (m^2/day)	1.625 – 142.75

11. GROUND WATER QUALITY

i) Presence of Chemical Constituents	EC for Shallow aquifer is 33 to 1498 and for deeper aquifer is 605 to 2100 µS/cm at 25°C, P^H - 6.7 to 7.9 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	2798.23
ii) Total Annual Ground Water Extraction	1229.78
iii) Ground Water Resources for Future use	1541.29
iv) Stage of Ground Water Development	43.95 %
v) Category	Safe

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) In active coal-mining areas where huge quantity of groundwater is regularly pumped during mining, it's impact on the ground water regime is appreciable in & around Nawapara.

(ii) In some areas the water level remains more than 5m in the post-monsoon period in this block which may be a matter of concern in future.

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 Gharghoda 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 GHARGHODA BLOCK, RAIGARH DISTRICT, CHHATTISGARH" " is prepared by Sh. A.K.Biswal, Scientist-D (CGWB,NCCR,Raipur) and is the result of untiring efforts Sh. S.Acharya, Sc-D, (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 Gharghoda 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.

Sh. A.K.Biswal
(REGIONAL DIRECTOR (I/C))

EXECUTIVE SUMMARY

The Gharghoda block covers a geographical area of 433.04 sq. km. It is situated in the north central part of Raigarh district of Chhattisgarh lying between 22004' and 22024'30'' N latitudes and 83012' and 83030'' E longitudes comprising 61 village panchayats and 83 villages .According to 2011 census the total population of the block is 69970. About 7.31 % of the net sown area is irrigated by all sources. Ground water contributes nearly 52.7 % of the net irrigated area.

Gharghoda block experiences Sub-tropical climate characterized by extreme cold in winter and extreme hot in summer. The average annual rainfall is 1358.82 mm (average of last five years i.e 2012-2017). The annual temperature varies from 10^0C in winter to 46^0C in summer. The relative humidity Varies from 85 % in rainy season to 35-40 % during winter. The block is mainly drained by the rivers-Kurket which is perennial in nature. The drainage system in Gharghoda block originates at the northern part and flow towards South direction before joining the Mahanadi river.

Geomorphologically the Gharghoda block is characterized by Structural plain on Gondwana rock. The general elevation of the plain is around 300 m amsl. The elevation in case of structural hills ranges from 400 to 657 m amsl. This region has a general slope towards the south. The foothills are characterized by pediments.

Geologically Gharghoda block is mainly covered by rocks comprising semi consolidated rock belonging to Gondwana Super group with some patches of plutonic rocks in northern part.

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 Gharghoda block is (i) Gondwana Super Group.

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 17 m bgl. The average yield of Gondwana sandstone is 4.32 lps with a transmissivity of 1.35 to to 142.75 m²/day and average drawdown is 23.8 m. One to three sets of most potential fracture zone lies between 100 to 200 m depth in Gondwana sandstone.

67 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 3.4 to 13.1 mbgl with an average of 7.02 mbgl and during post-monsoon period it ranges from 1.92 to 8.69 mbgl with an average of 5.4 mbgl. The fluctuation ranges from 0.01 to 5.6 m with an average fluctuation of 2.04 m. The long term ground water level trend indicates that there is no appreciable change in water level both in pre-monsoon and post monsoon period at most of the locations. The average weathered thickness of the phreatic aquifer is around 18 m.

The regional ground water flow direction is towards south & south-west. 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 Gharghoda block is 2798.23 ham. The Net Ground Water Availability for future use is 1541.29 ham. Current Annual Ground Water Extraction for all purposes is 1229.78 ham out of which 1007.97 ham is for irrigation. The overall Stage of Ground Water Extraction in the block is 43.95 %. The Annual GW Allocation for domestic Use as on 2025 is 224.93 ham. As per the NAQUIM study in the block, from supply side of ground water management, construction of 281 nos of irrigation tube wells (60 to 150 m deep with diameter of 100 to 150 mm) or 624 nos of irrigation dug wells (5 to 20 m deep with diameter varies from 1 to 4 m) may be done at suitable places that can create an irrigation potential of 499 ha of paddy, 1122.5 ha of wheat, Ground Nut, Sunflower and 1496.67 ha of Mustard & Pulses.

Similarly in a long term sustaining basis 28 nos. of percolation tank, 95 nos. of nala bunding/cement plug/check dam, 229 nos of recharge shaft and 170 nos of gully plug/gabion structures can be constructed to recharge the area of deeper water level that can recharge 12.33 mcm ground water.

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 Gharghoda 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 Gharghoda 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 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 GHARGHODA BLOCK, RAIGARH DISTRICT, CHHATTISGARH".

A.K.Biswal

Scientist-D

AQUIFER MAPPING AND MANAGEMENT PLANS
IN GHARGHODA 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 multi disciplinary 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 Gharghoda block was studied under NAQUIM program in 2015-16.

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 12 nos. of exploratory wells & 4 nos of observation wells were drilled by CGWB in various periods in different formation, 67 nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 75 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:

Gharghoda Block is situated in the north central part of Raigarh district of Chhattisgarh and is bounded on the north by Lailunga block, in the west by Dharamjaigarh block, in the east by Tamnar block and in the south by Kharsia block. The area lies between $22^0$04' and $22^0$24'30'' N latitudes and $83^0$12' and $83^0$30'' E longitudes. The geographical extension of the study area is 433.04 sq.km representing around 6.30 % of the district's geographical area.

Administrative map of the block is shown in **map-1**. Kurket river flowing southwards along with its tributaries 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 Gharghoda block as per 2011 Census is 69970 out of which rural population is 69970 living in 83 nos of villages. The decadal growth rate of the block is 18.72 as per 2011 census. The population detail is given in table-1 below –

Table- 1: Population Break Up

Block	Total population	Rural population	Urban population	Nos of Villages/ village panchayats
Gharghoda	69970	69970	Nil	83/61

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) 1358.82 mm with 50 to 60 rainy days. The rainfall detail is presented in table-2.

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

Block	Rainfall in mm				
	2012-13	2013-14	2014-15	2015-16	2016-17
Gharghoda	1497	1540.3	1207.2	1290	1259.6
Average	1358.82				

Source: Land and Revenue Department, Raigarh district

1.7 Agriculture and Irrigation:

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 Gharghoda block is given in Table 3 (A, B, C, D).

Table-3 (A): Land use pattern in Gharghoda 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
Gharghoda	4575	4720	9047	6689	23877	1927	22582

Source: District Statistical Book-2017

Table-3 (B): Cropping pattern in Gharghoda 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					
Gharghoda	21087	1495	17310	33	2	184	3232	1406	170	32	6

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

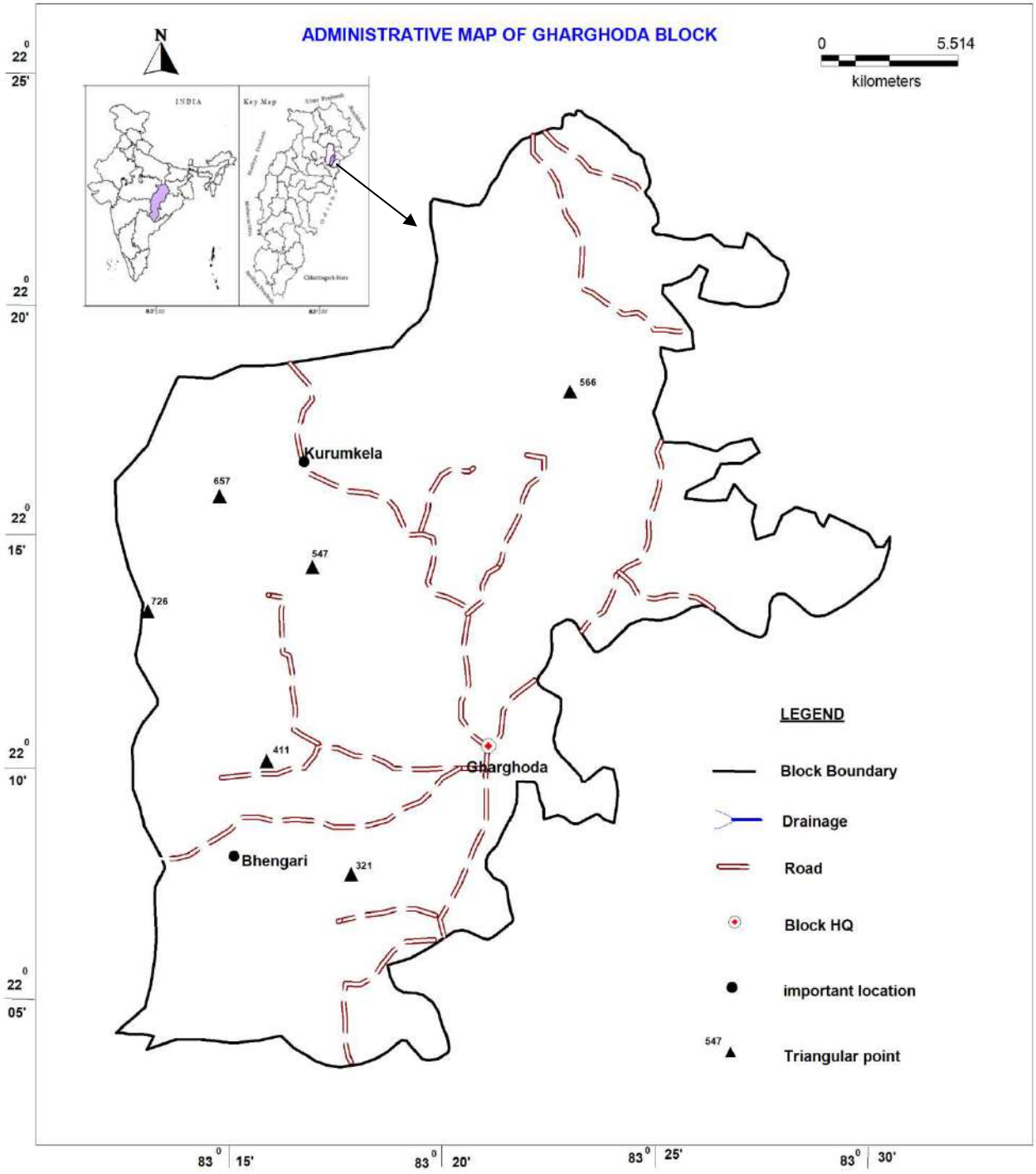
Blocks	Canal (private and Govt.)		Bore wells/ Tube wells		Dug wells		Talabs		Irrigated area by other sources	Irrigated area by GW sources	Net Irri-gated area	Irrigated area more than once	Gross irrigated area	% of Net irrigated area to net area sown
	Nos	Irrigated area (ha)	Nos	Irrigated area	Nos	Irrigated area	Nos	Irrigated area						
Gharghoda	12	236	368	836	394	84	77	91	407	920	1746	1233	1887	7.31

Source: District Statistical Book-2017

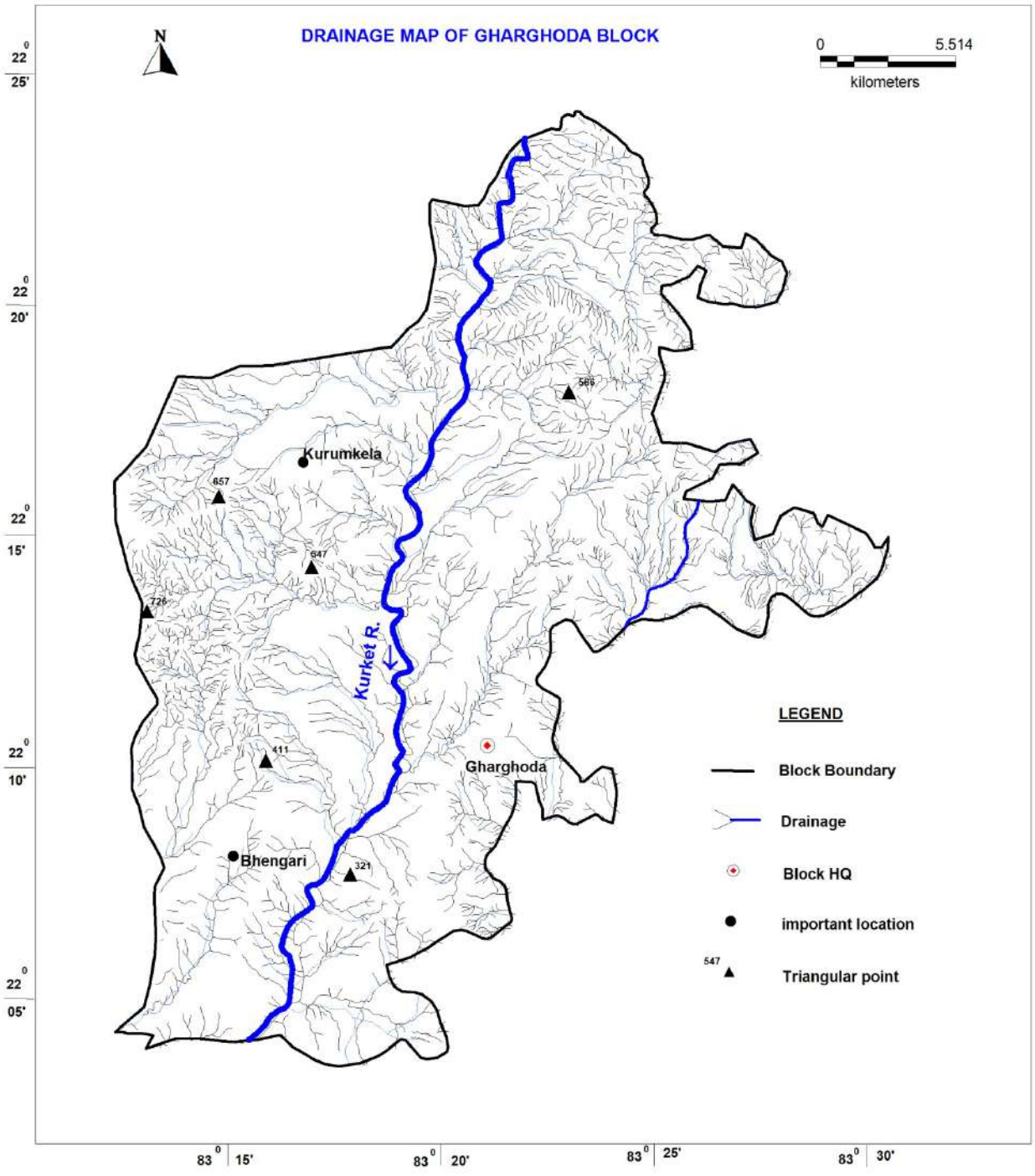
Table 3 (D): Statistics showing Agricultural land Irrigated

Block	Net Irrigated Area	Net Irrigated Area by ground water	Percentage of Area Irrigated by ground water
Gharghoda	1746	920	52.7 %

Map-1: Administrative map of Gharghoda block



Map-2: Drainage map of Gharghoda block



CHAPTER-2

DATA COLLECTION & GENERATION

2.1 Introduction:

About 16 nos. of exploratory wells drilled by CGWB out of which 4 are observation in various periods in different formation (table-4), 67 nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 75 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 Gharghoda block.

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

Block	Gondwana formation	Gunderdih Shale	Charmuria Limestone	Chandrapur Sandstone	Crystallines	Total
Gharghoda	12	-	-	-	-	12

2.2 Exploration:

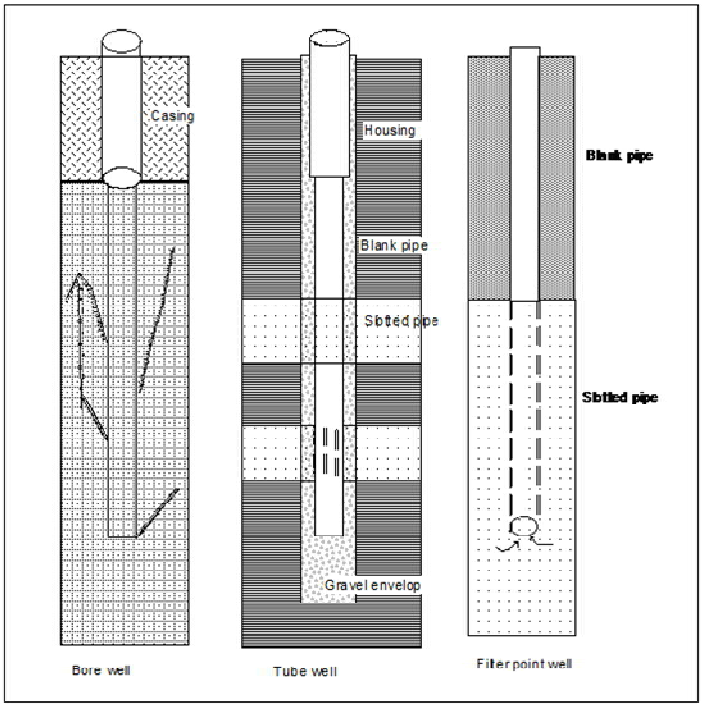
Hard and soft rocks need separate well design. Since Gharghoda block is mostly covered by semi-consolidated rock, so well construction is done with rotary drilling methods. During the exploration, cutting materials are collected in every 3 m interval of depth and kept in a wooden box prepared for the 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. Variable discharge test, SDT (Step draw down test) has been conducted in several wells of Gondwana semi consolidated formation through three or four steps. The well loss and formation loss components of draw down were calculated by determining the well loss coefficients (B) and formation loss coefficients (C). The well efficiency and specific capacity determined by SDT can also be indicative of hydraulic characteristics of the aquifer. The details of the exploratory well is given in **Annexure-I.**

2.2.1 Well design:

In semi-consolidated Gondwana rocks, gravel pack tube wells are constructed by rotary rig. The pilot hole is drilled first up to the desired depth followed by geophysical logging. Based on the litho log and geophysical log well assembly (combination of blank and slotted pipes) is recommended (**Fig. 1).** Well assembly is lowered after the reaming of the well bore by bit of suitable size. Lowering of assembly is followed by gravel shrouding and development of the well by cleaning the slots by jetting and air compressor.

It has been observed that State and private agencies have drilled bore wells in semi-consolidated Gondwana rocks by DTH method but the wells did not withstand pumping whereas the durability of such bores are more when they are fitted with hand pumps which implies that the semi-consolidated Gondwana rocks of the state have enough strength to stand without the support of mud cake but can't sustain pumping. The bentonite mud used during drilling operation is difficult to remove by the prevailing well development techniques for these rocks and resulted in chocking of pores as well as decline in well efficiency. So, local mud can be used as alternative for drilling which can easily be removed by developing the well as a result the efficiency of the well can be improved. Even large diameter wells drilled by DTH method followed by gravel shrouding and well development by jetting can be a cheaper alternative for construction of well in Gondwana rocks.

Fig-1: Well Design



2.3 <u>Water Level data</u>:

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 67 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 <u>Hydrochemical data</u>:

The hydrochemical analysis of the ground water of the block was based mostly on the analysis of 75 nos of 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 Gharghoda 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, SO_4 and F by Spectrophotometer, NO_3 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

Gharghoda 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 Gharghoda 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 Gharghoda block.

CHAPTER-3

AQUIFER DISPOSITION

3.1 Principal & Major aquifer groups:

The aquifer material controlling ground water flow in Gharghoda 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 up to 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 group in Gharghoda block is (**Map-3**):

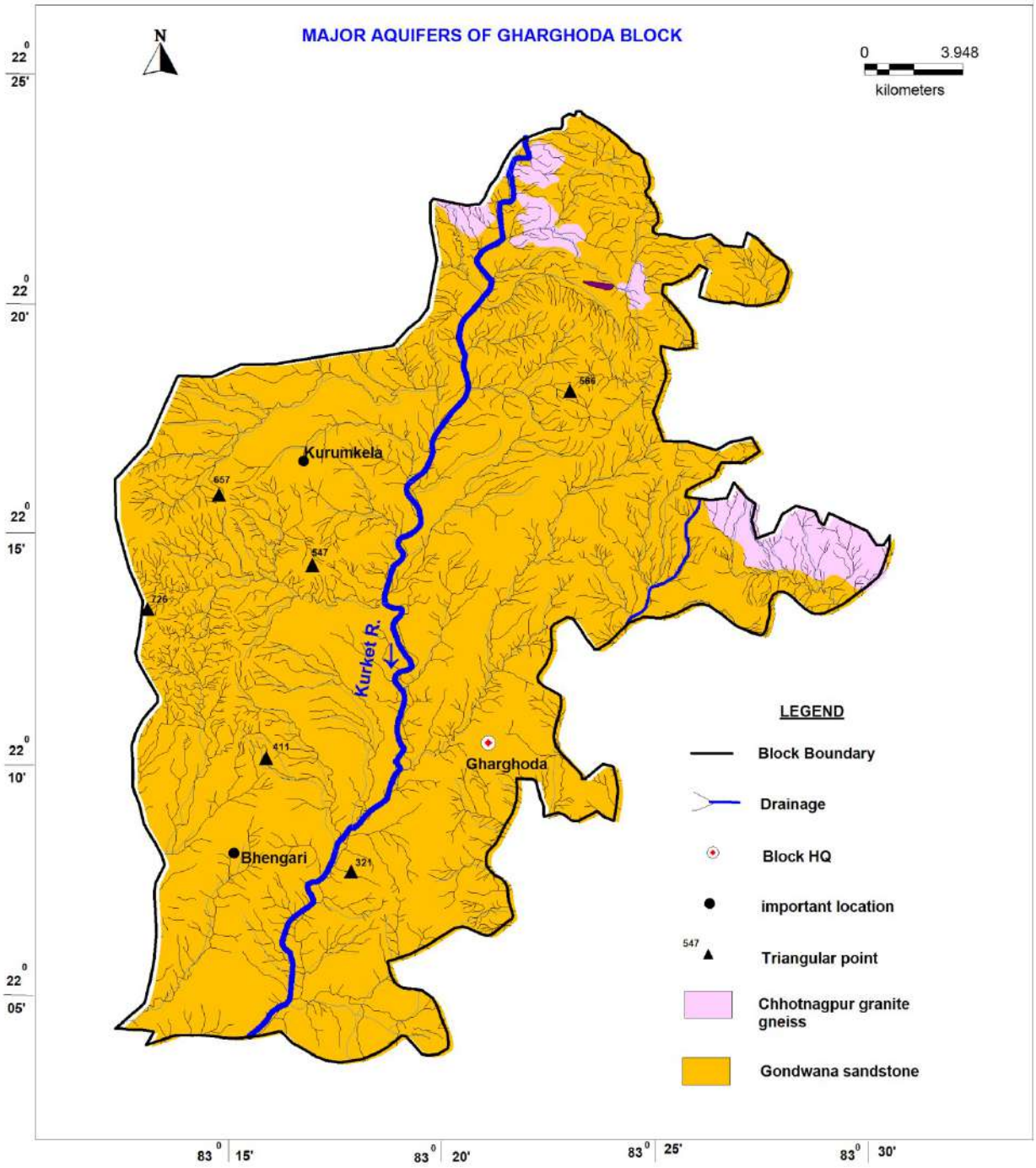
(i) Gondwana Sandstone

(i) Gondwana Sandstone: All the parts of the block is covered by Gondwana Formation except few patches which are covered by plutonic & has no problem of sustainability. The weathered zone followed by granular and fractured zone provides sufficient water to the wells. In the Gondwana formation the deeper aquifer to a depth of 400 m bgl has been deciphered. The deeper aquifer zones in Gondwana Formation are more productive than shallower zones. The tube wells constructed beyond 200m depth have good discharge. All other wells having depth range of 200m have limited discharge. In these wells the upper 30m zone has not been tapped. The Gondwana rock of the area is divided in to (a) Talchir Formation (2) Karharbari Formation (b) Barakar Formation and (c) Kamthi Formation. The Gondwana rock is faulted and Intrusives are rarely present. The average yield of Gondwana sandstone is 4.32 lps with a transmissivity of 1.35 to 142.75 m^2/day and average drawdown is 23.8 m. One to three sets of most potential fracture zone lies between 100 to 200 m depth in Gondwana sandstone.

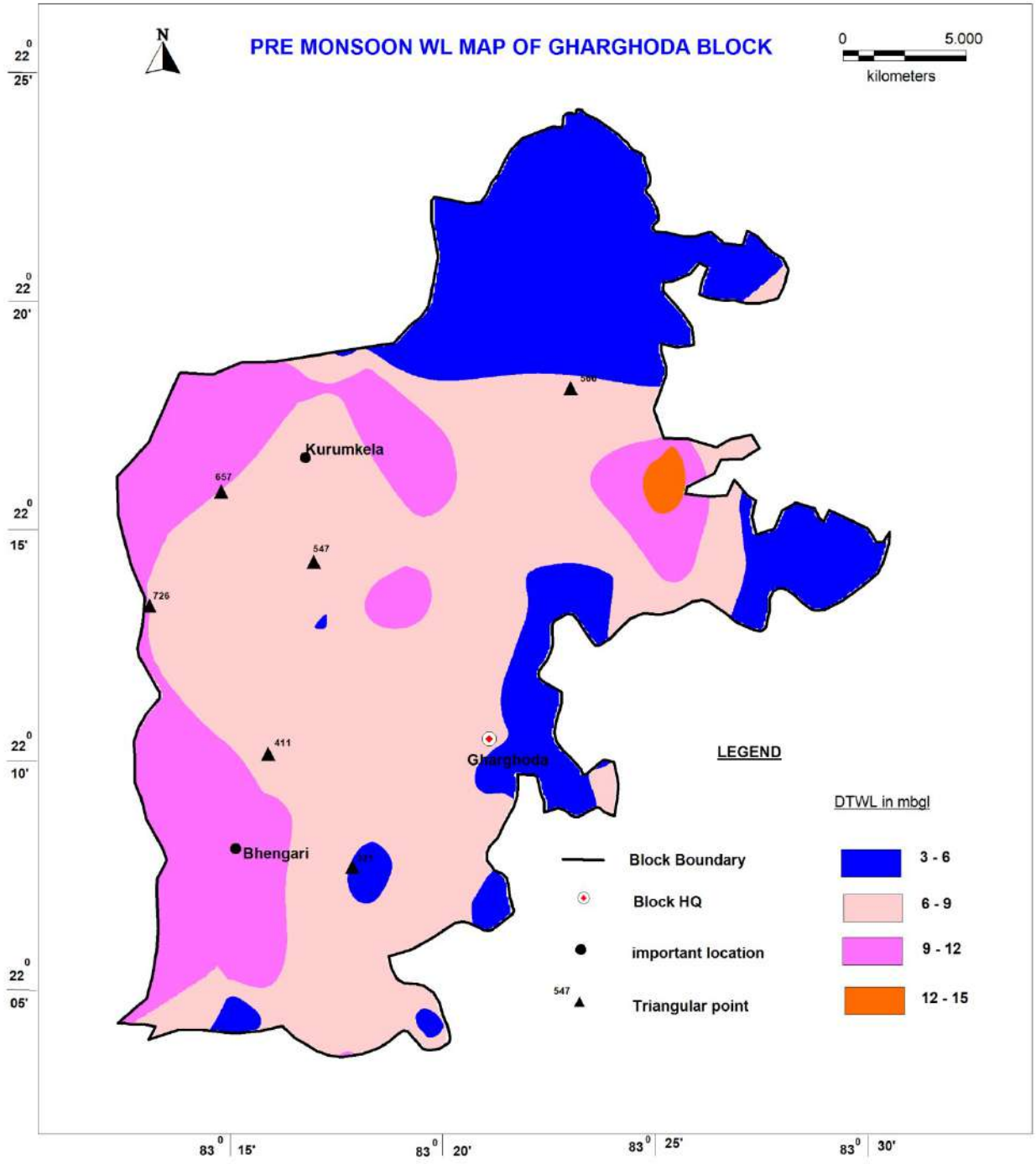
3.2 Ground Water Regime monitoring:

During the study, 67 nos. of observation wells were 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 3.4 to 13.1 mbgl with an average of 7.02 mbgl and during post-monsoon period it ranges from 1.92 to 8.69 mbgl with an average of 5.6 mbgl. The fluctuation ranges from 0.01 to 5.60 m with an average fluctuation of 2.04 m. The long term ground water level trend indicates that there is no appreciable change in water level both in pre-monsoon and post monsoon period at most of the locations . The average weathered thickness of the phreatic aquifer is around 18 m. The water level map prepared for the district is presented in (**Map-4 A, B &C**).

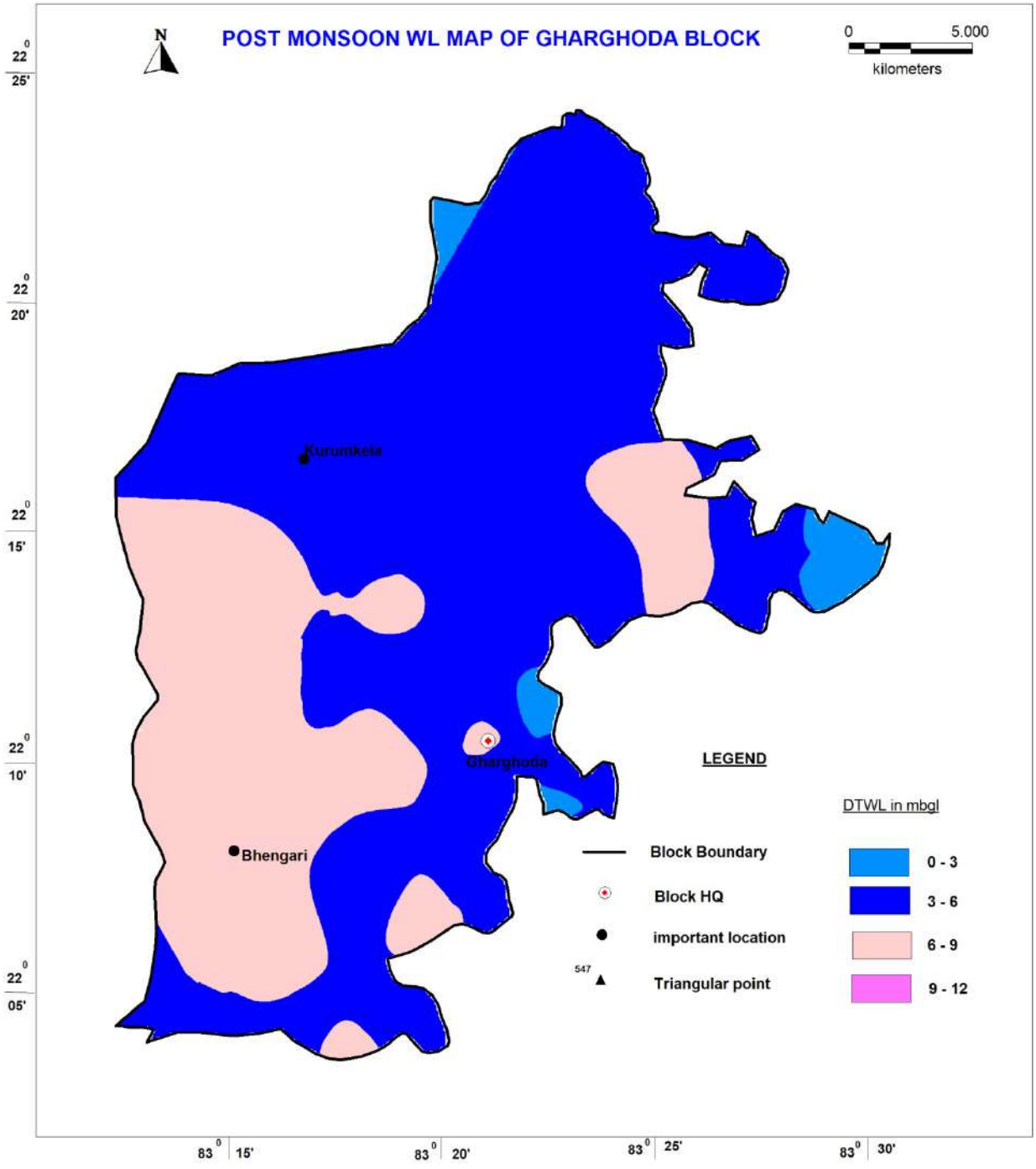
Map-3: Major Aquifer map of Gharghoda block



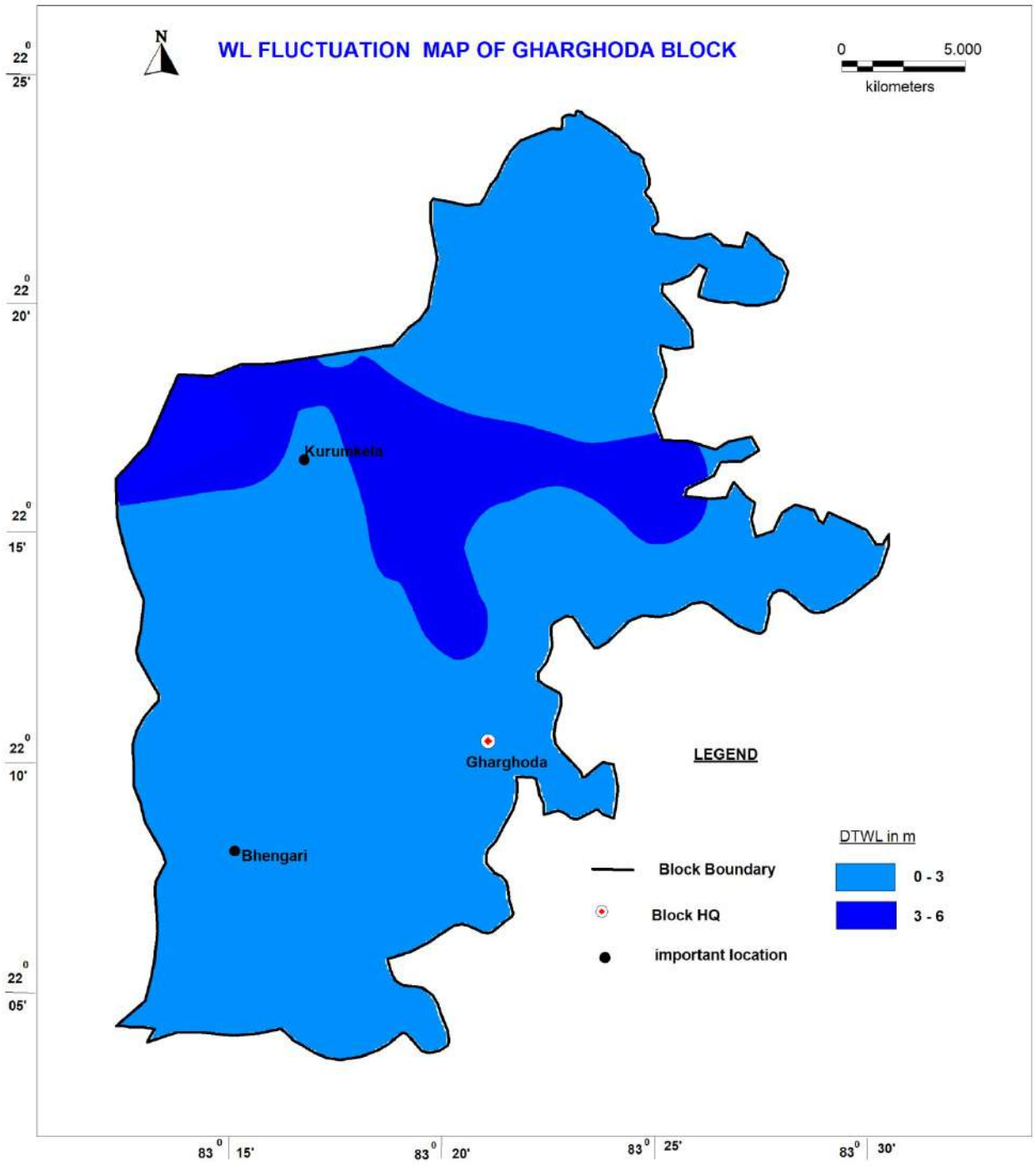
Map-4 (A): Pre-monsoon depth to water level map of Dharamjaigarh block



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



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



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 Gharghoda 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 50 % of the wells show declining trend to the tune of 0.01 to 0.002 m/yr. The rising trend is shown by 50 % of wells in the tune of 0.00 to 0.002 m/yr. The hydrograph of some of the wells are presented in **Fig-2.** 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 Gharghoda block

SN	Block	Site name	Longitude	Latitude	Trend (2010-2019) postmonsoon	Remarks
1	Gharghoda	Gharghoda	83.35	22.17	-0.002714	Declining
2	Gharghoda	Chimtapani	83.42	22.27	0.002275	Rising
3	Gharghoda	Dumarpali	83.28	22.29	0.001401	Rising
4	Gharghoda	Bhangari	83.25	22.13	-0.017466	Declining

3.2.2 Ground Water flow direction:

The regional ground water flow direction is towards south-west. 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 Gharghoda 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 Gharghoda block is 2798.23 ham. The Net Ground Water Availability for future use is 1541.29 ham. Current Annual Ground Water Extraction for all purposes is 1229.78 ham out of which 1007.97 ham is for irrigation. The overall Stage of Ground Water Extraction in the block is 43.95 %. The Annual GW Allocation for domestic Use as on 2025 is 224.93 ham. The block wise resource is presented in table 6.

Table-6: Resources as estimated in 2017 of Gharghoda 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)
Gharghoda	2798.23	1007.97	24.04	197.77	1229.78	224.93	1541.29	43.95	Safe	No	

3.3.2 Static Ground Water Resources:

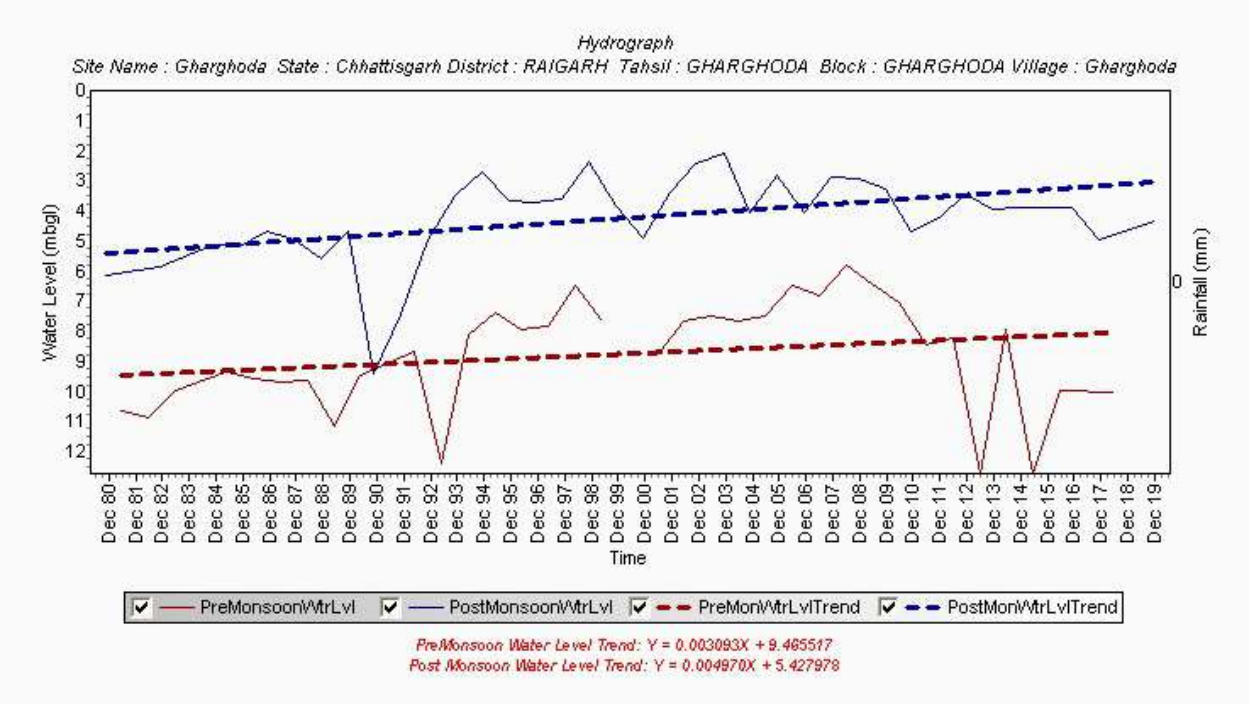
An attempt has been made to assess the Static Ground Water Resources Gharghoda block which is the resource that remains available below the dynamic zone of water table fluctuation. This is not replenished every year and extracting this water is ground water mining. The quantum of ground water available 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 Gharghoda block.

Table-7: Ground water Resources of Gharghoda block

Block	Recharge worthy Area (Ha)	Stage of Extraction in %	Static Resource in Ham	Dynamic Resource in Ham
Gharghoda	29935	43.95	1314.745	2798.230

The table shows that the total static ground water resource of Gharghoda a block is 1314.745 ham beside the dynamic ground water resource of 2798.23 ham.

Fig- 2: Hydrograph of Gharghoda



3.4 <u>Ground Water Quality</u>:

Ground water quality of shallow aquifer as well as deeper aquifer in Gharghoda block for drinking, irrigation and industrial purposes is assessed on the basis of analysis of ground water samples collected from 73 nos. of observation wells for shallow aquifer & 2 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 <u>Water quality for all purposes:</u> 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	6.7	8.3	7.7	7.9
2	EC(in µS/cm at 25° C)	33	1498	605	2100
3	Total Alkalinity	0	235.24	169.67	214.75
4	HCO_3	6	287	207	262
5	Cl	4	312	28	50
6	SO_4	0	91	0	0
7	F	0	1.4	0	0
8	TH	15	470	150	730
9	Ca	4	98	4	98
10	Mg	1.1	68	16	19
11	Na	1.1	79	43	
12	K	0.7	134	19	

The above table-5.5 indicates that the ground water of Gharghoda 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 Gharghoda block.

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

3.4.4 Type of Ground Water: The ground water of Gharghoda block is 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.

3.5 Ground Water Issues:

i. Throughout the study area, the water quality (of the shallow aquifer) is good although in a few places Nitrate content and total alkalinity is considerably high in shallow groundwater.

ii. In some areas the water level remains more than 5 m in the post- monsoon period in this block which may be a matter of concern in future.

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 Gharghoda block were prepared:

(i) Aquifer map 2-dimensionsl, (**Map-5 A,B,C)**
(ii) Ground water Development Potential & Artificial Recharge Prospect (**Map-6)**

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) Since the stage of ground water extraction for Gharghoda block is 43.95 %, the block can be developed through tube wells and dug wells both to achieve the stage of extraction 60%. The following table-9 depicts the numbers of ground water abstraction structure to be constructed for further development in the block.

Table-9: Irrigation tube wells and dug wells to be constructed in Gharghoda block

Block	**Stage of ground water extraction (%)**	**Number of TW Recommended (Assuming unit draft as 1.6 ham/structure/year)**	**Number of DW Recommended (Assuming unit draft as 0.72 ham/structure/ year)**	**Irrigation potential likely to be created for paddy (Ha)**	**Irrigation potential likely to be created for wheat, Ground Nut, Sunflower (Ha)**	**Irrigation potential likely to be created for Mustard & Pulses (Ha)**
Gharghoda	43.95	281	624	499	1122.5	1496.67

(iii) The stage of ground water development for Gharghoda block is 43.95 % and it has been observed from there is deeper post monsoon water level in shallow aquifer zone at many places. So in these places where the post monsoon piezomteric head is below 10 mbgl, artificial recharge structures may be constructed in a long term basis to arrest the non-committed run-off to augment the ground water storage in the area. The details of artificial recharge structures to enhance ground water resource are presented in the table-10 respectively.

Table-10: Details of AR structures in Gharghoda 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
Gharghoda	28	95	229	170	12.33

From the table 9, it is depicted that 281 nos of irrigation tube wells or 624 nos of irrigation dug wells or combination of these two may be constructed in the block that can likely to create an irrigation potential of 499 ha for paddy, 1122.5 ha for wheat, Ground Nut, Sunflower and 1496.67 ha for Mustard & Pulses respectively.

From the table 10, it is depicted that 28 nos. of percolation tank, 95 nos. of nala bunding/ cement plug/check dams , 229 nos. of recharge shafts and 170 nos. of gully plug/gabion structures may be constructed at suitable locations that can enhance the ground water source to 12.33 mcm more.

(iii) 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.

(iv) 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.

(v) 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.

(vi) 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.

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

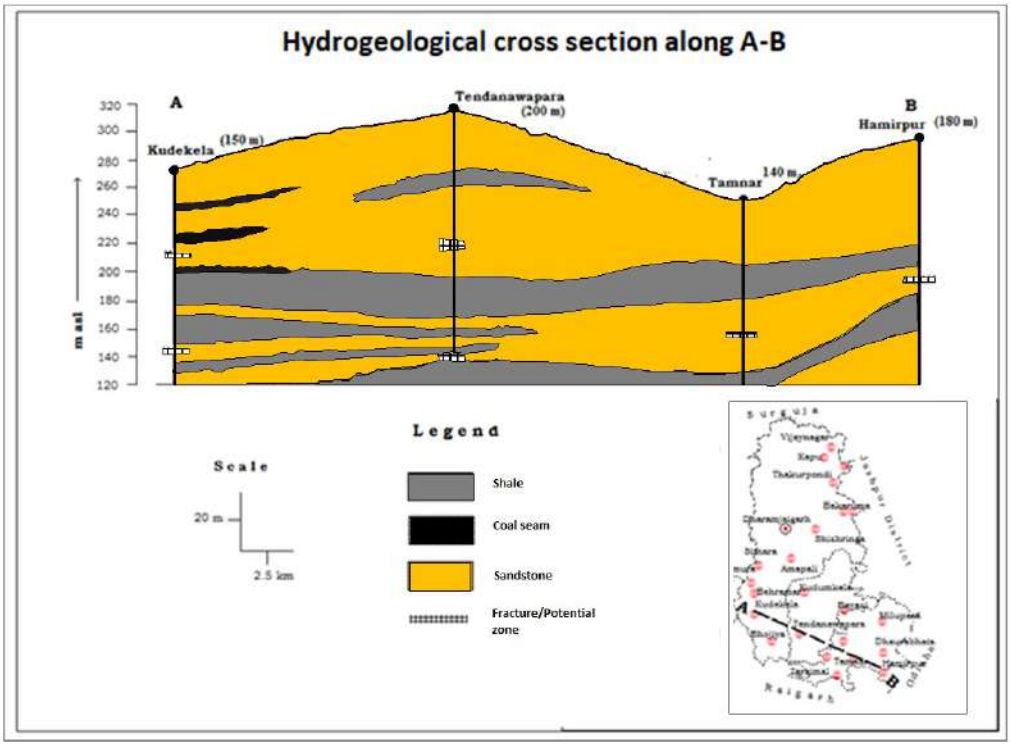
(ix) Even if farmers use solar pump or other method of ground water irrigation for summer paddy, it should not be flooding method. Proper pipes are to be used to transfer water from one plot to another.

(x) 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.

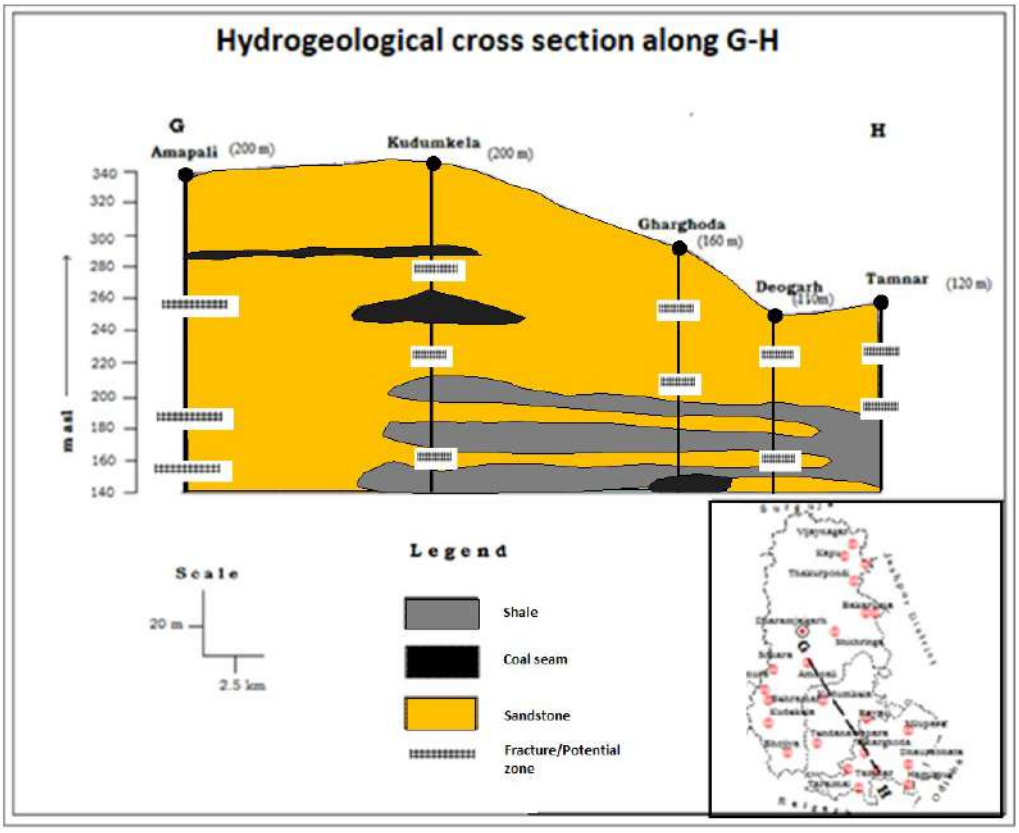
(xi) Supports for the technology development for harvesting and disposal of by-products in agriculture fields which will also increase the fertility of soil.

(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.

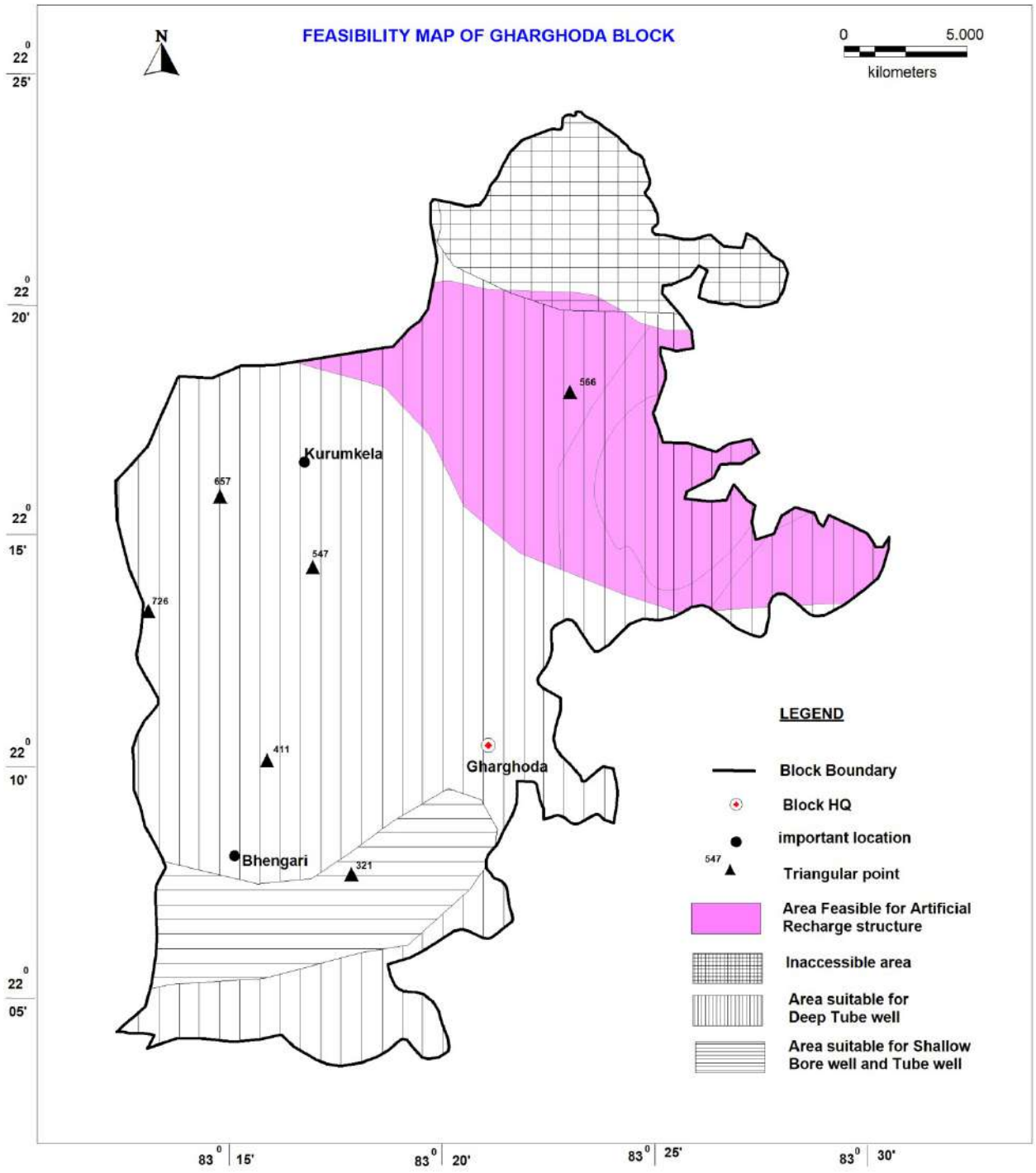
Map-5 (A): Hydrogeological cross section in NE-SW direction



Map-5 (B): Hydrogeological cross section in NE-SW direction



Map-6: Ground Water Development prospect map of
Gharghoda block



CHAPTER-V

SUM UP

5.1 Conclusions:

Area: 433.04 sq.km taken for study. Average annual rainfall is 1358.82 mm. 33% of the net irrigated area is irrigated by groundwater. The Principal Aquifer System in the block is Gondwana formation both in phreatic and fractured condition and the major aquifer group in the block is Gondwana sandstone. Kurket and Kola River flowing towards south-west forms the major drainage system in the block. Paddy, Wheat and Gram are the major crops produced in the block.

The average ground water level of phreatic aquifer during pre monsoon period is 7.02 mbgl with a range from 3.4 to 13.1 mbgl and during post-monsoon period it is 4.99 mbgl with a range from 1.92 to 8.69 mbgl. The fluctuation ranges from 0.01 to 5.6 m with an average fluctuation of 1.872.04 m. The long term ground water level trend indicates that there is no appreciable change in water level both in pre-monsoon and post monsoon period at many of the locations. The average weathered thickness of the phreatic aquifer is around 18 m.

The average yield of Gondwana sandstone is 4.32 lps with a transmissivity of 1.35 to to 142.75 m^2/day and average drawdown is 23.8 m. One to three sets of most potential fracture zone lies between 100 to 200 m depth in Gondwana sandstone.

High nitrate content at some locations & deeper water level (more than 5m in the post-monsoon period) in some areas are the major issues so far as ground water scenario in the block is concerned. Annual Extractable Ground Water Recharge is 2798.23 ham and present stage of ground water extraction is 43.95 % thus under safe category. Since the stage of development of groundwater in the block is only 43.95 %, there is ample scope of development. Since the stage of development of groundwater in the block is only 43.95 %, there is ample scope of development. In order to achieve 60% stage of ground water development in this block, development may be taken up by constructing 281 nos of tube wells or 624 nos of dug wells at suitable places that can create an irrigation potential of 499 ha of paddy, 1122.5 ha of wheat, Ground Nut, Sunflower and 1496.67 ha of Mustard & Pulses . However in a long term sustaining basis, we have to go for artificial recharge, particularly to recharge the area of deeper water level. As such 28 nos. of percolation tank, 95 nos. of nala bunding/cement plug/check dam, 229 nos of recharge shaft and 170 nos of gully plug/gabion structures can be constructed that can recharge 12.33 mcm ground water.

5.2 Recommendations

- Since the stage of ground water development for Gharghoda, from supply side of ground water management, construction of 281 nos of irrigation tube wells (60 to 150 m deep with diameter of 100 to 150 mm) or 624 nos of irrigation dug wells (5 to 20 m deep with diameter varies from 1 to 4 m) may be done at suitable places that can create an irrigation potential of 499 ha of paddy, 1122.5 ha of wheat ,Ground Nut, Sunflower and 1496.67 ha of Mustard & Pulses.

- Similarly in a long term sustaining basis 28 nos. of percolation tank, 95 nos. of nala bunding/cement plug/check dam, 229 nos of recharge shaft and 170 nos of gully plug/gabion structures can be constructed to recharge the area of deeper water level that can recharge 12.33 mcm ground water.

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ANNEXURE-I: Exploration details in Gharghoda block

SL.NO	LOCATION	LAT	LONG	DEPTH (m)	CASING (m)	FORMATION	ZONE ENCOUNTERED	YIELD (lps)	DRAW DOWN (m)	TRANSMISSIVITY IN m^2/sec	STORATIVITY
1	Bayasi	22.2208	83.4	300.76	294	Barakar	75-95,116-122,131-137,149-157,183-189,192-198,204-208,215-221,228-234,238-252,272-282,286-292	7.885	25.73	28.36	
2	Kudumkela	22.2722	83.2708	304.74	302	Barakar Fm	65-79,100-108,135-149,163-179,198-212,267-277,281-300	7.885	30.09	27.7	
3	Dumarpali	22.2897	83.2828	350	326	Barkar Fm	273-280,285-323	3.53		4.16	
4	Gharghoda	22.1708	83.3542	300.46	282	Barkar Fm	93-95,98-101,139-141,152-155,181-201,203-213,226-254,259-264,266-268,276-279	6.3			
5	Kotrimar	22.2208	83.4	300	292	Barkar Fm	63-75,94-100,120-135,140-147,150-156,217-229,285-290	7.887	19.6	142.75	0.049
6	Phaguram	22.2361	83.325	350.94	245	Barakar Fm	110-117,124-150,160-167,200-223,238.5-241.40	5.93	32.69		
7	Phuthamara	22.3528	83.4528	205.01	103	Barakar Fm	40-48,55-70,80-100	3.88	12.74	29.21	
8	Samaruma	22.0833	83.3417	223.92	208	Barakar Fm	66-81,126-138,157-163,184-205	7.76	9.4		
9	Bhendra	22.1506	83.3336	201.7	24.8	Siltstone	61.40-64.50	1	25.45	1.625	
10	TUPAKDHAR	22.244	83.38	159.3	12.5	Barakar sandstone		1.2			
11	Tendanawapara	22.1417	83.2458	291.58	180	0.0-200. Kamthi Fm 200.-291.58 Barakar	65-90,93-115,145-153. ,159-165,168-177	5.5	23.12	51.975	0.00055

12	Kotrimar OW	22.2208	83.4	299.24	298	Barkar Fm	61-66,69-78,120-123,126-138,147-153,183-186,263-272, 277.5-283.5,291.5-296				
13	Phaguram OW	22.2361	83.325	250.94	211	Barakar Fm	85-88,109-115,150-158,200-206	4.43	15.92		
14	Samaruma OW	22.0833	83.3417	201.5	198	Barakar Fm	177-195	0.38	39.6		
15	Baroud EW	22.28718	83.34218	147	147	Barakar Fm	102-113,	3.5	26.82		
16	Tendanawapara OW	22.1417	83.2458	187		Kamthi Fm	65.0-90.0,93.0-115.0,145.0-153.0,159.0-165.0,168.0-177.0	3.16		10.64	

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

S.No	Village	Long	Lat	Source	Pre-Monsoon SWL (mbgl)	Post-Monsoon SWL (mbgl)	Fluctation (m)
1	Amlidih	83.3327	22.1126	DW	7.30	7.00	0.30
2	Bhalumar	83.3447	22.1194	DW	6.60	4.20	2.40
3	Bhangari	83.2508	22.1328	DW	10.10	6.80	3.30
4	Chimtapani	83.4167	22.2722	DW	12.35	7.80	4.55
5	Kotrimal	83.39781	22.23154	DW	5.85	4.50	1.35
6	Kurmibhuna	83.3665	22.28	DW	8.20	5.00	3.20
7	Samarumi	83.3458	22.0842	DW	7.00	5.30	1.70
8	Nawadih	83.3	22.32556	DW	3.95	2.9	1.05
9	Pusalda	83.30472	22.30444	DW	9.8	4.9	4.90
10	Pusalda	83.30417	22.30167	DW	10.1	5.15	4.95
11	Dumarpali	83.27917	22.28972	DW	6.5	4.8	1.70
12	Chimtapani	83.42056	22.27444	DW	13.1	7.5	5.60
13	Phuthamuda	83.42889	22.2975	DW	6.1	3.7	2.40
14	Phuthamuda	83.43028	22.29694	DW	6.3	3.9	2.40
15	Kusumghat	83.27472	22.29972	DW	9.7	5.25	4.45
16	Harradih	83.29322	22.04737	DW	9.8	7.98	1.82
17	Gadgaon	83.28126	22.04753	DW	4.15	3.48	0.67
18	Rabo	83.26369	22.06475	DW	6.18	4.39	1.79
19	Dokrabura	83.28005	22.07569	DW	7.1	5.17	1.93
20	Chharratangar	83.29758	22.09024	DW	6.6	5.83	0.77
21	Pandripani	83.30554	22.12875	DW	5.7	5.04	0.66
22	Kharamura	83.32752	22.15019	DW	7.8	5.91	1.89
23	Bade Gumda	83.30056	22.17327	DW	8.15	7.08	1.07
24	Chhote Gumda	83.28942	22.1769	DW	6.6	6.1	0.50
25	Katandih	83.27892	22.15051	DW	8.8	6.78	2.02
26	Bilaskhar	83.25096	22.09261	DW	10.7	8.69	2.01
27	Daharidih	83.25165	22.07786	DW	5.4	4.69	0.71
28	Tumidih	83.32981	22.06962	DW	5.9	4.18	1.72
29	Bhalumar	83.34384	22.11964	DW	6.15	3.67	2.48
30	Barpali	83.35861	22.14886	DW	7.5	5.36	2.14
31	Chhota Nawapara	83.35484	22.1605	DW	4.65	3.46	1.19
32	Jhariapali	83.37115	22.15195	DW	3.4	2.24	1.16
33	Kanchanpur	83.33253	22.19692	DW	7.1	4.21	2.89
34	Bahirkela	83.29822	22.1974	DW	7.15	4.8	2.35
35	Malidih	83.28884	22.21076	DW	6.8	4.3	2.50
36	Dhangrapara	83.28654	22.21836	DW	5.4	4.08	1.32
37	Gharghori	83.29077	22.22391	DW	7.9	6.61	1.29

38	Beldipa	83.29794	22.23249	DW	6.2	4.73	1.47
39	Boronakunda	83.27187	22.20803	DW	8.4	6.78	1.62
40	Nawagarh	83.27216	22.18863	DW	7.1	6.12	0.98
41	Chaldonia	83.35276	22.11299	DW	4.9	4.27	0.63
42	Karuwahi	83.49174	22.16625	DW	6.8	4.13	2.67
43	Dholnara	83.46724	22.17442	DW	5	4.4	0.60
44	Rodhopali	83.44695	22.16397	DW	6.5	2.4	4.10
45	Chirimura (Hirapur)	83.42882	22.17884	DW	8.6	6.08	2.52
46	Kerakhol	83.41772	22.19762	DW	7.5	5.62	1.88
47	Kolam	83.43211	22.16799	DW	5.9	4.75	1.15
48	Mauhapali	83.41663	22.13759	DW	5.7	4.55	1.15
49	Dolesara	83.43361	22.14439	DW	7.6	4.22	3.38
50	Devgarh (Chidarpara)	83.39647	22.13126	DW	7	5.81	1.19
51	Patrapali	83.39651	22.1516	DW	6.15	3.4	2.75
52	Rengal Behari	83.38203	22.1683	DW	5.9	5.12	0.78
53	Barkaspali	83.4092	22.16065	DW	6.8	6.14	0.66
54	Banai	83.39659	22.18051	DW	4.7	3.36	1.34
55	Charbhata	83.37243	22.18448	DW	4.8	1.92	2.88
56	Gharghoda	83.35191	22.17556	DW	6.5	6.49	0.01
57	Auraimuda	83.38142	22.20284	DW	5.1	3.18	1.92
58	Kotrimal	83.39781	22.23154	DW	6	4.49	1.51
59	Raikera	83.4208	22.22956	DW	8.9	6.77	2.13
60	Naya Rampur	83.46964	22.23097	DW	4.3	3.06	1.24
61	Bichhnara	83.46522	22.24657	DW	4.8	4.36	0.44
62	Tilaipali	83.48186	22.2415	DW	5.6	2.78	2.82
63	Teram	83.34444	22.22289	DW	7.7	4.33	3.37
64	Rumkera	83.35411	22.2381	DW	6.15	4.4	1.75
65	Patrapali	83.34524	22.24491	DW	8.8	5.89	2.91
66	Phaguram	83.32028	22.23845	DW	8.9	4.18	4.72
67	Karichhapar	83.31451	22.23192	DW	10.4	7.52	2.88

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

S.NO.	Location	pH	TDS	EC	CO_3	HCO_3	Total Alkalinity	Cl	F	SO4	Ca	Mg	Na	K	TH	PO_4	SiO_2	NO_3
1	Gharghoda	7.1	776.4	1294	0	238	195.08	156	0.2	76	98	32.4	79	33.5	380	0.12	5.5	
2	Bhengari	7	112.2	187	0	49	40.16	21	0	3.4	14	6	9.6	7.4	60	0.14	4.1	
3	Bhalumar	7.1	119.4	199	0	73	59.84	21	0.1	7.8	14	7.2	8.1	10.9	65	0.14	10.5	
4	Amlidih	7	236.4	394	0	98	80.33	50	0.1	18.1	28	12	22.8	10.7	120	0.14	4.2	
5	Samarumi	7	31.2	52	0	24	19.67	11	0	1.6	6	3.6	1.1	0.7	30	0.1	2.4	
6	Teram	6.9	228.6	381	0	201	164.75	14	0.3	8.3	38	12	11.5	5.7	145	0.11	6.6	
7	Porda	7.2	216	360	0	207	169.67	18	0.8	9.7	26	16.8	19.4	10.3	135	0.13	4.8	
8	Kurmibhuna	7.1	87	145	0	67	54.92	11	0.3	2	12	7.2	2.2	2.2	60	0.12	5.3	
9	Dumarpali	6.7	44.4	74	0	37	30.33	7	0.1	2.4	10	2.4	2	1.9	35	0.15	12.5	
10	Baroud	7.3	262.8	438	0	207	169.67	25	0.4	11.8	38	15.6	19.9	7.8	160	0.14	6.6	
11	Kotrimal	7.4	223.2	372	0	183	150.00	21	0.6	11.1	30	18	9.4	9.3	150	0.12	6	
12	Chimtapani	7.2	130.8	218	0	110	90.16	14	0.2	3.3	6	19.2	5.6	2.3	95	0.15	6.8	
13	Harradih	7.9	620.8	970	0	244	200.00	67	0.1	47	66	7	20	134	195			137
14	Gadgaon	7.6	124.8	195	0	61	50.00	18	0	7	14	8	9	10	70			22
15	Rabo	7.5	56.96	89	0	18	14.75	18	0	1	6	2	7	8	25			13
16	Dokrabura	7.4	135.04	211	0	37	30.33	18	0.1	7	10	6	7	26	50			37
17	Chharratangar	7.9	513.92	803	0	287	235.25	67	0.2	4	76	8	21	85	225			22
18	Amladih	7.2	145.92	228	0	49	40.16	18	0	21	16	4	11	24	55			25
19	Pandripani	7.5	142.08	222	0	49	40.16	32	0	2	8	12	9	17	70			26
20	Kharamura	7.6	105.6	165	0	79	64.75	21	0	4	20	4	8	10	65			4
21	Bade Gumda	7.7	97.28	152	0	43	35.25	28	0	1	14	5	9	4	55			5
22	Chhote Gumda	7.8	153.6	240	0	79	64.75	28	0.2	6	12	5	13	36	50			5
23	Katandih	7.5	21.12	33	0	12	9.84	7	0	0	4	1	3	1	15			3
24	Bhengari	6.9	182.4	285	0	6	4.92	43	0	0	14	10	19	8	75			70
25	Bilaskhar	6.8	25.6	40	0	12	9.84	4	0	1	4	1	2	1	15			7

26	Daharidih	7.7	153.6	240	0	67	54.92	25	0	6	14	7	20	13	65			24
27	Tumidih	7.7	40.96	64	0	18	14.75	11	0	1	8	1	5	3	25			7
28	Samaruma	7.5	206.72	323	0	49	40.16	36	0.1	13	10	14	30	7	85			55
29	Bhalumar	7.4	95.36	149	0	49	40.16	18	0.1	4	12	5	8	11	50			8
30	Barpali	7.9	239.36	374	0	201	164.75	21	0.7	0	28	16	10	27	135			2
31	Chhota Nawapara	7.9	470.4	735	0	159	130.33	85	0.2	31	42	13	54	50	160			80
32	Jhariapali	7.9	417.92	653	0	250	204.92	67	0.7	15	26	25	43	39	170			6
33	Kanchanpur	7.4	272.64	426	0	31	25.41	82	0	3	32	8	21	29	115			45
34	Bahirkela	7.8	958.72	1498	0	171	140.16	312	0.9	54	74	68	74	26	470			60
35	Malidih	8.2	289.92	453	0	201	164.75	36	0.8	15	40	18	23	6	175			5
36	Dhangrapara	8	62.08	97	0	18	14.75	14	0	0	6	5	5	7	35			20
37	Gharghori	7.7	412.16	644	0	146	119.67	28	0.2	23	52	13	23	38	185			95
38	Beldipa	8	280.32	438	0	238	195.08	32	1.2	10	30	14	42	2	135			0
39	Boronakunda	8.1	154.24	241	0	92	75.41	25	0.1	9	22	8	7	9	90			4
40	Nawagarh	7.7	151.04	236	0	67	54.92	25	0	12	14	7	12	15	65			19
41	Chhaldonia	8.2	492.8	770	0	220	180.33	64	0.2	42	26	14	25	107	125			42
42	Karuwahi	8.1	154.88	242	0	73	59.84	36	0.3	2	16	8	16	8	75			11
43	Kerakhol	7.6	330.88	517	0	98	80.33	89	0	11	22	11	54	19	100			23
44	Kolam	8.2	446.72	698	0	250	204.92	64	0.7	33	34	40	17	31	250			25
45	Dolesara	8	199.68	312	0	134	109.84	25	0.3	11	32	6	12	23	105			6
46	Devgarh	7.7	237.44	371	0	55	45.08	71	0.1	5	22	13	27	4	110			25
47	Patrapali	8.1	689.28	1077	0	195	159.84	146	0.7	38	62	38	59	21	315			87
48	Rengal Behari	8.1	307.84	481	0	195	159.84	50	0.4	0	24	18	22	26	135			2
49	Barkaspali	8.1	277.12	433	0	226	185.25	28	0.8	0	26	14	18	31	125			2
50	Banai	8	569.6	890	0	214	175.41	78	0.9	49	26	32	57	45	200			31
51	Charbhanta	8.3	561.92	878	12	153	145.41	185	1.4	35	22	42	75	6	230			7
52	Ghorghora	7.9	482.56	754	0	165	135.25	96	0.4	31	36	22	45	34	180			46
53	Kognara	8.1	229.76	359	0	226	185.25	14	1	1	18	32	4	4	180			1
54	Auraimuda	7	92.8	145	0	18	14.75	36	0.1	0	8	7	7	4	50			2

55	Kotrimal	8.3	372.48	582	6	128	114.92	78	0.2	29	36	20	24	23	175			31
56	Raikera	7.6	163.84	256	0	85	69.67	36	0.2	7	20	12	12	6	100			10
57	Nayarampur	8.3	511.36	799	9	165	150.25	96	0.6	40	42	25	37	36	210			54
58	Bichhnara	7.8	289.92	453	0	116	95.08	53	0.5	21	26	16	23	30	130			33
59	Tilaipali	7.8	275.84	431	0	104	85.25	57	0.3	17	22	7	30	26	85			19
60	Teram	7.9	261.76	409	0	159	130.33	21	0.5	32	32	11	21	9	125			2
61	Rumkera	7.9	326.4	510	0	122	100.00	57	0.2	19	32	14	19	39	140			51
62	Patrapali (II)	8.3	497.28	777	6	153	135.41	107	0.4	37	36	19	68	15	170			16
63	Phaguram	8.3	511.36	799	12	140	134.75	124	0.7	42	26	31	65	11	195			17
64	Karichhapar	8	244.48	382	0	159	130.33	14	1	17	38	5	15	35	115			28
65	Nawadih	7.5	87.04	136	0		0.00	7	0.3	0	14	4	6	4	50			3
66	Pusalda	7.5	163.84	256	0		0.00	36	0.2	11	14	11	10	15	80			21
67	Pusalda	7.5	101.12	158	0		0.00	18	0.2	11	12	12	10	15	80			21
68	Dumarpali	7.1	48.64	76	0	37	30.33	18	0.1	0	8	1	8	5	25			4
69	Chimtapani	7.6	198.4	310	0	110	90.16	36	0.2	13	34	6	9	14	110			30
70	Chimtapani	7.5	80	125	0		0.00	7	0.2	1	14	5	2	6	55			0
71	Phuthamuda	7.5	218.88	342	0		0.00	46	0.1	24	20	10	16	29	90			16
72	Phuthamuda	7.5	216.96	339	0		0.00	43	0.1	24	22	8	15	29	90			16
73	Kusumghat	8	544	850	0		0.00	78	0.4	91	68	34	45	19	310			3

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

S.NO.	Location	pH	TDS	EC	CO_3	HCO_3	Total Alkalinity	Cl	SO_4	Ca	Mg	Na	K	TH	PO_4	SiO_2	Fe	NO_3
1	Dumarpali	7.9	363	605	0	262	214.75	28	0	34	16	43	19	150			0	0
2	Phaguram	7.7	1260	2100	0	207	169.67	50		260	19			730				

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